European
Commission

JRC SCIENCE FOR POLICY REPORT

Best Available Techniques (BAT) Reference Document for Waste Treatment ~~Industries~~

Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control)

JOINT RESEARCH CENTRE
Institute for Prospective Technological Studies
Sustainable Production and Consumption Unit
European IPPC Bureau

Draft 1 (December 2015)

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JRC99304

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Title Best Available Techniques (BAT) Reference Document for Waste Treatment

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This document is one from the series of foreseen documents listed below (at the time of writing, not all documents have been drafted):

Reference Document on Best Available Techniques (BREF)	**Code**
Ceramic Manufacturing Industry	CER
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
Emissions from Storage	EFS
Energy Efficiency	ENE
Ferrous Metals Processing Industry	FMP
Food, Drink and Milk Industries	FDM
Industrial Cooling Systems	*ICS*
Intensive Rearing of Poultry and Pigs	IRPP
Iron and Steel Production	IS
Large Combustion Plants	LCP
Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers Industries	LVIC-AAF
Large Volume Inorganic Chemicals – Solids and Others Industry	LVIC-S
Large Volume Organic Chemical Industry	LVOC
Management of Tailings and Waste-rock in Mining Activities	MTWR
Manufacture of Glass	GLS
Manufacture of Organic Fine Chemicals	OFC
Non-ferrous Metals Industries	NFM
Production of Cement, Lime and Magnesium Oxide	CLM
Production of Chlor-alkali	CAK
Production of Polymers	POL
Pulp and Paper Industry	PP
Production of Speciality Inorganic Chemicals	SIC
Refining of Mineral Oil and Gas	REF
Slaughterhouses and Animals By-products Industries	SA
Smitheries and Foundries Industry	SF
Surface Treatment of Metals and Plastics	STM
Surface Treatment Using Organic Solvents	STS
Tanning of Hides and Skins	TAN
Textiles Industry	TXT
Waste Incineration	WI
Waste Treatment	*WT*
Wood and Wood Products Preservation with Chemicals	WPC
Wood-based Panels Production	WBP
Reference Document (REF)	
Economics and Cross-media Effects	ECM
General Principles of Monitoring	MON

Electronic versions of draft and finalised documents are publicly available and can be downloaded from http://eippcb.jrc.ec.europa.eu

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ACKNOWLEDGEMENTS

Still to be updated

[Note to TWG: it is proposed to insert here acknowledgements to individuals and organisations for their active participation in the WT BREF review. These acknowledgements could be presented as shown below, mentioning the WT TWG members' names and the organisation they represented for this review. Please indicate whether or not you agree with this proposal, especially with the fact that names are cited. Another solution could be to mention only the organisations' names.]

Acknowledgements

There are a large number of individuals and organisations to whom we are especially grateful for their assistance and participation in this review. These include representatives from the European Commission, from EU and EFTA Member States, from industry, and from environmental non-governmental organisations.

European Commission

We would like to thank our colleagues from the European Commission that have provided valuable input during the different stages of this project:

Name		**Representative of**
First name	Last name	DG XX
First name	Last name	DG XX
First name	Last name	DG XY

EU and EFTA Member States

We are grateful to the following representatives from EU and EFTA Member States who actively participated and provided valuable inputs during the different stages of this project.

Name		**Representative of:**
First name	Last name	MS (e.g. AUSTRIA)
First name	Last name	MS (e.g. AUSTRIA)
First name	Last name	MS (e.g. SWEDEN)

Representatives from industry

We are grateful to the following representatives from industry who actively participated and provided valuable inputs during the different stages of this project.

Name		**Representative of**
First name	Last name	Industrial organisation (e.g. FEAD)
First name	Last name	Industrial organisation (e.g. FEAD)
First name	Last name	Industrial organisation (e.g. HWE)

Moreover, we would like to express our gratitude to all the industrial operators that participated in the data collection by filling in questionnaires.

Environmental non-governmental organisation

We are grateful to the following representatives from environmental non-governmental organisations who actively participated and provided valuable inputs during the different stages of this project.

Name		**Representative of**
First name	Last name	NGO (e.g. E.E.B.)

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PREFACE

Preface section was entirely rewritten according to Standard Texts; Executive Summary section was removed according to BREF Guidance indications.

1. Status of this document

Unless otherwise stated, references to ‘the Directive’ in this document refer to Directive 2010/75/EU of the European Parliament and the Council on industrial emissions (integrated pollution prevention and control) (Recast).

This document is a working draft of the European IPPC Bureau (of the Commission's Joint Research Centre). It is not an official publication of the European Union and does not necessarily reflect the position of the European Commission.

2. Participants in the information exchange

As required in Article 13(3) of the Directive, the Commission has established a forum to promote the exchange of information, which is composed of representatives from Member States, the industries concerned and non-governmental organisations promoting environmental protection (Commission Decision of 16 May 2011 establishing a forum for the exchange of information pursuant to Article 13 of the Directive 2010/75/EU on industrial emissions (2011/C 146/03), OJ C 146, 17.05.2011, p. 3).

Forum members have nominated technical experts constituting the technical working group (TWG) that was the main source of information for drafting this document. The work of the TWG was led by the European IPPC Bureau (of the Commission's Joint Research Centre).

3. Structure and contents of this document

General information
Chapter 1 provides general information on the Waste Treatment sector.

For the sake of clarity, the waste treatment sector has been divided into four chapters, each split into several sections as shown in below.

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Structure and content of Chapters 2 to 5

Chapter number	Item	Section number	Item
Chapter 2	Processes and techniques commonly used for waste treatments	This chapter deals with common process steps such as reception, storage, handling, blending and mixing, cleaning and washing	
Chapter 3	Mechanical treatment of waste	Section 3.1	Mechanical treatment in shredders of metal waste
		Section 3.2	Mechanical treatment in shredders of equipment containing VFCs or VHCs
		Section 3.3	Mechanical treatment of waste with calorific value
Chapter 4	Biological treatment of waste	Section 4.2	Aerobic treatment (including composting)
		Section 4.3	Anaerobic treatment (or anaerobic disgestion – AD)
		Section 4.4	Mechanical biological treatment (MBT)
Chapter 5	Physico-chemical treatment (PCT) of waste	Section 5.1	PCT of solid and/or pasty waste
		Section 5.2	Re-refining of waste oil
		Section 5.3	PCT of waste with calorific value
		Section 5.4	Regeneration of spent solvents
		Section 5.5	Regeneration/recovery of pollution abatement components/FGT waste
		Section 5.6	Treatment of excavated contaminated soil
		Section 5.7	Physico-chemical and/or biological treatment of water-based liquid waste
		Section 5.8	PCT of waste containing POPs or mercury
		Section 5.9	Regeneration of acids and bases

Applied processes and techniques

General information on the industrial processes and techniques used within the sector are provided as shown below.

Structure of general information on processes and techniques

Treatment type	Section number
Processes and techniques commonly used for waste treatment	Section 2.1
Mechanical treatment of waste	Sections 3.1.1, 3.2.1 and 3.3.2
Biological treatment of waste	Sections 4.2.1, 4.3.1 and 4.4.1
Physico-chemical treatment (PCT) of waste	PCT of solid and/or pasty waste:Section 5.1.2
	PCT of waste with calorific value: Section 5.3.2
	PCT of POP-containing waste: 5.8.1.1
	PCT of mercury-containing waste:
	Other PCT treatments: Section 5.X.1

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Current emission and consumption levels

Data and information concerning the environmental performance of plants within the sector, and in operation at the time of writing, in terms of current emissions, consumption and nature of raw materials, water usage, and use of energy, are provided as shown in below.

Structure of data and information concerning current emission and consumption levels

Treatment type	Section number
Processes and techniques commonly used for waste treatment	Section 2.2
Mechanical treatment of waste	Sections 3.1.2, 3.2.2 and 3.3.3
Biological treatment of waste	Sections 4.2.2, 4.3.2 and 4.4.2
Physico-chemical treatment (PCT) of waste	PCT of solid and/or pasty waste: Section 5.1.3
	PCT of waste with calorific value: Section 5.3.3
	PCT of POP-containing waste: 5.8.1.2
	PCT of mercury-containing waste: Section 5.8.2.2
	Other PCT treatments: Section 5.X.2

Techniques to consider in the determination of BAT

Techniques to prevent or, where this is not practicable, to reduce the emissions from plants in this sector that were considered in determining the BAT are presented in more detail as shown below. This information includes, where relevant, the environmental performance levels (e.g. emission and consumption levels) that can be achieved by using the techniques, the associated monitoring and the costs and the cross-media issues associated with the techniques.

Structure of techniques to consider in the determination of BAT

Treatment type	Section number
Processes and techniques commonly used for waste treatments	Section 2.3
Mechanical treatment of waste	Sections 3.1.3, 3.2.3 and 3.3.4
Biological treatment of waste	All types of biological treatments: Section 4.5.1
	Aerobic treatment of waste: Section 4.5.2
	Anaerobic treatment of waste: Section 4.5.3
	Mechanical biological treatment: Section 4.5.4
Physico-chemical treatment (PCT) of waste	PCT of solid and/or pasty waste: Section 5.1.4
	PCT of waste with calorific value: Section 5.3.4
	PCT of POP-containing waste: Section 5.8.1.3
	PCT of mercury-containing waste: Section 5.8.2.3
	Other PCT treatments: sections 5.X.3

Best available techniques (BAT) conclusions

Chapter 6 presents the BAT conclusions as defined in Article 3(12) of Directive 2010/75/EU.

Emerging techniques

Chapter 7 presents information on 'emerging techniques' as defined in Article 3(14) of Directive 2010/75/EU.

Concluding remarks

Concluding remarks and recommendations for future work are presented in Chapter 8.

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4. Information sources and the derivation of BAT

This document is based on information collected from a number of sources, in particular through the TWG that was established specifically for the exchange of information under Article 13 of the Directive. The information has been collated and assessed by the European IPPC Bureau (of the Commission's Joint Research Centre) who led the work on determining BAT, guided by the principles of technical expertise, transparency and neutrality. The work of the TWG and all other contributors is gratefully acknowledged.

The BAT conclusions have been established through an iterative process involving the following steps:

- identification of the key environmental issues for the Waste Treatment sector;
- examination of the techniques most relevant to address these key issues;
- identification of the best environmental performance levels, on the basis of the available data in the European Union and worldwide;
- examination of the conditions under which these environmental performance levels were achieved, such as costs, cross-media effects, and the main driving forces involved in the implementation of the techniques;
- selection of the best available techniques (BAT), their associated emission levels (and other environmental performance levels) and the associated monitoring for this sector according to Article 3(10) of, and Annex III to, the Directive.

Expert judgement by the European IPPC Bureau and the TWG has played a key role in each of these steps and the way in which the information is presented here.

Where available, economic data have been given together with the descriptions of the techniques presented in the sections mentioned in above. These data give a rough indication of the magnitude of the costs and benefits. However, the actual costs and benefits of applying a technique may depend strongly on the specific situation of the plant concerned, which cannot be evaluated fully in this document. In the absence of data concerning costs, conclusions on the economic viability of techniques are drawn from observations on existing plants.

5. Review of BAT reference documents (BREFs)

BAT is a dynamic concept and so the review of BREFs is a continuing process. For example, new measures and techniques may emerge, science and technologies are continuously developing and new or emerging processes are being successfully introduced into the industries. In order to reflect such changes and their consequences for BAT, this document will be periodically reviewed and, if necessary, updated accordingly.

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6. Contact information

All comments and suggestions should be made to the European IPPC Bureau at the Institute for Prospective Technological Studies at the following address:

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Reference Document on Best Available Techniques for the Waste Treatment

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WORKING DRAFT IN PROGRESS

List of Tables

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

List of Figures

WORKING DRAFT IN PROGRESS

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SCOPE

~~This document together with other BREFs in the series (see list on the reverse of the title page), are intended to cover the activities described in Section 5 of Annex I of the IED Directive, namely Waste Management. One BREF covers waste incineration and some thermal waste treatments such as pyrolysis and gasification (point 5.2 of Annex I of the Directive). Although point 5.4 of Annex I includes waste landfills, this document does not cover BAT for landfills. Thus, the scope of this document focuses on the following points of Annex I of the Directive:~~

- ~~*installations for the disposal or recovery of hazardous waste as defined in the list referred to in Article 1 (4) of Directive 91/689/EEC, as defined in Annexes II A and II B (operations R1, R5, R6, R8 and R9) to Directive 75/442/EEC with a capacity exceeding 10 tonnes per day*~~
- ~~*installations for the disposal of waste oils as defined in Council Directive 75/439/EEC of 16 June 1975 with a capacity exceeding 10 tonnes per day*~~
- ~~*installations for the disposal of non-hazardous waste as defined in Annex II A to Directive 75/442/EEC under headings D8 and D9, with a capacity exceeding 50 tonnes per day.*~~

~~The Recovery (R) and Disposal (D) codes of Annexes II A and II B of Directive 75/442/EEC which refer to IPPC Directive changed according to the Commission Decision 96/350/EC. Because this last amendment corresponds to the most recent classification of R and D operation codes, the following table reflects, in agreement with the view of the IEF and TWG and following the aim of the IPPC Directive, the type of waste operation codes that are covered in this document.~~

~~Waste treatment activities covered in this document~~

~~Waste treatment activity~~	~~R/D code 96/350/EC~~
~~Use of waste principally as a fuel or other means to generate energy~~	~~R1~~
~~Solvent reclamation/regeneration~~	~~R2~~
~~Recycling/reclamation of other inorganic materials (excluding metals and metal compounds covered in R4)~~	~~R5~~
~~Regeneration of acids or bases~~	~~R6~~
~~Recovery of components used for pollution abatement~~	~~R7~~
~~Recovery of components from catalysts~~	~~R8~~
~~Oil re-refining or other uses of oil~~	~~R9~~
~~Exchange of wastes for submission of any of the operations numbered R1 to R11~~	~~R12~~
~~Storage of wastes pending any of the operations numbered R1 to R12 (excluding temporary storage, pending collection, on the site where it is produced)~~	~~R13~~
~~Biological treatment not specified elsewhere in Annex II of 96/350/EC which results in final compounds or mixtures which are discarded by means of any of the operations numbered D1 to D12~~	~~D8~~
~~Physico chemical treatment not specified elsewhere in Annex II of 96/350/EC which results in final compounds or mixtures which are discarded by means of any of the operations numbered D1 to D12 (e.g. evaporation, drying, calcination, etc.)~~	~~D9~~
~~Blending or mixing prior to submission to any of the operations numbered D1 to D12~~	~~D13~~
~~Repacking prior to submission to any of the operations numbered D1 to D13~~	~~D14~~
~~Storage pending any of the operations numbered D1 to D14 (excluding temporary storage, pending collection, on the site where it is produced)~~	~~D15~~

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This BAT reference document (BREF) concerns the following activities specified in Annex I to Directive 2010/75/EU, namely:

- *5.1. Disposal or recovery of hazardous waste with a capacity exceeding 10 tonnes per day involving one or more of the following activities:*
  - *(a) biological treatment;*
  - *(b) physico-chemical treatment;*
  - *(c) blending or mixing prior to submission to any of the other activities listed in points 5.1 and 5.2* [of Annex I to Directive 2010/75/EU]*;*
  - *(d) repackaging prior to submission to any of the other activities listed in points 5.1 and 5.2* [of Annex I to Directive 2010/75/EU]*;*
  - *(e) solvent reclamation/regeneration;*
  - *(f) recycling/reclamation of inorganic materials other than metals or metal compounds;*
  - *(g) regeneration of acids or bases;*
  - *(h) recovery of components used for pollution abatement;*
  - *(i) recovery of components from catalysts;*
  - *(j) oil re-refining or other reuses of oil;*

- *5.3*
  - *(a) Disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day involving one or more of the following activities, and excluding activities covered by Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment:*
    - *(i) biological treatment;*
    - *(ii) physico-chemical treatment;*
    - *(iii) pre-treatment of waste for incineration or co-incineration;*
    - *(iv) treatment of* […] *ashes;*
    - *(v) treatment in shredders of metal waste, including waste electrical and electronic equipment and end-of-life vehicles and their components.*
  - *(b) Recovery, or a mix of recovery and disposal, of non-hazardous waste with a capacity exceeding 75 tonnes per day involving one or more of the following activities, and excluding activities covered by Directive 91/271/EEC:*
    - *(i) biological treatment;*
    - *(ii) pre-treatment of waste for incineration or co-incineration;*
    - *(iii) treatment of* […] *ashes;*
    - *(iv) treatment in shredders of metal waste, including waste electrical and electronic equipment and end-of-life vehicles and their components.*

    When the only waste treatment activity carried out is anaerobic digestion, the capacity threshold for this activity shall be 100 tonnes per day.

- *5.5. Temporary storage of hazardous waste not covered under point 5.4* [of Annex I to Directive 2010/75/EU] *pending any of the activities listed in points 5.1, 5.2, 5.4 and 5.6* [of Annex I to Directive 2010/75/EU] *with a total capacity exceeding 50 tonnes, excluding temporary storage, pending collection, on the site where the waste is generated.*
- 6.11 *Independently operated treatment of waste water not covered by Directive 91/271/EEC and discharged by an installation* [undertaking activities covered under points 5.1, 5.3 and 5.5 above].

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This BREF does not address the following:

- surface impoundment of waste;
- disposal or recycling of animal carcases or animal waste;
- direct recovery (i.e. without pretreatment) of waste as a substitute for raw materials in installations performing activities covered in other BREFs, i.e. direct recovery of lead

batteries, zinc or aluminium salts or recovery of the metals from catalysts covered in the BREF for the non-ferrous metals industries; paper waste recycling covered in the BREF for the production of pulp, paper and board; use of waste as raw material in cement kiln covered in the BREF for the production of cement, lime and magnesium oxide;

- waste incineration, co-incineration, pyrolysis and gasification;
- landfill of waste;
- in situ remediation of contaminated soil (i.e. unexcavated);
- treatment of slags and bottom ash.

Other reference documents which could be relevant for the activities covered by this BREF are the following:

Reference document	Subject
Economics and Cross-Media Effects (ECM)	Economics and cross-media effects of techniques
Emissions from Storage (EFS)	Storage, transfer and handling of solids and liquids
Energy Efficiency (ENE)	General aspects of energy efficiency
Monitoring of emissions to air and water from IED installations (ROM)	Monitoring of emissions to air and water
Production of Cement, Lime and Magnesium Oxide (CLM)	Waste quality control and safety management for the use of hazardous waste materials
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	Waste water treatment techniques and treatment of water-based liquid waste

The scope of this document does not include matters that only concern safety in the workplace or the safety of products because these matters are not covered by the Directive. They are discussed only where they affect matters within the scope of the Directive.

The remainder of this chapter seeks to clarify which activities of the whole waste management chain are included in this document.

The waste management sector and this document

The chain of activities involved in waste management is long and extends outside the scope of the ~~IPPC~~ IED. The following figure tries to summarise which activities from the waste management sector are covered in the series of BREFs.\

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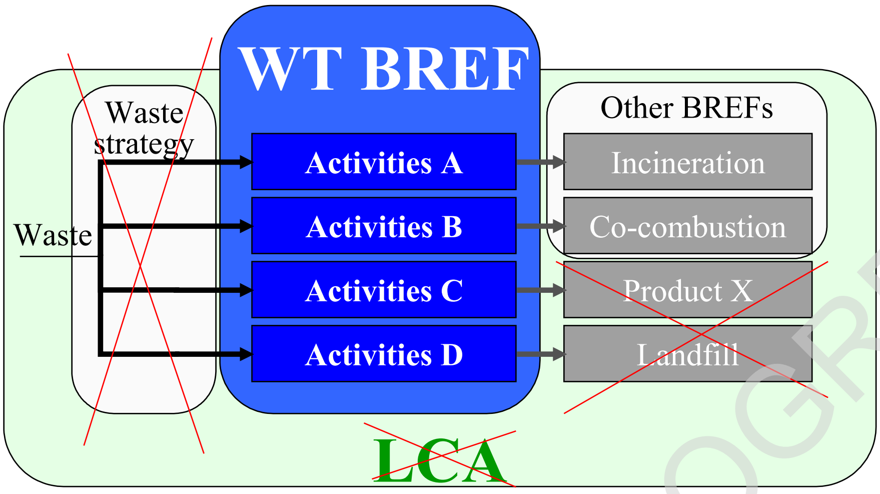

NB: Crossed out areas are not covered in this document.
LCA: Life Cycle Assessment.

Waste management and this document

A full Life Cycle Assessment (LCA) applied to a certain waste can consider all the links in the waste chain as well as the impact of the final product/waste on the environment. ~~IPPC~~ The IED is not intended to address these analyses but instead focuses on installations. For example, minimisation of the amount and/or toxicity of the waste produced at source in industrial installations is intrinsic to ~~IPPC~~ the IED and is covered by ~~each Industrial~~ sectoriel BREFs (see list preceding the Preface of this document). Another example shows that waste management also covers strategic decisions on what type of waste is dealt with in each available waste treatment/process/option or what treatment is applied to such a waste. This decision depends on the waste treatment options available at local, regional, national or international level, which also depends on the location where the waste is produced.

As shown in the previous figure, the actual combustion of waste is not included in the scope of this document. It is addressed in ~~each individual~~ sectoriel BREFs, where the different combustion processes are analysed depending on the industrial sector in which they are applied (e.g. waste incineration, large combustion plants, cement kilns). By including the processing of waste to be used as fuel, this document covers the treatments that can be applied to make different types of waste suitable for the fuel quality required by different combustion processes.

Some materials are categorised according to legislation, for example as recovered fuel (REF), refuse-derived fuel (RDF) or solid recovered fuel (SRF). It is not the intention ~~here~~ of this document to enter into a discussion of the definition of any waste term. ~~For example on the latter issue, some information can be found in CEN proposals~~. Also, some of those materials can be classified as hazardous according to legislation.

In general, this document does not aim to address the following topics:

- defining end-of-waste criteria;
- defining by-product criteria;
- defining product specifications or quality criteria for waste output;
- defining acceptance criteria for installations not covered by the WT BREF;

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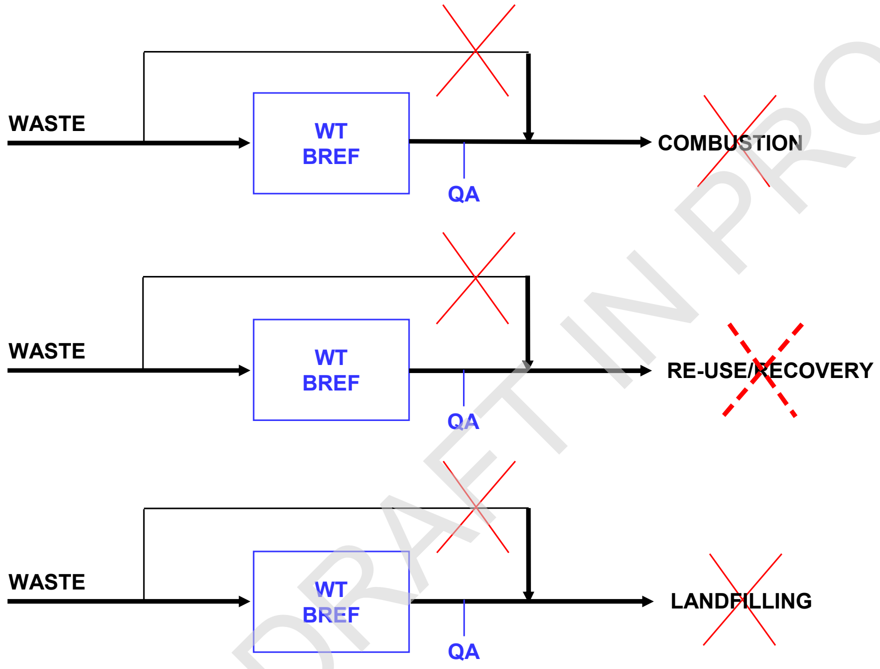
- determining whether a waste is hazardous or non-hazardous.

This document includes those treatments that can make a waste reusable or recoverable. However this document does not include reuse or recovery options that go directly from one industrial sector to another without treatment (e.g. reuse of foundries' sand or some compatible catalysts as a raw material in cement kilns, reuse of waste metals in non-ferrous metal processing). This issue is shown in the next figure.

As mentioned above, no techniques related to landfills are included in this document. The only issues covered are those related to the treatment of waste to make it more suitable for landfilling.

The following figure tries to clarify and summarise the issues covered in the above paragraphs.



Note: QA: quality assurance

Examples of waste treatments not covered in this document

~~**Waste activities treatments covered in this document**~~

~~Considering all the issues/arguments stated above, Annex I of the IPPC IED Directive, the other BREFs produced or under production and, the legal advice of the European Commission, the following table lists the waste treatment activities that are covered in this document:~~

~~Waste and waste treatment installations covered in this document~~

~~**Waste and waste treatment installations covered in this document**~~

~~**Treatment**~~	~~**Type of waste or examples of type of waste**~~	~~**Additional information**~~

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~~**Treatment**~~	~~**Type of waste or examples of type of waste**~~	~~**Additional information**~~
~~Installations dealing mainly with treatments that result in outputs for disposal~~		~~The TWG recognised that in many cases there are installations where it is very difficult to differentiate between outputs as materials for other uses or for disposal, e.g. variations due to market reasons, waste availability or waste composition, which may mean that depending on conditions at the time the output might be recycled, disposed of, or in certain economic conditions, even sold as a product/raw material for other processes~~
~~All types~~	~~Excavated soil~~	
~~All types~~	~~Materials containing CFCs~~	~~Some HCFC incinerators~~
~~All types~~	~~Materials contaminated by POPs (e.g. PCBs and dioxins)~~	~~Communication from the Commission to the Council, the European Parliament and the Economic and Social Commitee (COM(2001) 593). The communication refers to IPPC and BAT (pp. 7,15,17) but specifically to the waste treatment BREF (so-called Waste R&D). It says: 'In the context of the BAT Reference document on Waste R&D activities, to be prepared in 2002 to 2004, special attention will be given to determining BAT for the treatment of waste materials contaminated by PCBs and dioxins.' The incineration of such materials are not covered in this document~~
~~All types~~	~~Oil/water sludge~~	
~~All types~~	~~Plastics containing pollutants~~	
~~All types~~	~~Sludge from WWTPs~~	
~~All types~~	~~Spent catalysts~~	~~The catalyst treatment sector includes those treatments that can make a spent catalyst re-usable or regeneratables. However, this document cannot include the use options that go directly from one industrial sector to another without any treatment being necessary (e.g. reuse of catalysts as raw material in cement kilns, reuse of waste metals in non-ferrous metal processing). Those issues are covered in each industrial sector BREF. This document will consider and analyse the impact of the different types of waste to be handled and transformed so that the waste ends up in a suitable form to be used in certain processes.~~ ~~Catalyst regeneration can be carried out on-site or off-site. This document deals with off-site installations. Spent catalysts can sometimes be regenerated in industry in process-integrated plants. The regeneration of catalysts carried out in industry in integrated plants as an associated activity is not going to be covered in this document. For this reason, this document focuses on standalone regeneration installations~~
~~All types~~	~~Waste contaminated with mercury~~	
~~**Common treatments**~~		
~~Blending and mixing~~		
~~Repackaging~~		
~~Storage of waste and raw materials~~		~~Storage BREF~~ ~~Intermediate waste storage~~

WORKING DRAFT IN PROGRESS

~~**Treatment**~~	~~**Type of waste or examples of type of waste**~~	~~**Additional information**~~
~~Waste reception, sampling, checking and analysis~~		~~Associated activities to waste facilities~~
~~Waste transfer and handling installations~~		
~~Waste transfer stations (hazardous or non-hazardous)~~		
~~**Biological treatments**~~		
~~Aerobic/anaerobic treatments~~	~~Excavated contaminated soil~~	~~Ex-situ remediation~~
~~Aerobic/anaerobic treatment~~	~~Non-source-separated waste (e.g. mixed municipal waste)~~	~~Pretreatment prior to disposal, generating a material not suitable to be used as a compostable product~~
~~Biological treatment~~	~~Biodegradable aqueous liquids e.g. food wastes, methanol and other water miscible solvents~~	~~Bulk liquid wastes tankered into waste water treatment works~~ ~~Aerobic and/or anaerobic treatment depending upon the configuration of the works~~
~~Mechanical and biological treatments~~		~~Pretreatment prior to disposal~~
~~**Physico-chemical treatments**~~		
~~Acid neutralisation~~	~~Hydrochloric, sulphuric, nitric, hydrofluoric, phosphoric acids and acidic salts, such as aluminium chloride, etc.~~	~~Mixing of acids with either waste alkalis or raw materials, such as lime. Nitric and hydrofluoric acids are usually dealt with separately~~
~~Alkali treatment/neutralisation~~	~~Sodium and potassium hydroxide, lime, ammonia solution, ammonium salts and amine compounds~~	~~Caustic, alkalis and lime neutralised with acids. Air stripping can treat aqueous ammonia solutions. Ammonium salts and amines should be maintained at pH <9 to prevent a gaseous release~~
~~Chromic acid treatment~~	~~Chromium oxide (CrO^3) is acidic, toxic, water soluble and an oxidising agent~~	~~Conversion of Cr^{6+} to less hazardous Cr^{3+}, by the addition of a reducing agent, such as sodium metabisulphite followed by precipitation~~
~~Cyanide treatment~~	~~Cyanide salts, e.g. sodium cyanide from metal surface treatments~~	~~Conversion of cyanide to less hazardous cyanate maintaining pH >10 using on oxidising agent~~
~~Dewatering~~	~~Sludge created by sedimentation~~	~~Production of a solid filter cake by filtration through fabric filter cloths/centrifuges or filter presses~~
~~Ex-situ treatments~~	~~Excavated contaminated soil~~	
~~Filtration~~	~~Effluent from dewatering, also used for aqueous materials contaminated with oil~~	~~Micro- and ultrafiltration to remove particulates. Nanofiltration and reverse osmosis can be used to remove dissolved molecules, but are not currently utilised for physico-chemical treatments~~
~~Harbour reception facilities~~	~~Contaminated water~~	
~~Oil water separation~~	~~Aqueous materials contaminated with oil~~	~~Tilting plates or coalescing separators utilising differences in specific gravity~~
~~Physico-chemical treatment~~	~~Asbestos~~	
~~Physico-chemical treatment~~	~~Contaminated wood~~	
~~Physico-chemical treatment~~	~~Contaminated refractory ceramics~~	

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~~**Treatment**~~	~~**Type of waste or examples of type of waste**~~	~~**Additional information**~~
~~Physico-chemical treatments~~	~~Liquid, sludge and solid wastes (e.g. salts and solutions containing cyanides, pesticides, biocides and contaminated wood preserving agents)~~	~~Physico-chemical treatments are used in practice in a very broad sense including all measures to treat liquid, sludgy and solid wastes.~~ ~~Phase separation (particulates removal, de-emulsification, separation of unsoluble liquids, precipitation, sedimentation), mechanical treatments, evaporation, dewatering, drying, stabilisation and solidification of waste, neutralisation, detoxification, calcination, blending, mixing~~
~~Precipitation~~	~~Metals, for example, Zn, Ni, Cr, Pb, Cu~~	~~Precipitation using acids and alkalis to adjust the pH to achieve minimum solubilities~~
~~Separation of mercury from waste~~	~~Waste contaminated with mercury~~	
~~Separation, physico-chemical treatment~~	~~Oil/water mixtures and emulsions~~	
~~Settlement~~	~~Effluent containing neutralised acids/alkalis, precipitated metals and other solid particulates~~	~~The particles are allowed to settle out of the effluent. The particles and the efficiency of settlement can be assisted by the addition of a flocculant.~~ ~~Dissolved Air Flotation (DAF) to produce a floating flocculated solid is used at some installations (mainly for organic sludges)~~
~~Solidification and stabilisation~~	~~Fly and bottom ashes before landfilling.~~ ~~In some cases, for liquid and semi-solid hydrocarbons. Mineral industrial solid waste and sludges~~	~~Bottom ashes are mostly covered by other BREFs as part of their processes.~~ ~~Mixing of wastes with absorbents or binders, e.g. bentonite, ash, kiln dust, to reduce the environmental impact~~
~~UV and ozone treatments~~	~~Contaminated water~~	
~~**Treatments to recover mainly the waste material**~~		
~~Re-concentration~~	~~Acid and bases~~	~~Plants for the thermal regeneration of HCl and the reconcentration of spent~~ H^2SO^4~~. The rest of the regeneration processes of sulphuric acid are covered in the Large Volume Inorganic chemical BREF~~
~~Recovery of materials~~	~~Waste from pollution abatement~~	
~~Recovery of metals~~	~~Liquid and solid photographic waste~~	
~~Regeneration~~	~~Organic solvents~~	
~~Regeneration~~	~~Spent ion exchange resins~~	
~~Regeneration and treatment~~	~~Spent activated carbon~~	~~Includes the regeneration of activated carbon. Regeneration of spent activated carbon in the mercury based chlor-alkali production is covered in the chlor-alkali BREF~~
~~Re-refining~~	~~Oils~~	
~~**Treatments to produce mainly a fuel**~~		
~~Preparation of waste to be used as fuel~~	~~Hazardous and non-hazardous materials~~	~~All types of treatments (e.g. regrouping, blending, mixing, separation) for the preparation of waste to be used in all types of combustion processes (incineration, large combustion plants, cement kilns, chemical works, iron and steel, etc.)~~
~~Preparation of solid waste fuel~~	~~Non-hazardous waste~~	~~e.g. from municipal solid waste, commercial waste~~
~~Preparation of solid waste fuel~~	~~Hazardous waste~~	

WORKING DRAFT IN PROGRESS

~~**Treatment**~~	~~**Type of waste or examples of type of waste**~~	~~**Additional information**~~
~~Preparation of liquid fuel from liquid waste, e.g. oil processing or blending~~	~~Waste oils~~ ~~Oils (including vegetable oils)~~ ~~Oil contaminated with water~~ ~~Organic solvents~~	~~All types of treatments which are applied to waste oils or waste solvents will be covered within this document (e.g. cleaning of waste oils and further processing, refining).~~ ~~Coarse filtering, heating and/or centrifuging and blending to produce material to be burned~~

WORKING DRAFT IN PROGRESS

1 GENERAL INFORMATION

Still to be updated

[2, Concawe 1996] [4, Monier, V. and Labouze, E. 2001] [13, Eunomia Research & Consulting 2002] [14, Brodersen, J.; Crowe, M.; Jacobsen, H. and Tsotsos, D. 2002] [21, Viscolube 2002] [23, Militon et al. 2000] [24, Militon et al. 1998] [25, UK Department of the Environment 1991] [26, UK, H. 1995] [31, LaGrega et al. 1994] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [69, UNEP 2000] [77, Schmidt et al. 2002] [78, Eucopro 2003] [80, Iswa 2003] [81, Ruiz, C. 2002] [82, Pretz et al. 2003] [84, Ribi, J. 2003] [98, WT TWG 2004] [100, WT TWG 2004]

1.1 The purpose of waste treatment

Secondary products are inherent to any industrial process and normally cannot be avoided. In addition, the use of products by society leads to residues. In many cases, these types of materials (both secondary products and residues) cannot be reused by other means and may become not marketable. These materials are typically given to third parties as waste for further treatment to recover or dispose of.

The reason for treating waste ~~is not always the same and~~ often depends on the type of waste and the nature of its subsequent fate. Some waste treatments and installations are multipurpose. In this document, the basic reasons for treating waste are:

- to reduce the hazardous nature of the waste;
- to separate the waste into its individual components, some or all of which can then be put to further use/treatment;
- to reduce the amount of waste which has to be finally sent for disposal;
- to transform the waste into a useful material.

The following are examples of subsequent fates that can have an impact on the preliminary treatment:

~~The waste treatment processes may involve the displacement and transfer of substances between media. For example, some treatment processes results in~~

I. a liquid effluent sent to sewer; ~~and~~
II. a solid waste sent to landfill;~~, and others result in emissions to air mainly due~~
III. a solid waste sent to to incineration;~~. Alternatively, the waste may be rendered suitable for another treatment route, such as in~~
IV. the combustion of recovered fuel oil;
V. the marketing of a compost product.

There are also a number of important ancillary activities associated with waste treatment, such as waste acceptance and storage, either pending treatment on site or removal off site, that are unavoidable to fulfil the purpose of treating waste.

The next section contains some information taken from previous Annex III to the WT BREF. Information in the Annex not used in the tables below has been removed.

WORKING DRAFT IN PROGRESS

1.2 Types of waste and waste production in the EU

[4, Monier, V. and Labouze, E. 2001] [23, Militon et al. 2000] [24, Militon et al. 1998] [25, UK Department of the Environment 1991] [26, UK, H. 1995] [31, LaGrega et al. 1994] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [69, UNEP 2000] [77, Schmidt et al. 2002] [78, Eucopro 2003] [80, Iswa 2003] [81, Ruiz, C. 2002] [82, Pretz et al. 2003] [98, WT TWG 2004]

This section summarises the types of waste produced in the EU and its classification in the EU, as well as summarising the production of waste in individual EU countries and some other European countries. Waste treatment installations are designed to manage waste. This waste is the input (called raw material in other industrial sectors) to these installations. Since the IED Annex I has capacity thresholds for Waste Management activities, clearly not all the waste produced in the EU is treated by installations covered by the IED.

In the waste treatment sector as a whole, the physico-chemical properties of such inputs can vary widely. Waste can be liquid to solids from a physical properties perspective), organic to inorganic in character from a chemical properties perspective.

The European Waste Framework Directive classifies waste according to the activities that generate the waste, categorising the waste into twenty different groups as listed below.

WORKING DRAFT IN PROGRESS

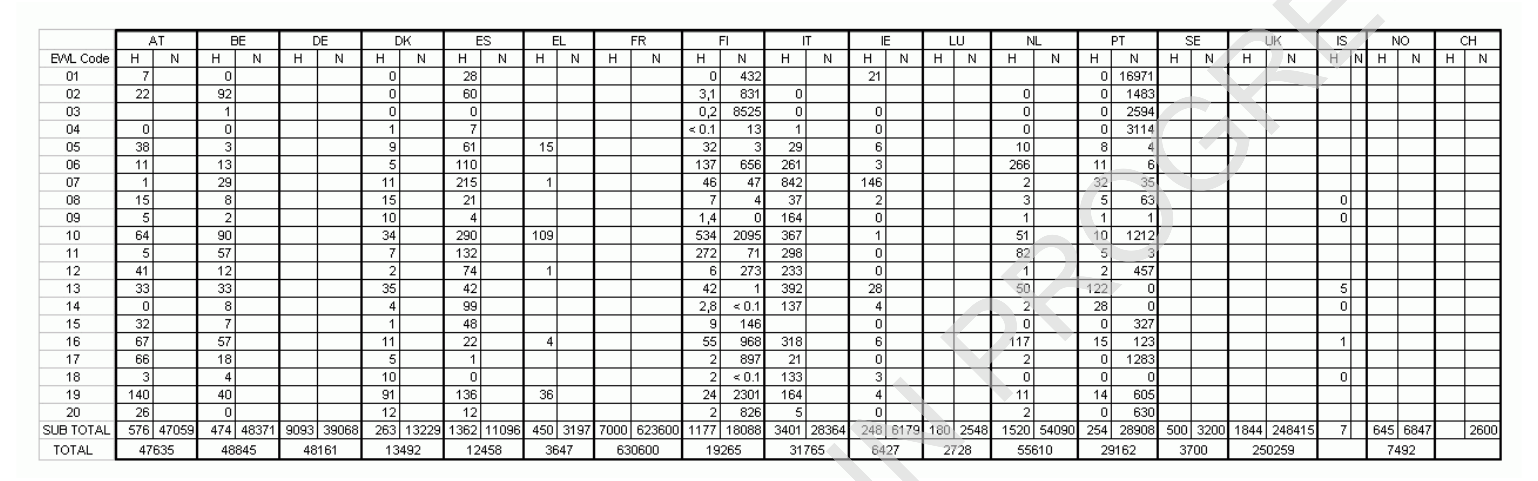
Table 1.1: European Waste List (EWL) as per amended Commission Decision 2000/53/EC

2-digit code	Groups of wastes
01	Wastes resulting from exploration, mining, quarrying, physical and chemical treatment of minerals
02	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing
03	Wastes from wood processing and the production of panels and furniture, pulp, paper and cardboard
04	Wastes from the leather, fur and textile industries
05	Wastes from petroleum refining, natural gas purification and pyrolytic treatment of coal
06	Wastes from inorganic chemical processes
07	Wastes from organic chemical processes
08	Wastes from the manufacture, formulation, supply and use (MFSU) of coatings (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks
09	Wastes from the photographic industry
10	Wastes from thermal processes
11	Wastes from chemical surface treatment and coating of metals and other materials; non-ferrous hydro-metallurgy
12	Wastes from shaping and physical and mechanical surface treatment of metals and plastics
13	Oil wastes and wastes of liquid fuels (except edible oils, 05 and 12)
14	Waste organic solvents, refrigerants and propellants (except 07 and 08)
15	Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified
16	Wastes not otherwise specified in the list
17	Construction and demolition wastes (including excavated soil from contaminated sites)
18	Wastes from human or animal health care and/or related research (except kitchen and restaurant wastes not arising from immediate health care)
19	Wastes from waste management facilities, off-site waste water treatment plants and the preparation of water intended for human consumption and water for industrial use
20	Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions

In order to give a snapshot of the waste situation in Europe, the following tables show the amount of waste generated in each Member State (MS) and some other European countries, for each category of waste mentioned above. It should be noted that a waste with the same physico-chemical characteristics may appear with different codes.

WORKING DRAFT IN PROGRESS

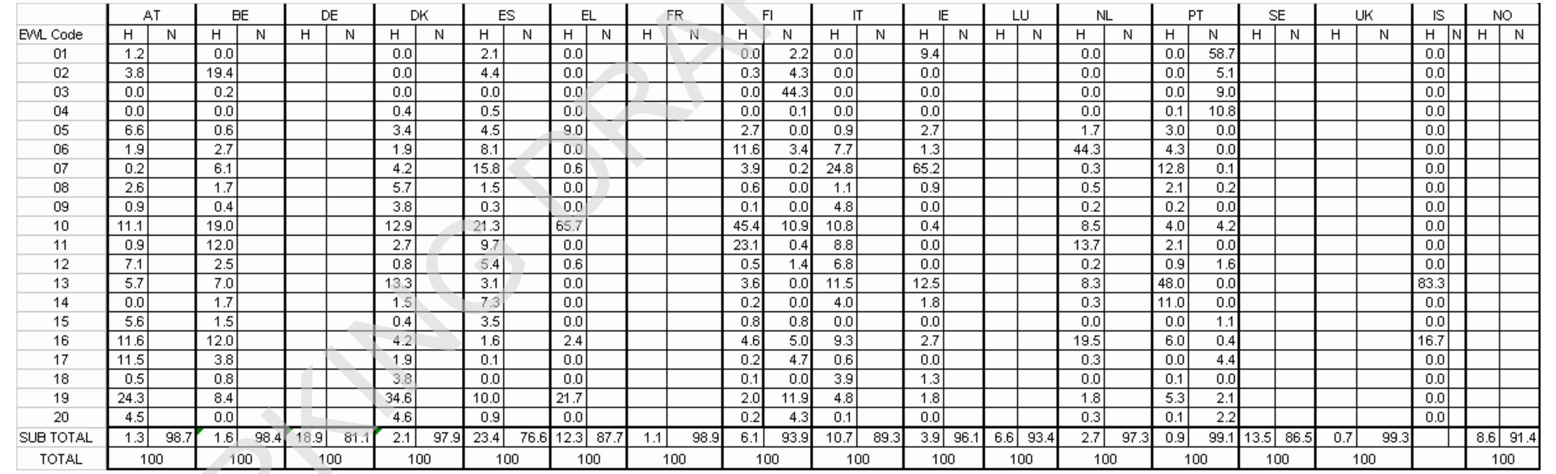
Table 1.2: Amount of each type of waste generated by European country



	AT		BE		DE		DK		ES		EL		FR		FI		IT		IE		LU		NL		PT		SE		UK		IS		NO		CH	
EWL Code	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N
01	7		0				0		28						0	432			21						0	16971										
02	22		92				0		60						3,1	831	0						0		0	1483										
03			1				0		0						0,2	8525	0		0				0		0	2594										
04	0		0				1		7						< 0.1	13	1		0				0		0	3114										
05	38		3				9		61		15				32	3	29		6				10		8	4										
06	11		13				5		110						137	656	261		3				266		11	6										
07	1		29				11		215		1				46	47	842		146				2		32	35										
08	15		8				15		21						7	4	37		2				3		5	63					0					
09	5		2				10		4						1,4	0	164		0				1		1	1					0					
10	64		90				34		290		109				534	2095	367		1				51		10	1212										
11	5		57				7		132						272	71	298		0				82		5	3										
12	41		12				2		74		1				6	273	233		0				1		2	457										
13	33		33				35		42						42	1	392		28				50		122	0					5					
14	0		8				4		99						2,8	< 0.1	137		4				2		28	0					0					
15	32		7				1		48						9	146			0				0		0	327										
16	67		57				11		22		4				55	968	318		6				117		15	123					1					
17	66		18				5		1						2	897	21		0				2		0	1283										
18	3		4				10		0						2	< 0.1	133		3				0		0	0					0					
19	140		40				91		136		36				24	2301	164		4				11		14	605										
20	26		0				12		12						2	826	5		0				2		0	630										
SUB TOTAL	576	47059	474	48371	9093	39068	263	13229	1362	11096	450	3197	7000	623600	1177	18088	3401	28364	248	6179	180	2548	1520	54090	254	28908	500	3200	1844	248415	7		645	6847		2600
TOTAL	47635		48845		48161		13492		12458		3647		630600		19265		31765		6427		2728		55610		29162		3700		250259				7492			

Note: Data in kilotonnes per year. H: hazardous, N: non-hazardous

Table 1.3: Percentage of each type of waste generated by European country



	AT		BE		DE		DK		ES		EL		FR		FI		IT		IE		LU		NL		PT		SE		UK		IS		NO	
EWL Code	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N	H	N
01	1.2		0.0				0.0		2.1		0.0				0.0	2.2	0.0		9.4				0.0		0.0	58.7					0.0			
02	3.8		19.4				0.0		4.4		0.0				0.3	4.3	0.0		0.0				0.0		0.0	5.1					0.0			
03	0.0		0.2				0.0		0.0		0.0				0.0	44.3	0.0		0.0				0.0		0.0	9.0					0.0			
04	0.0		0.0				0.4		0.5		0.0				0.0	0.1	0.0		0.0				0.0		0.1	10.8					0.0			
05	6.6		0.6				3.4		4.5		9.0				2.7	0.0	0.9		2.7				1.7		3.0	0.0					0.0			
06	1.9		2.7				1.9		8.1		0.0				11.6	3.4	7.7		1.3				44.3		4.3	0.0					0.0			
07	0.2		6.1				4.2		15.8		0.6				3.9	0.2	24.8		65.2				0.3		12.8	0.1					0.0			
08	2.6		1.7				5.7		1.5		0.0				0.6	0.0	1.1		0.9				0.5		2.1	0.2					0.0			
09	0.9		0.4				3.8		0.3		0.0				0.1	0.0	4.8		0.0				0.2		0.2	0.0					0.0			
10	11.1		19.0				12.9		21.3		65.7				45.4	10.9	10.8		0.4				8.5		4.0	4.2					0.0			
11	0.9		12.0				2.7		9.7		0.0				23.1	0.4	8.8		0.0				13.7		2.1	0.0					0.0			
12	7.1		2.5				0.8		5.4		0.6				0.5	1.4	6.8		0.0				0.2		0.9	1.6					0.0			
13	5.7		7.0				13.3		3.1		0.0				3.6	0.0	11.5		12.5				8.3		48.0	0.0					83.3			
14	0.0		1.7				1.5		7.3		0.0				0.2	0.0	4.0		1.8				0.3		11.0	0.0					0.0			
15	5.6		1.5				0.4		3.5		0.0				0.8	0.8	0.0		0.0				0.0		0.0	1.1					0.0			
16	11.6		12.0				4.2		1.6		2.4				4.6	5.0	9.3		2.7				19.5		6.0	0.4					16.7			
17	11.5		3.8				1.9		0.1		0.0				0.2	4.7	0.6		0.0				0.3		0.0	4.4					0.0			
18	0.5		0.8				3.8		0.0		0.0				0.1	0.0	3.9		1.3				0.0		0.1	0.0					0.0			
19	24.3		8.4				34.6		10.0		21.7				2.0	11.9	4.8		1.8				1.8		5.3	2.1					0.0			
20	4.5		0.0				4.6		0.9		0.0				0.2	4.3	0.1		0.0				0.3		0.1	2.2					0.0			
SUB TOTAL	1.3	98.7	1.6	98.4	18.9	81.1	2.1	97.9	23.4	76.6	12.3	87.7	1.1	98.9	6.1	93.9	10.7	89.3	3.9	96.1	6.6	93.4	2.7	97.3	0.9	99.1	13.5	86.5	0.7	99.3			8.6	91.4
TOTAL	100		100		100		100		100		100		100		100		100		100		100		100		100		100		100				100	

Note: Data in percentages per year. The raw subtotal corresponds to the percentage of hazardous and non-hazardous waste generation for each country
Source: [6, ANPA and ONR 2001] [14, Brodersen, J.; Crowe, M.; Jacobsen, H. and Tsotsos, D. 2002] [15, Langenkamp, H. and Nieman, H. 2001] [60, WT TWG 2003] [83, Oteiza, J. M. 2002] [98, WT TWG 2004]

WORKING DRAFT IN PROGRESS

Table 1.4: Estimated waste arisings in selected countries

Country	Municipal	Industrial	Agricultural	Mining	Demolition	Sewage sludge	Hazardous
Belgium	3.5	27.0	53.0	7.1	0.7	0.7	0.9
Denmark	2.4	2.4	-	-	1.5	1.3	0.1
France	1.7	50.0	400.0	10.0	-	0.6	3.0
Germany	19.5	61.0	-	9.5	12.0	1.7	6.0
Greece	3.1	4.3	0.09	3.9	-	-	0.4
Ireland	1.1	1.6	22	1.9	0.2	0.6	0.02
Italy	17.3	40.0	30.0	57.0	34.0	3.5	3.8
Luxembourg	0.17	1.3	-	-	4.0	0.02	0.004
Netherlands	6.9	6.7	86.0	0.1	7.7	0.3	1.5
Portugal	2.4	0.7	0.2	3.9	-	-	0.16
Spain	12.5	5.1	45.0	18.0	-	10	1.7
UK	35.0	70.0	250.0	25.0	32.0	1.0	4.5
US	209.0	760.0	150.0	14.0	32.0	10	275.0 [a]
Japan	48.0	312.0	63.0	26.0	58.0	2	6.6

Units in million tonnes
[a] Includes waste water
Source: OECD (1991) and Department of the Environment (1992) in
[57, Petts, J. and Eduljee, G. 1994]

The following sections cover more specific information, classified by type of waste. Not all types of waste are covered as in some cases the sector is minor or no information has been provided.

WORKING DRAFT IN PROGRESS

1.2.1 Municipal solid waste (MSW)

Table 1.5 shows a gross summary of the different components of MSW in the Member States as well as the total production of MSW in some European countries.

Table 1.5: Municipal solid waste composition in the EU and production in different European countries

Country	Paper	Textiles	Plastics	Glass	Metals	Biodegradable waste		Others	Total
Austria	670	63	340	284	166	750	29 %	236	2509
Belgium									5014
Czech republic									3200
Cyprus									370
Denmark	505		122	94	42	923	36 %	894	2580
Estonia									560
Finland	536			116	53	662	32 %	735	2102
France	6250	750	2750	3250	1000	7250	29 %	3750	25000
Germany									40017
Greece	640	144	272	144	160	1568	49 %	272	3200
Hungary									4300
Ireland									1503
Italy	3300		1050	900	450	6450	43 %	2850	15000
Luxembourg	36	4	15	13	5	83	44 %	33	189
Netherlands	1785	230	395	445	230	2630	38 %	1220	6935
Poland									11800
Portugal	1074	154	503	254	109	1627	36 %	811	4532
Slovenia									1020
Spain	3025	689	1511	984	589	6303	44 %	1195	14296
Sweden	1408	64	224	256	64	960	25 %	224	3200
UK	7400	400	2000	1800	1400	3800	19 %	3200	20000
Norway									2722

Data in ktonnes and correspond to years between 1993 and 1997
Source: [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [64, EEA 2002] [98, WT TWG 2004]

Table 1.6 shows the metals that might be present in municipal solid wastes.

Table 1.6: Metals in municipal solid waste

Metal	Present due to
Cd	Plastic pigments, batteries
Cr	Colours, pigments in plastics, textile dyes and leather tanning

Source:[71, COWI A/S 2002]

1.2.2 Contaminated waters

Table 1.7 shows the amount of contaminated water generated in France.

Table 1.7: Amount of polluted water generated in France

Type of waste water	Amount (kt/yr)
Mix of water, hydrocarbons and sediments	10

Source: [24, Militon et al. 1998]

Table 1.8 describes efforts to reduce the quantities of waste, illustrated with the aid of statistics from the German federal state of North Rhine Westphalia.

WORKING DRAFT IN PROGRESS

Table 1.8: Waste treated by PCT plants in North Rhine Westphalia/Germany in 1990 and projected quantity for 2005

Governmental districts of NRW (Germany)	Quantities of waste (m^3/yr)		
	In 1990	Projected quantity for 2005	
		Projection of 1994 [1]	Projection of 1996 [2]
Arnsberg	278300	204000	102600
Detmold	78300	66000	35300
Duesseldorf	337800	251200	140700
Cologne	264400	206000	98700
Münster	83400	69500	59600
Total	**1042200**	**796700**	**436900**
Valuation	**100 %**	**76 %**	**42 %**

NRW: North Rhine Westphalia

[1] Strategic Concept for Special Waste Disposal in NRW, 4th Edition, 1994, WAZ Press, Duisburg

[2] Strategic Concept for Special Waste Disposal in NRW, 5th Edition, 1996, WAZ Press, Duisburg

Source: [77, Schmidt et al. 2002] [98, WT TWG 2004]

The changes in projected quantities of waste to be treated by PCT plants indicate which measures are most successful in achieving effective reductions in quantities of waste. These measures consist of production-integrated measures as well as improvements in production processes and, especially, auxiliary substances and additives.

Despite these measures to avoid and reduce the quantities of waste, waste which arises in the course of production still has to be contended with. However, reductions in the quantities of waste can frequently lead to a build up associated with a more expensive treatment procedure. Physico-chemical plants constantly adapt to these changes technically, operationally and organisationally.

1.2.3 Sewage sludge

Table 1.9 and Table 1.10 show the amount of sewage sludge ~~produced~~ generated in some European countries and the European average composition of sewage sludge.

Table 1.9: Amount of sewage sludge generated in some European countries

Country	Quantity (kt dry matter)
Austria	211.9
Belgium	113
Denmark	200
Finland	158
France	878
Germany	2661
Greece	86
Ireland	43
Italy	NI
Luxembourg	13
Netherlands	349
Portugal	239
Spain	787
Sweden	236*
UK	1193
Norway	93

Data corresponding to year 1998, except * that correspond to year 1995

NI: no information

Source: [64, EEA 2002] [98, WT TWG 2004]

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Table 1.10: Ranges of contamination and content of sewage sludge

Compound	Concentration (mg/kg dry matter)
N	3500 – 46000
P	10400 – 45000
Cd	0.7 – 3.8
Cr	16 – 840
Cu	220 – 641
Hg	0.6 – 4
Ni	8 – 85
Pb	20 – 325
Zn	290 – 2580
Source:[64, EEA 2002]	

1.2.4 Waste acids and bases

The European Waste List (EWL) specifies several waste acids and bases (e.g. sulphuric, hydrochloric, hydrofluoric, phosphoric, nitric acids, calcium hydroxide, soda and ammonia). HF is not regenerated; it is only neutralised. Bases are not typically regenerated; they are typically neutralised. An exception may be represented by the ~~regeneration~~ recovery of black liquors in the pulp industry (covered in the PP (Production of Pulp, Paper and Board) BREF ~~Pulp and Paper BREF~~) [185 Pulp and Paper BREF]

1.2.5 Waste adsorbents

The adsorption of pollutants onto activated carbon, charcoal and ion exchange resins has been a common treatment technique for removing contaminants (e.g. COD, POPs, inorganics) from waste water and gaseous emissions for many years. Activated carbon is also used for the removal of VOCs from gaseous emissions (e.g. pesticide manufacture/formulation). Regeneration procedures for the spent carbon have been primarily limited to thermal reactivation technologies. Resins have found selective uses where recovery and reuse of the organic contaminant is an important objective, or where the contaminants are in reasonably high concentrations. They can also be used for inorganic removal and recovery (e.g. colour removal in the sugar industry, dyestuff and paper mill industries, for phenol removal, for processing new antibiotics, and for polishing high purity waters). Charcoal is primarily used as a fuel. As it is destroyed by combustion processes, charcoal is typically not regenerated ~~reactivated~~.

1.2.6 Waste catalysts

Catalytic methods are used extensively in the production of inorganic and organic chemicals, in petroleum technology, in the processing of synthetic gaseous and liquid fuels, in pollution control, and in energy conversion. Some examples of the use of catalysts are shown in Table 1.11.

Table 1.11: Examples of industrial sector where catalysts are used

Industrial sector	Examples
Production of inorganic chemicals	Hydrogen, ammonia, sulphuric acid, etc.
Production of organic chemicals	Organic synthesis, hydrogenation, dehydrogenation, acid catalysed dehydration reactions, oxychlorination
Petroleum refining	Reforming, desulphurisation, hydrocracking, cracking, isomerisation, lube oil hydrofinishing
Pollution control techniques	NO_x abatement using SCR, off-gas from combustion purification
Source:[81, Ruiz, C. 2002]	

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The type of compounds used as catalysts depends on the process but metals, metal oxides and acids are the ones most commonly used, as shown in
Table 1.12.

Table 1.12: Overview of the types of catalysts used for industrial purposes

	Importance	Examples
Metals	They are among the most important and widely used industrial catalyst components	Ag, Au, and the platinum group metals Transition metals: Fe, Co, Ni, Mo, Ru, Rh, Pd, W, Re, Os, Ir and Pt. Nontransition metals: Cu, Zn, As, Se, Ag, Cd, Sn, Sb, Te, Au, Hg, Pb and Bi.
Metal oxides	They are common catalyst supports and catalysts.	Al^2O^3, SiO^2- Al^2O^3, V^2O^5, ZnO, NiO, MoO^3, CoO, WO^3.
Metal sulphides		MoS^2, WS^2
Acids	Insulators that show the transition from basic to amphoteric and acidic character	Na^2O, MgO, Al^2O^3 , SiO^2 , and P^2O^5
Bases	Limited industrial applications	$Ba(OH)^2$, $Ca(OH)^2$, Na
Multifunctional catalysts		$Bi^2O^3.MoO^3$
Ion exchangers		
Organometallic complexes		
Others		$Co(acetate)^2$, amines, benzoil peroxide, etc
Source:[81, Ruiz, C. 2002]		

Theoretically, a catalyst remains unchanged after its use. However, when a catalyst may lose its activity because of deactivation (by, e.g. poisoning (by, e.g. P, S, As, Se, Te, Bi, C), fouling or sintering) and re-dispersion of the active centres of the catalysts. As a consequence, waste catalysts are mainly composed of the same materials as the native catalyst but contaminated with some additional components.

1.2.7 Wastes from combustion processes

Combustion wastes are generated during the combustion of coal, (heavy) liquid fuels or waste in large combustion plants, industrial heaters and boilers, and incinerators. Two types of wastes are produced in combustion processes. One type is the bottom ashes (slags) generated in the combustion chamber and the second corresponds to the flue-gas treatment (FGT) waste (sometimes so-called ‘air pollution control’ (APC) residues), regulated according to the European Legislation as hazardous waste. FGT waste can come from any combustion process (e.g. incinerators, large combustion plants, industrial boilers) and they are typically treated before reuse or being landfilled.

The term ‘APC residue’ is used with slightly differing meanings in the literature: strictly speaking the term only covers the solid residues (i.e. sludge and gypsum from wet systems, and excess reagent and reaction products from dry/semi-dry systems) generated to minimise emissions of acidic components in the flue-gas. Considering this definition, fly ashes should not be included. However, from a management point of view, all these solid residues (the fly ash, which is the major component, (most important by amount and even boiler ash in some Member States) are usually handled in combination (notably in the dry and semi-dry systems).

FGT waste is used as including all types of solid residues ~~produced~~ generated in or after the heat recovery systems (boiler/economiser). This includes fly ash, boiler ash, excess lime and reaction products (dry/semi-dry), sludge from scrubber solution treatment and gypsum (wet). No special

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emphasis is placed on managing sludge and gypsum separately, as the amounts are relatively small compared to fly ash.

Table 1.13 and Table 1.14 indicate the waste generated by coal fired power plants and the total in some European countries.

Table 1.13: Waste from coal-fired power plants

Country	Fly ash	Slag and bottom ash	Gypsum	Other products from gas cleaning	Sludge	Total[1]
Austria	334.5	24.9	74.5	2.0	0.3	436.2
Belgium						1135
Denmark	1158	152	374	100	n.a.	1784
Finland						1274
France	1840 - 1940					2100
Germany						25310
Greece	10					10080
Ireland						450
Italy	872	182	4	3	2	1063
Luxembourg						
Netherlands						1525
Portugal	272	30				302
Spain	531					531
Sweden						600
UK	5100	1400				6500
Norway						

Data in kt/yr correspond to years from 1993 to 1999 depending on the country. Data contains ashes (bottom and fly) as well as residues from flue-gas cleaning (gypsum).

[1] Corresponds to waste from energy production plants

Source: [24, Militon et al. 1998][64, EEA 2002] [66, RAC/CP 2003]

Table 1.14: Amounts of FGT waste in some European countries

Data in ktonnes		Type of FGT system			
Country		Dry/semi-dry	Wet	Not specified	Total
Austria	Residues	0	8.1	0	8.1
	Waste	0	450.0	0	450.0
Belgium	Residues	2.7	0	4.4	7.1
	Waste	90.1	0	101.2	191.3
Denmark	Residues	26.6	30.9	5.1	62.6
	Waste	745.6	1348.8	234.6	2329.0
Germany	Residues	284.4	377.4	13.2	675.0
	Waste	3807.0	10027.0	247.0	14081.0
France	Residues	83.2	122.4	5.9	211.5
	Waste	551.7	1971.4	121.6	2644.7
Hungary	Residues	11.1	0	0	11.1
	Waste	352.2	0	0	352.2
Italy	Residues	0	0	50.2	50.2
	Waste	0	0	1109.4	1109.4
Netherlands	Residues	0	54.0	30.4	84.4
	Waste	0	1492.0	887.0	2379.0
Norway	Residues	0.4	3.4	0	3.8
	Waste	17.5	126.7	0	144.2
Portugal	Residues	27.4	0	0	27.4
	Waste	321.8	0	0	321.8
Spain	Residues	58.8	0	0	58.8

WORKING DRAFT IN PROGRESS

	Waste	817.9	0	0	817.9
Sweden	Residues	43.0	29.0	14.8	86.8
	Waste	699.8	901.8	327.4	1929.0
United Kinddom	Residues	30.9	0	0	30.9
	Waste	1074.1	0	0	1074.1
Switzerland	Residues	0	65.7	0	65.7
	Waste	0	2462.6	0	2462.6
Total	Residue	396.3	530.3	148.0	1074.6
	Waste	6266.2	12819.5	3787.9	22873.6
Source:[80, Iswa 2003] [100, WT TWG 2004]					

An overview of the main components of solid FGT waste is given in Table 1.15.

Table 1.15: Main components of the FGT waste

Solid component	Dry/semi-dry systems	Wet systems
Fly ash/boiler ash	Always	Always
Excess reagent + reaction products	Always: can be mixed with fly ash; contain Cl salts and/or gypsum	-
Dioxin sorbent	Optional: usually included	Optional: usually handled separately or reused as a neutralisation agent in Waste Water Treatment Plant
Sludge	-	Always: sometimes mixed with fly ash/boiler ash (Bamberg model)
Gypsum	Included in reaction products	Obtained if no liquid effluent: handled separately if recovery is intended
Cl salts	Included in reaction products; recovery possible in some cases	Obtained if no liquid effluent: recovery possible in some cases
Source: [80, Iswa 2003] [98, WT TWG 2004]		

1.2.8 Waste oil

Waste oil (WO) is a term defined by European law as any mineral-based lubrication or industrial oils which have become unfit for the use for which they were originally intended, and in particular used combustion engine oils and gearbox oils, and also mineral lubricating oils, oils for turbines and hydraulic oils (Council Directive 85/101/EEC). WOs are classified as hazardous waste by European law and should be collected so that they can be safely treated. Waste oil contaminated with more than 50 ppm of PCBs is not included in this category because they are treated differently by EU legislation.

WOs cover a wide range of materials, with further differences arising from their previous use under differing conditions. In this document, the term ‘used oil’ is understood to include only those WOs which arise from the use of lubricating oils. Slop oils recovered from drainage systems, refineries, fuel storage sites, etc. are another type of waste oil. They may end up in used oil collection systems, where they can decrease the value of the used oil. Oil filters and carburetor filters contain around 30 % hydrocarbons.

Used oils can be categorised according to market considerations as follow:

- (black) engine oils: these represent more than 70 % of used oil. The largest potential source of used oils is from vehicle use, particularly engine oils
- black industrial oils: these represent about 5 % of used oil
- light industrial oils: these represent about 25 % of used oil. They are relatively clean and their market value is high. Their market is very specific and independent from the classical supply routes of regeneration.

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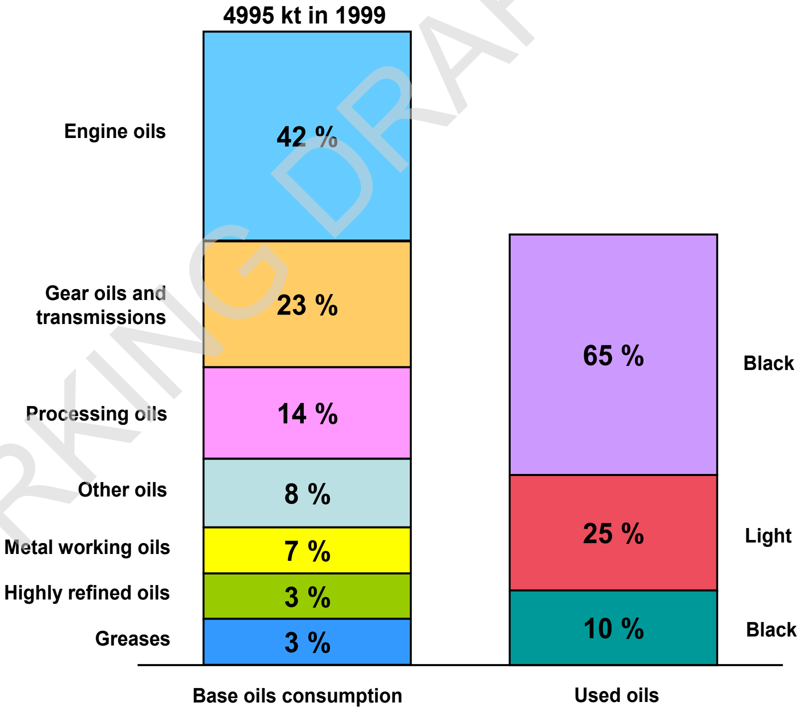
Used oil composition is becoming more and more complex due to different factors:

- the increasing use of dispersants, as well as esters and polyalphaolefins, e.g. to increase the life of the oil. However, as a result, the resulting WO has become more complex and dirty over time
- the progressive displacement of conventional mineral based auto lubricants by 'synthetic' products which have enhanced performance characteristics. Whereas some of these synthetic products can be regenerated along with mineral oils, others (those based upon esters for instance) are less suitable to regeneration because they tend to be less stable in the presence of caustic (often used by regeneration processes) and less stable to the hydro-finishing step.

A low proportion of base oil (less than 2 % of the total consumption) originates from agricultural sources, being produced from either sunflower or rape-seed. These bio-lubricants are used in applications where their characteristics represent a real advantage, in particular:

- their good biodegradability. This is important when lubrication losses into the environmental media, e.g. soil and water, can occur during use (woodcutting with motor saws, boats, cutting oils, etc.)
- their high viscosity index and low volatility for instance.

The fate of 1.1 million tonnes of used oils generated in Europe in 1993 was unrecorded. This represents approximately 20 % of the total virgin lubricating oils market. The following **Figure 1.1** shows that the amount of waste oil recovered in EU has increased to ~50 %. In 1995, the Australian Industry Commission [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] estimated that, of the world's total available waste oil, only 44 % was collected.



Source: [4, Monier, V. and Labouze, E. 2001]

Figure 1.1: Base oils consumed and used oils generated in the EU

WORKING DRAFT IN PROGRESS

More information on the amount collected in each MS and on issues related to the waste oil market can be found in [4, Monier, V. and Labouze, E. 2001] ore information about the typology of lubricants and the different types of WO is given below.

Lubricants and waste oils

Table 1.16 below details:

- the typology of lubricants and a split of the lubricant consumption according to this typology
- the average ratio to be considered for each category of lubricant to assess the WO generated during their use
- the type of WO, black oils (from engine origin or industrial origin) or light oils, generated in each case.

WORKING DRAFT IN PROGRESS

Table 1.16: EU lubricant collectable waste oil

Lubricants Consumption					**WO**		
Category	**Application**	**Use**	**European Consumption 1999 (kt)**	**% of consump-tion**	**Ratio (oil consumed /WO generated)**	**WO 1999 (kt)**	**Type of WO**
Engine oils	Engine oils for passenger cars	To diminish friction between moving parts of engine	2098	42 %	59 %	1238	Black oils
	First fill oils for passenger cars						
	Engine oils for commercial vehicles						
	First fill oils for industrial vehicles						
	Multipurpose diesel oils						
	Two-stroke engine oils						
	Other engine oils						
Gear oils & transmi-ssions	Automatic transmission fluids	To inhibit wearing out of gears and bearings and also to inhibit oxidation and corrosion	1149	23 %	24 %	276	Black oils
	Automotive gear oils						
	Industrial gear oils						
	Hydraulic transmission oils						
	Shock absorber oils						
Greases	Automotive greases	To diminish friction between moving parts of engine	150	3 %	27 %	40	Black oils
	Industrial greases						
Metal working oils	Quenching oils	In metal working for lubricating and cooling of both tools and the metals to be worked	350	7 %	0 %	0	Lost
	Neat oils for metalworking						
	Soluble oils for metalworking						
	Rust prevention products						
Highly refined oils	Turbine oils		150	3 %	48 %	72	Light oils
	Electrical oils						
Other oils	Compressor oils	To inhibit wearing out of gears and bearings and also to inhibit oxidation and corrosion	400	8 %	61 %	244	Black oils
	General machine lubricants						
	Other oils for non-lubricating uses						
Processing oils	Process oils		699	14 %	77 %	538	Light oils
	Technical white oils						
	Medical white oils						
TOTAL			**4996**	**100 %**	**50 % on average**	**2408**	

Source:[4, Monier, V. and Labouze, E. 2001]

WORKING DRAFT IN PROGRESS

Table 1.17: UK lubricant collectable waste oil estimates (tonnes)

End Use	Sales 1999 (tonnes)	recoverable[1]%	Potentially collectable (tonnes)
Gasoline and diesel engines	249488	65	162167
Agricultural engines	15000	65	9750
Other engines	7288	0	0
Marine engines	37728	25	9432
Aviation and turbine oils	2214	50	1107
Total engine oils	311718		182456
Hydraulic and transmission	96352	80	77082
Other gear oil	53815	80	43052
Total gear/transmission oils	150167		120134
Total greases	11815		1177
Total metal working oils	35548		7110
Turbine and electrical oils	27070	95	25717
General machine lubricants	15219	50	7610
Non-lubricating industrial oils	11792	10	1179
Other industrial oils	10939	20	2188
Total other oils	65020		36693
Total processing oils	129908		0
Deliveries to blenders	86151	50	43075
Total all lubricants	**790327**	**(49.4)**	**390646**

[1]Estimates based on CONCAWE WQ/STF-26 study
Source:[4, Monier, V. and Labouze, E. 2001]

1.2.9 Waste solvents

In this document, the term ‘waste solvent’ is to be understood as including all those wastes from organic substances used as solvents, also including those used in organic chemical processes and from manufacture, formulation, supply, and those used in coatings (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks.

Table 1.18: Production of solvents and treatment of waste solvents

Country	Annual production (kt/yr)	Treated (kt/yr)
ES		127
FR	800	90.7
IT		58.3

Source: [24, Militon et al. 1998] [66, RAC/CP 2003]

1.2.10 Waste plastics

Plastics are mainly organic polymers with different compositions. Typical polymers are polystyrene (PS), polyethylene terephthalate (PET), polypropylene (PP), polyurethane (PU), polyacrylonitrile-butadiene-styrene (ABS), polycarbonate (PC), polyamides (PA), polybutylene terephthalate (PBT), polyethylene (PE), polyvinyl chloride (PVC), etc. Waste plastics can be differentiated according to its type of use as shown below:

WORKING DRAFT IN PROGRESS

Table 1.19: Waste plastics

Sectors	Polymers contained in the plastic waste
Packaging	PE, PP, PS, PET, etc.
Automotive	PP, PU, ABS, etc.
Electrical	PS, ABS, PP, etc.
Electronics	PC, PA, PBT, etc..
Building + Construction	Foams: PU, Expanded PS, Mix of PS, etc. Pipes: PE, PVC, etc.
Agricultural (films)	PE
Source:[36, CEFIC 2002] [98, WT TWG 2004]	

The requirements for each type of use greatly differs and the choice of plastic is made by the user, typically a downstream producer, on a cost performance ratio. Table 1.20 shows some examples of metals that are present in plastics.

Table 1.20: Presence of metals in plastics

Metal	Use	Comment
Pb	PVC stabiliser	About 0.7 – 2 % Pb as stabiliser in many types of rigid PVC for outdoor use
	Pigment in plastic	Lead chromate for yellow and red colours contains 64 % lead
Cd	Stabilisers (e.g. PVC)	About 0.2 %, up to a maximum of 0.5 % cadmium used as stabiliser in rigid PVC for outdoor applications (window profiles, sidings).
	Pigment	
Cr (Cr(III) and Cr(VI))	Colours and pigments	
Source: [71, COWI A/S 2002] [98, WT TWG 2004]		

1.2.11 Waste wood

Contaminated wood can arise from electrical and telephone fence posts, supports in railways and from all wood treated for use outdoors. This type of wood is typically treated and some of the product for treatment may contain metals. The treatments that they receive are based on creosote and pentachlorophenol, metallic salts, copper sulphate, CFK treatment (Cu, F, Cr treatment), CCB treatment (Cu, Cr, B treatment) or CCA treatment (Cu, Cr, As treatment). Table 1.21 shows some data on the amount of this type of waste generated in one MS (France).

Table 1.21: Amount of contaminated wood generated

Type of contaminated wood	Amount of waste generated per year	
	(m^3/yr)	(t/yr)
Wood treated with creosote	150000	75000
Wood treated with CCA	80000	40000
Source: [24, Militon et al. 1998]		

1.2.12 Cyanide wastes

Cyanide wastes typically arise in solutions that have been used for a variety of operations in the metals/electroplating industries, such as cleaning, de-tarnishing, printing and electroplating solutions. Typically, the waste consists of solid or liquid cyanide salts. Cyanide wastes also arise as fused solids within a container or in block form when molten salts have been used for heat treatment purposes.

WORKING DRAFT IN PROGRESS

The volume of cyanide wastes arising has significantly decreased in recent years, mostly due to the replacement of cyanide-based cleaners by surface-active agents and the use of copper pyrophosphate plating solutions in place of copper cyanide.

1.2.13 Other inorganic waste

Waste containing silver mainly arises from film processing, but to a lesser degree also some from the custome sector and the dental sector, which also produces waste contaminated with mercury.

1.2.14 Refractory ceramics waste

The level of contamination of refractory ceramics depends on its utilisations. For example, it is known that ceramics used in the combustion of heavy fuel contain cadmium, vanadium, nickel and sulphur and that sulphur is common in refractory ceramics used in petrochemistry. The amount of waste generated per year in France is 200 kt [24, Militon et al. 1998].

1.2.15 Hazardous waste from the construction and demolition sector

Table 1.22 shows the amount of hazardous waste generated from the construction and demolition sector in some European countries.

Table 1.22: Amount of hazardous waste generated from the construction and demolition sectors in some European countries

Country	Quantity (kt)
AT	8.4
DE	490.0
DK	8.4
EL	0.9*
ES (Region of Catalonia)	185.5
IE	159.0

Data from 1996 except for DE that corresponds to 1993
* Data refer only to asbestos
Source: [64, EEA 2002] [66, RAC/CP 2003]

1.2.16 Waste contaminated with PCBs

Some types of waste contaminated with PCBs are electrical transformers, capacitors, transformer oils and waste oils (waste oil contaminated with more than 50 ppm of PCB is considered by European Legislation to be a special waste which cannot be treated in the same way as waste oils). Some commonly found materials may also become polluted with PCBs (soils, building materials, waste clothing, other debris, etc.). These can typically be decontaminated by treatment with a solvent, and the resulting solvent and PCBs mixture may then be processed.

The uses of PCBs can be classified into three categories:

Closed applications
As the name implies, closed uses are those in which the PCBs are enclosed and cannot escape during normal use. The main examples are transformers and capacitors, which are sealed pieces of electrical equipment. Apart from accidents (fire, mechanical damage, etc.) the PCB will remain in a safe environment, at least until the end of the working life of the equipment in which it is enclosed.

WORKING DRAFT IN PROGRESS

Partially closed applications

In these, oil containing PCB is employed as a fluid which is called upon to move during use, for example as a heat transfer fluid or as a hydraulic fluid, in pumps or in switches. This movement implies the presence of joints and seals in the equipment, offering the possibility that these items of equipment can release small amounts of fluid during normal operation.

Open applications

In open applications, the PCBs are generally incorporated into a formulation, usually in small or very small quantities. Such products can be lubricants, adhesives, paints, inks, etc. The PCBs can become very dispersed depending on each application, and it is virtually impossible to destroy them. The solution to this problem is instead found further upstream, i.e. to ban the incorporation of PCBs in such products; this of course is already done in most countries, although many products manufactured earlier may still be in use.

This classification is useful since it indicates the likelihood with which the PCB can be released, intentionally or unintentionally, thereby leading to a PCB contamination problem.

WORKING DRAFT IN PROGRESS

1.3 Installations for the treatment of waste

SECTION STILL TO BE UPDATED
TWG please provide updated information about the WT sector

This section summaries the waste treatment sector in the EU. A short explanation of the treatments performed is included here.

The waste sector is highly regulated in the EU. For this reason many legal definitions of common terms used in this sector are available (e.g. waste, hazardous waste). Some definitions are available in the European Waste Framework Directive and amendments to it.

Ultimately, waste is either recovered or disposed of. Waste treatment installations therefore carry out operations for the recovery or disposal of waste. Waste treatment installations are not typically considered to produce a product like other industrial sectors. Instead, it is considered that they provide services to society to handle their waste materials. A waste treatment facility typically covers the contiguous land, structures, and other areas used for storing, recovering, recycling, treating, or disposing of waste.

As in the case with the classification of waste types, waste treatment (WT) activities are legally classified by Annex II of the Waste Framework Directive. A copy of this classification is provided in the Annex of this document, together with examples of their application.

The concept of a facility dedicated to the management of waste is not new. Long before the enactment of waste legislation (hazardous or non-hazardous), companies which produced waste already recognised the need for the specialised treatment and disposal of their wastes. Many waste producers constructed and operated their own dedicated facilities, typically on-site facilities.

Other companies that generated waste, and do not have have suitable site or do not generate a sufficiently large volume of waste to justify the investment in an on-site facility, transported their waste off site to specialised facilities for treatment and disposal. Such facilities are typically referred to as commercial, off-site facilities. The commercial waste management industry thus began the development of these off-site facilities in the late 1960s. His role was to collect and transport waste to specialised off-site facilities where they carried out the treatment and disposal of that waste.

Just as there are many types of waste, there are many ways in which wastes can be managed. For example, there are at least 50 commercially applied technologies for the treatment of hazardous waste. A waste facility may function with just one technology, or it may combine multiple technologies, particularly if it is a commercial facility serving a number of waste producers.

There are some differences between a typical commercial off-site facility and an on-site facility typically specializing in the treatment of a particular type of waste. This derives in part from the fact that an off-site facility accepts waste from outside the local community, while an on-site facility handles only that waste generated by what could be a long-standing and important economic activity in the community. From a technical perspective, the off-site facility generally handles a wider range of waste types and is typically larger and more complex.

For example, off-site waste facilities may be categorised as follows:

- installations focused mainly on recovering material as a saleable product (typically solvents, oils, acids, or metals). Some use the energy value in the waste

WORKING DRAFT IN PROGRESS

- installations focused on changing the physical or chemical characteristics of a waste, or degrade or destroy the waste constituents, using any of a wide variety of physical, chemical, thermal, or biological methods
- installations focused on permanent emplacement of waste on or below the surface of the land. Such installations are not covered in this document.

The following sections within this section cover more specific information gathered, on the types of waste installations, classified by the main type of waste treatment carried out. Not all types of waste treatments covered in this document are covered in this section, possibly because such a treatment may be considered quite minor.

1.3.1 Shredders

[107 Mech. Subgroup,2014]

Shredders of metal waste
About 350 mixed scrap shredders are operating in Europe in 2014.

Mixed scrap shredders are generally capable of processing between 25 and 400 tonnes per hour, this throughput being dependent upon the size of the shredder box and the power of the rotor drive motor. In general, mixed scrap shredders will utilise some form of magnetic separation to extract the ferrous content from the mixed stream, and some form of air classification to separate the non-ferrous content from the non-metallic materials. Material is generally transported, between stages and to storage bunkers, on conveyors.

The majority of such shredders are located in the open air, not enclosed within buildings.

Shredders of Waste Electrical and Electronic Equipment (WEEE)
Due to the WEEE Directive (2012/19/EU), dedicated WEEE shredding plants were installed in the last 15 years, a majority of them treating equipments such as fridges and cooling appliances, containing volatile fluorocarbons (VFC) or volatile hydrocarbons (VHC).

These installations are generally capable of processing automatically 35 to 45 devices per hour in a two phases process: once the loose inner parts of the temperature exchange equipment are removed, and oil and VFC and/or VHC are properly extracted to be further treated (i.e. in accordance with Regulation EC/1005/2009), the devices are shredded into smaller material components. These components (ferrous scrap, mixed non-ferrous scrap, foam, and plastics) are separated from one another in a downstream sorting process.

1.3.2 Waste transfer installations

Operations carried out in these installations include: reception, bulking, sorting, transferring pending, prior to submission to a disposal/recovery operation. In some cases, blending and mixing may also be carried out in these installations. Waste transfer stations may involve individual operations or may be an integrated part of a treatment process. All sites typically undertake some kind of bulking operation to agglomerate the solids, where liquids are decanted from one container to another. The liquid transfer can be from a tanker to a holding tank, or from fractions of litre up to a more than 200 litre drum. Operations typically carried out are inspection, sampling, physical sorting and packaging, decanting, blending, drum emptying, storage, drum/IBC reclamation and in some cases disposal of wiping cloths, solidification and the crushing of oil filters. Waste transfer stations tend to fall into two categories according to the objective of the installation:

- **focus on the output stream.** This corresponds to sites that act as a feeder for other processes: e.g. solvent regeneration, incineration, chemical treatment. These sites target

WORKING DRAFT IN PROGRESS

specific waste streams that can be checked, analysed and bulked up to provide a steady feedstock for an associated process. They may also take in and process a variety of other materials in order to provide a full service to their clients. These sites tend to handle a much higher proportion of certain waste streams and acceptance, storage and control systems are therefore designed for these wastes

- **focus on the input waste.** These sites are independent transfer stations and generally accept a full range of materials from the neighbouring area. Typically they also bulk and blend materials to produce a range of waste streams suitable for disposal through different treatment, recovery and disposal processes, but they do not usually target any specific waste group. There may be a bias towards particular waste streams, but this will likely be due to local patterns of waste arisings and commercial opportunities, rather than the need to provide a feedstock for a particular downstream process.

The majority of operations linked to waste preparation may be distinguished under two groups:

- **regrouping/reconditioning.** Here the aim is to group together wastes in small or medium quantities, when they have the same nature and when they are compatible. The resulting waste though still has to be treated. The purpose of regrouping is to obtain larger and more homogeneous volumes for waste treatment, to improve safety (e.g. facilitation of handling) and to rationalise the logistics cost. The combination of processes used in waste preparation and in pretreatment operations depends on the specifications of final treatment
- **pretreatment.** Here the aim is to adapt the waste to the type of recovery and/or disposal of the final treatment available. Pretreatment covers several aspects. It can be defined as those operations that lead to homogenisation of the chemical composition and/or physical characteristics of the wastes. Pretreatment produces a waste, which may be very different from the initial waste, although not from a regulatory point of view. This pretreated waste still has to be treated in a recovery and/or disposal plant. At the end of the pretreatment process, the pretreated waste should comply with chemical and physical specifications that are fixed by the end users.

Grouping and pretreatment activities may be located at the same site as the final treatment, on the waste production site or on a particular dedicated site. Nevertheless, regardless of the location, the operating processes are the same.

Table 1.23 below shows the number of waste transfer installations and capacity in different European countries.

WORKING DRAFT IN PROGRESS

Table 1.23: Waste transfer installations

Country	Number of known installations		Known capacity (kt/yr)	
	Hazardous	Non-hazardous	Hazardous	Non-hazardous
Belgium	10			
Denmark	0		0	
Germany	125			
Greece	6			
Spain	68			
France			3000	
Ireland	12			
Italy	0		0	
Luxembourg	1			
Netherlands	2			
Austria	16			
Portugal	5	143	3975 m^3	Y
Finland	5	01	58	0
United Kingdom	439	2073		
Iceland	0		0	
Norway	0		0	
TOTAL	689	2216		

[1] No non-hazardous installations, other than facilities where waste is unloaded in order to permit its preparation for futher treatment.

Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Source: [23, Militon et al. 2000] [38, Azkona et al. 2000] [39, Weibenbach, T. 2001] [60, WT TWG 2003] [98, WT TWG 2004]

1.3.3 Installations containing a biological treatment of waste

Refer to the Scope chapter of this document to see which biological treatments of waste are covered. However, note that the data contained in Table 1.24 refer to all biological treatments, including those not covered in the Scope. The reason for this is that available statistics typically refer to national data and it is difficult to separate information of only those installations covered in the Scope of this document.

WORKING DRAFT IN PROGRESS

Table 1.24: Installations for the biological treatment of waste

Country	Number of known installations		Known capacity (kt/yr)	
	Hazardous	Non-hazardous	Hazardous	Non-hazardous
Belgium	5	Y		
Denmark	1	0		0
Germany	57	200		
Greece	0	Y	0	
Spain	3	Y	140	
France	0	Y	0	
Ireland	1	Y		
Italy	74	3		180
Luxembourg	0	Y	0	
Netherlands	7	Y		
Austria	8	16 [1]	103	706 1
Portugal	1	9	88	514
Finland	20	41	98	305
Sweden		Y		
United Kingdom	0	173		
Iceland	0	0	0	0
Norway	0	Y	0	
TOTAL	177	442	429	1705

Y: exists but no data are available

[1] Data corresponds to MBT only

Data in this table correspond to all types of biological treatments and not only to those related with the ones inside the scope of this document. Therefore, the number of installations covered by this document will be less than the figures appearing in this table

Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Source:[23, Militon et al. 2000] [38, Azkona et al. 2000] [39, Weibenbach, T. 2001] [60, WT TWG 2003] [98, WT TWG 2004]

In Finland there are 561 waste water treatment installations in which the septic tank sludges are also treated. There are 41 installations (aerobic 27 and anaerobic 14) for treating non-hazardous wastes. Besides the non-hazardous waste installations mentioned in Table 1.24 ,there are also 129 composting facilities, with a total capacity of 542 kt/yr.

In some countries (e.g. UK and Italy), biological treatment is mainly carried out by water companies, utilising existing capacity on waste water treatment works. It is estimated that there are potentially around 30 possible installations. The volumes of waste treated are small, typically less than 1 % of the input of the waste water treatment works, but in some cases this represents a significant COD load (in one case, 50 % of total COD input to the waste water treatment works). However, this type of treatment poses questions because there is a possibility of diluting contaminants as well as contaminating the sewage sludges coming from this kind of treatment.

1.3.4 Installations for the physico-chemical treatment of waste waters

This sector is represented by a large range of processes which are classed as ‘chemical treatments’. These range from blending systems with no actual chemical interactions to complex plants with a range of treatment options, some custom designed for specific waste streams.

The process is designed to treat waste waters (contaminated with, e.g. acid/alkalis, metals, salts, sludges), but usually accepts a range of organic materials as well, e.g. process plant washings and rinsings, residues from the oil/water separation, cleaning wastes, interceptor wastes, etc. These could contain almost any industrial material. It is likely that the treatment process will

WORKING DRAFT IN PROGRESS

have some effect on the organic materials, for example due to some chemical oxidation of COD, some organics could be adsorbed or entrained in the sludge or, in emulsion treatment, part of the organic content could become separated from the aqueous phase.

These treatment systems remove and/or detoxify hazardous constituents dissolved or suspended in water. The selection and sequence of unit processes will be determined by the characteristics of the incoming wastes and the required effluent quality. An example of a physico-chemical treatment facility of waste waters typically contains the following unit processes: cyanide destruction, chromium reduction, two-stage metal precipitation, pH adjustment (e.g. neutralisation), solid filtration, biological treatment, carbon adsorption, sludge dewatering, coagulation/flocculation and some others.

Table 1.25: Installations for the physico-chemical treatment of waste

Country	Number of known installations		Known capacity (kt/yr)	
	Hazardous	Non-hazardous	Hazardous	Non-hazardous
Belgium	8	Y		
Denmark	4	Y		
Germany	249	9000		
Greece	0	0	0	0
Spain	49		901	
France	19	Y	301	
Ireland	4	Y		
Italy	147	Y		
Luxembourg	1	0		0
Netherlands	30	0		0
Austria	33	Y	515	
Portugal	2	Y	22000 m^3	
Finland	36	0 [1]	144	0
United Kingdom	32	289		
Iceland	0	0	0	0
Norway	4	Y		
TOTAL	618	9289	1883	

Y: exists but no data are available

[1] No non-hazardous installations with this operation only

Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Source: [38, Azkona et al. 2000] [39, Weibenbach, T. 2001] [60, WT TWG 2003] [98, WT TWG 2004]

The physico-chemical (Ph-c) treatment of waste water typically divides the waste into another type of waste (typically solid) and an aqueous effluent which is not usually considered waste as it is part of another legislation.

Ph-c plants are essential to medium and small companies including commercial enterprises. Waste which must be treated by Ph-c plants will, in future, continue to be produced (in the course of production); obligatory acceptance of waste by generally accessible Ph-c plants is an advantage for trade and industry, facilitating correct disposal of waste and easing the economic burden for industry and trade.

The following principal configurations can be identified:

- company in-house Ph-c plants. These are specialised for the treatment of the waste produced by a company
- generally accessible Ph-c plants (service plants). These are suitable for the treatment of waste produced in certain regions.

WORKING DRAFT IN PROGRESS

1.3.5 Installations for the treatment of combustion ashes and flue-gas cleaning residues

During combustion processes, solid waste may be generated. Such solid waste is typically called ‘ashes’. Two types are usually present; one called ‘bottom ash’, typically recovered at the bottom of the combustion chamber and another called ‘fly ash’ that is smaller and flows with the combustion fumes. This latter one is usually recovered with flue-gas cleaning equipment. Such flue-gas cleaning equipment is not only applicable to fly ash but also to extract from the other pollutants flue-gases. In doing so, different types of waste can be generated. This section contains those installations that treat such a variety of waste generated during combustion processes as well as other flue-gas cleaning processes.

Combustion ashes and flue-gas cleaning residues are one of the main waste stream treated by stabilisation and solidification processes, either in the combustion plant (e.g. in some incinerators), or on waste treatment facilities. Other methods are vitrification, purification and recycling of some components (e.g. salts). Another method of treating combustion ashes involves the fusion of ash by plasma at very high temperatures in order to vitrify the structure. One installation exists in France with a total treatment capacity of 3.5 kt per year.

1.3.6 Installations for the treatment of waste contaminated with PCBs

Incineration, when available, is the most widely available and used technology for PCB destruction. The complete destruction of PCB by incineration only takes place under well defined conditions (e.g. high temperature and a higher residence time). Because of the cost of incineration, however, and its unavailability in many countries, alternative technologies are sometimes used.

1.3.7 Installations for treatment of waste oil

Used lubricating oils can be recovered to a quality essentially equal to some groups of base oils used to produce lubricating oils (some base oil groups III and IV rarely, if ever, contain re-refined oils). This process is typically referred to as ‘oil re-refining’.

The recovery of oil from waste is typically a part of the waste industry. There are licensed sites that specialise in the recovery of oil from different waste streams. In addition, a number of chemical treatment plants and transfer stations have oil separation units that undertake a first separation of oil from water before sending the oil layer through to a specialist plant for further processing. Some factors that define this sector are:

- companies that serve particular industrial sectors tend to offer a general waste service to that sector, and this may include waste oils
- companies that collect used lubricating oils from garages are also likely to collect oil filters, steering, brake and transmission oils, antifreeze and batteries
- companies handling transformer oils are likely to collect oils with some small amounts of PCBs
- some chemical and biological treatment plants undertake small-scale oil recovery operations as part of their pretreatment processes. These are generally simple gravity separation systems.

There are large numbers of dedicated oil treatment and processing plants in the EU. Some companies carry out simple purification, removing the sediment and water from waste oil. Two type of treatments are applied to waste oils. One refers to its use as fuel and the other one corresponds to the re-refining of it so that part of it (typically 50 – 60 %) can be reused as a base

WORKING DRAFT IN PROGRESS

oil for lubricants. Oil processors show a wide range of intrinsic knowledge about their operations.

There are a wide variety of processes and licensors currently offering ways to deal with waste oils. There are four main processes used for the treatment of waste oils: blending, separation-chemical treatment, distillation and cracking.

In all waste oil treatment processes, the economic and calorific values of the waste oils are recovered to varying degrees. The two main techniques used are re-refining and direct burning (mainly in cement factories), each accounting for about 30 % of the total quantity recovered. The two other methods which, together, account for the remaining third are reprocessing and reclaiming, the latter principally being used for hydraulic oils.

The level of knowledge about oils is markedly different between sites. Partly due to the fact that waste oil is an extremely complex and changing material with a huge potential range of individual components that are not all categorised at present.

Data currently available regarding waste oil (WO) management in Europe are of very poor quality, particularly concerning regeneration. Figure 1.2 shows a summary of the percentages of the types of treatments used for the WO in each EU country. According to data from the sector in 1993, the used oils collected where disposed of by direct burning (32 %), by re-refining to base oils (32 %), by reprocessing to industrial fuel (25 %) and by reclaiming specific industrial oils 11 %. These percentages however have since changed considerably, as shown in the following Figure 1.2

WORKING DRAFT IN PROGRESS

Source: [4, Monier, V. and Labouze, E. 2001] [60, WT TWG 2003] [98, WT TWG 2004]

Figure 1.2: Management of waste oils in the EU in 1999

Re-refining

About 220 kt of re-refined base oil was produced in 2000 according to [4, Monier, V. and Labouze, E. 2001], which accounts for less than 5 % of the overall base oil demand in Europe.

In recent years, the level of regeneration carried out has noticeable decreased in some EU countries which were pioneers in its use such as France, Germany, Italy and others such as the UK. This is tempered by the fact that there are some new projects emerging in several countries: France, Germany, Italy, Spain.

The known installed feed capacity for re-refining base oil throughout Europe is just over 500 kt/yr, with installation capacities ranging from 35 to 160 kt/yr. Currently, there are around 400 re-refining facilities worldwide, with an overall capacity of 1800 kt/yr. Although most of these plants are located in East Asia (India, China and Pakistan), their individual capacity is mainly low, c.a. 2 kt/yr each, on average. Most of these plants use acid/clay and there are few which produce good quality re-refined base oils or which take into account environmental issues.

Table 1.26: Installations for re-refining waste oil in European countries

Country	Number of known installations	Known capacity (kt/yr)
Belgium	2	45
Denmark	1	40
Germany	8	770
Greece	1	40
Spain	2	69
France	2	200
Ireland	0	0
Italy	7[1]	273[1]
Luxembourg	0	0
Malta	2	2.4
Netherlands	0	0
Austria	0	0
Poland	1	80
Portugal	0	0
Finland	5	88
Sweden	0	0
United Kingdom	3 [2]	5 [2]
Yugoslavia	1	
TOTAL	35	1612.4

[1] two installations are currently not working. Capacity of the two installations not working is 25 kt/yr.

[2] A TWG member questionned such figures to not be correct

Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Source: [2, Concawe 1996] [4, Monier, V. and Labouze, E. 2001] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [21, Viscolube 2002] [60, WT TWG 2003] [84, Ribi, J. 2003] [98, WT TWG 2004]

Re-refining plants can adjust the quantity of re-refined base oil and fuels produced according to the international and local situation (crude oil prices, market demand, subsidies, etc.).

Preparation of waste oil to be used mainly as fuel

About 50 % of WOs (i.e. waste oil from ship and tank cleaning, waste oil from oil/water separator, waste oil from emulsions, etc.) is not waste lubricant oil or cannot be regenerated into base oil. These WOs can be converted into other oil products (e.g. fuel).

About 50 % of WOs were used as fuel in the EU in 1999. About 400 kt of WO are burned in cement kilns at the European level, which represents about 17 % of the total WO and 35 % of the WO burned, with the rate varying greatly between different countries. It represents the major

WORKING DRAFT IN PROGRESS

exploitation route in France, Greece and Sweden, but only one of several alternative routes in Austria, Belgium, Italy and the United Kingdom. Some other sectors in the EU using WO as fuel are:

- blast furnaces, as a substitute for coke (e.g. Belgium)
- brick kilns (e.g. Spain)
- ceramic kilns (e.g. Spain)
- large combustion plants (e.g. Spain)
- lime kilns (e.g. Spain, Belgium)
- cracking plants, to produce new fuels (e.g. in Belgium in accordance with legal standards)
- port receiving facilities which convert waste oil into ship's fuel (e.g. Malta)
- waste incinerators (e.g. 2 kt in 2002 in hazardous waste incinerators in Belgium)
- space heaters (e.g. service stations, greenhouses, etc.)
- asphalt plants.

The two latter applications are no longer used in Flanders (Belgium) because of more stringent environmental regulations brought into force in January 1999. Table 1.27 indicates the amount of used oil burned in some EU countries

Table 1.27: Volumes of used oil burned in EU per year

Burning options	Amount of waste oil (kt)	%
Cement kilns	307	42
Mixed with fuel oil	213	29
Other	120	16
Waste incinerators	52	7
Garage heaters	40	6
Total burned	**732**	**100**

Data only correspond to Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Spain and the United Kingdom.
Note: Obtaining a complete set of data on volumes of used oil burned in all EU countries in this study is difficult as details of the burning options are not consistently recorded.
Source: [2, Concawe 1996]

There is also a significant volume of oil contaminated waters collected for recovery. These wastes have a net negative value but are processed so as to maximise the recovery of the hydrocarbon for use as a fuel.shows some installations carrying out this activity.

WORKING DRAFT IN PROGRESS

Table 1.28: Installations where waste oils are used as fuel or where waste oil is reprocessed to produce a fuel

Country	Number of known installations			Known capacity (kt/yr)		
	Using waste oil in direct burning	Using reprocessed waste oil as fuel	Non-hazardous oil	Using waste oil in direct burning	Using reprocessed waste oil as fuel	Non-hazardous oil
Belgium	1	10				
Denmark	4	Y				
Germany	12	1		310	100	
Greece	0					
Spain	4	Y	1			
France	60			725		
Ireland		Y				
Italy	2					
Luxembourg	0	0		0	0	
Malta	0	1		0	4.7	
Netherlands		Y				
Austria	4	0	0		0	0
Portugal	Y	Y	1			
Finland	3	4	1	155	54.5	0.2
Sweden	2	3				
United Kingdom	160	Y				
TOTAL	252	19	3	1190	159.2	0.2

Y: exists but no data is available

Note: Columns related to non-hazardous oil correspond to the production of biodiesel from used vegetable oil.

Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Source:[4, Monier, V. and Labouze, E. 2001] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [84, Ribi, J. 2003] [98, WT TWG 2004]

Under EU legislation, it is illegal to dispose of WO in landfills, storm water or waste water drains. In some cases, used oil is applied to unsealed roads as a dust suppressant in some rural areas. About 25 % of the WO in the EU was unaccounted eliminated for in 1999.

1.3.8 Installations for treatment of waste solvent

Solvents are extensively used in chemical and biological processes. During these processes, waste solvent is produced and it is recycled in-house. These treatments are an integral part of the chemical/biological processes and they are covered in the different BREF documents. However for economic or technical reasons, sometimes the waste solvents are delivered to a third party (e.g. waste manager) for treatment. In some cases, the product of the treatment is returned to the waste producer and in other cases this does not happen.

Waste solvents are also produced in the area of solvent-based surface treatment (such as cleaning or degreasing in many different industrial sectors and in dry cleaning installations). In most cases, the contaminated solvents or the bottoms of the distillation columns (solvent content 1 – 10 % in the case of closed cleaning installations/devices with internal distillation devices) are delivered to solvent distillation installations and regenerated. The quality of the distillation products is as good as that of new solvents.

In accordance with the Waste Framework Directive, the first option for waste solvents, as well as for the rest of waste, is that it should be recycled. This has helped to generate an active solvent recycling market. Similarly to waste oils, waste solvents which are not suitable for regeneration because of certain compositions or because of very low purity can also be recovered as a secondary liquid fuel (SLF), for example, in the cement industry and hazardous

WORKING DRAFT IN PROGRESS

waste incinerators. A fundamental difference with waste oils is that waste solvent qualities fluctuate much more than the quality of waste oil.

Solvent regeneration facilities separate contaminants from waste solvents and thus restore the solvent to its original quality or may be to a lower grade product (e.g. in the case of lacquer thinner). Distillation (batch, continuous, or steam) is used by most commercial solvent processors, and typically recovers about 75 % of the waste solvent. The residue, known as 'distillation bottoms', can be a liquid or a sludge, depending upon a number of conditions, and typically requires management as a hazardous waste. Other separation technologies used by solvent processors include: filtration, simple evaporation, centrifugation, and stripping.

Table 1.29: Waste solvent installations in European countries

~~Country~~	~~Number of known installations~~	~~Known capacity (kt/yr)~~
~~Belgium~~	~~5~~	~~>8~~
~~Denmark~~	~~0~~	
~~Germany~~	~~21~~	
~~Greece~~	~~3~~	
~~Spain~~	~~14~~	~~64~~
~~France~~	~~27~~	~~90.7~~
~~Ireland~~	~~2~~	
~~Italy~~	~~2~~	
~~Luxembourg~~	~~0~~	
~~Netherlands~~	~~8~~	
~~Austria~~	~~2~~	
~~Portugal~~	~~1~~	~~10000 m~~^{3}
~~Finland~~	4	~~11~~
~~United Kingdom~~	~~8~~	~~>12~~
~~Iceland~~	~~0~~	
~~Norway~~	~~11~~	
~~TOTAL~~	~~108~~	~~185.7~~

~~Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.~~
~~*Source*: [24, Militon et al. 1998] [38, Azkona et al. 2000] [39, Weibenbach, T. 2001] [60, WT TWG 2003] [85, Cruz-Gomez, M. J. 2002]~~

Table 1.30: EC /EFTA Countries - Solvent Recovery Installations (2015 ESRG Members estimate)

Number of installations	**CAPACITIES (kt/yr.)**
41	**912**

Table 1.30 taken from a 2015 ESRG survey of its members shows that 41 major EU based installations had a combined treatment capacity of some 912 kt/yr. However it is noted that actual capacity is limited by the specific operation being undertaken and the associated complexity of the individual process.

1.3.9 Installations for the treatment of waste catalysts, waste from pollution abatement and other inorganic waste

The treatment of waste catalysts depends on the type of catalyst (catalytic active substance and supporting structure or carrier) as well as the included by-products from the catalytic process. These treatments include: regeneration of catalysts to be reused as catalysts again, recycling of

WORKING DRAFT IN PROGRESS

components from catalysts and disposal in landfills. An example installation is an Austrian facility for the recovery of Ni from food industry catalysts (Fe/Ni alloy).

Hydrometallurgical technology can be used to extract and concentrate metals from liquid waste. Non-liquid wastes first require dissolution.

In Malta, there are two underground asbestos storage sites and one overground pending treatment. The asbestos originated from ships being repaired in dock yards and from unused asbestos pipes.

Table 1.31: Installations for the treatment of waste catalysts, waste from pollution abatement and other inorganic waste in European countries

Country	Treatment of waste catalysts		Treatment of other inorganic waste (excluding metals and metal compounds)		Recovery of waste from pollution abatement	
	Number of known installations	Known capacity (kt/yr)	Number of known installations	Known capacity (kt/yr)	Number of known installations	Known capacity (kt/yr)
Belgium	0	0	13		1	
Denmark	0	0	3		1	
Germany	1		63		2	
Greece	5		0	0	0	0
Spain	0	0	6	195	15	3
France	3	4.9	0	0	0	0
Ireland	4		0	0	0	0
Luxembourg	0	0	0	0	0	0
Malta			3			
Netherlands	2		17		1	
Austria	3		14		0	0
Portugal	0	0	0	0	0	0
Finland [1]	0	0	9	3	0	0
Iceland	0	0	0	0	0	0
Norway	2		1		0	0
TOTAL	**20**	**4.9**	**129**	**198**	**20**	3

[1] The treatment of 1 million lamps containing mercury is not included.
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.
Source: [24, Militon et al. 1998] [38, Azkona et al. 2000] [39, Weibenbach, T. 2001] [98, WT TWG 2004]

1.3.10 Installations for treatment of activated carbon and resins

Most waste activated carbon and resin is a result of water purification processes. It is very difficult to estimate the regeneration throughput in Europe, mostly due to the fact that many operators regenerate their adsorbent on site (often sporadically) rather than sending it to large centralised reactivation plants.

Activated carbon is used in three principal applications: the treatment of drinking water; in the food and drink industry, for example for removing colour in the refining of sugar; and in general industrial applications, e.g. removal of VOCs from process vent streams. These applications affect the type of contamination on the carbon and the regeneration process that is then required. For example, carbon which has been used in industrial applications (‘industrial carbons’), such as in effluent treatment, requires a more stringent pollution abatement system than that used for the treatment of potable water or for that from the food industry.

WORKING DRAFT IN PROGRESS

At some point in the lifetime of the process, the carbon will become exhausted with the material that it is adsorbing. The carbon should then be regenerated or, if this is not possible, disposed of. The choice of route is naturally determined by economics and scale. In the treatment of potable water, the carbon is used in large quantities and is contained in large open topped concrete-lined carbon beds. These have a life expectancy before exhaustion of a few years. When they are regenerated, they result in large quantities to be treated. It is this application that represents the most common in the UK in terms of volume and it is regenerated either on site by a purpose built plant or transported off site for regeneration by a merchant operator. Because of the nature of the market there is a tendency that more regeneration facilities, once designed purely for 'in-house' materials, now offer a merchant regeneration service.

There are at least 19 sites in Europe regenerating activated carbons from off site. The estimated numbers are mentioned in the next Table 1.32

Table 1.32: Activated carbon installations in European countries

Country	Number of known installations	Known capacity (kt/yr)
Belgium	2	
Germany	3	
France	1	
Italy	5	
Netherlands	1	
Austria	1	
Finland	1	
Sweden	1	
United Kingdom	4	
TOTAL	19	>50

Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.
Source: [98, WT TWG 2004]

The most common reactivation furnaces are direct fired rotary kilns and multiple hearth furnaces. Indirect fired rotary kilns, fluidised bed, vertical tube type and infrared are sometimes used. The type of granular activated carbon (GAC) reactivation furnaces in use worldwide in early 1990 are shown in Table 1.33.

Table 1.33: Type of GAC reactivation furnaces in use worldwide

Type of GAC reactivation furnace	Number of units
Multiple hearth	>100
Fluidised bed	<20
Indirect fired rotary kiln	>50
Direct fired rotary kiln	<30
Vertical tube-type	<30
Infrared furnaces (horizontal and vertical)	<9

Source: [26, UK, H. 1995]

Quantitative figures for ion exchange resin regeneration facilities are not available.

WORKING DRAFT IN PROGRESS

1.3.10.1 Installations for the treatment of waste acids and bases

There are several installations in the EU which regenerate HCl. No installations have been identified to recover HBr. Waste sulphuric acid can be regenerated in the following ways:

- thermal decomposition of waste/spent/recovered sulphuric acid, the result then being used as a primary or supplementary source of SO_2 feed to a sulphuric acid contact process. This is covered in the LVIC(AAF) BREF [40, EIPPCB 2003], s is any process that produces SO_2 as a feedstock by decomposition/calcinations.
- a process based on the reconcentration of weak/spent/waste sulphuric acid, with or without separation of potential impurities (e.g. salts). This will be included in this document
- industrial processes that use sulphuric acid and include a recycling of the spent sulphuric acid as an integral part of the process. This will be covered in the BREF where the industrial process is covered (e.g. BREF LVIC-solids and others for titanium dioxide production).

Table 1.34: Installations for the regeneration of waste acids or bases

Country	Number of known installations	Known capacity (kt/yr)
Belgium	1	
Denmark	1	
Germany	2	
Greece	0	
Spain	1	42
France	3	2
Ireland	1	
Luxembourg	0	
Netherlands	0	
Austria	4	
Portugal	0	
Finland	0	
Iceland	0	
Norway	0	
TOTAL	**13**	44

Values correspond to regeneration installations covered by this document and the LVIC-AAF BREF
Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.
Source: [24, Militon et al. 1998] [38, Azkona et al. 2000] [39, Weibenbach, T. 2001] [98, WT TWG 2004]

Acid recovery usually involves the separation of unreacted acid from an acid waste such as spent pickle liquor generated by the steel industry. One method used in the steel industry, involves cooling the sulphuric acid to precipitate ferrous compounds. In another method, acid can be regenerated by injecting it into a spray roaster.

1.3.11 Installations for the treatment of contaminated wood

In some cases, contaminated wood is directly incinerated. In other cases, contaminated wood is thermally treated by carbonisation/pyrolysis. All these treatments are covered by the WI BREF. However, in some cases treatments are used focused on the extraction of heavy metals from the solid residue generated by carbonisation of contaminated wood – these processes are covered in this document. One installation is in operation in France.

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1.3.12 Installations for the treatment of contaminated refractory ceramics

Two installations are in operation in France with a total treatment capacity of 50 kt per year.

1.3.13 Installations for the preparation of waste to be used as fuel

Currently, there are several factors driving the concept of using waste as a fuel in combustion processes:

- Waste Framework Directive and its amendments sets a waste management hierarchy. This gives a preference to recycling and recovery (including the use of waste as a source of energy)
- waste sector regulations, such as the ‘packaging waste’ Directive, ‘end-of-life vehicles’ Directive, ‘waste from electrical and electronics’, ‘waste incineration’ Directive, ‘waste catalogue’, ‘dangerous substances’ Directive and ‘dangerous preparation’ Directive may also influence the option
- the Landfill Directive prohibits the landfilling of waste with a high content of biodegradable materials. Therefore, there is a need to establish alternative ways for treating the respective waste fractions. Co-incineration is one option among others (e.g. incineration, mechanical biological treatment)
- under the requirement of the Kyoto protocol, greenhouse gas emissions have to be reduced worldwide. Co-incineration of waste fractions as a replacement for conventional fuels may be one option to reduce greenhouse gas emissions
- as liberalisation of the energy market intensifies economic pressure on the energy producers/consumers. The co-combustion of waste opens a new scope of business for them, which makes operation of combustion plants more attractive economically
- to reduce the cost of fuel used in the combustion processes.

The term ‘waste fuel’ is used in this document for all types of waste materials that are prepared to be used as fuel in any combustion process. Waste fuels can be gaseous, liquid or solids. For instance, liquid waste fuels can be prepared from waste oils, solvents, and distillation bottoms. The way the liquid waste fuel is going to be used in the combustion process influences the way the waste fuel is prepared. For example, some liquid waste fuels can be prepared by blending different wastes that have high calorific values and feed them independently into the combustion chamber or they can be mixed/blended with conventional fuels (e.g. waste oil and fuel oils). Some liquid wastes, for instance oils, normally need pretreatment to remove bottoms, sediments, and water. This may be achieved through separation and dehydration.

Some combustion processes that may use waste as (part) fuel are the combustion plants for the production of heat and/or power, marine engines, cement kilns, blast furnaces in iron and steel production, brick kilns in the production of ceramics, lime kilns and asphalt production. The type of furnace or boiler used, the combustion conditions (e.g. temperature) that the process should operate, the impact on the emissions or products and the type of fuel already in use has a strong influence in which the type of waste(s) may be acceptable and how the waste fuel is prepared.

The purpose of those installations is to guarantee the following aspects:

- optimise the valorisation of certain waste avoiding its landfilling
- the quality of thermal destruction
- provide the required physico-chemical properties of the waste fuel to end user.

The basic principles of waste fuel production are the following:

WORKING DRAFT IN PROGRESS

- the chemical and physical quality of the fuel shall meet any specifications or standards ensuring environmental protection, protection of the kiln/furnace process, and quality of the material produced, where the combustion process where the waste fuel is used produces a product (e.g. cement)
- energy and mineral contents must remain stable to allow optimal feed in the kiln/furnace
- the physical form must allow safe and proper handling, storage and feeding.

Table 1.35: Installations for the preparation of waste to be used as fuel

Country	Number of known installations		Known capacity (kt/yr)	
	Hazardous	**Non-hazardous**	**Hazardous**	**Non-hazardous**
Belgium	12	Y		
Denmark	4	13		
Germany	16	34		
Greece	0	0		
Spain	33	5	204	
France	54	Y	542	1400
Ireland	2	Y		
Italy		27		2080
Luxembourg	0	Y		
Netherlands	1	Y		
Austria	8	10		
Portugal	0	Y		165
Finland	7	37	106	800
Sweden	Y	Y		
United Kingdom	Y	Y		
Iceland	1	Y		
Norway	2	Y		
TOTAL	**140**	126	852	4445

Y: exists but no data are available

Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Source: [23, Militon et al. 2000] [24, Militon et al. 1998] [38, Azkona et al. 2000] [39, Weibenbach, T. 2001] [60, WT TWG 2003] [98, WT TWG 2004]

Preparation of municipal solid waste to be used as fuel

The current best estimate of the quantity of solid recovered fuels produced and consumed in Europe is about 1.4 Mt/yr, as set out below.

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Table 1.36: Summary of European solid recovered fuels market in 2000 in Europe

Country	Producers	Production			Consumption		Export/Import +	CK
		kt/yr	toe/yr	kt/yr	kt/yr	toe/yr	kt/yr	%
Belgium	7	<100	<50000	<100	<50000	n.a.	n.a.	(100)
Denmark	1	0	0	0	0			
Germany	19	500 (650)	250000 (325000)	500 (650)	250000 (325000)	n.a.	n.a.	85
Greece		0	0	0	0			
Spain		n.a.	n.a.	n.a.	n.a.			
France	3	0	0	0	0			
Ireland		<200 (250)	<100000 (125000)	<200 (250)	<100000 (125000)	n.a.	n.a.	
Italy	25	0	0	0	0			
Luxembourg	23	0	0	0	0			
Netherlands		250 (350)	100000	15	6000	-145	60000	20
Austria	26 3	160	50000	100	50000			7
Portugal	8	0	0	0	0			
Finland	10	170	58000	170	58000	n.a.	n.a.	0
Sweden	4	1		1		+500 2		
United Kingdom		60 (100)	30000 (50000)	60 (100)	30000 (50000)	n.a.	n.a.	
Iceland		0	0	0	0			
Norway	29	1		1				
TOTAL	155	1380						

toe/yr = tonnes oil equivalent per year (It is assumed that solid recovered fuel has a calorific value of 21 MJ/kg, although it is lower in Finland and the Netherlands, and oil has a calorific value of 42 MJ/kg)
CK = % of consumption that occurs in cement kilns

The figures in this table are only indicative as they do not correspond to the same harmonised definition used throughout the European Union

[1] There is no overall statistic for Sweden or Norway because this fuel is used in ordinary heat/power plants and in waste incinerators without a demand for detailed specifications. Data for Sweden (2001) are: waste incineration plants for district heating 856000 t/yr and power plants for district heating 455000 t/yr.

[2] No exact figures exist, but approximate figures give 500 kt of waste imported in 1999. 90 % consisted of wood, paper, plastic and rubber.

[3] A TWG member thinks that this value is too high but has not provided any alternative value.

Source: [15, Langenkamp, H. and Nieman, H. 2001] [82, Pretz et al. 2003] [98, WT TWG 2004]

Industry's best estimate of solid recovered fuel production in 2005 is about 11 Mt/yr. (Table 1.37)

WORKING DRAFT IN PROGRESS

Table 1.37: Forecast/potential for the European solid recovered fuels market in 2005

Country	**Production**		**Consumption**		**- Export/Import +**		**Δ 2000**
	kt/yr	toe/yr	kt/yr	toe/yr	kt/yr	toe/yr	**%**
Belgium	100	50000	100	50000	n.a.	n.a.	0
Denmark	0		0				
Germany	3000	1500000	4000	2000000	+1000	+500000	
Greece	500	250000	500	250000	n.a.	n.a.	
Spain	1000	500000	1000	500000	n.a.	n.a.	
France	1000	500000	0	0	-1000	-500000	
Ireland	500	250000	500	250000	n.a.	n.a.	
Italy	1000	500000	1000	500000	n.a.	n.a.	
Luxembourg	50	25000	50	25000	n.a.	n.a.	
Netherlands	1000	400000	600	240000	-400	-160000	
Austria	500	250000	500	250000	n.a.	n.a.	400
Portugal	500	250000	500	250000	n.a.	n.a.	
Finland	350	120000	350	120000	n.a.	n.a.	100
Sweden	500	250000	1000	4500000	+500	+200000	
United Kingdom	600	300000	600	300000	n.a.	n.a.	
Switzerland	0	0	0	0			
Iceland	0		0				
Norway	150	75000	150	75000	n.a.	n.a.	
Total	10750	5220000					

Notes: toe/yr = tonnes oil equivalent per year (It is assumed that solid recovered fuel has a calorific value of 21 MJ/kg, although it is lower in Finland and the Netherlands, and oil has a calorific value of 42 MJ/kg)

Δ 2000 = Difference from year 2000

It is assumed that no solid recovered fuel (SRF) is exported outside the European Union.

The figures in this table are only indicative as they do not correspond to the same harmonised definition used t by the European Commission.

Note: Numbers within this table may not reflect the real number of installations or capacity. The main reasons are that the market is so dynamic that numbers change rapidly and/or because no data have been provided by the TWG at all on certain topics. Cells without numbers mean that no information has been provided.

Source:[82, Pretz et al. 2003]

The consumption of hard coal and lignite for power production in the EU was 145 Mtoe/yr in 1999 (European Commission 1999 Annual Energy Review). Using this figure, it can be calculated that the total production of solid recovered fuel as forecast in Table 1.37 for 2005 (i.e. more than 5 Mtoe/yr) represents a substitution rate of 3.5 %.

Preparation of waste fuel from hazardous waste

The use of hazardous waste as fuel started in the mid seventies when the petroleum crisis drastically increased the cost of the fuel oil and also when, in different countries, new regulations were issued concerning waste disposal. As a large amount of energy-rich waste (mainly solvents) was available, the co-processing of waste in cement kilns was an obvious answer to the situation on both environmental and economical terms. Later, in order to increase the energy saving, more and more sophisticated pretreatment processes have been developed, first to produce liquid waste fuel and more recently, i.e. in the nineties to produce solid waste fuel.

Estimated data were provided by some EU companies and are shown below in Table 1.38. These data are based on the market situation in EU-15.

WORKING DRAFT IN PROGRESS

Table 1.38: Production and site numbers of preparation of waste fuel mainly from hazardous waste in EU-15

Preparation of waste fuel from hazardous wastes	**Number of installations**	**2001 Production (kt/yr)**
Liquid waste fuel from organic liquid	107	650
Liquid waste fuel from fluidification	7	108
Liquid waste fuel from emulsions	3	48
Liquid waste fuel	117	806
Solid waste fuel	26	465
Total	143	1271

Note: The data correspond to estimations established in December 2002
Liquid waste fuel (excluding oils). Data have been established for regrouping and pretreatment plants from France, Belgium, the Netherlands, Germany, Italy, Switzerland, Spain, Portugal, Ireland, United Kingdom, Sweden, Norway, Czech Republic and Slovakia. The size and capacity of a liquid waste fuel pretreatment plant varies widely, from 5000 to 100000 tonnes/year. For regrouping facilities, the typical size of a plant ranges from 1000 to 20000 tonnes/year.
Solid waste fuel. Data have been established for pretreatment plant production in 2001 from France, Belgium, the Netherlands, Germany, Italy, Switzerland, Spain, Portugal, Poland, Norway and Slovakia. The average size capacity of a solid waste fuel pretreatment plant is 18000 tonnes/year, with capacities ranging from 2000 to 70000 tonnes/year.
Source:[78, Eucopro 2003] [98, WT TWG 2004]

WORKING DRAFT IN PROGRESS

1.4 Economics [~~and institutional aspects~~] of the waste treatment sector

Waste treatment is typically a high volume low return process. A fixed or lowered base price, either for the incoming waste or for the recycled product, has placed the commercial emphasis on maximising throughput and reducing cost overheads.

Cost and price of waste treatment is typically established on the basis of investments and running costs. However, in some cases, prices may be determined by operators at the 'low' end of the market. In some other cases, the prices are fixed by agreement between the waste producer and the waste manager, where these may be different for a particular waste depending on who has produced it. Although there are exceptions, and also particularly for older plants, investment levels have been low, due to the low returns and competition with the low prices of landfills. It is expected that high levels of investment will be required to meet the standards set by the actual regulatory regime.

The industry has generally maximised the constructive use of some waste types to treat other wastes, this is expected to continue, particularly using waste as a raw material.

Competition exists between regional, national and international companies. One example is in the collection of waste oil, where national collectors work on large volumes as an economy of scale while local/regional operators, compete with the advantage of having lower overhead costs.

Hazardous waste management facilities typically, under the duty to tender delivery, accept all types of hazardous waste for correct disposal without regard to competition. However, some dedicated facilities, which may be in competition for certain types of waste, would only need to bid for any hazardous waste that they can handle. In this respect, different configurations have been developed for the designated hazardous waste management facilities and competing facilities.

Some WT plants, due to their regionalisation and/or the need for proximity, contribute to a substantial decrease in waste transportation. However, other WT plants are working on a superregional, national or even international basis mainly depending on the specialisation of certain treatment operations.

~~Impact of new waste legislation on the waste treatment sector~~
~~Waste production is avoided in accordance with Council Directive 75/442/EEC of 15 July 1975 on waste; where waste is produced, it is recovered or, where it is technically and economically impossible, it is disposed of while avoiding or reducing any impact on the environment. It is worth mentioning that the IPPC Directive would have a direct impact on the waste treatment industry as well as on producers of waste.~~

Regulatory conditions are being put in place, some of them at EU level (e.g. for incineration, landfilling, electrical and electronic waste, end-of-life vehicles), to break the cycle of high volume, low return and low investment. This is expected to lead to greater investment in the sector and a move towards developing techniques to treat those wastes which were previously directly landfilled, or to improving processes which before were not treating the wastes effectively for example by means of ~~. This will require the development of dedicated~~ plants ~~and, probably,~~ or equipment for the treatment of specific wastes.

As a consequence of the ~~Whilst~~ restrictions on landfilling introduced by legislation[1], ~~which will be introduced by the Landfill Directive, will require more~~ treatment of waste either prior to or

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[1] E.g. Directive 1999/31/EC on landfill and related Council Decision 2003/33/EC on landfill acceptance criteria

WORKING DRAFT IN PROGRESS

instead of landfill ~~this may~~ is leading to the continuing development of ~~sites utilising~~ recycling, recovery, stabilisation and fixation processes for a number of waste streams.~~ techniques. However, these techniques are still quite basic and subject to a number of serious problems.~~

~~Waste oil treatment is also likely to increase and change, especially as the implementation of the Landfill Directive bans the landfilling of oil/water streams from 2002 to 2007.~~

Regulatory compliance ~~could be thought of as a separate function reacting to external forces, yet in reality this~~ is essentially the driving force for waste treatment ~~the entire~~ facilities. The market for waste facilities is heavily influenced by dynamic regulatory programmes that continue to undergo significant change. ~~The operation of a facility is thus geared around managing waste in a manner that meets, if not exceeds, environmental regulations. This is no easy matter due to the large amount of regulation the industry is subject to.~~

Waste oils
Environmental consciousness in the 1980s has had a number of consequences on the waste oils treatment sector, in particular:

- the shutting down of many acid/clay re-refining plants, mainly in the US, for both economic and environmental reasons
- the use of improved equipment and devices to reduce the potential pollution from burning used oil
- the development of improved re-refining technologies for both environmental and product quality reasons.

Physico-chemical (Ph-c) treatment plants
There are continuous changes in the production process modifying the type of waste as well as the auxiliary substances used. In this respect, even the Ph-c plants are subject to constant adaptation processes, both in terms of the procedures used and the controls. Furthermore, changes in the regulatory frameworks also lead to plant reconfigurations; in general, these changed regulations aim at a significant reduction in Ph-c plant emissions. The reconfiguration can affect all the functional areas of a Ph-c plant, including plant technology, process materials, laboratory equipment, and even the general and specialist knowledge of the staff.

Preparation of municipal solid waste (MSW) to be used as fuel
The history of use MSW as fuel goes back to the oil crisis of the '70 ~~30 years ago~~. Then RDF (refuse-derived fuel) was promoted as a substitute low cost fuel, although the fuel was never fully accepted by the market. However, in the past 10 years there has been a growing interest within the cement, lime, steel and energy industries in fuels derived from waste, mainly due to economic reasons. Existing European energy policy targets and waste management policy give an impetus to the usage of waste derived fuels based on non-hazardous wastes. These fuels, with an average content of 50 - 60 % on biogenic, may contribute considerably to the reduction of CO_2 emissions and the doubling of the share of renewable energy. Moreover, due to market liberalisation and the need for cost reductions, industry is increasingly becoming more interested in less expensive homogenous substitute fuels of a specified quality. ~~At present, the main end-users are the industries. However,~~ The market ~~potential for the future~~ is the heat-and-power and ~~cement and lime~~ sectors.

Waste management policy aiming at a reduction in landfill disposal of biodegradable waste directly influenced the development of facilities for the production of waste fuels. Also the (high) tax system applied to landfilling is a major driving force in some Member States. Contrary to enforced changes 30 years ago due to the oil crisis, the producers of the waste fuels took the initiative for a quality system that should guarantee the properties of the solid waste fuel produced out of MSW and therefore make it a more reliable product. Quality systems exist in several Member States now. ~~CEN was given a mandate by the Commission to develop standards for so-called 'solid recovered fuel' (SRF) based on non-hazardous wastes these are currently underway~~

WORKING DRAFT IN PROGRESS

The main outlets of SRF are currently in the cement and lime industries, ~~The use in~~ coal-fired power stations, ~~is an emerging sector.~~ steel mills that use SRF as a carbon substitute. In Nordic countries, SRF is mainly used for the production of heat in industries and district heating. ~~The breakdown of the fuel consumption used to produce cement is given in Table 1.39.~~

Table 1.39: Fuel consumption by the European cement industry

~~Fuel~~	~~%~~
~~Petroleum coke~~	~~39~~
~~Hard coal~~	~~36~~
~~Fuel oil~~	~~7~~
~~Lignite~~	~~6~~
~~Gas~~	~~2~~
~~Waste~~	~~10~~
~~*Source*: [82, Pretz et al. 2003]~~	

~~The specific energy consumption for cement is 3 – 4 MJ/kg clinker. Assuming 0.75 kg clinker/kg cement, a substitution rate of fuel of 30 – 50 % and a LHV of SRF of 19 MJ/kg, this means there is a potential use of 6 – 11 Mt SRF/yr. Assuming an energy consumption of 4 MJ/kg lime, at the same substitution rate as for cement kilns, this means a potential of 1 – 2 Mt SRF/yr could be used for an annual production of 20 Mt of lime.~~

~~The estimated use of SRF in hard coal and lignite for power production in the EU is 14 – 29 Mt SRF/yr (supposing a substitutation rate at a minimum of 5 – 10 % on heat bases). The total potential market for SRF may be 21 – 42 Mt/yr, which is a substantial amount of the SRF that could be produced from MSW and other combustible wastes. There are large differences between countries. Germany still has a lot of lignite and coal fired power plants. France, has a policy geared towards using nuclear power plants, and therefore only has few coal fired power plants. In the 'CEN report on Solid Recovered Fuels' [15, Langenkamp, H. and Nieman, H. 2001]a potential of SRF use is indicated as between 33 and 50 Mt/yr. The conclusion is that the SRF production is increasing and can become an essential link in the waste management system.~~

WORKING DRAFT IN PROGRESS

1.5 General environmental issues related to installations that treat waste

Waste composition is very variable and the potential range of components that might be present is enormous. Due to such variance in components and composition, there are very few common emissions from waste management operations since each site has a slightly different combination of unit operations, and accepts a different range of wastes based on local circumstances.

The intention of this section is to give a short overview of the main environmental issues in the sector. A more precise picture of the environmental issues of the sector is developed in Chapter 3.

Air emissions

Most waste installations have emissions to air of carbon dioxide, ammonia and particulate matter. Certain organic substances can be commonly identified at almost every site and it is worth noting that most sites create some kind of particulate emission simply through handling products. Issues such as odour and volatile organic compounds are also relevant. Other contaminants that might be found at some sites are hydrogen chloride, ammonia, amines, hydrogen sulphide. Other components that may occur are PAHs and dioxins mainly because they are imported with the waste to be treated. These are a problem from both a health and an environmental point of view. They are formed during the incomplete combustion of organic matter (e.g. incineration, co-incineration, combustion of some fuels) and via reformatting during cooling down of the off-gas. PAHs are relatively difficult to break down. Table 1.40 shows the main air emissions from waste treatment operations.

Table 1.40: Main air pollutants emitted by waste treatments and their main sources

Main air emissions	Waste treatment operation
Acids (HCl)	Incineration Physico-chemical treatments
Ammonia	Biological treatments Physico-chemical treatments
Carbon oxides	Energy systems Thermal treatments Biological treatments
Microbiological pollution	Biological treatments Biofilters
Nitrogen oxides (N^2O, NO, NO^2)	Energy systems Thermal treatments Biological treatments
Sulphur oxides	Energy systems Thermal treatments
Particulates (including metals)	Energy systems Storage and handling of solids Thermal treatments
Volatile organic compounds (VOC)	Biological treatments Waste oil treatments Waste solvent treatments Hydrocarbons/water separation systems Storage and handling of organic substances

Note: Refer to Chapter 3 for specific emissions to different waste treatment operations.

Water emissions

Most waste installations declare an emission of total nitrogen, total organic carbon, total phosphorus and chloride to water. Table 1.41 gives a summary of the main water emissions from waste treatment operations.

WORKING DRAFT IN PROGRESS

Table 1.41: Main water pollutants (parameters) emitted by waste treatments and their main sources

Main water emissions	Waste treatment operations
Chlorinated compounds (e.g. AOX)	Waste solvents treatments
Metals (e.g. As, Cd, Cu, Hg, Ni, Sn, Zn)	Biological treatments Common storage and handling of waste Physico-chemical treatments of metal extraction, finishing waste, fine chemicals and organic manufacture. Waste oil treatments
Organic chemicals (e.g. BOD, COD, TOC, hydrocarbons, phenols, BTEX)	Waste oil treatments Waste solvent treatments Energy systems
Total nitrogen	Physico-chemical treatments Biological treatments
Total phosphorus	Physico-chemical treatments Biological treatments
Note: Refer to Chapter 3 for specific emissions to different waste treatment operations.	

~~Waste~~ Outputs

Generally, the output from WT installations is a treated waste. However, those outputs can be differentiated in two types. One type refers to the treated waste (typically representing the main part of the output) that in some cases can be reused elsewhere. The other type is represented by the waste generated by the treatment process itself. The appearance of the latter one does not only just depend on the type of waste treated, but also on the type of treatment given to the waste. Indeed, this second type of waste is more dependent on the treatment than on the actual type of waste treated.

Soil and groundwater contamination

In the past, unprecautionary handling of wastes has been at the origin of land contamination, as has been the case in almost all industrial sectors. As is the case in many other industries, the waste treatment industry is not currently an activity which leads to land contamination. According to the process and the type of wastes used, prevention actions have been developed such as retention, impermeabilisation, and undergroundwater monitoring, in order to prevent and control soil and groundwater contamination.

WORKING DRAFT IN PROGRESS

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2 PROCESSES AND TECHNIQUES COMMONLY USED FOR WASTE TREATMENT

From ex-**Section 2 "Applied processes and techniques"**

~~This section describes those treatments and processes within the waste treatments sector which are included within the Scope of this document. This chapter is for those interested in gaining a general understanding of the processes and activities found in the industrial sector, and for those interested in the interrelationships between the industrial processes and the topics described in later chapters of this document, i.e. consumptions, emissions and best available techniques.~~

~~Therefore, the aim of this chapter is not to replicate published engineering information already available in general literature. This means that some techniques widely used in the WT sector will not be described in this chapter because they are simple unit operations widely explained elsewhere. For those techniques, summary tables will be presented which will highlight as far as possible the purpose, the principle and the users.~~

~~Structure of this chapter~~

~~The processes and activities found in the WT sector are divided into six sections in this document. Such structure/classification should not be interpreted as any attempt to neither interpret IED IPPC Directive or any EU waste legislation Such structure should not be interpreted as any attempt to, nor give guidance if a waste treatment is "Recovery" or "Disposal" under the EU waste legislation. [98, WT TWG 2004]~~

~~The sections are:~~

This chapter describes (in Section 2.1) ~~covers~~ those ~~stages~~ processes commonly found in the waste sector that are generally applied and that are not specific to any individual type of waste treatment (WT)~~ (e.g. reception, blending, sorting, storage, energy system, management~~). ~~The unit operations associated with these treatments are also covered.~~ ~~Figure 2.1 shows a flow diagram for a typical waste treatment installation. The brown boxes correspond to the parts that will be covered in this first section~~. This chapter also gives information about the data collection used to review this document as well as an overview of the emissions encountered across the sector (Section 2.2). Finally, Section 2.3 addresses the techniques to consider in the determination of BAT for the processes commonly found in the waste treatment sector.

- ~~*common techniques*~~.

- ~~*biological treatments* and some mechanical-biological treatments (e.g. aerobic/anaerobic digestions). The unit operations associated to these treatments are also covered.~~
- ~~*physico-chemical treatments*. This covers treatments such as precipitation, decanting, neutralisation and centrifuging, solvent recovery and any thermal treatments not included in the WI BREF.~~
- ~~treatments applied to waste in order to enable the *recycling/regeneration* of materials (e.g. catalysts, solvents, waste oils, etc.). The unit operations associated to those treatments are also covered~~
- ~~treatments applied to turn a waste into a material that can be *used as a fuel* in different industrial sectors. The unit operations associated to these treatments are also covered~~
- ~~end-of-pipe techniques used in waste treatment installations for the *abatement of emissions*.~~

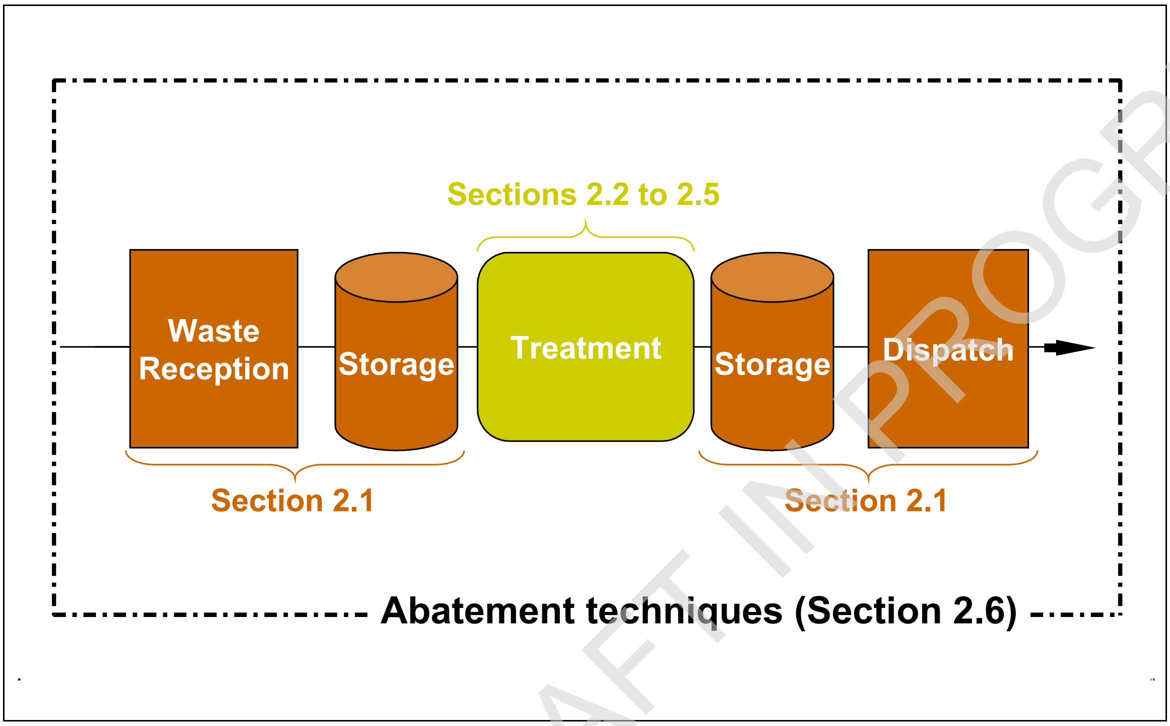
~~The unit operations associated to these treatments are also covered in the respective section.~~

~~Sometimes classifying a complex treatment under a specific category is difficult and certain block such exceptions to any of these categories are indicated by cross-referencing other categories might be present.~~

WORKING DRAFT IN PROGRESS

~~Note: This figure only tries to give a snapshot of how information is structured in this document.~~
~~Within the block 'preparation of waste to be used as fuel', the combustion process is not included under the scope of this document. For further information, please refer to Scope section.~~

~~Figure 3 and Figure 2.1 illustrates the classification mentioned above. This classification is also repeated in each of the following chapters to maintain coherence and to make it easier for the reader to cross-reference information.~~



~~**Figure 2.1: Typical operations in waste treatments and how these have been distributed in this and subsequent chapters**~~

Many processes and techniques listed in this chapter are briefly described, with information provided in the structure shown in Table 2.1. This same structure is used for each process and technique, to help the reader to easily assess the information within this document.

WORKING DRAFT IN PROGRESS

Table 2.1: Information contained in the description of each technique/process included in Chapter 2

Name of the type of information	Type of information included
Purpose	A brief explanation of what ~~this type of WT~~ the process is used for
Principle of operation	The type of process carried out and a brief explanation of it
Feed and output streams	The type of waste that can be treated by the treatment, as well as details of any products of the operation
Process description	A brief description of the process. Where appropriate, figures and diagrams will be used
Users	Reference to the number of plants using the technique in Europe and worldwide. Also, details of which WT sector(s) use(s) this type of technique
Source: [98, WT TWG 2004]	

~~*Waste treatment installations*~~

~~While the waste is in storage, a treatment schedule is developed to that identify ies:~~

- ~~the waste to be treated,~~
- ~~its storage location,~~
- ~~any necessary preparations,~~
- ~~the treatment method, and~~
- ~~the rate at which the waste is to be fed.~~

~~At the start of the waste treatment, the waste is typically fed by bulk materials handling systems, such as pipelines or conveyors, to the equipment used to perform the prescribed treatment steps. Treatment operations may be carried out on a batch or continuous basis.~~

~~Different types of approaches are common for waste treatment installations. They can broadly be classified into three groups:~~

- ~~waste installations included in the same place where the waste is produced. These typically serve a rather small number of wastes types and can provide only a restricted number of treatments~~
- ~~specific dedicated waste installations, which may provide one or several operations but which typically treat only a small number of waste types or which produce a relatively small amount of output~~
- ~~integrated waste treatment installations. Some waste treatment installations are not standalone installations only containing a single type of treatment. Some of them are designed to provide a wide variety of services, and they are designed to treat a great variety of waste types. As mentioned in Section 1.1, waste treatment installations are designed to produce required waste treatment services. For example, sometimes they are designed to provide a certain type of treatment to deal with a large amount and variety of different waste types (e.g. aqueous wastes, municipal solid wastes). Figure 2.2 is one example of such a complex installation.~~

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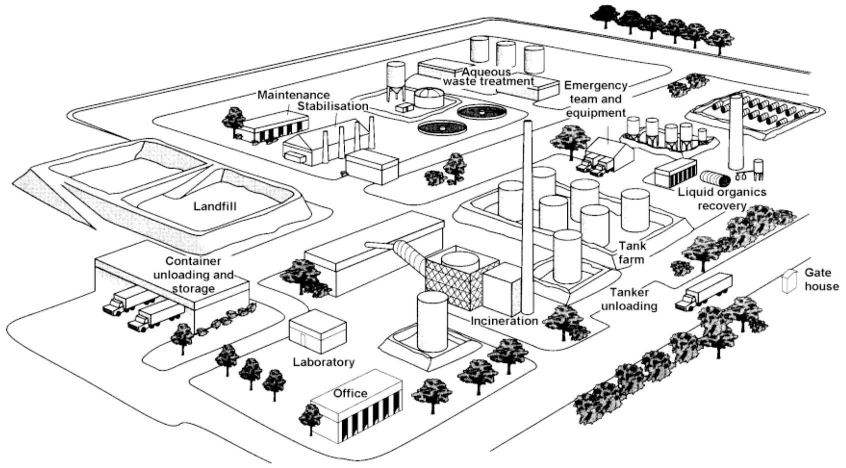

~~*Source*: [31, LaGrega et al. 1994]~~

Figure 2.2: Example of an integrated waste treatment installation

~~Table 2.2 matches the operations carried out at WT installations with the components of the fully integrated facility. It is important to note that all components operate under an umbrella of a number of special measures. These special precautionary measures include security, inspections, maintenance, training, incident prevention, emergency planning, safety, monitoring, and auditing.~~

Table 2.2: Examples of operations subsystems and their components

	~~**Operations subsystems**~~				
~~**Facility components**~~	~~**Pre-shipment waste analysis**~~	~~**Waste receiving**~~	~~**Waste storage and preparation**~~	~~**Waste treatment**~~	~~**Solid outputs management**~~
~~Analytical laboratory~~	~~**X**~~	~~X~~			
~~Truck waiting area~~		~~X~~			
~~Gatehouse~~		~~X~~			
~~Weighbridge~~		~~X~~			
~~Drum unloading and storage~~		~~X~~	~~X~~		
~~Tank farm~~		~~X~~	~~**X**~~		
~~Bulk waste and waste preparation~~		~~X~~	~~X~~		
~~Biological treatment~~				~~X~~	~~X~~
~~Physico/chemical treatment~~				~~X~~	~~X~~
~~Stabilisation plant~~				~~X~~	~~X~~
~~Regeneration~~				~~**X**~~	
~~Preparation of waste to be used as fuel~~				~~**X**~~	~~**X**~~
~~Incinerator*~~				~~X~~	~~X~~
~~Landfill cells*~~					~~X~~
~~* Not covered in this document~~					
~~*Source*: [31, LaGrega et al. 1994] [98, WT TWG 2004] [100, WT TWG 2004]~~					

~~*What processes are applied to each type of waste?*~~

~~In order to select which type of treatment may be given to a certain waste, decision trees have been developed.~~

WORKING DRAFT IN PROGRESS

2.1 Applied processes and techniques [~~Common techniques applied in the sector~~]

Ex-Section 2.1

[24, Militon et al. 1998], [24, Militon et al. 1998] [29, Inertec; dechets, F. and Sita 2002] [31, LaGrega et al. 1994] [34, Babtie Group Ltd 2002][60, WT TWG 2003][69, UNEP 2000] [73, Irish EPA 2003] [75, Watco 2002] [77, Schmidt et al. 2002] [78, Eucopro 2003] [82, Pretz et al. 2003] [98, WT TWG 2004] [103, VROM 2004] [104, UBA Germany 2004]

~~This section discusses the pre-treatments/activities or post-treatments/activities (see the introduction to Chapter 2 and Figure 2.1) commonly used in the WT sector and included under the scope of this document. It also includes some treatment activities that are frequently commonly used in the whole sector. For example, it includes process steps techniques used for repackaging, crushing, sieving, drying, blending, sorting, homogenisation, scrapping, fluidification, washing, baling, regrouping and storage, transportation, reception and traceability control, as well as management techniques used in waste treatment installations. Only those techniques important from an environmental point of view are reported. described in detail. Other techniques considered to be generic techniques or very specialised techniques have not been described but have been listed in the two last sections of this Section 2.1. Those techniques applied for the abatement of emissions (e.g. air filters, biofilters, waste water treatments) are briefly mentioned and are indicated here and widely analysed in the last three sections of Chapter 4.~~

This section discusses the process steps commonly used in the WT sector and included within the scope of this document. Some process steps are also addressed in Section 2.3 'Techniques to consider in the determination of general BAT for the WT sector' as these steps are not only of importance for the good performance of the waste process itself but also for the environmental impact of the process. In order to avoid repetition, such process steps are only described very briefly in this section and extensive descriptions can be found in Section 2.3. Cross references are made when relevant.

2.1.1 Pre-acceptance and reception of waste

From ex-**Section 2.1.1 "Reception, acceptance, traceability and quality assurance"**

For most WT plants, the following order is relevant: a) pre-acceptance, b) acceptance, c) storage, d) treatment, and e) storage of residues and emissions. Each of these ~~previous~~ steps requires knowledge and control of the waste as well as specific acceptance and processing management. Knowledge of wastes, before they are accepted and treated, is a key factor for the management of a WT plant. ~~The aim of this section is to present the different types of controls and analyses which can be carried out during the waste treatment process, from the pre-acceptance and arrival of the waste at the site, to the final dispatch of the waste~~.

~~Pre-acceptance and acceptance procedures~~

~~Many WT sites (e.g. hazardous waste treatment facilities) require information and/or samples to be provided prior to the transport of waste to the site, to enable them to ensure that the waste is within the requirements of the site licence and will not adversely affect their treatment process. Pre-acceptance includes taking a sample, filling out an identification form, carrying out the analysis and then assessing whether the waste can be accepted into the installation. If it can be pre-accepted, the waste is transported into the installation, a second analysis is carried out to once again help make the decision of whether to accept or reject the waste. Then the acceptance procedure contains two stages: First, the pre-acceptance phase; and second the acceptance phase.~~

WORKING DRAFT IN PROGRESS

2.1.1.1 Pre-acceptance

Purpose

To ensure the type of waste to be treated is within the capacities of the plant and within the requirements of the site licence.

Principle of operation

Early communication between the waste producer and the WT plant ahead of agreement between both parties about the waste treatment. Pre-acceptance also includes the characterisation of waste to achieve sufficient knowledge of its composition.

Feed and output streams

Not applicable.

Process description

~~Pre-acceptance procedures of wastes follow three main steps:~~

~~a. information is provided from the waste producer. For example, a specific formula about the waste identification (main characteristics, health and safety considerations, how they are produced, etc.)~~

~~b. preliminary and complete analyses are carried out in order to characterise the waste~~

~~c. on the basis of all the information, the operator makes the final decision on whether to accept the wastes into the installation or not (bearing in mind the specifications included in its permit and other process requirements). There are always rules to accept wastes as complying with the description. Some of these rules are developed at national level and others are developed at installation level. For example, this can be certain percentages of differentiation or parameters restricted by the permit. In certain cases, a risk assessment may be carried out. The waste processor can evaluate the risk of contravention of certain rules in this way (e.g. national rules). An example of classification of the risk in the pre-acceptance phase may be:~~
   - ~~waste is classified as ‘high’ risk if the waste or the client are new~~
   - ~~waste is classified as ‘low’ risk if:~~
     - ~~it is a known waste from a known client and~~
     - ~~the waste is predictable in properties and composition and~~
     - ~~there are low risks of contamination or dilution of the waste with other wastes or material.~~

~~In certain cases, part of this procedure (e.g. the analysis) may have to be adapted, e.g. if dangerous conditions for sampling occur at the time or when there is a very small quantity of waste.~~

~~The purpose of the full characterisation before shipment is to satisfy the following requirements, to:~~

- ~~determine if the waste is acceptable for receipt at the facility in terms of:~~
  - ~~the facility’s permit~~
  - ~~the capability of the facility to treat or dispose of the waste~~
- ~~identify the inherent hazards of the waste so that appropriate precautions can be taken during its handling and storage at the facility to prevent incidents~~
- ~~determine the physical characteristics and chemical constituents of the waste to allow selection of effective waste processing and disposal methods~~
- ~~select the verification parameters to be tested upon arrival at the facility. These parameters can ensure that each shipment of waste is the same type as the fully characterised waste~~
- ~~select any treatability parameters to be tested that could vary, so as to influence how waste processing would be programmed~~
- ~~develop an estimate of the cost of treatment or disposal of the waste~~.

See Sections 2.3.2.1 to 2.3.2.4.

WORKING DRAFT IN PROGRESS

Users
All WT plants.

2.1.1.2 ~~[Reception and]~~ Acceptance

Purpose
To decide whether to accept or reject the waste upon its arrival at the WT plant.

Principle of operation
Acceptance procedures aim to confirm the characteristics of the waste, as identified in the pre-acceptance stage.

Feed and output streams
Not applicable.

Process description
~~Upon receipt, a unique code is assigned to the waste containers, or batch, to ensure that the waste is traceable at all times. Individual containers or specific storage locations are marked accordingly. Some waste oil recovery companies tend to check the incoming feedstock by interviewing the truck driver and subjecting top and bottom samples from the truck to visual and olfactory inspection. A classification of the risk in the acceptance phase may be:~~

- ~~wastes with high risk classification are typically always analysed at delivery~~
- ~~wastes with a low risk classification are occasionally tested on conformity with the data from the pre-acceptance phase. The process of acceptance is typically guided by receivers with a role independent from process operators or waste acquirers. The whole procedure classifying the risks of non-conformity with data from the pre-acceptance phase and the description of roles and responsibilities of the various persons involved in waste acceptance is typically part of the waste analysis plan.~~

~~Upon accepting the waste, the facility signs a declaration and sends a copy to the waste producer (originator). At that point, the facility may share liability, in some cases, with the producer and the transporter. In other cases, the waste producer maintains the responsibility of the waste treatment until the last treatment is performed. Thus, it is critical that the pre-shipment waste analysis has already been completed and the shipment scheduled. Without prior scheduling of the incoming shipment or if the shipment is improperly documented, the gatehouse will refuse entry to the truck.~~

See Sections 2.3.2.1 to 2.3.2.4.

Users
All WT plants.

~~**Sampling and analysis**~~
~~A proportion of the waste is screened at the site. The level of screening is a function of the amount of processing to be carried out, and the size of the container. For example, materials to be treated in an adjacent plant will be tested to check compatibility, as will drums of material for bulking and onward transfer. Screening systems vary from site to site according to the type of waste and its subsequent treatment. For example, screening may involve an initial check of the pH level, odour and flashpoint as the materials are unloaded, followed by a more detailed screening against the stated contents on the packing lists for materials that will be decanted at the site.~~

~~The way sampling and any analysis is carried out may vary depending on the purpose of the checks, for example pre-acceptance, acceptance, reception, process analysis, traceability, dispatch analysis, reception at the final user site or external analysis. CEN TC 292 work~~

WORKING DRAFT IN PROGRESS

~~provides information on sampling and sample preparation. Some more information is also available~~

~~**Laboratory**~~

~~Upon collection of the sample, the laboratory typically analyses a portion for the verification parameters and retain the remainder for subsequent testing of treatability parameters. Upon verification of the waste shipment, the truck is directed to an unloading area where it is emptied and then reweighed before it leaves the facility. The essential tasks of the laboratory are:~~

- ~~acceptance and identification~~
- ~~establishing the treatment programme~~
- ~~process control~~
- ~~final inspection.~~

~~A waste analysis plan is a critical part of a facility. The plan specifies the parameters for which each waste will be analysed, the sampling and analytical methods to be used, and the frequency of analysis. Before a facility treats, stores, or disposes of a waste, it must profile the waste, including a detailed chemical and physical analysis of a representative sample of the waste. Commercial facilities require this full characterisation prior to shipment by the waste producer. Representative sampling of a waste shipment is conducted upon arrival at the facility to verify that the composition of the shipped waste matches the information given on the fully characterised waste sheets.~~

~~Plant laboratories assume central importance, for example in physico-chemical treatments of waste waters. Both process simulations to establish treatment programmes and analytical work is undertaken to determine the sequence of processes in the sense of process controls as well as emissions (waste water, exhaust air); the treatment programme contains exact instructions regarding how the waste is to be treated, which chemicals are to be used – according to type and quantity/dosage – and which controls and documents are drawn up. One example of these interrelationships is diagrammatically represented in Figure 2.3.~~

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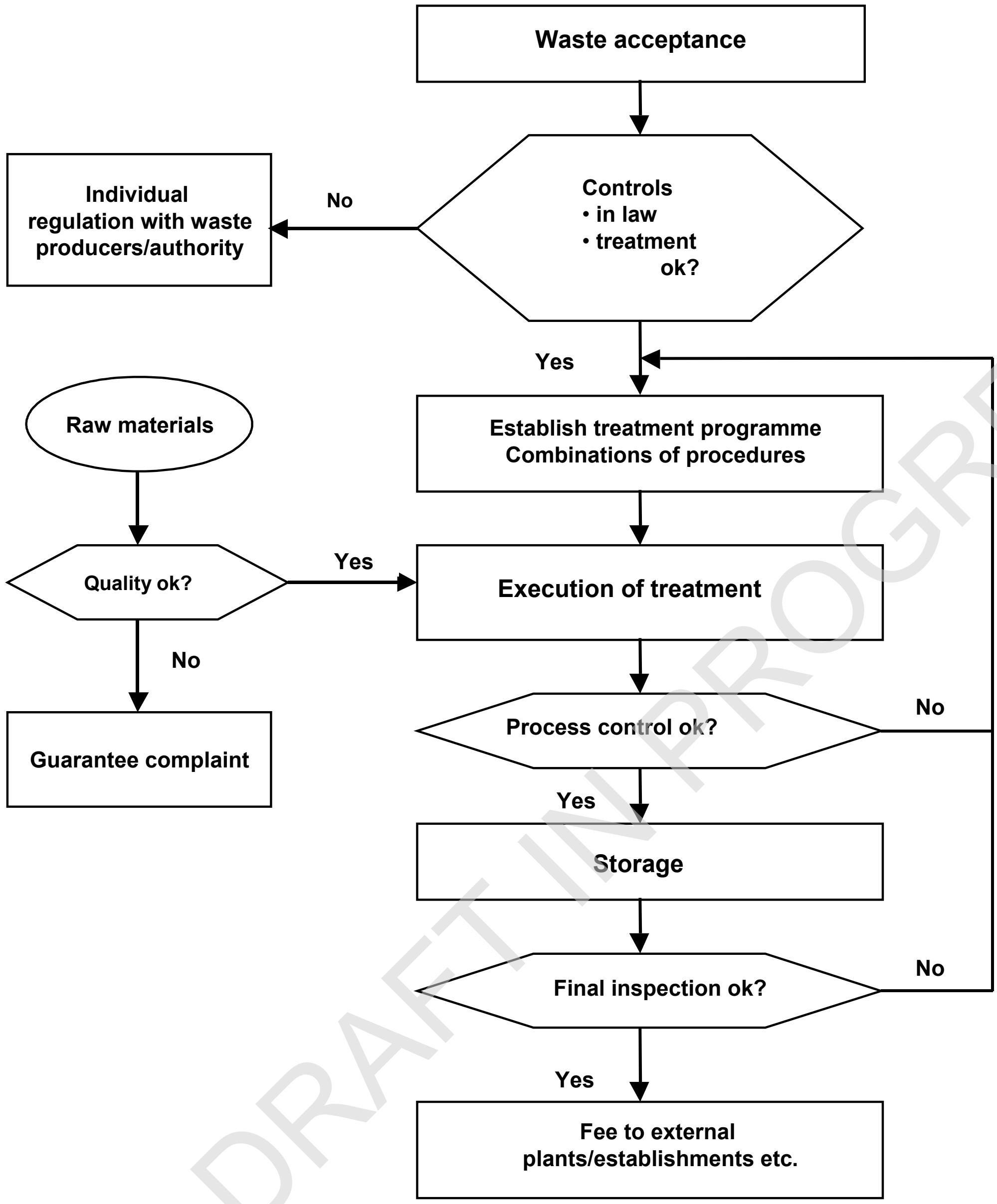


~~*Source*: [77, Schmidt et al. 2002]~~

~~**Figure 2.3: Simplified flow chart of an example of checking/inspection in a physico-chemical treatment plant of waste waters**~~

~~**Reception**~~

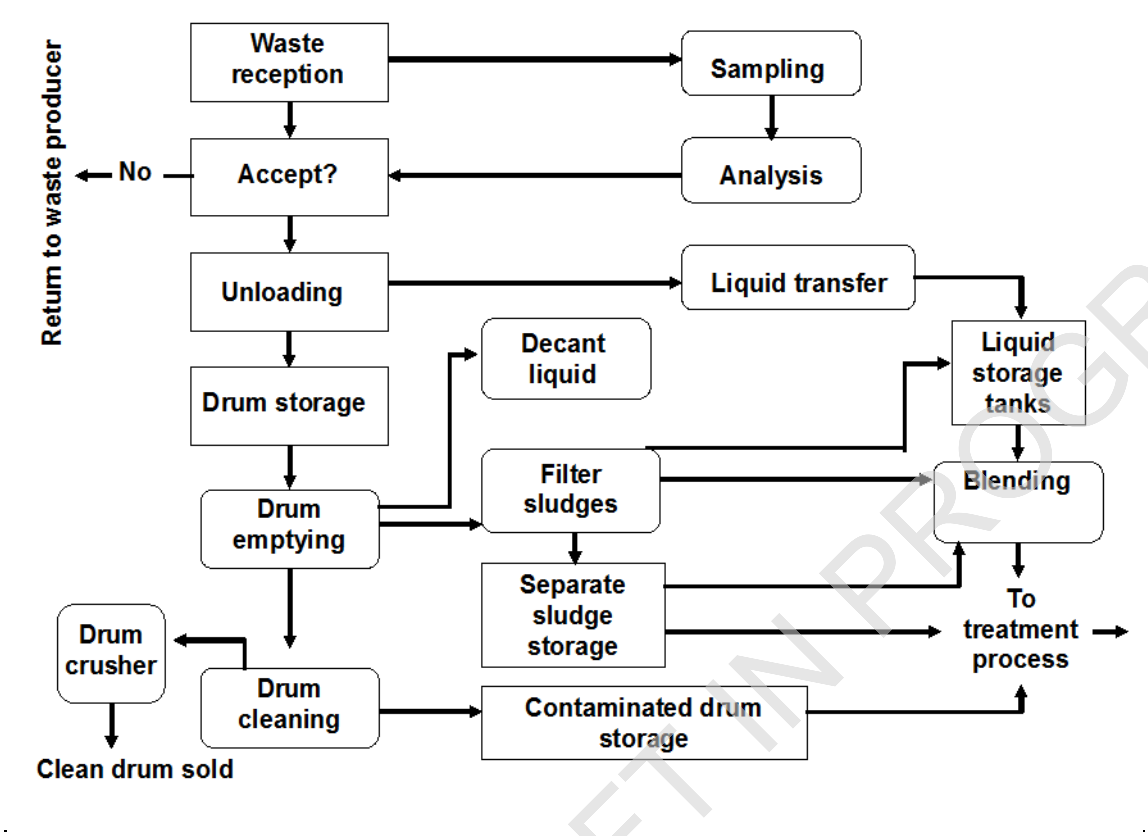
~~Typically, wastes are physically inspected when they arrive at the site, to check the integrity of the containers and to visually verify the waste type. Most sites have a regular daily inspection of containers' integrity at the site.~~

~~Waste shipments typically arrive by truck at a facility's gatehouse. Scheduled and properly documented shipments are directed to the receiving station where any packaging is checked, the loaded truck is weighed, and representative samples are collected to test the verification parameters. The waste may arrive as bulk liquids in a tank truck, containerised liquids or sludges in drums, bulk shipments of contaminated soil in dump trucks, or by a number of other methods. Collecting a representative sample can pose a difficult task considering that a waste may be in multiple phases and states or have pockets of high contamination. The receiving station must use previously established procedures for each situation to ensure the collection of a representative sample.~~

~~The mere 'emptying' of a truck can pose a difficult challenge if the waste has stratified, a container has leaked, or if a solidification reaction has occurred. For such abnormal~~

WORKING DRAFT IN PROGRESS

~~situations, facilities typically plan procedures and are prepared with special equipment to resolve such problems. Finally, the truck may need to be cleaned to remove any trace residues.~~



~~*Source:* [57, Petts, J. and Eduljee, G. 1994]~~

~~**Figure 2.4: Example of waste reception and acceptance at a facility handling bulk liquids and drums**~~

~~**Quality assurance systems**~~
~~One part of the waste management in the installation is the logistical organisation, for example, of solid waste fuel processing. By choosing and using specific waste materials, solid waste fuel producers set a kind of quality assurance themselves. Quality assurance systems already exist and further regulations are in the development phase.~~

~~In the past, solid waste fuel was mainly produced from process related wastes as mono-batches which were easier to handle because of their constant qualities. Nowadays, high calorific fractions of municipal solid wastes and of other mixed wastes are in the picture as a source for the production of solid waste fuel. The aim of a quality assurance system is to attain and ensure constant qualities to increase acceptance by end users and permitting authorities. The requirements mainly concern product quality.~~

From ex-**Section 2.1.2 "Management techniques"** deleted because covered by EMS

~~**Management techniques**~~
~~This section covers . Some special precautionary measures in the operational and emissions management in the installation need to may be applied regarding:~~

- ~~security~~
- ~~inspection and maintenance~~
- ~~incident prevention~~
- ~~emergency planning~~
- ~~employee training~~

WORKING DRAFT IN PROGRESS

- ~~safety~~
- ~~monitoring~~
- ~~audits.~~

~~**Accidents**~~
~~Accident risk is inherent when dealing with waste and in particular hazardous waste. Wastes are heterogeneous in nature and are often intrinsically aggressive to plant and equipment. Any failure in the management of the waste, from the process of characterisation and checking of wastes to the operational control reactions and the mixing of wastes, will significantly increase the risk from unwanted or runaway reactions.~~

From ex-**Section 2.1.3 "Energy systems"** deleted because covered by EMS and energy efficiency BREF

~~**Energy systems**~~
~~Energy management issues are discussed in this section. Installations for the generation of steam and/or power are not covered here because they are covered by other BREF documents (e.g. large combustion plants, waste incineration).~~

~~Heat and power are needed to run an installation. Some common site equipment using fossil fuels include forklift trucks, small boilers, shredders and grinders. These take a mixture of standard vehicle diesel fuels, and a range of fuel oils. Some of this equipment can be powered either electrically or even pneumatically. Some sites have on site boilers for steam production.~~

~~The main uses of energy on a waste treatment facility are:~~

- ~~heating, lighting and power in facility buildings~~
- ~~power for treatment processes and facility equipment, such as pumps, air compressors, centrifuges, etc.~~
- ~~fuel to power vehicles.~~

~~Good design and management of energy systems are important aspects of minimising the environmental impact of a waste treatment facility.~~

2.1.2 Storage [~~and handling~~]

From ex-**Section 2.1.4 "Storage and handling"**

Purpose
The objectives of storage ~~are~~ is to store the waste safely before its ~~introduction~~ use as feed ~~into~~ for the waste treatment.

Principle of operation

- To provide adequate accumulation time. For example, during periods when treatment and disposal process systems are out of service, or when there is to be a time separation between treatment and dispatch of waste, or for the purpose of controls and inspections, or to accumulate enough waste to use the full capacity of the treatment, etc.
- To uncouple the treatment and dispatch of waste.
- To allow effective use of classifying procedures to be made during storage/accumulation periods.
- To facilitate continuous treatment processes. Continuous treatment processes are not capable of reacting to sudden and significant changes in the composition and reactions of waste while guaranteeing a specific treatment result. For this reason, homogenisation of the various properties and level of treatability of the waste must be achieved and ensured by intermediate storage/accumulation of the waste to be treated. ~~Storage/reservoirs must therefore be set up before the actual treatment in Ph-c plants under continuous operation~~
- To facilitate mixing, blending, and repackaging of the waste as deemed necessary.

WORKING DRAFT IN PROGRESS

- To allow the staged input of various wastes with reagents into the subsequent unit treatment processes.
- To collect a reasonable amount of waste prior to sending it for certain treatments ~~(e.g. transfer stations).~~

Feed and output streams
Not applicable.

Process description
From small packages to large-scale storage (regrouping)
Wastes can be sorted into different categories depending on the bulk shipment of compatible materials to specific disposal or treatment sites. For example, small containers may be packed into 205-litre drums with vermiculite as a packing filler for easier handling and transfer. Larger containers may simply be sorted into different waste categories and stored on pallets prior to onward shipment.

Certain wastes are decanted and bulked into larger containers, for example:

- laboratory containers or small commercial containers into 205-litre drums or intermediate bulk containers (IBCs);
- drummed waste may be transferred into IBCs;
- the liquid fraction of drummed waste is decanted into IBCs;
- the aqueous fraction of two-phase wastes is decanted;
- part of tanker loads can be stored to await further material to make up a full load.

Decanting the waste reduces the tonnage of packaging materials associated with the onward transfer; and produces a consistent set of larger units that can be stored more easily at the site and that are packaged and labelled ready for onward transit. This will be important for the onward receiving site, which may need a controlled and checked stream of material for their process.

One role of waste solvent facilities is to ~~regroup~~ gather together and recondition small volumes (drums, etc.) to prepare them as fuels or to regenerate a solvent ~~that can be~~ for reuse~~d~~. The goal of a solvent ~~regroupment~~ merging/liquid fuel preparation facility is to prepare a tailor-made, stable and homogeneous waste, which fits the requirements of its final uses (recycling, incineration or co-incineration).

Transfer of materials
The next stage destination for waste may be for reclamation, treatment or disposal, and may be processed at an adjacent site within the same complex, or it may ~~need to~~ be transferred to other vehicles for onward transfer.

The choice of transportation for the material depends on the physical form of the material to be transported. In other words, the transport of gases, liquids and solids ~~all~~ involves different techniques. Solids are transported by conveyor belts, forklift trucks, trucks, pneumatic conveyors, load shovels, cranes, walking floor, etc. Liquids and semi-liquids are transported by pumps, pipes, conveyor belts, screws, elevators, etc., and gases by compressors and pipes.

~~Due to consistent efforts to avoid waste arising and the separate collection of any waste arising,~~ The handling of small quantities up to approximately 1 m^3 is particularly significant. Systems have been developed in some countries to separate the collection and transport of waste (e.g. the AS container system in Germany).

~~**Package acceptance**~~
~~Physico-chemical treatment plants accept waste, by tanker, truck, pipeline or ship, and generally store the waste prior to treatment, either in small containers or tanks.~~

WORKING DRAFT IN PROGRESS

Reclamation of containments
The majority of incoming containers (glass, metal or plastic) are shredded or crushed prior to recycling or disposal. Some drums and IBCs are sorted for reuse within the transfer operations and others are washed (or vented) prior to reuse or sale.

Ways of storage and facilities
~~Tank farms can be an integral part of a transfer and bulking operation, or can operate as stand alone activities. Bulk storage is likely to becoming more common as more wastes require treatment under the Landfill Directive. As this occurs there is likely to be difficulties in matching the wastes arising to the finite capacity of treatment plants, and consequently more interim storage units will be needed. Attention is drawn to the Storage BREF, the Seveso II Directive and to national regulations.~~

Liquids may be stored in tanks and/or containers (e.g. glass containers, drums, big containers), storage cells, storage buildings and outside storage (e.g. waste waters). Solids can be stored in heaps, sacks and bulk bags, silos and bunkers, and packed. Solid waste can be stored in closed areas, for example a closed building (e.g. with an appropriate filtering system and exhaust gas treatment to lower odour and air emissions), and handled with a crane, travelling crane or conveyor belt or silos (e.g. cylindrical or parallelepiped silos with a screw or a walking floor to extract the solid waste).

~~Upon unloading, the wastes are moved into storage, which may consist of tanks or impoundments for bulk liquids, hoppers for solids and sledges, or pads and warehouses for containers.~~

Some sites can store blended or raw waste material pending transfer for use in another process.

~~Storage areas are often the most visible aspects of the installation. The key issues for operators to address in relation to waste storage on the installation includes the following:~~

- ~~location of storage areas~~
- ~~storage area infrastructure~~
- ~~condition of tanks, drums, vessels and other containers~~
- ~~stock control~~
- ~~segregated storage~~
- ~~containment used to protect the environment and workers health.~~

~~Containers used to store shredded drums or intermediate bulk containers (IBC) are also covered in this document.~~

~~An important safety consideration in storage and handling is fire prevention and protection.~~

Tanks are also used to store wastes. This may be part of a medium-scale bulking operation to ensure that partial tanker loads are bulked to give a full load for onward transfer to the next process; or a large-scale tank farm operation. The former tends to have limited controls, similar to the storage of fuels on the site. Tanks are typically in the open, on hardstanding and bunded. The type of storage applied will depend on the need for homogenisation in the storage unit.

Often storage in containers also involves classification processes, the containers used also being fitted with skimming apparatus to remove floating material and suction apparatus to remove sediment. If classification procedures are disabled, the waste may instead undergo continuous agitation to maintain a state of homogeneity.

The storage, treatment and ~~after~~ post-treatment functions are not separated but rather take place in the same container. A batch treatment process is used.

WORKING DRAFT IN PROGRESS

Storage capacity
Storage capacities ~~need to be~~ are designed to typically ensure a continuous service. Other issues ~~to be~~ that are considered are the re-treatment of the output if its quality does not meet the required specifications and the dispatch frequency.

See Section 2.3.13.2 for more details about waste storage.

Users
All WT plants.

2.1.3 Handling

From ex-**Section 2.4 "Storage and handling"**

Purpose and principle of operation
To handle and empty incoming waste packages.

Feed and output streams
Not applicable.

Principle of operation
The handling of material requires its correct packaging and load safety. Small quantities are packed in packaging units that are easy to handle, e.g. bottles or boxes. And large quantities in containers of 100–12 000 litres ~~content volume~~ for example. Prior to treatment, the units/containers ~~have to be~~ are emptied. For this purpose, appropriate devices are necessary, e.g.:

- tools for opening;
- holding and clamping devices;
- lifting and rotating devices.

~~In order to limit the variety of technical devices and, in order to ensure handling, the packaging units/containers are safe and efficient. The units/containers are combined with the systems~~. The emptying process requires:

- experienced staff;
- knowledge about material/wastes;
- safety equipment/devices;
- measures/facilities for emission control;
- suitable and easily manageable intercepting tanks;
- regulation of the destination of the emptied units/containers.

Likewise, the upper bodies of the transport vehicles ~~have to be~~ are emptied; this is usually done by means of pumps or in a free flow along a gradient. Experience shows that residues always remain inside the units/containers or in the upper bodies of the vehicles. ~~Without regard to the kind of their subsequent utilisation, these enclosures have to be completely emptied and cleaned.~~ ~~As experience shows,~~ Emptying is often hampered by sedimentation of solid, adhesive and hardening components in the waste. This may make it necessary, e.g. when emptying the upper bodies of the tank and suction vehicles, to remove the hardened components with tools or manually. It is advantageous for the process flow if the solid material can be transported in a lower container (folding plates, slides, etc.).

After emptying, the units/containers/upper bodies ~~have to be~~ are cleaned independent of their further utilisation. Exceptions to this rule can be made if:

- the units/containers are disposed of as waste and the adhesive residues of the transported waste do not make a difference;

WORKING DRAFT IN PROGRESS

- if the subsequent utilisation is identical to the previous one.

The residues resulting from emptying, as well as the washing residues, are treated in the same way as the waste unless this is not possible due to its consistency. For example, sludge from the disposal of petrol or oil separators can be processed and recovered partly by simple washing procedures while the water phase has to be subjected to physico-chemical treatment. Washing is usually done with water. The effect can be enhanced by pressure (up to 100 bar), temperature (up to 80 ºC and vapour) and/or adding of solvents and/or tensides.

Process description

Unloading of fluid wastes

Fluid wastes are accepted and sedimentation is carried out. The fluid wastes are delivered either in containers, tank vehicles or suction pressure vehicles. When they are delivered in containers, they are picked up from the ~~conveying band~~ conveyer belt by a handling device, transported to the preselected receiving basin and there semi-automatically emptied. The contained coarse solids are removed and collected in containers. The fluid phase follows the downward slope and flows into the sedimentation basin. The sedimentation basins ~~(8 in total) are~~ selected by a control system.

When they are delivered in tank or suction pressure vehicles, they drive into the emptying area and their tanks are connected to the sieve filter via a tube. The fluid wastes flow from the tanks through the tube to the sieve filter, where coarse impurities (e.g. gloves and cloths) are removed. Metal elements are removed via a magnet separator. Afterwards, they are transferred via a pipe system into a basin preselected by a control system.

~~Drum emptying may be a simple bulking operation, and a sensible screening operation to check the contents of drums prior to landfill, as happens in some countries. The latter mentioned practice is actually forbidden by the Landfill Directive.~~

From ex-Section 4.1.4.9 "Automatic unloading of drums"

Automatic unloading of drums

An automatic unloading station is used to unload waste from drums without human intervention, avoiding accidents, e.g. when handling hazardous waste. It also reduces the length of time that the conditioned waste remains on site, and optimises the process of cleaning the containers.

The unloading station includes the following (from upstream to downstream):

- A drum supply station driven by pneumatic motorisation. The drums, transported by means of a forklift, are placed onto a set of conveyors with motorised rollers, ensuring that the containers are then directed to the grip station.
- A grip station for the drums equipped by a hydraulic clamp. A hydraulic clamp equipped with three lugs distributed along the circumference of the drums permits the latter to be directed, travelling in a translocatory motion, to the different terminals of the station.
- A station for the cutting, scraping, washing and ejection of the drum bottom. The disposal of the pasty waste is assured by two parallel vertical H-bars, one of the sharp flanges of which rubs against the inside casing of the drum, causing friction. The shape of the upper part of the bars is one that is adapted to the penetration of thick matter. The washing of the drums, in line with the high pressure/low flow rate principle, permitting a reduced consumption of water, is assured by nozzles placed inside metal sheaths.
- A station for the disposal, scraping, and high-pressure cleaning of the shell of the drum. After disposal and cleaning, the drums are pressed by two rams in the direction of their largest dimension. Appropriate casings are provided so as to retain the spatters and strappings of the drums. The pressed drums are then directed to a collection container by a roller conveyor.
- A station for the pressing and removal of the cleaned drums.

WORKING DRAFT IN PROGRESS

- A control cabin.
- VOC emissions prevention. The volatile organic compounds emitted by the cutting, disposal and washing stations are collected by hoods connected to a ventilation device and are treated in an incineration unit.

~~The station is designed to accept standard drums of 120 and 200 litre capacities capable of being fully opened and closed. Its disposal capacity is 250 drums/day.~~

From ex-**Section 2.1.9 Other common techniques**

Repackaging

Repackaging (e.g. baling) is applied in some plants due to the disaggregated nature of some types of waste: it is sometimes necessary to compact ~~them~~ it to make ~~them~~ it easier to use in the following process. Pressure machinery is used to pack the waste into a certain physical form.

Repackaging is also used for municipal solid waste to be used as a fuel and for plastic, paper and metal bales. The size and form of the bale ~~is~~ are typically optimised for its transport and reuse.

See Section 2.3.13.3 for further details on waste handling.

Users

All WT plants.

Reference literature

[63, Syke 2003] [78, Eucopro 2003] [98, WT TWG 2004]

Deleted: too specific.

~~**Computer-controlled high rack storage area for hazardous wastes**~~

~~The high rack storage area serves as a secure storage and control area of wastes which have been delivered in closed containers. Non-packaged wastes cannot be put in storage. The storage area has 1680 storage positions in 2 store vessels and is geared to 250 to-bin and from-bin transfers. For these transfers the high rack area disposes of chain conveyors and bucket elevators. For fire prevention the reception area has fixed fire extinguishers that are coupled with acoustic alarm signal systems. Additionally, portable fire extinguishers are installed. From the high rack storage area, the wastes are transferred to the individual facilities where they are disposed of, recovered or pretreated for disposal or recovery.~~

2.1.4 Blending and mixing

Ex-**Section 2.1.5 "Blending and mixing"**

Wastes, once produced, are in principle kept separate from other wastes. The reason for this is that the reuse/recovery of homogeneous streams is generally easier than that of composite streams. Under certain conditions, however, different waste streams can be processed just as well, or sometimes even better, if they are composite. ~~In~~ This section~~, it is~~ explores the different principles ~~rules~~ that may be applied ~~on~~ regarding whether or not mixing/blending may be allowed and under what conditions this can be carried out. However it is not the aim of this document to further elaborate on existing provisions for blending and mixing of wastes, such as those contained in Directive 2008/98/EC on Waste and Directive 1999/31/EC on the Landfill of Wastes.

Purpose

Due to the heterogeneous nature of waste, blending and mixing are required in most waste treatment operations in order to guarantee a homogeneous and stable feedstock of the wastes that will be finally processed.

WORKING DRAFT IN PROGRESS

The term ‘blending’ is used more for mixing liquids than for solids, unless mixing a solid into a liquid. The term ‘mixing’ is used more for solids and semi-solid materials (e.g. pasty material).

Principle of operation

Certain types of wastes will require prior mixing or blending before treatment. For example, the concentration of waste constituents can vary considerably because of differences in incoming waste strengths. This is particularly true at most commercial treatment facilities. Mixing can control such variations to a range that will not upset the performance of the subsequent unit treatment processes. However, this issue should not be confused with dilution ~~and this is the reason why these treatments are many times prohibited (e.g. hazardous waste and landfill Directives) over a wide range of concentrations~~. Blending and mixing are processes carried out because it is a technical requirement from the WT facility to guarantee a homogeneous and stable feedstock and not techniques to facilitate acceptance of waste.

~~As is prescribed in the Hazardous Waste Directive 91/689/EEC, mixing and blending operations are not permitted unless this is explicitly established in the licence of a collector or processor. An exemption from the permit requirement may be applied by the competent authority if establishments or undertakings carry out waste recovery and if competent authorities have established general rules for each type of mixing and blending laying down the types and quantities of waste and the conditions under which the mixing and blending may be applied and if Art 4 of the Waste Framework Directive is taken into account by establishing these general rules for the concerning establishments and undertakings. In this exemption case, registration of the establishments and undertakings is mandatory in order to ensure that the establishments and undertaking comply with the stated general rules. The following basic principles apply for granting such a licence:~~

- ~~the mixing of wastes must be prevented from leading to a risk to human health and adverse effects on the environment~~
- ~~mixing must be prevented from leading to any of the wastes to be mixed being treated or processed to a lower quality level than is desirable~~
- ~~the mixing of wastes must be prevented from leading to environmental damage by the diffuse dispersal of environmentally hazardous substances.~~

~~The following elaboration of the basic principles for the mixing of waste applies to both hazardous and non-hazardous waste. Hazardous wastes must be kept separate from one another. Mixing can only be permitted if it will not result in risks to humans and the environment, and if there will be no problems with safety due to the mixing for all types of operations (for example safety risks for workers, neighbours of the plant etc.). Article 2, paragraph 3 of the Hazardous Waste Directive states that such an operation can only take place if a licence has been granted. Conditions may be attached to a licence, making it possible for the hazardous wastes referred to in the licence to be mixed with other (hazardous) wastes, preparations and other products referred to in the licence. Where the primary function of mixing wastes is to achieve dilution of a specific species in order to comply with less stringent regulations, this is prohibited. Within the boundaries of the licence for mixing and blending, the waste treatment manager is responsible for writing and applying operational guidelines on mixing and blending. Firstly, the basic principles for granting a licence are elaborated. Secondly, principles and considerations are given for writing operational guidelines for mixing and blending given these boundaries of a permit.~~

~~**Principle of operation**~~

~~Mix two or several wastes in order to typically generate a single output.~~

Feed and output streams

Applicable to solid and liquid waste. Outputs can also be in solid or liquid phase.

~~**Process description**~~

WORKING DRAFT IN PROGRESS

~~The basic principles referred to above in the purpose section (risk prevention, substandard processing and prevention of diffuse dispersal) have, as their main objective, protection of human health and of the environment against harmful influences and promotion of the recovery of wastes within these boundary conditions. For the sake of a high level of protection and effective supervision, these general basic principles need to be translated, in licensing procedures, into operational criteria on the basis of which it can be clearly determined if the mixing/blending of wastes can be allowed. The following elaboration of the basic principles is prescriptive:~~
The basic principles governing the mixing/blending of wastes are the following:

- The mixing of substances that react strongly with each other (causing heat, fire, gas formation) or explosive substances (explosion) ~~must be~~ is prevented. Mixing ~~must be prevented from givin~~g does not give rise to risks to human health ~~and~~ or the environment, ~~both~~ either during the mixing operation itself~~, and~~ or during the subsequent treatment process. ~~For licensing purposes,~~ This means that ~~the acceptance and processing policy of licence holders is drawn up in such a way that~~, before wastes are combined, it is assessed whether this combination can take place safely. This can be achieved by carrying out compatibility tests before mixing/blending for any purpose for any type of waste (see Section 2.3.2.7).
- The mixing of wastes ~~must be prevented from leading~~ does not lead to a lower level of processing waste than the best possible level of waste management or ~~from leading~~ to the application of non-environmentally sound waste management. This means, for example, that, if a recovery operation is the minimum standard of processing, a waste stream mixing of such wastes with other wastes in order to bring the mixture to any disposal route ~~shall~~ is not ~~be~~ accepted. For instance, the mixing of liquid wastes or clinical wastes with other wastes for the purpose of landfilling is not permitted. Mixing of wastes with a POP content above the low POP content (as defined under the Basel and Stockholm Treaties) with another material solely for the purpose of generating a mixture with a POP content below the defined low POP content is not allowed because this is not environmentally sound.
- The mixing of wastes ~~must~~ does not lead ~~be prevented from leading~~ to the undesired diffuse dispersal of environmentally hazardous substances. The effects of diffuse dispersal are determined by the types and concentrations of environmentally hazardous substances in combination with the processing route to be chosen, the emissions occurring and the quality and purpose of the residual substances released. In combination, it ~~must be~~ is necessary to assess~~ed~~ what the negative consequences are of processing the environmentally hazardous substances concerned with regard to emissions into the soil, water, air or in residual substances and how these negative consequences compare with the environmental effects of another processing route. This assessment ~~must~~ also takes into consideration the cyclical character of future reuse.

Process description
~~For solid wastes, the waste may be mixed with a crane, a closed mixer or a closed mixer with a turn-cup and an axis with knives. Blending operations generally involves large volumes, i.e. the discharge of tankers into tanks.~~

Technical equipment to mix or blend waste depends mainly on the aggregation states of the substances to be mixed or blended, the desired degree of homogeneity from mixing, the ability of wastes and additives to be mixed and the anticipated reactions and reaction products resulting from mixing or blending. Different types of mixers are used (propeller mixers, turbo mixers, blade mixers, auger mixers, roller mixers, drum mixers, tumble mixers, rotary mixers and gravity mixers, etc.). In principle, this technology can be divided into static and dynamic mixers. Static mixers mix or blend substances through turbulence as a result of the flow of wastes and additives, e.g. cascades. Dynamic mixers produce turbulence, e.g. through the turning motion of a propeller or by rotating a container with equipment. The following devices are used:

WORKING DRAFT IN PROGRESS

Solid or paste-like wastes

- A kneader may be used in cases where the components to be mixed are available in a highly viscous, plastic or paste-like form without any bulky materials. The mixture is separated, stretched and combined again by kneading tools that move against one another.
- A forced aeration mixer is typically used for paste-like to lumpy wastes.
- Augers and/or plough-share mixers are typically used to mix granular, powdery or fibrous wastes. They are also used to produce agglomerates.
- A free-fall mixer may also be used for dry, fine-grained to powdery wastes that do not vary especially in terms of particle size or density.
- In addition, excavators or wheel loaders and cranes with grapples are utilised. This technology is used in particular to mix wastes in a bunker at a waste incineration plant. The objective is to homogenise the waste.
- Shredders and screens can also mix waste. A shredder is used to reduce the size of different materials. The shredder's primary function is to feed components of the plant with small batched quantities. Screens help to classify and homogenise non-adhesive substances.

Liquid, pasty and pumpable wastes

- Agitators are primarily used to produce an optimal mixture of liquid or paste-like wastes. In some instances, this technology also avoids separation.
- Tanks (if necessary with agitators) can homogenise liquid or paste-like wastes in preparation for feeding into a plant. As means of storage, tanks also help combine many small batches into larger transportation units.
- Pumps are also used for all methods of transporting liquid or paste-like wastes, for instance to empty collection tanks in refuse trucks. Different types of liquid may also be mixed in the process.

Users

Blending and mixing is typically applied only when the quality and analytical values of the waste inputs are under or equal to the values of acceptance in the planned output treatment plant. These operations take place in all waste treatment activities (biological treatment, fuel preparation, contaminated soils, waste oils, etc.), and sometimes are quite specific to each WT activity. ~~Some of these issues are also covered in the individual sections for each WT activity.~~

From ex-Section **4.1.5 Segregation and compatibility testing**

Some examples of mixing and blending rules applied to certain types of processes and wastes are reported below.

Treatment of wastes contaminated with POPs

Mixing and blending of wastes for recovery could be allowed if the concentration of POPs does not exceed the low POP contents ~~as~~ defined in the Basel and Stockholm Treaties. This is reflected in the technical guidelines for the environmentally sound management of wastes consisting of, containing, or contaminated with POPs and ~~with~~ PCBs that were recently adopted by the 7th Conference of the Parties to the Basel Convention. In Table 2.3 the low POP contents are presented. However, mixing wastes for other treatment routes such as soil cleaning, preparing animal feed, preparing fertilisers, etc. can be prohibited even if the low POP content is not exceeded.

Table 2.3: Maximum concentrations allowed for mixing wastes for recovery

Compound	Low POP content
Dioxins/furans	0.015 TEQ mg/kg
PCBs	50 mg/kg
Other POPs	50 mg/kg

Source: [103, VROM 2004]

WORKING DRAFT IN PROGRESS

Heavy metals - Cd, Hg, Tl

When the ~~three~~ basic principles of mixing and blending ~~and their elaboration~~ are taken into account, competent authorities may allow the ~~following~~ maximum concentrations presented in Table 2.4 in wastes for mixing for co-firing or co-incineration~~, as presented~~. Emissions of the heavy metals mercury, cadmium and thallium into the air will occur when wastes containing such components are used in cement kilns and power stations. Diverting anything above the maximum concentration levels is, therefore, not allowed. Competent authorities can divert from these maximum concentrations by prescribing a lower level in the permit for mixing and blending, if the acceptance criteria of the receiving plant make this necessary. In this respect, it is relevant to note that a distinction has to be made in concentrations allowed for mixing and in concentrations to determine the allowable air emission limits.

Table 2.4: Maximum concentrations allowed for mixing wastes for co-firing or co-incineration

Metals	Maximum concentration (mg/kg dry matter)
Mercury	10
Cadmium	100
Thallium	100

Source:[103, VROM 2004]

Waste containing contaminants other than those mentioned above may be mixed in order to meet the acceptance criteria for the processing plant. Naturally this does not apply to the previously mentioned residual substances and residues from processing, which contain high concentrations of contaminants.

Reference literature

[115, UBA Germany 2012] [Directive waste, 144] [Directive Landfill, 150]

Ex-**Section 2.3.3.4 "Conditioning"** deleted. Covered by section "Physico-chemical treatment of solid and/or pasty waste"

2.1.5 Treatment of laboratory smalls

From ex-**Section 2.1.7 "Treatment of smalls"**

Purpose

The aim is to identify different types of wastes for their correct treatment.

Principle of operation

From ex-**Section 2.4 "Storage and handling"**

Laboratory smalls essentially consist of substances in containers of less than five litres capacity. They generally contain pure chemical elements and compounds from laboratories or arise when laboratory stores are cleared. The majority of operators offer a packing and collection service for laboratory smalls.

Laboratory smalls are usually sorted and bulked into drums (e.g. 205 litres or other sizes depending on the further treatment) either in designated enclosed buildings with positive ventilation and flameproof lighting or within open-sided roofed areas.

From ex-**Section 2.1.7 "Treatment of smalls"**

The substances that are to be treated are manually sorted and repackaged, crushed if necessary, conditioned and transferred to internal and/or external disposal plants.

WORKING DRAFT IN PROGRESS

Process description
The system is divided into three spatially separated parts:

- Sorting of chemicals. This is carried out with a sorting cabin and an aspiration device for the separation of laboratory chemicals for different processing paths (e.g. recycling, disposal (incineration) and deposit in underground disposal).
- Packing treatment for emptying fluid containers with a volume of 0.1–200 litres. The small volumes are combined for the purpose of creating large batches (solvents or acids). These are disposed of in the downstream high-temperature incineration or recovered in the in-house physico-chemical treatment plant. A downstream facility crushes the emptied containers.
- Treatment of plant protection products, reactive and odour-intensive substances in a special cabin.

Users
Treatment of hazardous wastes from private households, universities, laboratories and business enterprises.

2.1.6 Cleaning and washing

From ex-**Section 2.4 "Storage and handling"**

Purpose and principle of operation
Washing and cleaning of vehicles and receptacles/containers.

Feed and output streams
Not applicable.

Process description
After delivery and emptying, the vehicles/constructions and receptacles/containers could be cleaned on site (e.g. under agreement with the transport company) or off site except where the receptacles/containers are disposed of, the adherent residue is not harmful, or the constructions, receptacles or containers are used again to transport similar waste.

Because of the many different kinds of drums/containers/constructions, the cleaning – apart from the exceptions – is performed manually using spraying devices, high-pressure rinsing devices, or brushing and brooming techniques. Cleaning can be performed inside or outside, in order to guarantee the reuse of the drums/containers/constructions. Cleaning inside is important to prevent substances being carried over. This may be crucial, for example, when the limit of organochlorine~~-organic~~ adsorbable materials in the waste water ~~of a Ph-c plant~~ (AOX value) is 1 mg/l, and this concentration can be affected by leftover concentration in the receptacles ~~refilling~~ (e.g. by residues with corresponding AOX ingredients). Typically, a separate treatment of cleaning waters is carried out in order to assure that the sewer is not contaminated by such waters.

A facility for cleaning the containers can be an automatic installation which cleans their exterior and interior. The cleaning process is computer-controlled by means of contact-free sensors. ~~The maximum capacity of the facility is 10 containers per hour~~. The working movements of the handling devices are carried out hydraulically. The cleaning devices are supplied with water by ~~two~~ high-pressure pumps ~~with a capacity of 132 kW each~~. The washing water is run in a closed loop over the existing water treatment system.

Table 2.5 gives an overview of the cleaning and washing steps.

From ex-**Section 2.1.9 "Other common techniques"**

Table 2.5: Cleaning and washing steps

WORKING DRAFT IN PROGRESS

Technique	Purpose	Users
Cleaning	Remove contamination that would otherwise prohibit waste materials being recovered	PCB capacitors and transformers
Washing	~~One purpose for~~ Washing may ~~be to~~ enable the ~~reuse of~~ drums to be reused in the installation or ~~for selling~~ to be sold to other installations for reuse. Drum washing operations often include no real treatment other than washing and settlement. A number of reprocessors wash the oil filters and provide a semi-cleaned metal fraction for recycling.	Most treatment plants incorporate a road tanker washing-out facility to enable the removal of residues from vehicle tanker barrels. May also be applied to storage tanks and drums. Physico-chemical treatment plants.
Sedimentation	Solid components within the fluid wastes are separated and the wastes are pretreated for further processing	Preparation of liquid waste fuel
Source: [60, WT TWG 2003], [78, Eucopro 2003], [98, WT TWG 2004], [103, VROM 2004], [104, UBA Germany 2004]		

Users
All WT plants.

2.1.7 Reduction of solid waste size

From ex-**Section 2.1.8 "Size reduction"**

Purpose
Adapt the solid waste granulometry for further treatments or to extract wastes which are difficult to pump or decant. And to reduce and make the particle size homogeneous.

Principle of operation
Techniques used in the installations are shredding, sieving, fractionating, conditioning and confectioning. Slow-motion shredders, hammers and dedicated shredders are used.

Feed and output streams
Bins and aerosol cans are fed into the system. The gases are treated in a cleaning facility and the liquid and solid components are disposed of or sent for recovery.

Process description
Some examples are described below:

Bin shredder
The treatment facility consists of a shredder for the comminution of empty, half-empty and full bins with sizes ranging from 1 litre to 1000 litres. The feed system works with an electronic wheel loader. The shredder itself is placed in a pressure surge-proof channel which is 12 metres high with an offloading area on top. The bins are transported by the electric wheel loader through the open door to the shredder. Afterwards, the door closes and the shredding process starts automatically. In the next step the shredded material falls into a tank, which, after complete filling, is transported from the channel to further processing steps. The released exhaust gases are treated in a regenerative post-combustion facility. Other protection devices are a double-layered vacuum-controlled polyethylene high-density foil on the bottom and ~~an~~ automatic nitrogen and water flooding in the closed channel.

Deleted because it repeats ex-Section 4.5.3.13 (see below)

~~*Aerosol can shredder*~~
~~The treatment facility consists of a shredder for aerosol can crushing, two condensation units and one collecting tank. The collecting tank has a filling device for condensed and warmed~~

WORKING DRAFT IN PROGRESS

~~(outside temperature) gases. This tank has also a nitrogen supply device for cooling the condenser and for the inertisation facility. Other parts of the facility are a collection tank for liquid waste solvents and a bin for scrap metal. The shredder crushes the aerosol cans batch-wise. The shredder works in a nitrogen environment (inert) and is gas-proof. The gases and other active agents that may still be contained in the aerosol cans are released within the shredder. These released gases (mostly propellants) are run over the condensation unit and condensed. The condensate is stored in a gas collection tank. In the next step the gases are filled into compressed gas cylinders and transported to an incineration facility for hazardous waste. The uncondensed gases are transported to a regenerative exhaust air cleaning facility, where they are combusted. The solid residues from crushing (scrap metal) are separated from the liquid substances. The liquid and the solid components are separately discharged over different locks. The solid components, e.g. metal fraction, are forwarded to recovery or disposal. The liquid compounds, e.g. paint and hairspray, are temporarily stored in a tank and then decanted into 800 litre bins. The 800 litre bins are transported to a combustion plant for hazardous wastes where the liquid waste is used for auxiliary firing (thermal recycling).~~

From ex-**section 4.5.3.13 "Cryogenic grinding"**

Cryogenic grinding

Cryogenic grinding is a treatment of size reduction and sieving of deep cooled full and empty packaging under an inert atmosphere. The aim is to separate the used packaging of paint, ink, and similar substances into fractions, e.g. to be used as fuel and as secondary metals and plastic but reducing the emissions of VOC and volatile compounds due to the low temperatures used.

The first operation is the separation ~~between~~ of the liquid and the solid fractions. The solid fraction is further processed by grinding, sieving and metal separation at temperatures of -100 °C to -196°C (typically with liquid nitrogen). At these temperatures, the materials become brittle and an easy separation, using classical tools, is possible.

In the cryogenic treatment of used packaging of paint and similar materials, the following steps are included:

a. Comminution in a shredder and addition of nitrogen for inertisation of the atmosphere. The liquid fraction (e.g. paint sludge) is separated by sieving.
b. Cryogenic (deep cooling) treatment with liquid nitrogen (-196 ºC). Through this treatment, the material hardens and, due to the different coefficients of components expansion, the binding reduces.
c. Separation of the packaging (e.g. metal and plastic) and the content (e.g. paint sludge) by means of a hammer mill and a vibrating sieve.
d. Collection of the metal fraction by ferromagnetic separation for reuse.
e. Addition of sawdust to the sludge as an adsorbent to make it solid. The plastic fraction and the sludge are sent for recycling as a fuel.

~~Achieved environmental benefits~~

Due to the inert atmosphere used during the grinding process, the risk of explosions is minimised. The sludge fraction is prepared to be used as fuel. In comparison with the direct incineration of such wastes, the recovery of energy is higher because metals are eliminated before incineration. The separation of other materials, e.g. metals and plastic, enables its use.

~~Cross-media effects~~

Electricity is required for the cryogenic process and for the production of nitrogen. ~~Air~~ Emissions to air, e.g. VOCs and volatile hydrocarbons, may be generated. To reduce the VOC emissions to air, the off-gases are collected and cleaned by means of an activated carbon filter. The exhaust gases are cleaned of volatile hydrocarbons by means of an activated carbon filter. The residual emissions are estimated to be 0.06 kg/t of used packaging waste.

WORKING DRAFT IN PROGRESS

~~Operational data~~

The end product of the operation is organic waste as a powder, metals, non-ferrous metals and plastics. The electricity consumption of ~~electricity by~~ the cryogenic process is approximately 31 kWh/t of used packaging waste. The amount of nitrogen consumed is approximately 0.67 t/t of used packaging waste. As an adsorbent ~~to~~ for the sludge, sawdust is used. The amount consumed is 170 kg/t of waste. The used sawdust is a waste material, which means a saving of primary materials.

~~Applicability~~

~~Some examples are the preparation of solid waste fuel from used packaging of paint and similar substances. This equipment is frequently used for the processing of metal and plastic packagings, filled with paints, ink, oil sludge, varnish, glue, resin, etc. and rubber based wastes (e.g. tyres). Packaging of other hazardous wastes, e.g. pesticides, halogenated chemicals and laboratory chemicals, cannot be treated by this process because of the risk of toxic substances diffusion.~~

~~Example plants~~

~~In the Netherlands there is an example plant with a capacity of 17500 tonnes per year~~

From ex-Section 2.1.10 on example plants

Glass crushing

Windscreen glass is laminated with polyvinyl butyrate, and this is removed in a preliminary crushing process and sent to landfill. The glass crushing operation handles municipal and industrial glass. Sites typically do not take coated glass from electronic equipment.

Users

Bin and aerosol can treatment facilities. Preparation of waste to be used as fuel. Applied to different types of waste such as plastic or metal drums, oil filters, municipal solid waste, solid bulk waste, waste wood, aerosol and glass.

Reference literature

[78, Eucopro 2003] [98, WT TWG 2004] [103, VROM 2004]

From ex-Section 2.1.10 on example plants

~~Examples of waste treatment installations where only the common techniques are applied~~

~~Some waste treatment activities are very specific and particularly related to the type of waste that is processed. Some examples are listed below.~~

Moved to Section 5.8

~~Cleaning transformers containing PCBs~~

~~Technologies, for cleaning transformers can be divided into three main categories:~~

- ~~draining of the PCB oil from the transformer, followed by decontamination of this oil, and reinjection of the cleaned product into the transformer for re-use~~
- ~~extraction of the PCB oil, by solvent washing of the transformer, followed by dismantling and further decontamination of the components to allow recycling of the metal components~~
- ~~after suitable pretreatment, PCB oils may be treated with hydrogen at elevated temperatures. Here, the transformers are not recovered as such.~~

~~One example of the second case is the following: Carcases of used transformers are cleaned by means of trichloroethylene (TCE) wash. Here, the carcase is filled with the solvent and allowed to stand for an extended period before the solvent is replaced with fresh TCE. This operation is repeated (typically three times) until the carcase passes the requisite 'swab test'. During the~~

WORKING DRAFT IN PROGRESS

~~cleaning operation, the transformer carcase is left open to the atmosphere or loosely covered with a steel plate. As a consequence, the activity results in evaporative losses of TCE to the air.~~

~~Typically this activity is carried out at specialist sites, which clean the PCB contaminated transformers and bulk the PCB contaminated oils. Their wastes: oils, drums, cleaning waters and cleaning solvent sludge are all sent for off-site incineration.~~

~~Cleaned transformer carcases and windings are sent for reclamation after thorough cleaning with TCE.~~

~~Cleaning of capacitors containing PCBs~~

~~Capacitors are similar to transformers in that they are made up of an active core, held in a metallic casing. However, the active core is not copper windings, but instead consists of interwoven rolls of fine aluminium foil, separated by thin films of paper and/or plastic. The techniques used for cleaning these capacitors are:~~

- ~~the casing of the capacitor is removed and decontaminated by solvent washing; this is a straightforward decontamination process since the casing is non-porous. The core is incinerated~~
- ~~the possibility of going one step further and treating of the core after its removal from the casing. This decontamination step usually involves a shredding of the core, and treatment with a solvent. This allows the level of residual PCBs to be reduced~~
- ~~the technology which allows the largest amount of recycling is similar to the above, but this also treats the mixed aluminium/plastic/paper residue to separate out these components, by solvent washing. The aluminium metal can then be re-used; the only component to be disposed of is the mixed paper/plastic shreds.~~

Deleted because of repetition of ex-Section 4.5.3.13 (see above)

~~Aerosol crushers~~

~~The aerosol destructor may take manufacturing rejects or materials from collection banks. The potential contents are usually known. These can include propellant gases (this could be LPG, butane, propane, dimethyl ether or HCFC) and the active ingredients. A proportion of the aerosols are empty whilst others may still retain certain propellant gases, although this number is not quantified. Other rejects may have failed their pressure tests and will probably loose propellant on the way to the destructor unit. Any propellant still in the aerosol cylinders constitutes a risk of accident during the treatment.~~

~~At least one installation in France deals with aerosol treatment.~~

Moved to Section 5.8.2

~~Fluorescent tubes/lamp processing~~

~~Separate mercury from lamp tubes. Currently, this is a tiny activity in some countries, but existing operations are now experiencing an increasing demand for their services. At this time, most use a crushing process. However, another process recently developed is a process without crushing with a 99 % recovery of the mercury.~~

CFC deleted

~~Treatment of wastes containing CFCs~~

~~In the EU, it is mandatory to collect CFCs for disposal. It is usual that the lubricating oil collected from the draining of refrigerants is also treated to remove residual CFC prior to being recovered. CFCs can later be incinerated. Few incineration plants in the EU have HF recovery.~~

From ex-**Section 2.1.9 "Other common techniques"**

~~This section contains generic techniques used in the waste treatment sector. They are mainly mechanical treatments. They are typically used as pre-treatments but some are also used as post-treatments (e.g. sieves). They are shown in the which also states the purpose of the treatments and where they are used.~~

WORKING DRAFT IN PROGRESS

Other process steps have been moved to the related sections of Section 2.1.

Table 2.6: Common process steps techniques applied in waste treatment

~~**Technique**~~	~~**Purpose**~~	~~**Users**~~
~~Re-packaging (e.g. baling)~~	~~Due to the disaggregated nature of some types of waste, it is sometimes necessary to compact them to make them easier to use in the following process.~~ ~~Pressure machinery is used to pack the waste into a certain physical form~~	~~Used for municipal solid waste to be used as a fuel and for plastic, paper and metal bales~~ ~~The size and form of the bale is typically optimised for its transport and re-use~~
~~Screening/sifting~~	~~treatment to separate certain particle sizes~~	~~Post-treatment of output from shredder~~
~~Sieving~~	~~Used to separate big particles. Vibrating sieves, static sieves and rotary sieves are used~~	~~Preparation of waste to be used as fuel~~
~~*Source:* [60, WT TWG 2003], [78, Eucopro 2003], [98, WT TWG 2004], [103, VROM 2004], [104, UBA Germany 2004]~~		

2.1.8 Other than normal operating conditions

Other than normal operating conditions are very diverse throughout the waste sector and may cover conditions such as:

- start-up;
- shutdown;
- momentary stoppages (which, for example, may cause flaring at plants performing anaerobic treatment of biowaste or oil re-refining);
- leaks (such as leachate in biological treatments, fugitive emissions of methane at plants performing anaerobic treatment of biowaste, damage of retention bund, tank overfilling, etc.)
- malfunction or breakdown of the abatement equipment or part of the equipment (for instance, fabric filter of a dust-containing silo not functioning);
- malfunction of instruments related to the process control or used for emission monitoring (such as instrumentation drift);
- testing of new apparatuses;
- calibration of the monitoring system;
- testing of new waste or a new waste treatment process.

Reference literature
[183, TWG 2014]

WORKING DRAFT IN PROGRESS

2.2 Current emission and consumption levels

From ex-Chapter 3

2.2.1 General information on the data collection

This section summarises the installation-specific data gathered during the data collection carried out over the course of the BREF review process [160, WT TWG 2014].

Overall, 338 plants across Europe submitted filled-in questionnaires to the EIPPCB. Subsequently, the EIPPCB sent numerous requests for clarification and additional information to the TWG which resulted in many corrections. Some 11 questionnaires were discarded because the waste treatment was outside the scope of this BREF, or the questionnaire contained too little data.

Table 2.7 below gives an overview of the plants which took part in the data collection.

Table 2.7: Overview of the plants which participated in the data collection

Location	Number of installations	Share
AT	26	8.0 %
BE	13	4.0 %
CZ	2	0.6 %
DE	75	22.9 %
DK	10	3.1 %
GR	1	0.3 %
ES	26	8.0 %
FI	8	2.4 %
FR	49	15.0 %
IE	3	0.9 %
IT	25	7.6 %
NL	21	6.4 %
NO	4	1.2 %
PL	5	1.5 %
PT	5	1.5 %
RO	2	0.6 %
SE	6	1.8 %
UK	46	14.1 %
All	**327**	**100.0 %**

These 327 plants are referred to hereafter in this document as 'reference plants' or as belonging to the 'reference list'.

In order to facilitate the data collection and the subsequent data analysis, the activities of the waste treatment plants were categorised in predefined combinations of waste process and waste stream:

- mechanical treatment in shredders of metal waste;
- mechanical treatment of waste with calorific value;
- aerobic treatment of source-separated bio-waste;
- anaerobic treatment of bio-waste;
- mechanical biological treatment (MBT) of mixed solid waste containing bio-waste;
- physico-chemical and/or biological treatment of water-based liquid/pumpable waste;

WORKING DRAFT IN PROGRESS

- blending/mixing;
- immobilisation of solid and/or pasty waste;
- physico-chemical treatment of waste with calorific value;
- re-refining and other preparations for reuse of waste oils;
- treatment of excavated contaminated soil;
- regeneration of spent solvents;
- regeneration / recovery of pollution abatement components / FGT waste;
- treatment of waste containing mercury;
- regeneration of acids and bases;
- treatment of waste containing POPs;
- recovery of components from catalysts;
- temporary storage of hazardous waste;
- repackaging of hazardous waste;
- other combinations of treatment/waste.

As some of the plants have more than one combination of waste process/waste stream, the 338 questionnaires represent a total of 475 combinations.

In addition, each plant may have more than one emission point to air and/or more than one emission point to water, each emission point corresponding to one or several activities (i.e. combination waste process/waste stream) of the installation. The 338 questionnaires represent a total of 483 emission points.

After verification and correction of the questionnaires, and in order to allow the data analysis, each plant was classified according to its main waste treatment activity, this being understood as the activity which is of most relevance for the emissions of the plant.

The distribution of plants based on this classification is shown in Figure 2.5.
19 % of the emission points are related to mechanical treatment of waste, 36 % to biological treatment of waste and 40 % to physico-chemical treatment of waste, the remaining 5 % concerning common treatment processes such as temporary storage, repackaging, and blending/mixing as well as a few plants carrying out other types of activities.

WORKING DRAFT IN PROGRESS

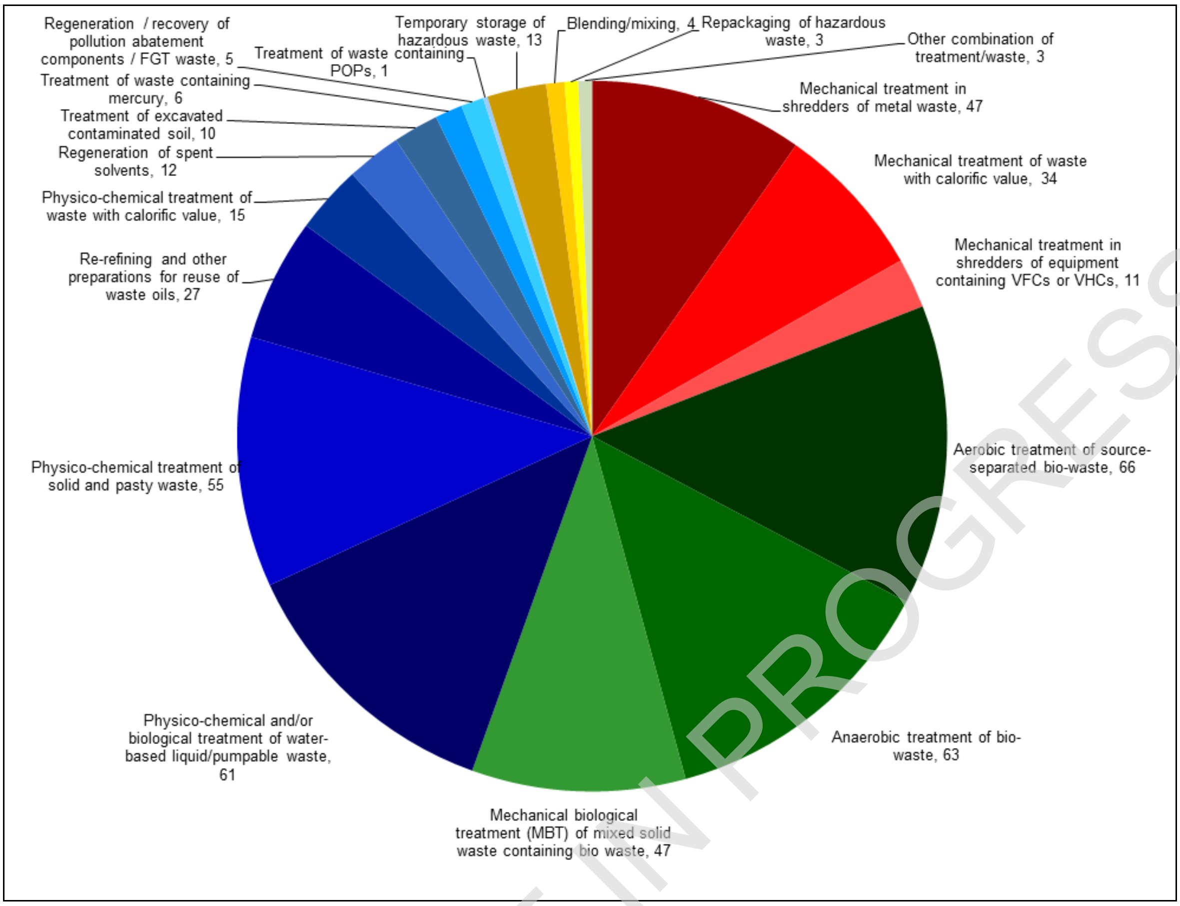


Figure 2.5: Distribution of plants which participated in the data collection

2.2.2 General information about the levels of emission

Information about emission and consumption levels is given in Chapters 3 to 5 for each combination of waste stream/waste treatment. This section does not aim at repeating this information but at giving a transversal overview across the waste treatment sector of the main pollutants released to the atmosphere, in order to understand the relative significance of the various sectors for a given pollutant. More details such as the monitoring regime and the monitoring standards used can be found in Section 2.3.3 and in Chapters 3 to 5.

As for emissions to water, and in order to avoid repetition in this document, the reader may refer to Section 5.6 which covers the most significant emissions to water in the waste treatment sector.

In the document, the concentration values for emissions to air and for emissions to water provided via the data collection [160, WT TWG 2014] are reported as follow:

- In tables:
    - periodic monitoring: range of the average over the three reference years of the provided values;
    - continuous monitoring and 24-hour flow-proportional composite sample (in water): range of the highest provided average values.

- In figures:
    - periodic monitoring: the plots represent the average over the three reference years of the provided values, the error bars represent the minimum and the maximum of the values provided over the three reference years;
    - continuous monitoring and 24-hour flow-proportional composite sample (in water): the plots represent the maximum average values provided over the three

WORKING DRAFT IN PROGRESS

reference years, the error bars represent the minimum and the maximum of the values provided over the three reference years.

~~This section contains emissions and consumptions data for the pretreatments/activities and post-treatments/activities commonly used in the WT sector. It contains those emissions and consumptions related to the waste treatment processes described in Section 2.1. This covers those sites that transfer, bulk and store wastes. [16, UK Environment Agency 1996] [26, UK, H. 1995] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [98, WT TWG 2004] [103, VROM 2004] [104, UBA Germany 2004]~~

Ex-Section **3.1.1 Waste IN in common treatments** deleted. Does not have added value

~~The type of wastes that may be involved in these processes is very wide especially for hazardous waste. Table 2.8 gives the percentages of sites that process a certain type of waste at hazardous waste transfer stations in the UK. Non-hazardous waste transfer stations cover municipal solid waste, etc.~~

Table 2.8: Common waste streams processed at hazardous waste transfer stations in the UK

~~**Waste streams**~~	~~**% of sites processing each waste stream**~~
~~Non-chlorinated solvent~~	~~67~~
~~Scrap metal~~	~~53~~
~~Scrap metal (drums)~~	~~47~~
~~Chlorinated solvent~~	~~40~~
~~General inorganic liquid/sludge~~	~~40~~
~~General organic~~	~~40~~
~~Waste for incineration~~	~~40~~
~~Contaminated waste for landfill~~	~~40~~
~~Drums/IBCs~~	~~33~~
~~Non-hazardous waste for landfill~~	~~33~~
~~Oil~~	~~33~~
~~Batteries~~	~~27~~
~~Asbestos~~	~~13~~
~~Fluorescent tubes~~	~~7~~
~~Oil filters~~	~~7~~
~~Oil/water mixtures~~	
~~Acids and alkalis~~	

~~[34, Babtie Group Ltd 2002]~~

~~Some examples of waste IN for some common techniques are reported below:~~

~~**Computer controlled high rack storage areas for hazardous wastes**~~
~~More than 600 different types (fluid, paste-like and solid hazardous wastes) of waste are treated.~~
~~**Treatment of small quantities**~~
~~This typically includes treatment, sorting and packing of hazardous wastes from private households, universities, laboratories, business enterprises and other customers. Additionally, the system can offer the possibility to condition inorganic material for underground disposal.~~

~~**Shredding**~~
~~The treatment is used for hazardous and non-hazardous waste. The wastes treated are solid and paste-like wastes, non-pumpable wastes like print and lacquer sludge, oil and other machining sludge.~~

Ex-**Section 3.1.2 "Consumptions of common treatments"** deleted. Data is given in each section related to a specific waste stream / waste treatment (Chapters 3 to 5).

WORKING DRAFT IN PROGRESS

~~Although a number of sites run entirely on electricity, some have mobile or stationary plants that use diesel or fuel oils, or they have their own power plants that use gas (natural or biogas) or gasoil. Some common equipment that use fossil fuels are fork lift trucks, small boilers, shredders and grinders. These take a mixture of standard vehicle diesel, and a range of fuel oils. Some waste plants in the UK have quantified their fuel use as ~200 tonnes per year. The proportion of raw materials (i.e. purchased reagents) used is relatively low as, in the first instance, wastes are used to treat other wastes. However, some new raw materials are used, as summarised in Table 2.9.~~

Table 2.9: Examples of commonly used raw materials in waste treatments

~~**Raw material**~~	~~**Application**~~	~~**Principal environmental characteristics**~~
~~Calcium hydroxide (lime)~~	~~Usually purchased in powder form for acid treatment~~	~~• hazardous substance~~ ~~• powder difficult to handle~~ ~~• produces large sludge volumes~~ ~~• for example, the treatment of sulphuric acid results in a large net production of calcium sulphate sludge~~
~~Sodium hydroxide (caustic soda) solution~~	~~Abatement reagent, typically used in wet scrubbing systems to control acid gases or as a scrubbing liquor in oil reprocessing~~	~~• hazardous substance~~ ~~• very low levels of mercury may be found in some grades of caustic soda, and these may be transferred to the installation effluent (see Section)~~
~~Ferric chloride solution~~	~~Additive to aid precipitation of metals and as a conditioning agent for sludge formation (as it helps with floc formation)~~	~~• strongly coloured in the event of a spillage or incident~~
~~Sodium hypochlorite~~	~~Used in the treatment and abatement for cyanide wastes scrubbing and odour control~~	~~• strong oxidising agent~~ ~~• stored away from potentially incompatible substances~~
~~De-emulsifiers~~	~~Used to 'crack' emulsified oil water mixtures in oil recovery processes~~	~~• high oxygen demand risk, if released to water in the event of an accident~~
~~*Source:*[33, UK EA 2001] [98, WT TWG 2004]~~		

Ex-**Section 3.1.3 "Emissions from common treatments"** deleted. Data is given in each section related to a specific waste stream / waste treatment (Chapters 3 to 5).

~~Following the same structure as followed in Section 2.1, some individual sections on common treatments are discussed. At the end, the other common treatments not described before are covered in a tabulated form.~~

~~**Energy systems**~~

~~The use of fuels is a source of air emissions during combustion, and possibly of emissions to land as well due to spillage and leaks. The air emissions are predominantly CO_2 (carbon dioxide) and water from the combustion process, but can also include NO_x, SO_x, PM_{10}, PAHs, VOCs and CO (carbon monoxide). The emissions are related to the fuel specification and the age and use of the equipment (e.g. vehicles, biogas engines). Other pollutants that may appear are halogens (e.g. HCl and HF when waste is used as fuel within the installation) and metals.~~

~~The following table suggests a set of data that could be used to estimate the emissions. Data have been collected for three types of sources:~~

- ~~line sources, including roads and railways (g/km)~~
- ~~area sources, including emissions from agricultural and other land, and low intensity emissions from sources such as building heating systems~~
- ~~point sources, including emissions from industrial plants.~~

~~The type of fuel used to fire in the energy system (e.g. furnaces, boilers, afterburner) will determine the nature of pollutants present.~~

WORKING DRAFT IN PROGRESS

Table 2.10: Summary of data for small boilers using a distillate (gas), a residual oil (fuel oils 5,6) or diesel engines

	~~Type of fuel~~		
	~~Distillate~~	**~~Residual fuel~~**	**~~Diesel~~**
~~Air emissions~~			
~~CO21~~	~~3142~~	~~3112~~	~~3036 – 3142~~
~~PM~~			~~2.564~~
~~PM101~~	~~0.2~~	~~2.85~~	~~2.83~~
~~NOx1~~	~~3.46~~	~~7.54~~	~~33.9 – 48.8~~
~~N2O~~			~~0.041 – 1.3~~
~~CH4~~			~~0.17 – 0.336~~
~~NM-VOC1~~	~~0.09~~	~~0.12~~	~~7.08 – 10.898~~
~~CO1~~	~~0.06~~	~~0.5~~	~~15.8 – 26.548~~
~~SO21~~	~~3.6~~	~~47.4~~	~~0.8 – 10.106~~
~~SOx~~	~~19.56 x S2~~	~~20.42 x S2~~	
~~PAH@(g)~~	~~0.15~~	~~0.151~~	~~4.07~~
~~Ni (g)~~	~~Tiny~~	~~1.1~~	
~~Cu (g)~~			~~1.7~~
~~Zn (g)~~			~~1~~
~~HCl~~			~~0.038~~
~~HF~~			~~0.038~~
~~Water emissions~~			
~~BOD~~			~~0.038~~
~~COD~~			~~0.038~~
~~Suspended solids~~			~~0.038~~
~~TOC~~			~~0.415~~
~~Phenol~~			~~0.038~~
~~Total metals~~			~~0.038~~
~~Cl~~			~~0.038~~
~~F~~			~~0.038~~

~~Units: kg (unless specified) per tonne of fuel~~
~~1 Data sourced from the UK Emission Factors Database; gasoil (other sources) and Fuel Oil (other sources), from Australian National Pollution Inventory (converted from kg emissions per m3 fuel) and European Environment Agency~~
~~2 S is the % of sulphur in the fuel~~
~~@ as benzo (a) pyrene~~
~~*Source*: [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [43, EEA 2003], [98, WT TWG 2004]~~

~~Storage and handling~~

~~The main air emissions from the storage and transfer of waste are VOC emissions. According to the type of waste, dust may also be important. These comprise the major issues arising from handling wastes at transfer and treatment sites. The principal emissions arise from transfer and bulking activities since, in the majority of cases, any remaining residues in containers that may contain solvents will be vented to the air. General releases of VOCs from tanks due to thermal effects and releases from pipes and pumping systems can also occur but depend on the system installed in the plant structure.~~

~~Most of the fugitive emissions to air are from the transport, storage and bulking of organic wastes, primarily solvent wastes. Similar emissions are also expected from the transfer of ammonia wastes and from strong acid wastes.~~

~~The main emissions from decanting and bulking processes are to the air and may be related to the following although some of the practices mentioned below may be considered bad practices. If a practice is mentioned here, it does not mean that it occurs at the majority of sites):~~

- ~~caps on the receiving containers, these may be open during the working day and give a continuous emission, albeit through a small aperture, of volatile components. This emission~~

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~~is particularly related to the displacement of saturated vapour from within the container with each new addition of liquid~~
- ~~emissions directly from the liquids being transferred as the transfer takes place~~
- ~~empty containers (drums, or bottles) which contain a measurable amount of waste materials, which, through rinsing out, is discharged to the on-site treatment process or to the sumps for disposal later. In some cases, these containers are placed in a skip for disposal to landfill or, when the contents are volatile, left to evaporate to air either with or without shredding. Such practice is actually not in accordance with the Landfill directive. Where the sites handle a large amount of solvents, drum-crushing systems can be used to squeeze and collect additional waste solvent from the drums~~
- ~~the potential problem of leaks occurs during transfer, during displacement of the product in the headspace above the liquid layer, and when venting the residues from the original container. Where the material is held in storage tanks, there is an issue of outbreathing in response to atmospheric temperature and pressure. The problem is most acute with solvent transfers, but is also relevant to strong acids and wastes containing ammonia. Such practice is not considered to be a good environmental practice~~
- ~~the transfer of materials from tankers to storage tanks, which are therefore controlled on a number of sites, particularly when this involves low boiling point solvent waste. The weakest link and subsequently the main source of spillage during transfer from the vehicle to storage arises from the transfer hoses~~
- ~~although the volume lost during routine operations due to ill-fitting or damaged hoses may be relatively small, persistent spillages may have a cumulative effect on the surface of the area, which in the long term may damage the surface and lead to a fugitive emission~~
- ~~spillages may also be a source of odour~~
- ~~the manual transfer of materials from small containers to 205 litre drums and IBCs. Typically this transfer has no control on emissions and it is common practice for the empty containers (containing perhaps 1 %, or up to 0.5 litres, of the original content) to be vented to the air prior to landfill. Such practice is actually not in accordance with the Landfill Directive~~

- ~~with regard to monitoring and other activities on site, it is worth noting that:~~
    - ~~most sites have little or no monitoring data for calculating emissions to the air and some kind of rough estimation method is needed to relate potential air emissions to the number of tankers or containers emptied or filled at the site~~
    - ~~discharges to sewer or surface waters tend to have limited monitoring data as well, but the actual discharges are minimised by operational practices at the sites, such as bunding~~
    - ~~transfer stations also undertake a range of other practices that can create emissions. These include the evaporation of solvents to the air from tank cleaning, from industrial wipes and from solvent sludges.~~

~~The range of emissions is very large and dependent on the type of activity (e.g. differences are particularly notable between physico-chemical treatment plants and oil re-processing plants). Each transfer of waste, and processing of the original container can generate liquid and vapour emissions. Some emissions generated by this activity are:~~

- ~~tank bottoms from storage tanks~~
- ~~air emissions generated by bulking in tanks loading and in unloading tankers due to displacement to the air (note: some transfer stations have very well equipped systems for balancing tanker emissions and controlling the discharges from tanks)~~
- ~~evaporation emissions during decanting (e.g. VOCs) and bulking, also evaporation from wastes left in containers~~
- ~~general spillages during decanting and handling. Spillages are typically retained in the bunded area or discharged to the interceptor~~

WORKING DRAFT IN PROGRESS

- ~~air emissions generated by wiping cloths impregnated with solvents. In some installations, these are collected in sealed bin liners and then laid out to dry by evaporation to dryness prior to landfill. This is considered a bad environmental practice~~
- ~~VOCs from the venting of empty drums being washed out (washings to underground storage tanks prior to landfill) and, from the evaporation of blanket wash solvents washed to the underground tanks~~
- ~~emissions caused by bulking laboratory smalls. Emissions only typically occur in the event of spillages and are recorded in site diaries. General discussions at sites suggest that the number of substandard containers and badly labelled containers in this category are now minimal and that spillage and emissions due to poor containers is in fact rare~~
- ~~accidental breakage of waste containers~~
- ~~from storage tanks in the open, on hard-standing and bunded areas, and for which although the connections are over the bunded area, there is no system to deal with leaks from the collection/delivery systems and so the whole bunded area can become very contaminated. Rainwater in the bunded area will also become contaminated. On some sites, there is no provision to control displacement of air in the tanks during loading and unloading; others have very good control systems for both tanks and tankers. Air emissions are less well controlled. Tanks tend to have valve systems to regulate tank pressure and to allow inbreathing/outbreathing of headspace vapours. Emissions to the air can occur during tank charging or due to changes in atmospheric conditions. Small emissions will also occur during sampling and inspections. There is a potential for one-off larger emissions during tank cleaning~~
- ~~non-evaporated liquids and solids, which may end up being landfilled or drained to sewer. This is considered a bad environmental practice~~
- ~~fugitive air emissions from transfer operations between processes, especially with non-pumped systems. Also leaks from containers and from pressure/vacuum relief valves~~
- ~~solid/liquid and gaseous emissions due to a possible container break in handling (accidental damage), depending on the waste material. Because the accident is reported in the site diary, the emissions can be estimated when the material is known~~
- ~~in the case of the storage of waste oils, releases to the air come from condenser vents on hot oil storage tanks. On the storage tank, vents measurements for hydrocarbons are taken using Draeger tubes and typical values may be 10 to 20 mg/Nm^3 and peaking at 100 mg/Nm^3~~
- ~~investigations into the microbiological pollution of waste sorting plants revealed mould fungi concentrations in the air at the workplace of up to more than 106 cfu/m^3 (colony-forming units).~~

~~Complementary to the information above, next Table 2.11 shows potential emissions from transfer stations, bulking processes and storage.~~

WORKING DRAFT IN PROGRESS

Table 2.11: Potential emissions from transfer stations, bulking processes and storage

~~**Activity**~~	~~**Description of release**~~ ~~[1]~~	~~**Release type**~~	~~**Release to**~~
~~Filling of bulk storage tanks or IBCs by road tankers~~	~~Displaced air~~	~~VOCs~~	~~Air~~
	~~Losses from transfers~~	~~VOCs~~	~~Air~~
		~~Liquids~~	~~Soil~~
		~~Liquids~~	~~Water~~
~~Storage in bulk tanks~~	~~Vented material~~	~~VOCs~~	~~Air~~
	~~Tank bottoms~~	~~Waste~~	
~~Releases from pipes and pumping systems~~	~~All losses~~	~~VOCs~~	~~Air~~
		~~Liquids~~	~~Water~~
		~~Liquids~~	~~Soil~~
~~Gravity and vacuum emptying of drums, IBCs and other containers to bulk tanks~~	~~Displaced air~~	~~VOCs~~	~~Air~~
	~~Losses from transfers~~	~~VOCs~~	~~Air~~
		~~Liquids~~	~~Soil~~
		~~Liquids~~	~~Water~~
~~Storage and handling of empty IBCs~~	~~Washing~~	~~Liquids~~	~~Water~~
	~~Storage~~	~~VOCs~~	~~Air~~
	~~Disposal~~	~~Liquids/solids~~	~~Landfill~~
~~Storage and handling of empty drums and other similar containers~~	~~Crushing~~	~~VOCs~~	~~Air~~
		~~Liquids/solids~~	~~Water~~
		~~Liquids/solids~~	~~Soil~~
	~~Washing~~	~~Liquids/solids~~	~~Water~~
	~~Disposal~~	~~Liquids/solids~~	~~Landfill~~
	~~Storage~~	~~VOCs~~	~~Air~~
~~Maintenance of equipment~~	~~Tank cleaning/washing~~	~~Liquid/solid~~	~~Soil~~
		~~Liquid/solid~~	~~Water~~
		~~VOCs~~	~~Air~~
~~Planned evaporation of volatile liquids~~	~~Evaporation~~	~~VOCs~~	~~Air~~

~~[1] The wide range of possible emissions to air and sewer/controlled waters has to be estimated in relation to the range of activities and wastes handled at a particular site.~~

Source: ~~[34, Babtie Group Ltd 2002] [60, WT TWG 2003]~~

~~Emissions from some other common waste treatments~~

~~Table 2.12 summarises the most frequent activities/equipment found in common waste treatment processes and the emissions that may be generated.~~

WORKING DRAFT IN PROGRESS

Table 2.12: Activities/equipment that may lead to emissions from some common waste treatments

~~Process/activity~~	~~Compounds found in WT processes that may lead to emissions~~
~~Air stripping columns~~	~~May cause a discharge of ammonia into the air which can be calculated by mass balance~~
~~Cleaning wastes or aqueous organic wastes from the chemical industry~~	~~These can contain a range of volatile compounds, chlorinated compounds and phenolic compounds.~~ ~~The solid and muddy residues produced during cleaning are disposed of as waste. If necessary, the waste is conditioned according to the acceptance criteria of the waste disposal facility~~
~~Crushing of oil filters~~	~~Waste contained in oil filters are particulate matter containing combustion products, including high PAHs/metal fragments, etc. 'stuck' together with oil.~~ ~~The solids from these operations tend to go into the oil water separation system for treatment plants, and leave with the bottom sludge.~~ ~~PAHs escape into the air with the oil mist produced during crushing or may be retained in the oil, or remain on the solids components of the filter. The PAH emissions to the air are potentially carcinogenic~~
~~Cutting~~	~~During drum cutting operations, the former contents of the drum and any residues that may be still present can be a cause of emissions~~
~~Washing of containers and vehicles~~	~~Fugitive emissions occur to air and water. Typically, a contaminated effluent is generated as well~~
~~Crushing and shredding~~	~~Regardless of the technique employed, there is typically no provision for environmental control and the emissions depend on the composition of the waste held within the drum.~~ ~~In the shredding process, the temperature of the shredded items may reach several hundred degrees. Shredding will cause emissions to the air, depending on the efficiency of the scrubber or other kind of air cleaning equipment. Fluids still present in the waste (e.g. solvents, mercury) may be released to the interior of the plant and may either evaporate or leak to the ground or may be collected as sludge. Dust from the plant will be spread to the surroundings. Other outlets from a shredding plant include a magnetic metal fraction, non-magnetic metal fractions, sludge from the washing process, and a fluff fraction which is a mixture of plastics, insulation materials, paper, soil, etc.~~ ~~The fluff fraction may be disposed of for incineration but sometimes is landfilled (not considered a good practice). A quite significant amount of heavy metals follows the fluff fraction. In the middle of the nineties Danish shredder plants shredded about 300000 tonnes waste. The fluff from the operation was estimated to contain about 0.15 tonne mercury, 200 - 1000 tonnes lead, and 0.5 - 2.5 tonnes of cadmium. The emission of mercury to air from the operations was estimated at <0.05 tonne~~
~~Drum and road tanker cleaning~~	~~Cleaning operations which specialise in cleaning drums that previously contained solvent and oil wastes may release large percentages of waste to the air since the solvent wastes are flushed to the air occasionally and in certain locations, during the cleaning process. This appears to be a similar issue to the evaporation of solvents to the air during decanting at certain transfer stations.~~ ~~The presence of any former content or any residue in drums may cause emissions during cleaning/washing operations.~~ ~~At some sites, unwashed drums might go directly to landfill along with the associated residues.~~ ~~A site processing drums contaminated with oil and organic materials estimated a 40 t/yr solvent discharge to the air. Part of this emission is due to the standard transfer station practice of venting 'empty' drums to the air.~~ ~~A site recycling drums from the inorganic sector had a high metals level in the discharge to sewer, but was able to calculate the discharge from regular analyses.~~ ~~Most treatment plants incorporate a washing out facility to enable the removal of residues from vehicle tanker barrels. In some cases, vapours may become trapped within the sludges and appropriate actions need to be taken to avoid any uncontrolled releases~~
~~*Source*: [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [71, COWI A/S 2002] [73, Irish EPA 2003] [77, Schmidt et al. 2002]~~	

~~*Shredding*~~

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Table 2.13: Exhaust air from shredding treatment of solid hazardous waste

~~**Parameter**~~	~~**Concentration**~~	~~**Unit**~~
~~Dust~~	~~0.1~~	~~mg/Nm^3~~
~~SO^2~~	~~<0.06~~	~~mg/Nm^3~~
~~NO*~~	~~8~~	~~mg/Nm^3~~
~~TOC~~	~~5~~	~~mg/Nm^3~~
~~CO~~	4	~~mg/Nm^3~~
~~HCl~~	~~13.8~~	~~mg/Nm^3~~
~~PCDD/PCDF~~	~~0.001~~	~~ngTEQ/Nm^3~~
~~Odour~~	~~85~~	~~GE/m^3~~
~~Cl~~	~~<0.1~~	~~mg/Nm^3~~

~~The flows of the exhaust air are 8028000 and 5628000 m^3/yr for the can shredder and the bin shredder respectively.~~
~~*Source*:[104, UBA Germany 2004]~~

~~**Emissions occurring due to accidents**~~

~~The most significant environmental risks associated with waste treatment operations are the storage of hazardous wastes. This can involve emissions resulting from wastes reacting together, either from leaks and spillages or from treatment processes going out of control.~~

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Table 2.14: Example of most frequent accidents that may occur in WT installations

~~Procedure~~	~~Hazard~~	~~Hazardous event~~	~~Cause/possible initiating event~~
~~Sampling/ analysis~~	~~Toxic vapours~~	~~Chemical spray~~ ~~Blow-out~~ ~~Chemical spillage~~	~~Container under pressure~~ ~~Transfer from sampling vessel and withdrawal of sample (barrel-sampler)~~ ~~Waste not as expected~~
	~~Fire~~	~~Flammable materials ignite~~	~~Flammable vapour at point of sampling~~
~~General handling/ treatment~~	~~Toxic gases~~	~~Incompatible wastes mixed~~	~~Inadequate/incorrect information on wastes~~
		~~Waste spillage~~	~~Operator not working according to safe practices~~ ~~No safe operating procedures established~~ ~~Inadequate facility engineering~~ ~~Inadequate supervision~~ ~~Accidental discharge~~
~~Drum handling/ storage~~	~~Direct chemical contact~~	~~Blow-out~~	~~Contents under pressure~~
	~~Toxic gases~~ ~~Dusts~~	~~Spillages~~	~~Contents spilt during emptying/decanting~~ ~~Corroding/leaking drum~~ ~~Manual removal of contents~~
	~~Reaction~~ ~~Toxic gases~~	~~Mixing of incompatible wastes~~	~~Spillages/corroded drums Bulking up drums~~ ~~Wastes not conforming to labelling~~ ~~Wastes not adequately analysed~~
	~~Fire/ explosion~~	~~Flammable materials ignited~~	~~Unexpected flammable materials present~~ ~~Spark in taking lid off/flammable headspace~~ ~~Use of cutting tools to open drum~~ ~~Fire produces toxic degradation products~~
~~Unloading tankers~~	~~Toxic gases~~	~~Release as liquid/gas spray~~	~~Incompatible/reactive wastes mixed together~~ ~~Container under pressure/blow-out~~ ~~Unloading into wrong storage vessel~~ ~~Waste materials received 'hot' due to viscosity solidification/thickening difficulties~~ ~~Gross failure of tanker~~ ~~Vehicle impact~~ ~~Spillage on coupling/uncoupling, failure of coupling~~
	~~Fire/ explosion~~	~~Flammable/ explosive mixture ignited~~	~~Flammable atmosphere in 'empty tanker'~~
~~Waste storage tank farm~~	~~Fire/ explosion~~	~~Flammable liquid or vapours ignite~~	~~Flammable vapour vented-off~~ ~~Vapour release from spills~~ ~~Pipeline failure~~ ~~Flammable vapour in tank headspace~~
	~~Reaction~~	~~Incompatible wastes mixed~~	~~Wastes react in storage vessels pipeline or conveyor failure~~
	~~Toxic gases~~	~~Non-compatible or reactive waste mixed in store or reagent spillage~~	~~Inadequate information on waste~~ ~~Waste does not conform to process specification~~
		~~Significant levels of toxic gases/fumes evolved~~	~~Inadequate venting of tanks, etc.~~ ~~Poor materials handling practices~~

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~~Physico-chemical treatment~~	~~Toxic gases~~	~~Uncontrolled release during reaction~~	~~Failure of protective systems~~ ~~Incompatible waste mixed~~ ~~Wrong reagent added~~ ~~Too much/too little of reagents added~~ ~~Failure of pH control~~
~~Effluent dewatering from physico-chemical treatment~~	~~Toxic gases~~	~~Mixing incompatible effluents~~	~~Reaction not complete~~ ~~Residual contamination in effluents~~
~~Biological treatment~~		~~Fire~~	~~Biological degradation processes may cause self heating and auto-ignition. This does not only affects the biological treatment system. Auto-ignition may also occur in the bunker. In some cases fires can appear in the product storage area.~~ ~~A second reason for fires in solid waste fuel processing plants are particles that are still glowing.~~
~~*Source*:[57, Petts, J. and Eduljee, G. 1994] [82, Pretz et al. 2003] [98, WT TWG 2004]~~			

~~Generic air emissions from common waste treatments~~

~~VOC~~

~~There are no real data available at present on VOC emissions. The vast majority of sites that undertake air monitoring, undertake it on an irregular basis and are unlikely to take a sample at the times of maximum discharge. Air emissions are particularly difficult to monitor from these sites as operations are generally in the open air and gases are not always controlled. VOC emissions at a site may be due to:~~

- ~~a deliberate process activity at some sites carried out in order to reduce the flammability of wastes going to landfill. The quantities may be very small per unit of waste, but the operation takes place across a large number of sites and the accumulated effect may be very large. This practice is not common in the sector and is considered a bad practice so is now obsolete~~
- ~~the agitation or heating of mixed materials left to settle in contact with the atmosphere. Oil treatment tanks are one obvious example, but chemical treatment tanks or sludge mixing tanks are also sources~~
- ~~emissions of semi-volatile PAHs from crushing and sieving operations, particularly from the handling of oil filters at transfer stations~~
- ~~the transfer of liquids to bulking containers, with a subsequent displacement of the product headspace above the liquid layer~~
- ~~the venting of residues from original storage containers; and also from storage tanks outbreathing in response to atmospheric temperature changes.~~

~~There are example plants in the WT sector with no controls on discharges of volatile compounds into the air, indeed few processes have ever been designed to discharge pollutants to the air.~~

~~Acid emissions~~

~~The most serious air emissions are likely to arise from solvent transfer and storage activities, but they can also arise from chemicals such as strong acids and ammonia.~~

~~Ammonia emissions~~

~~Ammonia is detected in some WT sites. There is a general problem with ammonia emissions. However, this is usually easy to spot on site visits and by operators due to the low threshold concentration for odour detection, although it is harder to quantify. Locations where ammonia emissions have been detected are:~~

WORKING DRAFT IN PROGRESS

- ~~in solvent transfer and storage~~
- ~~in the pressing and storage of effluent sludge at several chemical treatment plants. This is an area that is rarely within the exhaust systems for the site and therefore emissions do not pass through the plant scrubbers. Furthermore, the scrubbing systems are usually caustic scrubbers~~
- ~~from strong ammoniacal solutions directly to the air after an air stripping at one site, although the site monitoring (only annual monitoring carried out) says that background atmospheric levels are minimal~~
- ~~effluent treatment plants~~
- ~~acid treatment of waste oils~~
- ~~wastes from the photographic industry are an example of a waste stream with a high concentration of ammonium salts and, although discharges to the air are not identified, this is a potential problem during transfer processes, giving rise to air emissions and potential contamination of water discharges.~~

~~Fugitive and diffuse emissions~~

~~In many installations, fugitive and diffuse emissions may be more significant than point source or channelled emissions. Common examples of the sources are:~~

- ~~open vessels (for example, the effluent treatment plant)~~
- ~~sampling activities~~
- ~~storage areas (for example, bays, stockpiles, lagoons, etc.)~~
- ~~the loading and unloading of containers~~
- ~~transferring/bulking up of material from one vessel to another~~
- ~~conveyor systems~~
- ~~pipework and ductwork systems (for example, pumps, valves, flanges, catchpots, drains, inspection hatches, etc.)~~
- ~~poor building containment and extraction~~
- ~~potential bypass of abatement equipment (to air or water)~~
- ~~spillages~~
- ~~accidental loss of containment from failed plant and equipment~~
- ~~tankers and vessels, manhole openings and other access points~~
- ~~displaced vapours in receiving tanks~~
- ~~cleaning or replacing of filters~~
- ~~drum cutting~~
- ~~waste water storage~~
- ~~drum storage~~
- ~~tank cleaning~~
- ~~tanker washing/cleaning.~~

~~Particulate emissions~~

~~Sites handling powders and wastes giving rise to dusts (e.g. fly ashes) often have particulates to emit to the air.~~

~~Noise and vibration~~

~~'Noise' refers to 'noise and/or vibration' typically detectable beyond the site boundary.~~

~~Odour emissions~~

~~Emissions to air tend only to be checked subjectively by using the sense of smell. Odour emissions are associated with point sources as well as fugitive sources. In addition to ammonia previously discussed, the handling of any substance that is or may contain a VOC (or other odorous substances, for example, mercaptans or other compounds containing sulphur) will potentially lead to odour noticeable in and beyond the installation boundary. Odours may arise from:~~

WORKING DRAFT IN PROGRESS

- ~~storage~~
- ~~the transfer or bulking up of wastes containing VOCs or other odorous substances~~
- ~~a failure to adequately inspect and maintain plant and equipment, which may lead to fugitive emissions, e.g. leaks from pumps.~~

~~Generic water emissions from common waste treatments~~
~~A distinction can be made between installations conducting 'dry' or solid phase operations, e.g. transfer or stabilisation, which do not produce a distinct liquid effluent; and those conducting liquid phase treatment, e.g. acid neutralisation and oil water separation.~~

~~'Dry' processes typically only produce effluents from activities such as from rainwater collection and incidents such as spills and leakages. In general terms, the strength of this effluent in terms of metals and COD levels will be relatively low. 'Wet' processes, in addition to the general effluent arising from yard drainage, etc., produce an effluent from the reaction, precipitation, settlement and dewatering processes.~~

~~Waste water may be generated in the installations due to:~~

- ~~unplanned discharges to drain (e.g. emergency control, fire)~~
- ~~spillage from storage~~
- ~~discharge to storm drain~~
- ~~discharge of bund and secondary containment contents~~
- ~~process waste water (each case is covered from Section 3.2 to 3.5).~~

~~Many transfer stations are associated with adjacent treatment plants and all run-off goes into that treatment system where is treated. Others collect the run-off and tanker this to landfill. Again there is no discharge to receiving waters or sewer. The remainder of the installations discharge either to surface water (unusual option) or to sewer. In the vast majority of EU countries, it is not permitted to make direct discharges to sewer or to controlled waters. A security storage is then needed in order to control or treat the water before discharge. Some typical emissions are summarised in Table 2.15:~~

Table 2.15: Point source emissions to water

~~Emission to~~	~~Unit process or activity~~
~~Sewer~~	~~Physico-chemical treatment. Final effluent from acid/alkali neutralisation and the precipitation of metals~~
	~~Oil reprocessing. Effluent treatment to remove oil from condensate and yard drainage~~
	~~Cleaning~~
~~Watercourse~~	~~Rainwater collection~~
	~~Yard drainage~~

~~*Source:*[33, UK EA 2001]~~

~~In principle, there will always be small quantities of every material decanted at the site discharged to sewer, due to drips and splashes even if there are no spills recorded. The most common materials to be bulked at transfer stations are dilute acids (often from metal treatment), caustic solutions, oils, non-halogenated solvents and aqueous organic wastes. The discharge is almost certain to contain organic carbons, nitrogen compounds (total nitrogen), chloride, some metals and, when bulking non-halogenated solvents, xylene. Discharges to sewer may reach COD levels of several thousand milligrams per litre. The nature of the discharge depends on the wastes being handled at the installation, which invariably involves a wide variety of substances, thereby resulting in a complex effluent.~~

~~Emissions to water also occur from washing containers and tanks if this occurs in the WT plant. Liquid discharges may arise from the washing and processing of containers prior to their re-processing, or from the washing of road tankers. One approach of estimating these emissions is to assume that the residual material in each type of container after emptying is 0.5 % of the~~

WORKING DRAFT IN PROGRESS

~~volume, and that all of this material is washed to sewer. In general, volatile residues from containers of solvent waste are evaporated directly to the air rather than being washed to sewer.~~

~~General leaks and spills can occur in waste transfer stations. Most sites are on hard standing and liquid and solid spills are eventually washed away to the main interceptors and then to sewer or to an adjacent treatment plant.~~

~~Generic releases to soil and process generated waste from common techniques~~

~~Most sites will have a continuous, but small, discharge of waste to the site base-ground due to drips, splashes, crushing residues, pipe connections, oil leaks, etc. and these may be washed to the surface water collection points by rainwater and site cleaning. Tank bottoms are another typical waste when storing waste.~~

~~Example of inventory of emissions from a waste transfer station~~

Table 2.16: Example of total estimated emissions from a waste transfer facility

~~Operation~~	**~~Emissions to air (kg/yr)~~**	**~~Emissions to sewer (kg/yr)~~**
~~Repacking and labelling of laboratory chemicals~~	~~0~~	~~0~~
~~Breakage/leaks during loading and storage~~	~~VOC as TRI 20.3~~	~~Small amounts of oil, but these will be picked up in weekly monitoring data and not doubly counted here~~
~~Decanting into IBCs~~	~~Dichloromethane 360~~ ~~Ethanal 48~~ ~~Trichloroethylene 60~~ ~~VOC as TRI 60~~ ~~VOC 1320~~ ~~Xylene 360~~	~~All solvent species~~ ~~Total nitrogen~~ ~~Total phosphorus~~ ~~Chloride~~ ~~TOC~~ ~~Metals~~
~~Transfer from IBCs to solvent storage tanks~~	~~ethanal 76~~ ~~VOCs 1330~~ ~~xylene 570~~	~~Xylene~~ ~~TOC~~
~~Fuel use for fork lifts (Use of 5 tonnes of diesel per year)~~	~~CO 79~~ ~~CO_2 15710~~ ~~NM-VOC 35.4~~ ~~NO_2 244~~ ~~PM_{10} 14.15~~ ~~SO_2 4~~	~~TOC~~
~~Sewer discharges~~	~~0~~	~~TOC 5980~~ ~~NH_3-N 14~~ ~~Cu 0.5~~ ~~Ni 0.5~~ ~~Zn 0.5~~ ~~Oil 150~~ ~~Xylene, toluene, TRI, trichloroethylene, Cl, P trace discharges~~
~~Totals~~	~~CO 79~~ ~~CO_2 15710~~ ~~Dichloromethane 360~~ ~~Ethanal 124~~ ~~NO_2 244~~ ~~PM_{10} 14.15~~ ~~SO_2 4~~ ~~TRI 80.3~~ ~~Trichloroethylene 60~~ ~~VOC 2706~~ ~~Xylene 930~~	~~TOC 5980~~ ~~NH_3-N 14~~ ~~(assumed cannot reach limit for nitrogen)~~ ~~Cu 0.5~~ ~~Ni 0.5~~ ~~Zn 0.5~~ ~~Oil 150~~ ~~Xylene, toluene, TRI, trichloroethylene, Cl, P~~

WORKING DRAFT IN PROGRESS

~~Overview of the installation~~

~~The above data correspond to a hazardous waste transfer station fitted with an impermeable base. It has bulking areas with blind sumps and a roof. The solvent storage tanks are in a separately bunded area with activated carbon filters on vents. Thermal out-breathings and head space displacement losses due to charging the storage tanks, are scrubbed prior to be discharged into the air. Loading, unloading and drum storage areas of the site are in the open and drain to the interceptor, hence to the sewer. There is a continual monitoring of pH and flowrate, and a weekly monitoring of COD, metals, oil, ammoniacal nitrogen and suspended solids on the sewer discharge. Packaging materials and old contaminated containers are sent to landfill.~~

~~The site handles a very wide range of materials, but mainly the following streams:~~

- ~~halogenated solvents comprising on average 80 % solvent; 20 % solids. Of the solvent fraction, 10 % is trichloroethylene; 10 % 1,1,1 trichloroethane; and 60 % dichloromethane~~
- ~~non-halogenated solvents, on average 70 % solvent, 30 % solids and water, with the solvents comprising 10 % toluene; 30 % xylenes; 10 % acetone, 20 % others, mainly MEK, ethanol, ethanal, methanol and aliphatic C_{10}-C_{12} hydrocarbons~~
- ~~the other major waste streams are dilute hydrochloric acid and zinc, sulphuric acid and phosphoric acid from metal processing, soluble oils, dilute caustic soda, dilute ammonia solutions from photographic processes, aqueous paint residues, aqueous adhesive residues and ethylene glycol. All of these are bulked prior to onward transfer or storage.~~

~~Waste OUT produced is 120 tonnes of waste fuel and 60 tonnes of halogenated materials per year. The installation handles 120 tonnes of waste from IBCs filled at the site and a further 260 tonnes of waste that arrives in IBCs.~~

~~*Source*: [34, Babtie Group Ltd 2002] [60, WT TWG 2003]~~

~~Emissions from specific waste treatments~~

~~Table 2.17: Emissions from specific waste treatment processes~~

~~Specific waste treatments~~	~~Air~~	~~Water~~	~~Waste~~
~~Aerosol destructor crusher~~	~~In some cases, propellants are discharged to the air via the exhaust fan~~	~~A mass balance suggests that emissions to water could be as much as 250 t/yr, but there is insufficient detail on the tonnage of liquid waste produced at present to make an accurate calculation~~	~~Liquids from the crushing process are collected and sprayed onto the adjacent landfill~~
	~~The active ingredients and carrier solvents can include materials such as paint thinners, alcohols, and possibly some pesticides~~		
~~CFC recovery treatments~~	~~The oil waste will contain some CFCs that evaporate in the air. A small additional discharge will occur during routine sampling~~	~~Discharges can be estimated~~	~~CFC refrigerants are recovered for re-use and generate a small stream of oil, that is sent for further treatment.~~ ~~A tiny amount of used dessicant (contaminated with oil) goes to landfill each year~~
~~Delivery storage and transfer of materials~~	~~VOCs, acids or ammonia wastes~~		
~~Glass crushing~~	~~There are large problems with particles, despite the presence of extractor fans, with dust settling on equipment, the plant and on the finished product. Abatement equipment is not fitted~~		

WORKING DRAFT IN PROGRESS

~~PCB cleaning~~	~~A monitoring programme typically covers PCB discharges to the air, to surface waters and to the land in the vicinity of the installation.~~ ~~The trichloroethylene (TCE) is distilled on site for re-use, and the residual sludge is sent for incineration.~~
~~Cleaning of transformers containing PCBs~~	~~Decontamination of PCB transformers is never completely applied to all components, and this means that a residue remains which must be incinerated. In the best case this will be just the porous parts (wood and paper), unless the solvent technique is applied for long process times, and a product will finally be obtained which can be sent for land-filling if the residual PCB levels are legally acceptable.~~ ~~There is potential for fugitive emissions of PCB via the formation of aerosols.~~
~~*Source*: [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [69, UNEP 2000] [98, WT TWG 2004]~~	

Ex-Section **3.1.4 Waste OUT from common waste treatments** deleted. It does not have added value

~~Depending on the type of operation of the treatment technique, the physical and/or chemical properties of wastes may change when common techniques are applied. However, it is found that some common techniques (e.g. storage, acceptance, reception) do not change the chemical or the physical properties of the waste IN. On the other hand, others such as, for example, blending, mixing, crushing, shredding, change the properties of the waste IN.~~

2.2.2.1 Dust emissions to air

Figure 2.6, Figure 2.7and Figure 2.8, give an overview of the dust emissions to air from all 182 waste treatment plants on the plant reference list that measure dust.

The plants with the highest dust concentrations in emissions to air carry out as their main waste treatment process: mechanical treatment in shredders of metal waste (Section 3.1), MBT (mechanical biological treatment, see Section 4.4), physico-chemical treatment of solid and/or pasty waste (Section 5.1) and anaerobic treatment of bio-waste (Section 4.3).

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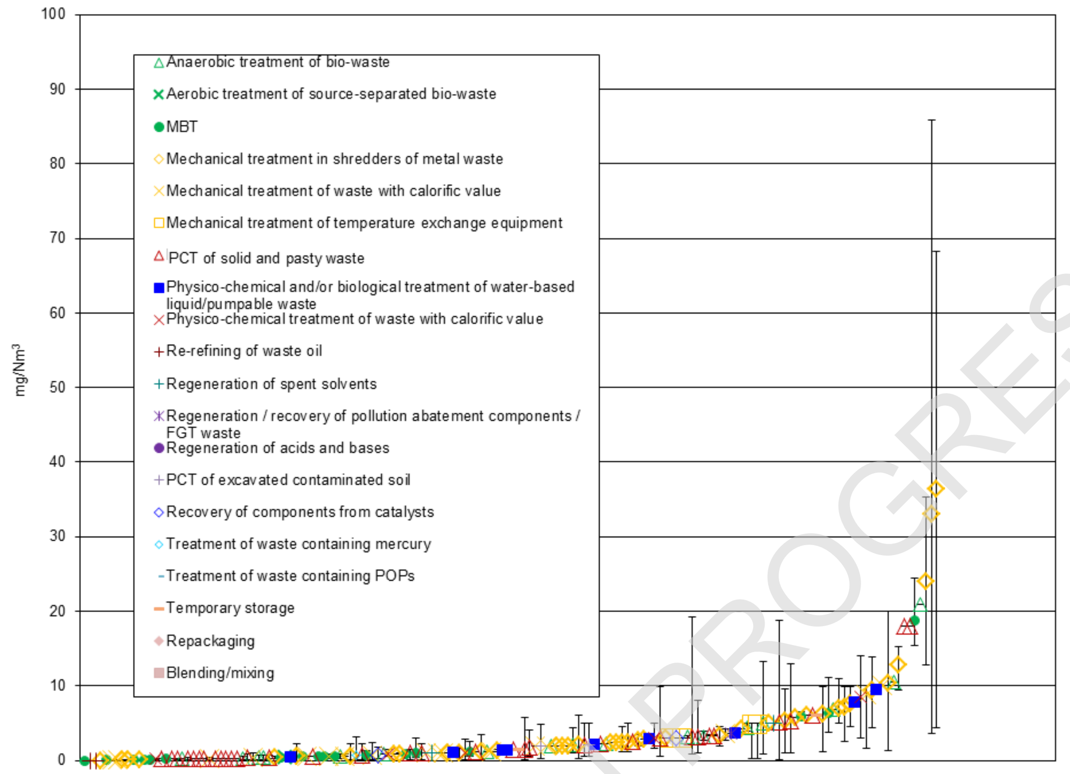

NB: The plant codes are not indicated for legibility reasons.

Figure 2.6: Dust emissions to air from all waste treatment plants (periodic measurements)

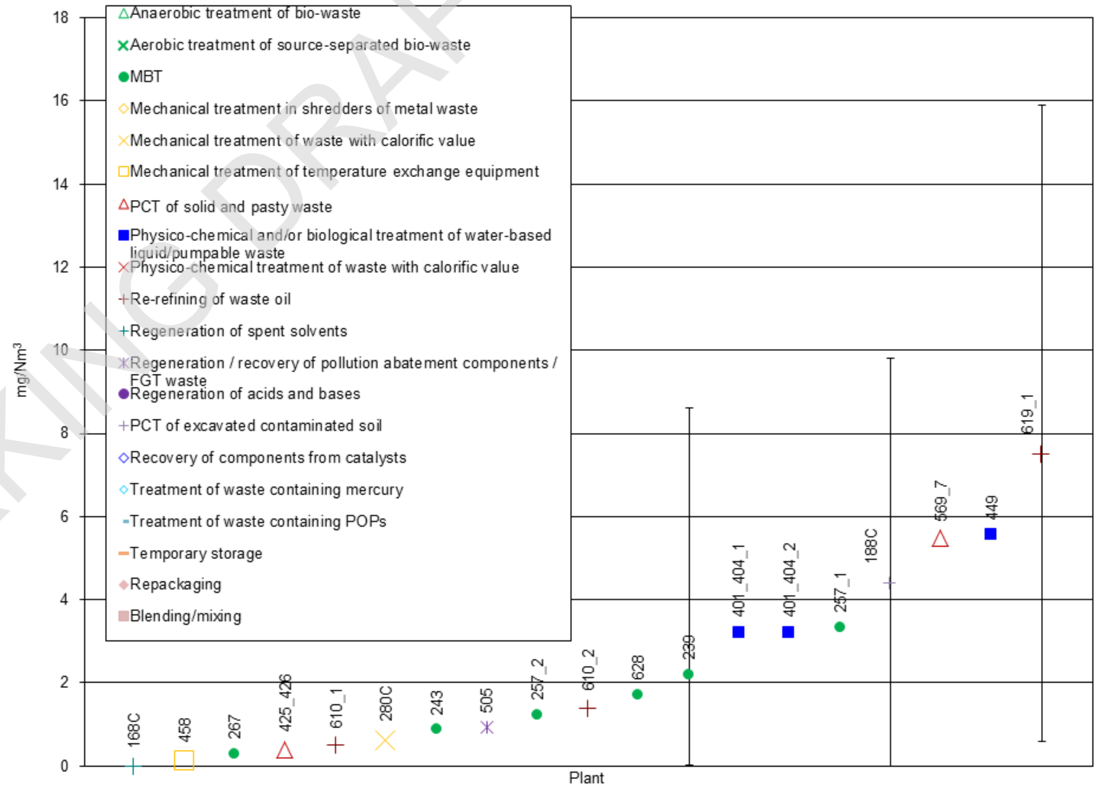

Figure 2.7: Dust emissions to air from all waste treatment plants (continuous measurements – long-term average)

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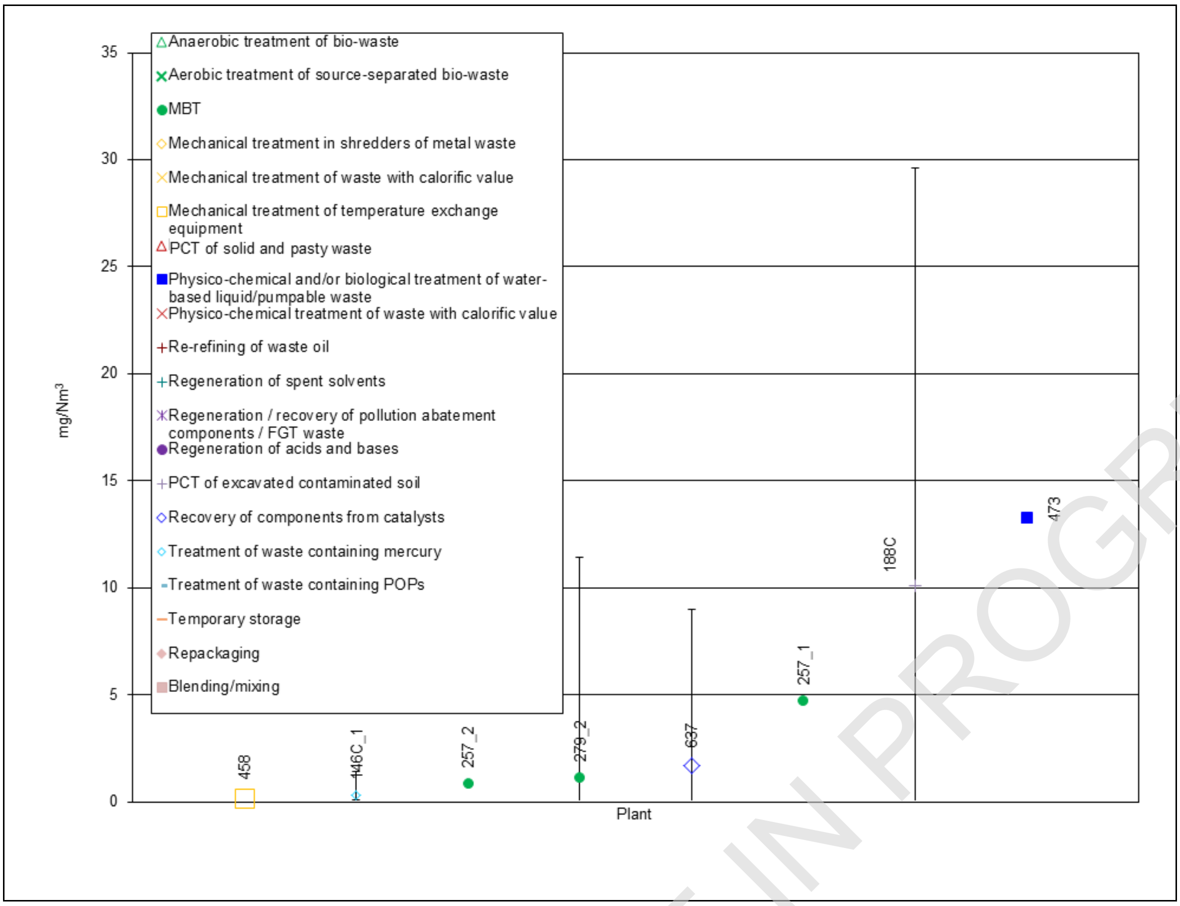

Figure 2.8: Dust emissions to air from all waste treatment plants (continuous measurements – short-term average)

2.2.2.2 Organic compound emissions to air

As for emissions of organic compounds to air, three parameters are monitored by the plants from the reference list: TVOC, TOC and NMVOC. For each parameter, measurements are carried out periodically or continuously, with long-term or short-term averaging. These various measurements are shown in Figure 2.9 to Figure 2.18.

In a few cases, very high concentration values correspond to plants performing regeneration of waste solvents (Section 5.4) where the emissions flow rate is very low. In those cases, the concentration of organic compounds in the emissions is not the proper parameter to reflect the amount of organic compounds released to the atmosphere. As a summary, the plants with the highest concentrations of organic compounds in emissions to air are plants which perform:

- regeneration of waste solvents, as already mentioned above, and physico-chemical treatment of waste with calorific value (Section 5.3);
- mechanical treatment in shredders of metal waste;
- physico-chemical and/or biological treatment of water-based liquid/pumpable waste; and
- aerobic treatment of source-separated bio-waste (Section 4.2).

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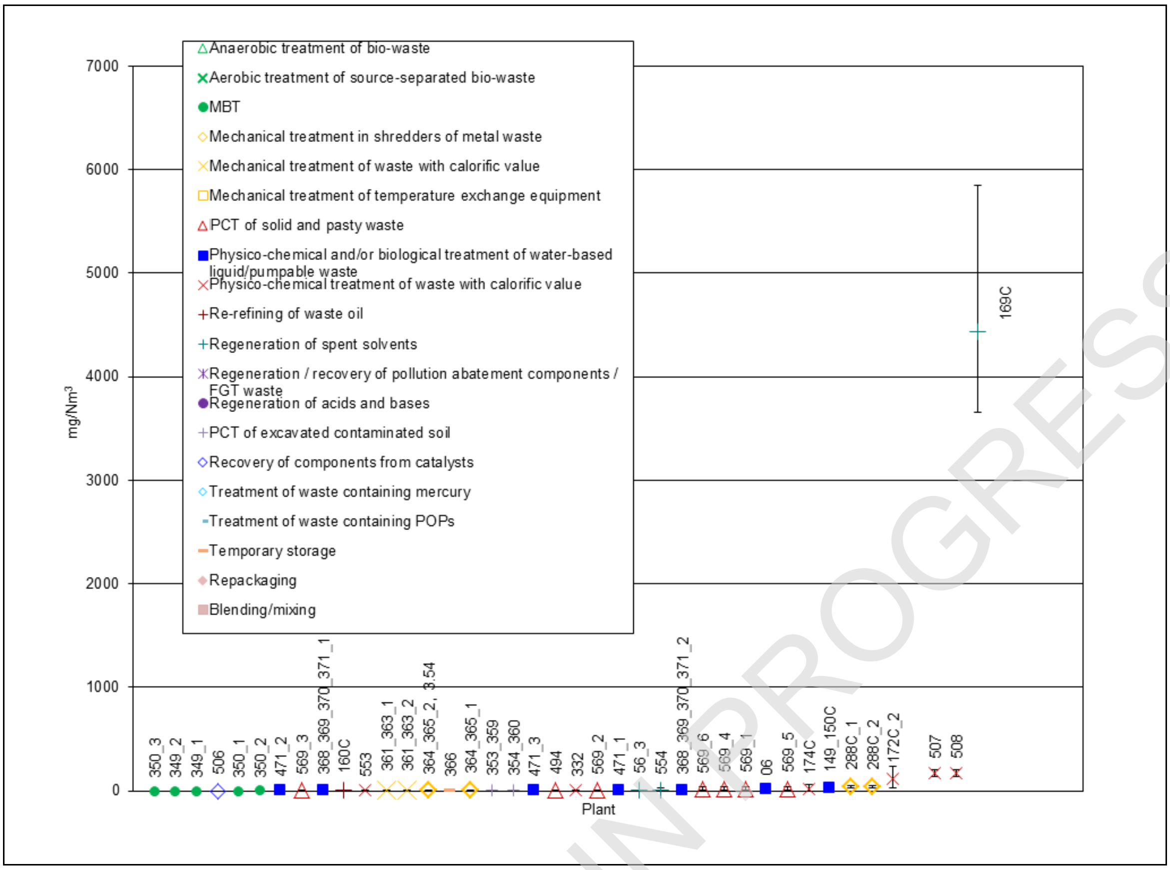

Figure 2.9: TVOC emissions to air from all waste treatment plants (periodic measurements)

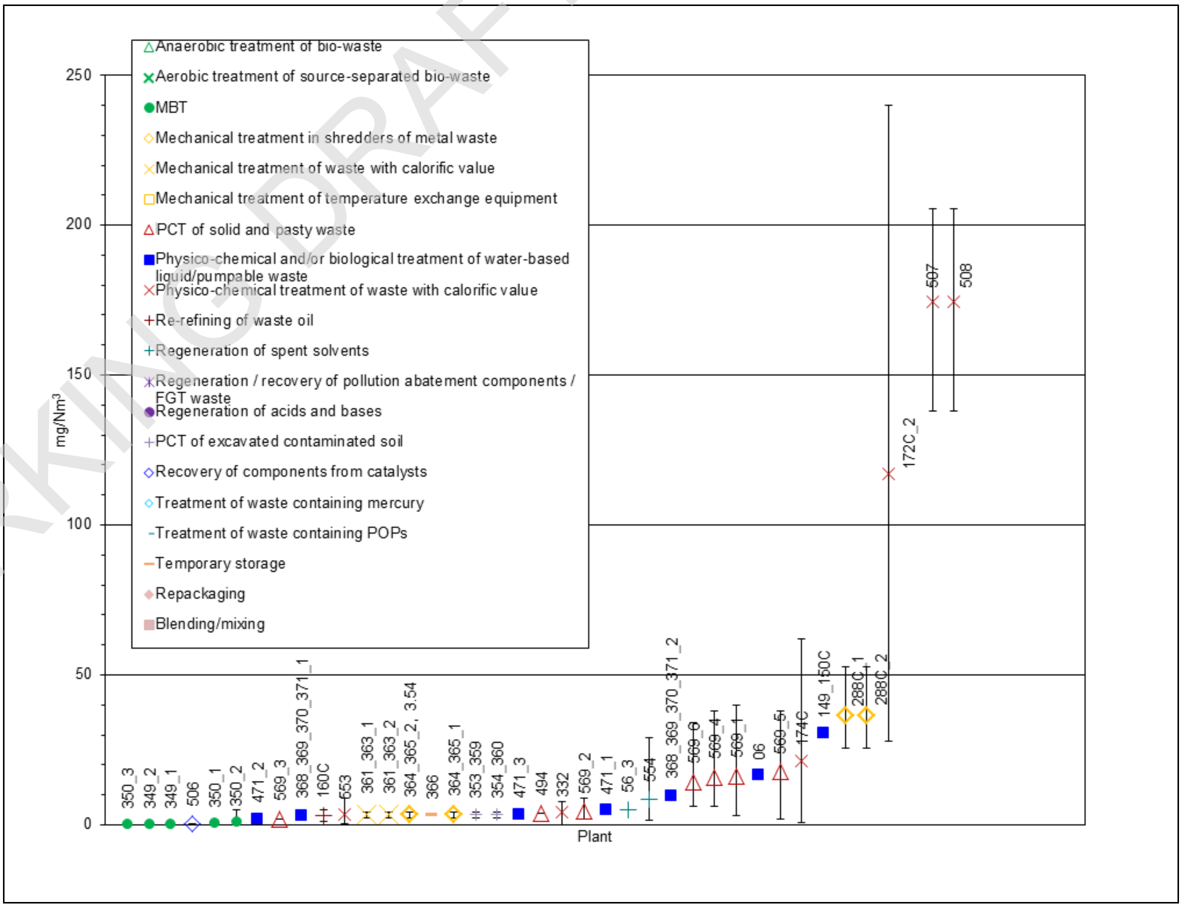

Figure 2.10: Detail of TVOC emissions to air from all WT plants (periodic measurements)

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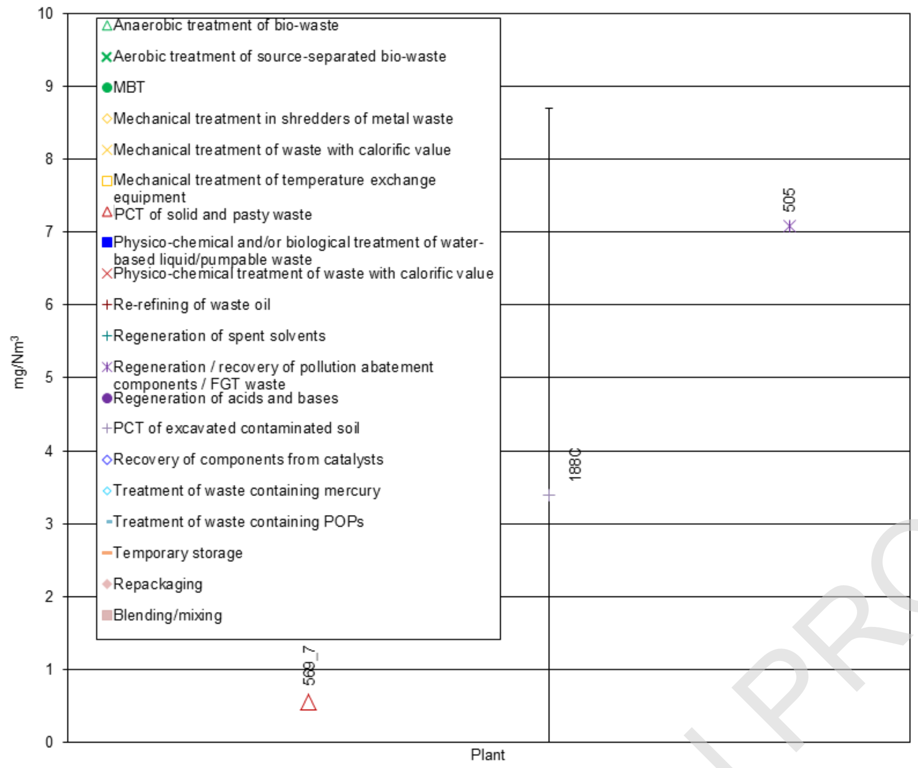

Figure 2.11: TVOC emissions to air from all waste treatment plants (continuous measurements – long-term average)

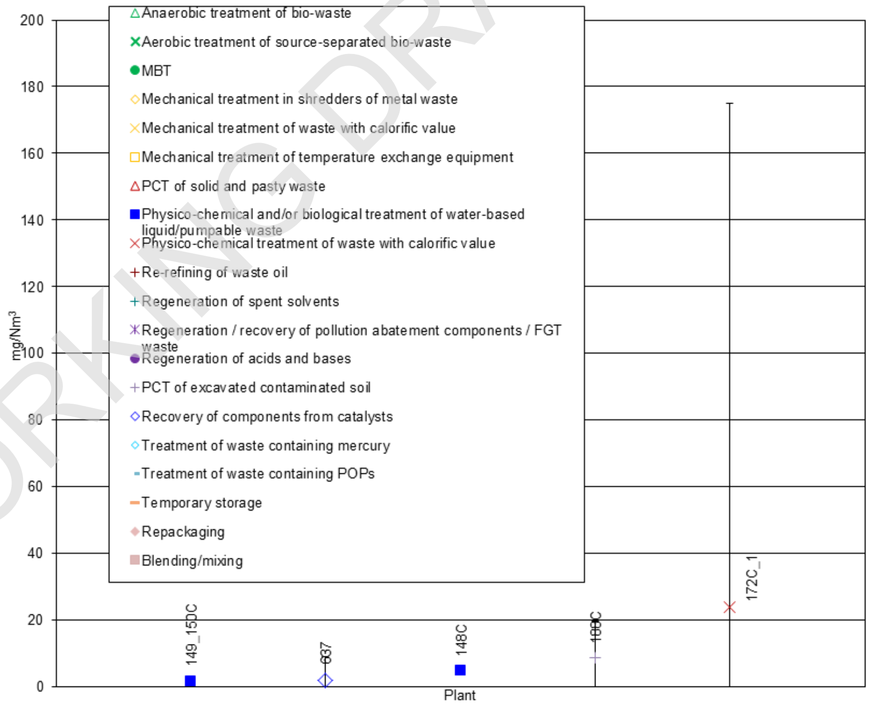

Figure 2.12: TVOC emissions to air from all WT plants (continuous measurements – short-term average)

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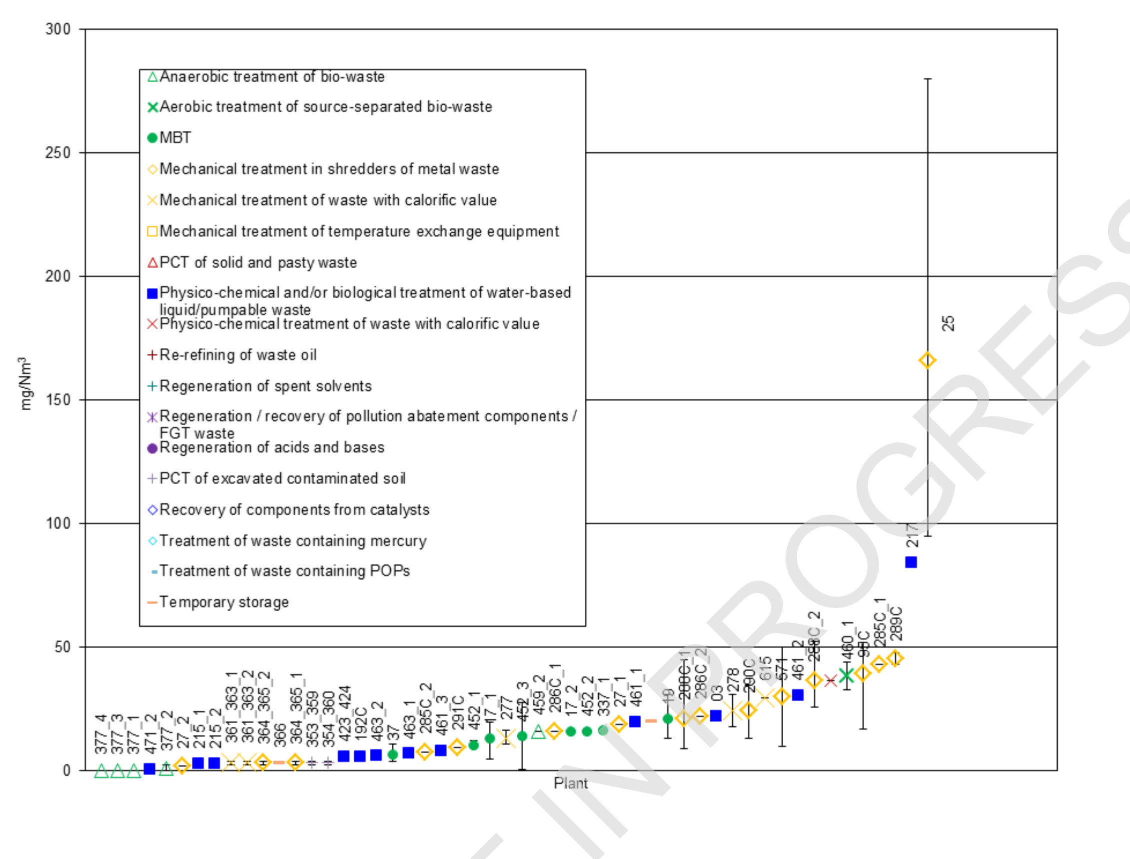

Figure 2.13: TOC emissions to air from all WT plants (periodic measurements)

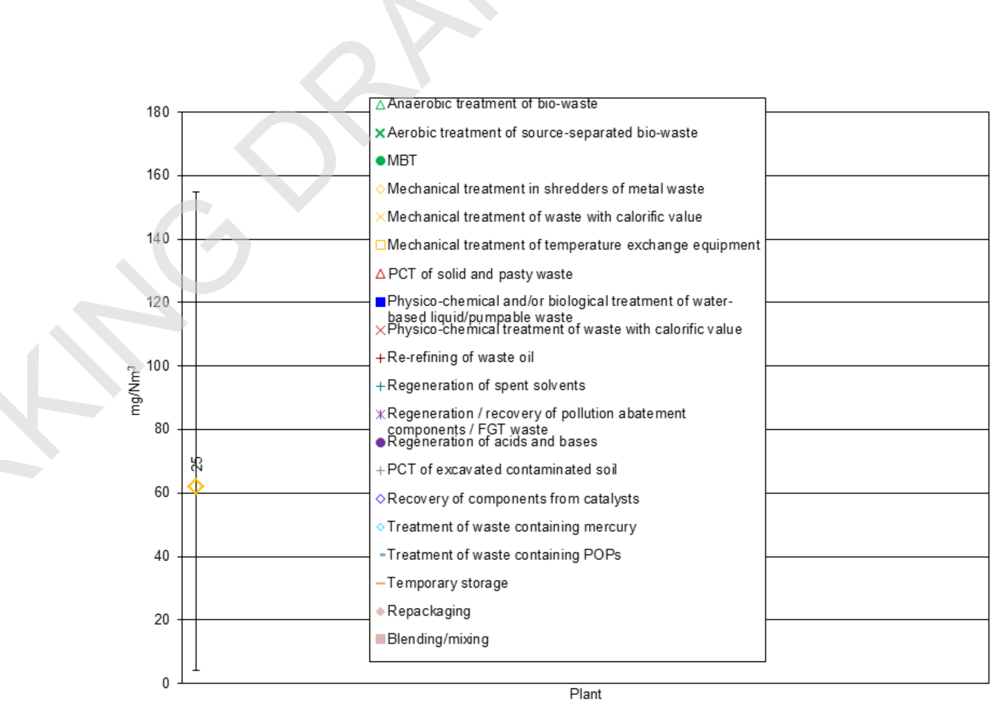

Figure 2.14: TOC emissions to air from all WT plants (continuous measurements – short-term average)

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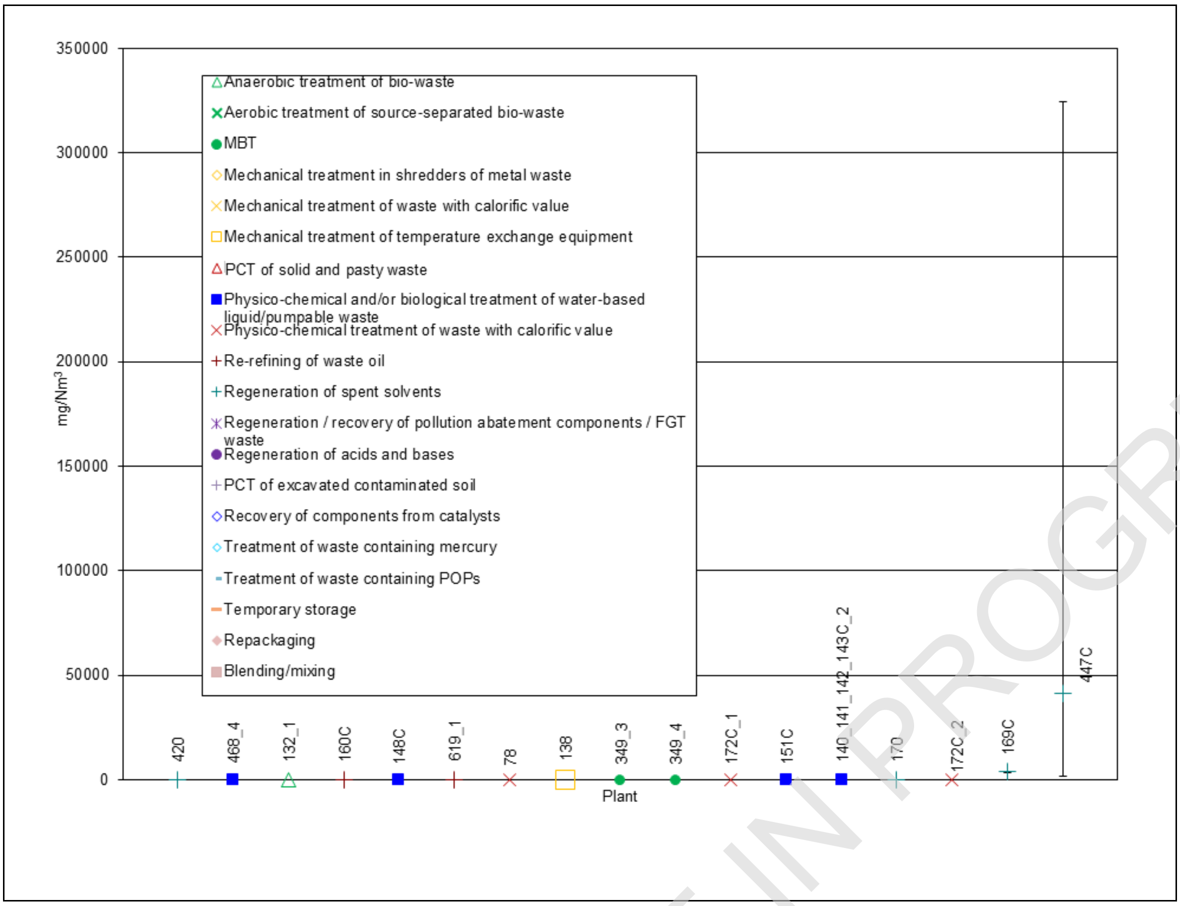

Figure 2.15: NMVOC emissions to air from all WT plants (periodic measurements)

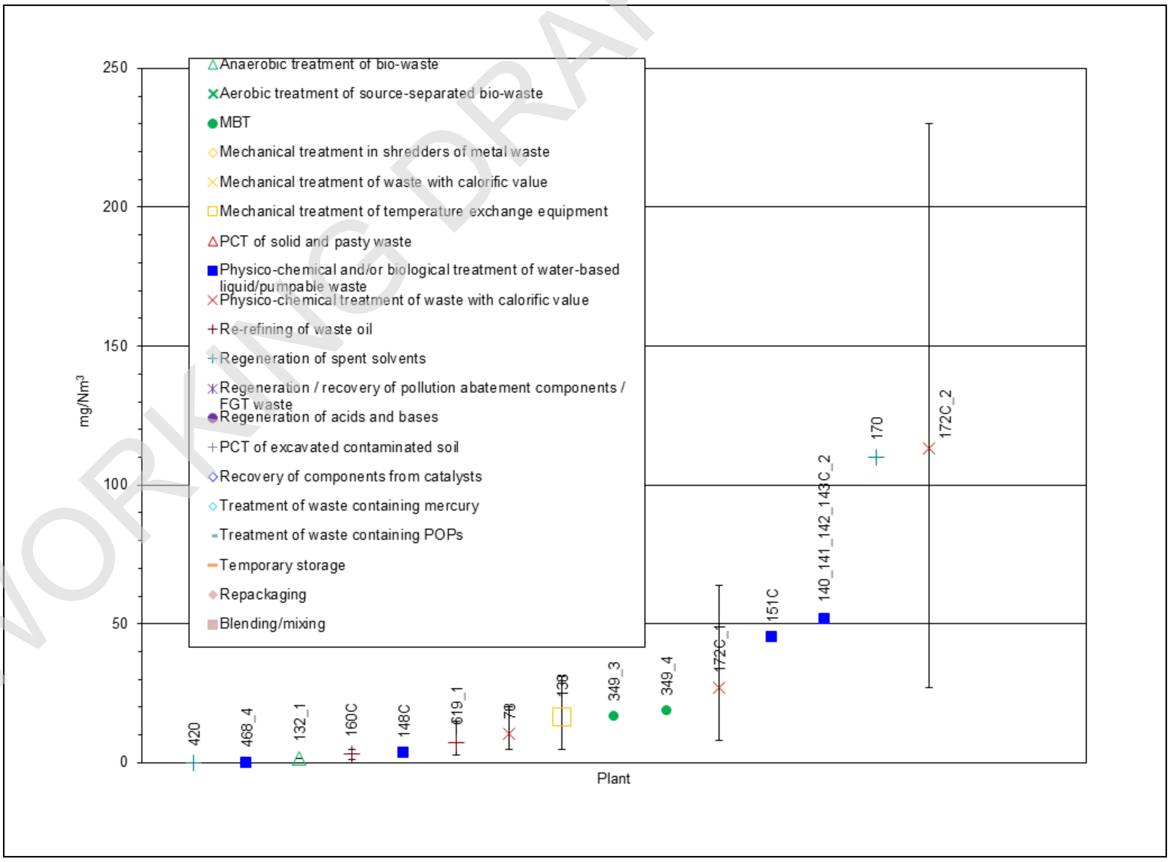

Figure 2.16: Detail of NMVOC emissions to air from all WT plants (periodic measurements)

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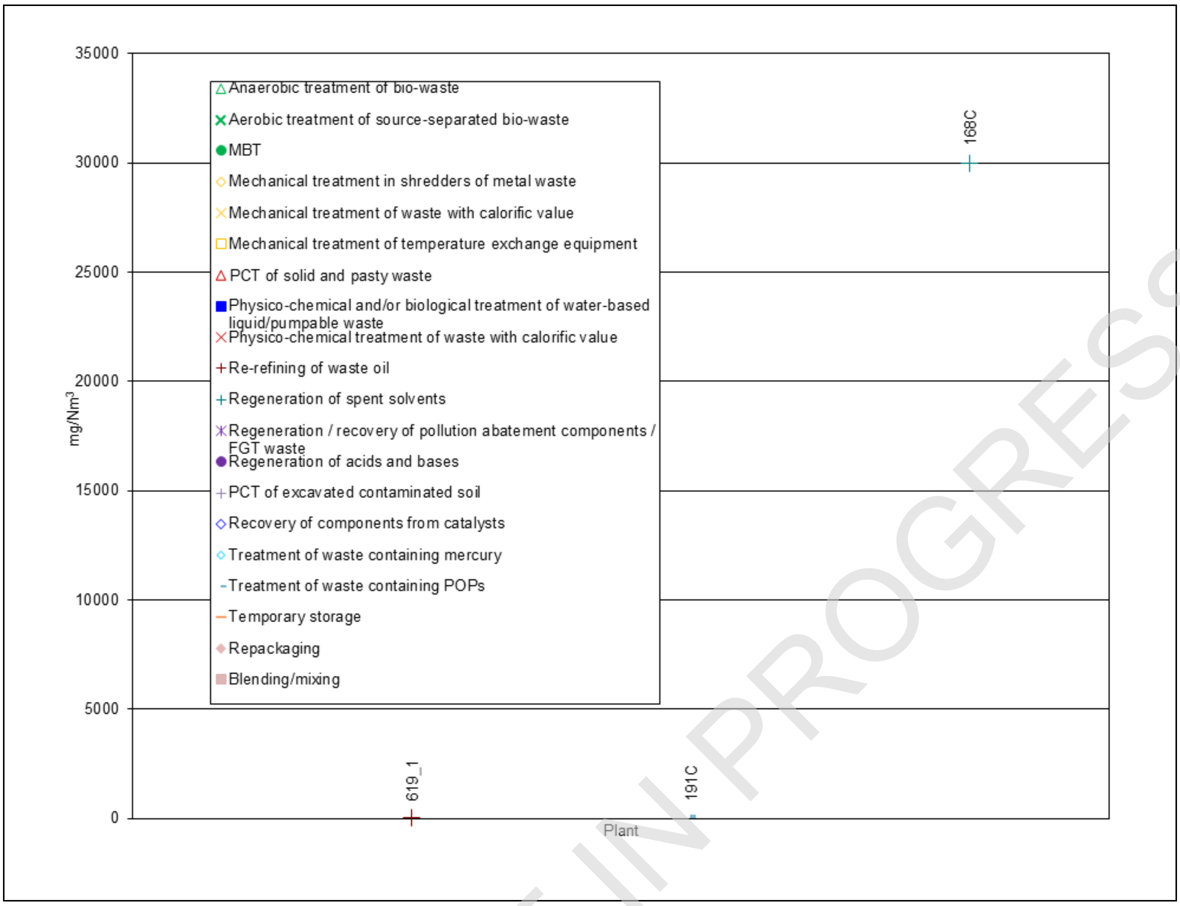

Figure 2.17: NMVOC emissions to air from all WT plants (continuous measurements – long-term average)

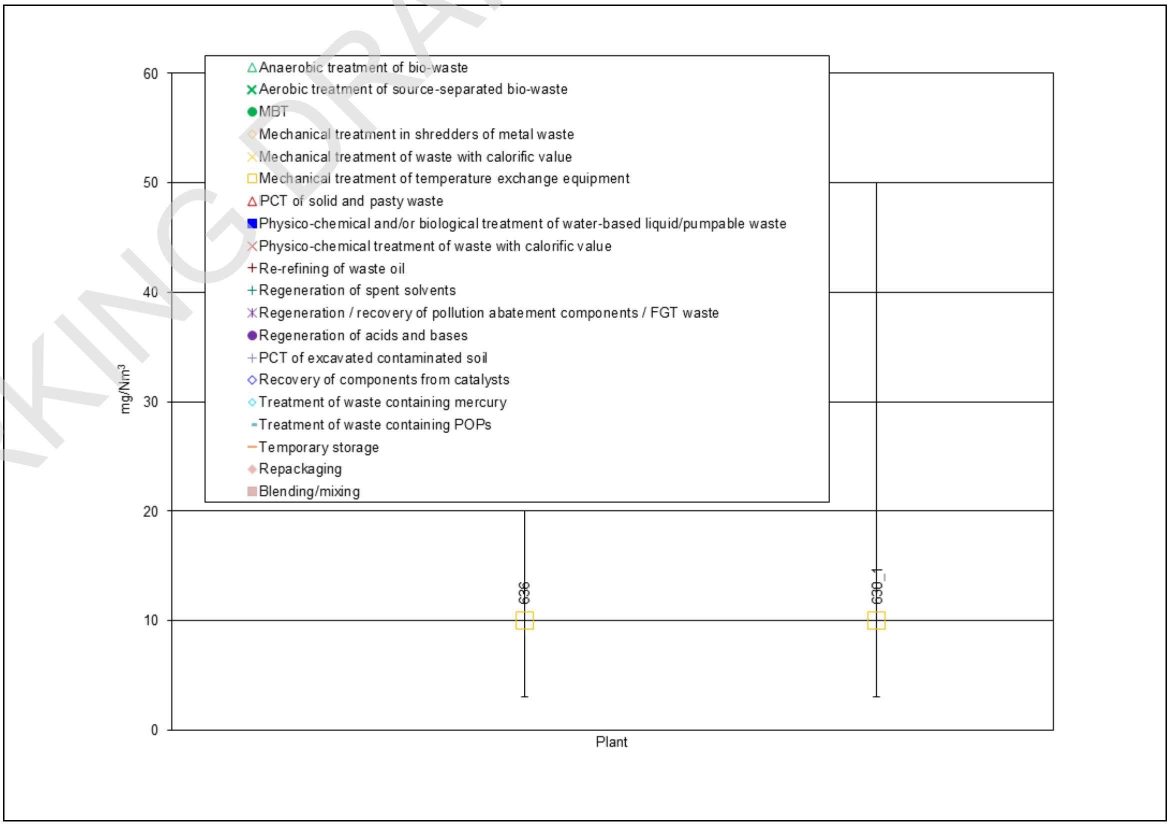

Figure 2.18: NMVOC emissions to air from all WT plants (continuous measurements – short-term average)

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2.2.2.3 Ammonia emissions to air

Figure 2.19, Figure 2.20 and Figure 2.21 give an overview of the NH_3 emissions to air from all 74 waste treatment plants on the plant reference list that measure NH_3. Plants measuring NH_3 are mainly those carrying out biological treatments (Section 4), physico-chemical and/or biological treatment of water-based liquid/pumpable waste (Section 5.6) and, to a lesser extent, physico-chemical treatment of solid and/or pasty waste (Section 5.1).

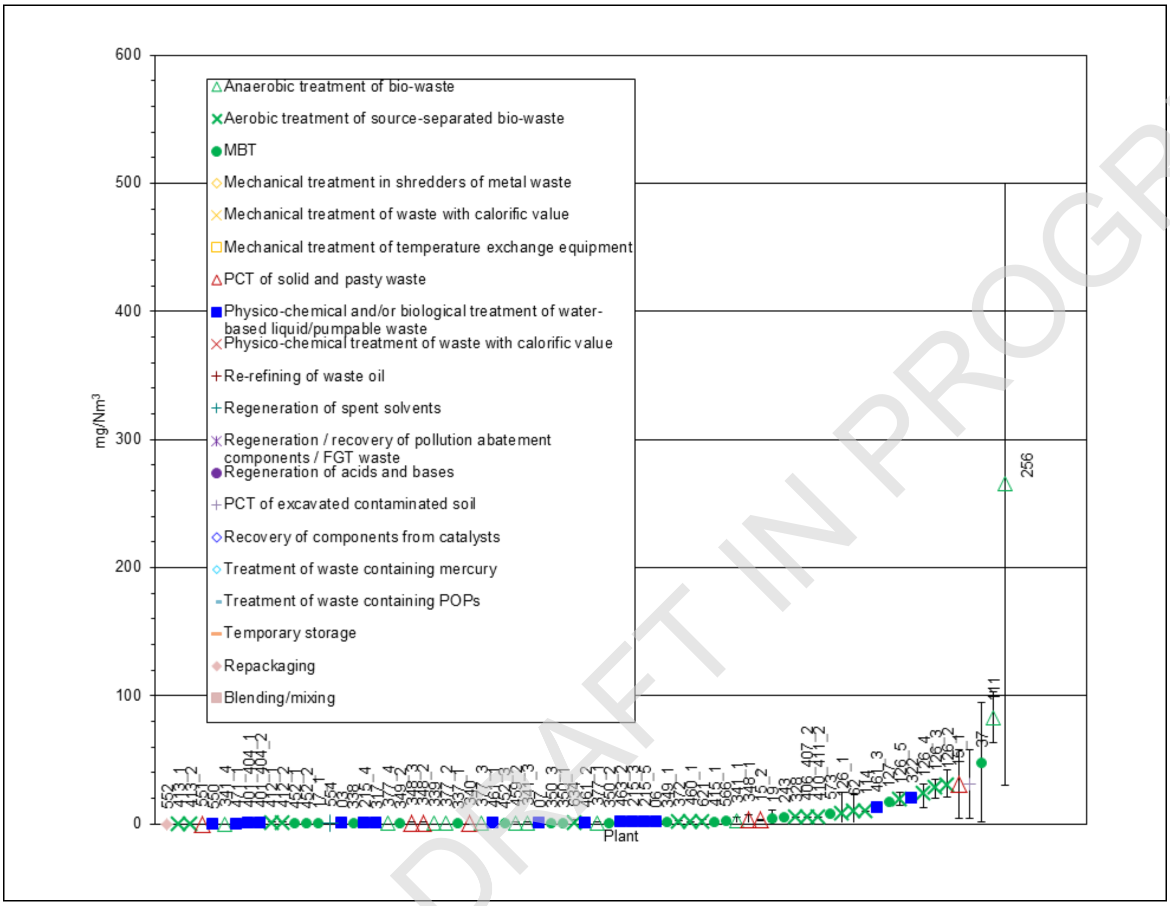

Figure 2.19: NH_3 emissions to air from all WT plants (periodic measurements)

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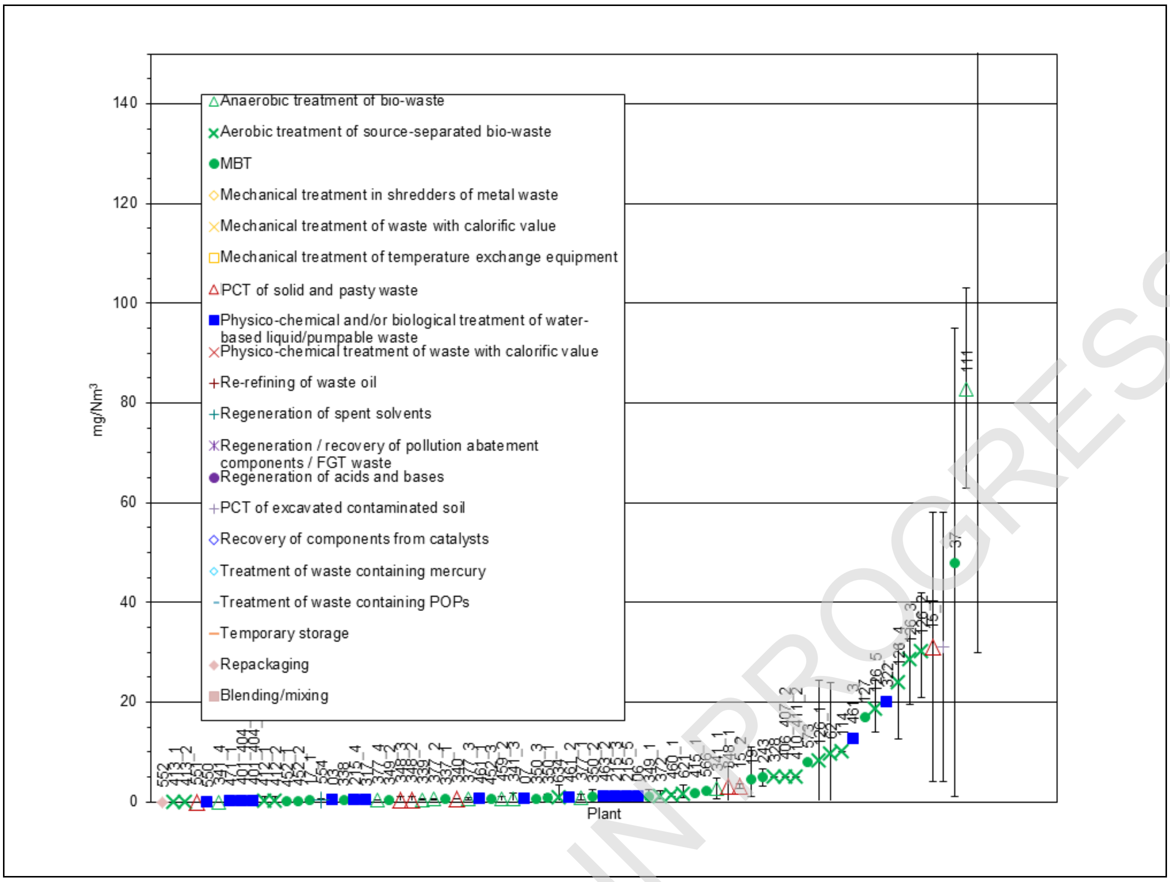

Figure 2.20: Detail of NH_3 emissions to air from all WT plants (periodic measurements)

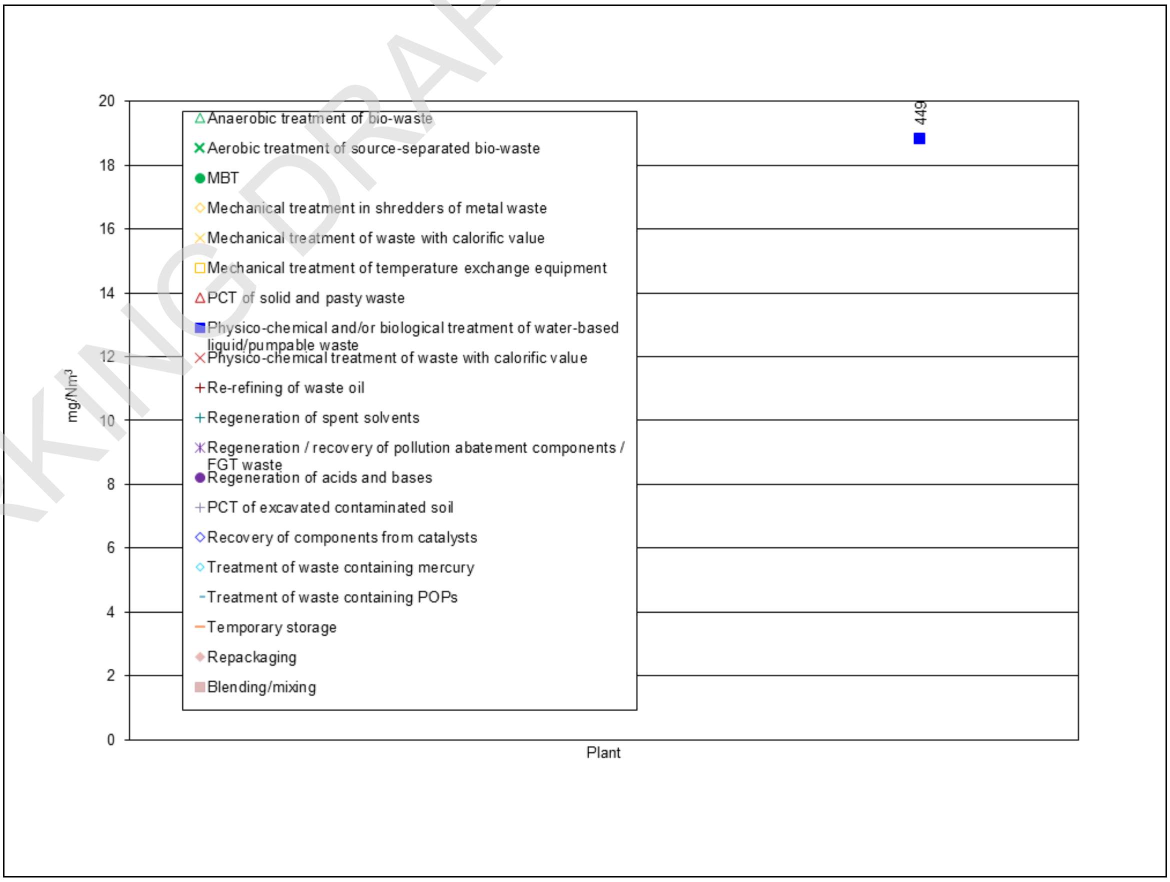

Figure 2.21: NH_3 emissions to air from all WT plants (continuous measurements – long-term average)

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2.3 Techniques to consider in the determination of general BAT for the WT sector

Introduction from ex-Section 4 replaced by standard text

This chapter describes techniques (or combinations thereof), and associated monitoring, considered to have the potential for achieving a high level of environmental protection in the activities within the scope of this document. The techniques described will include both the technology used and the way in which the installations are designed, built, maintained, operated and decommissioned.

It covers environmental management systems, process-integrated techniques and end-of-pipe measures. Waste prevention and management, including waste minimisation and recycling procedures are also considered, as well as techniques that reduce the consumption of raw materials, water and energy by optimising use and reuse. The techniques described also cover measures used to prevent or to limit the environmental consequences of accidents and incidents, as well as site remediation measures. They also cover measures taken to prevent or reduce emissions under other than normal operating conditions (such as start-up and shutdown operations, leaks, malfunctions, momentary stoppages and the definitive cessation of operations).

Annex III to the Directive lists a number of criteria for determining BAT, and the information within this chapter will address these considerations. As far as possible, the standard structure in Table 2.18 is used to outline the information on each technique, to enable a comparison of techniques and the assessment against the definition of BAT in the Directive.

This chapter does not necessarily provide an exhaustive list of techniques which could be applied in the sector. Other techniques may exist, or may be developed, which could be considered in the determination of BAT for an individual installation.

Table 2.18: Information for each technique

Heading within the section	Type of information included
Description	A brief description of the technique with a view to being used in the BAT conclusions.
Technical description	A more detailed and yet concise technical description using, as appropriate, chemical or other equations, pictures, diagrams and flow charts.
Achieved environmental benefits	The **main** potential environmental benefits to be gained through implementing the technique (including reduced consumption of energy; reduced emissions to water, air and land; raw material savings; as well as production yield increases, reduced waste, etc.).
Environmental performance and operational data	Actual and **plant-specific** performance data (including emission levels, consumption levels – of raw materials, water, energy – and amounts of residues/wastes generated) from well-performing installations/plants (with respect to the environment taken as a whole) applying the technique accompanied by the relevant contextual information. Any other useful information on the following items: • how to design, operate, maintain, control and decommission the technique; • emission monitoring issues related to the use of the technique; • sensitivity and durability of the technique; • issues regarding accident prevention. Links between inputs (e.g. nature and quantity of raw material

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	and fuel, energy, water) and outputs (emissions, residues/wastes, products) are highlighted, in particular where relevant to enhancing an understanding of different environmental impacts and their interaction, for example where trade-offs have been made between different outputs such that certain environmental performance levels cannot be achieved at the same time. Emission and consumption data are qualified as far as possible with details of relevant operating conditions (e.g. percentage of full capacity, fuel composition, bypassing of the (abatement) technique, inclusion or exclusion of other than normal operating conditions, reference conditions), sampling and analytical methods, and statistical presentation (e.g. short- and long-term averages, maxima, ranges and distributions). Information on conditions/circumstances hampering the use of the (abatement) technique at full capacity and/or necessitating full or partial bypassing of the (abatement) technique and measures taken to restore full (abatement) capacity.
Cross-media effects	Relevant negative effects on the environment due to implementing the technique, allowing comparison between techniques in order to assess the impact on the environment as a whole. This may include issues such as: • consumption and nature of raw materials and water; • energy consumption and contribution to climate change; • stratospheric ozone depletion potential; • photochemical ozone creation potential; • acidification resulting from emissions to air; • presence of particulate matter in ambient air (including microparticles and metals); • eutrophication of land and waters resulting from emissions to air or water; • oxygen depletion potential in water; • persistent/toxic/bioaccumulable components (including metals); • generation of residues/waste; • limitation of the ability to reuse or recycle residues/waste; • generation of noise and/or odour; • increased risk of accidents. The Reference Document on Economics and Cross-media Effects (ECM) should be taken into account.
Technical considerations relevant to applicability	It is indicated whether the technique can be applied throughout the sector. Otherwise, the main general technical restrictions on the use of the technique within the sector are indicated. These may be: • an indication of the type of plants or processes within the sector to which the technique cannot be applied; • constraints to implementation in certain generic cases, considering, e.g.: o whether it concerns a new or an existing plant, taking into account factors involved in retrofitting (e.g. space availability) and interactions with techniques already installed, o plant size, capacity or load factor, o quantity, type or quality of product manufactured, o type of fuel or raw material used, o animal welfare, o climatic conditions. These restrictions are indicated together with the reasons for them.

WORKING DRAFT IN PROGRESS

	These restrictions are not meant to be a list of the possible local conditions that could affect the applicability of the technique for an individual plant.
Economics	Information on the costs (capital/investment, operating and maintenance including details on how these costs have been calculated/estimated) and any possible savings (e.g. reduced raw material or energy consumption, waste charges, reduced payback time compared to other techniques), or revenues or other benefits including details on how these have been calculated/estimated. Cost data are preferably given in euro (EUR). If a conversion is made from another currency, the data in the original currency and the year when the data were collected is indicated. The price/cost of the equipment or service is accompanied by the year it was purchased. Information on the market for the sector in order to put costs of techniques into context. Information relevant to both newly built, retrofitted and existing plants. This should allow assessment, where possible, of the economic viability of the technique for the sector concerned. Information on the cost-effectiveness of the technique (e.g. in EUR per mass of pollutant abated) and related assumptions for their calculation can be reported. The Reference Document on Economics and Cross-media Effects (ECM) and the Reference Document on the General Principles of Monitoring (MON) are taken into account with regard to economic aspects and monitoring costs, respectively.
Driving force for implementation	Where applicable, specific local conditions, requirements (e.g. legislation, safety measures) or non-environmental triggers (e.g. increased yield, improved product quality, economic incentives – e.g. subsidies, tax breaks) which have driven or stimulated the implementation of the technique to date. This subsection should be very short using bullet point lists.
Example plants	Reference to a plant(s) where the technique has been implemented and from which information has been collected and used in writing the section. An indication of the degree to which the technique is in use in the EU or worldwide.
Reference literature	Literature or other reference material (e.g. books, reports, studies) that was used in writing the section and that contains more detailed information on the technique. When the reference material consists of a large number of pages, reference will be made to the relevant page(s) or section(s).

When possible, this chapter provides information from real activities that can be, or are being, implemented by this sector, including the associated costs. Wherever possible, the information provided gives the context in which the technique can be used effectively.

The aim of this chapter is to present techniques which may be applicable to more than one type of waste treatment, in order to avoid repetition in the chapters of this document dedicated to one type of waste treatment (namely Chapters 3 to 5). This means that those chapters may refer to techniques presented here when relevant, as well as introducing additional techniques which are specific to the type of waste treatment concerned.

~~Organisation of the chapter~~

WORKING DRAFT IN PROGRESS

~~As in previous Chapters 2 and 3, each section of this chapter deals with a specific waste treatment activity and contains the process and abatement techniques worth considering in the determination of BAT. If different process techniques may be applicable for one activity, they are discussed within each section. Sections in sections from to in this chapter have been structured in the same way, i.e. the section first addresses the pollution prevention techniques applicable in the specific process/activity section referred to, and secondly the end-of-pipe techniques that may be applicable to reduce the emissions coming from that process/activity. These end-of-pipe (EOP) techniques are grouped on a media/pollutant bases to clarify the sequence of techniques applicable as, in some cases, the number of EOP techniques that may be applicable is quite extensive. This structure should not be interpreted as any attempt to give guidance if a waste treatment is (R)ecovery or (D)isposal under the EC waste legislation.~~

~~At the end of this chapter, there are three sections which contain the end-of-pipe (EOP) techniques applicable to waste gas, waste water and process generated waste. These sections describes the 'common' EOP techniques that may be applicable to more than one type of process/activity. Consequently, the descriptions of those EOP techniques are found in their own sections, i.e. Sections 4.6, 4.7, and 4.8, and not in the separate activities/process sections.~~

~~In some cases, techniques/procedures are grouped together and analysed under the same heading in this chapter. This is the result of finding a right balance between the necessary information to determine BAT and keeping this document to a user-friendly size. For example, this document contains a lot of information on acceptance procedures applied to waste treatment installations. In this instance, it has been decided to include all these procedures together under the same technique heading and to then discuss all the related items/topics under that heading. If this approach was not applied, this document would be much bigger and much repetition could occur.~~

From ex-**Section 4.1 Common techniques to consider in the determination of BAT**

~~This section contains techniques considered to have a good environmental operating performance (e.g. use of a good energy system) or that can help lead to a good environmental performance (e.g. environmental management systems). The majority of these techniques are applied at an installation level and are not specific to any of the particular processes described separately in Sections 4.2 to 4.5.~~

Ex-**Section 4.3.1.1 "Planning of the operation of a Ph-c plant"** deleted except items a, b, d and e distributed in different sections

WORKING DRAFT IN PROGRESS

2.3.1 Organisational techniques to improve environmental performance

2.3.1.1 Environmental management ~~tools~~ system (EMS)

From ex-Section 4.1.2.8

~~**Description**~~

~~The best environmental performance is usually achieved by the installation of the best technology and its operation in the most effective and efficient manner. This is recognised by the IPPC Directive definition of 'techniques' as *'both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned'*.~~

~~For IPPC installations an Environmental Management System (EMS) is a tool that operators can use to address these design, construction, maintenance, operation and decommissioning issues in a systematic, demonstrable way. An EMS includes the organisational structure, responsibilities, practices, procedures, processes and resources for developing, implementing, maintaining, reviewing and monitoring the environmental policy. Environmental Management Systems are most effective and efficient where they form an inherent part of the overall management and operation of an installation.~~

~~Within the European Union, many organisations have decided on a voluntary basis to implement environmental management systems based on EN ISO 14001:1996 or the EU Eco-management and audit scheme EMAS. EMAS includes the management system requirements of EN ISO 14001, but places additional emphasis on legal compliance, environmental performance and employee involvement; it also requires external verification of the management system and validation of a public environmental statement (in EN ISO 14001 self-declaration is an alternative to external verification). There are also many organisations that have decided to put in place non-standardised EMSs.~~

~~While both standardised systems (EN ISO 14001:1996 and EMAS) and non-standardised ('customised') systems in principle take the *organisation* as the entity, this document takes a more narrow approach, not including all activities of the organisation e.g. with regard to their products and services, due to the fact that the regulated entity under the IPPC Directive is the *installation* (as defined in Article 2).~~

~~An environmental management system (EMS) for an IPPC installation can contain the following components:~~

- ~~definition of an environmental policy~~
- ~~planning and establishing objectives and targets~~
- ~~implementation and operation of procedures~~
- ~~checking and corrective action~~
- ~~management review~~
- ~~preparation of a regular environmental statement~~
- ~~validation by certification body or external EMS verifier~~
- ~~design considerations for end-of-life plant decommissioning~~
- ~~development of cleaner technologies~~
- ~~benchmarking.~~

~~These features are explained in somewhat greater detail below. For detailed information on components (a) to (g), which are all included in EMAS, the reader is referred to the reference literature indicated below.~~

a. ~~definition of an environmental policy~~
   ~~Top management are responsible for defining an environmental policy for an installation and ensuring that it:~~
   - ~~is appropriate to the nature, scale and environmental impacts of the activities~~

WORKING DRAFT IN PROGRESS

- ~~includes a commitment to pollution prevention and control~~
- ~~includes a commitment to comply with all relevant applicable environmental legislation and regulations, and with other requirements to which the organisation subscribes~~
- ~~provides the framework for setting and reviewing environmental objectives and targets~~
- ~~is documented and communicated to all employees~~
- ~~is available to the public and all interested parties~~

~~b. planning, i.e.:~~

- ~~procedures to identify the environmental aspects of the installation, in order to determine those activities which have or can have significant impacts on the environment, and to keep this information up-to-date~~
- ~~procedures to identify and have access to legal and other requirements to which the organisation subscribes and that are applicable to the environmental aspects of its activities~~
- ~~establishing and reviewing documented environmental objectives and targets, taking into consideration the legal and other requirements and the views of interested parties~~
- ~~establishing and regularly updating an environmental management programme, including designation of responsibility for achieving objectives and targets at each relevant function and level as well as the means and timeframe by which they are to be achieved~~

~~c. implementation and operation of procedures~~

~~It is important to have systems in place to ensure that procedures are known, understood and complied with, therefore effective environmental management includes:~~

- ~~structure and responsibility~~
  - ~~defining, documenting and communicating roles, responsibilities and authorities, which includes appointing one specific management representative~~
  - ~~providing resources essential to the implementation and control of the environmental management system, including human resources and specialised skills, technology and financial resources~~
- ~~training, awareness and competence~~
  - ~~identifying training needs to ensure that all personnel whose work may significantly affect the environmental impacts of the activity have received appropriate training.~~
- ~~communication~~
  - ~~establishing and maintaining procedures for internal communication between the various levels and functions of the installation, as well as procedures that foster a dialogue with external interested parties and procedures for receiving, documenting and, where reasonable, responding to relevant communication from external interested parties~~
- ~~employee involvement~~
  - ~~involving employees in the process aimed at achieving a high level of environmental performance by applying appropriate forms of participation such as the suggestion-book system or project-based group works or environmental committees.~~
- ~~documentation~~
  - ~~establishing and maintaining up-to-date information, in paper or electronic form, to describe the core elements of the management system and their interaction and to provide direction to related documentation.~~
- ~~efficient process control~~
  - ~~adequate control of processes under all modes of operation, i.e. preparation, start-up, routine operation, shutdown and abnormal conditions~~
  - ~~identifying the key performance indicators and methods for measuring and controlling these parameters (e.g. flow, pressure, temperature, composition and quantity)~~
  - ~~documenting and analysing abnormal operating conditions to identify the root causes and then addressing these to ensure that events do not recur (this can be facilitated by a 'no-blame' culture where the identification of causes is more important than apportioning blame to individuals)~~

WORKING DRAFT IN PROGRESS

- ~~maintenance programme~~
    - ~~establishing a structured programme for maintenance based on technical descriptions of the equipment, norms etc. as well as any equipment failures and consequences~~
    - ~~supporting the maintenance programme by appropriate record keeping systems and diagnostic testing~~
    - ~~clearly allocating responsibility for the planning and execution of maintenance.~~
- ~~emergency preparedness and response~~
    - ~~establishing and maintaining procedures to identify the potential for and response to accidents and emergency situations, and for preventing and mitigating the environmental impacts that may be associated with them~~

~~d. checking and corrective action, i.e.:~~

- ~~monitoring and measurement~~
    - ~~establishing and maintaining documented procedures to monitor and measure, on a regular basis, the key characteristics of operations and activities that can have a significant impact on the environment, including the recording of information for tracking performance, relevant operational controls and conformance with the installation's environmental objectives and targets (see also the Reference document on Monitoring of Emissions) [46, EIPPCB 2003]~~
    - ~~establishing and maintaining a documented procedure for periodically evaluating compliance with relevant environmental legislation and regulations.~~
- ~~corrective and preventive action~~
    - ~~establishing and maintaining procedures for defining responsibility and authority for handling and investigating non-conformance with permit conditions, other legal requirements as well as objectives and targets, taking action to mitigate any impacts caused and for initiating and completing corrective and preventive action that are appropriate to the magnitude of the problem and commensurate with the environmental impact encountered~~
- ~~records~~
    - ~~establishing and maintaining procedures for the identification, maintenance and disposition of legible, identifiable and traceable environmental records, including training records and the results of audits and reviews~~
- ~~audit~~
    - ~~establishing and maintaining (a) programme(s) and procedures for periodic environmental management system audits that include discussions with personnel, inspection of operating conditions and equipment and reviewing of records and documentation and that results in a written report, to be carried out impartially and objectively by employees (internal audits) or external parties (external audits), covering the audit scope, frequency and methodologies, as well as the responsibilities and requirements for conducting audits and reporting results, in order to determine whether or not the environmental management system conforms to planned arrangements and has been properly implemented and maintained~~
    - ~~completing the audit or audit cycle, as appropriate, at intervals of no longer than three years, depending on the nature, scale and complexity of the activities, the significance of associated environmental impacts, the importance and urgency of the problems detected by previous audits and the history of environmental problems – more complex activities with a more significant environmental impact are audited more frequently~~
    - ~~having appropriate mechanisms in place to ensure that the audit results are followed up~~
- ~~periodic evaluation of legal compliance~~
    - ~~reviewing compliance with the applicable environmental legislation and the conditions of the environmental permit(s) held by the installation~~
    - ~~documentation of the evaluation~~

~~e. management review, i.e.:~~

WORKING DRAFT IN PROGRESS

- ~~reviewing, by top management, at intervals that it determines, the environmental management system, to ensure its continuing suitability, adequacy and effectiveness~~
- ~~ensuring that the necessary information is collected to allow management to carry out this evaluation~~
- ~~documentation of the review~~

~~f. preparation of a regular environmental statement:~~

- ~~preparing an environmental statement that pays particular attention to the results achieved by the installation against its environmental objectives and targets. It is regularly produced – from once a year to less frequently depending on the significance of emissions, waste generation etc. It considers the information needs of relevant interested parties and it is publicly available (e.g. in electronic publications, libraries etc.)~~
- ~~when producing a statement, the operator may use relevant existing environmental performance indicators, making sure that the indicators chosen:~~
  - ~~give an accurate appraisal of the installation's performance~~
  - ~~are understandable and unambiguous~~
  - ~~allow for year on year comparison to assess the development of the environmental performance of the installation~~
  - ~~allow for comparison with sector, national or regional benchmarks as appropriate~~
  - ~~allow for comparison with regulatory requirements as appropriate~~

~~g. validation by certification body or external EMS verifier:~~

- ~~having the management system, audit procedure and environmental statement examined and validated by an accredited certification body or an external EMS verifier can, if carried out properly, enhance the credibility of the system.~~

~~h. design considerations for end-of-life plant decommissioning~~

- ~~giving consideration to the environmental impact from the eventual decommissioning of the unit at the stage of designing a new plant, as forethought makes decommissioning easier, cleaner and cheaper~~
- ~~decommissioning poses environmental risks for the contamination of land (and groundwater) and generates large quantities of solid waste. Preventive techniques are process-specific but general considerations may include:~~
  - ~~avoiding underground structures~~
  - ~~incorporating features that facilitate dismantling~~
  - ~~choosing surface finishes that are easily decontaminated~~
  - ~~using an equipment configuration that minimises trapped chemicals and facilitates drain-down or washing~~
  - ~~designing flexible, self-contained units that enable phased closure~~
  - ~~using biodegradable and recyclable materials where possible~~

~~i. development of cleaner technologies:~~

- ~~environmental protection should be an inherent feature of any process design activities carried out by the operator, since techniques incorporated at the earliest possible design stage are both more effective and cheaper. Giving consideration to the development of cleaner technologies can for instance occur through R&D activities or studies. As an alternative to internal activities, arrangements can be made to keep abreast with – and where appropriate – commission work by other operators or research institutes active in the relevant field~~

~~j. benchmarking, i.e.:~~

- ~~carrying out systematic and regular comparisons with sector, national or regional benchmarks, including for energy efficiency and energy conservation activities, choice of input materials, emissions to air and discharges to water (using for example the European Pollutant Emission Register, EPER), consumption of water and generation of waste.~~

~~*Standardised and non-standardised EMSs*~~

WORKING DRAFT IN PROGRESS

~~An EMS can take the form of a standardised or non-standardised ('customised') system. Implementation and adherence to an internationally accepted standardised system such as EN ISO 14001:1996 can give higher credibility to the EMS, especially when subject to a properly performed external verification. EMAS provides additional credibility due to the interaction with the public through the environmental statement and the mechanism to ensure compliance with the applicable environmental legislation. However, non-standardised systems can in principle be equally effective provided that they are properly designed and implemented.~~

~~Achieved environmental benefits~~

~~Implementation of and adherence to an EMS focuses the attention of the operator on the environmental performance of the installation. In particular, the maintenance of and compliance with clear operating procedures for both normal and abnormal situations and the associated lines of responsibility should ensure that the installation's permit conditions and other environmental targets and objectives are met at all times.~~

~~Environmental management systems typically ensure the continuous improvement of the environmental performance of the installation. The poorer the starting point is, the more significant short-term improvements can be expected. If the installation already has a good overall environmental performance, the system helps the operator to maintain the high performance level.~~

~~Cross-media effects~~

~~Environmental management techniques are designed to address the overall environmental impact, which is consistent with the integrated approach of the IPPC Directive.~~

~~Operational data~~

~~No specific information reported.~~

~~Applicability~~

~~The components described above can typically be applied to all IPPC installations. The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.~~

~~Economics~~

~~It is difficult to accurately determine the costs and economic benefits of introducing and maintaining a good EMS. A number of studies are presented below. However, these are just examples and their results are not entirely coherent. They might not be representative for all sectors across the EU and should thus be treated with caution.~~

~~A Swedish study carried out in 1999 surveyed all 360 ISO-certified and EMAS-registered companies in Sweden. With a response rate of 50 %, it concluded among other things that:~~

- ~~the expenses for introducing and operating EMS are high but not unreasonably so, save in the case of very small companies. Expenses are expected to decrease in the future~~
- ~~a higher degree of co-ordination and integration of EMS with other management systems is seen as a possible way to decrease costs~~
- ~~half of all the environmental objectives and targets give payback within one year through cost savings and/or increased revenue~~
- ~~the largest cost savings were made through decreased expenditure on energy, waste treatment and raw materials~~
- ~~most of the companies think that their position on the market has been strengthened through the EMS. One-third of the companies report increasing revenue due to EMS.~~

~~In some Member States reduced supervision fees are charged if the installation has a certification.~~

WORKING DRAFT IN PROGRESS

~~A number of studies ([55, Klemisch, H. and Holger, R. 2002][56, Clausen J., M. Keil and M. Jungwirth 2002] show that there is an inverse relationship between company size and the cost of implementing an EMS. A similar inverse relationship exists for the payback period of invested capital. Both elements imply a less favourable cost-benefit relationship for implementing an EMS in SMEs compared to larger companies.~~

~~According to a Swiss study, the average cost for building and operating ISO 14001 can vary:~~

- ~~for a company with between 1 and 49 employees: (CHF 64000) EUR 44000 for building the EMS and (CHF 16000) EUR 11000 per year for operating it~~
- ~~for an industrial site with more than 250 employees: (CHF 367000) EUR 252000 for building the EMS and (CHF 155000) EUR 106000 per year for operating it.~~

~~These average figures do not necessarily represent the actual cost for a given industrial site because this cost is also highly dependent on the number of significant items (pollutants, energy consumption, etc.) and on the complexity of the problems to be studied.~~

~~A recent German study [47, Schaltegger et al. 2002] shows the following costs (see Table 2.19) for EMAS for different branches. It can be noted that these figures are much lower than those of the Swiss study quoted above. This is a confirmation of the difficulty to determine the costs of an EMS.~~

Table 2.19: Cost of application of EMAS

~~Costs for building (EUR):~~	~~Costs for validation (EUR):~~
~~range: 18750 – 75000~~ ~~average: 50000~~	~~range: 5000 – 12500~~ ~~average: 6000~~

~~A study by the German Institute of Entrepreneurs [48, UNI/ASU 1997] gives information about the average savings achieved for EMAS per year and the average payback time. For example, for implementation costs of EUR 80000 they found average savings of EUR 50000 per year, corresponding to a payback time of about one and a half years.~~

~~External costs relating to verification of the system can be estimated from guidance issued by the International Accreditation Forum [49, IAF 2003].~~

~~Driving forces for implementation~~
~~Environmental management systems can provide a number of advantages, for example:~~

- ~~improved insight into the environmental aspects of the company~~
- ~~improved basis for decision-making~~
- ~~improved motivation of personnel~~
- ~~additional opportunities for operational cost reduction and product quality improvement~~
- ~~improved environmental performance~~
- ~~improved company image~~
- ~~reduced liability, insurance and non-compliance costs~~
- ~~increased attractiveness for employees, customers and investors~~
- ~~increased trust of regulators, which could lead to reduced regulatory oversight~~
- ~~improved relationship with environmental groups.~~

~~Example plants~~
~~The features described under (a) to (e) above are elements of EN ISO 14001:1996 and the European Community Eco-Management and Audit Scheme (EMAS), whereas the features (f) and (g) are specific to EMAS. These two standardised systems are reported to be applied in seven WT installations. Examples reported are in installation for the treatment of waste oils, waste solvents, preparation of waste fuel from hazardous waste and from non-hazardous waste.~~

WORKING DRAFT IN PROGRESS

~~**Reference literature**~~
~~[44, TWG 2003] [50, EC 2001] [51, ISO 1996] [98, WT TWG 2004]~~

Description
A formal system to demonstrate compliance with environmental objectives.

Technical description
The Directive defines ‘techniques’ (under the definition of 'best available techniques') as ‘both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned’.

In this respect, an environmental management system (EMS) is a technique allowing operators of installations to address environmental issues in a systematic and demonstrable way. EMSs are most effective and efficient where they form an inherent part of the overall management and operation of an installation.

An EMS focuses the attention of the operator on the environmental performance of the installation; in particular through the application of clear operating procedures for both normal and other than normal operating conditions, and by setting out the associated lines of responsibility.

All effective EMSs incorporate the concept of continuous improvement, meaning that environmental management is an ongoing process, not a project which eventually comes to an end. There are various process designs, but most EMSs are based on the plan-do-check-act cycle (which is widely used in other company management contexts). The cycle is an iterative dynamic model, where the completion of one cycle flows into the beginning of the next (see Figure 2.22).

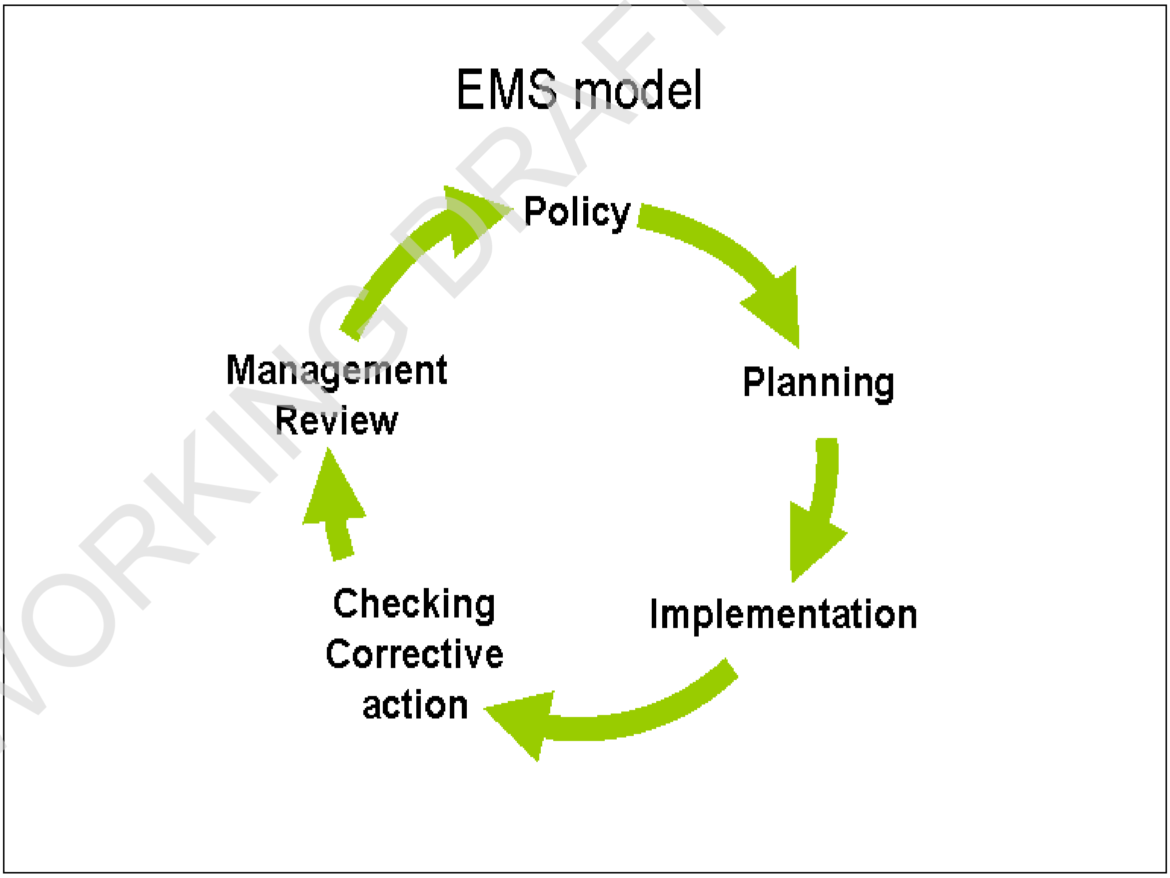

Figure 2.22: Continuous improvement in an EMS model

WORKING DRAFT IN PROGRESS

An EMS can take the form of a standardised or non-standardised ('customised') system. Implementation and adherence to an internationally accepted standardised system, such as EN ISO 14001:2004, can give higher credibility to the EMS especially when subjected to a properly performed external verification. EMAS provides additional credibility due to the interaction with the public through the environmental statement and the mechanism to ensure compliance with the applicable environmental legislation. However, non-standardised systems can, in principle, be equally effective provided that they are properly designed and implemented.

While both standardised systems (EN ISO 14001:2004 or EMAS) and non-standardised systems apply in principle to organisations, this document takes a narrower approach, not including all activities of an organisation, e.g. with regard to their products and services, due to the fact that the Directive only regulates installations/plants.

An EMS can contain the following components:

I. commitment of the management, including senior management;
II. an environmental policy that includes the continuous improvement of the installation by the management;
III. planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;
IV. implementation of procedures paying particular attention to:

  a) structure and responsibility,
  b) training, awareness and competence,
  c) communication,
  d) employee involvement,
  e) documentation,
  f) efficient process control,
  g) maintenance programmes,
  h) emergency preparedness and response,
  i) safeguarding compliance with environmental legislation;

V. checking performance and taking corrective action paying particular attention to:

  a) monitoring and measurement (see also the Reference Report on Monitoring of Emissions to Air and Water from IED-installations) ([139, COM 2015]),
  b) corrective and preventive action,
  c) maintenance of records,
  d) independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;

VI. review of the EMS and its continuing suitability, adequacy and effectiveness by senior management;
VII. following the development of cleaner technologies;
VIII. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;
IX. application of sectoral benchmarking on a regular basis.

Specifically for waste treatment sector activities, the following features are included in the EMS:

X. waste treatment strategy that includes inventories of waste input streams (see Section 2.3.2.1);
XI. procedures to ensure the wastes' compatibility before mixing/blending (see Section 2.3.2.7).

WORKING DRAFT IN PROGRESS

In some cases, the following features are part of the EMS:

XII. odour management plan (see Section 2.3.5.1);
XIII. noise and vibration management plan. (see Section 2.3.10.1);
XIV. residues management plan (see Section 2.3.12);
XV. incident management plan (see Section 2.3.13.1).

Achieved environmental benefits
An EMS promotes and supports the continuous improvement of the environmental performance of the installation. If the installation already has a good overall environmental performance, an EMS helps the operator to maintain the high performance level.

Operational data
No information provided.

Cross-media effects
None reported. The systematic analysis of the initial environmental impacts and scope for improvements in the context of the EMS sets the basis for assessing the best solutions for all environmental media.

Technical considerations relevant to applicability
The components described above can typically be applied to all installations within the scope of this document. The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

Economics
It is difficult to determine accurately the costs and economic benefits of introducing and maintaining a good EMS. There are also economic benefits that are the result of using an EMS and these vary widely from sector to sector.

External costs relating to verification of the system can be estimated from guidance issued by the International Accreditation Forum [140, IAF 2010].

Driving force for implementation
The driving forces for the implementation of an EMS include:

- improved environmental performance;
- improved insight into the environmental aspects of the company which can be used to fulfil the environmental requirements of customers, regulatory authorities, banks, insurance companies or other stakeholders (e.g. people living or working in the vicinity of the installation);
- improved basis for decision-making;
- improved motivation of personnel (e.g. managers can have confidence that environmental impacts are controlled and employees can feel that they are working for an environmentally responsible company);
- additional opportunities for operational cost reduction and product quality improvement
- improved company image;
- reduced liability, insurance and non-compliance costs.

Example plants
EMSs are applied in a number of installations throughout the EU.

Reference literature
[138, COM 2014], [141, Reg. 1221/ 2009],[142, DG Environment 2010],[143, ISO 2004], [158]

WORKING DRAFT IN PROGRESS

2.3.1.2 Utilisation of qualified personnel in the plant

From ex-**Section 4.1.2.10 "Utilisation of qualified personnel in the facility"**

Description
The waste treatment plant is operated by adequate staff, in terms of number, qualification and competence.

Technical description
Training, awareness and competence of staff are parts of the Environmental Management System (see Section 2.3.1.1).

Some examples of techniques related to staff are as follows:

a. ~~general provisions:~~ At all times the operator of a WT plant needs to have sufficient staff available and on duty with the requisite qualifications. All personnel need to undergo specific job training ~~and further education~~.
b. ~~supervisory staff:~~ The supervisory staff and all heads of sections in the waste management facility plant ~~need to be~~ are reliable and technically qualified and ~~they need to~~ have appropriate practical experience. Technical qualifications may have been obtained from a successfully completed course at a state or state-approved technical university, university of applied science or school of engineering. Technical expertise ~~will~~ can also be recognised on the basis of comparable training or on many years of practical experience.
c. ~~other staff:~~ Other staff ~~must be~~ is reliable and technically skilled. This technical skill may be based, for example, on formal qualifications in areas such as community services and waste disposal, on many years of practical experience, or on comparable training.

Achieved environmental benefits
Improvement of ~~and prevents~~ the environmental performance of the facility. Qualified people and training are essential in WT operations, both for the waste producers (sorting, collecting, etc.) and for the WT operator. Health, safety, security and environmental protection all depend on the good management of the installation and, as a result, on workers' qualifications.

Cross-media effects
~~Not known.~~None.

Environmental performance and operational data
~~This is a management tool.~~
It ~~might happen~~ may be that delivered wastes might cause problems, so it is advantageous if the staff in charge are alert ~~on~~ to problematic wastes. However, staff are kept aware of all materials which might cause problems during processing. Depending on the ~~applied~~ machines used, these might be large bulky parts or other components like metals. If the staff are highly alert, ~~an~~ almost continuous processing with a small range of quality fluctuations might be guaranteed.

Technical considerations related to applicability
Fully applicable to the whole WT sector. The number, qualification and competence of the personnel are proportionate to the plant size and to the complexity of the waste treatment processes.

Economics
Qualified people typically are more expensive. Putting in place training programmes (either in-house or externally subcontracted) will incur some extra costs for the operator.
Driving force for implementation
Improvement of the plant performance.

Example plants
There are many examples in the sector.

WORKING DRAFT IN PROGRESS

Reference literature
[82, Pretz et al. 2003] [87, UBA Germany 2003] [98, WT TWG 2004]

Ex-**Section 4.1.2.5 "Management techniques"** deleted because of repetition of Sections 2.3.6.1 and 2.3.1.2.

Ex-**Section 4.1.2.6 "Identification of economies of scale and synergies**" deleted. This is about relations between operators.

~~**Description**~~
~~Where there are a number of separate installations (particularly where there are different operators), there may be a possibility to identify some installation wide issues and opportunities for interactions between the installations, whereby the overall performance of each installation may be improved. In particular by sharing or combining information or activities and enhancing co-operation. Some examples of this include:~~

~~a. improving communication procedures between the various permit holders; in particular those needed to ensure that the risk of environmental incidents is minimised~~
~~b. utilising benefits from the economies of scale to justify the installation of a shared CHP plant (see energy sections within Section)~~
~~c. combining combustible wastes to justify a combined waste to energy (see energy sections within Section)~~
~~d. utilising the waste from one activity possibly as a feedstock for another~~
~~e. utilising the treated effluent from one activity, if it is of an adequate quality, as the raw water feed for another activity~~
~~f. combining effluents to justify a combined or upgraded effluent treatment plant~~
~~g. avoiding accidents from one activity which may have a detrimental knock-on effect on a neighbouring activity~~
~~h. avoiding land contamination from one activity affecting another – or possible problems that one operator may own the land on which the other is situated.~~

~~**Achieved environmental benefits**~~
~~Can increase the energy efficiency, reduce waste generation, reduce water consumption and reduce water emissions from the overall complex.~~

~~**Cross-media effects**~~
~~Some of these communications may be difficult if related with legal issues concerning competition.~~

~~**Applicability**~~
~~Applicable where synergies are identified and where more than one activity is carried out.~~

~~**Economics**~~
~~Typically decreases the overall cost of the waste treatments.~~

~~**Driving force for implementation**~~
~~Typically increases the economic viability of the waste treatments.~~

~~**Example plants**~~
~~Many examples exist in the sector.~~

~~**Reference literature**~~
~~[33, UK EA 2001] [60, WT TWG 2003]~~

From ex-**Section 4.1.2.7 "Provision of full details on the activities to be carried out"**

~~**Description**~~

Deleted: This is about information requested by the Authority (implementation issue)

WORKING DRAFT IN PROGRESS

~~The provision of adequate process descriptions of the activities and of the applied abatement and control equipment is important, to enable the regulator to gain a good understanding of the applied process. Appropriate items that can help to build up a good picture of the plant include:~~

~~a. a description of the waste treatment methods and procedures in place in the installation~~
~~b. providing pipe and instrumentation flow diagrams of the installation (e.g. R-/I-Fliesbilder)~~
~~c. diagrams of the main plant items where they have some environmental relevance, and also process flow diagrams (schematics). For example, plant design diagrams of the storage, tanks, and the treatment and abatement facilities, although in isolation these will typically not be enough to enable the proper environmental evaluation~~
~~d. details of chemical reactions and their reaction kinetics/energy balance~~
~~e. an equipment inventory, detailing plant type and design parameters, for example, flashpoints~~
~~f. details on the waste types to be subjected to the process~~
~~g. a control system philosophy and how the control system incorporates the environmental monitoring information~~
~~h. details of the venting and emergency relief provisions~~
~~i. operating and maintenance procedures~~
~~j. details on how protection is provided during abnormal operating conditions such as momentary stoppages, start-up, and shutdowns.~~

Deleted: already covered by EMS

~~Furthermore, with regard to information, it is important for operators:~~
~~k. to have access to all the necessary regulations relating to operational safety and order and a schedule of work rules before the initial operation of the plan~~
~~l. to have an instruction manual. The instruction manual contains all the measures needed to ensure proper and safe disposal of wastes occurring during normal operation, maintenance operations, and during operational disturbances. All processes should be harmonised with alarm and emergency schedules. The instruction manual also details the duties and responsibilities of operating staff, the working instructions, the arrangements for maintenance and inspection, as well as reporting, documentation and storage requirements. This manual needs to be updated as necessary and should be available before the initial operation of the plant~~
~~m. to have an operational diary, to detail operating conditions and as evidence of the proper running of the plant. The operational diary will contain all the relevant information related to the day-to-day operation of the waste management facility plant, and will in particular:~~
  - ~~record all waste treated in the plant, and any other materials that are recycled or disposed of in some other manner outside the plant~~
  - ~~act as a register of the accepted waste~~
  - ~~act as a register of any material recycled or disposed of in some other manner outside the plant~~
  - ~~provide documented evidence in disputes, e.g. in cases where the delivery of waste material does not correspond to the details contained in the pre-acceptance documentation. In this case, the diary will detail all the measures taken~~
  - ~~record special incidents, and in particular the details of any operational disturbances, including details on the possible causes and the corrective measures taken~~
  - ~~record running times and downtimes of the plant~~
  - ~~record the results of investigations and self-checking measurements~~
  - ~~record the nature and scope of all maintenance measures~~
  - ~~record the results of the function controls~~

~~n. to keep the operational diary up to date. All additional supporting statements required by the appropriate authority also need to be documented in the operational diary. In one system, the operational diary might involve collecting single sheets filled out by persons from the different assets areas. The operational diary could also be managed using electronic data~~

WORKING DRAFT IN PROGRESS

~~processing. Regardless of whether it is kept in electronic or paper format, it should always be kept in safe custody and protected from unauthorised access~~

~~o. to keep the operational diary for a period of five years~~

~~p. to report any incidents which lead to a significant deviation from normal operation immediately to the appropriate authority, in particular those bringing the plant to a standstill~~

~~q. to prepare an annual survey of the activities carried out and the wastes treated. The annual survey can also contain a quarterly balance sheet of the waste and residue streams, including the auxiliary materials used, for each site. The annual survey should be submitted to the appropriate authority within a period of three months after the end of the year.~~

~~Achieved environmental benefits~~
~~Helps assess operators proposals and in particular the opportunities for further improvements.~~

~~Cross-media effects~~
~~Not known.~~

~~Operational data~~
~~Management operation.~~

~~Applicability~~
~~Fully applicable in all WT installations. However, technique d (see description above) is sometimes seen as difficult to be applied to some installations due to the complex mixtures that represent some wastes as well as the variability in composition of the waste.~~

~~Driving force for implementation~~
~~This is typically a part of the operation permit.~~

~~Example plants~~
~~Common technique.~~

~~Reference literature~~
~~[33, UK EA 2001] [60, WT TWG 2003] [87, UBA Germany 2003] [98, WT TWG 2004] [101, WT TWG 2005]~~

2.3.2 Operational techniques to improve environmental performance

From ex-**section 4.1.1 "Techniques to improve knowledge of the waste IN"**

This section covers those techniques that help the operator to characterise the waste input to be treated. The rigour with which this characterisation is done is essential to the subsequent waste treatment operations. Failure to adequately screen waste samples prior to acceptance and to confirm its composition on arrival at the installation has often historically led to subsequent problems, including ~~an~~ inappropriate storage and mixing of incompatible substances, an accumulation of wastes and an unexpected treatment, and hence unexpected emission profiles.

2.3.2.1 Waste pre-acceptance

Description
Pre-acceptance procedures are techniques to ensure the technical (and legal) suitability of the waste treatment operation for a particular waste.

Technical description

(i) The waste pre-acceptance procedure requires the following in writing prior to the arrival of the waste at the facility:

- the name, location and contact details of the original waste producer;
- details of the process giving rise to the waste;

WORKING DRAFT IN PROGRESS

- an appropriate description of the waste including its physical form, comprehensive chemical composition (performed on a representative sample or samples of the waste), and hazardous properties;
- confirmation that the waste is not radioactive except where the facility is permitted to accept such waste;
- the estimated quantity expected to be delivered to the operator per load and in a year;
- information on the nature and variability of the waste production process(es);
- the European List of Waste code for the waste.

Verification of the written information provided may be required, and this may require contact with or a visit to the producer. Additional factors may become apparent when dealing with staff directly involved in the waste production.

(ii) A representative sample of the waste is obtained and analysed if:
- the chemical composition or variability of the waste is unclear from the information supplied by the customer, or there are doubts about whether the sample analysed is representative of the waste; and
- the waste is to be treated at the operator's facility (this allows tests to be conducted regarding the planned treatment to determine that the treatment will be safe and effective).

(iii) A representative sample is not required where, for example, the waste is:
- asbestos;
- a pure product chemical or aerosol where the chemical composition and hazardous properties are available in a REACH compliant safety data sheet;
- laboratory smalls in containers of less than 30 litres;
- contaminated clothing, packaging or rags;
- an 'article', for example batteries, lighting tubes, paint cans and WEEE;
- solid non-hazardous waste (except for mirror entries when the waste composition is unknown);
- contaminated wood and roofing material;
- produced in an emergency - such wastes must remain as a quarantined waste until a full characterisation has been completed

(iv) Following the full characterisation of the waste, a technical assessment is made of the suitability of the waste for treatment or storage to ensure permit conditions can be met. It is ensured that the waste complies with the installation treatment capabilities.

(v) The personnel dealing with the pre-acceptance procedure have the necessary professional skills, training and/or experience to deal with all issues relevant for the management of the wastes in the facility.

(vi) Material flow analysis for the components in the waste will help identify the flow(s) and fate(s) of the components in the waste. This analysis can be helpful in choosing the most appropriate forms of treatment for the waste, either directly at the site or at any subsequent treatment site. It also helps in ensuring that hazardous components are correctly treated and either destroyed or removed, when not desired, from the product cycle into a 'sink' and not diluted into the recycling/product cycle.

(vii) Records of pre-acceptance are kept for at least three years following receipt of the waste in an advanced computerised process control system. When the enquiry does not lead to the waste being received there is no requirement to keep records.

(viii) The information required at pre-acceptance is reassessed:
- if the waste changes;

WORKING DRAFT IN PROGRESS

- if the process giving rise to the waste changes;
- if the waste as received is found not to conform to the pre-acceptance information;
- in any case, on an annual basis.

From ex-**Section 4.1.1.2 "Pre-acceptance procedure to assess if waste is suitable to be stored or/and treated in the installation"**

(ix) ~~Applying~~ odour criteria are applied to reject mercaptans, low molecular weight amines, acrylates or other similarly highly odorous materials that are only suitable for acceptance under special handling requirements.

Waste pre-acceptance procedures are based on a risk approach considering, for example, the risks posed by the waste in terms of process safety, occupational safety and environmental impact as well as the knowledge of the previous waste holder(s).

Achieved environmental benefits
These techniques can help operators identify and then reject unsuitable wastes which could lead to adverse reactions or uncontrolled emissions during treatment.

Environmental performance and operational data

From ex-**Section 4.1.1.2 "Pre-acceptance procedure to assess if waste is suitable to be stored or/and treated in the installation"**

Pre-acceptance for waste oil treatment
As a general requirement, this step is not critical for a waste oil treatment plant, but it would be required if the waste ~~is~~ was destined for treatment at a mineral oil refinery for example. Typically the waste comes from a large number of small-volume sources, such as garages, but its composition is essentially fixed. Pre-acceptance procedures relating to information collection need to be applied for one-off industrial arisings of waste oil and arisings from sources where other chemicals and potential contaminants may be handled, for example, from chemical manufacturing. Contamination of waste oil by substances such as solvents does occur and although relatively low levels of contamination can be accommodated by the operator, in so far ~~that~~ as it may not affect the sale of the recovered oil, the contamination still needs to be identified. Low-flashpoint solvents will give rise to handling difficulties as the plants are not set up ~~for~~ to deal~~ing~~ with flammable materials. Petrol contamination often occurs, ~~this~~ which significantly reduces the flashpoint of the material and will thus significantly increase the risk of accidents. Care is taken in choosing and interpreting the most appropriate flashpoint determination. Solvents will also be driven off in the heating process, therefore increasing VOC emissions. Contamination with PCBs can transfer those PCBs to either the product, which may give rise to dioxin formation if used in a subsequent combustion, to the tank bottom oil sludges or to the effluent.

Pre-acceptance of Laboratory smalls
If drums are used for laboratory smalls, a list of the contents is created and stored within the drum below the lid. Similarly for other types of packages containing laboratory smalls, a list of contents is created and appropriately stored within or attached to the packaging. Each packed drum (or other package) is then labelled with respect to the hazard for carriage (e.g. ADR regulations). The level of supervision or management of this type of situation depends on a number of factors. In any case a full list of the contents needs to be produced. For operators who accept wastes packaged by their customers, packing guidance is typically provided to the customer. Waste producers need written procedures regarding the segregation, packaging and labelling of laboratory smalls.

Scoping study for physico-chemical plants
Sites need to undertake a scoping study to identify materials that are not covered by their effluent monitoring programme but are accepted at the site. The main areas to consider are as follows:

WORKING DRAFT IN PROGRESS

- Aqueous wastes containing solvents which may then be emitted due to the heat of the process.
- High-nitrogen wastes with ~~a~~ the potential for ammonia emissions to air.
- Wastes containing phosphorus: not all sites are required to monitor regularly for 'total phosphorus' so at these sites it may be easier to estimate this emission from the intake of phosphoric acid.
- Occasional inorganic wastes, e.g. wastes containing arsenic. Again, in most cases it will be easier to calculate the annual emission from occasional waste ~~IN~~ input data rather than to extend the monitoring programme.

Biological treatment plants

The initial assessment and periodic verification required shall be proportionate to the risk posed by the type and nature of the relevant waste. For example, green waste from a landscaper is of a lower risk than mixed municipal waste and will therefore require a lesser degree of scrutiny at pre-acceptance. [109, Bio. subgroup 2014]

Cross-media effects

None.

Technical considerations relevant to applicability

The requirement to characterise the waste, including sampling and analysis, also applies to waste transfer and treatment facilities. There is often reluctance amongst third parties to divulge the identity of the waste producer as this may be of commercial benefit. This however cannot override the fundamental requirement for the operator to check the information on the waste provided by the waste producer (not just the current holder), who is naturally in the best position to verify the waste.

Economics

No information provided.

Driving force for implementation

Safety of the process equipment and workers, as well as legislative requirements for specific waste treatment activities and permit requirements.

Example plants

Commonly used in the waste treatment sector.

Reference literature

[12, ÖWAV Working Commitee 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [87, UBA Germany 2003] [98, WT TWG 2004] [101, WT TWG 2005], [109] [146, PCT]

From ex-**Section 4.1.1.2 "Pre-acceptance procedure to assess if waste is suitable to be stored or/and treated in the installation"**

~~**Description**~~

~~Systems and procedures can be put in place to ensure that wastes are subject to the appropriate technical appraisal to ensure the suitability of the proposed treatment route. Some pre-acceptance techniques and procedures applied to assess wastes are:~~

~~(x) carrying out suitable checks before any decision is made to accept the waste~~

~~(xi) having an initial screening step, involving the provision of information and representative samples of the waste. The waste producers and operator at the receiving site will both ensure that reliable and comprehensive information has been provided to determine the suitability of the waste for the treatment (or recovery) process in question. This also applies if wastes are only to be stored or bulked at the installation, so that the information can be provided to the next holder of the waste and the ultimate disposal route identified~~

WORKING DRAFT IN PROGRESS

~~(xii)~~ ~~providing details on the nature of the process(es) producing the waste, including the variability of the process. As the circumstances of waste production may vary, sound professional judgement is required to ensure that the relevant questions are asked. Operators need to ensure that a technical appraisal is carried out by suitably qualified and experienced staff who understand the capabilities of the site. These staff ought to be independent of the sales staff responsible for obtaining the customer's business.~~
~~(xiii)~~ ~~providing the chemical composition of the waste, its handling requirements and its hazards~~
~~(xiv)~~ ~~providing and analysing a representative sample(s) of the waste from the production process producing such waste from the current holder~~
~~(xv)~~ ~~undertaking a comprehensive characterisation of the waste for each new waste enquiry~~
~~(xvi)~~ ~~requiring a verification of the written information provided by the waste holder. This may require a visit to the waste producer, as additional factors may become apparent when dealing directly with staff involved in the waste production~~
~~(xvii)~~ ~~carefully verifying the information received at the pre-acceptance stage, including the contact details for the waste producer and a full description of the waste regarding its composition and hazardousness. This can also be carried out by dealing directly with the waste producer~~
~~(xviii)~~ ~~maintaining all records at the installation relating to the pre-acceptance for cross-referencing and verification at the waste acceptance stage. The length of time that the records need to be held needs to be determined, taking into account whether the waste is actually delivered to the site or when it is likely to be delivered~~
~~(xix)~~ ~~applying odour criteria to reject mercaptans, low molecular weight amines, acrylates or other similarly highly odorous materials that are only suitable for acceptance under special handling requirements~~
~~(xx)~~ ~~providing and checking details of the waste code according to the European Waste List (EWL)~~
~~(xxi)~~ ~~making inquiries to the operator of the WT plant about whether the WT installation in question is permitted to treat the declared waste and whether the WT operator is prepared to accept the waste. (see comments in the operational data section)~~
~~(xxii)~~ ~~carrying out a procedure for risk assessment~~
~~(xxiii)~~ ~~issuing an acceptance declaration by the WT operator which describes all necessary conditions and measures to be taken into account by the waste customer (e.g. waste producer). Also all internal rules within the receiving plant to treat the waste stream should be laid down in written form at the same time.~~

~~Achieved environmental benefits~~
~~These techniques can help operators identify and then not accept unsuitable wastes which could lead to adverse reactions or uncontrolled emissions during the WT activity. They will thus ensure that only waste suitable for the specific WT activity is accepted into the site for that WT.~~

~~Actual experience of these techniques has shown that reliance cannot be placed solely upon these techniques to always provide sufficient information. It is not unusual for the waste producer and the operator to be separated by a third party and in some cases even three or four different parties. These may be haulage contractors, brokers, or waste transfer operators. Where there is a lengthy chain, information may be lost or inaccurately reproduced. These techniques however can allow operators to determine the suitability of the waste for the activity before arrangements are in place to accept the waste. Other benefits include:~~

- ~~the provision of information keeps the number of links in a chain down. This helps avoid information loss or misrepresentation~~
- ~~helping operators to screen out unsuitable wastes to prevent potential problems~~
- ~~confirming the composition details, allowing identification of a number of verification parameters to test the waste arriving at the site~~
- ~~helping to identify any substances within the waste which may affect the treatment process or which may react with other reagents~~
- ~~helping to accurately define any hazards related to the waste~~

WORKING DRAFT IN PROGRESS

- ~~identifying any substances within the waste which might be unaffected by the treatment process and which could, therefore, be transferred in an unaltered state to the residues or effluent~~
- ~~helping to determine the cost of the disposal option identified~~
- ~~ensuring regulatory compliance (depending on the country).~~

~~**Cross-media effects**~~
~~These are related with the specific physico-chemical analysis performed.~~

~~Related with technique k (see description above), waste codes do not give much information in many cases about the composition of the waste classified. Wastes with the same waste code may have totally different compositions and qualities.~~

~~**Operational data**~~
~~Includes administrative and laboratory work.~~

~~Related to technique c (see description above), there are cases where the composition of the waste cannot be known (i.e. collection of hazardous waste from households). In these cases, the operators collecting and accepting such waste need to have the necessary experience to handle it safely.~~

~~Related to technique k (see description above), it is the duty of the waste producer to decide on the appropriate waste code of the EWL. This is not a task for the WT operator.~~

~~In some cases, the verification referred in technique l of the description above may take place before the first contact with the WT operator for the pre-acceptance procedure and/or before signing the agreement.~~

~~**Applicability**~~
~~The requirement to characterise the waste, including sampling and analysis, equally applies to waste transfer as well as treatment facilities. There is often a reluctance amongst third parties to divulge the identity of the waste producer as this may be of commercial benefit. This however cannot override the fundamental requirement on the operator to check the information on the waste provided by the waste producer (not just the current holder), who is naturally in the best position to verify the waste. Some application examples are shown below~~
~~**Economics**~~
~~Extra administration costs (e.g. packaging, labelling).~~

~~**Driving force for implementation**~~
~~Typically these procedures are included in the national legislation of various countries, in guidance notes or in the operating permits of the plants. The chemical components and parameters which have to be analysed are also often defined.~~

~~Taking samples of heterogeneous wastes is especially difficult and needs experienced operators. The work of CEN TC 292 or the German LAGA papers on waste samples may give some guidance.~~
~~**Example plants**~~
~~Many of these techniques are commonly used in the WT sector. For example, the merchant UK physico-chemical sites require all customers to provide a good waste description and a sample for analysis prior to acceptance at the site. The sites need to know the waste composition in order to be able to create a suitable end-product at the site that can meet sewer discharge standards and produce a cake suitable for landfill.~~

Ex-**Section 4.1.2.1 "Techniques to determine the type of waste treatment applied to each waste"** deleted. The waste treatment route is determined at pre-acceptance stage and confirmed at acceptance.

WORKING DRAFT IN PROGRESS

2.3.2.2 Waste composition characterisation

Ex-Section 4.1.1.1 "Waste composition characterisation" and ex-**Section 4.3.2.2 'Laboratory activities'** are deleted and replaced by this text

Description

Combination of analyses to be carried out at pre-acceptance stage to achieve sufficient knowledge of the waste composition.

Technical description

Waste composition characterisation is an essential step in the pre-acceptance procedure. For instance, hazardous wastes are very complex mixtures. Only a combination of analyses can ensure that sufficient knowledge is available for the safe handling and treatment of hazardous waste.

Waste composition characterisation is not a protocol carried out at the acceptance step but at the pre-acceptance step. This protocol is not carried out for each waste or each new waste but when the information gathered on the waste is not sufficient to ensure the compliance with regulatory requirements and to determine the adequate waste treatment route.

Quality

Analyses are carried out as much as possible under ISO 17025 [168] accreditation. The test sample for analysis from the laboratory sample is prepared according to standard [172]. In particular, when multiple immiscible phases or fractions are present, the analysis will be performed on each phase and the results may be combined to provide the final result.

Analysis of liquid waste

This may include the following:

(i) In case of presence of suspended solids or separated phases, and when the analysis methods applied to the liquid sample are suspected to not extract and quantify the compounds present in solid particles or in the separate phase, the sample must be separated into two fractions by a suitable method (filtration, centrifugation, decantation), the mass of each fraction must be determined, and comprehensive analysis of the separated liquid fraction and solid fraction or each phase performed

(ii) The following parameters may be measured:

- Density of the sample.
- Water content
- Ash content by calcination at 550 °C
- For waste water and aqueous waste, the pH, redox potential and electrical conductivity are measured directly in the water. For pastes and oil, the measurements are performed after water extraction from the crude sample with a ratio of 10 l/kg of dry matter in a closed container to limit exchanges with the atmosphere
- If the waste is saline (conductivity > 0.15 S/m), it is preferable, to ensure a correct speciation of metals, to measure the chlorides and preferably all the halogens that are soluble in water
- If the presence of cyanide is suspected, it is advised to determine the free and complexed cyanide separately
- Metal content (except 12 heavy metals) and other elements (silicium, sulphur, phosphorus, etc.)
- The 12 heavy metals (As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Zn) are determined individually and quantitatively. Any specific classical method of (partial) extraction of these metals may be used.
- Chromium (VI) if its presence is suspected
- Content of volatile and semi-volatile substances

WORKING DRAFT IN PROGRESS

- Particular substances controlled by regulations with limit values < 1 w/w-% are determined, if suspected, by classical quantitative analysis.
- Mass balance of liquid waste

Analysis of solid waste
This may include the following:

(i) As an option, measurement of the bulk density of the laboratory sample without pretreatment, to inform the user of the nature of the waste;

(ii) The following parameters may be measured:

- Water content. Pretreatment of the waste may be needed (not for volatile compounds) by air drying at 40 °C, grinding and sieving.
- Ash content (calcinated residue) by calcination at 550 °C.
- For solids, pH, redox potential and electrical conductivity are measured in a water extract of crude sample with a ratio of 10 l/kg of dry matter
- If the waste is saline (conductivity of leachate > 0.15 S/m), it is desirable, to ensure a correct speciation of metals, to measure the chlorides and preferably all the halogens in the extract of 10 l/kg DM
- If the presence of cyanide is suspected, it is advised to determine the free and complexed cyanide separately
- Metal content (except 12 heavy metals) and other elements (silicium, sulphur, phosphorus, etc.)
- The 12 heavy metals (As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Zn) are determined individually and quantitatively. Any specific classical methods of (partial) dissolution of these metals may be used
- Chromium (VI) if its presence is suspected
- Content of volatile and semi-volatile substances
- Particular substances controlled by regulations with limit values < 1 w/w-% are determined if suspected by classical quantitative analysis.
- Mass balance of solid waste:

Environmental performances and operational data
An accurate knowledge of the hazardous waste allows:

- the hazardous criteria to be defined;
- the impact on the Seveso status of the installation to be assessed;
- the compliance with the mixing rules to be ensured.

It is also a very important tool to ensure that hazardous substances that are prohibited for recycling are correctly managed and extracted from the recycled part of the waste like POPs, Substances of Very High Concerns (SVHC) and substances subject to authorisation (listed in Annex XIV to the REACH regulation).

Consequently, the complete protocol described in the technical description is the most up-to-date one to avoid any detrimental effects on the environmental due to a lack of knowledge of the composition of hazardous waste (during handling and treatment).

Cross-media effects
There are no cross-media effects.

Technical considerations relevant to applicability
The protocol described is very accurate for all organic substances but can lead to a more open interpretation for inorganic substances (mainly metal compounds).
All analyses in the protocol give information on elemental composition (metals, halogens, etc.). If the operator or the producer of the waste do not have mineralogical information about the

WORKING DRAFT IN PROGRESS

waste, it is very difficult to interpret the analytical results and provide the right information on the speciation of metals. In this situation and in order to have a complete picture for the characterization of hazardous waste, a 'worst case' approach can be used where, for example, a specific metal is considered as it was the most dangerous compound which is likely to be present depending on the physico-chemical context.

Economics
The cost of the whole protocol is around EUR 1000 per sample.

Driving force for implementation

- Better knowledge on hazardous waste.
- Compliance with the Waste Framework Directive and classification of waste.
- Compliance with the Seveso Directive.

Example plants
Operators of hazardous waste treatment plants in France use this protocol when necessary.

Reference literature
[176, AFNOR 2013], [151, Hennebert et al. 2015], [146, PCT Subgroup 2015], [168, CEN 2005], [172, CEN 2015], [173, CEN 2006], [174, CEN 2007] [170, ISO 2012] [171, ISO 2012], [169, ISO 2011] [177, AFNOR 2002], [175, CEN 2007], [178, AFNOR 1988], [179, CEN 2005], [180, CEN 2002], [181, CEN 2006],

2.3.2.3 Waste acceptance

Description
Acceptance procedures aim to confirm the characteristics of the waste, as identified in the pre-acceptance stage.

Technical description
The waste acceptance procedure provides details of the following steps which are undertaken by operators when the waste arrives at the facility.

Acceptance principles

(i) Other than in an emergency, the operator only receives onto the site prebooked wastes that have been adequately pre-accepted and that are consistent with the pre-acceptance information.
(ii) All wastes are checked and verified against pre-acceptance information and transfer documentation before being received on site.
(iii) The operator follows clear and unambiguous criteria for the rejection of wastes and the reporting of all non-conformances to the competent authorities.
(iv) Waste is only received and accepted under the supervision of a suitably qualified person.
(v) All transfer documentation is checked and validated.
(vi) The operator ensures that the facility has the necessary capacity to receive the waste for all storage areas (quarantine, reception, general and bulk) and treatment processes. Wastes are not received if the capacity is not available. The physical and licensed capacity must be sufficient for the storage and, if relevant, the storage must respect the summation of hazardous quantities as defined in the Seveso classification of the plant.
(vii) When there is a risk of radioactive contamination, the waste is checked to determine that it is not radioactive waste.

Sampling

(viii) Other than some wastes such as:

WORKING DRAFT IN PROGRESS

- pure waste chemicals;
- asbestos;
- contaminated clothing, packaging or rags;
- 'articles';
- laboratory smalls;

all wastes, bulk or containerised (including from every container), are representatively sampled and undergo verification and compliance testing. Reliance solely on the written information supplied is not acceptable.

(ix) A representative sample is one that takes account of the full variation and any partitioning of the load such that worst case scenarios are accounted for.

(x) Sampling takes place on site under the supervision of the site's qualified staff. Where the driver arrives at the site with a sample taken elsewhere there is a full risk assessment to check that the sample is representative, reliable and was only taken for specific health or safety purposes (for example, air- or water-reactive wastes).

(xi) A record of the sampling regime, process and justification is maintained in the advanced computerised waste process control system.

(xii) Acceptance samples are retained on site for a minimum of two days after the waste has been treated or removed from the facility including all residues from its treatment.

Inspection and analysis

(xiii) The tests required for verification purposes at acceptance (for example, metal content, total petroleum hydrocarbons, colour, pH, and odour) are listed in the advanced computerised waste process control system. If visual inspection is not feasible (e.g. for occupational safety reasons), the compliance of the waste input is checked by analytical equipment (e.g. viscometry, infrared, chromatography, mass spectrometry), laboratories and adequate human resources.

(xiv) Analysis of waste is carried out by a laboratory with suitably recognised test methods. Where the waste received is hazardous the laboratory is on site.

Reception

(xv) It is ensured that all containers are adequately labelled and in sound condition (undamaged and not corroded; lids are well-fitted; and caps, valves, bungs are present and secure) before being offloaded. Any unsound or unlabelled containers are put into quarantine and dealt with appropriately. Labelling includes the unique tracking system reference number, the date of arrival on site and at least a primary hazard code. This information is added to the advanced computerised waste process control system.

(xvi) Following visual inspection, waste containers are offloaded into a dedicated reception area to await sampling and verification.

(xvii) Any containers in the reception area are sampled and verified as compliant within one working day of receipt and transferred to the relevant general storage area on site, or quarantine if appropriate. Wastes are not deposited within a reception area without adequate space.

(xviii) Quarantine storage is for a maximum of five working days. Written procedures are in place for dealing with wastes held in quarantine, together with a maximum storage volume. For some limited and specific cases (for example detection of radioactivity) the quarantine storage could be longer.

(xix) Where containers hold laboratory smalls, each container is opened within one day of receipt to check that the contents remain undamaged and that the inventory is as expected. All of the contents in each drum must be compatible and sorted by primary hazard. Once sorted and secure, the laboratory smalls' containers are moved to compatible general storage.

(xx) The residual waste quarantine, reception, general and bulk storage capacity of the installation is kept up-to-date in an advanced computerised waste process control

WORKING DRAFT IN PROGRESS

system; a prebooking system ensures that the residual waste storage capacity is sufficient for the incoming acceptable waste inputs.

(xxi) Bulk loads (liquid or solid) can only be offloaded once they have been fully verified as compliant. No interim storage is acceptable except in an emergency situation. Verification testing includes consistency with pre-acceptance information, compatibility with appropriate bulk load storage, and checking treatability and compatibility with the treatment matrix using laboratory-scale simulation.

From ex-**Section 4.1.1.5 "Reception facilities"**

(xxii) Separate spaces are foreseen in the reception area for the separation of extraneous materials or oversized pieces.

(xxiii) The ~~to have a~~ designated sampling point(s) or reception area~~. These~~ need to be in close proximity to the laboratory/checking facility and need to be visible.

(xxiv) The reception area is equipped with a suitably sealed drainage system to prevent contaminated run-off, a separate collection system for spills which is separated from rainwater collection drains, and a sealed underground area which is safely protected against the wastes needing to be treated (related to techniques in Section 2.3.11).

(xxv) ~~to ensure that~~ The offloading, sampling point/reception and quarantine areas have an impervious surface with self-contained drainage, to prevent any spillage entering the storage systems or escaping off site.

(xxvi) ~~to immediately segregate~~ Wastes are immediately segregated to remove possible hazards due to incompatibility, which could result in the waste failing to meet acceptance criteria.

(xxvii) ~~to ensure~~ It is ensured that incompatible substances do not come into contact with spills from sampling, for example within a sump serving the sampling point. Absorbents need to be made available to deal with any spills.

Waste acceptance procedures are based on a risk approach considering, for example, the risks posed by the waste in terms of process safety, occupational safety and environmental impact as well as the knowledge of the previous waste holder(s).

Achieved environmental benefits

The acceptance procedure confirms the validity of the pre-acceptance checks and information and therefore helps ensure that no unsuitable wastes are accepted which could lead to adverse reactions or uncontrolled emissions during treatment.

Environmental performance and operational data

From ex-**Section 4.1.1.3 "Acceptance procedures when the waste arrives at the WT installation"**

Waste oil treatment plants

Typically these plants place a greater emphasis on the final acceptance procedures than those at the pre-acceptance stage.

Acceptance of laboratory smalls

The procedures for accepting laboratory smalls into a site are essentially identical to those for drummed wastes. They differ from the 'normal' waste inputs to the site in that they are in a pure concentrated form. In situations where the operator has undertaken the identification and packaging on behalf of the customer, the on-site verification can be restricted to opening the drums to check that the containers are undamaged. In such cases, the load is accompanied by documentation confirming the checking and packing. In situations where the drum has been packed by the customer, full checks~~ing~~ and verification need to be adequately undertaken by the operator. Checking the packaging and segregation needs to include emptying the drum as soon as possible (for example, within a matter of days) and repackaging the waste once all the necessary checks have been made. If, on opening a drum, it is found that it contains incompatible substances, or that the substances have not been packaged adequately, then the drum needs to be sorted and repacked immediately, and the site non-conformance procedures followed.

WORKING DRAFT IN PROGRESS

Physico-chemical treatment sites

These sites check the waste on arrival by visual inspection and by sampling. The sampling system varies in the breadth of analysis and in the frequency of sampling. There may be a simple screen for flashpoint and pH or a sample taken for rapid laboratory determination of these elements and the metals content and also a rough organic screening. The frequency of sampling is partly determined by the source of the waste: most sites focus their sampling and analysis on one-off fluctuating streams and reduce the sampling frequency for process streams that are regularly accepted.

Table 2.20: Control procedures identified at physico-chemical treatment plants

Control procedures ~~identified at physico-chemical treatment plants~~	**Percentage of plants where this practice occurs (%)**
Site enclosed or on a fully impermeable base	77
Return of rainwater (except from ~~of~~ administration buildings, roofs) and tanker washings to plant	77
Sampling of larger waste streams, or a fixed proportion	62
Input tonnage weighed	54
Partial scrubber systems	38
Full scrubber systems	15
Sampling of all wastes	8
NB: Data correspond to 13 different physico-chemical treatment sites that were analysed. *Source*:[34, Babtie Group Ltd 2002] [60, WT TWG 2003]	

Physico-chemical plants test a proportion of the incoming waste streams, although they always test new waste streams, and need to know a reasonable amount about the ~~intake~~ waste input in order to operate their process effectively. Sites require samples of the waste to carry out a preliminary screening prior to acceptance of any waste on site and, furthermore, they undertake checking routines when the waste actually arrives.

WORKING DRAFT IN PROGRESS

Waste catalyst
Materials are checked for unforeseen impurities and contamination and this can be cost-effective in maintaining a cleaner product and reducing emissions.

Waste activated carbon
Activated carbon received for regeneration needs be identified as a discrete batch and analysed, so that the substances to be desorbed during the treatment are known and it can be confirmed that the plant has the capability to process them within the constraints of the authorisation. The applicant sets out clearly the types of contaminant on the activated carbon that ~~it is~~ are intended for regeneration. ~~to be regenerated~~.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics

From ex-**Section 4.1.1.3 "Acceptance procedures when the waste arrives at the WT installation"**

Waste characterisation and analysis costs for protecting the works are typically high. It may cost up to EUR 3000 (GBP 2000) per analysis for a rig test mimicking the effect of a waste on the waste water treatment works.

From ex-**Section 4.1.1.5 "Reception facilities"**

Reception facilities for waste water treatment works, for example tanker unloading and storage, may cost around EUR 1.5 million (GBP 1 million). Operational costs are relatively low and mainly involve administrative costs.

Driving force for implementation
Safety of the process equipment and workers, as well as legislative requirements for specific waste treatment activities and permit requirements.

Example plants
Common techniques for many plants in the waste sector.

Reference literature
[16, UK Environment Agency 1996] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [81, Ruiz, C. 2002] [87, UBA Germany 2003] [98, WT TWG 2004] [100, WT TWG 2004] [101, WT TWG 2005] [146, PCT], [75, Watco 2002] [77, Schmidt et al. 2002] [82, Pretz et al. 2003] [107, Mech. subgroup 2014]

~~**Description**~~
~~On-site verification and compliance testing needs to take place to confirm: 1) the identity of the waste, 2) the description of the waste, and 3) the consistency with the pre-acceptance information and proposed treatment method. Some acceptance techniques and procedures (after the pre-acceptance) applied to assess waste are given in the lists below, these include:~~

a. ~~not accepting wastes at the installation unless a clearly defined treatment method and disposal/recovery route is determined, together with there being sufficient capacity available at the installation before the waste is accepted. Other than pure product chemicals and laboratory smalls, no wastes should be accepted at the installation without sampling, checking and testing being carried out. Reliance solely on the written information supplied is not acceptable and physical verification and analytical confirmation is required~~
b. ~~implementing of sampling procedures~~

WORKING DRAFT IN PROGRESS

c. ~~for waste treatment or transfer, carrying out the bulk of the characterisation work at the pre-acceptance stage. This ensures that the acceptance procedures carried out when the waste arrives at the site can serve to confirm the characteristics of the waste~~
d. ~~putting in place measures to fully document and deal with acceptable wastes arriving at the site, such as a pre-booking system, to ensure, e.g. that sufficient capacity is available~~
e. ~~enforcing requirements that the waste is accompanied by information describing the physical and chemical composition, hazard characteristics, the presence of incompatible substances and any handling precautions. Hazardous wastes also need to be accompanied by consignment notes and this information should specify the original waste producer~~
f. ~~having clear and unambiguous criteria for the rejection of wastes and reporting all non-conformances~~
g. ~~utilising a laboratory with suitably accredited test methods to carry out the analyses~~
h. ~~checking the details of the waste code according to the European Waste List (EWL)~~
i. ~~using a risk assessment procedure to select and, if necessary, to perform analysis of the waste. An example is shown in the Example plants section.~~

~~Other issues which may be addressed by the acceptance procedure concern:~~

- ~~vehicle waiting, load inspection, sampling and off-loading areas~~
- ~~traffic control~~
- ~~procedures for checking paperwork arriving with the load~~
- ~~procedures for unloading to allow inspection and sampling~~
- ~~location of designated sampling point(s)~~
- ~~visual / organoleptic load inspection (for some liquid and hazardous waste loads, this may not be applicable)~~
- ~~drum and package labelling procedures~~
- ~~infrastructure, such as bunds and sampling areas~~
- ~~assessing consistency with pre-acceptance information and the proposed treatment method~~
- ~~sample retention systems, that is with regard to determining the appropriate period of retention~~
- ~~record keeping in relation to waste producer details, analysis results and treatment methods~~
- ~~procedures for periodic reviews of pre-acceptance information~~
- ~~dispatch conditions.~~

~~Achieved environmental benefits~~
~~This second acceptance stage, includes procedures for when the waste arrives at the site, and serves to confirm the characteristics of the pre-accepted waste, without the time pressure and potential hazard of checking a waste from scratch at the gate. These techniques prevent unsuitable wastes being accepted, which could otherwise lead to adverse reactions or uncontrolled emissions, and these techniques therefore ensure that the accepted waste is suitable for the WT activity. Moreover, this minimises the time the vehicle delivering the waste is kept waiting preventing problems due to, e.g. accidents, leaks. This procedure also prevents waste being rejected and being sent back out onto the public highway.~~

~~Cross-media effects~~
~~Equal to pre-acceptance procedures.~~

~~Operational data~~
~~Equal to pre-acceptance procedures. In some cases, it may be difficult to perform a proper sampling (e.g. drums with used and contaminated clothes or gloves).~~

~~Applicability~~
~~Some examples of industrial applicability are described below:~~

~~Driving force for implementation~~
~~Such analyses are commonly regulated by national legislation and permits. Hazardous waste legislation, for example, ensure that storage, handling, classification, packaging and labelling of waste is carried out correctly.~~

~~Example plants~~

WORKING DRAFT IN PROGRESS

~~Applied across the whole WT sector. An example for using a risk assessment procedure to select and, if is necessary, to perform analysis of the waste may be 1st case: wastes with high risk classification are always analysed at delivery; 2nd case: wastes with a low risk classification are occasionally tested on conformity with the data of the pre-acceptance phase.~~

From ex-**Section 4.1.1.5 "Reception facilities"**

~~(xxviii)~~ . ~~Written procedures are put need to be in place for:~~

- ~~a. dealing with wastes held in quarantine,~~
- ~~b. detailing and monitoring the maximum storage volume,~~
- ~~c. packaging procedures,~~
- ~~d. repackaging of the waste before return to the waste holder.~~

~~After acceptance, the waste can be moved to another storage area (for bulk waste, this is typically a bulking area).~~

~~marking on a site plan the inspection, unloading and sampling areas~~

~~(xxix) to offload wastes in containers in a dedicated reception area pending acceptance sampling. Such storage needs to be for a maximum period of one week. During this period there needs to be no bulking-up or mixing of drums or decanting of the contents into bulk storage. Wastes need to be segregated within this reception area according to compatibility, with the segregation being carried out immediately upon offloading~~

~~(xxx) to immediately assess the wastes deposited within the reception area,~~

~~(xxxi) to ensure that the installation personnel who are involved in the sampling, checking and analysis procedures are suitably qualified and adequately trained, and that the training is updated on a regular basis~~

~~(xxxii) once the analysis has confirmed the waste is acceptable, to create a batch for treatment or a load for off-site removal. Once a batch has been assembled for treatment, the operator can create a composite sample for analysis prior to treatment. The actual scope for the analysis depends upon the intended treatment but always needs to be specified~~

~~(xxxiii) to ensure that at every step of the waste receipt at the WT plant (pre-acceptance procedures, acceptance procedures, reception facilities) the staff taking and handling the samples have the necessary knowledge and expertise~~

~~(xxxiv) to have a designed storage area at the facility that is suitable for the wastes received~~

~~(xxxv) to have a clear procedure dealing with wastes where inspection and/or analysis prove that they do not fulfil the acceptance criteria of the plant or do not fit with the waste description received during the pre-acceptance procedure. This procedure should include all measures required (e.g. by the permitting or national/international legislation) to inform competent authorities, to safely store the delivery for any transition period or to reject the waste and send it back to the waste producer or to any other authorised destination.~~

~~Some specific techniques applied to load arrival are:~~

~~(xxxvi) to weigh all incoming loads, unless alternative reliable volumetric systems linked to specific gravity data are available~~

~~(xxxvii)to not accept any load on the site unless sufficient storage capacity exists~~

~~(xxxviii) to ensure that all documents are checked and approved, and that any discrepancies need to be resolved before the waste is accepted~~

~~(xxxix) visually inspecting the load - where possible inspection checks need to be undertaken before off-loading, In any event though, the inspections are need to be carried out immediately upon the arrival of the load at the installation~~

~~(xl) checking every container to confirm the quantities against the accompanying paperwork. All containers need to be clearly labelled and need to be equipped with well-fitting lids, caps and valves, secure and in place. Containers not having the right specifications need to be rejected. Following inspection the waste needs to then be off-loaded into a dedicated sampling/reception area~~

~~(xli) applying a waste tracking system from the point of acceptance until the first treatment step which changes the physical or chemical character of the waste, e.g. by an identifying system (e.g. label, code) for any container or drum stored in the plant. The~~

WORKING DRAFT IN PROGRESS

~~information may contain any necessary data regarding health and safety, further treatment, waste code, original producer, date of arrival on site, etc.~~

~~(xlii) where containers are bulked, transposing from the original container onto the bulk container the earliest date of arrival of the bulked wastes.~~

~~Achieved environmental benefits~~

~~Environmental performance and operational data~~

~~A laboratory for chemically analysing the samples is part of this structured technique needed. Related to technique a (see description above), some samples are also not taken for immediate controls and analysis. Some samples, for example, are kept in case authorities require further controls.~~

~~Cross media effects~~

~~Most spills and leaks during sampling only occur on a small scale, e.g. resulting from releases from the back valve of a tanker if the sample is obtained in this way.~~

~~Biological degradation may cause high temperatures and, in some cases, this can cause fire. Moreover, the disposed wastes can already contain glowing particles, e.g. incompletely burned coal. Depending on the delivered wastes, the receiving area/bunker can be equipped with technical installations to fight fires, because some wastes tend to auto-ignite especially wastes with a high organic content.~~

~~Technical considerations relevant to applicability~~

~~Fully applicable to all sites however in some situations (e.g. non-hazardous waste treatment facilities) it may not be practicable or economic to have the laboratory on site.~~

Economics

Driving force for implementation

~~Some sort of reception facilities for the waste to be treated is necessary in all WT installations,. In some countries, it is not obligatory to have a quarantine storage area, and externally accredited laboratory is not legally required.~~

Example plants

~~All WT installations have some sort of reception facilities. Many sites have a pre-booking system for wastes and the reception area will then have a list of the contents of each load expected that day. Some sites have one bunded and covered reception area, others have different bunded and covered reception areas for different groups of waste. Gas chromatography and mass spectroscopy can be used to identify components of solvents and waste oils but its use requires skilled interpretation and costs are high.~~

~~The receiving area is normally covered and the doors are often closed because of odour, dust or noise emissions. The receiving area or bunker has an air ventilation installation, which collects the exhaust air. To prevent leaking air from the inside, some plants are equipped with an air ventilation system which creates a negative pressure in the receiving area or bunker.~~

Heading of ex-Section **4.1.2 'Management systems'** deleted

~~Managerial techniques typically applied to the waste treatment installations as a whole are included in this section.~~

Utilities and raw material management

WORKING DRAFT IN PROGRESS

Ex-Section **4.1.3 Utilities and raw material management** partially moved to Section 2.3.7, 2.3.8 and 2.3.9, and partially deleted

Ex-Section **4.1.3.1 Use of cleaner fuels** deleted: outside WT BREF scope

~~**Description**~~

~~The use of cleaner fuels has a direct impact on emissions from the combustion of those fuels. Fuels with less carbon, sulphur or particulate content per unit of energy will cause fewer emissions. For example, consider using electric or LPG powered vehicles. The use of cleaner fuels may conflict when energy is recovered from waste (e.g. the use of waste as fuel in the next Section since they may also generate higher emissions in certain circumstances. Such an issue needs to be analysed case by case.~~

~~**Achieved environmental benefits**~~

~~Reduction mainly in the emissions of carbon, sulphur and nitrogen oxides and particulates.~~

~~**Economics**~~

~~Typically, cleaner fuels are more expensive.~~

~~**Reference literature**~~

~~[60, WT TWG 2003] [73, Irish EPA 2003] [98, WT TWG 2004]~~

Ex-**Section 4.1.3.2 "Use of cleaner fuels"** deleted because outside scope (combustion technique)

Ex-Section **4.1.3.3 Use of waste as fuel** deleted: outside WT BREF scope

~~**Description**~~

~~Waste can be used as fuel in some waste treatment installations. Majority of these installations are covered by the WID and by WI BREF, and are not covered here. However, the use of fuel gases from waste installations (e.g. landfill and biogas) and certain types of hazardous waste (e.g. certain fractions of waste oils) are not covered in these documents. When using these type of fuels, some techniques that can be considered are:~~

a. ~~certifying burners, i.e. certify that they burn at the level that it is required~~
b. ~~rules concerning acceptable conditions for burning could include:~~
    - ~~correct maintenance and operation of burners to ensure maximum combustion~~
    - ~~controls on both the size of the burner and the volume of oil burned~~
c. ~~using pollution control equipment attached to burners, and monitoring of emissions and ash disposal (see Section).~~

~~**Achieved environmental benefits**~~

~~Uses of a resource typically available on site. Due to the higher standards required by the WID, the incineration of waste typically generates lower emissions.~~

~~**Cross-media effects**~~

~~In some installations with low control, the incineration of waste may generate higher emissions of some substances.~~

~~**Economics**~~

~~Typically, waste fuels are cheaper than conventional fuels. For example, the likely control for small used oil burners would be a specified maximum contaminant emission from burners. This would require those burning used oil to test their air emissions to ensure they do not exceed stated levels. This is likely to be less effective and more expensive than installing input controls. In the case of small amounts of waste oils being used as fuels, testing air emissions is more difficult and more expensive than testing an input of oil, and if emissions do exceed stated levels, some damage may already have been done before the burner can be stopped. For smaller~~

WORKING DRAFT IN PROGRESS

~~burners, the cost of output controls may likely negate the financial benefit of burning used oil over other fuels. Output controls for ash disposal would seek to direct how, and possibly where, ash could be disposed of safely.~~

~~**Driving force for implementation**~~
~~Waste incineration is covered by the Directive 2000/76/EC.~~

~~**Example plants**~~
~~For example, waste oil re-refining facilities use light ends from waste oil distillations as fuel. Combustion flue-gas scrubbing with caustic soda may be required to reduce acid gas emissions from a waste oil treatment plant. Then, stripping of process water is carried out for H_2S removal with the off-gases being routed to the process heaters for thermal destruction and then to the air via the flue-gas scrubbing system.~~

~~Large volume burners of any fuel are already required to have pollution control equipment in place, and many also have to monitor their emissions, as the potential effects, if something goes wrong, are deemed to be high.~~

~~**Reference literature**~~
~~[10, Ministry for the Environment 2000] [26, UK, H. 1995] [73, Irish EPA 2003] [98, WT TWG 2004]~~

Ex-**Section 4.1.2.9 "Promote good collaboration between waste producer and holder"** deleted**.** Collaboration is indeed important but it cannot really be imposed

2.3.2.4 Waste sampling

Description
The sampling procedure is used as part of the pre-acceptance and acceptance steps to select the waste samples which will undergo characterisation, analyses or tests.

Technical description
A sampling procedure is designed based on the following principles:

(i) a risk approach based on the type of waste (e.g. hazardous or non-hazardous); knowledge of the customer (e.g. waste producer); the impact of potential mixing or blending; and the possibilities for subsequent treatment;
(ii) the relevant physico-chemical parameters are checked (e.g. by viscometry, infrared, chromatography and mass spectrometry as appropriate);
(iii) sampling procedures are customised for:
  - bulk liquid;
  - bulk solids;
  - large and small containers/vessels (the number of samples increases with the number of containers/vessels and the variability of the waste).
  - laboratory smalls;
(iv) the procedure contains details of the sampling of wastes in drums within designated storage, e.g. the timescale after receipt;
(v) the following information is determined and recorded:
  - the sampling regime for each load, together with a record of the justification for the selection of each option;
  - a suitable location for the sampling points;
  - the capacity of the sampled vessel (for samples from drums, an additional parameter would be the total number of drums);
  - the number of samples and degree of consolidation;
  - the operating conditions at the time of sampling;

WORKING DRAFT IN PROGRESS

(vi) in the case of cold ambient temperatures, a temporary storage may be needed in order to allow sampling after defrosting;
(vii) a laboratory to analyse all the samples in a timely manner at the required speed.

Particularly for hazardous wastes, this often means that the laboratory (with suitable equipment) needs to be on site.

From ex-**Section 4.1.1.4 "Waste input sampling"**

~~Sampling is typically based on a risk approach considering the hazardousness of the waste as well as the knowledge of the previous waste holder. A good sampling procedure considers the following issues:~~

a. ~~the physical state of the waste homogeneity/heterogeneity)~~
b. ~~the number of samples and sample sizes for waste materials not delivered in containers. The number of samples taken is based on an assessment of the risks of potential problems, and may depends on the number of containers. In extreme situations, small containers must all be checked against the accompanying paperwork.~~
c. ~~The procedure should include a system for recording the number of samples and the degree of consolidation~~
d. ~~the number of samples and sample sizes for waste materials delivered in containers~~
e. ~~sampling procedures for all incoming wastes including bulk (liquids and solid) wastes and wastes in drums and containers, and laboratory smalls.~~
f. ~~having a system to insure that the waste samples are analysed~~
g. ~~details of the sampling of wastes in drums within designated storage, e.g. the time-scale after receipt~~
h. ~~The verification and compliance testing to confirm with the identity and description of the waste~~
i. ~~maintenance at the installation of a record of the sampling regime for each load, together with the justification for the selection of each option~~
j. ~~sampling tankered wastes prior to acceptance. This way there is no storage pending sampling~~
k. ~~of samples for a certain period of time (e.g. 0.5 – 2 months) after the waste has been treated or removed off site, including all the residues from its treatment~~
l. ~~externally taken samples or analysis reports, i.e. the driver of the vehicle carrying the waste may arrive at the installation with a sample or with an analysis that has been taken at some stage beforehand. This is typically an exception and is only considered if:~~
    - ~~there are health and safety and environmental control considerations, for example, water reactive substances which would make sampling difficult~~
    - ~~the following written information has been supplied: the physical and chemical composition, hazard characteristics, the presence of incompatible substances and any handling precautions, and information specifying the original waste producer and process~~
    - ~~the waste has been taken directly from the production site to the waste treatment installation~~
    - ~~the sampling staff can provide proof of adequate qualifications and/or training.~~

~~For the sampling of bulk liquid wastes, some issues to note are:~~

m. ~~deliveries in bulk road tanker may be accompanied by a 'wash-out' certificate or a declaration of the previous load so that contamination by this route can be checked~~
n. ~~the key requirement is to obtain a sample that is representative of the load, that is, the sample needs to take account of the full variation and any partitioning within a bulk load so that 'worst case' scenarios are accounted for. Samples are usually taken from one of three points on the tanker:~~
    - ~~top hatch~~
    - ~~back valve~~
    - ~~sight glass~~

WORKING DRAFT IN PROGRESS

~~Taking a sample through a top hatch of the surface of the liquid may not be representative, but may be useful in establishing whether there may be a layer of, for example, solvent or some other immiscible substance, which may be unsuitable for treatment. Top samples need to be obtained from the cross-section of the load, that is, a core sample should be taken.~~

~~o. to avoid the need for taking samples from the back valve of tankers which would likely result in small spillages, e.g. by mean of gantries can be constructed~~

~~For sampling drummed waste (depending on the type of packaging), some issues to note are:~~

~~p. the contents can only be identified with certainty if every container is sampled. Acceptance therefore involves sampling every container, however, the analysis of composite samples is usually acceptable with such a sampling regime. This way a representative sample is obtained by taking a core sample from the base of the container~~
~~q. ensuring that lids, bungs and valves are replaced immediately after sampling~~
~~r. the supervision of the operator visual controls for every container and the sampling procedure need to be defined under~~
~~s. utilising the opening, visual control and adapted sampling of all drums is done above a certain capacity, for example of more than 200 litres~~
~~t. packaged wastes fugitive materials: in closed areas kept in depression or inside dedicated chambers with extractor hoods in case that waste.~~

One procedure and five guides for sampling from a source of waste are available:

- EN 14899 Characterization of waste - Sampling of waste materials - Framework for the preparation and application of a Sampling Plan;
- CEN/TR 15310-1 Characterization of waste - Waste Collection - Part 1: Guide on the selection and application of criteria for sampling under various conditions;
- CEN/TR 15310-2 Characterization of waste - Waste Collection - Part 2: Guide on sampling techniques;
- CEN/TR 15310-3 Characterization of waste - Waste Collection - Part 3: Guide on procedures for sub-sampling in the field;
- CEN/TR 15310-4 Characterization of waste - Waste Collection - Part 4: Guide to the packaging procedures for storage, conservation, transportation and delivery of samples;
- CEN/TR 15310-5 Characterization of waste - Sampling of waste - Part 5: Guide on the process of developing a sampling plan.

In the case a sampling plan cannot be implemented according to those methods, the holder of the waste will follow the procedures in use in the profession for the waste studied.

The sampling phase results in a laboratory sample.

~~Operational data~~
~~Specific laboratory equipment is necessary to practice sampling.~~
~~Driving force for implementation~~
~~A series of drafts focused on European sampling standards are available, e.g. 'sampling of liquid and granular waste materials including paste-like materials' prepared by the Technical Committee CEN/TC 292 - Characterisation of waste. The CEN/TC 343 has also prepared a technical specification on the sampling of solid recovered fuels.~~
~~Other internationally consolidated standards are, for example, ISO 10381 (soil sampling) and ISO 5667 (waste water, sludge and sediments sampling). These standards include technical specifications for sample handling and preservation.~~

Achieved environmental benefits
- Improvement of the overall environmental performance of the waste treatment installation.
- Prevention of accidents and incidents and related uncontrolled emissions.

WORKING DRAFT IN PROGRESS

- ~~Sampling is a key issue in building up a good knowledge of the waste to be treated, and therefore in preventing problems during the treatment~~. Some techniques also prevent fugitive emissions (e.g. causing odour) during sampling.

Environmental performance and operational data

Appropriate equipment is needed to sample and analyse different types of waste.

~~For example,~~ For digestion of sludges, sampling is carried out to ensure batches are neither toxic nor inhibitory to digestion. In addition, generally for all types of waste sampling, the sampling procedure ensures that adequate sampling and analysis is carried out to characterise the waste. The number of samples taken is based on an assessment of the risks of potential problems. Sampling regimes at the pre-acceptance stage do not necessarily have to include sampling of every drum, for example, 'the square root of (n+1)' rule may be applied provided acceptance screening includes the sampling of every container. In some instances, physical sampling may not be necessary, for example in the case of gas cylinders or scrap batteries. In other cases such as for drummed wastes, large numbers of samples will be necessary as characterisation requires the sampling of all containers. The sampling of process wastes must take account of the variability of the process, and several samples may be required to sufficiently characterise the waste. ~~The waste producer can ensure that the sample is representative of the waste, reliable and obtained by a person with a technical appreciation of the sampling process by including the following information:~~

- ~~location of the sampling point, e.g. the effluent tank~~
- ~~capacity of vessel sampled (for samples from drums, an additional parameter would be the total number of drums)~~
- ~~method of sampling, e.g. sampling tap (mid flow), 'top' sample~~
- ~~number of samples and degree of consolidation~~
- ~~operating conditions at the time of sampling, e.g. normal operation, shutdown, maintenance and/or cleaning.~~

~~In addition, the waste producer can ensure the sample is representative by:~~

- ~~clearly labelling samples and any hazard identified~~
- ~~including systems to allow sample tracking and auditability within the installation.~~

Cross-media effects

None.

Technical considerations relevant to applicability

Relevant for all types of waste. Waste sampling procedures are based on a risk approach considering, for example, the risks posed by the waste in terms of process safety, occupational safety and environmental impact as well as the knowledge of the previous waste holder(s).

Economics

From ex-**Section 4.1.1.5 "Reception facilities"**

An on-site laboratory may be costly for simpler treatment plants (see Table 2.21).

WORKING DRAFT IN PROGRESS

Table 2.21: Economics of laboratory and monitoring equipment in a waste oil treatment facility

Techniques	**Capital cost (GBP)**	**Operating cost (GBP)**
Analytical laboratory (1),(2)	40 000	20 000
Continuous monitoring equipment (2)	10 000	1000
Technical specifications		
Capacity	10 000 t/yr	
Oil types	Used lubricating oils	
Process operation	Batch	
Waste gas flow	0–50 Nm^3/hr	
Age of plant	10 years old	
Age of pollution control equipment	2 years old	

NB:
(1) Assumes no new building required and relatively simple laboratory equipment. Staffing includes one full-time technician.
(2) The costs of continuous monitoring equipment vary enormously according to the number of substances monitored, analytical techniques used and the supplier selected.
Source: [26, UK, H. 1995] [98, WT TWG 2004]

Driving force for implementation

~~A series of drafts focused on European sampling standards are available, e.g. 'sampling of liquid and granular waste materials including paste-like materials' prepared by the Technical Committee CEN/TC 292 - Characterisation of waste. The CEN/TC 343 has also prepared a technical specification on the sampling of solid recovered fuels.~~

~~Other internationally consolidated standards are, for example, ISO 10381 (soil sampling) and ISO 5667 (waste water, sludge and sediments sampling). These standards include technical specifications for sample handling and preservation.~~

Prevention of accidents and incidents.

Example plants

All waste plants do some kind of sampling.

Reference literature

[12, ÖWAV Working Commitee 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [78, Eucopro 2003][87, UBA Germany 2003] [98, WT TWG 2004] [101, WT TWG 2005] [146, PCT],

2.3.2.5 Waste tracking system and waste inventory

Description

A waste tracking system for the site holds all the information generated during pre-acceptance, acceptance, storage, treatment and/or removal off site.

Technical description

From ex-**Section 4.1.2.3 "Techniques to increase the traceability of waste"**

~~Any~~ The waste tracking ~~or traceability~~ system ~~to be adopted~~ needs to be capable of reporting all of the following:

- total quantity of waste present on site at any one time, in appropriate units, for example, 205-litre drum equivalents;
- breakdown of waste quantities being stored pending on-site treatment, classified by treatment route;
- breakdown of waste quantities on site for storage only, i.e. awaiting onward transfer;
- breakdown of waste quantities by hazard classification;
- ~~indicate~~ where the waste is located on site relative to a site plan;

WORKING DRAFT IN PROGRESS

- ~~compare~~ the quantity on site ~~against~~ compared to the total permitted;
- ~~compare~~ the time the waste has been on site ~~against~~ compared to the permitted time limit.

~~Some techniques which can be applied to increase the traceability of a waste in a waste treatment installation are:~~

~~a. to record and reference the information on waste characteristics and the source of the waste stream, so that it is available at all times. A reference number needs to be given to the waste and needs to be obtainable at any time in the process for the operator to identify where a specific waste is in the installation, the length of time it has been there and the proposed or actual treatment route. This is an important component in the management of the installation~~

~~b. to regularly review and keep up-to-date waste stream information, i.e. updating information with any changes~~

~~c. to put in place an internal tracking system and stock control procedure for all wastes, cross-referenced to the unique reference number raised at the pre-acceptance stage (see Section)~~

~~d. to apply a tracking system to hold all the information generated during pre-acceptance, acceptance, storage, treatment and/or removal off site. Records can be made and kept up-to-date on an ongoing basis to reflect deliveries, on-site treatment and dispatches. Documentation provided by the driver, written results of acceptance analyses, and details of off-loading points or off-site transfer locations need to be added to the tracking system documentation. All records relating to pre-acceptance need to be maintained at the installation for cross-referencing and verification at the waste acceptance stage. Records typically need to be held for two to six months after the waste has been treated or removed off site~~

~~e. to give each waste stream a unique reference number and to 'follow' the waste during its acceptance, storage, treatment or removal off site. If the waste is a regular arising waste, then the document should be unique to that waste batch~~

~~f. to have documentary systems or a computer database/series of databases, which are regularly backed up. The tracking system operates as a waste inventory/stock control system and includes: date of arrival on site, waste producer details, details on all previous holders, an unique identifier, pre-acceptance and acceptance analysis results, package type and size, intended treatment/disposal route, an accurate record of the nature and quantity of wastes held on site, including all hazards, where the waste is physically located in relation to a site plan, at what point in the designated disposal route the waste is currently at, etc.~~

~~g. to maintain the account for the treatment or disposal route method to which a particular type of waste is to be subjected~~

~~h. to have a good quality packaging and labelling system for incoming containers.~~

~~Achieved environmental benefits~~

~~The system provides documentary evidence of the treatment given to a certain waste, detailing when the waste has entered the site, where it has come from, with which other compounds has it been mixed and stored and where and when it has been shipped. These techniques enable the waste treatment operator to:~~

- ~~take advantage of any synergies between wastes~~
- ~~prevent unwanted or unexpected reactions~~
- ~~ensure that emissions are either prevented or reduced~~

WORKING DRAFT IN PROGRESS

- ~~manage the throughput of wastes.~~

~~**Cross-media effects**~~
~~Not identified.~~

~~**Applicability**~~
~~Widely applied in the WT sector. In the case of small WT plants, the adaptation of some traceability systems (e.g paper to computer based) may be difficult.~~

~~The application of some of the techniques mentioned above, may not be possible when installations operate on a continuous or semi-continuous basis. Some examples are when waste liquids from different batches are put together into the storage tank, when solid wastes are put into the bunker and mixed with other waste or when the physico-chemical properties of the waste change. Traceability systems for small volumes or quantities is more difficult to apply.~~

~~**Driving force for implementation**~~
~~To help the operator manage the installation.~~

~~It is commonly demanded by the waste authorities of the waste producer, to report that the waste is treated according to all relevant legislation and technical rules. This system helps as well to track how and when the treatment has been carried out.~~

~~**Example plants**~~
~~Commonly used in WT installations. Fundamentally important for the waste transfer installations.~~

Records are made in the advanced computerised waste process control system and kept up to date on an ongoing basis to reflect deliveries, on-site treatment and despatches. The tracking system operates as a waste inventory/stock control system and includes as a minimum:

- date of arrival on site;
- producer details;
- previous holders;
- a unique reference number;
- pre-acceptance and acceptance analysis results;
- package type and size;
- intended treatment route;
- accurate
- records of the nature and quantity of waste held on site, including all identified hazards ;
- where the waste is physically located in relation to a site plan;
- where the waste is in the designated waste treatment route (for batch treatment);
- identification of the operator's staff who have taken any decisions regarding pre-acceptance, acceptance, storage, treatment or rejection of waste streams.

From ex-**Section 4.8.3 "Techniques to reduce the accumulation of residues within the installation"**

As a way of keeping an up-to-date waste inventory, the waste tracking system also aims at avoiding an accumulation of waste, which may in turn lead to the deterioration or deformation of the containers. It also helps in identifying any ageing waste on site and in ensuring that any accumulations of liquids in bunds, sumps, etc. are dealt with promptly.

The waste tracking system is based on a risk approach considering, for example, the risks posed by the waste in terms of process safety, occupational safety and environmental impact as well as the knowledge of the previous waste holder(s).

WORKING DRAFT IN PROGRESS

Achieved environmental benefits
Prevention of accidents and incidents.

Environmental performance and operational data
The tracking system helps ~~to maintain records to~~ ensure sufficient knowledge is available as to what wastes have entered a particular vessel/tank. For example, once a waste has entered bulk storage or a treatment process, the tracking of individual wastes will not be feasible. However, the tracking of residues/compounds that will be building up within a vessel between desludging events can be carried out in order to avoid any incompatibility with incoming wastes.

For bulk liquid wastes, the objective is to maintain a stock control record of the route through the process; whereas drummed waste control needs to utilise the individual labelling of each drum to record the location and duration of storage.

Typically, for such tracking systems, computer databases are required. Implementation of an effective system also requires additional administrative work. ~~Traceability~~ Tracking systems need to ~~question~~ ascertain what exactly has to be traced and when.

Cross-media effects
None.

Technical considerations relevant to applicability
No information available.

Economics
No information available.

Driving force for implementation

- Compliance with facility permit, specifically any restrictions on capacity either for the whole site or specific waste streams.
- Compliance with the requirements of the Seveso Directive.

Example plants
Common across the waste management sector.

Reference literature
[33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [98, WT TWG 2004] [100, WT TWG 2004]**[146, PCT],**

2.3.2.6 Waste segregation [~~and compatibility testing~~]

From ex-Section **4.1.5 Segregation and compatibility testing**

Description
A primary ~~aid for source reduction~~ principle for waste reduction at source is to avoid mixing wastes. The principle is that a mixture of a small amount of hazardous waste with a larger amount of non-hazardous waste creates a large amount of material that must be treated as a hazardous waste.

Technical description
~~More information can be found in Section 2.1.2~~. Some techniques and principles to consider for waste segregation are as follows:

a. Not making the waste a liquid if it is dry.
b. Having proper labelling of all lines and containers. This will greatly increase the likelihood that plant personnel will follow any change in practices intended to enhance segregation of wastes.

WORKING DRAFT IN PROGRESS

c. Only allowing the mixing of polluted wastes of different pollution strengths if the mixed waste is treated according to the treatment process for the more polluted waste.
d. Keeping the cooling water separate from the waste streams (e.g. from waste waters).
e. Considering and, when appropriate, applying segregation when storing materials (see also Section 2.3.13.2).
f. Having rules restricting the types of wastes that can be mixed together. Some purposes of such rules are to reduce the risk for the environment or workers' safety due to mixing of incompatible wastes (see Section 2.3.2.7). ~~the environmental risk, for safety reasons or to prevent dilution.~~
g. Assessing wastes' compatibility before mixing/blending (see Section 2.3.2.7).
h. In case of mixing, the traceability of hazardous wastes must be guaranteed.

Achieved environmental benefits
To avoid incidents caused by accidental or intentional mixing of incompatible wastes.

~~Keeping wastes segregated greatly facilitates any required treatment. A lot of problems could be prevented, when an appropriate separation at the source (at production site of the waste) is executed. The key is to segregate incompatible wastes by placing them in separate areas constructed of suitable materials. In some cases if stored together, incidents such as leaks could result in a mixing of incompatible wastes. Different chemical reactions could then occur, with some reactions potentially producing excessive pressure and/or heat, thus posing fire or explosion hazards. Others could produce toxic fumes or gases.~~

~~For example, unsegregated used oils typically have a lower value than fuel oil. Contaminated waste oils have the potential to cause pollution when used in combustion processes. Segregated used lubricants can have a higher recovery value as fuel.~~

~~The feeding process in the preparation of solid waste fuels from MSW is very important because it has a great influence on the waste OUT qualities. An effectual homogenisation has to be guaranteed and highly contaminated loads should be barred from solid waste fuel processing because they might downgrade the product qualities.~~

Environmental performance and operational data

From ex-**Section 4.1.4.13 "Carrying out a compatibility test prior to transfer"**

Table 2.22 presents an example of a compatibility chart and indicates that careful planning must be ~~given~~ applied to chemical storage. For example, ‘acids, minerals, non-oxidising’ substances (number 1) can generate heat and violent polymerisation reactions when mixed/blended with aldehydes (number 5).

WORKING DRAFT IN PROGRESS

Table 2.22: Example of a compatibility chart for the storage of hazardous waste

No.	Name of reactivity group																																									
1	Acids, minerals, non-oxidising	1																																								
2	Acids, minerals, oxidising		2																																							
3	Acids, organic		G H	3																																						
4	Alcohols, glycols	H	H F	H P	4																																					
5	Aldehydes	H P	H F	H P		5																																				
6	Amides	H	H GT				6																																			
7	Amines, aliphatic, aromatic	H	H GT	H		H		7																																		
8	Azo compounds, diazo comp., hydrazines	H G	H GT	H G	H				8																																	
9	Carbamates	H G	H GT						H G	9																																
10	Caustics	H	H	H		H				H G	10																															
11	Cyanides	GT GF	GT GF	GT GF					G			11																														
12	Dithiocarbamates	H GF F	H GF F	H GF GT		GF GT		U	H G				12																													
13	Esters	H	H F						H G		H			13																												
14	Ethers	H	H F												14																											
15	Fluorides, inorganic	GT	GT	GT												15																										
16	Hydrocarbons, aromatic		H F														16																									
17	Halogenated organics	H GT	H F GT					H GT	H G		H GF	H						17																								
18	Isocyanates	H G	H F GT	H G	H P			H P	H G		H P G	H G	U						18																							
19	Ketones	H	H F						H G		H	H								19																						
20	Mercaptans, other organic sulphides	GT GF	H F GT						H G									H	H	H	20																					
21	Metals, alkali, alkaline earth, elemental	GF H F	GF H F	GF H F	GF H F	GF H F	GF H	GF H	GF H	GF H	GF H	GF H	GF GT H	GF H				H E	GF H	GF H	GF H	21																				
22	Metals, other elemental and alloys as powders, vapours or sponges	GF H F	GF H F	GF					E F GT	U	GF H							H E	GF H		GF H F		22																			
23	Metals, other elemental and alloys as sheets, rods, drops, moldings, etc.	GF H F	GF H F						H F G									H F						23																		
24	Metals and metal compounds, toxic	S	S	S			S	S			S														24																	

WORKING DRAFT IN PROGRESS

No.	Name of reactivity group																																									
25	Nitrides	GF H F	H F E	H GF	GF H E	GF H			U	H G	U	GF H	GF H	GF H				GF H	U	GF H	GF H	E				25																
26	Nitrites	H GT F	H F GT						U													H P			S	GF H	26															
27	Nitro compounds, organic		H F GT			H			H E													H GF E				H GF E		27														
28	Hydrocarbons, aliphatic, unsaturated	H	H F			H																	H E						28													
29	Hydrocarbons, aliphatic, saturated		H F																											29												
30	Peroxides and hydroperoxides, organic	H G	H E		H F	H G		H GT	H F E	H F GT		H E GT	H E GT					H E	H	E	H F GT	H E	P G		H G	H GF E	H P GT		H P		30											
31	Phenols and cresols	H	H F						H G										H P			GF H				GF H					H	31										
32	Organophosphates, phosphoyhioates, phosphodithioates	H GT	H GT						U		H E											H									U		32									
33	Sulphides, inorganic	GT GF	HF GT	GT		H			E										H												H GT			33								
34	Epoxides	H P	H P	H P	H P	U		H P	H P		H P	H P	U								H P	H P	H P		H P	H P					H P	H P	U	H P	34							
101	Combustible and flammable materials, misc.	H G	H F GT																			H G F				H GF F					H F GT					101						
102	Explosives	H E	H E	H E					H E		H E			H E								H E	H E	H E	E	E					H E	H E		H E	H E	H E	102					
103	Polymerisable compounds	P H	P H	P H					P H		P H	P H	U									P H	P H	P H	P H	P H					P H	P H		P H			H E	103				
104	Oxidising agents, strong	H GT		H GT	H F	H F	H F GT	H F GT	H E	H G GT		H F GT	H F GT	H F	H F		H F	H GT	H F GT	H F	H F GT	H F E	H F E	H F		H F E	H F GT	H E	H F	H F	H G	H F	H F GT	H F GT	H F G	H F G	H E	H F GT	104			
105	Reducing agents, strong	H GF	H F GT	H GF	H GF F	GF H F	GF H	H GF	H G				H GT	H F				H E	GF H	GF H	GF H						H GF	H E			H E	GF H	GT GF H		H	GF H	H E	H P GF	H F E	105		
106	Water and mixtures containing water	H	H						G										H G			GF H	GF H		S	GF H								GT GF						GF GT	106	
107	Water-reactive substances									Extremely reactive! Do not mix with any chemical or waste material!																																107
	No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	101	102	103	104	105	106	107

NB: Key: Reactivity code (capital letter): consequences of mixing/blending

H: Heat generation
F: Fire
G: Innocuous and non-flammable gas generation
GT: Toxic gas generation
GF: Flammable gas generation
E: Explosion
P: Violent polymerisation
S: Solubilisation of toxic substances
U: May be hazardous but unknown

Source:[31, LaGrega et al. 1994]

WORKING DRAFT IN PROGRESS

From ex-Section **4.1.5 Segregation and compatibility testing**

Cross-media effects
None for segregation of waste.

~~In some cases, mixing waste may present a higher risk (due to the potential chemical incompatibility of some components) and may discard the opportunities for recycling~~.

Technical considerations related to applicability
~~Some techniques mentioned in the description section are applied to waste IN, others to the waste OUT and others are used during the management of the installation (e.g handing and storage of waste). The major impediments to waste segregation programmes are those materials that go to plant trash that do not belong there. Examples to note include laboratory samples, which must be disposed of as hazardous wastes. Other materials include solvents and pigments, for which special receptacles must be provided.~~

~~Some plants have separated bunkers for different kinds of waste, e.g. household wastes, commercial wastes similar to household wastes and production specific commercial wastes.~~

Technique (a) (see description above) is sometimes considered not applicable for safety reasons.

~~Application of the basic principles of mixing and blending as described in Section 2.1.2 (risk prevention, substandard processing and prevention of diffuse dispersal) is different for each treatment route. Wastes may be treated in routes and may end up as a fuel, as a building material, as a fertiliser, as an animal feed, as a feedstock for new products, etc. Given the strongly varying character of the numerous processes, this elaboration will lead to very different results for each route. The choice of the treatment that is made will evidently affect the possibilities for the mixing of wastes. For each waste treatment route, the type and concentrations of environmentally hazardous substances differ and the operational criteria for assessment of the mixing activity will, therefore, also differ.~~

~~Before mixing wastes, there is a general assumption that some types of wastes are not suitable for recycling or re-use at all. This may concern wastes from several cleaning processes, for example FGT residues, fly ash, hardening salts, filter cakes containing bearing metals from detoxification-neutralisation-dewatering, blast furnace gas dust, etc. Mixing of these wastes and residues from cleaning processes, which contain high cumulative concentrations of environmentally hazardous substances, is not permitted in any processing route for recovery. These are wastes that must be disposed of and whose environmental risks must be rendered harmless prior to disposal through immobilisation or particle separation techniques. The issues about waste treatment selection are covered in Section~~

Economics
Some solid waste streams can be segregated effectively through minor changes in equipment. Typically, the disposal of mixed waste will be more expensive than the treatment of a stream composed of a single type of waste.

Driving force for implementation
~~Hazardous waste Directive (91/689/EEC) and waste Directive (75/442/EEC) provide the EC legislation framework for the mixing and blending of waste. Some countries define national rules (e.g. in some countries it is absolutely forbidden to mix slag/bottom ash from different sources).~~

Directive 1999/31/EC on the Landfill of Waste and Directive 2008/98/EC on Waste provide the EU legislation framework for the mixing and blending of waste.

WORKING DRAFT IN PROGRESS

~~Mixing and blending rules on an operational level are within the boundaries of the permit and other (legal and voluntary) obligations and are written and applied under the responsibility of the waste treatment operator. They take into account risk and safety approaches in order to:~~

- ~~avoid accidents, which may cause risks to human health and adverse effects on the environment~~
- ~~prevent technical and mechanical incidents which can cause damage to installations.~~

~~So, blending and mixing rules on an operational level are generally linked with:~~

- ~~regulations in the permit (non-authorised wastes, obligations to keep wastes separated)~~
- ~~regulations dedicated to safety~~
- ~~internal and operational procedures (for example, quality control, ISO 14000 certification)~~
- ~~pre-acceptance and acceptance procedures~~
- ~~prescription of compatibility tests (during pre-acceptance and acceptance procedures).~~

Example plants
Segregation of waste oils in order to produce a material with a higher value than fuel oil is common practice.

~~*Thermal processes*~~
~~In most cases, it is pointless to treat some wastes (some examples in the Applicability section above) by thermal processes. However, if the organic matter content in the original waste is more than 10 %, a thermal treatment may be needed. One criterion for assessing the effectiveness of incineration is, for example, to measure the 'loss due to burning' after the thermal treatment. If the 'loss due to burning' amounts to less than 5 % of the dry weight of the newly created residue, the treatment is effective. An alternative criterion for the effectiveness of incineration is a level of organic carbon below 3 % in the residue.~~

Reference literature
[31, LaGrega et al. 1994] [60, WT TWG 2003] [61, UBA Germany 2003] [77, Schmidt et al. 2002] [82, Pretz et al. 2003] [98, WT TWG 2004] [100, WT TWG 2004] [103, VROM 2004] [115, UBA Germany 2012]

2.3.2.7 [~~Carrying out a~~] Waste compatibility assessment [~~test prior to transfer~~]

Description
Set of verifications and tests to detect any unwanted and potentially dangerous chemical reactions between wastes (polymerisation, gas evolution, exothermic reaction, decomposition, crystallisation, precipitation, etc.) during mixing, blending or other treatment operations.

Technical description

From ex-**Section 4.1.4.13 "Carrying out a compatibility test prior to transfer"**

~~**Description**~~
~~A good compatibility test should cover the following elements:~~

a. ~~a sample from the receiving tank/vessel/container is mixed in a proportional ratio with a sample from incoming waste stream, which is proposed to be added to the tank/vessel/container~~

b. ~~the two samples need to cover the 'worst case' scenario of likely constituents~~

c. ~~any evolved gases and the cause of possible odour need to be identified~~

WORKING DRAFT IN PROGRESS

~~d. if any adverse reaction is observed, an alternative discharge or disposal route needs to be found~~

~~e. due considerations need to be taken of the implications of scale-up from laboratory compatibility testing to bulk transfer~~

~~f. the particular compatibility test parameters will be driven by the wastes being bulked. As a minimum, records of testing need to be kept, including any reactions giving rise to safety parameters (increase in temperature, evolution of gases or raising of pressure), operating parameters (viscosity change and separation or precipitation of solids) and other parameters such as an evolution of odours.~~

Compatibility assessment can be done at pre-acceptance, acceptance and before any step in the waste treatment process.

The compatibility assessment is adapted to each waste storage and treatment operation. For example, it can consist of specific procedures for solid wastes, for long reaction times, for waste in small packages, etc.

In order to prevent any adverse or unexpected reactions and releases before transfer involving the following activities, testing takes place prior to the transfer:

- tanker discharge to bulk storage;
- tank-to-tank transfer;
- transfer from container to bulk tank;
- bulking into drums or IBCs;
- bulking of solid waste into drums or skips.

A list of unacceptable waste is established based on the facility's permit and on whether the waste poses specific risks to the installation or process such as, inter alia:

- risk of explosion (e.g. presence of ammunition, mixing processes that could lead to explosion);
- corrosion to the installation (e.g. strong acids);
- risk of uncontrolled reactions (e.g. presence of peroxides or strong oxidants; or polymerising components such as certain isocyanates);
- risk of the evolution of gases (e.g. presence of cyanides, sulphides, dissolved gas).

The above list is very specific for the treatment operation and final treatment and requires the waste operator to establish it case by case for their specific operation.

The type of compatibility test varies according the type of waste and the waste treatment operation (for example, unloading, grouping, homogenisation). The compatibility tests are defined based on a risk approach considering, for example, the risks posed by the waste in terms of process safety, occupational safety and environmental impact as well as the knowledge of the previous waste holder(s).

The main principle is to mix a first waste sample with a sample of a second waste with which it will be mixed. The compatibility test is done in a laboratory and is performed under the same adiabatic conditions as the full-scale mixing. The test considers the following elements:

- temperature increase, exothermic reaction;
- physical aspect/behaviour of the mixing (e.g. several phases or not, emulsions);
- potential precipitation, crystallisation, polymerisation and other chemical reactions;
- gas emission.

WORKING DRAFT IN PROGRESS

The time of the test varies, for example from 15 minutes to 24 hours, according to the type of waste.

In order to better characterise the reactivity of the waste, additional tests could be needed such as oxidant and reduction tests, pH determination, release test, etc. The rejection criteria of the compatibility tests may be unique or combined and are defined according to the type of waste and waste treatment process, and can be temperature modifications (for example, an increase of 3 °C upon mixing indicates incompatible wastes), mixing aspects (if polymerisation occurs the wastes are not compatible for mixing), etc.

Any evolved gases and causes of odour are identified. If any adverse reaction is observed, an alternative discharge or disposal route is found.

Achieved environmental benefits
~~Prevents~~ Prevention of ~~any~~ adverse or unexpected reactions and releases before transfer to storage tanks.

Environmental performance and operational data
To ensure the occupational safety of the test, a risk assessment is carried out prior to the test and integrated into the test procedure. Operators executing a compatibility test are equipped with personal protective equipment, such as safety goggles, gloves, protective clothing, etc. The compatibility tests are carried out under a fume hood in operation.

From ex-Section **4.1.5 Segregation and compatibility testing**

Some examples of compatibility tests typically applied in the waste sector are as follows:

- Compatibility tests for storage (see Section 2.3.2.7).
- Simulation of the effects associated with ~~the~~ neutralisation in a laboratory experiment.
- Selection and dosage of the correct precipitation and flocculation agents must be determined in any event through experimentation.
- Experimental laboratory tests are necessary to determine which chemicals are best suited for oxidation/reduction and what the reaction is like.
- Laboratory tests carried out to identify the quantity of activated carbon necessary for cleaning the waste water. The most important results are the charge value, e.g. g TOC/g of activated carbon, and the necessary contact time.
- Since the dosing point is particularly important when using organic splitting agents, controls by the laboratory during the process are required.
- Examination of the following parameters (see Table 2.23) when evaporation/distillation systems need to be applied.

Table 2.23: Ingredients affecting evaporation

Ingredients	Remarks	Evaporator type
Undissolved solids	Already present or occurring due to precipitation	Evaporators without incrustation and with mechanical equipment for the removal of solids
Volatile substances forming incrustations or gumming	During thermal dissolution	Evaporators with short holding periods and/or small temperature differences between heating and boiling phases
Water vapour-volatile ingredients	With a high concentration in the initial solution	Evaporators with special vapour treatment
Boundary-surface active materials	Foam-forming	Evaporators with special separation design and/or addition of anti-foaming agents
Source: [77, Schmidt et al. 2002]		

The laboratory is equipped with equipment (e.g. turbo-agitators used only briefly for mixing, slow agitators for floc formation), which roughly simulates the plant conditions.

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Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable to the waste treatment sector.

Economics
No information available.

Driving force for implementation
To avoid incidents due to the mixing of incompatible wastes.

Example plants
Common technique used across the waste management sector.

Reference literature
[16, UK Environment Agency 1996] [31, LaGrega et al. 1994] [33, UK EA 2001] [60, WT TWG 2003] [78, Eucopro 2003][98, WT TWG 2004] [100, WT TWG 2004] [146, PCT]]

Ex-Section **'4.1.4.14 Segregation of storage'** deleted: already in EFS BREF Section 5.1.2

2.3.2.8 Waste sorting

Description
Sorting techniques for the preparation of the waste input before treatment (presorting). Waste presorting aims to prevent unwanted material to enter the waste treatment process.

Technical description
Sorting is a common process step in waste treatment activities, which is performed, among other reasons, for:

- ensuring that the waste input is able to be treated in the subsequent waste treatment process;
- improving the waste treatment process recovery rate;
- ensuring the adequacy of the output for its further use.

From ex-**Section 4.5.3.6 "Positive and negative sorting"**

~~**Principle of operation**~~
Two different ~~processing~~ sorting strategies exist: positive and negative sorting:

a. Positive sorting means that only the desired materials (e.g. with high calorific values and low contents of harmful substances) are sorted out of the material flow. This strategy leads to a higher amount of landfill material and often to a higher quality of the output such as solid waste fuel.
b. Negative sorting strategies only separate the materials which are not desired in the output (e.g. if it is required to reduce the content of chlorine in the waste stream because it may cause problems when the waste stream is incinerated or co-incinerated, one possibility may be to reduce the content of PVC plastic in the waste stream). With this strategy, the amount of landfill material might be less because other materials which might contain a higher content of harmful substances end up in the output ~~product~~.

~~**Achieved environmental benefits**~~

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~~Improve the quality of the waste separated or to avoid problems with the further treatment of certain waste streams.~~

~~Cross-media effects~~
~~Some contaminants cannot be sorted out, because they are retained or are hidden in the material, so scanning devices cannot recognise them.~~

~~Users~~
~~Applied in the production of solid waste fuel from municipal solid waste. Depending on the required quality, negative or positive sorting may be applied. If a high grade material flow is requested, negative sorting is advisable and the revenue for the product is higher than for positive sorting, but the amount of product produced is less.~~

~~Economics~~
~~With regard to the economic aspects of positive and negative sorting, it is not possible to make a general statement~~.

~~Driving force for implementation~~
~~Depending on the extent of processing and the desired quality of the solid waste fuel, the amount of materials sent to landfill can vary widely.~~

~~Example plants~~
~~Some waste strategies just separate the inert material and metal fraction, and also lower the organic and water contents. The rest ends up in the product, which thus automatically lowers the amount of material going to landfill.~~

Sorting may be performed manually of automatically:

Manual separation

Manual separation employs visual examination of the waste material by staff on a picking line to either selectively remove a target material from a general waste stream or to remove contamination from an output stream to increase purity. This technique generally targets recyclables (glass, plastic, etc.) and any contaminants, hazardous materials and oversize materials such as WEEE. Removed materials will be deposited into chutes or further conveyors that then transfer materials to storage bays.

Manual separation takes place within a covered cabin isolated from the rest of the mechanical treatment hall, to limit staff exposure to dust and particulates, vehicle movements and vibration. A consistent material feed rate is preferable to prevent surges in material and allows for a more efficient manual sorting rate. The following aspects are considered for optimisation of manual sort operations:

- throughput (tonnes/hour);
- depth of material on conveyors (m^3/hour);
- height and width of manual sorting conveyor belts (mm);
- position of chutes and guardrails.

Automatic separation

From ex-**Section 4.5.3.11 "Automatic picking"**

The material passes a vibrating chute which feeds a conveyor belt. A metal detector is located under the conveyor belt, which sends specific data of for each particle to the computer unit. Additionally, a colour camera located above the conveyor belt processes particle information to the computer unit. Both information lines are analysed by special software, before the computer unit transmits impulses, instructing the nozzles to blow out the single particle or to allow it to pass (positive or negative sorting). Both the accepted and the rejected products are then transported by single belts to further treatment or storage.

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With a belt width of 1200 mm and depending on the feed material, it is possible to handle a throughput of 2–8 t/h, for a grain size of 3–250 mm.

~~**Achieved environmental benefits**~~

~~Increases the classification efficiency of the different materials of the waste.~~

~~**Example plants**~~

~~Automatic picking is gaining increasing recognition in the waste treatment sector, especially if a product with certain specifications is required.~~

Table 2.24 shows the examples of sorting techniques wich are described in this section

Table 2.24: Examples of sorting techniques

Metals separation	Magnetic separation of ferrous metals
	Electromagnetic separation of non-ferrous metals
	All-metal separators
Optical sorting	
X-ray separation	
Density separation	Air classification
	Ballistic separation
	Sink-float tanks
	Vibration tables
Size separation	

Metals separation

Magnetic separation of ferrous metals

From ex-**Section 4.5.3.3 "Magnetic separation of ferrous metals"**

~~**Description**~~

~~Some techniques include:~~

~~a. installing an overband magnetic separator lengthwise over the conveyor belts right above the trajectory of the material~~

~~b. resorting the material with a magnetic drum separator or with a magnetic pulley, since small ferrous particles could still remain under a non magnetic layer~~

~~c. increasing the conveyor belt's velocity gaining a low level of the material~~

~~d. use the overfed feed design for the magnetic drum separator.~~

Magnetic separation is a common process step in a WT installation. Magnetic separators can be used to extract iron and steel as a resource, e.g. extracting tin~~plate~~ cans from lightweight packaging. This can also be used to provide the essential service of removing any ferrous metals from the waste, thereby avoiding downstream operating troubles and improving the product quality, e.g. magnetic separators are used in cable recycling processes to remove the metals, to protect the knives of rotary cutters from blunting or snapping and for the subsequent cleaning of the copper product.

Magnetic separation can also be used on feedstock where ferrous metals require to be negatively picked as a contaminant, for example organic material.

Magnetic separators are used when ferrous metal is present in the waste. Due to the fact that stainless steel is not, or is only slightly, magnetisable, usually magnetic separators cannot extract stainless steel.

~~**Driving force for implementation**~~

WORKING DRAFT IN PROGRESS

~~The application of magnetic separation depends on the type of waste processed and on the waste fuel requirements. Some examples are:~~

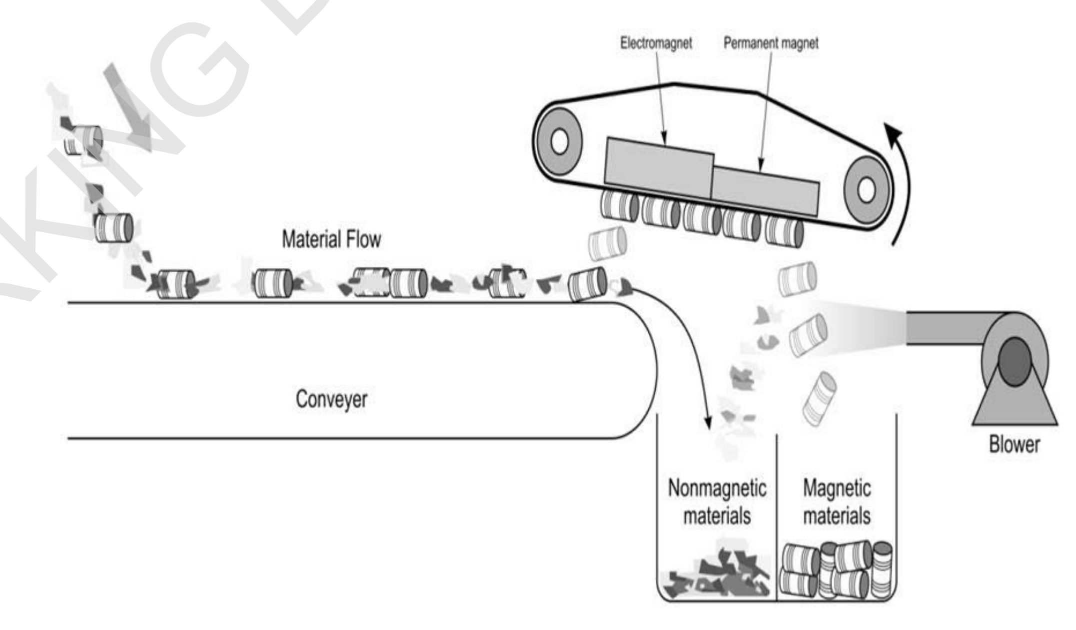
- ~~using ferrous (or non-ferrous) metal separation to reduce abrasion if a fine comminution with cutting is necessary for the product requirements~~
- ~~ferrous or non-ferrous separation or/and separation of fine fraction by screening is helpful if the ash content is limited~~
- ~~enrichment with an air classifier is necessary if the firing technology allows only particles with a low sedimentation velocity in the solid waste fuel~~

Overband magnetic separator
The mixed feedstock will be presented via conveyor with the magnet array typically positioned over the conveyor line. Ferrous metals will be attracted to the magnet and positively sorted from the feedstock. A conveyor belt positioned around the magnets can be used to transfer the ferrous metals to a dedicated container. Non-magnetic material will continue along the conveyor and fall onto a further inline conveyor or be deposited into a dedicated receptacle.

In order to utilise the entire magnet, the feed conveyor is located directly under the magnet. The rate of extraction is used as an indicator to determine the optimal speed of the conveyor for achieving the highest efficiency in terms of ferrous recovery percentage: by sorting, for example, municipal solid waste (MSW) with a certain content of plastics with a large surface area, overband magnetic separators will inevitably extract these plastics together with the ferrous items. ~~To minimise this discharge~~, Increasing the belt velocity is recommended to minimise this discharge. Generally, overband magnetic separators give very ~~high~~ good results, up to 98 w/w-% iron output. The following aspects are important for the optimisation of the magnetic separation:

- location of the separator at optimum distance dependent on the density and speed of the feedstock;
- magnet and belt width;
- magnet and belt length;
- magnetic field depth; and
- drive motor size.

An example of an overband magnetic separator is shown in Figure 2.23 below



Source: [113, UK 2013]

Figure 2.23: Overband magnetic separator schematic

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Magnetic drum

~~The mode of operation of how the~~ Material is ~~can be~~ fed into a magnetic drum separator ~~is~~ either via an overfed layout or an underfed layout. In an overfed layout, the material is charged onto the drum, right before the crest, using a vibrating chute. In this case, only magnetisable items are held on the drum shell until they reach the limit of the magnetic field, at which point the material falls off the drum and is collected behind a non-magnetisable separating plate.

In an underfed layout, the drum shell attracts ferrous metals through the air gap and drops them – similar to an overband magnetic separator – but not before leaving the magnetic field. For homogeneous feeding, the use of vibrating chutes is indispensable.

Installation in line (lengthwise) to the belt is preferred since it aids effective separation of the loosened material out of the trajectory. If the magnet is aligned transversally to the material (i.e. suspended across the conveyor belt), the power of the magnet must be several times higher than in a lengthwise alignment, since sometimes non-magnetic objects are situated on top of ferrous items, which the magnet then has to work through.

The advantage of the overfed layout in magnetic drum separators is that ferrous parts are directly placed in contact with the strongest magnetic field and, as a consequence, fine-grained and slightly magnetisable items can be well separated.

Normally in waste processing, the underfed operation is only relevant for special applications, e.g. shredder scrap processing. The approach pole of this drum causes a strong and far-reaching magnetic field to securely extract the shredded and compacted scrap. The transport of the ferrous material to the dropping line will be achieved by additional weak poles. Because of the strong abrasion during scrap sorting, the drum shell is manufactured with an 8 mm thick plate made of hard manganese steel.

The efficiency of magnetic separation of ferrous metals can be increased by:

a. installing an overband magnetic separator lengthwise over the conveyor belts right above the trajectory of the material;
b. resorting the material with a magnetic drum separator or with a magnetic pulley, since small ferrous particles could still remain under a non-magnetic layer;
c. increasing the conveyor belt's velocity, ~~gaining~~ to achieve a low level of ~~the~~ unwanted material;
d. use the overfed feed design for the magnetic drum separator.

Electromagnetic separation of non-ferrous metals

From ex-**Section 4.5.3.4 "Separation of non-ferrous metals"**

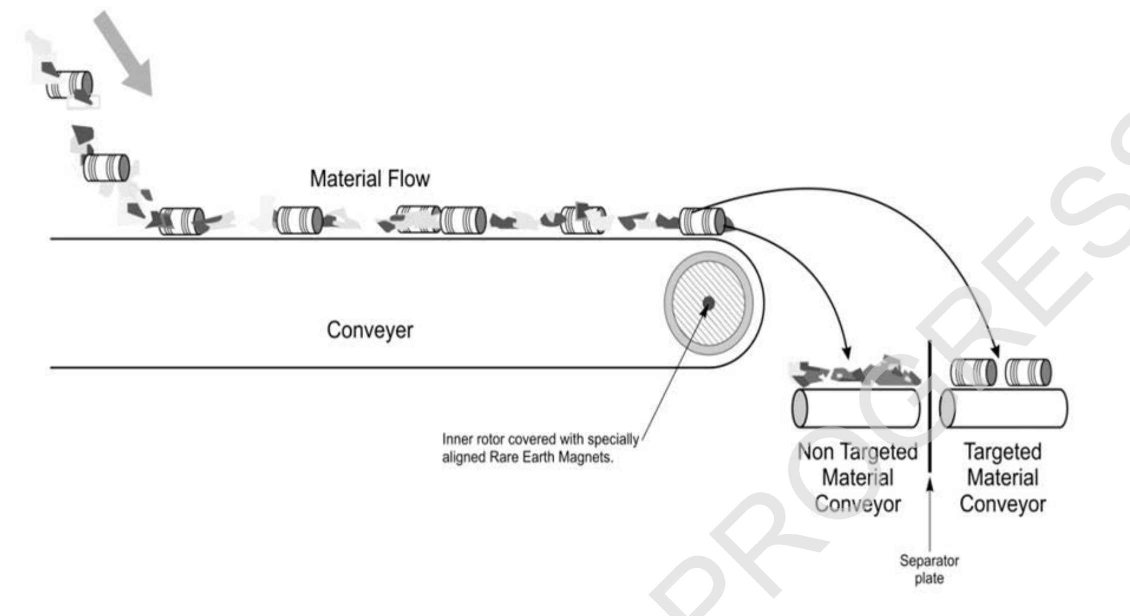
Non-ferrous metals are sorted out by means of eddy current separators. An eddy current is induced by a series of rare earth magnetic or ceramic rotors at the head of a conveyor that spins at high speed independently of the conveyor. This process induces temporary magnetic forces in non-magnetic metals of the same polarity as the rotor, causing the metals to be repelled away and then separated from the other feedstock.

The separator is fed with a mixed waste stream, containing non-ferrous metals such as aluminium die-cast metals, copper, etc. As these separators can sort out non-ferrous particles with a grain size between 3 mm and 150 mm, a pre-screening step might be advantageous to increase the separation of non-ferrous metals from the waste

The magnetic pole system is positioned either eccentrically or centrically. Central pole systems experience problems with small iron particles, which can find a way between the conveyor belt and the drum shell. These particles are attracted along the whole perimeter of the drum, become hot and can lead to damage of the plastic drum. Additionally, the position of the magnetic pole

WORKING DRAFT IN PROGRESS

system in eccentric systems is variable, so that the strongest field can be directed to the rejection zone. **Figure 2.24** below shows an example of an eddy current separator.



Source: [113, UK 2013]

Figure 2.24: Eddy current separator schematic

~~Some~~ techniques for improving the separation include:

a. conditioning the grain size of the non-ferrous elements of the waste to be between 3 mm and 150 mm before their separation by an eddy current separator;
b. using a high-frequency alternating magnetic field in order to improve the separation of fine-grained non-ferrous metals;
c. positioning the magnetic pole system eccentrically;
d. using vibrating chutes to achieve a single grain layer, in order to give good sorting results;
e. separating the fine-grained ferrous particles with a magnetic drum in an overfed layout before feeding the eddy current.

It is difficult to separate longish and planar components, such as aluminium foil and copper wires, because of the weak eddy current in these materials.

All-metal separators

From ex-**Section 4.5.3.5 "All-metal separators"**

All-metal separators are applied for the automatic separation of ferrous and non-ferrous metals, mainly ~~applied~~ for plastics processing. High throughputs can be realised if the material is diversified before auto-recognition.

~~In the preparation of solid waste fuel, all-metal separators are mainly applied for plastics processing.~~ These ~~aggregates~~ devices are ~~applied~~ used if the content of metal in the feed material is low, when other metal separation operations do not work efficiently enough because of very high demands on the product qualities, or when downstream ~~aggregates~~ equipment (e.g. rotary cutters) has to be protected.

Detection coils are able to detect metal particle sizes of approximately 1 mm and larger. The shape and the mass are not important for the separation process.

WORKING DRAFT IN PROGRESS

~~Normally~~ Usually, all-metal separators operate with a detection coil which is placed ~~transverse~~ at right angles to the direction of transport and cut into single segments. If a metal particle enters the high-frequency alternating magnetic field of the coil it influences the field. This change is ~~collected~~ detected by an electronically controlled microprocessor which is able to identify the coil segment close to the metal particle. This particle is separated by one or more air jets located close to the detection coils. The metals are separated by a partition plate.

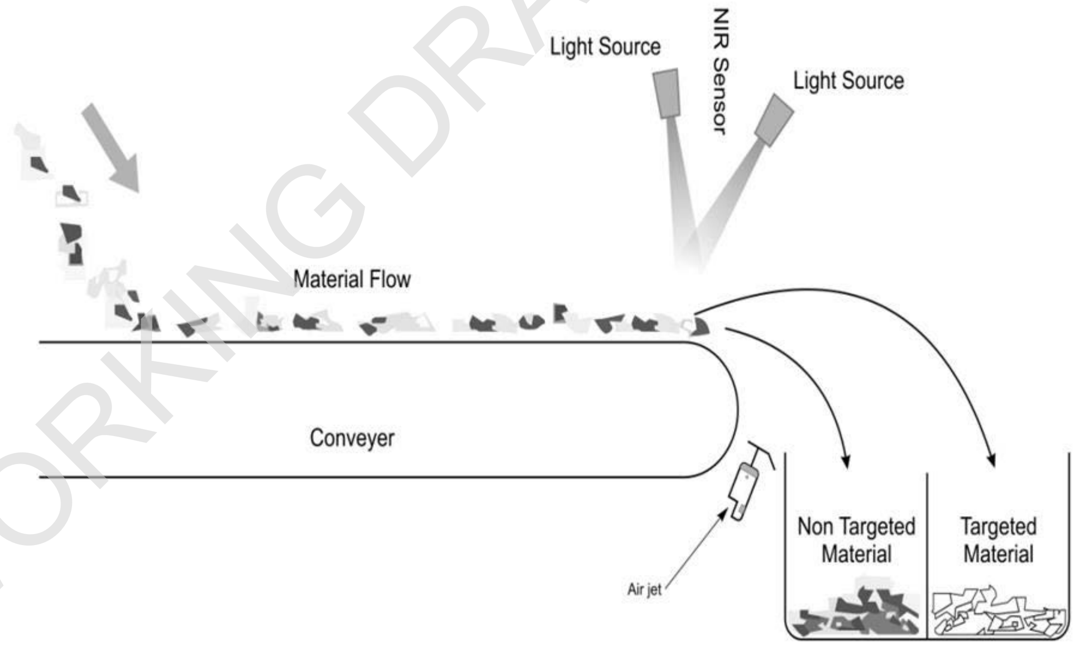
~~**Users**~~
~~Applied in plastic processing.~~

Optical sorting systems using near infrared spectroscopy

From ex-**Section 4.5.3.10 "Near infrared spectroscopy"**

Optical sorting systems are used to separate components according to colour.

Material which has to be separated is often fed on a belt conveyor. The conveyor usually operates at fast velocities so that its function is almost like an isolating device. Halogen lamps and the detector are installed above the belt conveyor. The detector consists of a near infrared spectroscopy (NIR) sensor which scans the whole width of the ~~belt~~ conveyor belt and transmits the characteristic spectra of the different materials to a data processor. The signals are compared with a database. The analysis considers the calculation of the actual position on the ~~belt~~ conveyor belt and the measurement results in only a split second. The sorting then occurs with an air jet batten in front of the discharge end. The air jet lifter is equipped with several single air jets at a distance of about 30 mm apart. Each air jet is fed by a pressure reservoir and is steered by magnetic valves. The data processor transmits a signal if the detection of a particle is positive and the air jet blows it out. Here one or more air jets can be activated. The pressure surge blows out the particle which is then separated from the material flow by a partition plate.
Figure 2.25 below gives an example of an optical separator.



Source: [113, UK 2013]

Figure 2.25: Optical separator schematic

The process leads to the separation of the waste input constituents, e.g. selective separation of beverage cartons, paper, cardboard, mixed plastics such as polyethylene (PE), polypropylene

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(PP), polystyrene (PS), polyethylene terephthalate (PET) and polyvinyl chloride (PVC). Reduction of the heavy metal content (e.g. Sb, Cd, Pb) and chlorine of the waste stream may also occur because specific waste containing these components may separate.

This technique is applied, for example, to reduce the content of some compounds in the waste fuel in order to achieve the quality required in the waste fuel produced.

Auto-recognition devices can sort particle sizes between approximately 30 mm and 300 mm. The operation width of the ~~belt~~ conveyor belts varies between 500 mm and 1400 mm. The throughput of pre-classified light packaging with particle sizes between 50 mm and 200 mm amounts to between 1 t/h and 6 t/h.

The actual recovery of potential recyclables depends on the waste qualities, although approx. 80–90 % separation is achievable. The achievable product qualities are 90–97 %.
TWG, please confirm the yields above

Nevertheless, the separation of dark brown and black materials is impossible since the NIR light is almost completely absorbed and hence no irradiation is reflected to the sensor.

The application of this technique generates a waste stream with a higher content of chlorine and metals that needs to be treated.

~~Reduction of the heavy metal and chlorine content of the solid waste fuel. Some standards are actually prepared by CEN TC 343 WG 2. Chlorine is one of the parameters used to define recovered fuel classes. The chlorine content actually discussed is around 3 %, which means that plastics containing organic chlorine, i.e. essentially PVC, are accepted in a limited proportion.~~

~~Several examples exist in Germany on the use of NIR for the production of solid waste fuel~~.

X-ray systems

Metal composites are sorted according to various material densities, halogen components or organic components with the aid of x-rays. Sorting can be according to light and heavy metals or plastics.

Density separation

Air classification

Air classification (or air separation, or aeraulic separation) is a process of approximate sizing of dry mixtures of different particle sizes into groups or grades at cutpoints ranging from 10 mesh to sub-mesh sizes. Air classifiers (also called windshifters) complement screens in applications requiring cutpoints below commercial screen sizes and supplement sieves and screens for coarser cuts where the special advantages of air classification warrant it. [147,AIR CLASSIFICATION PRINCIPLES]

The interior space of a classifying device, where solid particles interact with air stream, is the separation zone. Four basic separation zones are known, which include gravitational-counterflow, gravitational-crossflow, centrifugal-counterflow and centrifugal-crossflow zone. [148, ARTICLE AIR CLASSIFICATION], **Figure 2.26** shows the principle of air classification.

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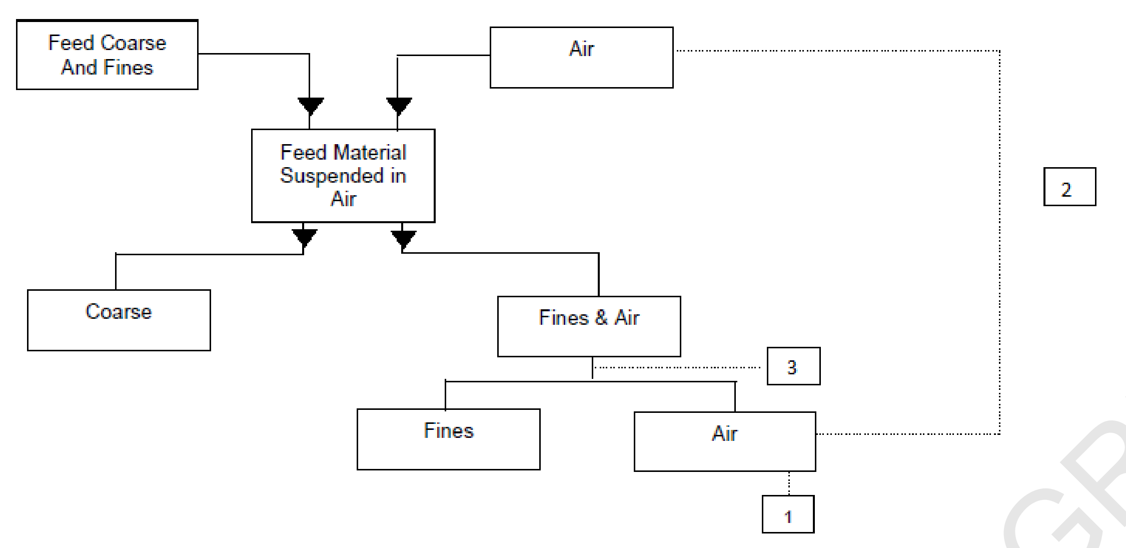

NB: The air is either released to atmosphere (1) to form an 'open air system' or recirculated (2) to form a 'closed air system'. Sometimes the fines and air mixture go to another process (3) such as another classifier or a directly fired pulverised coal burner, etc.
Source: [147,AIR CLASSIFICATION PRINCIPLES]

Figure 2.26: Principle of air classification

From ex-**Section 4.5.3.9 "Improvements of the dust filters in the cyclones of air classifiers"**

The air velocity for dry papers, thin-walled plastics and plastic films for example is approximately 11–12 m/s. The minimum recovery of this high calorific lightweight material is approximately 70 %. The throughput rate of air classifiers is limited by the specific load, with a maximum capacity of 0.35 kg solids/(m^3 air · h).

~~Description~~

~~Reuse of the~~ Air that has been used for air classifiers and blowdown is re-used: approximately 30 % of the air of the circular flow is discharged on the pressure side of the ventilator and cleaned by a dust filter.

~~Achieved environmental benefits~~

This operation offers the following advantages:

- the filter to separate the dust can be designed much smaller, since the air to be cleaned is less than a third of the volume from the conventional operation;
- no air loaded with dust is discharged at the loopholes for the feeding conveyor or the heavyweight discharge;
- the circulating air does not concentrate dust particles or moisture;
- the air velocity at the separation zone can be precisely adjusted by butterfly valves.

~~Operational data~~

~~The amount of air consumed by the air classifiers depends on the geometry of the classification duct.~~

~~Applicability~~

~~In terms of applications in recycling processes, not all available air classifiers can be applied. In most cases, they need to be specially designed to treat large particles.~~

Sink-float tanks

This method uses the different material densities to separate two solids. A tank is filled in with a media (for example water) and the materials to be separated: the solid denser than the media sinks whereas the solid less dense than the media floats.

WORKING DRAFT IN PROGRESS

From ex-**Section 4.5.3.7 "Use of pneumatic assistance for size reduction"**

~~**Description**~~
~~The use of pneumatic assistance for processing the material discharged from comminution (size reduction).~~

~~**Achieved environmental benefits**~~
~~Some benefits are:~~

- ~~the unwanted content of extremely fine-grained material in the end-product is reduced~~
- ~~the rotors, including the cutters and the housing, are cooled down~~
- ~~the energy demand is reduced~~
- ~~the transportation of material is assisted.~~

~~**Applicability**~~
~~Applied in size reduction activities.~~

~~**Reference literature**~~
~~[82, Pretz et al. 2003]~~

Ballistic separation
The ballistic separator, or ballistic sieve, is composed of a series of parallel paddles, with orbital motion, arranged with a variable angle with respect to the horizontal.
The multiple paddles submit the incoming waste to a strong shaking. The materials fed into the ballistic separator, having different physical characteristics (weight, shape, surface…), assume different trajectories following the orbital movement of the paddles. Lightweight and flat materials are thus conveyed towards the top of the ballistic separator, while the heavy and rolling materials are conveyed towards the bottom. Along the way, thanks to the continuous shaking of the material, the powders and the fine fraction are screened through the perforated surface of the paddles.
This separation technique generates therefore three fractions: the fraction screened, the light fraction and the heavy fraction. [182]

Vibration tables
Vibration tables are also known as gravity separators or density separators. The principle of separation is the motion of particles moving according to density and size in a slurry (in the case of wet tables, or wet density separator) across an inclined table, which oscillates backwards and forwards essentially at right angles to the slope, in conjunction with riffles which hold back the particles which are closest to the deck. This motion and configuration causes the fine high-density particles to migrate closest to the deck and be carried along by the riffles to discharge uppermost from the table, while the low-density coarser particles move or remain closer to the surface of the slurry and ride over the riffles, discharging over the lowest edge of the table.

In the case of air tables, the feed and separation are dry (dry density separation), with the moving bed of particles being fluidised by low-pressure air being blown through a canvas deck, which together with the deck slope, absence of riffles and the oscillating motion of the table, causes fine low-density particles to move to the top of the bed and coarser high-density particles to move closest to the deck, the latter discharging off the lowest part of the table. [152, ARTICLE FALCONER]

Size separation

From ex-**Section 2.5.1.1 "Preparation of solid waste fuel by mechanical (and biological) treatment from non-hazardous wastes"**

Screening or sieving ~~classification~~ can be carried out by drum screens, linear and circular oscillating screens, flip-flop screens, flat screens, tumbler screens and moving grates. A very important processing step within classification is the screening step before and after grinding.

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Screens are applied to allow mass and volume division by particle size. It is noticeable that in small particle size mixtures the content of hazardous substances accumulates compared to the amount found in the screen overflow. A classification with sieves is applied in waste treatment processing when:

- materials from an upstream process need to undergo some kind of conversion to make them suitable for further processing steps, i.e. separation into defined size fractions;
- the separation of coarse or fine particle sizes is required;
- a comminution material has a high content of particles of the final particle size and only oversized particles are reduced in size again;
- certain materials need to be concentrated; in this case, the processing is called sorting classification (this also includes separation of the small size fractions, which often contain a high content of heavy metals substances).

From ex-**Section 4.3.1.17 "Sieving"**

~~Description~~

~~See Section 5.6.~~ Some techniques to optimise ~~for~~ sieving operations include the following:

a. Avoiding overload of the sieving equipment (either optically by monitoring the equipment controls or automatically by blocking ~~out~~ the filler pump by means of the ~~level indicator~~ storage container’s level indicator).

b. Correctly cleaning the filter apertures as required (optical, empirical). Some good cleaning measures include applying rapid cleaning and steam or high-pressure water jetting.

c. Ensuring that there is an unimpaired discharge of filter underflow and overflow at all times (through use of optical, filler pump shut-off mechanisms or other controls).

~~Achieved environmental benefits~~

~~The sieving of waste is performed as an initial treatment procedure. The separation out of particles which may harm equipment, processes or products is beneficial for all successive waste treatment measures.~~

~~Operational data~~

The advantages of sieves are ~~in~~ their simple, robust construction, their low maintenance needs and the fact that they are user-friendly, and offer good reliability. The disadvantages are generally caused by the wastes themselves, e.g. clogging of the filter apertures can occur as a result of the degree of viscosity of liquid waste, which then impedes separation.

~~Reference literature~~

From **ex-Section 4.5.3.8 "Drum screens"**

~~Depending on the velocity of the drum, different operating modes may be utilised: cascade or cataract.~~ **Figure 2.27** shows ~~these~~ two operating modes of the drum screeners.

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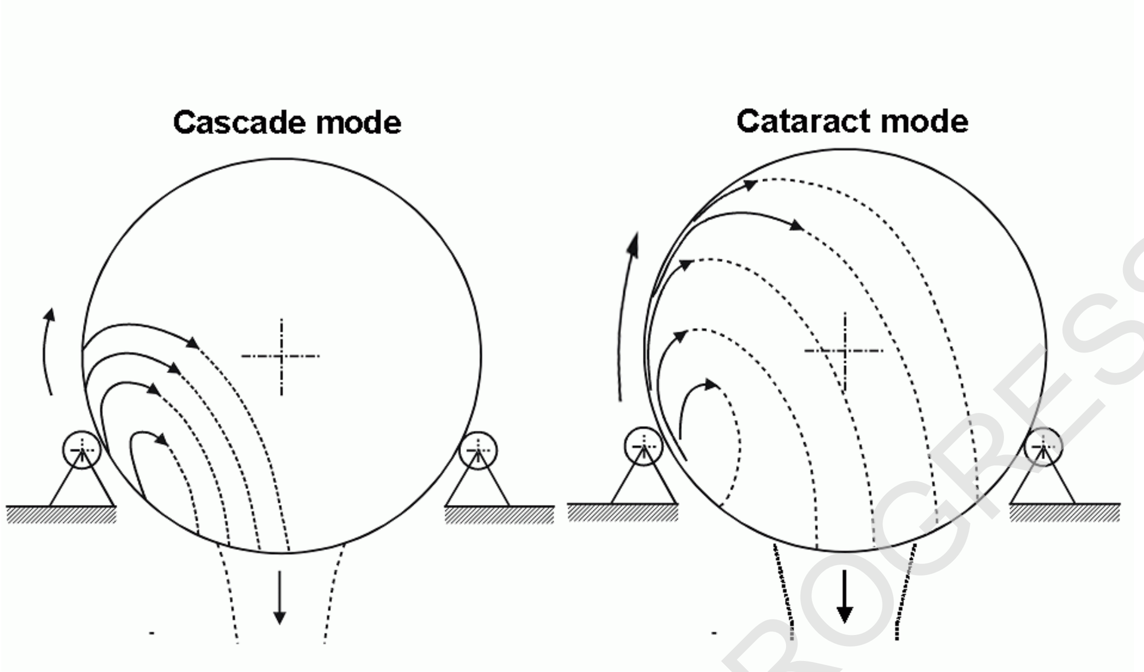

Source: [82, Pretz et al. 2003][98, WT TWG 2004]

Figure 2.27: Drum screeners

The drum screen shows the best results at a rotational speed of 70 % of the critical speed in the cataract mode. The disadvantage of the cascade mode is that the screen will create lumps and fines will not be well liberated.

To increase the efficiency, lifters are fixed inside the screen to pick up the material and to carry it higher, so that the material falls down onto a free area. Feeding material with a high content of coarse particles (approximately 100–250 mm) often causes problems with blocking of the screen, which then leads to a decrease in efficiency and a high content of fine particles in the overflow.

~~**Achieved environmental benefits**~~
~~Increase the separation ratio.~~

Advantages of drum screeners are:

- the operation does not need vibrations to be set up;
- greater homogenisation is possible; and
- the cleaning of surfaces of ~~adhering~~ adhesive small particles, which often contain a high content of heavy metal substances, is possible.

To protect the screen against blocking, bushings which can be welded on have proven to be effective.

Trommel screens are used (e.g. as an initial screening stage in MBT) to separate coarsely separated feedstock material into two or more fractions based on size. This will typically separate a fraction with a particle size of 50–100 mm (undersize fraction) in diameter from larger materials >100 mm (oversize fraction).

The input material is fed into a cylindrical rotating drum, where the material is lifted by the action of the drum and falls onto free areas of the drum (see **Figure 2.28**) The drum will be fitted with specific sized apertures that will enable targeted particle size material to fall through onto an in-line conveyor. Oversize material unable to pass through the apertures such as plastic bottles will move forward through the trommel and be ejected from the back of the screen onto

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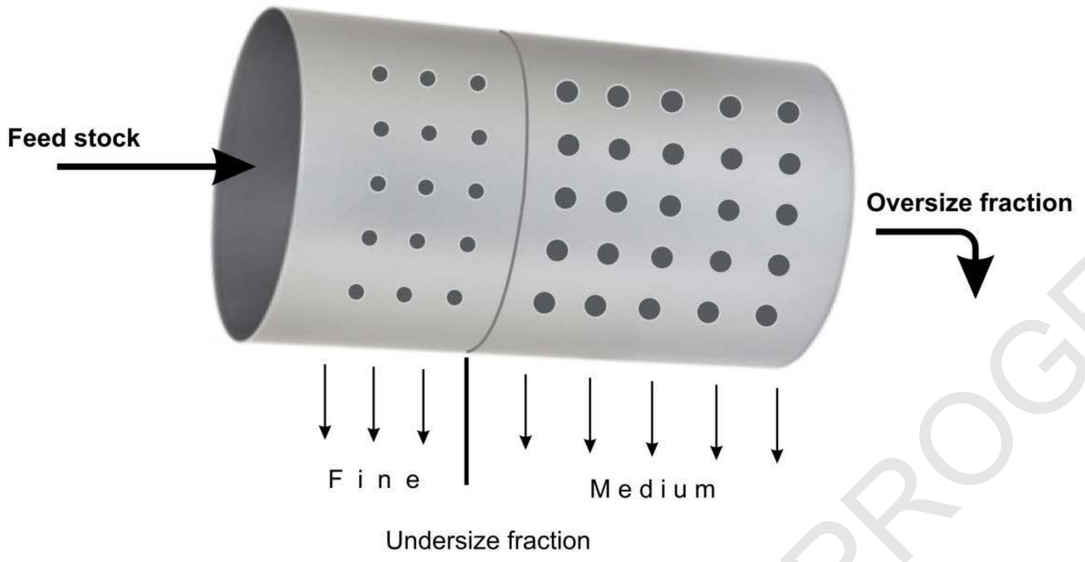
a separate in-line conveyor. The trommel may be inclined to aid movement of material through the screen and prevent backflow of material out of the entrance.



Source: [113, UK 2013]

Figure 2.28: **Trommel screen**

The trommel may also be fitted with a variable speed drive which provides the benefit that the operator can adjust the speed depending on the density and type of feedstock passing through the screen. Trommels can also be designed with multiple sized apertures occurring in stages, which enable the targeting of more than one fraction to be separated along the length of the trommel starting with the smallest size at the beginning of the screening stage.

Some aspects for optimisation of trommel design and positioning for screening operations are:

- capacity (tonnes/hour);
- diameter of drum;
- length of trammel;
- speed of rotation;
- angle of drum (from horizontal plane);
- position of flights within drum (to assist material carriage).

Achieved environmental benefits

- Reduction of the risk of incidents/accidents and prevention of the correlated uncontrolled emissions.
- Improvement of the waste treatment efficiency.

Environmental performance and operational data

Some operational data are given under 'technical description'.

Cross-media effects

None.

Technical considerations relevant to applicability

Not all sorting techniques are adapted to all types of incoming waste. Manual sorting may be restricted by occupational safety considerations.

WORKING DRAFT IN PROGRESS

Economics

No information available.

Driving force for implementation

Increase in recovery rate.

Example plants

Sorting technologies used in waste treatment plants from the reference list are given in Table 2.25 below.

Table 2.25: Examples of sorting techniques used in waste treatment plants from the reference list

Type of sorting	Plant number	Main type of waste treatment performed by the plant
Manual sorting	261, 623, 635	Aerobic treatment of excavated soil
	251, 459, 592	Aerobic treatment of source-separated bio-waste
	482_483	Physico-chemical treatment of solid and/or pasty waste
	244, 257, 434, 452, 453, 454, 573	MBT
	25, 26, 27, 29, 30, 54, 95C, 100, 137, 282C, 285C, 286C, 288C, 289C, 290C, 291C, 293C, 294C, 309, 316, 364_365, 432, 455, 456, 464, 478, 516, 571	Mechanical treatment in shredders of metal waste
	629, 630, 636	Mechanical treatment of temperature exchange equipment
	116, 133, 312, 326C, 361_363, 632	Mechanical treatment of waste with calorific value
	354_360	Treatment of excavated contaminated soil
	449	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
	299	Repackaging of hazardous waste
	200	Temporary storage of hazardous waste
Ferromagnetic separation	481	Aerobic treatment of excavated soil
	21, 62, 125, 260, 261, 262, 406_407, 410_411, 412, 413, 414, 460, 531	Aerobic treatment of source-separated bio-waste
	20, 132, 251, 255, 259, 268, 382, 459	Anaerobic treatment of bio-waste
	450	Blending/mixing
	336, 340, 425_426	Physico-chemical treatment of solid and/or pasty waste
	17, 19, 37, 89, 127, 239, 243, 244, 257, 266, 279, 337, 434, 452, 453, 454, 519, 566, 573, 594, 628	MBT
	25, 26, 27, 28, 29, 30, 54, 95C, 100, 136, 137, 282C, 285C, 286C, 288C, 289C, 290C, 291C, 293C, 294C, 364_365, 432, 441, 455, 456, 464, 478, 588, 590	Mechanical treatment in shredders of metal waste
	470, 629, 630, 636	Mechanical treatment of temperature exchange equipment
	24, 31, 32, 34, 35, 115, 122C, 133, 219, 269, 270, 273, 277, 278, 280C, 312, 325C, 326C, 361_363, 442C, 443C, 472, 493, 574, 615, 627, 632, 633	Mechanical treatment of waste with calorific value
	354_360, 489	Treatment of excavated contaminated soil

WORKING DRAFT IN PROGRESS

	401_404	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
	506	Recovery of components from catalysts
	311	Repackaging of hazardous waste
	589	Treatment of waste containing mercury
Eddy current separation	19, 37, 127, 243, 244, 257, 266, 279, 337, 434, 452, 453, 454, 519, 566, 573, 594, 628	MBT
	25, 26, 28, 29, 30, 54, 95C, 100, 136, 282C, 288C, 289C, 290C, 291C, 293C, 294C, 364_365, 432, 441, 455, 456, 464, 478, 516, 571, 588, 590	Mechanical treatment in shredders of metal waste
	470, 629, 630	Mechanical treatment of temperature exchange equipment
	24, 31, 35, 115, 122C, 269, 270, 273, 277, 278, 280C, 312, 361_363, 493, 627	Mechanical treatment of waste with calorific value
	354_360	Treatment of excavated contaminated soil
	311	Repackaging of hazardous waste
Induction all-metal separation	459	Anaerobic treatment of bio-waste
	340	Physico-chemical treatment of solid and/or pasty waste
	17	MBT
	29, 95C, 137, 455, 456, 464, 571	Mechanical treatment in shredders of metal waste
Electrostatic separation	464	Mechanical treatment in shredders of metal waste
Near infrared separation	261	Aerobic treatment of source-separated bio-waste
	266, 267, 279, 337, 452, 594	MBT
	464, 571	Mechanical treatment in shredders of metal waste
	32, 122C, 270, 278, 280C, 615, 632, 633	Mechanical treatment of waste with calorific value
X-ray sorting	441	Mechanical treatment in shredders of metal waste
	24, 280C	Mechanical treatment of waste with calorific value
Optical separation other than NIS	453, 519, 573	MBT
	441, 464	Mechanical treatment in shredders of metal waste
	280C	Mechanical treatment of waste with calorific value
Wind shifter / air/aeraulic separation	62, 110, 125, 406_407, 410_411, 412, 413, 418, 419, 460, 518, 520, 521, 531, 608, 623	Aerobic treatment of source-separated bio-waste
	255, 256, 268, 459	Anaerobic treatment of bio-waste
	17, 37, 239, 243, 244, 257, 279, 337, 519, 628	MBT
	25, 27, 29, 30, 54, 136, 285C, 286C, 288C, 289C, 290C, 291C, 293C, 294C, 364_365, 441, 455, 470, 478	Mechanical treatment in shredders of metal waste
	470, 630, 636	Mechanical treatment of temperature exchange equipment
	24, 32, 34, 35, 133, 270, 273, 277, 280C, 312, 326C, 361_363, 443C, 493, 615, 627, 632, 633	Mechanical treatment of waste with calorific value

WORKING DRAFT IN PROGRESS

	354_360	Treatment of excavated contaminated soil
	401_404	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
	311	Repackaging of hazardous waste
Sink-float separation	20, 459, 526, 529	Anaerobic treatment of bio-waste
	37, 244, 628	MBT
	630	Mechanical treatment of temperature exchange equipment
Ballistic separation	62, 125, 406_407, 410_411, 412, 413	Aerobic treatment of source-separated bio-waste
	127, 130, 244, 452, 453, 628	MBT
	442C, 574, 632	Mechanical treatment of waste with calorific value
	401_404	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
	589	Treatment of waste containing mercury
Density separation (wet)	382, 459, 534	Anaerobic treatment of bio-waste
	336	Physico-chemical treatment of solid and/or pasty waste
	415	MBT
	630	Mechanical treatment of temperature exchange equipment
	24	Mechanical treatment of waste with calorific value
	354_360	Treatment of excavated contaminated soil
	421_422, 423_424, 449	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
Density separation (dry)	460	Aerobic treatment of source-separated bio-waste
	243, 244, 519	MBT
	29, 441, 464	Mechanical treatment in shredders of metal waste
	630	Mechanical treatment of temperature exchange equipment
	280C	Mechanical treatment of waste with calorific value
Screening / Sieving	105, 625	Aerobic treatment of excavated soil
	21, 62, 69, 73, 74, 104, 110, 114, 124, 125, 126, 260, 261, 262, 331, 406_407, 410_411, 412, 413, 414, 416, 417, 418, 419, 460, 518, 520, 521, 525, 530, 531, 537, 542, 543, 546, 547, 548, 572, 621, 622, 623, 631	Aerobic treatment of source-separated bio-waste
	20, 111, 132, 255, 256, 259, 268, 377, 382, 459, 592	Anaerobic treatment of bio-waste
	450	Blending/mixing
	15, 336, 340	Physico-chemical treatment of solid and/or pasty waste
	17, 37, 89, 127, 130, 239, 243, 244, 257, 266, 267, 337, 349, 350, 415, 434, 452, 453, 454, 519, 566, 573, 628	MBT
	25, 26, 28, 29, 30, 54, 95C, 100, 282C, 285C, 286C, 293C, 294C, 364_365, 432, 455, 456, 464, 478, 516	Mechanical treatment in shredders of metal waste

WORKING DRAFT IN PROGRESS

	629	Mechanical treatment of temperature exchange equipment
	24, 31, 34, 35, 116, 122C, 133, 219, 269, 270, 273, 280C, 325C, 326C, 361_363, 443C, 493, 574, 615, 627, 632, 633	Mechanical treatment of waste with calorific value
	14, 353_359, 354_360	Treatment of excavated contaminated soil
	401_404, 421_422, 423_424	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
	469	Physico-chemical treatment of waste with calorific value
	366	Temporary storage of hazardous waste
	589	Treatment of waste containing mercury
Other	21, 129, 372, 518, 520, 521	Aerobic treatment of source-separated bio-waste
	265	Anaerobic treatment of bio-waste
	336	Physico-chemical treatment of solid and/or pasty waste
	453, 519, 566, 573	MBT
	30, 282C, 309, 316, 441, 464, 590	Mechanical treatment in shredders of metal waste
	138	Mechanical treatment of temperature exchange equipment
	117, 280C	Mechanical treatment of waste with calorific value
	153C	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
	311	Repackaging of hazardous waste

Reference literature

[82, Pretz et al. 2003][98, WT TWG 2004] [101, WT TWG 2005] [113, UK 2013] [77, Schmidt et al. 2002] 147, 148, 152, 182

Ex-**Section 4.1.2.4 "Waste treatment efficiency surveillance"** deleted. It concerns the efficiency of the process, not environmental performance.

Ex-**Section 4.1.4.11 "Computer controlled high rack storage area for hazardous wastes"** deleted. Already covered by section "waste tracking system and waste inventory"

From ex-**Section 4.8.3 "Techniques to reduce the accumulation of residues within the installation"**

~~**Description**~~

~~Some techniques include:~~

a. ~~making a clear distinction between sales and technical staff and their roles and responsibilities. If non-technical sales staff are involved in waste disposal enquiries then a final technical assessment prior to approval needs to be made. It is this final technical checking that needs to be used to avoid a build up of the accumulation of wastes and to ensure that sufficient capacity exists on site. It is not the commercial streams which regulate the waste arrival on the site, but rather should be a specific stream of co-ordination, involving technical staff as well~~

WORKING DRAFT IN PROGRESS

~~b. keeping a monitoring inventory of the waste on-site by using records of the amount of wastes received on-site and records of the wastes processed~~

~~**Achieved environmental benefits**~~

~~In some reported plants, failure to ensure an adequate throughput of wastes has led to a large number of waste, drums and containers being stored. The wastes involved are typically unchecked and drums are often simply just left to deteriorate. Such situations are often associated with large scale site clearances and may be accompanied by competitive pressures and customer's insistence to accept additional waste streams. Typically the wastes involved are difficult to handle and/or treat and may have been transferred between various operators, with a consequent loss of information about the original producer and composition.~~

~~Longstanding accumulations may also compromise standards relating to record keeping, which in turn may result in the loss of identity of the waste, further exacerbating the storage situation.~~

~~**Driving force for implementation**~~

~~Typically in operating permits, the amount of different kinds of waste to be allowed for storage is well defined. Generally, operators have limited capacities in their permit and a delay may be given to state the time between the waste reception and its treatment.~~

~~**Reference literature**~~

~~[33, UK EA 2001] [60, WT TWG 2003]~~

2.3.3 Monitoring

2.3.3.1 Overview

Real data are required on the precise effects of the activities of the industrial site on the environment. It is thus necessary to conduct a planned, regular sampling and monitoring programme. The parameters monitored include:

- point sources, diffuse and fugitive emissions to the atmosphere, water or sewer;
- wastes, particularly hazardous wastes;
- contamination of land, water and air;
- use of water, fuels, energy, oxygen, nitrogen and other gases (e.g. argon);
- discharge of thermal energy, noise, odour and dust;
- effects on specific parts of the environment and ecosystems;
- on-site accidents and near misses;
- staff injuries;
- transport accidents;
- complaints from community residents.

Monitoring, however, is not restricted to analytical measuring. It also includes regular maintenance, visual and safety checks.

Parallel to this document, a Reference Report on Monitoring of Emissions to Air and Water from IED-installations (ROM) [139, COM 2015] exists to which the reader is referred for further information. [138, COM 2014]

Ex-**Section 3.7 "Monitoring"** deleted and replaced by Sections 2.3.3.2 to 2.3.3.4

~~**[33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [78, Eucopro 2003] [98, WT TWG 2004]**~~

WORKING DRAFT IN PROGRESS

~~This section gives an outline of the monitoring and reporting practices found in the waste treatment sector. This section aims to cover practices already in use in Europe in order to provide better guidance to the permitting authorities on the selection of the appropriate monitoring methodologies, the frequency of monitoring, compliance assessment criteria and appropriate environmental monitoring. However, this section does not select any specific type of measurement methology, frequency or evaluation procedures or discuss specific compliance assessment criteria. Some guidance information on these issues may be found in the Monitoring reference document (see back of the front page).~~

~~The compounds or parameters monitored and the frequency of monitoring are very variable in the waste treatment sector. They depend on the type of waste processed, as well as on the type of processes/activities carried out. Monitoring should be adapted to the type of emissions (e.g. batch release or continuous release) and on the type of treatment (e.g. whether there is likely to be~~ ~~NO_x~~ ~~emissions). and indicate some monitoring practices applied in some EU countries.~~

~~**Table 2.26**: Monitoring practices applied to waste treatment plants in the EU~~

~~**Compound or parameter to monitor**~~	~~**Purpose and/or typical monitoring frequency**~~
~~*Process variables*~~	
~~Efficiency of the treatment process as a whole. The precipitation of metals from solution for removal in the filter cake. The degree of transfer between the incoming waste and the emissions (to air, solid waste to land and liquid effluent to sewer of, for example, pesticides or solvents)~~	~~Continuous~~
~~Reaction monitoring (acid/alkali neutralisation) to ensure that the reaction is under control and proceeding towards the anticipated result~~	~~Continuous and automatic monitoring of pH and temperature~~
~~Cyanide treatment. pH to be maintained at >10~~	~~Continuous pH; continuous free chlorine and continuous CN content~~
~~Treatment of phenolic solutions. Reaction monitoring~~	~~Process temperature, pH and redox potential continually monitored~~
~~Waste oil reprocessing. Temperature in heating vessels and condenser outlets at <90 °C~~	~~Continuous and recorded~~
~~Stabilisation~~	~~To ensure product (from each batch) meets declared specification~~
~~Fresh water use across the installation and at individual points of use~~	~~Normally continuous and recorded~~
~~Energy consumption across the installation and at individual points of use~~	~~Normally continuous and recorded~~
~~*Air emissions*~~	
~~Point source emissions, e.g. scrubbers from reactors, mixing vessels, storage vessels, drum crushers, vents from extraction systems, biofilters, e.g. total carbon and speciated VOCs~~	~~Daily to weekly – under a representative range of operating conditions~~
~~Waste oil reprocessing – heating vessels, warm oil receiving tanks and filtration plant~~	~~Weekly – under a representative range of operating conditions~~
~~Oil process tanks and condenser outlets~~	~~Continuous temperature~~
~~Combustion emissions~~	~~Quarterly, or less frequent stack testing for CO,~~ ~~NO^x, and possibly SO^x,~~ ~~particulates depending upon process~~

WORKING DRAFT IN PROGRESS

~~Fugitive emissions: boundary fence monitoring to detect releases from, for example, drum storage areas, total carbon and speciated VOCs~~	~~Weekly under a representative range of operating conditions~~
~~Odour~~	~~Daily as well as dynamic dilution olfactometry at appropriate intervals~~
~~Compound or parameter to monitor~~	**~~Purpose and/or typical monitoring frequency~~**
~~Noise~~	~~Usually only if required by regulator or if there is a potential for community nuisance. Normally takes the form of a one-off survey by external consultants~~
~~Dichloromethane~~	~~Most sites that are expected to receive cleaning solvents are required to monitor this compound~~
~~Water emissions~~	
~~AOX~~	
~~BTEX~~	
~~COD/BOD~~	~~Flow weighted sample or composite samples, weekly analysis, reported as flow weighted monthly averages~~
~~Dissolved oxygen~~	~~Continuous~~
~~Flowrate~~	~~Continuous and integrated daily flowrate. Flow-proportional samplers are commonly used to take composite samples. These may be supplemented as well by spot samples on bulk tanks ready for discharge~~
~~Metals~~	~~Daily, twice a week, weekly or monthly depending upon process. In some countries, this depends on the effluent rate (e.g. <10 m^3/day, <100 m^3/day, >100 m^3/dday)~~
~~Nitrogen~~	~~Daily, twice a week, weekly or monthly depending upon process. In some countries this depends on the effluent rate (e.g. <10 m^3/d, <100 m^3/d, >100 m^3/d)~~
~~Odour~~	
~~PAHs~~	
~~pH~~	~~Continuous~~
~~Phenols~~	
~~Phosphorus~~	~~Daily, 2 times per week, weekly or monthly depending upon process. In some countries this depends on the effluent rate (e.g. <10 m^3/d, <100 m^3/d, >100 m^3/d)~~
~~Suspended solids~~	~~Continuous~~
~~Temperature~~	~~Continuous~~
~~TOC~~	~~Continuous. This parameter is typically easier to control than COD or BOD when there is chlorine in the water release~~
~~Turbidity~~	~~Continuous~~
~~Waste emissions~~	
~~Amount~~	~~These data are reported at least annually to the authorities~~
~~*Source*: [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [78, Eucopro 2003] [98, WT TWG 2004]~~	

WORKING DRAFT IN PROGRESS

~~Table 2.27: Monitoring practices for some waste treatment processes used in the EU~~

~~**Waste treatment sector**~~	~~**Monitoring practices**~~
~~Chemical plants~~	~~Sites that have extensive abatement systems are unlikely to undertake regular monitoring of the exhaust gases. A typical monitoring programme is a quarterly stack analysis, however this is highly unlikely to coincide with any peaks in the discharge rate of particular species~~
~~Transfer stations, bulking processes and storage~~	~~Simple formulae are available to assess the discharge of VOCs through the filling of storage tanks, decanting liquids into bulk containers, venting of liquids from containers, and washing of tanks, drums or tankers. Essential data will depend on the activity concerned, but will generally consist of information such as numbers of tankers/drums/containers, their size and the composition of the waste stream.~~ ~~As waste generally originates from a number of different sources and is usually mixed, data pertaining to composition of the waste stream are likely to be difficult for operators to accurately determine and detailed records are not routinely kept. Without these data, emission calculations will need to be based on the primary constituent of the waste or on the waste source.~~ ~~There are four types of techniques for emission estimation: sampling or direct measurement; mass balance; fuel analysis or other engineering calculations; or by emission factors (see the Monitoring BREF)~~
~~Oil treatment plant~~	~~A draft computer model has been developed in the UK to calculate emissions from basic information about intake tonnage and the quantity and oil content of discharges to sewer and landfill. The model requires adjustment to give answers that are compatible with the specification for residual fuel oils used in power stations and the known content of residuals in sewer discharges and sludges to landfill.~~ ~~The computer model does not provide an estimation for total nitrogen, phosphorus, chloride or COD to sewer and these will have to be calculated from monitoring data where this is available~~
~~Waste oils processing~~	~~Discharges to the air are more complex to calculate only having the knowledge from input, as releases are less defined and the behaviour of oils undergoing different processes is not clear~~
~~Waste solvent~~	~~Rigorous daily sampling regimes at tank vents and biofilters (where applicable) for TOC. Also an analysis of chemical compounds every fortnight at a series of process and fenceline monitoring points.~~
~~*Source*:[34, Babtie Group Ltd 2002] [60, WT TWG 2003]~~	

~~**Monitoring practices in physico-chemical treatment plants of waste waters**~~

~~The monitoring issues with the physico-chemical treatment of waste waters cover:~~

- ~~wastes containing phosphorus: not all sites are required to monitor regularly for total phosphorus so it may be easier to make an estimate of this emission from the intake of phosphoric acid~~
- ~~occasional inorganic wastes: for example wastes containing arsenic. Again, it is easier to calculate the annual emission from occasional waste IN data than to extend the monitoring programme.~~

~~Emissions to the air are the least well monitored discharges from physico-chemical treatment plants.~~

WORKING DRAFT IN PROGRESS

~~The main discharges to the air could be based on monitoring, but fugitive emissions will need to be estimated, as will the possibility of organic contaminants.~~

~~Almost all Ph-c sites have a complex set of conditions relating to water discharge that regulate sampling and monitoring frequency, and which set both the maximum concentration allowed for different species in the effluent and a maximum daily, weekly or monthly quantity of different species. This requires flow-proportional monitoring, or the monitoring of each batch before discharge of a set volume. Either system provides the data to calculate annual emissions for a number of main species. The problem in estimating emissions to water is restricted to those species that are known to exist, but for which there is no monitoring data, and to unexpected species that arrive with particular waste streams. Other inorganic species, such as arsenic, could probably be estimated from site intake data since treatments of wastes contaminated with those components are typically occasional activities.~~

~~Monitoring and sampling practices applied to the preparation of waste fuel from hazardous waste~~

~~More information on sampling is available in Section Each type of waste needs a specific sampling protocol based on the physico-chemical properties of the waste [98, WT TWG 2004]~~

~~Sampling of individual waste deliveries~~

~~Liquids (from tank trucks, i.e. solvents, waste oil)~~

~~Samples are taken with the 2.5 m sampling tube from each compartment of the truck or container (around 1 – 2 litres each). The sampling tube has to be rinsed with the liquid prior to sampling. The tube is inserted slowly down to the bottom of the tank with the valve end down. After closing the valve, the tube is lifted and the liquid is filled into an aluminium can.~~

~~Samples are combined and, after homogenisation (agitation), a volume of around 0.5 litre is transferred to a plastic bottle and sent to the laboratory for analysis. The tube must be cleaned after each set of samples to avoid contamination of the next sample.~~

~~The plastic bottle must be carefully labelled with sample identification, date, etc.~~

~~Bulked solids (e.g. from open containers)~~

~~6 – 8 samples of around 0.5 - 1 kg each are taken with the sampling shovel from different parts and levels of the container. The samples are combined, manually homogenised and split by quartering. The finished sample of around 1 kg (plastic bottle or bag) is adequately labelled and transferred to the lab.~~

~~The sampling shovel must be cleaned with a rag after each set of samples. The rags are disposed of in a separate waste bin.~~

~~Drums (200 litres)~~

~~Depending on the nature of the waste (liquid, pasty or solid), samples are taken with either the short sampling tube, the aluminium shovel or the spoon from each drum (around 0.125 litres each). One sample of around 1 litre per every eight drums is combined and homogenised. One finished sample of around 1 litre is blended and homogenised from several individual batches of eight drums and transferred to the lab. The remaining sample quantity is returned to a selected disposal drum.~~

~~Drums with liquid and pasty materials together in one shipment batch must be sampled separately. The prepared sample must be carefully labelled.~~

~~Cans (small volume)~~

~~A representative and random sampling of each load must be carried out. The sampling procedures correspond to the procedures applied in the sampling of drums.~~

WORKING DRAFT IN PROGRESS

~~Blended and homogenised samples of around 1 litre for each physical state (liquid, pasty, solid,) are transferred to the lab. Several spot samples should be kept for reference.~~

~~Due to the inherent problems in sampling heterogeneous wastes from a large number of small volume containers, it is recommended to add a secondary (automatic) sampling station prior to the pre-mixer of the blending installation.~~

~~Upon receipt in the laboratory, all samples are registered in a specific receiving log.~~
~~*Storage of samples*~~
~~Samples must be retained in carefully labelled and sealed bottles in a separate storage room close to the lab. The storage room must be equipped with adequate air ventilation, temperature/humidity control and an exhaust air filter system (active carbon) to the outside.~~

~~Duration of sample storage (if not otherwise specified in the operating permit):~~

- ~~around 3 years for reference samples from the waste qualification tests~~
- ~~around 3 months for daily delivery samples~~
- ~~around 3 months for finished product or dispatch samples.~~

~~**Table 2.28**:~~ ~~Examples of parameters and analysis principles used in sampling~~

~~**Parameters**~~	~~**Examples of analysis principles**~~
~~Density~~	~~Weighing~~
~~Viscosity~~	~~Viscosimeter~~
~~Flashpoint~~	~~Open or closed cup~~
~~LHV~~	~~Calorimeters~~
~~Water content~~	~~Karl Fisher~~
~~pH~~	~~pH meters~~
~~Ash contents~~	~~Calcination at 900 – 975 °C~~
~~Chlorine~~	~~Calcination/titrimetry, ionic chromatography~~
~~Fluor~~	~~Calcination/potentiometry, ionic chromatography~~
~~Brome~~	~~Calcination/titrimetry, ionic chromatography~~
~~Iode~~	~~Calcination/titrimetry, ionic chromatography~~
~~Heavy metals~~	~~ICP, fluorescence X~~
~~PCB~~	~~GC/ECD~~
~~PCP~~	~~GC/ECD~~
~~Sulphur~~	~~ICP, fluorescence X, ionic chromatography, colorimetry~~
~~Alkalis~~	~~ICP, fluorescence X, atomic absorption~~
~~Compatibility test~~	~~Function of waste received~~
~~*Source*:[78, Eucopro 2003] [98, WT TWG 2004]~~	

~~One of the most important measures is environmental monitoring by collecting samples of the environmental media and testing for the presence of hazardous substances that may have been released by the facility. The objective is to detect potential problems before they impact on human health and the environment. Early detection should allow sufficient time for the adequate warning of potentially affected individuals and allow effective implementation of remedial measures. Important monitoring points are groundwater wells for storage, land disposal facilities, and air monitoring stations at critical locations around the facility. Monitoring could also include surface water, employees (e.g. blood samples), and flora and fauna.~~
~~*Air emission monitoring*~~

~~*Dust monitoring (for all types of substituted fuel production)*~~
- ~~channelled emissions: one control per year carried out at a certified laboratory~~

WORKING DRAFT IN PROGRESS

- ~~air treatment systems: follow up of the efficiency of the cyclone and bag filters by pressure drop or opacity measures~~
- ~~diffuse emissions of dust can be assessed by measurements with an owen gauge located on the site.~~

~~*VOC monitoring*~~

- ~~odour: standardised tests for odour detection (e.g. EN 13725, European Reference Odour mass, EROM) can be used to identify the influence of the process on neighbours and on the workers environment. Bag samples may also be made for qualification and quantification of the pollutants in a laboratory~~
- ~~diffuse emissions: diffuse emissions are measured inside and outside workshops by taking samples. Quantitative and qualitative analyses can be carried out~~
- ~~channelled measures: VOCs are measured either continuously by a FID system or according to spot measurements campaigns. These conditions are defined in the permit.~~

~~*Noise monitoring*~~

~~Due to the relatively low noise level, no specific monitoring is usually requested. But, measures can be carried out for workers health and safety and especially for environmental impact evaluation, notably when new equipment is commissioned.~~

2.3.3.2 Monitoring of emissions to water

From ex-**Section 4.7.7 "Reporting of the components in the effluent generated in waste treatment facilities"**

~~**Description**~~

~~This section is intended to give some guidelines on the type of water parameter (pollutans) to be analysed in the effluent coming out from a waste treatment installation. The following gives information on the water parameters analysed, the achievable levels, the frequency of the measurement and an indication of whether such a parameter is monitored continuously and which type of waste treatment installations requires the particular parameter.~~

WORKING DRAFT IN PROGRESS

Table 2.29: Water parameters monitored in waste treatment facilities

~~Water parameter~~	**~~Achieved emission levels (mg/l)~~**	**~~Time average (continuous, daily, monthly, yearly)~~**	**~~Example of WT installations where the parameter has been reported~~**
~~pH~~		~~Continuous~~	~~All~~
~~Dry Solids~~	~~17000 – 27000~~		~~Ph-c treatments~~
~~Suspended solids~~	~~0.1 – 79~~	~~Continuous~~	~~All~~
~~Conductivity (µS/cm)~~	~~900 – 21000~~	~~Continuous~~	~~Ph-c treatments~~
~~Total nitrogen~~	~~110 – 3500~~	~~Monthly~~	~~Biological and Ph-c treatments~~
~~Ammonia~~	~~10 – 2500~~		~~Biological and Ph-c treatments~~
~~Nitrite~~	~~0.01 – 10~~		~~All~~
~~Nitrate~~	~~0.9 – 10~~		~~Biological and Ph-c treatments~~
~~Total Phosphorus~~	~~<0.1 – 2.6~~	~~Monthly~~	~~Dealing with phosphorus waste e.g. in Ph-c treatments~~
~~Chloride total~~	~~1500 – 18240~~		~~Biological and Ph-c treatments~~
~~Chloride free~~	~~≤0.1 – 0.4~~		~~Ph-c treatments~~
~~Cyanide free~~	~~<0.01 – 0.1~~		~~Ph-c treatments~~
~~Fluoride~~	~~0.5 – 10~~		~~Ph-c treatments~~
~~Cyanide total~~	~~≤0.1~~		~~Ph-c treatments~~
~~Sulphate~~	~~65 – 1070~~		~~Ph-c treatments~~
~~Sulphite~~	~~≤1 - 50~~		~~Ph-c treatments~~
~~Sulphide~~	~~≤0.1~~		~~Ph-c treatments~~
~~Aquatic toxicity~~			
~~Microbial indicators (e.g. pathogens)~~			
~~Bacteria luminescence~~			
~~BOD~~	~~20 – 3000~~		
~~BTEX~~	~~<0.1 – 0.7~~		~~Ph-c treatments~~
~~COD~~	~~120 – 5000~~		~~All~~
~~Detergents~~	~~0.6 – 5.3~~		
~~Hydrocarbons~~	~~<0.1 – 3.8~~		~~All~~
~~PAH~~			
~~AOX~~	~~0.1 – 0.5~~		~~All~~
~~Phenols~~	~~0.1 – 1.9~~		~~Ph-c treatments~~
~~VOC~~	~~<0.01 – 0.1~~		~~Ph-c treatments~~
~~Solvents~~			
~~TOC~~			
~~TPH~~			
~~Metals~~		~~Monthly~~	~~Ph-c treatment~~
~~Ag~~	~~≤0.1~~		
~~Al~~	~~<0.1 – 2~~		~~Ph-c treatments~~
~~As~~	~~<0.01 – 0.1~~		~~Arsenic bearing wastes~~ ~~Ph-c treatments~~
~~Ba~~	~~≤5~~		~~Ph-c treatments~~
~~Cd~~	~~≤0.1~~		~~Ph-c treatments~~
~~Co~~	~~<0.1 – 1.0~~		~~Ph-c treatments~~
~~Cr(VI)~~	~~<0.01 – 0.1~~		~~Ph-c treatments~~
~~Cr~~	~~<0.1 – 0.5~~		~~Ph-c treatments~~
~~Cu~~	~~≤0.1 – 0.5~~		~~Ph-c treatments~~
~~Fe~~	~~0.1 – 5.2~~		~~Ph-c treatments~~
~~Hg~~	~~0.001 – 0.01~~		~~Ph-c treatments~~
~~Mn~~	~~<0.1 – 0.9~~		
~~Ni~~	~~<0.1 – 1.0~~		~~Ph-c treatments~~
~~Pb~~	~~<0.1 – 0.5~~		~~Ph-c treatments~~
~~Se~~	~~≤0.1~~		~~Ph-c treatments~~
~~Sn~~	~~<0.1 – 2.0~~		~~Ph-c treatments~~
~~Zn~~	~~<0.1 – 2.0~~		~~Ph-c treatments~~

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~~[33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [89, UBA Germany 2003] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [98, WT TWG 2004]~~

~~Achieved environmental benefits~~

~~Identifies and assists the monitoring of pollutants that are typically released.~~

~~Example plants~~

~~In general, the discharge consent reflects the type of activity carried out at the site, ie those handling large volumes of solvent are required to test for solvent content; others may be required simply to test for pH and COD.~~

~~Reference literature~~

~~[33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [89, UBA Germany 2003] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [98, WT TWG 2004]~~

Description

Proper operation of a waste treatment plant requires the monitoring and targeted adjustment of various process parameters in the effluent of the waste treatment plant.

Technical description

Monitoring of the relevant parameters can be accomplished by online measurements (that facilitate rapid intervention and control) or analytical results derived from waste water samples. Parameters to be monitored and the frequency of monitoring depend on the characteristics of the waste water, which are connected to the type of wastes treated in the installation, the final effluent discharge medium and the waste water treatment techniques used within the waste treatment plant.

Figure 2.29 summarises the information collected from the questionnaires on parameters monitored in different types of waste treatment plants.

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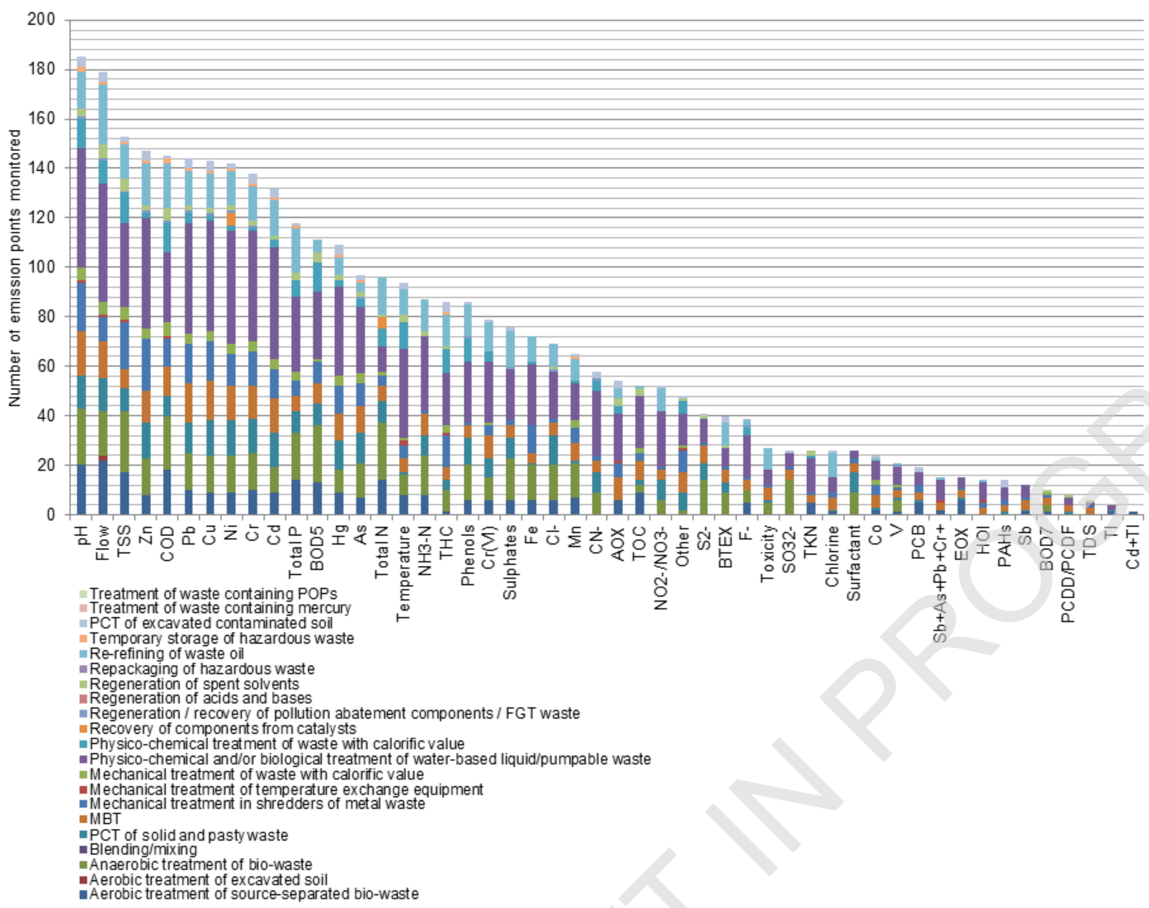

Figure 2.29: Parameters monitored in emissions to water by type of waste treatment

The monitoring of emissions is carried out in accordance with EN standards or, if EN standards are not available, ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality.

Achieved environmental benefits

Monitoring the waste water of a waste treatment plant helps to maintain the proper operation of the waste treatment plant and to detect accidental releases and thus helps to prevent any possible adverse environmental effects upon discharge of waste waters.

Environmental performance and operational data

This information is detailed later in this document for each type of waste treatment in the dedicated chapters (Chapters 3 to 5).

Cross-media effects

Some equipment, ancillary materials and energy are required for carrying out monitoring. The COD measurement relies on the use of very toxic compounds (i.e. mercury and chromate).

Technical considerations related to applicability

Generally applicable to all waste treatment plants where there are emissions to water.

Economics

The costs associated with monitoring the effluent waste water of a waste treatment plant relate to personnel and equipment used for sampling and measurement.

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Driving force for implementation
Legislation on water pollution.

Example plants
See examples in Chapters 3 to 5.

Reference literature
[139, COM 2015] [138, COM 2014]

2.3.3.3 Monitoring of channelled emissions to air

Description
Proper operation of a waste treatment plant requires the monitoring and targeted adjustment of various process parameters in the emissions to air of the waste treatment plant.

Technical description
Monitoring of the relevant parameters can be accomplished by online measurements (which facilitate rapid intervention and control) or analytical results derived from air samples. Parameters to be monitored and the frequency of monitoring depend on the characteristics of the type of wastes treated in the installation and the abatement techniques used within the waste treatment plant.

Figure 2.30 summarises the information collected from the questionnaires on parameters monitored in different types of waste treatment plants.

WORKING DRAFT IN PROGRESS

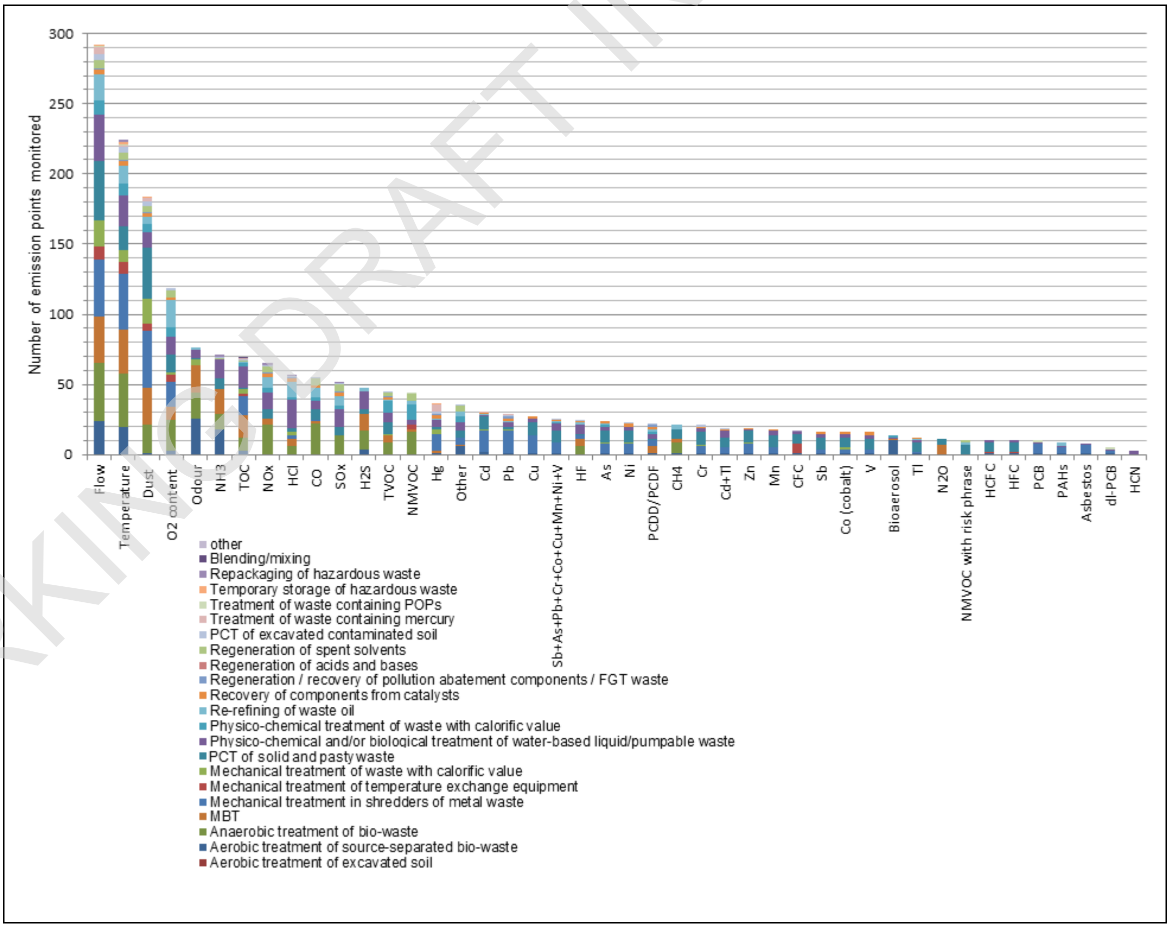

Figure 2.30: Parameters monitored in emissions to air by type of waste treatment

The monitoring of emissions is carried out in accordance with EN standards or, if EN standards are not available, ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality.

Achieved environmental benefits
Monitoring the waste gas of a waste treatment plant helps to maintain the proper operation of the waste treatment plant and to detect accidental releases and thus helps to prevent any possible adverse environmental effects upon emission of waste gas.

Environmental performance and operational data
This information is detailed later in this document for each type of waste treatment in the dedicated chapters (Chapters 3 to 5).

Cross-media effects
Some equipment, ancillary materials and energy are required for carrying out monitoring.

Technical considerations related to applicability
Generally applicable to all waste treatment plants where there are channelled emissions to air.

Economics
The costs associated with monitoring the waste gas of a waste treatment plant relate to personnel and equipment used for sampling and measurement.

Driving force for implementation
Legislation on air pollution.

Example plants
See examples in Chapters 3 to 5.

Reference literature
[139, COM 2015] [138, COM 2014]

2.3.3.4 Odour monitoring

Description
Odour monitoring is carried out using analytical methods (i.e. physical and chemical analysis) or sensorial approaches. Sensorial analyses, being assigned to the 'human sensor', are the cause of significant uncertainties.

Technical description
The techniques can be classified into three categories:

- for odour concentration determination (expressed in OU_E/m^3, to control limit values): dynamic olfactometry (measured according to the European standard EN 13725);
- for odour perception in the surrounding area (impact): odour surveys (see odour intensity mapping and odour wheels;
- for self-monitoring: electronic noses.

To determine the odour concentration, an air sample must be taken. The sampling techniques are similar to those used for measuring individual compounds.

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Techniques for odour monitoring are described in [138, COM 2014].

Example plants
See Chapters 3 to 5.

Reference literature
[138, COM 2014]

2.3.4 Techniques for the prevention and control of channelled emissions to air

2.3.4.1 Overview

This section contains techniques used in the waste treatment sector to prevent, reduce, abate or control the emissions to air. Emphasis needs to be placed on the prevention of the production and displacement of pollutants.

Point source emissions relate to those emissions that result from the collection of gas from a vessel or area and that are passed on, either via abatement or directly, to a stack or vent.

This section only covers those techniques most relevant to the waste treatment sector. ~~In general, most~~ These techniques have already been described and analysed in ~~other BREFs (special reference is made to~~ the CWW BREF [138, COM 2014]~~and WI BREF)~~. For this reason, it is not intended in this section to provide a complete analysis of each of the different techniques. Instead, only a short description of the techniques is given as well as examples of plants of the data collection where these techniques are applied.~~ For further information about the This section will focus only on issues relevant to the waste treatment sector, including discussions on what are considered to be good achievable emission values~~. Preventive techniques ~~were~~ are covered in the ~~previous~~ following chapters ~~sections~~ since they are very dependent on the type of process/activity carried out.

2.3.4.2 Cyclone

From ex-**Section 4.6.3 "Cyclone"**

Description
In all types of cyclones, centrifugal forces are used to separate solid particles or liquid droplets from flue-gases. Cyclone filters are used to remove heavier particulates, which 'fall out' as the flue-gases are forced into a rotating motion before they leave the separator again.

~~Two forms exist, e.g. a cyclone or multi-cyclone. The latter separates finer dusts.~~

~~Cyclones are effective for abating particles of sizes >10 µm. They are not effective against particle sizes <10 µm, which may thus require additional measures, e.g. fabric filters. Some benefits of using a cyclone include:~~

- ~~efficient over a large concentration range;~~
- ~~collected dust may be reused in the process.~~

~~**Environmental performance and operational data**~~
~~Cyclones are relatively reliable.~~
~~The separation capacity of cyclonic separators depends on the flow velocity of the air. The higher the flow velocity is, the higher the degree of separation is. However, an increase in flow velocity leads to a decrease of pressure inside the separator.~~

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~~High wear with abrasive dust is ensured. This technique may be only used in combination with a bag filter. It is not efficient at separating small particles.~~

~~Cyclones are effective for abating particles of sizes >10 µm. They are not effective against particle sizes <10 µm, which may thus require additional measures, e.g. fabric filters~~.

~~Operational conditions include:~~

- ~~monitoring of pH, flow rate and the level of scrubber liquors and scrubber pressure drop (pressure drop monitoring with alarm)~~
- ~~exit concentrations needing to be periodically monitored under different operating conditions.~~

~~Cyclones create a pressure drop in the gas flow requiring a higher energy consumption to overcome this drop and, therefore, lead to higher overall emissions.~~

~~Technical considerations relevant to applicability~~

~~Cyclones are used in hazardous waste fuel preparation, where these are used in the mixing vessel as part of the stabilisation process. They are also used for the treatment of the exhaust gases of physico-chemical plants.~~

~~Economies~~

~~Cyclones are relatively cheap.~~

Example plants

Table 2.30 shows the list of plants from the reference list equipped with a cyclone. Almost all of them carry out shredding of waste.

Table 2.30: Plants equipped with cyclonic separation

Plants equipped with cyclonic separation as an abatement technique	Main type of waste treatment
25, 26, 27, 28, 29, 54, 55, 136, 282C, 288C, 289C, 290C, 291C, 293C, 294C, 455, 456, 464, 478	Mechanical treatment in shredders of metal waste
133, 280C	Mechanical treatment of waste with calorific value
460	Aerobic treatment of source-separated bio-waste

Reference literature

[33, UK EA 2001] [78, Eucopro 2003] [82, Pretz et al. 2003]

2.3.4.3 Electrostatic precipitator (ESP)

From ex-**Section 4.6.4 "Electrostatic precipitator (ESP)"**

Description

~~Electrostatic precipitators use high voltage to attract and remove particulate matter from the flue gases.~~

An electrostatic precipitator (ESP) is a particulate collection device that removes particles from a flowing gas using the force of an induced electrostatic charge.

Technical description

~~There are two different kinds of operation; e.g. dry, which involves the collection of dust on electrodes under the influence of an electric field and wet, which is the same except the electrodes are cleaned to increase effectiveness~~.

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~~**Achieved environmental benefits**~~

~~Reduction of dust particulate emissions~~

~~**Environmental performance and operational data**~~

~~ESP show high collection efficiency for both coarse and small particles. ESP are efficient at high temperatures and for the collection of liquid particles.~~

~~**Technical considerations relevant to applicability**~~

~~It is used for the treatment of the exhaust gases of Ph-c plants.~~

~~This technique is not suitable for organic particles due to the high explosion risk they present.~~

Example plants

Table 2.31 shows the list of plants equipped with an ESP. This abatement technique is clearly not widespread in the waste treatment sector as only two plants are equipped with it.

Table 2.31: Plants equipped with an electrostatic precipitator (ESP)

Plants equipped with an ESP as an abatement technique	Main type of waste treatment
401_404	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
620	Re-refining and other preparations for reuse of waste oils

Reference literature

[33, UK EA 2001] [78, Eucopro 2003] [82, Pretz et al. 2003] [138, COM 2014]

2.3.4.4 Fabric filter

From ex-**Section 4.6.5 "Fabric filters"** and CWW BREF Section 3.5.1.3.5

Description

The creation of a barrier separates the dust from the flue-gases. Solid particles are trapped by a woven fabric while the gas flow can pass through it.

~~**Achieved environmental benefits**~~

- ~~Reduction of high collection efficiency for both coarse and small particles.~~
- ~~Efficient with a large concentration range.~~
- ~~Collected dust may be reused in the process.~~
- ~~High collection efficiency at high temperatures if special materials, e.g. Teflon, are used.~~

~~**Environmental performance and operational data**~~

~~Fabric filters are equipped with pressure drop monitoring, including alarms and often with measurement of inlet and exit concentrations. Pressure is often used as an instantaneous surrogate for concentration analysis. From time to time, however, a laboratory control is carried out on the exit concentration in order to quantify the emissions. An opacity meter or particle impingement detector can be used to monitor performance. There needs to be a programme in place for the regular cleaning of physical filters. Filter efficiency may be enhanced by precoating the filter cloth prior to being brought online. In situ cleaning can be achieved by air pulse, counter flow air or mechanical tapping. The reliability is highly dependent on the filter material. Fabric filters may create a risk of explosion.~~

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~~Table 2.32: Dust filtration by a fabric filter~~

~~Characteristics~~	~~Fabric filter~~
~~Input flow range (m^3/hour)~~	~~1000 to 50000~~
~~Input concentration (mg/Nm^3)~~	~~100 to 5000~~
~~Output concentration (mg/Nm^3)~~	~~<10~~
~~Risks~~	~~Explosion~~
~~Consumption/generation (per tonne of waste fuel produced)~~	
~~Electricity (kWh/t)~~	~~2.5 to 3.5~~
~~Fuel/gas (litre)~~	-
~~Reactant (nature and kg)~~	-
~~Residues~~	-
~~Costs per unit of waste fuel produced per year (EUR/(t*y))~~	
~~Investment cost~~	~~Up to 4~~
~~Operation cost~~	~~0.15~~
~~Maintenance cost~~	~~0.1~~

~~[78, Eucopro 2003]~~

~~Cross-media effects~~

~~Cyclones and fabric filters create a pressure drop in the gas flow, requiring a higher energy consumption to overcome this drop. and therefore this leads to higher overall emissions. A major source of hazardous waste at a number of industries is the dust emanating from air pollution control equipment (e.g. from a baghouse). As with sewerage systems, common dust collectors are utilised in different production areas resulting in a mixing of different types of dust and, thereby, precluding recycling. In some cases, modifications can be made to dust collectors so that each different source of waste goes to a different compartment, thereby, preventing the mixing of different waste types and increasing the recycling potential.~~

~~Technical considerations relevant to applicability~~

~~Applied for both fugitive emissions and point source emissions to air. Fabric filters are typically used as secondary or tertiary gas cleaning devices in combination with a cyclone or a dry scrubber located upstream. Fabric filters are not generally suitable for use in moisture-laden streams or those with acidic, tarry or sticky characteristics. This is due to the adverse effects of fabric 'blinding' and adherence problems.~~

~~Bag filters are used in the preparation of waste fuel. They are also used in the mixing vessel in the stabilisation process in the production of aerosol cans (e.g. for the removal of dust) and for the treatment of the exhaust gases of physico-chemical plants.~~

Example plants

Table 2.33 shows the plants from the reference list equipped with a fabric filter This abatement technique is essentially used in dust-generating processes such as mechanical treatment of waste or Physico-chemical treatment of solid/pasty waste.

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Table 2.33: **Plants equipped with a fabric filter**

Plants equipped with a fabric filter as an abatement technique	Main type of waste treatment
100, 29, 293C, 294C, 364_365, 432, 455, 464, 588, 590	Mechanical treatment in shredders of metal waste
24, 31, 34, 35, 122C, 133, 269, 270, 277, 278, 280C, 312, 326C, 361_363, 442C, 443C, 615, 627, 632	Mechanical treatment of waste with calorific value
458, 630, 636	Mechanical treatment in shredders of temperature exchange equipment
17, 243, 244, 257, 267, 279, 337, 628	MBT
15, 176, 181C, 187C, 222, 223, 224, 225, 226, 228, 229, 340, 399, 425_426, 613, 614	Physico-chemical treatment of solid/pasty waste
40, 188	Treatment of excavated contaminated soil
506, 637	Recovery of components from catalysts
505	Regeneration/recovery of pollution abatement components/FGT waste
299	Repackaging of hazardous waste
306, 366	Temporary storage of hazardous waste
589	Treatment of waste containing mercury
347	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
260	Aerobic treatment of source-separated bio-waste
485	Anaerobic treatment of bio-waste

Reference literature

[31, LaGrega et al. 1994][33, UK EA 2001] [78, Eucopro 2003] [82, Pretz et al. 2003] [98, WT TWG 2004] [119, COM 2006]

Ex-**Section 4.6.6 "Lamella separator" deleted** as no example has been found in the questionnaires.

2.3.4.5 Absolute filter

Based on text from CWW BREF Section 3.5.1.3.9

Description

In absolute filters (e.g. HEPA = high-efficiency particle air filter, ULPA = ultra-low penetration air filter), the filter medium is paper or matted glass fibre with a high packing density. The waste gas stream is passed through the filter medium, where particulate matter is collected. The dust cake that forms on the filter medium can increase the collection efficiency. The filter medium is pleated to provide a smaller A/C ratio (volume flow rate to surface area).

The most common designs are a box filter cell and a cylindrical filter cell. In a box cell, the pleated medium is placed in a rigid, square frame constructed of wood or metal. The air flows from the front to the back of the filter. In a cylindrical filter cell, a metal cap seals the medium at one end. The air flows from the outside to the inside of the filter.

Example plants

Table 2.34 shows the plants from the reference list equipped with absolute filtration.

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Table 2.34: Plants equipped with absolute filtration

Plants equipped with absolute filtration as an abatement technique	**Type of waste treatment**
327, 588, 589, 590	Treatment of waste containing mercury
187C	Physico-chemical treatment of solid and/or pasty waste
260	Aerobic treatment of source-separated bio-waste

Reference literature
[138, COM 2014]

2.3.4.6 Thermal oxidation

Ex-**Section 4.6.19 "Oxidation treatments"**, ex-**Section 4.6.14 "Incineration", ex-Section 4.6.15 "Combined combustion", ex-Section 4.6.18 "Regenerative thermal oxidiser"** deleted and replaced by text based on CWW BREF Section 3.5.1.2.5.

Description
Thermal oxidation (also often referred to as 'incineration', 'thermal incineration' or 'oxidative combustion') is the oxidation of combustible gases and odorants in a waste gas stream by heating a mixture of contaminants with air or oxygen above its autoignition point in a combustion chamber and maintaining it at a high temperature for sufficient time to complete combustion to carbon dioxide and water.

Thermal oxidisers are used to reduce emissions from almost all VOC sources, including reactor vents, distillation vents, solvent operations and operations performed in ovens, dryers and kilns. They can handle minor fluctuations in flow, but large fluctuations require the use of a flare. Their fuel consumption can be high when low-loaded waste gases are fed so thermal units are best suited for smaller process applications with moderate to high VOC loadings.
Several types of thermal oxidisers are operated:

- the straight thermal oxidiser,
- the regenerative thermal oxidiser,
- the recuperative thermal oxidiser,
- gas engines, kilns or steam boilers.

Example plants
Table 2.35 below shows the plants from the reference list equipped with thermal oxidation systems.

Table 2.35: Plants equipped with a thermal oxidation system

Plants equipped with a thermal oxidation system as an abatement technique	**Main type of waste treatment**
239, 243, 244, 257, 267, 279, 628	MBT
425_426, 494, 569	Physico-chemical treatment of solid/pasty waste
188C	Treatment of excavated contaminated soil
505	Regeneration/recovery of pollution abatement components/ FGT waste
368_369_370_371, 401_404	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
394	Regeneration of spent solvents
160C, 570, 620, 624	Re-refining and other preparations for reuse of waste oils
191C	Treatment of waste containing POPs
78, 172C, 469	Physico-chemical treatment of waste with calorific value
327	Treatment of waste containing mercury

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506, 637	Recovery of components from catalysts

Reference literature

[138, COM 2014]

Ex-**Section 4.6.16 "Catalytic combustion" and Section 4.6.17 "Regenerative catalytic oxidiser" and** ex-**Section 4.6.20 "Non-thermal plasma treatment"** deleted because no example of application has been found in the questionnaires.

Ex-**Section 4.6.13 "Low oxidative processes"** deleted because no example has been found in the questionnaires

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2.3.4.7 Biofiltration

Ex-**Section 4.6.10 "Biofilters"** deleted and replaced by text based on CWW BREF section 3.5.1.2.1

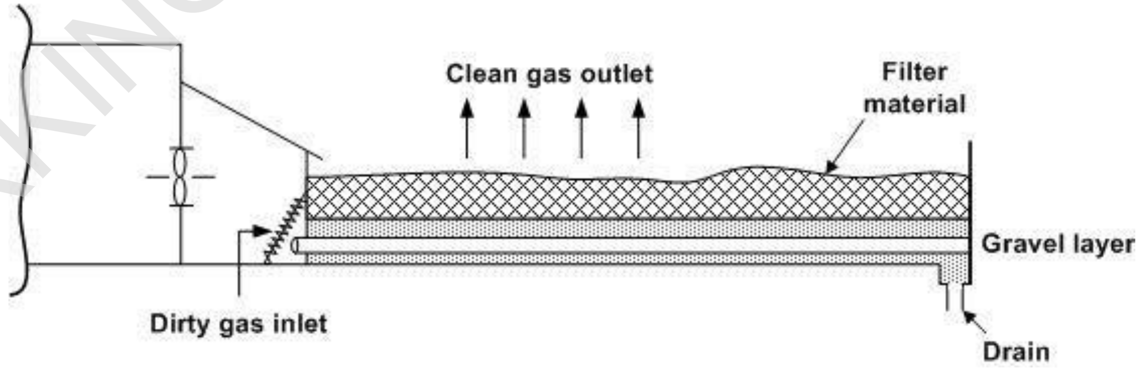
Description

The waste gas stream is passed through a bed of organic material (such as peat, heather, compost, root wood, tree bark, peat, compost, softwood and different kinds of combinations) or some inert material (such as clay, activated carbon, and polyurethane), where it is biologically oxidised by naturally occurring microorganisms into carbon dioxide, water, inorganic salts and biomass.

Biofiltration is well suited to low concentrations of pollutants that are easily soluble in water. It is normally not suitable, however, for waste gases containing many different and/or changing pollutants. Furthermore, methane is not abated because the residence time needed would be too long for normal filter dimensions.

When concentrations of nitrogenous, sulphurous or chlorous organic or inorganic compounds are too high, the formation of nitric acid, sulphuric acid and hydrochloric acid respectively may acidify the filter material, rendering it useless, and thus drastically increase the required replacement frequency. When applying biofiltration, it is important that the filter material has a pH value in the range of 7–8 to decompose organic components. At a pH value of 6.5 the decomposition speed decreases. The residence time of the gas in the filter should be at least 30–45 seconds in order to properly abate odorous components and solvents (e.g. toluene).

A biofilter construction is shown in **Figure 2.31**.



Source: [138, COM 2014]

Figure 2.31: Biofilter construction

Biofilters can be divided into open biofilters and enclosed biofilters.

For some odorous compounds (e.g. mercaptans, H_2S), abatement efficiencies of 75 % are a minimum. Using a scrubber and biofilter in combination can improve the performance. For other odorous compounds, the abatement efficiency is somewhat lower.

Example plants

Table 2.36 shows the list of reference plants equipped with a biofilter. These are mainly plants carrying out biological treatment of waste.

Table 2.36: Plants equipped with a biofilter

Plants equipped with a biofilter as an abatement technique	Main type of waste treatment
62, 114, 261, 262, 328, 372, 406_407, 410_411, 412, 413, 414, 416, 460, 511, 518, 520, 537, 542, 543, 608, 609, 621, 623, 634, 635	Aerobic treatment of source-separated bio-waste
71, 111, 251, 255, 256, 265, 268, 339, 341, 377, 459, 484, 485, 526, 528, 529, 541	Anaerobic treatment of bio-waste
17, 19, 37, 127, 243, 244, 266, 267, 279, 337, 338, 349, 350, 415, 452, 454, 566, 573	MBT
32, 161C, 278, 280C	Mechanical treatment of waste with calorific value
212	Mechanical treatment in shredders of temperature exchange equipment
340, 495_496, 569	Physico-chemical treatment of solid/pasty waste
03, 07, 08, 156C, 163C, 607	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste

Reference literature

[138, COM 2014]

2.3.4.8 Condensation and cryogenic condensation

Ex-**Section 4.6.8 "Condensation"** deleted and replaced by text based on BREF CWW section 3.5.1.1.2.

Description

Condensation is a technique that eliminates VOC vapours from a waste gas stream by reducing its temperature below its dew point.

There are different methods of condensation, depending on the operating temperature range and including:

- coolant condensation, for a condensation temperature down to about 25 °C;
- refrigerant condensation, for a condensation temperature down to about 2 °C;
- brine condensation, for a condensation temperature down to about -10 °C;
- ammonia brine condensation, for a condensation temperature down to about -40 °C (one-stage) or -60 °C (two-stage);
- cryogenic condensation, for a condensation temperature down to about -120 °C, in practice often operated between -40 °C and -80 °C in the condensation device;
- closed-cycle inert gas condensation.

Example plants

Table 2.37 shows the plants from the reference list equipped with condensation (coolant or cryogenic) systems.

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Table 2.37: Plants equipped with a condensation system

Plants equipped with a condensation system as an technique	Main type of waste treatment
470, 629	Mechanical treatment in shredders of temperature exchange equipment
311	Repackaging of hazardous waste
327	Treatment of waste containing mercury
450	Blending/mixing
56, 168C, 169C, 170	Regeneration of spent solvents
605	Re-refining and other preparations for reuse of waste oils

Reference literature
[138, COM 2014]

Ex-**Section 4.6.9 "Temporary and long-term foams":** deleted since it deals with site remediation, VOC abatement for non-excavated soils (outside scope)

2.3.4.9 Adsorption

Ex-**Section 4.6.7 "Adsorption"** deleted and replaced by text based on CWW BREF Section 3.5.1.1.3

Description
Adsorption is a heterogeneous reaction in which gas molecules are retained on a solid or liquid surface (the adsorbent is also referred to as a molecular sieve) that prefers specific compounds to others and thus removes them from effluent streams. When the surface has adsorbed as much as it can, the adsorbed content is desorbed as part of the regeneration of the adsorbent. When desorbed, the contaminants are usually at a higher concentration and can either be recovered or disposed of.

Typical adsorbents include:

- **granular activated carbon** (GAC), the most common adsorbent with a wide efficiency range and not restricted to polar or non-polar compounds; GAC can be impregnated, e.g. with oxidants such as potassium permanganate or with sulphur compounds (improving the retention of heavy metals);
- **zeolites**, with properties depending on their manufacturing, working either as mere molecular sieves, selective ion exchangers or hydrophobic VOC adsorbers;
- macroporous **polymer** particles, which are used as granules or beads, without being highly selective with respect to VOCs;
- silica gel;
- sodium-aluminium silicates.

The application of adsorption encompasses:

- the recovery of VOCs (raw material, product, solvent, etc.) for reuse or recirculation; it may be used as a stand-alone system, as a concentration step to improve the viability of further recovery operations such as membrane separation or to treat the tail gas emissions from an abatement system;
- the abatement of pollutants (hazardous substances from production or treatment facilities (e.g. WWTP) such as VOCs, H_2S, odours, trace gases, etc.) that cannot be recirculated or otherwise used, possibly with GAC as an adsorbent which is then not regenerated but incinerated;
- the use as a guard filter after final treatment facilities.

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Example plants

Table 2.38 shows the list of plants from the reference list equipped with activated carbon adsorption. Activated carbon filters have been tested for a number of months in two metal shredder plants in Europe after different preliminary treatments of the air flow in order to protect against any deflagration risk, and to eliminate dust and/or heating to reduce the humidity content. [107, Mech. subgroup 2014]

Table 2.38: Plants equipped with activated carbon adsorption

Plants equipped with activated carbon adsorption as an abatement technique	Type of waste treatment
127, 244, 434	MBT
54, 364_365, 588, 590	Mechanical treatment in shredders of metal waste
32, 35, 277, 280C	Mechanical treatment of waste with calorific value
138, 458, 629, 630, 636	Mechanical treatment in shredders of temperature exchange equipment
176C, 181C, 425_426, 495_496	Physico-chemical treatment of solid/pasty waste
40, 188C, 353_359	Treatment of excavated contaminated soil
497	Regeneration/recovery of pollution abatement components/ FGT waste
311	Repackaging of hazardous waste
172C, 174C, 553	Physico-chemical treatment of waste with calorific value
59, 146C, 589	Treatment of waste containing mercury
03, 08, 140_141_142_143C, 148C, 149_150C, 151C, 156C, 163C, 216, 217, 317, 347, 463	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
324	Blending/mixing
56, 170, 394, 476, 554	Regeneration of spent solvents
92, 619, 620	Re-refining and other preparations for reuse of waste oils
191C	Treatment of waste containing POPs
260	Aerobic treatment of source-separated bio-waste
484, 485, 526, 528	Anaerobic treatment of bio-waste

Reference literature

[138, COM 2014]

Ex-**Section 4.6.21 "NO$_X$ abatement techniques"** deleted because related to combustion plants. Moreover, there are no examples of SCR or SNCR in the questionnaires.

2.3.4.10 Scrubbing

Ex-**Section 4.6.11 "Scrubbing" and ex- Section 4.6.12 "Chemical scrubbing"** deleted and replaced by text based on CWW BREF Sections 3.5.1.1.4 and 3.5.1.3.4

2.3.4.10.1 Wet gas scrubber

Description

Wet scrubbing (or absorption) is a mass transfer between a soluble gas and a solvent – often water – in contact with each other. Physical scrubbing is preferred for chemical recovery, whereas chemical scrubbing is restricted to removing and abating gaseous compounds. Physico-chemical scrubbing takes an intermediate position. The component is dissolved in the absorbing liquid and involved in a reversible chemical reaction, which enables the recovery of the gaseous component.

Scrubbing or absorption is widely used as a raw material and/or product recovery technique for the separation and purification of gaseous streams which contain high concentrations of VOCs, especially compounds soluble in water such as alcohols, acetone or formaldehyde. The use of

WORKING DRAFT IN PROGRESS

absorption as the primary control technique for organic vapours is subject to the availability of a suitable solvent, with a high solubility for the gas, low vapour pressure and low viscosity.

The major waste gas treatment applications of scrubbing processes are:

- the removal of gaseous pollutants, such as hydrogen halides, SO_2, ammonia, hydrogen sulphide (H_2S) or volatile organic solvents;
- the removal of dust with certain types of scrubbers (see Section 2.3.4.10.2).

Depending on the pollutants to be removed, several aqueous scrubbing liquids are used including the following:

- **Water**, to remove solvents and gases such as hydrogen halides or ammonia, with the main aim being to recover and reuse these contaminants.
- **Alkaline solutions** (e.g. caustic soda (i.e. sodium hydroxide) and sodium carbonate), to remove acid components such as hydrogen halides, sulphur dioxide, hydrogen sulphide (H_2S), phenols, chlorine; also used for second-stage scrubbing to remove residual hydrogen halides after first-stage aqueous absorption; biogas desulphurisation.
- **Alkaline-oxidation solutions**, i.e. alkaline solutions with oxidants such as sodium hypochlorite (NaClO), chlorine dioxide (ClO_2), ozone (O_3) or hydrogen peroxide (H_2O_2).
- **Oxidising solutions**, to recover NO_X from concentrated waste gases.
- **Sodium hydrogen sulphite solutions**, to remove odour (e.g. aldehydes).
- **Na_2S_4 solutions**, to remove mercury from waste gas.
- **Acidic solutions**, to remove alkaline components, e.g. ammonia, amines and esters. The dosing of the acid is done by means of pH regulation.
- **Monoethanolamine and diethanolamine solutions**, suitable for the absorption and recovery of hydrogen sulphide.
- **Organic solvents with low volatility**, e.g. chilled nonane for the recovery of light VOCs such as butanes and pentanes.

Example plants

As for the waste treatment sector, Table 2.39 shows the list of reference plants equipped with wet scrubbers (either water, acid or alkaline scrubbers).

Table 2.39: Plants equipped with a wet scrubbing system

Plants equipped with a wet scrubbing system as an abatement technique	Type of waste treatment
19, 37, 127, 239, 566, 573	MBT
25, 26, 27, 28, 54, 55, 95C, 282C, 288C, 289C, 290C, 291C, 364_365, 432, 441, 455, 456, 571	Mechanical treatment in shredders of metal waste
161C, 278	Mechanical treatment of waste with calorific value
15, 340, 348, 399, 425_426, 475, 495_496, 569	Physico-chemical treatment of solid/pasty waste
14, 188C	Treatment of excavated contaminated soil
552	Repackaging of hazardous waste
04, 06, 07, 08 140_141_142_143C, 144_145_147C, 154_155C, 192C, 194C, 215, 217, 317, 322, 368_369_370_371, 401_404, 461, 468, 550	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
168C, 169C, 394, 554	Regeneration of spent solvents
570, 605, 620, 624	Re-refining and other preparations for reuse of waste oils
114, 126, 260, 262, 328, 372, 416, 460, 608, 634	Aerobic treatment of source-separated bio-waste
71, 111, 251, 255, 268, 377, 459	Anaerobic treatment of bio-waste
332, 450	Blending/mixing
193C	Other

Reference literature

WORKING DRAFT IN PROGRESS

[138, COM 2014]

2.3.4.10.2 Wet dust scrubber

Description
Wet dust scrubbing is a variation of wet gas scrubbing (see Section 2.3.4.10.1), using the same or equivalent techniques to abate or recover particulate matter in addition to gaseous compounds.

A type of scrubber widely operated for dust abatement is the **Venturi scrubber**, the characteristic feature being the constriction of the duct – Venturi throat – causing an increase in gas velocity. Liquid is introduced into the scrubber and forms a film on the walls, which is atomised by the gas stream in the Venturi throat. Alternatively, with ejector Venturi scrubbers, the liquid is sprayed into the Venturi throat.

This technique allows the abatement of dust emissions as well as inorganic chemicals (such as SO_2, NH_3, NH_4Cl, VOCs) and heavy metals that may be attached to the dust.

Example plants
See Table 2.39.

Reference literature
[138, COM 2014]

2.3.4.11 Sorbent injection

Text based on CWW Section 3.5.1.4.2

Description
The principle of sorbent injection is the introduction of reactive material to, and its dispersion in, the waste gas stream. This material reacts with SO_X species to form a solid which has to be removed afterwards from the waste gas stream (often with a filter, e.g. a bag filter).

The most frequently used sorbents are:

- limestone and its derivatives;
- dolomite and its derivatives;
- sodium hydrogen carbonate (sodium bicarbonate);
- sodium carbonate (soda ash).

The choice of sorbent depends on the process conditions (temperature, flow rate, humidity, pollutant contents) and its availability.

These sorbents are also effective at removing other acid gases, particularly hydrogen chloride (HCl) and fluoride (HF). If these acid gases are intended to be recovered, the waste gas needs to be pretreated (water scrubbing, see Section 2.3.4.10.1).

Example plants
Table 2.40 shows the plants from the reference list equipped with sorbent injection systems.

WORKING DRAFT IN PROGRESS

Table 2.40: Plants equipped with a sorbent injection system

Plants equipped with a sorbent injection as an abatement technique	Type of waste treatment
243, 244, 267, 337	MBT
27	Mechanical treatment in shredders of metal waste
506, 637	Recovery of components from catalysts
03	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
235	Re-refining and other preparations for reuse of waste oils

Reference literature
[138, COM 2014]

2.3.5 Techniques [~~to prevent/reduce~~] for the prevention and control of odour and diffuse/fugitive emissions to air

2.3.5.1 Odour management plan [~~reduction techniques~~]

From ex-**Section 4.6.22 "Odour reduction techniques"**

~~More information can be found in Section .~~

Description
An odour management plan (OMP) is part of the environmental management system (EMS) of the installation (see Section 2.3.1.1) and includes elements to prevent or reduce odorous nuisances.

Technical description
The OMP includes:

- a protocol containing actions and timelines;
- a protocol for conducting odour monitoring;
- a protocol for response to identified odour incidents;
- an odour prevention and reduction programme designed to identify the source(s), to measure/estimate odour exposure, to characterise the contributions of the sources, and to implement prevention and/or reduction measures.

~~In designing and implementing a structured odour management plan, the plan needs to:~~

a. ~~describe the main activities which generate odour and/or the sources of odour, also covering any relevant environmental surveys which have been undertaken and the technical choices available for controlling odorous emissions~~
b. ~~initiate or further develop an inventory of the odorous materials used or generated, covering also all intentional and fugitive (unintentional) release points~~
c. ~~detail any routine monitoring undertaken to assess the odour exposure of receptors~~
d. ~~provide a system for reporting the results of monitoring and for recording any complaints received~~
e. ~~identify the actions needed to be taken in the event of abnormal events occurring or conditions which might lead to odour, or potential odour problems~~

Achieved environmental benefits
Prevention or reduction of the emissions of those odorous releases that may be offensive and detectable beyond the boundaries of the site.

WORKING DRAFT IN PROGRESS

Environmental performance and operational data
No information provided.

Cross-media effects
No information provided.

Technical considerations related to applicability
~~For complex installations, for example where there are a number of potential sources of odorous releases or where there is an extensive programme of improvements being put in place to bring odour under control, an odour management plan will typically be maintained.~~
The technique is applicable to new and existing plants provided that an odour nuisance in residential or other sensitive areas (e.g. recreational areas) can be expected and/or has been reported.

Economics
No information provided.

Driving force for implementation
Reduction of number of complaints from neighbourhood.

Example plants
No information provided.

Reference literature
[28, Scori 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [58, VDI and Dechema 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [76, Prantner 2002][77, Schmidt et al. 2002] [98, WT TWG 2004] [100, WT TWG 2004] [103, VROM 2004]

2.3.5.2 Techniques for the prevention or reduction of odour emissions from waste treatment

Based on CWW Section 3.5.5.4

Description
The techniques given below can be used to minimise odour emissions:

- minimise the residence time of odorous waste in collection and storage systems, in particular under anaerobic conditions (when relevant);
- use of chemicals to destroy or to reduce the formation of odorous compounds (e.g. oxidation or precipitation of hydrogen sulphide);
- optimise the aerobic treatment, e.g. by controlling the oxygen content, frequent maintenance of the aeration system, use of pure oxygen and/or removal of scum in tanks;
- cover or enclose facilities for storing, handling, collecting and treating odourous waste (including waste water and sludge) and collect the odorous waste gas for further treatment;
- end-of-pipe treatment.

Technical description

Table 2.41 provides an overview of end-of-pipe odour treatment techniques.

WORKING DRAFT IN PROGRESS

Table 2.41: Overview of end-of-pipe odour treatment techniques

Technique	Reported odour abatement efficiency (1)	Comments
Adsorption	80–99	–
Wet scrubbing	60–85	–
Alkaline oxidative scrubbing	80–90	Variant of the absorption technique
Thermal oxidation	98–99.9	–
Catalytic oxidation	80–95	–
Biofiltration (2)	70–99	Low shift of pollution to any other media. Few chemical agents added. Low energy consumption
Bioscrubbing (2)	70–80	–
Biotrickling	70–90	–
Moving-bed trickling filter	> 90	–
Ionisation	80–98	–
Photo/UV oxidation	80–98	–

(1) As reported in the corresponding sections of this document where the techniques are described.
(2) Biofiltration and bioscrubbing can be combined into one system to benefit from the advantages of both techniques. The bioscrubber would act as a humidifier and degrade a high portion of the odorous load. It will also display a buffering effect to prevent high concentrations of odorous substances from entering the biofilter, which otherwise might lead to a rise in temperature in the biofilter material due to an increasing degradation process. Elevated temperatures would result in a lower efficiency of the biofilter.
Source: [138, COM 2014]

See [138, COM 2014] for more details on odour abatement techniques.

Achieved environmental benefits
Reduction of odorous emissions.

Cross-media effects
The cross-media effects associated with the abatement techniques used (e.g. scrubber, incinerator/oxidiser) are described in the section of the BREF relevant to each specific technique. Management-type techniques have no cross-media effects. Removing surface scum and skimmings in waste water treatment tanks entails the use of energy.

Operational data
See [138, COM 2014].

Applicability
The techniques are generally applicable.

Economics
No information provided.

Driving force for implementation
The driving forces for the implementation of the techniques mentioned include:

- national legislation on odours (e.g. TA Luft in Germany);
- odour nuisances (especially from sludge treatment) in the case of nearby housing;
- occurrence of odorous substances from anaerobic reactors, especially when waste water contains high concentrations of sulphate, which is converted to sulphides.

Example plants
See Chapters 3 to 5.

WORKING DRAFT IN PROGRESS

Reference literature
[138, COM 2014]

2.3.5.3 Diffuse emissions reduction programme

Text based on CWW section 3.5.4.2

Description
Selection of operational and design measures as part of the EMS and which can be implemented to prevent or reduce diffuse emissions to air of dust, bioaerosols and/or VOCs.

Technical description
Several operational and design measures might be selected, on the basis of the expected type of emissions:

Limitation of potential emission sources

- To design piping layout appropriately by:
    - minimising pipe run length;
    - reducing the number of flanges (connectors) and valves;
    - using welded fittings and pipes.
- To use, if possible, pressure transfer (e.g. gravity) to eliminate the use of pumps.

Selection of high-integrity equipment

- Valves with double packing seals or equally efficient equipment.
- Fitting high-integrity gaskets (such as spiral wound, kammprofile or ring joints) for critical applications.
- pumps/compressors/agitators fitted with mechanical seals instead of packing.
- Magnetically driven pumps/compressors/agitators.

Selection of appropriate materials for equipment

- To ensure that all equipment (e.g. gaskets) is selected appropriately for each process application.
- To avoid corrosion by appropriate selection of construction material.
- To prevent corrosion by lining or coating of equipment, by painting pipes to prevent external corrosion and by using corrosion inhibitors of materials in contact with equipment.

Containment and collection of diffuse emissions

- To enclose (partially or completely) liquid effluent drainage systems and tanks used for liquid effluent storage/treatment. Emissions from tanks containing wastes that may generate emissions to air (such as VOCs) are controlled, e.g. with flow-balancing systems, and/or abated, e.g. with activated carbon filters.
- To minimise emissions during sampling by using closed sampling systems or in-line analysers.
- To install a maintenance drain-out system to eliminate open discharges from drains.
- To cover conveyor belts, especially the connection points and discharge areas.
- To enclose transfer points and sorting facilities.
- To ensure enclosure by work instructions or automation, e.g. closing doors.

From ex-**Section 4.6.1 "Generic prevention techniques"**

a. ~~using an~~ The enclosed systems or buildings are equipped with extraction, or are under negative pressure ~~depression~~, and are connected to a suitable abatement plant. ~~especially during processes involving the transfer of volatile liquids or handling wastes~~

WORKING DRAFT IN PROGRESS

~~that generate VOC emissions, including during tanker charging/discharging, and applying a suitably sized extraction system which can cover the holding tanks, pre-treatment areas, storage tanks, mixing/reaction tanks and the filter press areas, or to have having in place a separate system to treat vent gases from specific tanks (e.g. activated carbon filters from tanks holding waste contaminated with solvents)~~

From ex-**Section 4.3.2.3 "Immobilisation"**

b. ~~using~~ Extraction systems are designed to take into account the removal of the large volumes of air present due to the dimensions of the mixing areas and the need to have vehicular access for loading and unloading. It will also be necessary to demonstrate that the design of the extraction systems are capable of controlling all foreseeable emissions, other than in emergency situations.

~~c. having a central abatement system in place to handle the flow of air, as well as the peak loadings associated with charging and unloading~~

- To have localised extraction and/or misting/sprinkler systems on equipment with heavy dust formation (e.g. screening drums) or in storage areas, at handling or dust-intensive process steps such as unloading. These systems distribute a fine spray of water that stops the dust from rising while binding the water at the same time to prevent waste water.
- To have separate suction and abatement units for sorting and transportation units (no pressure release necessary in the case of shredders).

d. To use ~~using~~ wind barriers.

Selection of input waste

From ex-Section 4.6.22

f. Place emphasis on pre-acceptance screening (see Section 2.3.2.1) and on the rejection of specific wastes. For example, and particularly for odorous materials, they need to be handled in dedicated sealed handling areas which incorporate an extraction system leading to abatement equipment.

Storing waste

From ex-**Sections 4.1.4.1 "Generic techniques applied to waste storage", 4.1.4.2 "Techniques for the storage of drums and other containerised wastes"** and **4.1.4.5 "Restricting the use of open topped tanks, vessels or pits"**

a. To store containerised wastes under cover. Covered areas ~~need to~~ have adequate provision for ventilation (resulting in the storage area being kept above or below atmospheric pressure). This ~~can also be~~ applies to any container to any container held in general storage, reception storage (pending acceptance), quarantine, or which is being emptied, repackaged or otherwise managed.~~that is held in storage pending sampling and the emptying of containers.~~ The air is treated before it is released depending on the type of contamination, if any.

b. To store drums and containers of odorous materials in enclosed buildings connected to abatement units.

c. To store the waste and materials that can generate diffuse emissions of dust (e.g. SLF, SHF in the case of shredders) in closed or semi-closed containers.

d. ~~ensuring that~~ ~~incorporating~~ To install extraction systems for particulate abatement or spray damping in storage bunkers.

~~e. applying positive ventilation or keeping the storage area below atmospheric pressure~~

Handling waste

From ex-**Section 4.2.2 "Specific storage and handling techniques for biological treatments"** items

- To dampen the material that can generate diffuse emissions of dust with water before and during loading and conditioning processes.
- To reduce the drop height for the material.
- To avoid~~ing~~ traffic routes through the delivery area.
- To set speed limits for trucks.

WORKING DRAFT IN PROGRESS

- To minimise the storage time of wastes in the delivery area.

Mixing waste

From ex-**Section 4.3.2.3 "Immobilisation"**

e. To implement~~ing~~ measures to restrict dusty reagents.

~~f. restricting wastes to those with low concentrations of VOCs or odorous components (see Applicability and Cross-media Sections below)~~

~~g. employing controlled and enclosed methods of charging~~

h. To mix~~ing~~ reagents and waste using impellers or mixing systems integral to the mixing vessel.

i. To use screw feeders, gravity or pneumatic means for handling systems for bulk transfer of dry wastes and reagents.

j. To deliver~~ing~~ the feedstock by pipe into the mixing vessel.

Maintenance and cleaning

- To facilitate maintenance activities by ensuring access to potentially leaky equipment.
- To regularly control and maintain protective equipment, e.g. lamellar curtains.

From ex-**Section 4.2.2 "Specific storage and handling techniques for biological treatments"** items

f. To keep~~ing~~ the pollution of the exhaust air low by:
  - using surfaces and work equipment that are easy to clean;
  - cleaning the floor of the hall regularly with an appropriate sweep-suction cleaner or industrial vacuum cleaner.

- To reinforcement, maintain and wash driveways during periods of dry weather.
- To clean~~ing~~ sunshades, conveyor bands and other equipment at least once per week.
- To use a tyre-washing plant to prevent dispersion of waste by ~~the~~ vehicles ~~in~~to the outer areas of the plant.

From ex-**Section 4.6.1 "Generic prevention techniques".** Relates to soil excavation.

~~k. completely enclosing the entire site (e.g. in a dome)~~

~~l. using synthetic soil covers. The synthetic cover may be a thin (0.1 – 0.15 mm) plastic sheeting or consist of relatively thick (0.75 – 1 mm) plastic sheeting or geotextile material. The resistance of various polymers to chemicals, weather, gas permeability, and tears is documented. Typically the barrier material will be available in large rolls and can be quickly applied to even large soil piles. The synthetic cover must be secured against wind~~

From ex-Section 4.6.22

~~g. cover the maintenance requirements of the containment and the management of the operations where odour can be contained, for example within buildings~~

~~h. take into account the scrubber liquors to ensure that they are also closely monitored to ensure optimum performance, i.e. with respect to correct pH, on-time replenishment and replacement~~

~~i. cover the vacuum extraction requirements for installations causing odours~~

~~j. cover the enclosure requirements within buildings zones where VOC emissions are high and may provoke high odours.~~

From ex-Section 4.2.2

~~a. depositing dust through defogging systems, although this is not mandatory~~

~~b. using suction to extraction point sources and hall air, with subsequent dedusting~~

~~c. applying coverage of the belt conveyor~~

~~d. preventing or minimising large falling heights at interband transmissions~~

~~e. using slowly running comminution aggregates~~

~~f. regularly cleaning aggregate areas, hall floors and traffic routes~~

WORKING DRAFT IN PROGRESS

Achieved environmental benefits

Reduction of VOC, odour and dust emissions.

Environmental performance and operational data

From ex-Section 4.1.4

Common abatement systems can be connected to the venting systems for tanks, to reduce solvent losses to the air due to displacement when filling tanks and tankers. Sites handling dusty wastes may have specific hoods, filters and extraction systems.

Cross-media effects

Water usage when dampening the material.

A positive side effect of enclosure is the reduction of noise for workers on site.

Technical considerations relevant to applicability

Some of the design measures may be applicable only to new plants or plants undergoing refurbishment.

Not all measures are applicable for all types of diffuse emissions (dust, bioaerosols, odour, VOCs).

Economics

No information available.

Driving force for implementation

- Legislation on air pollution.
- Reduction of number of complaints from neighbourhood.

From ex-**Section 4.6.1 "Generic prevention techniques".** Relates to soil excavation.

~~**Achieved environmental benefits**~~

~~Reduces fugitive emissions to the air (e.g. dust, VOC and odour). The effectiveness of soil covers will depend on the depth of the cover and the percentage of contaminated soil that can be covered. Measured emission rates may be substantially reduced (e.g. >95 %) by the addition of compacted soil; however, lateral migration of VOCs may still occur.~~

~~If warranted, complete enclosure of the excavation site can be accomplished to minimise fugitive emissions. The enclosure acts to collect any emissions, which can then be vented to some type of control device suitable for point sources. The enclosure may be either air supported or self supported. If properly designed and operated, the enclosure may reduce fugitive emissions to negligible levels.~~

~~For small work areas, the use of wind barriers can reduce fugitive emissions (e.g. VOC) by lowering the effective wind speed at the soil surface. Commercial, porous wind fence material that is typically used for dust control has been found to be more effective than solid fence material.~~

~~Facilities which discharge odours and dust may be enclosed to prevent emissions and to reduce the amount of contaminated air which has to be cleaned afterwards. A well operating exhaust air collection system ensures a minimum of germs, fungi, spores, odours and dust particles. This may have positive effects on the physical health of the employees and reduces times absent due to sickness.~~

~~**Cross-media effects**~~

WORKING DRAFT IN PROGRESS

~~The synthetic cover barrier can be left in place indefinitely, although physical and photodegradation of the polymer will tend to limit the effective lifetime of thin barriers to a few weeks.~~

~~Soil covers will be less effective over long time periods and their use will tend to increase the total volume and mass of material that must be treated.~~

~~Operational data~~

~~The most commonly used VOC control approach for area sources, e.g. during excavation, is the use of covers to provide a physical barrier to vapour transport. The simplest barrier is the use of relatively clean soil as a cover for contaminated soil. The soil layer increases the necessary transport distance for vapour diffusion and thus greatly reduces, at least temporarily, the emission rate. The effectiveness of the cover will depend on its permeability to the vapours that are present and the percentage of the soil pile that is adequately covered. Laboratory measurements of a 0.5 mm PVC membrane showed relatively poor performance for limiting vapour diffusion.~~

~~Self-supported domes are more practical if trucks or other heavy equipment must regularly enter and leave the structure.~~

~~With respect to the need for dust removal in biological treatment plants, the upstream process plays a crucial role. In the humid exhaust gas from the biological process, potential dust emissions are effectively removed. All mechanical steps for the processing of dry materials inevitably lead to dust emissions. In this case, encapsulation of the aggregates in question is necessary. In these mechanical steps, the exhaust air has to be subjected to effective dust removal. Values of less than 10 mg/Nm^3 can be achieved by different techniques. Techniques in the prevention of the formation of bioaerosols and dusts in biological treatment plants include:~~

a. ~~ensuring that the optimum moisture content is maintained during the aerobic process~~
b. ~~ensuring that the digested material is turned regularly~~
c. ~~maintaining good housekeeping (see Section)~~
d. ~~erecting bunding/planting trees around the perimeter of the site.~~

Applicability

~~Synthetic covers are typically used to control VOC emissions from excavated soil in short term storage piles. Synthetic covers are also widely used to control VOC emissions during transport by rail or road.~~

~~There are severe limitations that limit the use of complete enclosures to the few sites where other control options are not acceptable. Air temperatures within the structure may be high enough to affect worker productivity and safety. The additional safety requirements, along with the additional time required for trucks getting in and out of the structure, will likely lengthen the time needed to complete the excavation and will thereby increase the costs.~~

~~For large working areas, fencing is less practical. VOC (and PM) emissions from storage piles can be minimised by controlling the placement and shape of the piles. When feasible, the piles can be placed in areas shielded from the prevailing winds at the site. The amount of surface area can be minimised for the given volume of soil by shaping the pile. The orientation of the pile will affect the wind velocity across the pile, with the lowest wind speed occurring when the length of the pile is perpendicular to the prevailing wind direction.~~

~~The selection of a VOC abatement technique to be applied depends mainly on the properties of the VOC. Moreover, these techniques are particularly sensitive to flowrates and concentration.~~

~~Economics~~

~~The capital cost of the structure for total enclosure is relatively high. Operating costs also can be very high if large volumes of air must be treated and exhausted to keep the concentrations of contaminants in the internal air within the dome at levels that are safe for workers health.~~

WORKING DRAFT IN PROGRESS

Table 2.42: Summary of emission control costs for area sources applied to excavation and removal

~~**Emission control technique**~~	~~**Material cost (USD/m^2 except if otherwise noted)**~~	~~**Comments**~~
~~Clay~~	~~4.15~~	~~Covers, mat and membrane~~
~~Soil~~	~~1.33~~	~~Assume 15 cm deep; does not include soil transport~~
~~Wood chips, plastic net~~	~~0.50~~	~~Chip costs vary with site~~
~~Synthetic Cover~~	~~4.40~~	~~Assume 1.14 mm thickness~~
~~Short-term foam~~	~~0.04~~	~~Assume 6 cm thick, USD 0.7/m^3 foam~~
~~Long-term foam~~	~~0.13~~	~~Assume 3.8 cm thick, USD 3.3/m^3 foam~~
~~Wind screen~~	~~40/m~~	~~Per linear metre~~

~~**[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]**~~

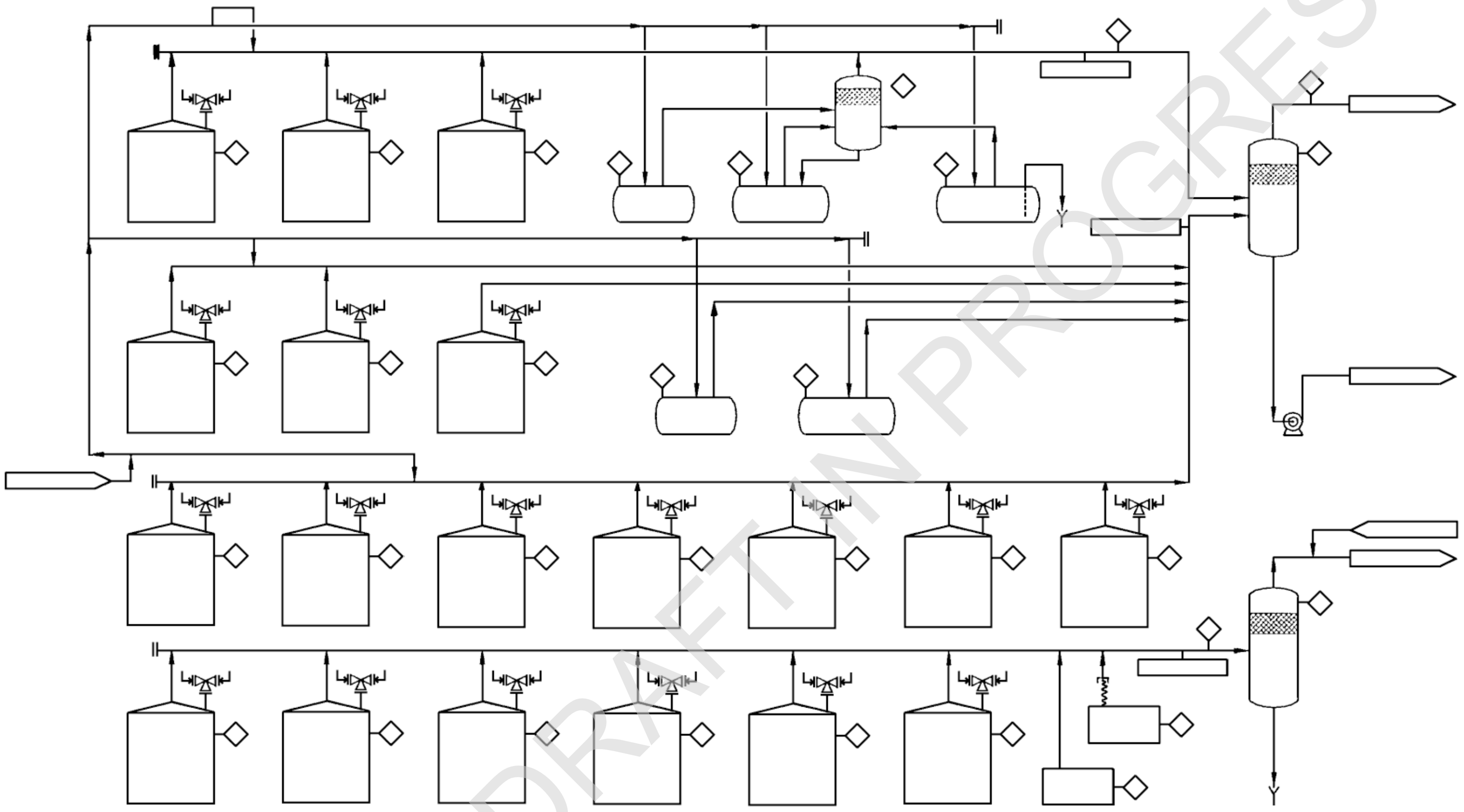
Example plants

The majority of chemical plants have an air extraction and scrubbing system for the main processing tanks and for any pretreatment operations that could produce a toxic gaseous discharge to air. Most WT plants have some abatement systems in place to control emissions to air, but the type and level of control vary widely.

From ex-**Section 4.1.4.1 "Generic techniques applied to waste storage"**

Sites storing organic wastes with a solvent content tend to have a carbon filter system to control discharges to air and to undertake some monitoring of the exit gas. Some VOCs can be returned to solution through aqueous scrubbers or mineral oil scrubbers, whilst other VOCs can be trapped in activated carbon filters. Roofed tanks are common when storing materials containing products with high vapour pressure. Special equipment is required when storing highly flammable products. Special care is typically taken in order to avoid leaks and spillages to the ground which would pollute the soil and groundwater or allow material to enter the surface water. Some sites have balancing systems (with nitrogen gas) to reduce the air displacement when filling the tanks. ~~Blanketing and balancing of~~ All storage tanks used in a re-refining process ~~is carried out~~ are blanketed and balanced. The amount of displacement to vents during the transfer of contents is minimised in some cases by connected vent pipes. See an example in **Figure 2.32** below.

WORKING DRAFT IN PROGRESS



APPAREC.	UNITA' DI MISURA	1	2	3	4	5	6	7	8	9	10	11	12
PRODOTTO	/	S-5 VISCOFLEX MC 38	S-102 VISCOFLEX MC 33	S-101 VISCOFLEX MC 33	V-201 RICEVITORE IMP. TCT	02-B2 RIC. BAROM. VACUUM	/	02-V1 RICEV. IMP. STRIPP. H2O	C-303 SEPAR. GAS CORRENTE "A1"	CORR. "A1" A KO DRUM 08-V1	S-33 GASOLIO MC 80	S-34 GASOLIO MC 80	TK-401 OL. DISOR. MC 750
CORRENTI	/	CORR. "A1"	CORR. "A1"	CORR. "A1"	CORR. "A1"	CORR. "A1"	/	CORR. "A1"	CORR. "A1"	CORR. "A1"	CORR. "A2"	CORR. "A2"	CORR. "A2"
STATO	/	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	/	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	GASSOSO IDROC+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2
TEMPERATURA	°C	140	140	140	35	55	/	35	40	40	30	30	120
PRESSIONE	mm/H20	/	/	/	1000	400	/	400	80	80	/	/	100

APPAREC.	UNITA' DI MISURA	13	14	15	16	17	18	19	20	21	22	23	24
PRODOTTO	/	V-302 RICEV. IMP. PREFLASH	CS-401 SEP. VAR. IMP. TDA	S-45 GASOL.+H2O MC 37	S-46 GASOL.+H2O MC 37	S-104 OL. DISOR. MC 60	S-60 VISCOFLEX MC 150	S-59 VISCOFLEX MC 150	S-56 VISCOFLEX MC 150	S-58 GASOLIO MC 150	CORR. "A2" A KO DRUM 08-V1	08-V1 SEPAR. GAS A COMBUST.	08-V1 GAS A COMBUST.
CORRENTI	/	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	COR."A1+A2" A COMBUSTIONE	COR."A1+A2"
STATO	/	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	LIQUIDO+ GAS+H2	GASSOSO IDROC+H2	GASSOSO IDROC+H2	GASSOSO IDROC+H2
TEMPERATURA	°C	30	30	30	30	50	140	140	140	30	30	30	30
PRESSIONE	mm/H20	200	100	/	/	/	/	/	/	/	/	20	−10

APPAREC.	UNITA' DI MISURA	25	26	27	28	29	30	31	32	33	34	
PRODOTTO	/	S-53 GASOLIO MC 150	S-52 GASOLIO MC 150	S-49 GASOLIO MC 150	S-51 GASOLIO MC 150	S-54 GASOLIO MC 150	S-97 [illegible] MC 120	VASCA V-1 H2O PROC. DA CENTR.	BRACCIO DI CARICO DENSIONE	COLLETTORE CORR. "B" A 08-V2	08-V2 SEP. A COND. A COMBUST.	
CORRENTI	/	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	
STATO	/	LIQUIDO+ TRAC. IDROC.	LIQUIDO+ TRAC. IDROC.	LIQUIDO+ TRAC. IDROC.	LIQUIDO+ TRAC. IDROC.	LIQUIDO+ TRAC. IDROC.	LIQUIDO+ TRAC. IDROC.	LIQUIDO	ARIA+TRAC. IDROCARB.	ARIA+TRAC. IDROCARB.	ARIA+TRAC. IDROCARB.	
TEMPERATURA	°C	30	40	30	30	30	35	30	SALTUARIO	/	30	
PRESSIONE	mm/H20	/	/	/	/	/	/	/	/	-30 mm/H20	-35 mm/H20	

Source: [21, Viscolube 2002]

Figure 2.32: Blanketing system in a storage system used in a waste oil re-refining facility

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One EU installation has blanketed all the storage tanks of the input and intermediate materials of the process. The only tanks that are not blanketed are for gas oil (different kinds) and water. Another EU installation has blanketed all the storage tanks of output and intermediate materials of the process. ~~Traps of~~ VOC and odour traps in storage tanks are common in many waste oil refineries. This type of installation is also common in the preparation of waste fuel from liquid organic wastes.

Reference literature

[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997] [28, Scori 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [78, Eucopro 2003] [82, Pretz et al. 2003] [88, UBA Germany 2003] [98, WT TWG 2004] [100, WT TWG 2004] [107, Mech. subgroup 2014] [138, CWW]

2.3.5.4 Leak detection and repair programme

From ex-**Section 4.6.2 "Leak detection and repair programme"**

Description

A leak detection and repair (LDAR) programme for plants handling ~~solvents and similar~~ volatile materials.

Technical description

An LDAR programme may include the following:

a. Identifying, and where possible, quantifying significant fugitive emissions to air from all relevant sources, estimating the proportion of total emissions which are attributable to fugitive releases for each substance.
b. Direct monitoring of valves, pump seals, etc. using a portable organic vapour analysing instrument to check for leaks (sniffing or optical gas imaging (OGI), [138, COM 2014]).
c. Using non-intrusive tank volume measurements.
d. Replacing filter pot lids when cleaning filters.
e. Storing filter slops in sealed drums.
f. Storing contaminated waters which have the potential for odours in covered tanks.
g. Using drum storage (see Section 2.3.13.2).
h. Ensuring that regular cleaning/desludging of tanks is carried out, using maintenance schedules to avoid large-scale decontamination activities.
i. Tanker washing if the load is likely to give rise to odour. The washing water/aqueous waste from the washing needs to be directly discharged to abated storage systems before opening the tankers. Open tankers for the minimum amount of time possible.
j. Undertaking maintenance activities for fixing any detected leaks, e.g. replacing valve packing.

Achieved environmental benefits

Detection of leaks of VOCs from valves, pumps and other piping components.

Environmental performance and operational data

No information available.

Cross-media effects

None.

Technical consideration related to applicability

Suitable for sites that contain a large number of piping components (e.g. valves) and that process a significant amount of lighter hydrocarbons (e.g. solvents).

Economics

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~~The cost of a leak detection survey and associated repairs can be partially offset by savings from reduced material losses to the air. Savings are dependent upon the value of the material being lost.~~

The investment costs for an analyser were reported to be EUR 5 000–20 000 for sniffing and EUR 70 000–100 000 for OGI. During operation, the main difference is the time required for surveying. When using sniffing methods, only about 500 components can be checked per day by a surveying team. In contrast, optical gas imaging techniques allow 15 000 to 20 000 components per day to be surveyed. Therefore, sniffing methods are generally less expensive in the case of small plants, while OGI is less expensive in the case of large plants [138, COM 2014]

In a typical US refinery or large petrochemical plant with over 200 000 regulated components, the annual cost for an LDAR programme is reported to exceed EUR 750 000 (actual cost USD 1 000 000, average 2010 USD/EUR exchange rate) with the US EPA Method 21 based on sniffing.

Driving force for implementation

- Legislation on air pollution.
- Optimisation of process performance.
- Health and safety of staff.

Example plants

No information available.

Reference literature

[33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [98, WT TWG 2004] [138, COM 2014]

2.3.5.5 Flaring

Text based on CWW section 3.5.1.5

Description

Flaring is a high-temperature oxidation process used to burn combustible components of waste gases from industrial operations. Flares are used for safety reasons or during non-routine operating conditions (e.g. start-ups, shutdowns).

Technical description

Flaring is used to safely combust vented flammable gases (hydrocarbons) at a pressure drop which does not compromise plant relief systems.

Flaring is also used at plants using anaerobic digesters to produce biogas (see section 4.3). These plants generate a methane-rich biogas which may be used to generate electricity and process heat. The (part of the) biogas that is not consumed or stored is flared.

Because flaring is both a source of pollution and leads to the burning of a potentially valuable product, its use should be limited to non-routine or emergency releases. Uncontrolled emissions (especially VOCs) from vents and relief valves should be routed to recovery systems, with flares serving only as a backup system.

See [138, COM 2014] for further details on flaring.

Techniques to prevent or reduce emissions from flaring are as follows ([145, COM 2015]):

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- **Correct plant design**: includes sufficient flare gas recovery system capacity, the use of high-integrity relief valves and other measures to use flaring only as a safety system for other than normal operations (start-up, shutdown, emergency).
- **Plant management**: includes organisational and control measures to reduce flaring events by balancing the gas system, using advanced process control, etc.
- **Flare design**: includes height, pressure, assistance by steam, air or gas, type of flare tips, etc. It aims to enable smokeless and reliable operations and ensure the efficient combustion of excess gases when flaring from non-routine operations.
- **Monitoring and reporting**: Continuous monitoring (measurements of gas flow and estimations of other parameters) of gas sent to flaring and associated combustion parameters (e.g. flow gas mixture and heat content, ratio of assistance, velocity, purge gas flow rate, pollutant emissions). Reporting of flaring events makes it possible to include flaring ratio as a requirement in the EMS and to prevent future events. Visual remote monitoring of the flare can also be carried out using colour TV monitors during flare events.

Achieved environmental benefits
Incineration of emergency releases.

Environmental performance and operational data
Abatement efficiencies and emission levels associated with flaring are given in Table 2.43.

Table 2.43: Abatement efficiencies and emission levels associated with flaring

Pollutant	Elevated flare		Ground flare	
	Abatement efficiency (1) (%)	Emission level (2) (mg/Nm^3)	Abatement efficiency (1) (%)	Emission level (2) (mg/Nm^3)
VOCs (including CH_4)	> 98 (3)	NI	> 99 (3)	NI
NO_X	NI	400 (200 ppm)	NI	400 (200 ppm)
	NI	108	NI	108
CO	NI	588	NI	588

(1) Efficiency depends on the specific plant configuration and operational conditions; the performances indicated are based upon half-hourly averages.
(2) The emission levels reported are indicative of what is being achieved at some industrial installations under normal operating conditions; because emission levels strongly depend on the specific plant configuration and operating conditions, the values given should be used with extreme caution for permitting.
(3) Under optimum conditions, i.e. heat content of waste gas > 8–11 MJ/Nm, low flows and low heat content achieve lower combustion efficiencies (as low as 65 %).
NB: NI = No information provided.
Source: [138, COM 2014]

The achievable emission levels mentioned in Table 2.43 report the destruction of air pollutants (VOCs) by flaring. The other parameters (NO_X) refer to emissions caused by flaring. Flaring has no waste gas treatment installed, hence pollutants generated by the incineration of waste gases which contain sulphur and/or halogens, NO_X, carbon monoxide, soot, etc. are normally not controlled. For these reasons, ground flares are not suited for toxic gases. The combination/recombination reaction to form dioxins, however, is not favoured because of the lack of a 'recombination window' and metal surfaces acting as catalysts.

The abatement performance of flaring, as described in the table above, will be > 98 % if the flare is designed and operated properly. Important parameters for achieving the optimum combustion efficiency are described below under operational data. The performance range under non-optimum conditions may be well below 98 %.

See [138, COM 2014] for more operational data.

Cross-media effects

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Flare emissions will include, at minimum, nitrogen oxides (NO_X), carbon monoxide (CO), and uncombusted flared gas compounds (e.g. VOCs). In addition, if the flared gas contains sulphur-bearing compounds, emissions will also include hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), thus causing potential odour nuisances (mainly for ground flares).
The main utilities and consumables include:

- smoke suppressants (steam, air, water, natural gas);
- ignition gas for the ignition pilot (propane or butane);
- purge gas (nitrogen or fuel) to keep the system on overpressure;
- pilot gas;
- energy.

Flaring can cause noise emissions. The most significant noise sources are:

- smoke suppressant injection;
- combustion processes;
- vents.

The suppression of noise is a crucial environmental issue and is thus an important design aspect that needs to be addressed for new flares. Noise avoidance aspects include:

- reducting or attenuating the high-frequency steam jet noise by using multiport steam injectors, which can also lead to increased coke formation under low flow conditions; orifice design to cope with this drawback is essential;
- installing the injectors in a way that allows the jet streams to interact and reduce the mixing noise;
- increasing the efficiency of the suppressant with better and more responsive forms of control;
- restricting the steam pressure to < 0.7 MPa gauge;
- using a silencer around the steam injector as an acoustic shield for the injectors;
- using air-blown flares or enclosed ground flares.

Further impacts include:

- light nuisance from elevated flares;
- odour nuisance because of insufficient combustion (mostly with ground flares).

Technical considerations related to applicability
Application limits and restrictions are given in Table 2.44.

Table 2.44: Application limits and restrictions associated with flaring

Parameters	Limits/restrictions
Typical gas flows (Nm^3/h)	0–1 800 000 (upper limit for elevated flares)
Minimum calorific value of incoming waste gas (MJ/Nm^3)	8–11
Combustion temperature (°C)	> 800
Pressure	Atmospheric
Oxygen content after incineration (%)	> 5 (muffle flare)
Flare velocity (m/s)	0–20 (to prevent flashback)

Source: [138, COM 2014]

Economics
Economics associated with flaring are given in Table 2.45.

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Table 2.45: Economics associated with flaring

Type of costs	Elevated flare	Ground flare
Investment/capital costs (EUR per 1 000 Nm^3/h)	~ 100 000–650 000 (1)	Could cost three to four times as much as elevated flares
Operating costs (per 1 000 Nm^3/h)	NI	NI
Labour	Can also vary widely; the skill of the maintenance personnel is the essential factor here	
Cost-effectiveness (per tonne of pollutant controlled per year)	NI	NI
Cost-determining parameters	Potential additional fuel	
Benefits	None	

(1) Onshore design without landing. The costs can vary widely because they are dependent on the number of hours the flare is used. Because a flare is primarily a safety system, the number of hours it is used will be low (10 to 100 hours per year).

NB: NI = No information provided.

Source: [138, COM 2014]

Driving force for implementation

The main driving force for implementation is safety.

Example plants

Table 2.46 shows the list of reference plants using flaring.

Table 2.46: Examples of plants using flaring

Main type of waste treatment	Plants using flaring
Anaerobic treatment of bio-waste	132, 251, 341, 415, 528, 529, 541, 592
Re-refining and other preparations for reuse of waste oils	605, 610, 619

Reference literature

[138, COM 2014] [145, COM 2015]

2.3.6 Techniques for the prevention and control of emissions to water

From ex-**Section 4.7 "Waste water management"**

~~This section only covers the management of waste water after it has already been contaminated. Prevention techniques to avoid the contamination of water or those techniques to reduce the consumption of water are not covered here and instead are included in Section 2.3.6.7.~~

~~This section only covers those techniques most relevant to the waste treatment sector. In general, most common techniques have already been described and analysed in many other BREFs (special reference should be made to the waste water and waste gas BREF [41, EIPPCB 2002]). For this reason, it is not the intention of this section to give a complete analysis of the different techniques, instead this section focuses only on those issues of particular relevance for the industrial sector covered in this document, as well as giving emission data for what is considered good achievable emission values in the Sector.~~

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~~The main purpose of waste water treatments is the reduction of the BOD content of liquid effluent (and as a consequence an associated reduction of COD).~~

2.3.6.1 Overview

From ex-Section **4.7.1 Management on the Waste water within the waste treatment sector**

Description

Treatment typically involves an agitation phase, which not only homogenises the slurry but also promotes the following actions:

- breakdown of solid particles;
- desorption of waste from solid particulates;
- contact between organic waste and microorganisms;
- oxidation of the slurry by aeration.

Waste water treatment combines chemical, physical and biological treatments. Usually this will include an aerobic stage, where the effluent is aerated in an aeration tank (0.5–3 days retention time) to convert soluble organics into microorganisms (sludge) and a cleaner final effluent. Biological degradation only occurs for ~~on~~ organics that are dissolved in water and not for ~~on~~ suspended or free-phase organics. In general, the treatment and purification of waste waters from waste treatment plants is an important element of these plants, mostly due to the potentially high pollution loads that may be in the waste water. A distinction can be made between separation and conversion processes.

Separation processes are, for instance:

- mechanical treatment;
- evaporation;
- adsorption;
- filtration;
- nanofiltration or ultrafiltration;
- reverse osmosis;
- centrifugation.

Whereas, conversion processes are, for example:

- wet oxidation using H_2O_2;
- ozonisation;
- precipitation/neutralisation;
- anaerobic and aerobic biological treatments of waste waters.

Figure 2.33 shows an example of an effluent management system for a WT plant.

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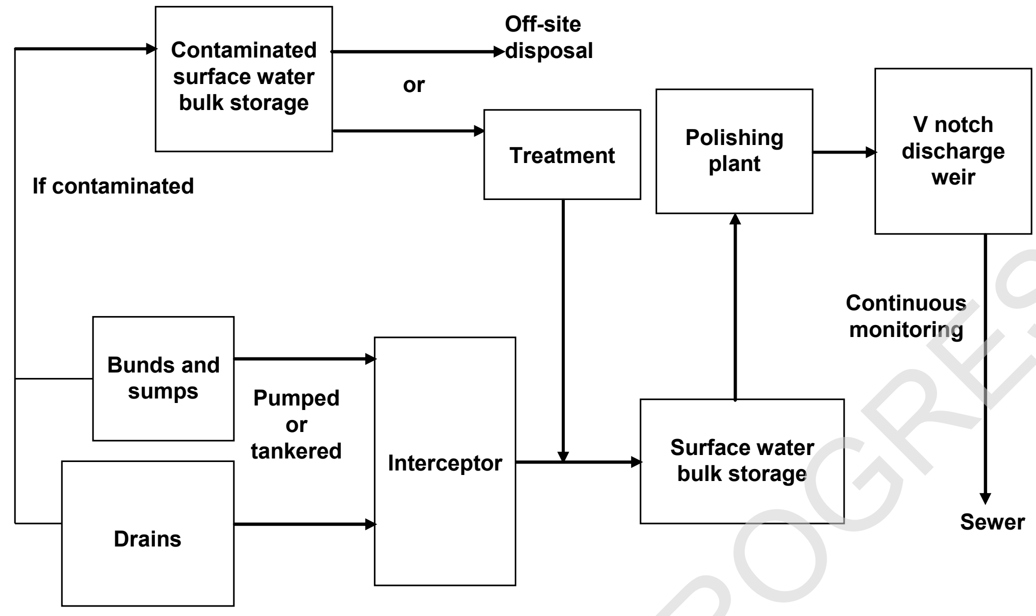

Source: [33, UK EA 2001]

Figure 2.33: Effluent management within a waste treatment plant

Sections 2.3.6.2 to 2.3.6.6 introduce the individual waste water treatment techniques as described in [138, COM 2014]. In the same way as for the techniques for the prevention and control of emissions to air (see Section 2.3.4), it is not intended in this section to provide a complete analysis of each of the different techniques. Instead, only a short description of the techniques is given as well as examples of plants of the data collection where these techniques are applied.

Table 2.47: Effluent management techniques

~~**Classification**~~	~~**Objective**~~	~~**Techniques**~~	~~**Section in this document**~~
~~Screening~~	~~To avoid introducing harmful and persistent substances into the system which will be unaffected by treatment~~	~~Pre-acceptance and acceptance measures~~	
~~Primary treatment~~	~~Removal or reduction of target substances from wastes~~		
~~Secondary treatment~~	~~Detoxification~~ ~~To convert dissolved substances into solids~~	~~Oxidation of cyanide or nitrite~~ ~~Reduction of chromium (VI)~~ ~~Precipitation of metals~~ ~~pH neutralisation~~ ~~COD reduction~~ ~~Settlement~~	
~~Tertiary treatment~~	~~Elimination of biodegradable organic and nitrogen compounds~~	~~Biological treatment~~ ~~Settlement~~ ~~Thickening and dewatering~~	
~~Final treatment~~	~~'Polishing' of effluent~~ ~~Recovery of substances from effluent~~	~~Filtration~~ ~~Membranes~~ ~~Wet air oxidation~~ ~~Adsorption~~	

~~Some techniques for effective waste water management include:~~

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Not specific to the waste treatment sector and/or repetition from other sections

a. ~~describing any off site treatment in the overall description of the waste water treatment system (in most cases this maybe an urban waste water treatment facility, such as a sewage works). Where effluent is treated off-site at a sewage treatment works, the waste water producers need to demonstrate that:~~
   - ~~the treatment provided at the sewage treatment works is as good as would be achieved if the emission was treated on site, based on the reduction of load (not concentration) of each substance to the receiving water~~
   - ~~the probability of sewer bypass, via storm/emergency overflows or at intermediate sewage pumping stations, is acceptably low~~
   - ~~action plans are in place to deal with any bypass occurring, e.g. knowing when the bypass is occurring, and rescheduling activities such as cleaning or even shutting then down while the by-pass is taking place~~
   - ~~a suitable monitoring programme is in place to check the emissions to sewer, taking into consideration the potential inhibition of any downstream biological processes and actions plan for any such event~~

b. ~~selecting the appropriate treatment technique for each type of waste water~~

c. ~~implementing measures to increase the reliability with which the required control and abatement performance can be carried out (for example, optimisating the precipitation of metals)~~

d. ~~identifying the main chemical constituents of the treated effluent (including the make-up of the COD) and making an informed assessment of the fate of these chemicals in the environment~~

e. ~~conducting daily checks (where there is daily discharge) on the effluent management system and maintaining a log of all checks having in place a system for monitoring effluent discharge and sludge quality~~

f. ~~having in place procedures to ensure that the effluent specification is suitable for the on-site effluent treatment system or discharge criteria~~

g. ~~avoiding effluent by-passing the treatment plant systems~~

~~Achieved environmental benefits~~

~~These techniques generally minimise emissions to load watercourses. They may also reduce the risk of contamination of process or surface water as well as reduce odour and VOC emissions.~~

~~Environmental performance and operational data~~

~~Cross media effects~~

~~The operation particularly relies on a good control of the feedstock to ensure that the waste does not inhibit the treatment process (e.g. biological).~~

~~Applicability~~

~~The reduction of water usage and waste water discharge is generally applicable applied in most waste treatment facilities. The waste treatment option applied depends on the type of contamination present in the waste water. However, measures for treatment of organic and inorganic contaminants are sometimes common. In some cases, specially for small sites, waste water treatments can be carried out off-site. These off-site central waste water treatments typically treat waste water from many installations, not only from WT installations.~~

~~Technique d (see description section above) needs to have in consideration that it is not realistic to perform an environmental impact assessment to all variations of the discharge of the WT installation.~~

~~The frequency of technique e (see description section above) is sometimes guided by a risk approach.~~

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~~Technique k (see description section above) can have restrictions to be applied due to the increase of the concentration of some soluble components that may interfere the waste treatment process.~~
~~Technique l (see description section above) may imply to have a further storage tank. This may potentially be costly and space is required especially for large and continuous flows.~~

~~**Driving force for implementation**~~
~~Water discharges are regulated by local/regional/national or international regulation.~~

~~**Example plants**~~
~~A large proportion of UK sites operate an enclosed system whereby rainwater falling on the processing areas is collected and returned to the processing plant. There are some examples of the re-use of water in immobilisation processes and in waste oil treatment plants after biological treatment. More examples for the re-use of water is in washing and cleaning purposes activities.~~

~~**Reference literature**~~

~~[28, Scori 2002] [29, Inertec; dechets, F. and Sita 2002] [30, Ecodeco 2002][33, UK EA 2001] [34, Babtie Group Ltd 2002] [44, TWG 2003] [60, WT TWG 2003] [77, Schmidt et al. 2002] [78, Eucopro 2003] [82, Pretz et al. 2003] [98, WT TWG 2004] [100, WT TWG 2004] [101, WT TWG 2005]~~

2.3.6.2 Equalisation

Text based on CWW BREF Section 3.3.2.1

Description
Buffer facilities ensure reasonably constant conditions of certain parameters, especially pH, hydraulic load (or flow rate) and contaminant loads/concentrations for the waste water treatment plant (WWTP).

Example plants
Table 2.48, shows the plants from the reference list performing equalisation of waste water.

Table 2.48: Plants performing equalisation of waste water

Plants performing equalisation of waste water	Main type of waste treatment
266, 415, 434	MBT
54, 136	Mechanical treatment in shredders of metal waste
40	Treatment of excavated contaminated soil
154_155C, 215, 216, 217, 317, 392, 393, 401_404, 486	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
605, 619, 620	Re-refining and other preparations for reuse of waste oils
73, 417, 418, 419	Aerobic treatment of source-separated bio-waste
341	Anaerobic treatment of bio-waste
152C, 174C	PCT of waste with calorific value

Reference literature
[138, COM 2014]

2.3.6.3 Neutralisation

Ex-**Section 4.3.1.3 "Neutralisation"** replaced by text based on CWW BREF Section 3.3.2.3.1

~~**Description**~~

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~~The purpose and principle of operation of the neutralisation is shown~~
~~. Some issues to consider include:~~

Items a and d of ex-Section 4.3.1.3 moved to Section 5.9.3.2

- ~~a. preventing the mixing of acidic/basic waste with other streams to be neutralised when the mix contains metals and complexing agents at the same time. This prevents the formation of metal complexes that are difficult (from an economic point of view) to separate afterwards. Complexing ions to watch out for include, for example, EDTA, NTA and cyanides~~
- ~~b. making the necessary neutralisation equipment robust and easy to use can help the equipment stand up to the vigours of use in Ph-c plants dealing with acidic/basic wastes needing neutralisation~~
- ~~c. ensuring that the customary measurement methods, i.e. with the aid of glass electrodes or similar sensors, are used in Ph-c plant operation for the neutralisation of waste matter if the electrodes are constantly cleaned and properly calibrated. Determination of the pH value is also possible by the measurement of prepared samples or by measurement using litmus paper~~
- ~~d. separately storing the neutralised waste water in order to avoid negatively affecting the quality of the treated waste water due to secondary reactions occurring if they were stored together. Final inspection of the treated waste water needs to be performed after a sufficient storage time has elapsed.~~

~~Achieved environmental benefits~~

~~Improves the neutralisation process performance and avoids downstream problems (e.g. preventing the mixing of wastes or other streams in a way that further treatment of the waste water is no longer possible).~~

~~Environmental performance and operational data~~

~~Cross-media effects~~

~~In a dilute aqueous system, it should be possible to conduct neutralisation processes without either deliberately or inadvertently producing gases. In such system processes involving potentially hazardous substances, for example, acid neutralisation can normally be performed without creating substances that require continuous abatement, for example,~~ ~~SO_x~~~~, etc.~~

~~Technical considerations relevant to applicability~~

~~Neutralisation can be applied with all mixable liquid waste.~~

~~If sulphuric acid (~~~~H_2SO_4~~~~) and milk of lime (~~~~$Ca(OH)_2$~~~~) are combined, gypsum (~~~~$CaSO_4 \cdot 2H_2O$~~~~) may be produced as a reaction product. The gypsum may lead to deposits and incrustation, causing serious operational disruption and necessitating extensive maintenance and repair measures. However, these problems can be minimised by adequate operation of the neutralisation process (using diluted~~ ~~H_2SO_4~~ ~~and pre-neutralisation with lime) and vigorous mixing. If NaOH instead of lime is used for neutralisation, other problems may occur. According to some experiences, high sulphate concentrations in the waste water caused by NaOH neutralisation may attack sewers made of concrete and consequently lead to odour emissions.~~

~~Economics~~

~~Driving force for implementation~~

~~Example plants~~

~~Reference literature~~

~~[33, UK EA 2001] [77, Schmidt et al. 2002] [98, WT TWG 2004]~~

Description

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Neutralisation is the process by which the pH of the incoming waste water is adjusted to the neutral pH level (approximately 7) by the addition of chemicals so as to make it biologically treatable in the waste water treatment plants and also to make it comply with discharge standards.

Example plants

Table 2.49 shows the plants from the reference list performing neutralisation of waste water.

Table 2.49: Plants performing neutralisation of waste water

Plants performing neutralisation of waste water	Main type of waste treatment
14	Treatment of excavated contaminated soil
04, 06, 153C, 154_155C, 192C, 322, 351_352, 395, 486, 550	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste

Reference literature

[138, COM 2014]

2.3.6.4 Mechanical separation of insoluble contaminants

2.3.6.4.1 Oil-water separation

Ex-**Section 4.3.1.5 "Break-up of emulsions"** replaced by text based on CWW Section 3.3.2.3.2.7

Description

The separation of oil and water and subsequent oil removal can be divided into:

- gravity separation of free oil, using separation equipment; and
- emulsion breaking, using emulsion-breaking chemicals.

Example plants

Table 2.50 and Table 2.51 show the plants from the reference list performing oil-water separation.

Table 2.50: Plants equipped with oil separators

Plants equipped with oil separators	Type of waste treatment
31, 133	Mechanical treatment of waste with calorific value
95C, 136, 288, 289, 290, 291, 441, 455, 456, 464, 478	Mechanical treatment in shredders of metal waste
605, 619	Re-refining and other preparations for reuse of waste oils
440	PCT of waste with calorific value
148C	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
307	Temporary storage of hazardous waste

Table 2.51: Plants performing emulsion breaking

Plants performing emulsion breaking	Type of waste treatment
569	Physico-chemical treatment of solid and/or pasty waste
07, 215, 216, 317, 322	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
307	Temporary storage of hazardous waste
282, 293	Mechanical treatment in shredders of metal waste

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Reference literature
[138, COM 2014]

2.3.6.4.2 Coagulation and flocculation

Text based on CWW BREF Section 3.3.2.3.2.2

Description
Coagulation and flocculation are used to separate suspended solids from waste water. They occur in successive steps which are intended to overcome the forces stabilising the suspended particles, allowing particle collision and the growth of the floc.

Coagulation is the first step. It aims at destabilising the particles' charge by neutralising their electrical surface charge. This is carried out by adding coagulants with charges opposite to those of the suspended solids to the waste water. This allows the particles to stick together into slightly larger particles.

Flocculation is a gentle mixing stage which aims at increasing the particle size. Collisions of microfloc particles cause them to bond to produce larger floc. This occurs in the presence of inorganic (formed by the coagulant) or added organic polymers. Contact times for flocculation range from 15 or 20 minutes to an hour or more.

Once the floc has reached the optimum size and strength, the waste water can be brought to sedimentation (see Section 2.3.6.4.4).

Example plants
Table 2.52 and **Table 2.53** show the plants from the reference list performing coagulation and flocculation of waste water respectively.

Table 2.52: Plants performing coagulation of waste water

Plants performing coagulation of waste water	Type of waste treatment
364_365	Mechanical treatment in shredders of metal waste
353_359, 354_360	Treatment of excavated contaminated soil
144_145_147C, 351_352, 401_404	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
170	Regeneration of spent solvents
366	Temporary storage of hazardous waste
152	PCT of waste with calorific value
569	Physico-chemical treatment of solid and/or pasty waste
361_363	Mechanical treatment of waste with calorific value

Table 2.53: Plants performing flocculation of waste water

Plants performing flocculation of waste water	Type of waste treatment
170	Regeneration of spent solvents
569	Physico-chemical treatment of solid/pasty waste
14	Treatment of excavated contaminated soil
07, 91, 215, 144_145_147C, 154_155, 351_352, 401_404	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste

Reference literature
[138, COM 2014]

WORKING DRAFT IN PROGRESS

2.3.6.4.3 Electrocoagulation

Text based on the CWW BREF

Description
The aim of electrocoagulation is to form precipitates and compounds between colloids so these substances can be separated in subsequent operations.

The release of coagulants in the waste water to be treated is realised by electrolytically dissolving an electrode (i.e. an anode, normally made of iron or aluminium). When the electrode is dissolved, gas is released (i.e. O_2, H_2) which results in a flotation effect. If necessary, a (support) flocculant can be added to improve the flotation yield.

Example plants
Only plant 152C is equipped with an electrocoagulation system. This plant performs PCT of waste with calorific value.

Reference literature
[138, COM 2014]

2.3.6.4.4 Sedimentation

Ex-**Section 4.3.1.16 "Sedimentation"** replaced by text based on CWW BREF Section 3.3.2.3.2.3

Description
Sedimentation, or clarification, is the separation of suspended particles and floating material by gravitational settling.

Example plants
See Table 2.54.

Table 2.54: Plants equipped with a sedimentation or decantation system

Plants performing sedimentation/decantation of waste water	**Type of waste treatment**
55, 136, 137, 294C, 364_365, 441, 455, 456, 464, 478, 571	Mechanical treatment in shredders of metal waste
14, 40, 353_359, 354_360	Treatment of excavated contaminated soil
144_145_147C, 149_150C, 154_155C, 192C, 216, 351_352, 392, 393, 486	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
170	Regeneration of spent solvents
366	Temporary storage of hazardous waste
172C, 174C	PCT of waste with calorific value
427	Physico-chemical treatment of solid and/or pasty waste
280C, 361_363, 443C	Mechanical treatment of waste with calorific value
481, 625	Aerobic treatment of excavated soil
104	Aerobic treatment of source-separated bio-waste
251	Anaerobic treatment of bio-waste
605, 619	Re-refining and other preparations for reuse of waste oils

Reference literature
[138, COM 2014]

WORKING DRAFT IN PROGRESS

2.3.6.4.5 Flotation

From ex-**Section 4.3.1.13 "Flotation"** replaced by text based on CWW BREF Section 3.3.2.3.2.4

Description

Flotation is a process in which solid or liquid particles or particulates are separated from the waste water phase by attaching to fine gas bubbles, usually air (nitrogen or fuel gas are commonly used in the oil industry). The buoyant particles accumulate at the water surface and are collected with skimmers.

Example plants

See **Table 2.55**.

Table 2.55: Plants performing flotation for waste water treatment

Plants performing flotation of waste water	Type of waste treatment
571	Mechanical treatment in shredders of metal waste
401_404, 423_424	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
152C	PCT of waste with calorific value
569	Physico-chemical treatment of solid and/or pasty waste
412	Aerobic treatment of source-separated bio-waste
235, 619	Re-refining and other preparations for reuse of waste oils

Reference literature

[138, COM 2014]

2.3.6.4.6 Filtration

From ex-**Section 4.3.1.12 "Filtration"** replaced by text based on CWW BREF Section 3.3.2.3.2.5

Description

Filtration is the separation of solids from waste water effluents passing through a porous medium.

In waste water treatment, filtration is frequently used as the final separation stage after sedimentation processes (see Section 2.3.6.4.4) or flotation (see Section 2.3.6.4.5), if low emissions of particulates are wanted, such as:

- separation of flocs, heavy metal hydroxides, etc. after sedimentation, to cope with discharge requirements;
- removal of activated sludge after the central biological WWTP, in addition to sedimentation, to improve the quality of biologically treated waste water effluent;
- dewatering of sludge, flotate, etc.;
- recovery of free oil, with rotary drum filters and the help of polymer addition.

Commonly used types of filter systems include:

- **the granular-medium filter or sand filter**, which is widely used as a waste water treatment device (the medium of sand filters need not literally be sand), mainly for waste water with a low solids content;
- the gravity **drum filter**, used for sewerage treatment and the removal of activated sludge flocs; its efficiency is dependent on the screen fabric;

WORKING DRAFT IN PROGRESS

- the **rotary vacuum filter**, which is used for oily sludge dewatering and slop de-emulsification;
- the **membrane filter** (see Section 2.3.6.4.7);
- the **belt filter press**, which is largely used for sludge dewatering, but also for liquid-solid separation operations;
- the **filter press**, which is usually used for sludge dewatering (see Section 2.3.6.7), but also for liquid-solid operations, and is suitable for high solid contents.

Example plants
See **Table 2.56**.

Table 2.56: Plants performing filtration of waste water

Plants performing filtration of waste water	Type of waste treatment
54, 55, 137, 364_365	Mechanical treatment in shredders of metal waste
40, 353_359, 354_360	Treatment of excavated contaminated soil
06, 90, 215, 216, 401_404, 486, 550	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
366	Temporary storage of hazardous waste
152C, 172C	PCT of waste with calorific value
427, 569	Physico-chemical treatment of solid and/or pasty waste
361_363	Mechanical treatment of waste with calorific value
620	Re-refining and other preparations for reuse of waste oils

Reference literature
[138, COM 2014]

2.3.6.4.7 Membrane filtration

Ex-**Section 4.3.1.15 "Membrane filtration" and** ex-**Section 4.7.6.3 "Membrane filtration"** replaced by text based on CWW BREF Section 3.3.2.3.2.6.

Description
Microfiltration (MF) and ultrafiltration (UF) are membrane processes that retain certain substances contained in waste waters on one side of the membrane.

Membrane filtration is applied when solid-free waste water is desired for downstream facilities, e.g. reverse osmosis or the complete removal of hazardous contaminants such as insoluble heavy metals. The choice between MF and UF depends on the particle size.

Common MF applications include:

- degreasing processes;
- metal particle recovery;
- metal plating waste water treatment;
- sludge separation after the activated sludge process in a central biological WWTP, replacing a secondary clarifier (activated membrane process), though UF can also be used.

Common UF applications include:

- removal of non-toxic degradable pollutants such as proteins and other macromolecular compounds and toxic non-degradable components, e.g. dyes and paints, with molecular weights greater than 1 000;

WORKING DRAFT IN PROGRESS

- segregation of oil/water emulsions;
- separation of heavy metals after complexation or precipitation;
- separation of components not readily degradable in sewerage treatment effluents, which are subsequently recycled to the biological stage;
- pretreatment step prior to reverse osmosis (see Section 2.3.6.5.4) or ion exchange (see Section 2.3.6.5.6).

Example plants
See **Table 2.57**.

Table 2.57: Plants equipped with membrane filtration for waste water treatment

Plants performing membrane filtration of waste water	Type of waste treatment
489	Treatment of excavated contaminated soil
140_141_142_143C, 151C, 159C, 194C, 216, 486	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
127, 244, 257	MBT
460	Aerobic treatment of source-separated bio-waste
459	Anaerobic treatment of bio-waste
605	Re-refining and other preparations for reuse of waste oils

Reference literature
[138, COM 2014]

2.3.6.5 Physico-chemical treatment of soluble non-biodegradable or inhibitory contaminants

From ex-Section 4.3.1

2.3.6.5.1 Precipitation of metals

Ex-**Section 4.3.1.4 "Chemical precipitation"** replaced by text based on CWW BREF Section 3.3.2.3.3.1

Description
Precipitation is a chemical reaction to form particulates (i.e. solid precipitate) that can subsequently be separated from the water portion by an additional process.

Typical precipitation chemicals are:

- lime (with lime milk, the preparation devices are part of the treatment unit) to precipitate heavy metals;
- dolomite to precipitate heavy metals;
- sodium hydroxide to precipitate heavy metals;
- sodium carbonate to precipitate heavy metals;
- calcium salts (other than lime) to precipitate sulphate or fluoride;
- sodium sulphide to precipitate heavy metals, e.g. arsenic, mercury, chromium, cadmium, nickel;
- polyorganosulphides to precipitate mercury.

Example plants
See **Table 2.58**

WORKING DRAFT IN PROGRESS

Table 2.58: **Plants using precipitation for waste water treatment**

Plants performing precipitation of waste water	Type of waste treatment
364_365	Mechanical treatment in shredders of metal waste
353_359, 354_360	Treatment of excavated contaminated soil
90, 91, 144_145_147C, 154_155C, 217, 317, 322, 351_352, 395, 423_424, 468, 550, 607	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
366	Temporary storage of hazardous waste
427, 569	Physico-chemical treatment of solid and/or pasty waste
361_363	Mechanical treatment of waste with calorific value
412, 413	Aerobic treatment of source-separated bio-waste
193C	Other

Reference literature
[138, COM 2014]

2.3.6.5.2 Chemical oxidation

Ex- **Section 4.3.1.7 "Techniques for the treatment of wastes containing cyanides"** and **ex-Section 4.7.6.4 "Ozone/UV treatment"** replaced by text based on CWW BREF Section 3.3.2.3.3.3

Description
Chemical oxidation is the conversion of pollutants by chemical-oxidising agents other than oxygen/air or bacteria into similar but less harmful or hazardous compounds and/or to short-chained and more easily degradable or biodegradable organic components. Chemical oxidation is also used to degrade organic compounds causing odour, taste and colour and for disinfection purposes.

Chemical-oxidising agents include:

- chlorine;
- sodium or calcium hypochlorite;
- chlorine dioxide;
- permanganate;
- ozone (with or without UV light);
- hydrogen peroxide;
- hydroxyl radicals generated by hydrogen peroxide (known as the Advanced Oxidation Process) in combination with:
    - ferrous salts (Fenton's agent), see [138, COM 2014] for a detailed description of an oxidation technique involving hydrogen peroxide and a ferrous ion catalyst;
    - ozone;
    - UV light;
    - pressure;
    - temperature.

From ex-Section 3.3.2 **Consumptions of physico-chemical treatments**

WORKING DRAFT IN PROGRESS

Table 2.59: Oxidation of cyanide and/or nitrite

~~Redox Reaction~~	~~Oxidising agent or reductor~~	~~pH~~	~~Observations~~
~~Oxidation of cyanide and nitrite~~	~~Sodium hypochlorite (NaOCl) or chlor gas (Cl^2)~~	~~for CN: ~ 10~~ ~~for NO^2: ~ 3~~	~~reaction relatively quick~~ ~~relatively high degree of salting up of the resultant waste water~~ ~~formation of organic materials, which are shown as AOX (Note: the limit value is AOX = 1 mg/l in the waste water to be introduced into the sewerage system)~~
~~Oxidation of cyanide and nitrite~~	~~Hydrogen peroxide (H^2O^2)~~	~~for CN: ~ 10, catalyst: Fe (II) salts~~ ~~for NO^2: ~ 4~~	~~reaction relatively slow~~ ~~negligible salting up of the waste water,~~ ~~no new formation of materials as AOX~~ ~~formation of mud, due to catalyst (Fe II salts)~~ ~~formation of foam (in particular in the presence of organic materials)~~
~~Oxidation of nitrite~~	~~Aminosulphonic acid (NH^2SO^3H)~~	~~~ 4~~	~~reaction slowed~~ ~~formation of sulphates~~ ~~formation of elementary nitrogen~~

~~[77, Schmidt et al. 2002]~~

From ex-**Section 4.3.1.10 "treatment of phenolic solutions by oxidation"**

~~It is possible to treat aqueous wastes containing phenol (3 – 5 w/w-%) by catalytic oxidation, using an oxidising agent and a metal catalyst or by a strong oxidising reagent (e.g. $KMnO_4$).~~

Example plants

See **Table 2.60**.

Table 2.60: Plants using chemical oxidation for waste water treatment

Plants performing chemical oxidation of waste water	**Type of waste treatment**
338	MBT
364_365	Mechanical treatment in shredders of metal waste
353_359, 354_360	Treatment of excavated contaminated soil
04, 91, 217, 317, 322, 401_404	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
366	Temporary storage of hazardous waste
361_363	Mechanical treatment of waste with calorific value
610, 619	Re-refining and other preparations for reuse of waste oils

Reference literature

[138, COM 2014]

2.3.6.5.2.1 Wet oxidation

Description

Wet oxidation (WO) is the reaction of oxygen in the aqueous phase at a high pressure and temperature, and is used to increase the solubility of oxygen in water.

Wet oxidation is applied to waste water which contains contaminants that are either not readily biodegradable or might disturb the biological process in a downstream biological WWTP, or

WORKING DRAFT IN PROGRESS

which have properties which are too harmful to allow them to be released into an ordinary sewer.

Example plants

Plant 368 performs wet oxidation at a temperature of 300 °C and a pressure of 130 bar. The reaction time is 30–40 minutes. Pollutants are converted to carbon dioxide, water, and intermediate oxidation products (low molecular weight organic compounds, such as acetic and propionic acid).

Reference literature

[138, COM 2014]

2.3.6.5.3 Chemical reduction

Ex-**Section 4.3.1.8 "Techniques for the treatment of wastes containing of chromium (VI) compounds"** replaced by text based on CWW BREF Section 3.3.2.3.3.4

Description

Chemical reduction is the conversion of pollutants by chemical-reducing agents into similar but less harmful or hazardous compounds. The target contaminants are inorganic compounds: chemical reduction is less effective with organic compounds.

Examples of such contaminants are:

- chromium (VI), which is reduced to chromium (III);
- chlorine or hypochlorite, which are reduced to chloride;
- hydrogen peroxide, which is reduced to water and oxygen;
- nitrite, using urea or amidosulphonic acid at a low pH.

Common chemical-reducing agents include:

- sulphur dioxide;
- sodium hydrogen sulphite/metabisulphite;
- ferrous sulphate;
- sodium sulphide and sodium hydrogen sulphide;
- urea or amidosulphonic acid (at low pH).

From ex-Section 3.3.2

WORKING DRAFT IN PROGRESS

Table 2.61: Reduction of chromate

~~**Redox Reaction**~~	~~**Oxidant or Reducing agent**~~	~~**pH**~~	~~**Observations**~~
~~Reduction of chromate~~	~~Sodium hydrogen sulphite (NaHSO^3)~~	~~∼ 2~~	~~fast reaction~~ ~~causes salting up of the waste water~~ ~~formation of mud~~
~~Reduction of chromate~~	~~sulphur dioxide (SO^2)~~	~~∼ 2~~	~~fast reaction~~ ~~slight salting of the waste water~~ ~~slight mud formation~~
~~Reduction of chromate~~	~~Sodium dithionite (Na^{2}S^{2}O^4)~~	~~pH independent~~	~~fast reaction~~ ~~leads to salting of the waste water~~ ~~formation of mud~~
~~Reduction of chromate~~	~~Iron (II) sulphate or chloride (FeSO^4/FeCl^2)~~	~~∼ 3~~	~~slow reaction~~ ~~leads to the salting up of the waste water~~ ~~formation of mud~~

~~[77, Schmidt et al. 2002]~~

Example plants

See **Table 2.62**.

Table 2.62: Plants using chemical reduction for waste water treatment

Plants performing chemical reduction of waste water	**Type of waste treatment**
364_365	Mechanical treatment in shredders of metal waste
353_359, 354_360	Treatment of excavated contaminated soil
04, 217, 317, 322	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
366	Temporary storage of hazardous waste
361_363	Mechanical treatment of waste with calorific value

Reference literature

[138, COM 2014]

2.3.6.5.4 Nanofiltration and reverse osmosis

Text based on CWW section 3.3.2.3.3.6

Description

A membrane process is the permeation of a liquid through a membrane, to be segregated into a permeate which passes through the membrane and a concentrate which is retained. The driving force of this process is the pressure difference across the membrane.

Nanofiltration (NF) and reverse osmosis (RO) membranes can hold back all particles down to the size of organic molecules and even ions.

NF is applied to remove larger organic molecules and multivalent ions in order to recycle and reuse the waste water or reduce its volume and simultaneously increase the concentration of contaminants to such an extent that subsequent destruction processes are feasible.

RO is a process to separate water and the dissolved constituents down to ionic species. It is applied when a high grade of purity is required. The segregated water phase is recycled and reused. Examples are:

WORKING DRAFT IN PROGRESS

- desalination;
- final removal of, for example:
    - degradable components if biological treatment is not available,
    - heavy metals,
    - toxic components;
- segregation of pollutants with the aim of concentrating or further processing them.

NF and RO are often used in combination with post-treatment techniques for the permeate, e.g. ion exchange (see Section 2.3.6.5.6) or GAC adsorption (see Section 2.3.6.5.8).

Example plants
See **Table 2.63**.

Table 2.63: Plants equipped with reverse osmosis system

Plants equipped with reverse osmosis system	Type of waste treatment
486	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
569	Physico-chemical treatment of solid and/or pasty waste
580	Aerobic treatment of source-separated bio-waste

Reference literature
[138, COM 2014]

2.3.6.5.5 Stripping

Ex-**Section 4.3.1.11 "Techniques for wastes containing ammonia"** replaced by text based on CWW BREF Section 3.3.2.3.3.16

Description
Waste water stripping is an operation in which waste water is brought into contact with a high flow of a gas current in order to transfer volatile pollutants from the water phase to the gas phase.

Stripping is applied to separate volatile contaminants from water, e.g.:

- chlorinated hydrocarbons, such as trichloroethene, perchloroethene, trichloromethane, dichloroethane, trichloroethane;
- ammonia and hydrogen sulphide; their volatility is strongly dependent on temperature and pH, thus pH control is essential (pH > 9.5 with ammonia, pH 2–3 with hydrogen sulphide);
- ammonia and hydrogen sulphide together in a two-stage steam stripping unit; [145, BREF REF]
- organic solvents, petrol, diesel fuel, low aromatics, phenol, mercaptans.

Example plants
See Table 2.64.

Table 2.64: Plants equipped with waste water stripping

Plants performing air/steam stripping of waste water	Type of waste treatment
04, 217	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
235, 619, 620	Re-refining and other preparations for reuse of waste oils
170	Regeneration of spent solvents

WORKING DRAFT IN PROGRESS

Reference literature
[138, COM] [145, COM]

2.3.6.5.6 Ion exchange processes

Ex-**Section 4.3.1.14 "Ion exchange processes"** replaced by text based on CWW BREF Section 3.3.2.3.3.10

Description
Ion exchange is the removal of undesired or hazardous ionic constituents from waste water and their replacement by more acceptable ions from an ion exchange resin, where the undesired ions are temporarily retained and afterwards released into a regeneration or backwashing liquid.

Ion exchange is applied to remove unwanted ionic and ionisable species from waste water, such as:

- heavy metal ions, cationic or anionic, e.g. Cr^{3+} or cadmium and its compounds, with low feed concentrations, and CrO_4^{2-} even with high feed concentrations;
- ionisable inorganic compounds, such as H_3BO_3;
- soluble, ionic or ionisable organic compounds, e.g. carboxylic acids, sulphonic acids, some phenols, amines as acid salt, quaternary amines, alkyl sulphates

Ion exchangers commonly in use are macroporous granule resins with cationic or anionic functional groups, such as:

- strong acid cation exchangers, neutralising strong bases and converting neutral salts into their corresponding acids;
- weak acid cation exchangers, able to neutralise strong bases and used for dealkalisation;
- strong base anion exchangers, neutralising strong acids and converting neutral salts into their corresponding bases;
- weak base anion exchangers, neutralising strong acids and used for partial demineralisation.

Example plants
See **Table 2.65** below.

Table 2.65: Plants using ion exchange for waste water treatment

Plants using ion exchange for waste water treatment	Type of waste treatment
06	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
193C	Other

Reference literature
[138, COM 2014]

2.3.6.5.7 Evaporation

Ex-**Section 4.7.6.1 "Evaporation"** replaced by text based on CWW BREF Section 3.3.2.3.3.14

Description
Evaporation of waste water is a distillation process where water is the volatile substance, leaving the concentrate as bottom residue to be disposed of. The aim of evaporation is to reduce the volume of waste water or to concentrate mother liquors. The volatile steam is collected in a condenser and the condensed water is, if necessary after subsequent treatment, recycled.

WORKING DRAFT IN PROGRESS

Example plants
See **Table 2.66** below.

Table 2.66: Plants performing evaporation of waste water

Plants performing evaporation of waste water	Type of waste treatment
266	MBT
489	Treatment of excavated contaminated soil
216, 473, 486	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
113, 341	Anaerobic treatment of bio-waste
92, 619	Re-refining and other preparations for reuse of waste oils

Reference literature
[138, COM 2014]

2.3.6.5.8 Adsorption

Ex-Section 4.7.6.2 "Adsorption" replaced by text based on CWW BREF Section 3.3.2.3.9

Description
Adsorption is the transfer of soluble substances (solutes) from the waste water phase to the surface of solid, highly porous particles (the adsorbent).

The adsorbent most commonly used is activated carbon. It is used as granulate (GAC) in columns or as powder (PAC) dosed to a treatment tank or basin. Other commonly used adsorbents are lignite coke, activated aluminium oxide, adsorber resins and zeolites.

GAC adsorption is applied to remove organic contaminants, mainly those with refractory, toxic, coloured and/or odorous characteristics, and residual amounts of inorganic contaminants, such as nitrogen compounds, sulphides and heavy metals. Granular medium filters, e.g. sand filters, are commonly used upstream of the GAC adsorber to remove the suspended solids present.

PAC adsorption is applied to the same contaminants as GAC.

Lignite coke is processed and applied like GAC and might replace it when lower cleaning effects are sufficient. Its lower price is set against its lower adsorption efficiency, thus requiring larger amounts of adsorbent or more frequent regeneration cycles.

Activated aluminium oxide is used to adsorb hydrophilic substances, e.g. fluoride and phosphate.

Adsorber resins are applied for the targeted removal of both hydrophobic and hydrophilic organic contaminants, e.g. to facilitate the recovery of the organic compounds. The resins tend to swell over the course of time by taking up the organic compounds.

Zeolites are applied to remove ammonia or heavy metals, e.g. cadmium. When applied for ammonia removal, they are only effective on very weak streams (up to 40 mg/l).

Example plants
See **Table 2.67** below.

WORKING DRAFT IN PROGRESS

Table 2.67: Plants equipped with an adsorption system for waste water treatment

Plants equipped with an adsorption system for waste water treatment	Type of waste treatment
55	Mechanical treatment in shredders of metal waste
91, 216, 217, 317	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
127, 244	MBT
427	Physico-chemical treatment of solid and/or pasty waste
619	Re-refining of waste oils
172C	PCT of waste with calorific value
170	Regeneration of spent solvents
40	Treatment of excavated contaminated soil

Reference literature

[138, COM 2014]

Ex-**Section 4.3.1.18 "Solvent extraction"** deleted. No examples of such a technique have been found in the questionnaires

~~**Description**~~

~~Some techniques include:~~

~~a. using well operated and regulated processes~~
~~b. returning the extraction solvent for re-use in a closed loop~~
~~c. using anti-foaming agents when faults occur in the extraction due to surface-active substances (e.g. tensides) resulting from the mixing processes~~
~~d. avoiding using solvents with comparable chemical characteristics to the component to be extracted, in order to avoid poor separation effects, e.g. azeotropic mixtures~~
~~e. improving the separative performance during extraction by increasing the temperature~~
~~f. separating substances which may have negative effects in pretreatment procedures.~~

~~**Achieved environmental benefits**~~

~~Enhances the environmental performance of the solvent extraction. Some reasons for using extraction include: its low energy consumption for the separation of substances, from low concentrated waste water up to the ppm range; the possibility of extracting insoluble substances, and also the high level of selectivity that can be achieved by using reactive components and suitable extracting agents during the extraction process.~~

~~**Cross-media effects**~~

~~Emissions of VOCs to the air.~~

~~**Economics**~~

~~There is a saving of raw material and transport costs if the distillation can be performed on site.~~

~~**Driving force for implementation**~~

~~**Example plants**~~

~~Many systems return the extraction solvent for re-use in a closed loop.~~

~~**Reference literature**~~

~~[33, UK EA 2001] [34, Babtie Group Ltd 2002][60, WT TWG 2003] [77, Schmidt et al. 2002] [98, WT TWG 2004]~~

Ex-Section 4.3.1.19 "Techniques when treating waste water containing precious metals" deleted, considering the few plants concerned. The process is however described in Chapter 2 (see conclusions of PCT workshop).

WORKING DRAFT IN PROGRESS

~~Description~~

~~Photographic liquid waste contains several toxic and not easily degradable compounds. By means of physico-chemical and biological treatment, including evaporation, the diffusion of these compounds to the environment is minimised. Some techniques are:~~

1. ~~for black and white photographic waste water, recovery of metals if the concentration of silver is greater than 50 mg/l, and purification is followed by evaporation and incineration of the concentrate in a grate furnace or cement kiln~~
2. ~~for colour photographic waste water, recovery of metals if the concentration of silver is greater than 100 mg/l and purification is followed by evaporation and incineration of the concentrate in a grate furnace or cement kiln.~~

~~Achieved environmental benefits~~

~~In comparison with detoxification, neutralisation and dewatering for the removal of metals by means of chemicals, there is a reduction in the consumption of chemicals and the sludge produced.~~

~~Cross-media effects~~

~~In comparison with a detoxification, neutralisation and dewatering for the removal of metals by means of chemicals, the consumption of energy is increased, e.g:~~

- ~~electricity for the electrolysis~~
- ~~heat for the evaporation.~~

~~Operational data~~

~~Sulphide precipitation and ultrafiltration generates sulphide sludge at approximately 5 to 10 kg/m^3 liquid photo processing waste water. From the sludge, silver and other metals are recovered in pyrometallurgic processes which generate slags as a residue. The physico-chemical and biological treatment of the desilvered photographic waste water generates sludge at approximately 0.1 to 0.2 t/t waste water.~~

~~Silver is recovered for re-use and concentrations of silver and other metals in the waste water are reduced. The recovery of silver is approximately 95 %. The silver content in the permeate of membrane filtration is <1 mg/l in the case of black and white photo processing waste water and <10 mg/l in the case of colour photo processing waste water.~~

~~Applicability~~

~~The techniques for recovery of metals are not only applicable to photographic waste waters, but also to other waste waters containing (precious) metals, e.g. the galvanic industry. Electrolysis gives a higher yield and costs less energy as metals are more precious and concentrations are higher. The capacity of one of the example plants for metal recovery ranges from 10 to 20 kt/yr.~~

~~The physico-chemical and biological treatment techniques for desilvered photographic liquid waste waters are applicable for similar waste waters. shows the acceptance criteria for desilvered photographic liquid waste and similar waste waters (with the same processing path). The capacity of one of the example plants for physico-chemical and biological treatment is approximately 100 to 200 kt/yr.~~

~~Driving force for implementation~~

~~Effluent standards based on the Surface waters Pollution Act.~~

~~Example plants~~

~~Two example plants in the Netherlands.~~

~~Reference literature~~

~~[98, WT TWG 2004] [103, VROM 2004]~~

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2.3.6.5.9 Distillation/rectification

Text based on CWW BREF Section 3.3.2.3.3.13

Description

Distillation or rectification is the separation of waste water from its contaminants by transferring them into the vapour phase. The enriched vapour phase is condensed afterwards.

Waste water distillation or rectification has a limited application. It is often used as a process-integrated measure to recover starting material and/or product from mother liquors. As a waste water treatment operation it is applied for the following reasons:

- to recover solvent after waste water extraction;
- to recover solvent from waste water, e.g. separation of alcohols from methyl cellulose production;
- to treat oil emulsions;
- as a pretreatment to remove the main contaminant content from the waste water stream in order to recover it and afterwards discharge the waste water to further downstream treatment;
- to recover organics from scrubbing liquors.

Example plants

Plant 216.

Reference literature

[138, COM 2014]

2.3.6.6 Biological treatment of waste water

From ex-Section 4.7.5

Description

~~For the elimination of biodegradable organic compounds and nitrogen compounds~~ Biological treatment processes have repeatedly been shown to be effective for the elimination of biodegradable organic compounds and nitrogen compounds. In contrast to other treatment techniques, biological treatment makes use of microorganisms that can react to the manifold boundary conditions of their existence and are therefore able to adjust optimally to the compounds that are to be degraded (adaptation). ~~Under anaerobic conditions different populations of bacteria evolve which allows for the degradation of a broad range of substances. In the optimal case, degradation proceeds to the point where inorganic substances such as CO_2 and H_2O are created (mineralisation). Some tertiary techniques include:~~

~~a. applying a biological treatment for waste water with a high BOD content. Harmful and persistent substances, constituting a proportion of the COD load such as solvents, pesticides, organo-halogens and other organic substances, may be adsorbed onto particulate and colloidal matter and then removed as a solid residue. The treatment process does not determine the efficiency of this and removal is highly variable. As a 'rule of thumb', to facilitate biodegradation, the COD/BOD ratio of effluent to sewer should typically not exceed 10:1~~
~~b. settlement~~
~~c. thickening and dewatering~~
~~d. wet air oxidation.~~

~~**Achieved environmental benefits**~~

~~Reduces BOD and consequently reduces the COD load of the waste water. At the same time nitrogen and some microelements (e.g. Zn) can be captured by the biological treatment. The degradation of organic compounds is carried out by micro-organisms whose activity depends largely on their environmental conditions, causing some degree of fluctuation in the efficiency of the process.~~

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Table 2.68: Effluent concentration of a Ph-c plant before and after tertiary waste water treatment

~~**Parameter**~~	~~**Feed (primary effluent)**~~		~~**Effluent after biological treatment (sequential batch reactor)**~~	
	~~**Minimum (mg/l)**~~	~~**Maximum (mg/l)**~~	~~**Minimum (mg/l)**~~	~~**Maximum (mg/l)**~~
~~COD~~	~~2500~~	~~12000~~	~~600~~	~~1500~~
~~NH^4-N~~ 1)	~~25~~	~~16000~~	~~<1~~	~~150~~
~~Nitrite~~	~~10~~	~~300~~	~~<1~~	~~<1~~
~~Nitrate~~	~~10~~	~~1000~~	~~<1~~	~~<1~~
~~Phenoles~~	~~10~~	~~500~~	~~<2~~	~~<2~~
~~Oil content~~	~~--~~	~~--~~	~~<0.5~~	~~--~~

1) ~~Effluent after biological treatment: Often around 20 mg/l~~

~~*Source*: [98, WT TWG 2004]~~

~~**Cross-media effects**~~

~~Mineralisation of organic substance and biomass production. Through adsorption processes and bioaccumulation, inorganic and non-degradable organic compounds may accumulate in the biomass.~~

~~**Operational data**~~

~~Certain organic and inorganic contents of the waste water may have a toxic effect on the bacteria population. Due to the nutrient demand of biological processes, low phosphorus concentrations can become the limiting factor for the life of bacterial (this problem may possibly be solved by a systematic addition of nutrients). For all biological treatment techniques currently in use, a number of special characteristics and boundary conditions have to be considered:~~

- ~~for biological degradation, nutrients (nitrogen, phosphorus) and trace elements (metals, etc.) are needed~~
- ~~optimal pH-ranges (usually pH 6.5 - 8.5) have to be maintained within the reactor~~
- ~~to keep the process running oxygen contents greater than 1 mg/l are necessary~~
- ~~activity of the micro-organisms increases with increasing temperature, up to an optimum at around 30 – 35 °C. Below 10 °C the reaction speed usually decreases drastically~~
- ~~for the functionality of the system the retention of biomass is of particular importance.~~

~~Biological plants should be designed with sufficient residence time to achieve an adequate breakdown of the more complex compounds present in the waste water.~~

~~The age of the sludge is also important. Optimum operating temperatures can also aid degradation. Some aerobic plants are currently planned to operate at around 30 °C~~

~~**Applicability**~~

~~Biological treatment is a very effective technique for the elimination of:~~

- ~~a large number of biodegradable organic carbon compounds. Even if the analysis of the waste water indicates low biological degradability (relation BOD$_5$/COD <0.1), 40 – 50 % of the COD can still be eliminated (with only small production of biomass)~~
- ~~nitrogen compounds. Organic nitrogen and ammonium can be transformed via nitrite to nitrate. Emission values below 10 mg NH$_4^+$-N/l can be achieved easily, values <1 mg NH$_4^+$-N/l are common. Nitrate or nitrite can be converted into elementary nitrogen.~~

~~**Example plants**~~

~~Widely used in the sector.~~

~~**Reference literature**~~

~~**[33, UK EA 2001] [89, UBA Germany 2003][98, WT TWG 2004]**~~

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2.3.6.6.1 Aerobic treatment

Text based on CWW BREF Section 3.3.2.3.4.3

Description

Aerobic treatment is the biological oxidation of dissolved organic substances using the metabolism of microorganisms. In the presence of dissolved oxygen – injected as air or pure oxygen – the organic components are converted (mineralised) into carbon dioxide, water or other metabolites and biomass (i.e. the activated sludge).

Aerobic waste water treatment generally represents the final biological step. It offers the advantage of a high rate of sludge growth which not only enables the handling of the various components of toxic waste water but also provides a COD removal efficiency that is normally superior to that of anaerobic treatment.

Common aerobic biological treatment techniques are:

- complete mix activated sludge process;
- membrane bioreactor process;
- trickling or percolating filter process;
- expanded-bed process;
- fixed-bed biofilter process.

Complete mix activated sludge

The **complete mix activated sludge process** is a method often used within the chemical industry and as such is the most common treatment technique for biodegradable waste water. The microorganisms are maintained as a suspension in the waste water and the whole mixture is mechanically aerated. The activated sludge mixture is sent to a separation facility from where the sludge is recycled to the aeration tank. The separation facility can be:

- a sedimentation or settling tank (see Section 2.3.6.4.4);
- an air flotation facility (see Section 2.3.6.4.6);
- a MF or UF membrane (see Section 2.3.6.4.7); (for a membrane bioreactor, see below).

The complete mix process is operated with several variants, depending on the amount of waste water, the availability of space, the requirements for emissions to air, etc. Examples of variants are:

- the oxidant agent: air or pure oxygen, the latter having the advantage of fewer stripping effects and less odorous release, because less gas is blown through the waste water, and of faster and more effective biological reaction;
- the aeration chamber: a more or less flat tank or a tower, the latter taking into account the higher degradation efficiency because of smaller air bubbles ascending in a high column of waste water and thus considerably increasing the air/waste water mass transfer;
- the clarification step: sedimentation or membrane filtration (membrane bioreactor, see below), the latter requiring less space, the former probably supported by a final flotation stage.

In general, the complete mix activated sludge process is applicable to all biodegradable waste water streams, be it as a high-load pretreatment of tributary streams or as the main part of a central WWTP.

Membrane bioreactor (MBR)

The **membrane bioreactor process**, as a combination of biological activated sludge treatment and membrane separation, is a biological treatment process used for urban and industrial waste water (see the CWW BREF [138, COM 2014] for more details on membrane bioreactors). The different variations of this process are:

WORKING DRAFT IN PROGRESS

- an external recirculation loop between the activated sludge tank and the membrane module;
- immersion of the membrane module in the aerated activated sludge tank, where the effluent is filtered through the hollow fibre membrane, and the biomass remains in the tank; this variant consumes less energy and results in a more compact plant.

These variants together with the conventional activated sludge process are shown in Figure 2.34.

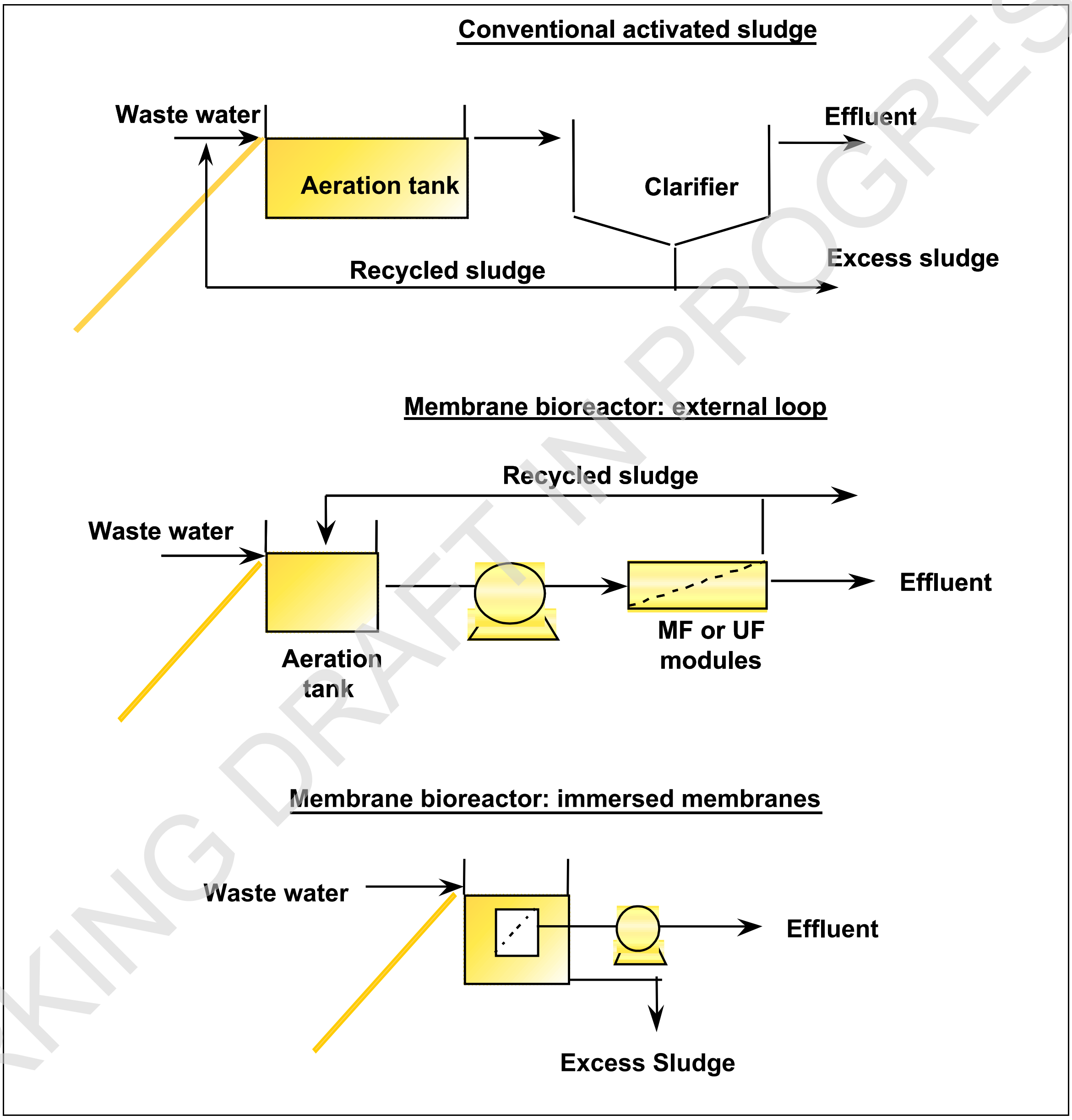

Figure 2.34: Variants of membrane bioreactor, compared with a conventional activated sludge process

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Trickling or percolating filter

In the **trickling or percolating filter process** the microorganisms are attached to a highly permeable medium through which the waste water is trickled or percolated. The filter medium normally consists of rock or various types of plastic.

The liquid is collected in an underdrain system and passes to a settling tank and part of the liquid is recycled to dilute the strength of the incoming waste water.

Expanded-bed

The **expanded-bed process** is operated as described for anaerobic treatment (see Section 2.3.6.6.2) with the distinction that air or oxygen is introduced and aerobic instead of anaerobic bacteria are fixed in the biofilm. The advantage of this version of aerobic treatment is the reduced space requirement with the same performance.

Fixed-bed biofilter

In the **fixed-bed biofilter process** the biofilm is maintained at the surface of a carrier. The waste water stream is treated when passing through this biofilm; suspended solids are retained in the filter, from where they are backwashed regularly. This technology has been developed as a compact (high turnover rate per volume and omission of a secondary clarifier) and odourless alternative to the conventional activated sludge process.

Biofilters are used to treat urban and some industrial waste water (e.g. effluent highly loaded with COD in the pulp and paper industry), but also to upgrade an existing activated sludge plant (which is the case with expanded-bed reactors too). The advantages of the fixed biofilm on the carrier material are the lower vulnerability to high salt contents and the better conditions for slow-growing bacteria because of the long-term retention in the system. Biofilters are also used as a direct pretreatment or final polishing step to an activated sludge process.

Example plants

Table 2.69 and Table 2.70 show the list of plants from the reference list equipped with activated sludge systems and MBR systems respectively.

Table 2.69: Plants equipped with an activated sludge system

Plants equipped with an activated sludge system	Type of waste treatment
127	MBT
170	Regeneration of spent solvents
07, 90, 140_141_142_143C, 151C, 154_155C, 159C, 194C, 368_369_370_371, 392, 393, 423_424, 468, 473, 607	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
111, 341	Anaerobic treatment of bio-waste
569	Physico-chemical treatment of solid and/or pasty waste
152	PCT of waste with calorific value
235, 610, 619, 620	Re-refining and other preparations for reuse of waste oils

Table 2.70: Plants equipped with an MBR system

Plants equipped with an MBR system	Type of waste treatment
154_155C	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
605	Re-refining and other preparations for reuse of waste oils

Reference literature

[138, COM 2014]

WORKING DRAFT IN PROGRESS

2.3.6.6.2 Anaerobic treatment

Text based on CWW BREF Section 3.3.2.3.4.1

Description

Anaerobic waste water treatment converts the organic content of waste water, with the help of microorganisms and without entry of air, to a variety of products such as methane, carbon dioxide, sulphide, etc.

Anaerobic waste water treatment is essentially used only as a pretreatment for waste water which is characterised by a high organic load (> 2 g/l) and a more or less constant quality. It is applicable mostly in sectors with effluents with consistently high BOD loads.

The biogas consists of about 70 % methane and 30 % carbon dioxide and other gases such as hydrogen and hydrogen sulphide. The process is carried out in an airtight stirred tank reactor, and the microorganisms are retained in the tank as biomass (sludge).

There are several reactor types available. The most commonly used are:

- anaerobic contact reactor;
- upflow anaerobic sludge blanket (UASB);
- fixed-bed reactor;
- expanded-bed reactor.

Example plants

Plant 592 is the only plant from the reference list performing anaerobic treatment of waste water.

Reference literature

[138, COM 2014]

2.3.6.6.3 Nitrogen removal by biological nitrification/denitrification

Text based on CWW BREF section 3.3.2.3.4.4

Description

Nitrogen, or more precisely ammonium, is removed by a special biological treatment that consists of two steps:

- aerobic nitrification, where special microorganisms oxidise ammonium (NH_4^+) to the intermediate nitrite (NO_2^-) which is further converted to nitrate (NO_3^-);
- anoxic denitrification, where microorganisms convert nitrate into nitrogen gas.

Example plants

See Table 2.71 below.

Table 2.71: Plants performing nitrification/denitrification of waste water

Plants performing nitrification/denitrification	Type of waste treatment
243, 244, 257	MBT
368_369_370_371, 392, 393	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste
20, 459	Anaerobic treatment of bio-waste
110, 460	Aerobic treatment of source-separated bio-waste
235, 610	Re-refining and other preparations for reuse of waste oils

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Plants 392 and 393 provided information on the optimisation of nitrification/denitrification, when treating waste with a low C/N ratio and containing mostly non-degradable carbon, by means of:

- fine-tuning the retention time;
- lowering aeration and recirculation rates;
- adding a suitable carbon source and nutrients (e.g. phosphate).

Reference literature
[138, COM 2014].

Ex-Section **4.7.6 Final waste water treatments** deleted: all techniques mentioned are described in dedicated sections

~~**Description**~~

~~Final treatment refers to any process that is considered a 'polishing' phase typically after the tertiary treatment if exist and which may also encompass the recovery of specific substances. Some techniques are listed in the following Table 2.72:~~

Table 2.72: Final waste water treatments

~~**Technique**~~	~~**Description**~~
~~Macro-filtration~~	~~Sand filtration, mixed media (for example, sand/anthracite blends) or more specialised types of filtration media, such as Granular Activated Carbon (GAC)~~
~~Strong reduction~~	
~~Wet air oxidation~~	~~Wet air oxidation is a destructive physico-chemical treatment method that is used to treat aqueous effluents with high COD levels, which are not suitable to be directly discharged to a WWTP, but that are too expensive to incinerate~~
~~Strong reduction with hydrazine~~	
~~Ion exchange~~	~~Removal of nitrate, metals and concentration of metals~~

~~**Achieved environmental benefits**~~

~~The benefits of these treatments is the final 'polishing' of the effluent and the recovery of substances from the effluent before its re-use or its emission to the sewer, surface waters, etc.~~

~~There may be some scope for the application of these filtration techniques (including sand filters) to remove particulates in effluent, thereby offering a means to reduce the level of suspended solids in the effluent.~~

~~Macro-filtration remove the suspended solids, certain chemicals, taste and odours.~~

~~**Cross-media effects**~~

~~Macro-filtration by GAC carbon needs regeneration, which is usually carried out by incineration.~~

~~**Operational data**~~

~~Filtration processes need pressure. In some cases, very high pressures are needed (e.g. as is the case with reverse osmosis).~~

~~Attempts at using wet air oxidation for some waste treatment has suffered from problems connected with heterogeneous and variable waste feedstock; and as a consequence there are no current applications in waste treatment. Though these are applied in other sectors, as is suitable for dedicated processes with specific waste streams on-site.~~

~~**Applicability**~~

~~Adsorption is simple and reliable and batch operation is possible.~~

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~~**Driving force for implementation**~~
~~The need for these treatments is dictated by three potential factors:~~

- ~~the requirement to meet the discharge conditions stated in the permits~~
- ~~to allow recycling of waste water for process water or wash-water~~
- ~~to aid recovery i.e. of oil from water contaminated with oil by, for example, ultra-filtration.~~

~~Filtration systems are currently being utilised by some water utilities for discharges from waste water treatment works, primarily in order to control the pathogens in the waste.~~

~~Hydrazine is a hazardous substance and reports state that its use is banned in at least one MS.~~
~~**Example plants**~~
~~There is an example plant where 90 % of the Hg emission comes from contamination in the soil, which subsequently leaks into the pipeworks. At Akzo Nobel in Bohus (Sweden), a mercury base chlor-alkali plant, the waste water mercury removal system consists of a mixing unit where hydrazine is added to the waste water, two sedimentation tanks, sand filters, activated carbon filters and ion exchange filters. The treated waste water flow was 7 m^3/h with a mercury content of 3000 - 5000 µg/l in 1997, with a resultant mercury concentration in the waste water of 5 - 8 µg/l, corresponding to an emission of 0.005 g Hg/tonne chlorine capacity. The total mercury emission to water from the site was approximately 0.045 g Hg/tonne chlorine capacity, which meant that about 10 % of the mercury emissions were process emissions with the other 90 % being indirect emissions of deposited mercury which end up in the run-off water.~~

~~**Reference literature**~~
~~**[25, UK Department of the Environment 1991] [26, UK, H. 1995][33, UK EA 2001] [77, Schmidt et al. 2002] [98, WT TWG 2004]**~~

Ex-**Section 4.7.8 "Examples of some waste water treatment plants in the sector"** deleted and replaced by data collection

~~[34, Babtie Group Ltd 2002]~~

~~An example of a WWTP used in waste oil treatment plants may include the aqueous waste going through a physico-chemical unit where ferric chloride is added as a flocculant and sludge is taken off to the filter press. The aqueous phase may then be dosed with polyelectrolytes and lime to raise the pH and to produce another sludge layer that then goes to the sludge press. Liquors from the press plus the supernatant liquors will go onto a biological treatment, but now the liquors will be substantially free from oil residues and metals, and the overall COD level will have also been reduced.~~

2.3.6.7 Integrated waste water management and treatment strategy

Description
Establishment and implementation of an integrated waste water management and treatment strategy.

Technical description
Various combinations of techniques described in Section 2.3.6 are used for waste water treatment, depending mainly on the waste input treated, and on local conditions (e.g. direct/indirect discharge).

The integrated waste water management and treatment strategy is based on the inventory of waste water streams by means of organisational and operational measures (see Sections 2.3.1 and 2.3.2). These include:

WORKING DRAFT IN PROGRESS

- segregation of waste water streams depending on the pollution load and the combination of techniques of the treatment process;
- reduction of the remaining pollutants (e.g. organics) after the physico-chemical treatment, e.g. by:
  - activated sludge system;
  - membrane bioreactor;
- reduction of remaining contamination with finishing techniques (post-treatment techniques) such as:
  - coagulation and flocculation;
  - sedimentation;
  - filtration;
  - flotation;
- in case of indirect discharge, ensure that the level of emission of the remaining pollutants does not have a negative impact on the downstream WWTP and the effective efficiency of this downstream installation for treating those remaining pollutants.

Achieved environmental benefits

The achieved environmental benefits of this technique include the reduction of emissions to water.

Environmental performance and operational data

Table 2.73 to Table 2.79 below present the reported emissions to water for TSS, COD, TOC, THC, HOI, phenols, nitrogen, phosphorus, metals (As, Cd, Cr, Ni, Pb, Cu, Hg, Zn), of waste treatment plants directly discharging to water. Additional information on e.g. the processes, the techniques used, waste input and output, can be found in each specific Chapter (i.e. Chapter 3 for mechanical treatment of waste, Chapter 4 for biological treatment of waste, and Chapter 5 for physico-chemical treatment of waste).

Table 2.73: TSS emissions of waste treatment plants directly discharging to water

Plant code	TSS (mg/l)	Monitoring	Waste treatment process
609	26	Grab sample	Aerobic treatment of waste
341	0	Grab sample	Anaerobic treatment of waste
350	16	Grab sample	Mechanical biological treatment of waste
464	16	Grab sample	Mechanical treatment in shredders of metal waste
478	20	Grab sample	
154	33	Composite sample	Physico-chemical and/or biological treatment of water-based liquid waste
156	18	24-hour flow-proportional composite sample	
192	20	24-hour flow-proportional composite sample	
368	31	24-hour flow-proportional composite sample	
392	27	Grab sample	
393	15	Grab sample	
427	23	24-hour flow-proportional composite sample	
449	18	Grab sample	
569	32	24-hour flow-proportional composite sample	Physico-chemical treatment of solid and/or pasty waste
620	3	Grab sample	Re-refining of waste oil

WORKING DRAFT IN PROGRESS

Table 2.74: TOC and COD emissions of waste treatment plants directly discharging to water

Plant code	TOC (mg/l)	COD (mg/l	Monitoring	Waste treatment process
341	NI	9	Composite sample	Anaerobic treatment of waste
350	NI	30	Grab sample	Mechanical biological treatment of waste
441	NI	106	Grab sample	Mechanical treatment in shredders of metal waste
368	40.8	122	24-hour flow-proportional composite sample	Physico-chemical and/or biological treatment of water-based liquid waste
421	0.5	NI	24-hour flow-proportional composite sample	
449	NI	75	Grab sample	
569	NI	88	24-hour flow-proportional composite sample	Physico-chemical treatment of solid and/or pasty waste
620	NI	33	Grab sample	Re-refining of waste oil

NI: no information

Table 2.75: THC and HOI emissions of waste treatment plants directly discharging to water

Plant code	THC (mg/l)	HOI (mg/l)	Monitoring	Waste treatment process
31	0.2	NI	Grab sample	Mechanical treatment of waste with calorific value
136	3.3	NI	Composite sample	Mechanical treatment in shredders of metal waste
464	3.9	NI	Grab sample	
478	0.2	1.1	Grab sample	
140	0.1	NI	24-hour flow-proportional composite sample	Physico-chemical and/or biological treatment of water-based liquid waste
154	0.05	NI	Composite sample	
156	0.3	NI	24-hour flow-proportional composite sample	
368	1.2	NI	24-hour flow-proportional composite sample	
620	0.2	NI	Grab sample	Re-refining of waste oil

NI: no information

Table 2.76: Phenols emissions of waste treatment plants directly discharging to water

Plant code	Phenol index (mg/l)	Monitoring	Waste treatment process
341	0.004	Grab sample	Anaerobic treatment of waste
140	0.03	24-hour flow-proportional composite sample	Physico-chemical and/or biological treatment of water-based liquid waste
144	0.2	24-hour flow-proportional composite sample	
156	0.1	24-hour flow-proportional composite sample	
368	0.06	24-hour flow-proportional composite sample	
421	0	24-hour flow-proportional composite sample	
90	0.01	Grab sample	Re-refining of waste oil
620	0.04	Grab sample	

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Table 2.77: Nitrogen emissions of waste treatment plants directly discharging to water

Plant code	Total N (mg/l)	Monitoring	Waste treatment process
609	0.3	Grab sample	Aerobic treatment of waste
341	5.8	Grab sample	Anaerobic treatment of waste
521	5.3	Grab sample	
478	7.2	Grab sample	Mechanical treatment in shredders of metal waste
392	40	Grab sample	Physico-chemical and/or biological treatment of water-based liquid waste
393	36	Grab sample	
569	12	24-hour flow-proportional composite sample	Physico-chemical treatment of solid and/or pasty waste
90	14	24-hour flow-proportional composite sample	Re-refining of waste oil
620	0.04	Grab sample	

Table 2.78: Phosphorus emissions of waste treatment plants directly discharging to water

Plant code	Total P (mg/l)	Monitoring	Waste treatment process
341	0.3	Grab sample	Anaerobic treatment of waste
441	1	Grab sample	Mechanical treatment in shredders of metal waste
140	2.9	24-hour flow-proportional composite sample	Physico-chemical and/or biological treatment of water-based liquid waste
192	3	24-hour flow-proportional composite sample	
368	2.1	24-hour flow-proportional composite sample	
392	0.9	Grab sample	
393	1.4	Grab sample	
449	0.3	Grab sample	
569	0.7	24-hour flow-proportional composite sample	Physico-chemical treatment of solid and/or pasty waste
90	1.3	24-hour flow-proportional composite sample	Re-refining of waste oil
620	0.8	Grab sample	

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Table 2.79: Metals emissions of waste treatment plants directly discharging to water

Plant code	As (mg/l)	Cd (mg/l)	Cr (mg/l)	Ni (mg/l)	Pb (mg/l)	Cu (mg/l)	Hg (mg/l)	Zn (mg/l)	Monitoring	Waste treatment activity
341	0.00005	NI	0.002	0.004	0.001	0.002	NI	0.001	Grab sample	Anaerobic treatment of waste
350	0.03	0.009	NI	0.07	0.02	0.02	0.0009	0.1	Grab sample	Mechanical biological treatment of waste
136	NI	NI	NI	0.009	0.1	0.07	NI	NI	Composite sample	Mechanical treatment in shredders of metal waste
464	NI	NI	NI	NI	NI	NI	NI	0.5	Grab sample	
478	0.002	0.0008	0.006	0.02	0.03	0.05	0.0001	0.5	Grab sample	
140	0.01	0.003	0.03	0.625	0.01	0.06	0	0.5	24-hour flow-proportional composite sample	Physico-chemical and/or biological treatment of water-based liquid waste
144	0.01	0.05	0.11	0.4	0.1	0.1	0.001	0.4	24-hour flow-proportional composite sample	
154	0.03	0.02	0.03	0.2	0.06	0.06	0.01	0.1	Composite sample	
156	NI	0.02	0.03	1	0.1	0.3	NI	2.6	24-hour flow-proportional composite sample	
192	NI	0.07	0.24	0.55	0.5	0.2	NI	1.1	24-hour flow-proportional composite sample	
368	NI	0.01	0.05	0.04	0.02	0.03	0.002	0.1	24-hour flow-proportional composite sample	
392	0.02	0.001	0.01	0.02	0.005	0.005	0.00006	0.02	Grab sample	
393	0.02	0.001	0.02	0.03	0.005	0.006	0.00005	0.03	Grab sample	
421	0.004	0.0002	0	0.02	0.0033	0.05	0	0.05	24-hour flow-proportional composite sample	
449	NI	NI	NI	NI	NI	NI	NI	0.5	Grab sample	
569	NI	NI	NI	0.3	0.1	0.1	NI	0.3	24-hour flow-proportional composite sample	Physico-chemical treatment of solid and/or pasty waste
90	NI	NI	0.01	0.04	NI	NI	NI	NI	24-hour flow-proportional composite sample	Re-refining of waste oil

WORKING DRAFT IN PROGRESS

620	NI	0.002	0.04	0.04	0.02	0.01	NI	0.03	Grab sample	
NI: no information										

Cross-media effects
Not identified.

Technical considerations relevant to applicability
See Section 2.3.6 and the CWW BREF [138, COM 2014] for technical considerations relevant to the applicability of individual techniques.

Implementing an integrated waste water management and treatment strategy is generally applicable.

Economics
No information available.

Driving force for implementation
Environmental legislation.

Example plants
See Table 2.73 to Table 2.79. This technique is widely used in the sector.

Reference literature
[108, Physico-Chem. Subgroup 2014] [146, PCT] [160, WT TWG 2014] [138, COM 2014]

From ex-Section 4.3.1.20 **Techniques for the treatment of aqueous marine waste** deleted as the techniques described are dealt with in Section 2.3. The process description is kept in Section 5.7.1

~~**Description**~~
~~The treatment of aqueous marine wastes can be distinguished between waste waters containing oil and waste waters containing chemicals. Some techniques are:~~

~~a. applying specific pretreatment processes in the case of waste waters containing metals (see Section above)~~
~~b. applying physico-chemical pretreatment and a biological treatment in the case of waste waters containing oil~~
~~c. treating the exhaust gases to reduce the VOC and odour emissions~~
~~d. defining acceptance and processing standards (maximum concentrations in the waste) for every treatment route~~
~~e. separating oils / chemicals, water and sludge~~
~~f. preparing the oil or chemical fraction for use as fuel if suitable~~
~~g. applying standards (maximum concentrations) for mixing wastes to be used as fuel~~
~~h. not mixing or diluting waste waters to meet effluent standards~~
~~i. dewatering the sludge and, if suitable, applying a thermal treatment for material re-use~~
~~j. treating the waste water.~~

~~**Achieved environmental benefits**~~
~~Compared to the discharge of untreated waste water or merely biological treatment, the described techniques reduce emissions of contaminants to surface waters.~~
~~**Cross-media effects**~~
- ~~production of a sludge that has to be disposed of or undergo further treatment~~
- ~~consumption of chemicals~~
- ~~consumption of energy~~
- ~~emissions to the air, e.g. VOC and odour.~~

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~~Operational data~~

~~The removal efficiencies of flocculation/flotation and aerobic biological treatments by a waste water treatment installation are presented in Table 2.80:~~

Table 2.80: **~~Removal efficiencies of flocculation/flotation and biological treatment of waste water~~**

~~Component~~	**~~Removal efficiency flocculation/flotation (%)~~**	**~~Removal efficiency aerobic biological treatment (%)~~**	**~~Waste water treatment Total efficiency (%)~~**[2]
~~Suspended particles~~	~~>99~~	-	~~>99~~
~~Oil~~	~~>99~~[1]	~~99~~	~~>99~~
~~COD~~	~~20~~	~~85~~	~~88~~
~~Phenols~~	-	~~99~~	~~99~~
~~Total N (Kjeldahl)~~	-	~~50~~	~~50~~
~~P~~	-	~~50~~	~~50~~
~~BTEX~~	~~75~~	~~99~~	~~99.7~~
~~PAHs~~	~~96~~	~~95~~	~~99~~
~~CN~~	-	~~75~~	~~75~~
~~EOX + VOX~~	~~30~~	~~97~~	~~98~~
~~EOX~~	~~85~~	~~85~~	~~98~~
~~Heavy metals~~	~~80~~	-	~~80~~
~~Cd~~	~~80~~	-	~~80~~
~~Hg~~	~~>90~~	-	~~>80~~

[1] ~~removal of oil layer~~
[2] ~~total of flocculation/flotation and biological treatments~~

~~Emissions of VOC to the air are released from tanks during storage and transfer, from treatment installations and from seal leakages. Emissions can be reduced by enclosed installations, inspection and maintenance to avoid leakages.~~

~~Treatment of the exhaust gases by filtering, scrubbing or incineration can reduce these emissions. A biofilter or activated carbon filter may be applied to prevent the emissions of VOC and odour. An alternative for reducing these emissions is aeration with oxygen instead of air. This reduces the flowrate of the air input and the exhaust gas. The disadvantages are the higher consumption of oxygen and the higher consumption of pumping energy to compensate the reduction of the mixing due to the fact that less air is blown in.~~

~~If exhaust gas treatment is applied, emissions vary from approximately 0.01 kg/m^3 waste water in the case of incineration, with an efficiency of 99.9 %, to 0.05 kg/m^3 waste water in the case of a wet scrubber.~~

~~Applicability~~
~~The capacities of the example installations range from 200 to 500 kt/yr.~~
~~Driving force for implementation~~
~~Effluent standards based on the Surface Waters Pollution Act in the Netherlands.~~

~~Example plants~~
~~Three example plants in the Netherlands.~~

~~Reference literature~~
~~[98, WT TWG 2004] [103, VROM 2004]~~

2.3.6.8 Sludge treatment techniques

Text based on CWW BREF Section 3.4.2

Description
Most waste water treatment processes result in sludge, although the amount, consistency and content depend on the waste water content and treatment technique. It is usually a liquid, or

WORKING DRAFT IN PROGRESS

semi-solid liquid, with a solids content between 0.25 w/w-% and 12 w/w-% and containing primarily the pollutants removed from the waste water. Excess activated sludge from a biological WWTP consists mostly of degradation (mineralisation) products and bacterial tissue as well as attached pollutants such as heavy metals.

Untreated sludge is not suitable for discharge or disposal, because:

- its content of pollutants offensive to air prevents its deposition;
- its content of pollutants offensive to water bodies prevents it from being discharged into a receiving river;
- the large amount of water it contains makes incineration an unattractive option because of the energy needed.

Mechanical, thermal and/or chemical techniques are used to reduce the sludge burden with the objective being to:

- reduce the quantity of waste sludge;
- achieve a better dewaterability of the sludge;
- provoke a release of the soluble chemical oxygen demand (COD) from the sludge;
- destroy the filamentous microorganisms responsible for sludge bulking.

Such treatment operations for WWTP sludge are:

- preliminary operations, such as:
    - grinding,
    - blending or mixing,
    - storage,
    - degritting;

- sludge thickening operations, such as:
    - gravity thickening,
    - centrifugal thickening,
    - flotation thickening (DAF),
    - gravity belt thickening,
    - rotary drum thickening;

- sludge stabilisation operations, such as:
    - chemical stabilisation (lime),
    - thermal stabilisation,
    - anaerobic digestion,
    - aerobic digestion,
    - dual sludge stabilisation;

- sludge conditioning, such as:
    - chemical conditioning,
    - thermal conditioning;

- sludge dewatering techniques, such as:
    - centrifugal dewatering,
    - belt filter presses,
    - filter presses;

- drying operations, such as:
    - rotary drying,
    - spray-drying,
    - flash drying,

WORKING DRAFT IN PROGRESS

  - evaporation

- thermal sludge oxidation, using techniques such as
  - fluidised-bed incineration,
  - multiple hearth drying/incineration,
  - wet air oxidation,
  - deep shaft oxidation,
  - incineration with other (e.g. solid) waste.

The treatment operations and disposal routes can be seen as single options or as a combination of single options. The listing mainly follows the path of degree of reduction and is not meant in any way as a ranking. The availability (or unavailability) of a disposal route can be a strong driver, at least at a local level, for the choice of the sludge treatment technique.

Ex-Section 2.6 "Techniques for the abatement of emissions" deleted: it is only one paragraph which does not have added value.

~~**[82, Pretz et al. 2003] [98, WT TWG 2004]**~~

~~There are many non-production techniques in use in the WT sector. In particular, techniques used to control and abate emissions to air, water and soil are also relevant for this document. Descriptions of many of these techniques can be found in the BREF on Waste Gas and Waste Water in the Chemical Industry and in Chapter 4 of this document (Sections 4.6 to 4.8) as well as in other BREFs (e.g. Waste Incineration). These techniques are not described in this section because they are typically techniques that might be considered in the determination of BAT, and consequently will be described and analysed in Chapter 4.~~

Ex-**Section 4.6.24 "Some examples of waste gas treatment applied to different waste treatments"** deleted because replaced by data collection.

~~lists some examples of waste gas treatment applications in different waste treatment processes. Typically, the type of waste gas abatement applicable to each case is a combination of techniques; some of them may not be mentioned in the examples below. Some examples are shown in Section~~

WORKING DRAFT IN PROGRESS

Table 2.81~~: Applicability of waste gas treatments~~

~~**Waste treatment activity/process**~~	~~**Technique applied**~~
~~Thermal desorption~~	~~Condensers~~ ~~Incineration~~ ~~Carbon adsorption~~ ~~Cyclones~~ ~~Venturi scrubbers~~ ~~Fabric filters~~ ~~HEPA filters~~ ~~Wet scrubbers~~ ~~Dry scrubbers~~
~~Vapour extraction from excavated soil~~	~~Carbon adsorption~~ ~~Catalytic incineration~~ ~~Incineration~~ ~~Internal combustion engines~~
~~*Ex-situ* bioremediation~~	~~Carbon adsorption~~
~~Soil washing~~	~~Carbon adsorption~~
~~Solvent extraction~~	~~Incineration~~
~~Bioventing~~	~~Activated carbon~~ ~~Catalytic oxidation~~ ~~Internal combustion engines~~ ~~Biofilters~~
~~Physico-chemical treatment of waste waters~~	~~Wet scrubbers~~ ~~Evaporation~~ ~~Stripping~~ ~~distillation~~
~~Preparation of waste fuel~~	~~Extraction~~ ~~Condensers~~ ~~Carbon adsorption~~ ~~Biofilters~~ ~~Thermal oxidation~~ ~~Incineration~~ ~~Scrubbing~~
~~Stabilisation~~	~~Absorption~~ ~~Adsorption~~ ~~Fabric filters~~ ~~Thermal oxidation~~ ~~Cyclones~~
~~Waste oil treatment~~	~~Condensation~~ ~~Thermal oxidation~~ ~~Biological oxidation~~
~~Drum crushing and shredding~~	~~Adsorption~~ ~~Absorption~~ ~~Thermal oxidation~~
~~*Source*: [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997] [77, Schmidt et al. 2002][90, UBA Germany 2003][98, WT TWG 2004]~~	

Ex-**Section 4.6.25 "Some examples of combined treatment of exhaust air"** deleted because replaced by the data collection.

~~This section shows some examples of the application of combined waste gas treatments in different waste treatment processes. Typically, the type of waste gas abatement applicable to each case is a combination of techniques; some of them may not be mentioned in the examples below.~~

WORKING DRAFT IN PROGRESS

Table 2.82: ~~Exhaust air treatment facility of a waste solvent treatment plant~~

~~Attached operational facilities~~	~~Production halls, tank farms, barrel treatment~~
~~Emission limit values~~	~~Organic contents according to the German TA-Luft~~
~~Size of building~~	~~940 m^2~~
~~Facility consists of~~	~~Activated carbon pre-filter (smoothing out emission peaks of the raw gas), two-fold~~
	~~Regenerative main filter, activated carbon (two-fold)~~
	~~High scrubber for emissions from tank farms and from loading processes, two-fold~~
	~~Strippers for the extraction of solvents from water (gas extraction with air), two-fold~~
	~~Biological water treatment for condensates from high scrubber and activated carbon step~~
	~~Cooling towers (outside of the building)~~
~~Technology~~	~~Adsorption to activated carbon~~
	~~Physical absorption to wash with recovery of solvents~~
~~Emission control~~	~~Online analysis of total carbon, perchloroethylene, methylene dichloride, trichloroethylene, glycols, BTX aromates~~
~~Input materials~~	~~Exhaust air streams contaminated with solvents (VbF, CHC and others)~~
~~Operational capacity~~	~~6000 m^3/h lightly polluted exhaust air from production halls~~
	~~400 m^3/h highly polluted exhaust air from tank farm and loading processes~~
~~Emission achieved values~~	~~With regard to organic substances contained in waste gas, except organic particle matter, a total mass flow of <57 kg/yr or a total mass concentration of <3.6 mg TOC/Nm³ are achievable each of which to be indicated as total carbon~~
~~*Source*:[86, UBA Germany 2003]~~	

Table 2.83: ~~Combined abatement of particulates and VOCs in a hazardous waste treatment plant~~

~~Abatement treatment composed of~~	~~a. collection of contaminated air with a network under depression~~ ~~b. group of cyclones and filters used in order to reduce the particulate concentration~~ ~~c. regenerative thermal oxidation system~~
~~Achieved environmental benefits~~	~~The regenerative thermal oxidation system is a non-burning system and has no combustion chamber. As a consequence it does not generate NO^*. Because the pollutants are degraded at high temperature (950 °C), they can achieve VOC concentrations in the outlet of less than 50 mg/Nm^3~~
~~Operational data~~	~~Electrical power is needed to maintain the high temperature and natural gas is necessary to run the process~~
~~Example plant~~	~~One plant in France~~
~~*Source*:[28, Scori 2002]~~	

From ex-**Section 4.6.26 "Some examples of abatement techniques comparisons applied to the preparation of waste fuel from hazardous waste"** deleted because replaced by data collection.

~~and compare some abatement techniques when applied to one specific waste treatment.~~

Table 2.84: ~~Comparison of bag filters and wet scrubbers for the abatement of dust emissions~~

~~Criteria~~	~~Bag filter~~	~~Wet scrubber~~
~~Dust treatment performance~~	~~+~~	~~-~~
~~Flexibility~~	~~+~~	~~+~~
~~Consumption~~	~~++~~	~~-~~
~~Costs~~	~~++~~	~~-~~
~~Risks (fire, explosion, etc)~~	~~+~~	~~++~~
~~Cross-media effects~~	~~+~~	~~-~~
~~Note: (-) poor, (+) acceptable and (++) well adapted~~ ~~*Source*: [78, Eucopro 2003]~~		

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Table 2.85: Comparison of VOC abatement technique

~~Criteria~~	~~Nitrogen trap~~	~~Biological treatment~~	~~Activated carbon~~	~~Combined combustion~~	~~Catalytic combustion~~	~~Regenerative thermal oxidiser~~
~~VOC performance~~	~~++~~	~~-~~	~~-/+~~	~~+~~	~~+~~	~~++~~
~~Consumption~~	~~-~~	~~++~~	~~++/ -~~	~~++~~	~~+~~	~~+~~
~~Costs~~	~~+~~	~~++~~	~~++~~	~~++~~	~~-~~	~~+~~
~~Flexibility~~	~~-~~	~~-~~	~~+~~	~~+~~	~~-~~	~~++~~
~~Risk (e.g. fire, explosion)~~	~~+~~	~~+~~	~~-~~	~~+~~	~~+~~	~~+~~
~~Cross-media effects~~	~~-~~	~~-~~	~~-~~	~~+~~	~~+~~	~~+~~
~~Note: (-) poor, (+) acceptable and (++) well adapted~~ ~~*Source*: [78, Eucopro 2003]~~						

2.3.7 Techniques for the reduction of water usage and waste water generation [~~use and prevent water contamination~~]

From ex-Section 4.1.3.6

Description

~~Water use should be minimised within the BAT criteria for the prevention or reduction of emissions and should be commensurate with the prudent use of water as a natural resource~~.

Some important – and normally easily retrofittable – production-integrated measures relevant to waste water are described in the CWW BREF. [118, COM 2003]

Their introduction, e.g. as water-saving measures, however, has to be carefully assessed. Though their influence is normally environmentally beneficial, they might under specific circumstances lead to negative impacts on other environmental aspects that might overshadow the benefits of water conservation or pollutant decrease.

~~Some general information about those issues have been analysed in the 'Common Waste water and waste gas treatment' BREF.~~ Some techniques to consider ~~for the WT sector~~ are:

Water saving

a. Drawing up a water-saving action plan and performing regular water audits, with the aim of reducing water usage and preventing water contamination, including: ~~A good water audit requires the following:~~
   - ~~the production of~~ flow diagrams and water mass balances; ~~for all activities using water~~
   - the establishment of water efficiency objectives; ~~by comparison with sector guidance or, where this is not available, national benchmarks~~
   - the ~~use~~ implementation of water pinch techniques or other water optimisation techniques.
   - ~~the use of the above information to identify and assess opportunities for a reduction in water use and so that an action plan can be prepared for the implementation of improvements, set against a given time-scale~~

b. Using water-efficient techniques at source.

c. Minimising the water used in cleaning and washing down (subject to the impact on dust emissions) by:
   - vacuuming, scraping or mopping in preference to hosing down;
   - evaluating the scope for reusing washing water;
   - using trigger controls on all hoses, hand lances and washing equipment;

From ex-**Section 4.1.6.2 "Techniques to reduce emissions from washing process"**

   - identifying the components that may be present in the items to be washed (e.g. solvents);
   - transferring washed waste to appropriate storage and then treating this in the same way as the waste from which it was derived.

WORKING DRAFT IN PROGRESS

- ~~using treated waste water from the WT plant; the resultant waste water can be recycled in the WWTP or back to the installation in the case of Ph-c treatment plants. In the latter case, the waste water is treated exactly the same way as waste which has been transported and delivered in the cleaned construction/receptacle/container~~.

d. Avoiding the use of potable water for processes and air pollution abatement techniques.

From ex-Section 4.1.3.6

Water recycling

e. Recycling water within the process as far as possible. This may require the identification of the scope for substituting water from recycled sources and the water quality requirements associated with each use. ~~Possible options where this may be possible are:~~

- ~~to recycle water within the process from which it arises, by treating it first if necessary. Where this is not practicable, it can be recycled to another part of the process which has a lower water quality requirement~~
- ~~to identify the scope for substituting water from recycled sources, identifying the water quality requirements associated with each use~~. ~~Less contaminated water streams, for example, cooling waters, need to be kept separate if there is some scope for its re-use, possibly even after some form of treatment~~

From ex-Section 4.7.1

a. Reusing ~~treated waste waters and~~ rainwater in the process (e.g. cooling water).

Discharge of waste water

From ex-Section 4.1.3.6

f. Separately discharging uncontaminated roof and surface water. ~~which cannot be used~~

g. Discharging rainwater to interceptors.

h. Ultimately carrying out some form of treatment on the waste water in the event of direct discharge to the environment. ~~However, in many applications, the best conventional effluent treatment produces a good water quality which may be usable in the process directly or when mixed with fresh water. While treated effluent quality can vary, it can be recycled selectively when the quality is adequate, and still reverting to discharge when the quality falls below that which the system can tolerate. The WT operator can identify where treated water from the effluent treatment plant could be used and justify where it cannot. In particular, the cost of membrane technology continues to come down in price, so much so that now this can be applied to individual process streams or to the final effluent from the effluent treatment plant~~

~~i. replacing the effluent treatment plant, leading to a much lower effluent volume. However, a concentrated effluent stream will remain but, where this is sufficiently small, and particularly where waste heat is available for further treatment by evaporation, a zero effluent system could be produced~~

From ex-**Section 4.3.1.1 Planning the operation of a Ph-c plant**

j. Preventing the ~~production~~ generation of waste water ~~is prevented~~ as far as possible by construction measures, e.g. roofing of the reception area.

Already in techniques for storage

~~k. undercovering some parts of the site to avoid contamination of rainwater (e.g. in the main waste treatment plant)~~

~~l. protecting systems to avoid liquid and solid spills being discharged directly to watercourses or to sewer~~

~~m. identifying, and where possible, quantifying significant fugitive emissions to water from all relevant sources, including estimating the proportion of total fugitive emissions for each substance~~

~~n. applying the following techniques to subsurface structures~~

- ~~establishing and recording the routing of all installation drains and subsurface pipework~~
- ~~identifying all subsurface sumps and storage vessels~~

WORKING DRAFT IN PROGRESS

  - ~~applying engineering systems to ensure leakages (e.g. from pipes) are minimised and where these occur, can be readily detected, particularly where hazardous substances are involved~~
  - ~~providing, in particular, secondary containment and/or leakage detection for such subsurface pipework, sumps and storage vessels~~
  - ~~establishing an inspection and maintenance programme for all subsurface structures, for example, pressure tests, leak tests, material thickness checks~~

~~o. applying the following techniques to surfacing structures:~~

  - ~~describing in detail the design (relevant information may include as appropriate: capacities; thicknesses; distances; material; permeability; strength/reinforcement; resistance to chemical attack; inspection and maintenance procedures; and construction quality assurance procedures), and conditions of the surfaces of all operational areas~~
  - ~~having in place an inspection and maintenance programme of impervious surfaces and containment kerbs~~
  - ~~justifying where operational areas have not been equipped with:~~
    - ~~an impervious surface~~
    - ~~spill containment kerbs~~
    - ~~sealed construction joints~~
    - ~~connection to a sealed drainage system.~~

p. ~~applying the techniques to bunds mentioned in Section~~

Achieved environmental benefits

The achieved environmental benefits include:

- reduction of water usage;
- reduction of pollutants released to water;
- reduction of sludge generation.

~~Reducing the water use may be a valid environmental (or economic) aim in itself. In addition, from the point of view of reducing polluting emissions, any water passing through an industrial process is degraded by the addition of pollutants, and therefore there are distinct benefits to be gained from reducing the water used, in particular:~~

- ~~associated benefits within the process such as a reduction in energy requirements for heating and pumping the water~~
- ~~reduction of water use reduces dissolution of pollutants into the water leading in turn to reduced sludge generation in the effluent treatment plant~~
- ~~a mass balance calculation carried out in the water can typically reveal where consumption reductions can be made.~~

Environmental performance and operational data

~~Some installations have reported that it is possible to reduce up to 90 % of the water consumption.~~

From ex-**Section 4.1.6.2 "Techniques to reduce emissions from washing process"**

The washing of drums and IBCs is usually only carried out where there is an adjacent treatment plant to accept the washing water~~s~~ or when there are other possibilities available to treat the washing water properly.

Washing and cleaning procedures are generally carried out using treated waste water. The resultant washing and cleaning waste water is returned to the process or to the WWTP plant for retreatment. In some cases, the WWTP is installed outside the WT plant.

Cross-media effects

There may be some cross-media effects depending on the concrete measures taken to reduce water usage (e.g. consumption of energy).

WORKING DRAFT IN PROGRESS

Recycling processes often generate risks for the quality of the recycled water (e.g. increase of the pollutant concentration). An upset in a waste water treatment process used prior to recycling may require another source of water to be used temporarily.

In some cases (e.g. biological treatment of waste), recycling water may generate odorous emissions and/or inhibit biological degradation.

Technical considerations relevant to applicability

Typically this is a part of an~~ integral~~ EMS (Section 2.3.1.1) ~~in~~ for the plant. ~~Some of these techniques are only applied to complex WT plants, to identify the opportunities for maximising the re-use, and for minimising the use of water.~~

The techniques mentioned above may have some applicability restrictions in the ~~case~~ event that water releases are continuous or batch and in the event ~~case~~ that the WWTP is installed on site or off site.

Economics

No information available.

~~Some economic incentives to apply this technique can be to:~~

- ~~reduce the necessary size of (a new) waste water treatment plant~~
- ~~reduce costs where water is re-used in-house or purchased from, or disposed of to, another party~~.

Driving force for implementation

- Environmental legislation.
- Economic incentives to reduce waste water generation and water usage. In some EU countries, there are incentive systems in place which ~~have the~~ aim to encourage a reduction in water usage.

Example plants

~~Flow diagrams and water mass balances are commonly used. Some sites have sub surface interceptors, storage tanks, mixing tanks and pipe runs and it may be difficult to see how the integrity of these could be determined. There may be emissions to the underlying ground from all of these installations that would generally be treated as a notifiable release.~~
See examples in Sections 4.5.1.5, 5.2.3.2 and 5.6.3.2.1 for reuse of water.

See Section 2.3.6.7 for waste water treatments carried out by plants with direct discharge to the environment.

Reference literature

[32, Vrancken et al. 2001][33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [98, WT TWG 2004] [33, UK EA 2001] [60, WT TWG 2003] [77, Schmidt et al. 2002]

Ex-Section **4.7.3 Primary waste water treatments** deleted: relates to oil/water separation and air stripping techniques which are dealt with respectively in Sections 2.3.6.4.1 and 2.3.6.5.5

~~**Description**~~

~~Some techniques include:~~

a. ~~ensuring that the effluent is free of visible oil. This check needs to include procedures to ensure the correct configuration, operation and maintenance of the oil/water separation plant~~
b. ~~performing air stripping in the aeration tanks of landfill leachates before it is mixed with waste water from the plant.~~

WORKING DRAFT IN PROGRESS

~~Achieved environmental benefits~~

~~Removes or reduces target substances from waste water. Related to technique b in the description section above, such a system is designed to remove any excess ammonia and methane from the leachates before these emissions go direct to the air or cause a risk of explosions in the sewer. An estimated discharge of five tonnes ammonia per year has been reported from one site.~~

~~Applicability~~

~~Air stripping is used to remove halogenated and non-halogenated hydrocarbons from dilute aqueous solution, to allow the residual solution to be processed within the WWTP without affecting effluent discharge standards. The hydrocarbons are recovered in carbon filters. Air stripping is ideally suited for low concentration streams (<200 ppm). The steam stripping process is capable of reducing VOCs in water to very low concentrations (i.e. ppb levels).~~

~~Reference literature~~

~~[33, UK EA 2001] [34, Babtie Group Ltd 2002] [98, WT TWG 2004]~~

Ex-Section **4.7.4 Secondary waste water treatments** deleted: general statements already in the following sections

~~Description~~

~~Some techniques include:~~

a. ~~having an in-house effluent treatment unit which uses vacuum filtration to remove colloidal solids~~
b. ~~ensuring that the levels of metals in solution are minimised, normally by adjusting the pH to the correct level required to maintain minimum solubility~~
c. ~~ensuring that the cyanide treatment (oxidation of cyanide) is carried out to completion, normally by maintaining pH >10 and preventing the carry over of NaOCl due to overdosing~~
d. ~~having in place a pH neutralisation system~~
e. ~~utilising a flocculation process to create a filter cake, with neutralisation of the filtrate and a discharge to sewer for the handling of latex emulsion waste and contaminated site rainwater. The final cake analysis will have a nitrogen concentration of ~ 51 mg/kg of cake.~~

~~Achieved environmental benefits~~

~~Precipitation and flocculation are employed to convert dissolved substances into solids and to concentrate them so that they can be separated by adapting an appropriate pH value.~~

~~Precipitation transfers dissolved inorganic and organic substances into the undissolved solid phase through a chemical reaction. During flocculation, physico-chemical processes (destabilisation, creation of micro- and macroflocs) are used to bring fine suspended or colloidal substances into a condition in which they can be separated from the fluid phase by mechanical procedures (e.g. sedimentation, flotation, filtration). In practice, precipitation and flocculation often take place in parallel with adsorption processes.~~

~~Operational data~~

~~Certain inorganic and organic complexing agents contained in the water can disrupt or inhibit the precipitation reaction.~~

~~High concentrations of neutral salts raise the residual solubility in the neutral precipitation of metals. If the requirements regarding the residual metal concentrations are not fulfilled, further treatment steps will be necessary, e.g. additional precipitation as sulphide, filtration, ion exchange, etc.~~

~~In order to ensure optimal conditions for precipitation and flocculation pretreatment may be necessary. This may involve a separation of light substances, emulsion splitting, complex destruction or a systematic removal, detoxification or avoidance of substances which may~~

WORKING DRAFT IN PROGRESS

~~disrupt the reaction or the subsequent separation of solids. This may also possibly lead to a requirement for the separate treatment of wastes and their waste waters.~~

~~If the waste water contains surface-active substances which can lead to foaming in the reaction containers, counteractive measures need to be taken.~~

~~**Applicability**~~
~~Chemical precipitation is employed mainly to remove metal ions from waste waters and for the chemical elimination of phosphate. Apart from the separation of precipitation products, flocculation also removes suspended solids and higher molecular compounds.~~

~~For precipitation and flocculation, the following points may be of importance and should be taken into consideration:~~

- ~~chemical precipitation should lead to compounds with correspondingly low solubility product~~
- ~~in order to ensure optimal contact between the reaction partners, good mixing is necessary in the precipitation reactor. Effective flocculation also requires a swift and even distribution of the flocculation agents. Applying stirring allows the creation of flocs that sediment well, although overly large shearing forces should be avoided~~
- ~~separation of the coagulation phase (compensation of the electrical potential of the colloids) and flocculation phase into two distinct steps is an appropriate way in many cases to achieve a good flocculation result~~
- ~~refeeding the contact sludge improves the production of compact, heavy flocs and ensures the optimal utilisation of reagents~~
- ~~a multi-stage precipitation and flocculation process supports the stepwise achievement of the optimal pH-value and the efficient/effective combination of different precipitation and flocculation techniques (e.g. hydroxide precipitation followed by sulphide precipitation).~~

~~**Reference literature**~~
~~[33, UK EA 2001] [89, UBA Germany 2003]~~

2.3.8 Techniques for the prevention or reduction of consumption of raw materials and chemicals

From ex-**Section 4.1.3.5 "Raw material selection"**

Description
~~This section deals with the selection and substitution of the raw materials used.~~
Waste is used instead of raw materials for the treatment of other wastes by substituting chemicals or raw materials.

Technical description
Some techniques are as follows:

a. Identify the raw and auxiliary materials, other substances and water that have been proposed for use. This involves ~~gathering~~ compiling a list ~~**together**~~ of the materials used (including ~~i.e.~~ generic information about the materials; note that grouping together those of a similar type is normally adequate rather than listing every commercial alternative used) which have the potential for significant environmental impact, including:
    - the chemical composition of the materials where relevant;
    - the quantities used;
    - the fate of the material (~~that is~~,i.e. approximate percentages going to each media and to the product);
    - the environmental impact where known (~~for example~~ e.g. degradability, bioaccumulation potential, toxicity to relevant species);

WORKING DRAFT IN PROGRESS

- any reasonably practicable alternative raw materials which may have a lower environmental impact (i.e. applying the substitution principle).

b. Justify (for example, on the basis of emissions, product quality and economic reasons), the continued use of any substance for which there is a less hazardous alternative.
c. Maintain a detailed inventory of the raw materials used on site.
d. Implement procedures for the regular review of new developments in raw materials and the regular implementation of any suitable materials that are less hazardous.
e. Have quality assurance procedures in place for the control of the content of raw materials.
f. Explore the options for the use of waste as a raw material for the treatment of other wastes, such as:
    a. ~~reuse the~~ spent lime from ~~incinerator lime injection~~ acid gas abatement systems;
    b. ~~reuse~~ waste strong acids; ~~in those treatments where acid is needed.~~
    c. fly ashes or air pollution control residues (APCr).

Achieved environmental benefits

The environmental benefits of this technique include:

- reduction of the use of chemicals and other materials;
- ~~substitute less harmful materials for those which can be more readily abated, and when abated can lead to substances which, in themselves, are more readily dealt with~~
- ~~help to~~ ~~develop~~ improvement of the understanding of the fate of by-products and contaminants, and their potential environmental impact.
- ~~be seen as a preferred option for some acid wastes, but depends on the volume and contamination of the waste.~~

Environmental performance and operational data

Due to the nature of ~~the~~ WT processes, the consumption of raw material is influenced by the variation of the input waste ~~IN~~. Moreover, there are cases where substitution of raw materials by waste is not possible. For example, raw lime has a much higher alkalinity than spent lime, and consequently larger volumes of ~~the~~ spent lime are required. This places a ~~limitation~~ constraint on ~~in relation to~~ the size of reactor vessel. This requires a similar scale-up with mixing tanks to produce the lime solution.

The following raw material substitutions are considered for application in the UK.(Table 2.86)

Table 2.86: Examples of raw material substitution

Raw material	Possible substitute
Sodium hydroxide	Only mercury-free NaOH is used(1)
Demulsifiers	Only fully biodegradable products with known safe degradation products are used
(1) Industry producers of NaOH consider that mercury-free NaOH should contain less than 50 µg/kg. *Source*: [33, UK EA 2001] [60, WT TWG 2003]	

In one plant (Plant 497), it is estimated that using APCr could reduce raw material consumption by 50 %. Other properties of the APCr can be beneficial as they are able to effectively precipitate soluble sulphates and fluorides which may be present from the acidic waste.

Cross-media effects

- ~~Possible, for example in the~~ When reusing ~~of~~ spent lime, attention is paid to the level of metal and organic contamination that may be present.
- When reusing APCr:
    - as the APCr contain other solid material besides lime, a greater quantity of slurry is required to have the same neutralisation capacity; this causes the process to be less efficient in terms of operational hours.
    - hydrogen may be generated.

Technical considerations related to applicability

WORKING DRAFT IN PROGRESS

The scope to minimise the potential environmental impact of the use of raw materials is sometimes limited in terms of the quantity used (waste minimisation) or of their nature (for example, presence of contaminants, use of less harmful alternatives).

The use of waste as a reagent may be limited, e.g. due to local constraints.

Driving force for implementation
The driving forces for implementation are economic and environmental reasons. For concentrated acids (> 70 w/w-%) there is a market for blended or reconcentrated acids. It has become viable to use 50 w/w-% acids, although this requires a greater energy input. ~~It is anticipated that the growth area for this market may be in the 20–30 % acids range.~~

~~Annex IV of the IPPC Directive states that considerations to be taken into account generally, and in specific cases when determining BAT, are the use of low waste technology and less hazardous substances, the recycling of substances generated and of waste, where appropriate~~.

Example plants

~~Ph-c plants are planned in such a manner that a maximum amount of recyclable materials can be separated and a minimum amount of auxiliary materials must be used. The consumption of auxiliary materials is minimised by as much as possible if the waste which is to be disposed of can be used (i.e. treatment of waste with waste) instead of manufactured materials.~~

Of 27 plants performing physico-chemical treatment of solid and/or pasty waste, seven (Plants 176, 181, 187, 348, 475, 495, 497 and 569) reported the use of waste input as a reagent. The amount of waste input used as raw material, which varies in relation to the type of process and waste input, and with the size of the plant, ranges from 2 000 tonnes to 42 000 tonnes (average over the three reference years). The waste input reportedly used as raw materials is fly ashes (used as blinders), mineral residues, acids, etc. Meanwhile, the reported amount of raw materials used (average over the three reference years) ranges from 1 400 tonnes to 22 000 tonnes.

Plant 497 reported the use of APCr as a replacement for hydrated lime in the neutralisation of waste acids. The plant was installed in September 2013. In the first six months of 2014 the plant processed approximately 843 tonnes of APCr. This represents approximately 280 tonnes of hydrated lime.

Reference literature
[33, UK EA 2001] [60, WT TWG 2003] [77, Schmidt et al. 2002] [98, WT TWG 2004]
[160, WT TWG 2014]

Ex-Section **4.1.2.2 "Guaranteed supply of waste"** deleted. It is process-oriented and not a technique as such.

2.3.9 Techniques for the efficient use of energy

From ex-**Section 4.1.3.4 "Measures to improve energy efficiency"**

2.3.9.1 Energy efficiency plan

Description
The energy efficiency plan gathers a set of organisational and technical measures aiming at using energy efficiently. It is part of the environmental management system (EMS).

Technical description
Extensive information about energy efficiency can be found in [153, BREF ENE]. Some techniques applicable to increase the energy efficiency of WT plants are as follows:

WORKING DRAFT IN PROGRESS

a. ~~developing an energy efficiency plan which appraises~~ Appraising the costs and benefits of different energy options.
b. ~~including energy management techniques as part of the whole environmental management system (EMS), including the~~ Monitoring ~~of~~ energy flows (consumption and generation by source) and the targeting of areas for reductions.
c. Defining and calculating the specific energy consumption of the activity (or activities), and setting key performance indicators on an annual basis (e.g. MWh/tonne of waste processed). For example, based on the primary energy consumption for the products or raw material inputs which most closely match the main purpose or production capacity of the plant.
d. Carrying out an energy survey to identify the opportunities for further energy savings.
e. Using combined heat and power (CHP).
f. Applying operating, maintenance and housekeeping measures to the most relevant energy consumption plants, such as:
    - air conditioning, process refrigeration and cooling systems (leaks, seals, temperature control, evaporator/condenser maintenance);
    - operation of motors and drives (e.g. high-efficiency motors);
    - compressed gas systems (leaks, procedures for use);
    - steam distribution systems (leaks, traps, insulation);
    - room heating and hot water systems;
    - lubrication to avoid high friction losses (e.g. mist lubrication);
    - boiler maintenance, e.g. optimising excess air;
    - other maintenance relevant to the activities within the plant;
    - reviewing equipment requirements on a regular basis;
    - minimising spillages and leaks by the use of drip trays; most fuel spills will be washed to the main site interceptors.
g. Using techniques that reduce energy consumption and thereby reduce both direct (heat and emissions from on-site generation) and indirect (emissions from a remote power station) emissions. For example, techniques covering:
    - building insulation;
    - use of energy-efficient site lighting;
    - vehicle maintenance;
    - efficient plant layout to reduce pumping distances;
    - phase optimisation of electronic motors;
    - heat recovery;
    - ensuring equipment is switched off, if safe to do so, when not in use;
    - ensuring on-site vehicle movements are minimised and engines are switched off when not in use.
h. Applying basic, low-cost, physical techniques to avoid gross inefficiencies; including insulation, containment methods, (for example, seals and self-closing doors) and avoiding unnecessary discharges of heated water or air (for example, by fitting simple control systems).
i. Applying energy efficiency techniques to building services.
j. Setting the time of operation of the high energy equipment to off-peak periods.
~~k. minimising the emissions of diesel engines~~
l. Using landfill gas to produce electricity and heat.
m. Using heat from the furnaces and engines for vaporisation processing, drying and for preheating activities.
n. Selecting the appropriate waste to be treated in the plant. Typically, plants not designed to treat a certain type of waste consume more energy when treating such waste.

Achieved environmental benefits

~~An energy efficiency plan could be summarised in a format similar to the example below in Table 2.89, together with supporting information from any appraisal procedure carried out. The plan is required to ensure that the operator has considered all relevant techniques.~~

WORKING DRAFT IN PROGRESS

Table 2.87: CO$_2$ saving from the integration of different improvement energy efficiency techniques

~~Energy efficiency option~~	~~CO$_2$ savings (tonnes)~~	
	~~*Annual*~~	~~*Lifetime*~~
~~7MW CHP plant~~	~~13500~~	~~135000~~
~~High efficiency motor~~	~~2~~	~~14~~
~~Compressed air~~	~~5~~	~~n.a.~~

~~[33, UK EA 2001]~~

Utilising an energy efficiency plan and switching to cleaner fuels can reduce the energy consumption and the environmental emissions of that energy use. An increase in the energy efficiency of the boilers and heaters reduces the emissions of VOCs, due to the more complete combustion and the minimisation of fuel losses.

Environmental performance and operational data

~~The place within the existing WT installation where the improvement is applied typically dependent on the existing installation.~~
No information available.

Cross-media effects

None.

Technical considerations related to applicability

The technique is fully applicable. However, in installations where several WT activities are performed, the energy consumption may be difficult to allocate to each activity due to the integrated approach typically used by the energy system.

These techniques are more extensively applied to large consumers of energy. For energy-intensive industries, the application of energy efficiency techniques to building services may only have a minor impact and should not distract effort away from the major energy issues. They can, nonetheless, find a place in the improvement programme, particularly where they can constitute more than 5 % of the total energy consumption.

Economics

Energy-efficient systems typically have higher investment costs. However, their operation costs are usually lower (or the revenues higher). Costs are typically higher for existing plants than for new plants. Some examples are shown in Table 2.88.

Table 2.88: Economics of the integration of different improvements to energy efficiency techniques

Energy efficiency option	Net Payback Value (NPV) (thousand EUR)	NPV/CO$_2$ saved (EUR/tonne)
7 MW CHP plant	2058	15
High-efficiency motor	0.75	52.5
Compressed air	n.a.	n.a.

NB: Indicative only, based on cost-benefit appraisal.
Source: [33, UK EA 2001]

The improvement of the energy efficiency needs to be balanced with the cost to achieve this. Waste treatments consume some sort of energy (electricity, steam, etc.) and the possibility to decrease the consumption in an existing plant may be rather limited in some cases. In such cases, the efforts required may not be economically or environmentally justified.

Driving force for implementation

WORKING DRAFT IN PROGRESS

Energy savings.

Reference literature

[33, UK EA 2001] [34, Babtie Group Ltd 2002] [44, TWG 2003] [73, Irish EPA 2003] [88, UBA Germany 2003] [98, WT TWG 2004]
[101, WT TWG 2005]

2.3.9.2 Energy balance

From **ex-Section 4.1.3.1 "Provision of a breakdown of the energy consumption and generation by source**

Description

In order to improve the energy system from an environmental point of view, the system needs to be well understood and fully reported. Below are some techniques that may be used:

a. Reporting energy consumption information in terms of delivered energy. For electricity, this may be converted to primary energy consumption using national/regional factors (e.g. in the UK for the public electricity supply, a conversion factor of 2.6 is typically used). An example format of how the information may be presented is given in Table 2.89 below.

Table 2.89: Example format of energy consumption reporting

Energy source	**Energy consumption**		
	Delivered (MWh)	**Primary (MWh)**	**% of total**
Electricity*			
Gas			
Liquid fuels			
Waste			
Other (operator to specify)			

* specify source
Source: Based on [33, UK EA 2001]

b. Reporting the energy exported from the plant.
c. Providing energy flow information (for example, diagrams or energy balances) showing how the energy is used throughout the process. This information may allow operators to define or calculate the specific energy consumption of the plant.

Achieved environmental benefits

Reduction of energy consumption.

Environmental performance and operational data

The reduction of emissions from the energy system can only be evaluated with a proper calculation of the actual emissions generated. The breakdown between generation and consumption can help to optimise the balance between them and hence to optimise the use of energy resources.

Cross-media effects

In some cases, the environmental benefit of this technique is limited. The reason is that the possibility to decrease the consumption in an existing plant may be limited, and possible efforts to decrease consumption need to be balanced against possible higher emissions from the treatment.

Technical considerations related to applicability

The technique is fully applicable throughout the WT sector. However, in certain circumstances (e.g. historical development of the installation/site, management of the installation), it may be difficult to relate consumption levels to each single process/treatment carried out within the

WORKING DRAFT IN PROGRESS

overall WT process. These reports are typically carried out every year or every six months. Higher frequencies may be applied in the case of a higher variation in the types of waste treated.

Economics
The requirements are basic and cost little.

Driving force for implementation
Reduction of energy costs.

Reference literature
[33, UK EA 2001] [73, Irish EPA 2003] [98, WT TWG 2004] [101, WT TWG 2005]\

2.3.10 Techniques for the prevention and control of noise and vibration emissions

From ex-Section 4.1.8

2.3.10.1 Noise and vibration management plan

Description
Implementation of a noise and vibration management plan ~~is typically~~ as part of the environmental management system (EMS) (see Section 2.3.1.1).

Technical description
Such a plan normally does the following:

a. Describes the main sources of noise and vibration (including infrequent sources), and the nearest noise-sensitive locations. This description covers the following information for each main source of noise and vibration within the installation:

- the source and its location on a scaled plan of the site;
- whether the noise or vibration is continuous/intermittent, fixed or mobile;
- the hours of operation;
- a description of the noise or vibration, e.g. clatter, whine, hiss, screech, hum, bangs, clicks, thumps or has tonal elements;
- its contribution to the overall site noise emission, e.g. categorised as high, medium or low unless supporting data are available.

b. Also provides the above information for the operation of infrequent sources of noise and vibration (such as infrequently operated/seasonal operations, cleaning/maintenance activities, on-site deliveries/collections/transport or out-of-hours activities, emergency generators or pumps and alarm testing).
c. Details the appropriate noise surveys, measurements, investigations (which can involve detailed assessments of sound power levels for individual plant items) or modelling that may be necessary for either new or existing installations taking into consideration the potential for noise problems.
d. Describes a protocol for response to identified noise and vibration incidents.

~~Sticking to the ‘noise and vibration’ plan encourages operators to:~~
~~d. adequately maintain any parts of the plant or equipment whose deterioration may give rise to increases in noise (e.g. to carry out maintenance of bearings, air handling plant and the building fabric, as well as specific noise attenuation measures associated with plant, equipment or machinery)~~
~~e. enclose noisy areas/activities inside buildings.~~

Achieved environmental benefits
Reduction of noise levels generated by the installation.

WORKING DRAFT IN PROGRESS

Environmental performance and operational data
No information.

Cross-media effects
None.

Technical considerations related to applicability
A common-sense approach needs to be adopted in determining which sources to include. The ones which need to be considered are those which may have an environmental nuisance impact; for example, a small unit could cause an occupational noise issue in an enclosed space but would be unlikely to cause an environmental issue. Conversely a large unit or a number of smaller units enclosed within a building could, for example, cause a nuisance only if the doors are left open. It also needs to be remembered that some noise, which is not particularly noticeable during the day, may become more noticeable at night.
The applicability is restricted to cases where a noise or vibration nuisance in residential or other sensitive areas (e.g. recreational areas) can be expected and/or has been reported

Economics
No information.

Driving force for implementation
~~A reduction of noise and vibrations.~~
Environmental legislation.

Example plants
No information.

Reference literature
[33, UK EA 2001] [98, WT TWG 2004]

2.3.10.2 Noise and vibration reduction at source and noise abatement

Description
Implementation of operational and maintenance techniques, as well as low-noise equipment and buildings.

Technical description
Techniques to reduce noise and vibration emissions include:

- appropriate location of equipment and buildings: noise levels can be reduced by increasing the distance between the emitter and the receiver and by using buildings as noise screens.;
- inspection and maintenance of equipment;
- use of low-noise equipment (e.g. compressor with noise level < 85 dB(A), speed-controlled pumps and fans);
- soundproofing of buildings to shelter any noisy operations including:
    - sound-absorbing walls and ceilings,
    - sound-isolating doors,
    - double-glazed windows;
- use of vibration or acoustic insulation, or vibration isolation;
- enclosure of noisy equipment;
- reduction of noise propagation by inserting appropriate obstacles such as protection walls, embankments, and buildings.

Achieved environmental benefits
Reduction of noise emissions.

WORKING DRAFT IN PROGRESS

Environmental performance and operational data
In mixed scrap shredding plants, local screening and localised noise barriers placed around particular activities or processes would achieve significant noise reductions. With use of the appropriate noise-absorbing materials, this could be 5–10 dB on the screened side.

Cross-media effects
None.

Technical considerations relevant to applicability
The location of equipment and buildings may be applicable to new plants only. Low-noise equipment can be installed when the old equipment is replaced.
The use of other noise-reducing equipment is subject to space availability.
Total enclosure of mixed scrap shredder plants is not appropriate due to possible deflagrations, but screening can be located along the entire length of shredders and enclosing whole metal recycling yards in order to control and reduce noise levels.

Economics
No information.

Driving force for implementation
Environmental legislation.

Example plants
No information.

Reference literature
[107, Mech. subgroup 2014] [138, COM 2014]

2.3.11 Techniques for the prevention of soil and ground water contamination

From ex-**Section 4.8.2 "Techniques to prevent the contamination of soil"**

Description
These techniques relate to water spills and other fugitive emissions into soil and groundwater: ~~as already dealt with in Section 2.3.6.7 and to decommissioning as already dealt with in Section~~

- Sealed surface and retention volume
- Adequate drainage infrastructure
- Design and maintenance provisions to allow detection and repair of leaks
- Security basin

Technical description
Some specific techniques include the following:

a. Providing and then maintaining the surfaces of operational areas, including applying measures to prevent or quickly clear away leaks and spillages, and ensuring maintenance of drainage systems and other subsurface structures.

From ex-Section 4.7.1

b. Utilising an impermeable base and internal site drainage systems which lead to storage tanks or to interceptors that can collect rainwater and any spillages. Interceptors with an overflow to the sewer usually need automatic monitoring systems, such as a pH check, which can shut down the overflow.

c. ~~having in place and operating an enclosure system whereby~~ Collecting rainwater falling on the processing areas ~~is collected~~ along with tanker washings, occasional spillages, drum

WORKING DRAFT IN PROGRESS

washings, etc.~~ and~~ Rainwater is returned to the processing plant or collected in a combined interceptor.

d. ~~collecting the raining~~ Rainwater is collected in a special basin for further treatment ~~in the case~~ if it is detected that it is contaminated (see also Section 2.3.13.1).

b. The drainage infrastructure is capable of collecting and discharging all run-off water in case of heavy rains. [107, Mech. Subgroup 2014]

~~e. only discharging the waste water from its storage only after the conclusion of all the treatment measures and a subsequent final inspection~~

~~f. use of landfill leachate as water input for the aerobic digestion~~

~~g. process and run-off water is handled by means of a closed circulation system~~

~~h. partial re-use of the water used for the production of polymer solution~~

i. ~~displacement methods of treating chemical process waters containing VOC (another specific example is contaminated groundwater), resulting in a lower COD content~~

c. Applying separate drainage systems and sumps to enable the isolation of specific areas of the site where waste is stored, handled and bulked, in order to contain all possible spills. ~~and to protect surface water drainage from contamination. These can help to reduce liquid emissions~~

~~j. .~~

d. ~~minimising the installation site and~~ Minimising the use of underground vessels and pipework. When underground or partially underground vessels are used, a secondary containment is put in place, and regular monitoring for potential leakages is carried out. When underground pipework is used, it is equipped within suitable inspection channels. [153, BREF text storage]

From ex-**Section 4.3.2.3 "Immobilisation"** point p

a. A regular inspection and maintenance programme of underground equipment ~~in place~~, including:
   - replacement of the underground or partially underground vessels without secondary containment by aboveground structures;
   - replacement of structures without secondary containment.

From ex-**Section 4.8.2 "Techniques to prevent the contamination of soil"**

e. ~~designing~~ Ensuring that the areas where water-endangering liquids are transferred are bunded. The bund ~~must be watertight~~ is designed so that in the event of an accident the hazardous liquid can be contained until security measures are in place. The bund has sufficient capacity to cope with any spillage and firefighting water (usually the greater of either 110 % of the largest vessel or 25 % of the storage of the total tank or vessel volume) and used to ensure containment of wastes and raw materials.

f. Ensuring that ~~the areas where water-endangering substances are handled, as well as~~ bunded areas are specially sealed against seepage, e.g. by painting, coatings, concrete quality, sealing systems applied on the inside. There, the sealing system needs to be capable of being inspected at any time.

From ex-**Section 4.1.7 "Techniques to prevent accidents and their consequences"**

a. Systems already applied for the prevention of fugitive emissions are generally relevant ~~in addition~~ to drainage systems too (see also Section 2.3.5.3):
   - procedures ~~need to be~~ are in place to ensure that the composition of the contents of a bund sump, or sump connected to a drainage system, are checked before treatment or disposal;
   - drainage sumps ~~need to be~~ are equipped with a high level alarm or sensor with a pump to suitable storage (not to discharge);
   - ~~there needs to be~~ a system is in place to ensure that the sump levels are kept to a minimum at all times;
   - high level alarms, etc. are not routinely used as the primary method of level control.

g. Pavements, drainage and bunds are inspected daily. Particular attention is paid to signs of damage, deterioration and leakage. Records are kept detailing any action taken. Damages

WORKING DRAFT IN PROGRESS

and deterioration are repaired as soon as practicable. If the containment capacity or the capability of the bund, sump or pavement is compromised (unless effecting a repair is more expedient and working with wastes in close proximity does not compromise safety) then the waste must be immediately removed until the repair is completed.

~~g. carrying out regular monitoring of subsurface vessels for potential leakages (e.g vessel level checks during periods of inactivity)~~

Moved and merged in Section 2.3.13.2

~~h. equipping the containers used for the storage/accumulation of water-endangering materials must be equipped with double-walls or standing them in bunded tanks. There their volume capacity needs to be measured in such a way that the total volume of the largest container can be collected or 10 % of the volume of all containers in each case, the larger volume is decisive~~

~~i. equipping the containers used for the storage/accumulation of water-endangering materials with overflow controls, linked by a signal relay to the control room, as well as optical and acoustic signals. There the pumps used to fill the containers, as well as associated shut off devices (e.g. slide gate valves) should be connected to the overflow control.~~

Achieved environmental benefits

The environmental benefits of this technique include:

- Prevention of ~~the~~ short- and long-term contamination of the site.
- Minimisation of underground vessels and pipes makes maintenance and inspections easier.

Environmental performance and operational data

Problems such as cracks, blocked outlets on drains, and drainage channels of gravel between concrete slabs have all been identified in some cases.

Cross-media effects

None identified.

Technical considerations related to applicability

Generally applicable.

Economics

No information provided.

Driving force for implementation

~~IPPC requires that in carrying out industrial activities there needs to be no pollution risk from the site.~~ Some EU directives and national legislation ~~also apply~~ are intended to prevent the contamination of soil.

Example plants

~~Some examples have been reported, where although most of the sites had an impermeable base and internal site drainage, the condition of these was suspect. Almost all hazardous waste transfer stations have a secure base, which is laid with falls that drain rainwater and liquid/solid spills to one or more liquid tanks or interceptors~~.

~~Ph-c~~ Plants performing physico-chemical treatment of waste are typically equipped with seal systems to prevent spillages which can lead to groundwater or subsoil contamination. Of fundamental importance for all technical emission protection measures is the selection of construction materials, which need to offer high resistance, e.g. against acids, alkalis, or organic solvents (depending on the application).

~~Most sites have an impermeable base and operate an internal site drainage (e.g. full concrete base).~~

WORKING DRAFT IN PROGRESS

Reference literature
[28, Scori 2002][33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [77, Schmidt et al. 2002] [90, UBA Germany 2003] [98, WT TWG 2004] [153,Bref text for storage]

2.3.12 Techniques for the prevention or reduction of residues generation

From ex-**Section 4.8 "Residue management"**

The word 'residue' is used in this subsection to mean the solid waste generated by the waste treatment activity and is not directly related to the type of waste treated in the plant. This is the same type of convention used ~~in Chapter 3 and~~ throughout this document (see also the Glossary). ~~Remember that Chapter 3 called the waste coming out from the installation as waste OUT. Waste OUT has a direct relation with the waste IN of the installation. In Chapter 3, such waste was called the process generated waste, as was shown by the schematic in~~ . ~~This section covers the following type of techniques:~~

- ~~techniques for the reduction of waste generated due to the treatment (analysed in each of the previous sections of this chapter)~~
- ~~management of the waste generated due to the treatment, and~~

~~those techniques focused on a reduction of the contamination of soil~~
This subsection covers the techniques to prevent or reduce the residues generated by waste treatment.

From ex-**Section 4.8.1 "Residue management plan"**

Description
The residue management plan is a set of measures to minimise the production of residues generated by the treatment of waste, to optimise their reuse or regeneration and to establish the proper disposal of internal residues or waste.

Technical description
~~Waste minimisation is a systematic approach to the reduction of waste at source, by understanding and it necessary changing the processes and activities to prevent and reduce waste.~~ A variety of techniques can be classified under the general term ~~waste~~ residue minimisation and they range:

- from basic housekeeping techniques;
- through statistical measurement techniques;
- to the application of clean technologies;
- to the use of ~~waste~~ residues as fuel.

In particular, some techniques include the following:

a. Undertaking an analysis of the sludge/filter cake to ensure that the treatment process objectives are being met and that the process is working effectively. ~~Filter cakes and treatment sludges are typically analysed less frequently but an analysis could still enable a calculation of the metals level to be made~~. Filter cakes and treatment sludges are normally not suitable for landfilling, as they do not fulfil the criteria of the Landfill Directive.
b. Identifying, characterising and quantifying each of the ~~waste~~ residue streams generated ~~and that need to be removed from the installation~~. Maintaining a ~~waste~~ residue tracking system can help operators to record the quantity, nature, origin and, where relevant, the destination, frequency of collection, mode of transport and treatment method of any ~~waste~~ residue which is disposed of or recovered on that site.
c. Identifying the current or proposed handling arrangements.

WORKING DRAFT IN PROGRESS

d. Fully describing how each ~~waste~~ residue stream is proposed to be recovered or disposed of. If it is to be disposed of, the explanation needs to cover why recovery is not technically or economically possible and then describe/explain the measures planned to avoid or reduce the impact on the environment.
e. Ensuring that the dry solids content is not less than 15 w/w-%, to facilitate the handling of the mixture.
f. Ensuring that dust accumulations requiring removal are analysed, in order to ensure the correct disposal route is chosen, for example, for pH, COD, heavy metals and other known contaminants from the spillage.

Some techniques for minimisation include the following:

g. Recycling the filter cake arising from treatment of acidic and alkali solutions and metal precipitation, as it may contain ~~percentage levels of~~ metals such as zinc and copper with options for metal recovery.
h. Recycling contaminated drums. Undamaged 205-litre drums and 800- and 1000-litre IBCs can be recovered with cleaning and reconditioning. Damaged containers for which there is no reconditioning market and which have held non-hazardous materials may be released into the secondary metals market. Where possible, empty containers which are in sound condition and which are free from, or which contain only insignificant quantities of, residual waste need to be sent for reconditioning and reuse or recycling.
i. Using multiuse containers instead of drums for all purposes if available.
j. Utilising ~~waste~~ residue with sufficient heat content and low contamination values (see ~~Energy System~~ Section 2.3.9) as primary/secondary fuel.
k. Applying housekeeping operations; these can be as simple as sweeping prior to washing floors and can substantially reduce ~~waste~~ residue volumes.

Achieved environmental benefits
The steps above help to ensure the prudent use of natural resources and can reduce ~~waste~~ residue generation in the WT plant. They reduce emissions from the management of the residues handled in the plants and minimise the amount of residue arising, as well as helping to identify a good disposal route.

~~Soluble contaminants may appear in the eluant with the water removed by the filter pressing operation.~~

Environmental performance and operational data
For technique (h) (in the description section above), before reusing drums, the labels and inscriptions need to be removed.
Cross-media effects
The burning of residues can lead to higher emissions to air than from the use of conventional fuels.

Technical considerations related to applicability
~~The use of residues as fuel is common in waste oil treatment facilities.~~

The reuse of packaging and palettes also depends on whether the packaging is made for reuse or not. In several cases such a reuse may conflict with ADR regulations if the packaging is not retrofitted appropriately.

For technique (h) (in the description section above), the recycling of drums needs to take into account the contamination of the drums by the content. Drums unsuitable for direct recycling are typically sent to appropriate treatment, e.g. incineration. ~~For example, polyethylene drums are completely incinerated, and steel drums are cleaned and typically sorted out from the slags and recycled afterwards~~. Landfilling of contaminated drums is typically excluded.

Economics

WORKING DRAFT IN PROGRESS

In terms of capital expenditure and operating costs, sludge treatment is a significant component and the management and disposal of solid waste will remain one of the most fundamental issues facing operators.

Driving force for implementation

~~The prevention and minimisation of generation of waste as well as reducing its hazardousness is a general principle of IPPC and waste hierarchy.~~

~~The types of waste produced on each site are in many countries part of the permitting process. The permit can also describe how to store such wastes and how often to analyse them.~~

The prevention of waste generation is a principle of the IED [122, Directive 2010/75/EU 2010] and the Waste Directive [144, WFD 98/EC 2008].

Reusing drums is restricted to cases where the drums are still fit for purpose, in accordance with ADR rules, and can readily be cleaned. All other drums have to be pretreated before the scrap can be reused.

Example plants

In Germany, the use of drums has been reduced as much as possible.

The use of residues as fuel is common in waste oil treatment facilities.

Reference literature

[33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [98, WT TWG 2004] [100, WT TWG 2004]

Ex-**Section 4.8.4 "Promoting the external residue exchange"** deleted. This is about relations between operators.

2.3.13 Techniques for the prevention or reduction of the environmental consequences of accidents and incidents

2.3.13.1 General techniques for the prevention or reduction of the environmental consequences of accidents and incidents

From ex-**Section 4.1.7 "Techniques to prevent accidents and their consequences"**

Description

~~IPPC requires, as a general principle, that necessary~~ Management and technical measures ~~should be~~ are taken to prevent accidents which may have environmental consequences, and to limit those consequences.

Technical description

Those measures ~~Some techniques~~ include the following:

Accident management plan

a. Producing a structured accident management plan within a timescale, which includes the following:
   - Identifying the hazards to the environment posed by the plant. Particular areas to consider may include waste types, overfilling of vessels, failure of plant and/or equipment (e.g. over-pressure of vessels and pipework, blocked drains), failure of containment (e.g. bund and/or overfilling of drainage sumps), failure to contain firefighting water, making the wrong connections in drains or other systems, preventing incompatible substances coming into contact, unwanted reactions and/or runaway

WORKING DRAFT IN PROGRESS

reactions, emission of an effluent before adequate checking of its composition has taken place, vandalism/arson, extreme weather conditions, e.g. flooding, very high winds.

- Assessing all risks (hazard multiplied by probability) of accidents and their possible consequences. Having identified the hazards, the process of assessing the risks can be viewed as addressing six basic questions:
  - what is the estimated probability of their occurrence? (source, frequency);
  - what may be emitted and how much? (risk evaluation of the event);
  - where does it go? (predictions for the emission – what are the pathways and receptors?);
  - what are the consequences? (consequence assessment – the effects on the receptors);
  - what are the overall risks? (determination of the overall risk and its significance for the environment);
  - what can be done to prevent or reduce the risk? (risk management – measures to prevent accidents and/or reduce their environmental consequences).

The depth and type of assessment will depend on the characteristics of the plant and its location. The main factors ~~which should be~~ taken into account are:

  - the scale and nature of the accident hazard presented by the plant and the activities;
  - the risks to areas of population and the environment (receptors);
  - the nature of the plant and complexity or simplicity ~~otherwise~~ of the activities and the relative difficulty in deciding on and justifying the adequacy of the risk control techniques.

~~b. having a documented system which can be used to identify, assess and minimise the environmental risks and hazards of accidents and their consequences~~

~~c. ensuring that the waste acceptance system of pre-acceptance sampling and analysis, followed by verification upon arrival at the installation forms a crucial role in accident prevention (see Section)~~

- Identifying the roles and responsibilities of personnel involved in accident management. Together with this, clear guidance needs to be available on how each accident scenario needs to be managed; for example, containment or dispersion, to extinguish fires or to let them burn.
- Establishing communication routes with relevant authorities and emergency services both before and in the event of an accident. Post-accident procedures need to include an assessment of the harm that ~~can be~~ may have been caused and steps need to be developed to redress this.
- Putting in place emergency procedures, including safe shutdown procedures and evacuation procedures.

d. Appointing one facility employee as an emergency coordinator to take leadership responsibility for implementing the plan. It is important that the facility offers training to its employees to perform their duties effectively and safely so that staff know how to respond to an emergency.

Event information collection and assessment system

In order to prevent recurrence of minor events that may lead to an accident:

e. Keeping an up-to-date plant log/diary to record all incidents, near misses, changes to procedures, abnormal events, and the findings of maintenance inspections. Leaks, spills and accidents can be recorded in the site diary. The incident and response are then available to estimate notifiable releases for the annual report.

f. Establishing procedures to identify, respond to and learn from such incidents.

Inventory

g. Maintaining an inventory of substances, which are present or likely to be present, which could have environmental consequences if they escape. It should not be forgotten that many apparently innocuous substances can be environmentally damaging if they escape (for example, a tanker of milk spilt into a watercourse could destroy its ecosystem). (The inventory is also related to traceability, see Section 2.3.2.5).

WORKING DRAFT IN PROGRESS

Compatibility

h. Having procedures in place for checking raw materials and wastes to ensure compatibility with other substances with which they may accidentally come into contact (see Section 2.3.2.7).

i. Keeping apart incompatible wastes and substances according to their hazard potential. Incompatible waste types need to be segregated by bays or stored in dedicated buildings. The minimum requirement involves a kerbed perimeter and separate drainage collection. Measures also need to be in place to prevent containers falling over into other storage areas.

~~j. providing adequate storage arrangements for raw materials, products and wastes~~

~~k. utilising an automatic system based on microprocessor control, passing valve control or tank level readings. Some examples are: ultrasonic gauges, high level warnings and process interlocks~~

~~l. documenting the control measures in place, including the evaluation of these measures and a decision about their adequacy~~

~~m. putting in place appropriate control techniques to limit the consequences of an accident, such as oil spillage equipment, isolation of drains, alerting of relevant authorities and evacuation procedures~~

~~n. providing appropriate containment, e.g. bunds and catchpots, building containment (see Section)~~

~~o. identifying and providing personnel training requirements as required~~

Emissions in case of accident

p. Ensuring that process waters, site drainage waters, emergency firefighting water, chemically contaminated waters and spillages of chemicals are, where appropriate, contained and, where necessary, routed to the effluent system, with a provision to contain surges and storm water flows, and treated before emission to controlled waters or the sewer. Sufficient storage needs to be provided to ensure that this can be achieved. Spill contingency procedures also need to be put in place to minimise the risk of an accidental emission of raw materials, products and waste materials and to prevent their entry into water. Any emergency firefighting water collection system needs to also take account of the additional firefighting water flows or firefighting foams. Emergency storage lagoons may be needed to prevent contaminated firefighting water reaching controlled waters (see also Section 2.3.7).

~~q. applying maintenance and testing to the same standards as the main plant or stand-by plants~~

r. Considering and, therefore if appropriate, planning for the possibility of containment or abatement for accidental emissions from vents and safety relief valves/bursting discs. Where this may be inadvisable on safety grounds, attention needs to be focused on reducing the probability of the emission.

Security

s. Having in place sufficient security measures, including personnel, to prevent vandals and inadvertent intruders who could be exposed by contact with waste, or from damaging the equipment, or illicit dumping. Most facilities use a combination of security guards, total enclosure (usually with fences), controlled entry points, adequate lighting, proper warning signs, and 24-hour surveillance. Typically, the guards also operate the gatehouse where they prevent entry of unscheduled trucks and monitor the entry of visitors.

~~t. having in place and following an inspection system containing a list of items to be inspected, a schedule, and the typical problems that may be encountered. The inspection should examine process equipment, storage areas, emergency equipment, monitoring equipment, and security devices. Basically, the inspection should check for equipment malfunctions, structural deterioration, operator errors, and discharges that could lead to the release of hazardous waste constituents~~

Fire protection

u. Having in place a fire protection and explosion protection system, containing prevention and detection equipment, and extinction equipment.

v. Applying suitable procedures and provisions for the storage of certain types of hazardous waste, for example, which may require automatic alarms and possibly sprinklers. The

WORKING DRAFT IN PROGRESS

facility must provide an adequate water supply for extinguishing fires plus the capability to collect and store firefighting water run-off. The storage or treatment of any water-reactive waste will necessitate an alternative type of fire protection system.

From ex-**Section 4.7.2 "Parameters to consider before mixing waste waters"**

a. Isolating drainage systems from flammable waste storage areas to prevent fire being spread along the drainage system by solvents or other flammable hydrocarbons.

From ex-**Section 4.1.7 "Techniques to prevent accidents and their consequences"**

Other protection measures

a. Maintaining the good state of the plant through a preventive maintenance programme and a control and testing programme.

From ex-**Section 4.3.1.1 "Planning of the operation of a Ph-c plant"**

b. All measurement and control devices ~~installations~~ have to be easily accessible and easy to maintain.
c. ~~control and testing system have to be established~~

From ex-**Section 4.1.7 "Techniques to prevent accidents and their consequences"**

d. ~~ensuring that~~ Plant control is maintained in emergency situations, considering the utilisation of process design alarms, trips and other control aspects, e.g. automatic systems based on microprocessor control and ~~passing~~ valve control or tank level readings, such as ultrasonic gauges, high level warnings, process interlocks and process parameters.
e. ~~applying, as appropriate, preventative~~ Techniques, such as suitable barriers, are used to prevent damage to equipment from the movement of vehicles (see Section 2.3.13.3).
f. Putting in place procedures to avoid incidents occurring as a result of poor communication among operating staff during shift changes and following maintenance or other engineering work.

Achieved environmental benefits

The most significant environmental risks associated with waste treatment operations are from the storage of hazardous wastes, from emissions resulting from wastes reacting together either from leaks or spillages or from treatment processes going out of control.

Combinations of inappropriate equipment and poor inspection and maintenance procedures can also increase the accident risks through, for example, tank overfill situations where level indicators may not be working or have not been correctly calibrated.

~~Leaks, spills and accidents will occur at any site. One transfer station suggests that there is likely to be an accidental break of a drum every quarter. Technique o (see description section above) helps operators to understand operational problems so that they can put in place measures which will prevent or minimise their occurrences in the future~~.

Environmental performance and operational data

~~Technique o~~ The event information collection system (see description section above) is typically a computer-based system.

Cross-media effects

Not ~~known~~.identified

Technical considerations related to applicability

~~Some of the techniques are WT sector specific but others are very general. Some are only relevant for hazardous waste treatments.~~
Information not available.

Driving force for implementation

WORKING DRAFT IN PROGRESS

- Mainly for health and safety reasons (reducing accidents). ~~Technique bb) in the description section above is a basic requirement of EC Directive 75/442 Article 9.~~
- Protection of assets.

Example plants

These techniques are standard procedures applied in all types of WT plants. However, waste treatment plants typically utilise a manually operated system.

Reference literature

[33, UK EA 2001] [34, Babtie Group Ltd 2002][60, WT TWG 2003] [73, Irish EPA 2003] [78, Eucopro 2003] [82, Pretz et al. 2003] [98, WT TWG 2004] [100, WT TWG 2004]

2.3.13.2 Techniques for the prevention or reduction of the environmental consequences of accidents and incidents when storing waste

From ex-**Section 4.1.4 "Storage and handling"**

~~However it needs to be pointed out that a horizontal entitled~~ As most of the techniques related to storage are covered in the EFS (Emissions from Storage) BREF [117, EFS] ~~is available and provides more information on the issue~~, this section only covers techniques to consider in the determination of BAT for storage and handling activities in a WT plant.

From ex-Section **4.1.4.1 'Generic techniques applied to waste storage'**. Some items are deleted as they are already in the EFS BREF, or moved to Section 2.3.5.3.

Description

Design, management and maintenance of storage and storage equipment for the prevention of leakages, incidents and accidents.

Technical description

These techniques include the following:

Storage design and location

a. Storage areas are located:
   - away from watercourses; ~~and sensitive perimeters~~
   - in such a way so as to eliminate or minimise the double handling of wastes within the plant.

b. ~~ensuring that~~ ~~the~~ Storage area drainage infrastructure ~~can~~ contains all possible contaminated run-off ~~and that drainage from~~, prevents incompatible wastes ~~cannot~~ coming into contact with each other, and ensures that fire cannot spread (see also the EFS BREF [117]).

c. ~~locating~~ Bulk storage vessels are located on an impervious surface which is resistant to the material being stored, with self-contained drainage to prevent any spillage entering the storage systems or escaping off site. ~~The~~ Bulk storage vessels ~~need to~~ have sealed construction joints. ~~within a bunded area with a certain capacity~~. ~~Some examples on capacity volumes applied are: at least 110 % (others 100 %) of the largest vessel or 25 % (others 50 %) of the total tank volume within the bund~~

d. ~~carefully considering the tank and vessel optimum design, in each case taking into account the waste type, storage time, the overall tank design and mixing system in order to prevent sludge accumulation and ease of desludging. Storage and treatment vessels need to be regularly desludged~~ Sludge build-up and emergence of foams in tanks is controlled, for example by regularly sucking out the sludge and using anti-foaming agents.

e. ~~automatic monitoring of the~~ Storage and treatment tanks ~~levels~~ are equipped with an automatic level monitoring system ~~with the tank level indicators~~ and an associated alarm system. ~~equipping tanks and vessels with suitable abatement systems, together with level meters with audible and visual high level alarms that equip tanks, vessels, silos,~~ These systems ~~need to be~~ are sufficiently robust (e.g. able to work if sludge and foam are present)

WORKING DRAFT IN PROGRESS

and regularly maintained~~ to prevent foaming and sludge build-up affecting the reliability of the gauges~~.

f. All connections between vessels can be closed via suitable valves.~~ ensuring that all connections between vessels are capable of being closed via suitable valves~~

g. Overflow pipes are ~~need to be~~ directed to a contained drainage system ~~which may be~~ (e.g. the relevant bunded area (see the EFS BREF [117]), or to another vessel provided suitable control measures are in place.

h. Tanks' and vessels' thickness, storage area engineering and design are validated by an independent expert. This validation is performed on a routine basis, and recorded. Where a particular control measure is deemed inadequate, waste must not be stored in that vessel, tank or storage area.

~~i. the control of, e.g. with existing flow balancing systems or simple activated carbon filters, some of the emissions from the tanks when they are agitated or treated when mixed, as well as generally from chemical treatment tanks or sludge mixing tanks~~

Storage capacity

From ex-**Section 4.3.1.1 "Planning of the operation of a Ph-c plant"**

q. ~~adequate the storage capacity has to be provided, since the time of demand and delivery usually do not coincide~~

From ex-**Section 4.1.4.10 "Techniques to improve stock control in storage"**

~~r. Provision of emergency storage capacity. This would be relevant in a situation where it would be necessary to transfer a waste from a vehicle, due to a defect or potential failure of the vehicle containment. These events are infrequent and available capacity within the installation may be a limiting factor~~

The storage capacity is adapted to, and consistent with, the process capacity. Measures are taken to avoid storage/accumulation of waste:

- waste acceptance planning;
- the maximum storage capacity is clearly stated and communicated;
- the quantity of stored waste is regularly verified against the allowed maximum capacity.

Wastes are treated on, or removed from, site as soon as possible, preferably within one month of receipt, and at a maximum within six months. This applies even when the waste might be used as a reactant. [146, PCT]

From ex-**Section 4.1.4.10 "Techniques to improve stock control in storage". TWG, please confirm.**

~~j. limiting the reception storage area to a maximum of one week only~~

From ex-**Section 4.1.4.1 1 'Generic techniques applied to waste storage'**

k. ~~taking measures (e.g acceptance planning, identifying the maximum capacity limit for that waste, and ensuring storage capacity is not exceeded) to avoid problems that may be generated from the storage/accumulation of waste. This is important as waste characteristics can change during storage/accumulation, e.g. they can compact and harden, or, as a result of mixing reactions can occur producing reaction products and waste water. In some cases homogenisation of the waste will only be possible with the aid of heating, or the addition of accessory agents, etc. and by also having knowledge of the reaction behaviour of the waste. Applying some simple preventive efforts can generally help mitigate these disadvantages.~~

~~l. clearly and unambiguously stating in writing the total maximum storage capacity of the site needs which should be together with details of the method used to calculate the volumes held against this maximum. The stated maximum capacity of storage areas should not be exceeded~~

Moved to Section 2.3.5.2 (prevent/reduce odour emissions)

~~m. optimising the controlling time lapse and temperature in the settling processes~~

~~n. controlling the decanting of settled layers by visual assessment of samples from different levels~~

WORKING DRAFT IN PROGRESS

Safe storage operation

General techniques related to safety storage conditions are described in the EFS BREF [117, EFS]. Specific techniques related to safety waste storage conditions include the following:

o. Systems are in place to ensure that loading, unloading and storage are safe considering any associated risks. This can include piping and instrumentation diagrams; ticketing systems; key locked coupling systems; colour coding points, fittings and hoses; use of specific coupling and hose sizes.

p. A site plan which identifies all of the tanks, vessels, storage areas, bunds and drainage on site is established and kept up to date. All containers must be adequately labelled in accordance with acceptance requirements (the unique tracking system reference number, the date of arrival on site and at least a primary hazard code). Containers must be handled and stored so that the label is readily visible and continues to be legible. The waste inventory (see Section 2.3.2.5) is readily available.

q. Storage areas of hazardous waste are clearly marked and signed with regards to the quantity and hazardous properties of the wastes stored in them. As a general rule, no open-topped tanks, vessels or pits must be used for storage or treatment of hazardous or liquid wastes.

r. When flammable materials are being stored or handled, particular attention is paid to avoid the build-up of static electricity. Leak detection and alarms (for example VOC alarms), and automatic fire suppression equipment are put in place.

s. All pipes, hoses, connections, couplings, transfer lines, etc. are fit for purpose and resistant to the wastes being stored. A suitable pipework coding system is used (e.g. RAL European standard colour coding).

t. Chemical incompatibilities and safe storage distances (for example given in chemical warehousing standards) guide the segregation and separation required during storage. This includes laboratory chemicals where incompatible substances must not be stored within the same container.

u. Aerosols are stored under cover in closed containers or cages.

v. Loading and unloading is supervised by site staff either directly or via CCTV.

w. Only well-maintained and adapted couplings are used; the couplings are able to withstand the maximum shut valve pressure of the transfer pump.

x. Vehicular (e.g. forklift) and pedestrian access to the whole storage area is available at any time, making possible the transfer of containers without having to move others, except for drums in the same row.

y. Substances known to be sensitive to heat, light, air and water are protected from such ambient conditions. These storage provisions apply to any container held in general storage, reception storage (pending acceptance), quarantine, or which is being emptied, repackaged or otherwise managed.

z. Drums and other mobile containers are moved between different locations (or loaded for removal off site) in accordance with written procedures. The waste tracking system (see Section 2.3.2.5) reflects these movements.

aa. Containers and drums are stored stably and upright on pallets. Storage on other containers more than two high is not allowed. Access for inspection on all sides is kept available. For example, one 1000-litre IBC on a pallet stacked no more than two high in rows, or four 205-litre drums on a pallet stacked no more than two high in rows.

bb. Containers are fit for purpose; they are kept undamaged, not corroded, leak-free, and within the manufacturer's use-by dates (particularly for plastic containers). Caps, valves and bungs are present and secure. Containers, and any pallets they may be stored on, are checked daily and non-conformances are recorded. Non-compliant containers must be made safe. Any unsound, poorly labelled or unlabelled containers are immediately and appropriately managed (e.g. relabelling, over-drumming, transferring container contents).

From ex-**Section 4.1.4.1 "Generic techniques applies to waste storage"**

cc. Storing organic liquid waste (e.g. with a flashpoint of less than 21 °C) under inert ~~nitrogen~~ atmosphere (e.g. nitrogen).

~~dd. specifying storage procedures for circumstances where vehicles carrying waste are to be parked on site overnight or on public holidays, when the site may be unsupervised over these periods~~

WORKING DRAFT IN PROGRESS

~~ee. clearly marking and signposting storage areas with regard to the quantity and hazardous characteristics of the wastes stored therein~~
~~ff. having an appropriate number of tanks for the different kinds of incoming and outgoing streams~~
~~gg. maintaining at all times clear vehicular (for example, forklift and pedestrian) access to the whole of the storage area, so that the transfer of containers is not reliant on the removal of others which may be blocking access, other than drums in the same row~~
~~hh. not using vessels beyond the specified design life, unless the vessels are inspected at regular intervals with written records kept to prove they remain fit for the purpose and that their intensity remain intact~~
~~ii. equipping some or all of the tanks with outlets on different heights of the tank to be able to take out certain layers of the content~~
~~jj. maintaining the availability and access to storage areas for containers holding substances that are known to be sensitive to heat and light under cover and protected from heat and direct sunlight~~
~~kk. only processing containers following written instructions. These instructions need to include which batch is to be processed and the type of container required to hold any residues~~
~~ll. not storing drums more than two high and always ensuring that there is access space for inspection on all sides. That is, four 205 litre drums on a pallet, stacked no more than two 205 litre drums high in rows~~
~~mm. storing containers with well-fitting lids, caps and/or with valves secure and in place~~
nn. ~~storing acid and alkali wastes that may be used in the odour treatment in a series of silos and then used to create an optimum balance of acid and alkali in jumbo tanks (or smaller units).~~

From ex-**Section 4.3.1.1 "Planning of the operation of a Ph-c plant"**

~~s. in order to prevent unwanted mixing, the reaction containers should also serve as storage containers~~

From ex-**Section 4.1.4.10 "Techniques to improve stock control in storage"**

~~t. use of over-drumming as an emergency measure. All appropriate information needs to be transferred onto the label of the new container. Moving large quantities of wastes in over-drums need to be avoided by re-drumming once the incident leading to the over-drumming has been dealt with~~

From ex-**Section 4.1.4.11 "Computer controlled high rack storage area for hazardous wastes"**

~~u. In order to prevent fires in the high rack area, the vessels are subject to inerting with nitrogen. An installed nitrogen accumulation plant produces nitrogen with a 2 % oxygen residue content, which is then discharged into the vessels. This process is continuously controlled and registered. In order to reduce gaseous emissions, the inert gas from the vessels is circulated by ventilators and filtrated by activated carbon.~~
v. ~~Each storage tank is put in a waterproof retention area and equipped with a level indicator. Gas effluent from events are collected and treated.~~

From **ex-Section 4.1.4.2 "Techniques for the storage of drums and other containerised wastes"**

Laboratory smalls

oo. Using a dedicated area/store which is equipped with all necessary measures related to the specific risk of the wastes for sorting and repackaging laboratory smalls or similar waste. These wastes are sorted according to their hazard classification, with due consideration for any potential incompatibility problems, and then repackaged. After that, they are moved to the appropriate storage area.
pp. Where laboratory smalls are decanted into larger containers, carrying this out in a closed building with a ventilation system and exhaust air treatment and a bunding system without drainage.
qq. Having a small bulking unit that is designed to allow laboratory smalls to be decanted into a lime slurry in 205-litre drums prior to disposal at the treatment plant. This will utilise a hood placed over the drum which is connected to an exhaust system and activated carbon

WORKING DRAFT IN PROGRESS

filter. The system is not airtight, since the operator has to be able to empty the bottles into the container, but it might provide a simple system for making an estimate of the discharges to air during the decanting of solvents at minimum cost.

rr. Sorting laboratory smalls at source in order to make reopening unnecessary.

ss. Producing and following written procedures for the segregation and packing of laboratory smalls. A qualified chemist/person ~~attend~~ present at the site of the waste producer/holder may help with checking the laboratory smalls, classifying the substances, and packaging the ~~containers~~ drums into specific containers accordingly.

~~tt. avoiding storing incompatible substances within the same drum/container (e.g. laboratory smalls)~~

From ex-**Section 4.1.7 "Techniques to prevent accidents and their consequences"**

~~w. implementing techniques and procedures to prevent the overfilling of storage tanks (liquid or powder), e.g. level measurements, independent high level alarms, high level cut-off, and batch metering (see Section 2.3.13.2)~~

~~uu. replacing underground or partially underground vessels without secondary containment, for example, double skinned with leakage detection, by aboveground structures~~

From ex-**Section 4.1.4.12 "Tank and process pipework labelling"**

~~vv. all vessels need to be clearly labelled with regard to their contents and capacity, and need to have an unique identifier enabling identification through the stock control and by cross-reference to pre-acceptance and acceptance records.. All labelling needs to be resilient enough to stay attached and legible throughout the whole storage time at the installation. Tanks need to be appropriately labelled depending on their use and contents, for example:~~

~~**Content**~~	~~**Example label**~~
~~Solvent~~	~~Highly flammable~~
~~Effluent~~	~~Waste water~~

~~ww. the label should differentiate between waste water and process water, combustible liquid and combustible vapour and the direction of flow (i.e. in or out-flow)~~

~~xx. written records need to be kept for all tanks, detailing the unique identifier; capacity, its construction, including materials; maintenance schedules and inspection results; fittings, and the waste types which may be stored/treated in the vessel, including flashpoint limit~~

~~yy. use of a suitable pipework coding system, for example, CEN European Standard Colour Coding, e.g.~~

~~**Colour**~~	~~**Coding**~~	~~**Content**~~
~~Green~~	~~6010~~	~~Water~~
~~Brown~~	~~8001~~	~~Combustible liquid/vapour~~
~~Red~~	~~3001~~	~~Firefighting water~~
~~Blue~~	~~5012~~	~~Compressed air~~

~~zz. tagging all valves with an unique identifier and showing this on the process and instrumentation diagrams~~

~~aaa. correctly sizing and maintaining all connections in an undamaged state.~~

EFS BREF Section 5.2.2.2.

~~connecting, where oil treatment is a pretreatment process within a chemical treatment plant, the head space above the oil settlement tank to the overall site exhaust and scrubber units. Some sites have local exhaust ventilation systems to balance air displacement when loading/unloading tankers~~

EFS BREF Section 5.3.1

~~using polymer sheeting to cover open solids storage facilities that may generate particulates~~

WORKING DRAFT IN PROGRESS

Relates to acceptance

~~dealing with waste streams containing VOCs separately and using plants dedicated to these waste streams~~

Already in EFS BREF

~~ensuring that storage vessels holding flammable or highly flammable wastes meet special requirements~~
~~ensuring that the vessels supporting structures, pipes, hoses and connections are resistant to the substances (and mix of substances) being stored~~

EFS BREF Section 5.2.2.1

~~preferably routing pipework above ground, although if it is underground the pipework needs to be contained within suitable inspection channels~~

Ex-Section **'4.1.4.2 Techniques for the storage of drums and other containerised wastes'** merged here. Some items are already in the EFS BREF (Section 5.1.2).

Ex-Section **'4.1.4.3 Techniques to improve the maintenance of storage'** merged here. Some items are already in EFS BREF Sections 5.1.1.1, 5.1.1.3.

Ex-Section **'4.1.4.4 Bunds for liquid storage'** merged here. Some items are already in EFS BREF Section 5.1.1.3.

Ex-Section **'4.1.4.5 Restricting the use of open topped tanks, vessels or pits'** merged here. Some items are already in EFS BREF Section 5.2.2.2

Achieved environmental benefits

~~The appropriate and safe storage of wastes helps to Reduce fugitive emissions (e.g. VOC, odours, dust) and the risks of leakages.~~
~~Reduce the amount of potentially contaminated water that may be produced in the event of any spillage. and of extending the useful life of the container.~~
~~Avoiding soil contamination~~
~~Segregated storage is necessary to Prevent incidents from incompatible substances reacting. and as a means of Preventing escalation should an incident occur.~~
~~Prevent the emissions which could be caused by storing incompatible substances together which might then react together.~~
The environmental benefits of this technique include:

- reduction of fugitive emissions (e.g. VOCs, odours, dust) and the risk of leakages;
- reduction of the amount of potentially contaminated water that may be produced in the event of any spillage;
- prevention of incidents from incompatible substances reacting, and of escalation should an incident occur.

Environmental performance and operational data

A management system is required since some of the above techniques relate to a quality management system (QMS).

Cross-media effects

None.

Technical considerations relevant to applicability

Some justification for a bunded area with a capacity of 110 vol-% of the largest vessel is for taking into account the build-up of rainfall.

WORKING DRAFT IN PROGRESS

Concerning the storage of containerised wastes under cover, the provision for ventilation by means of wall or roof vents ~~or by the actual construction of the area, for example, open barn~~ is seen to be a dilution of the emission to the air. Handling is usually more complicated in covered areas than in uncovered ones. It may be physically impossible to store some large containers under cover. ~~Covered plants also need to consider~~ It is also necessary to take into account the access requirements to covered storages for firefighting. ~~Related with technique a,~~
It is not necessary to store all containerised waste under cover. Typically, the waste and containers that are not sensitive to light, heat light, extreme ambient temperatures or water ingress are excluded. Under such circumstances, adequate bunding of storage areas and containment/treatment of water run-off is usually enough to ensure effective environmental protection.

Tagging all valves with an identifier which is then shown on the process and instrumentation diagram is not common practice, even in the chemical industry.

Economics
No information available.

Driving force for implementation
Prevention of accidents.

Example plants
Many examples exist in the sector.

Reference literature
[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997] [21, Viscolube 2002] [28, Scori 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [77, Schmidt et al. 2002] [78, Eucopro 2003][82, Pretz et al. 2003] [84, Ribi, J. 2003] [98, WT TWG 2004] [100, WT TWG 2004] [101, WT TWG 2005] [105, Mech. subgroup 2014] [153,Bref text for storage] [146, PCT subgroup 2015], [109, Bio. Subgroup 2014]

2.3.13.3 Techniques for the prevention or reduction of the environmental consequences of accidents and incidents when handling waste

From ex-**Sections 4.1.4.6 "Generic techniques applied to waste handling"** and **4.1.4.8 "Handling activities related to transfer into or from drums and containers"**

Techniques related to the prevention and reduction of diffuse emissions moved to Section 2.3.5.3

Description
Systems and procedures to ensure that wastes are safely handled and transferred to the appropriate storage or process.

Technical description
Some general techniques are as follows:

a. Ensuring that the transfer from a tanker to a drum (or vice versa) uses a minimum of two people to check the pipes and valves at all times.
b. Ensuring that transfers/discharges only take place after compatibility testing has been completed (see Section 2.3.2.7) and then only with the sanction of an appropriate manager. The approval specifies which batch/load of material is to be transferred; the receiving storage vessel; the equipment required, including spillage control and recovery equipment; and any special provisions relevant to that batch/load.
c. Having in place systems to prevent 'tanker drive off', i.e. a vehicle pulling away whilst still coupled.

WORKING DRAFT IN PROGRESS

d. Assuring that these processes are only carried out by people trained to do so and with an appropriate amount of time so as not cause pressure to work more quickly than deemed acceptable.
e. Having in place measures to ensure that the couplings are a correct fit; this will prevent the coupling loosening or becoming detached. Issues related to coupling include the following:
    - An installation providing and maintaining hoses can help to guarantee the integrity and fitness of the couplings.
    - Ensuring that special care is taken so that the coupling is able to withstand the maximum shut valve pressure of the transfer pump; otherwise a serious event could occur.
    - Protecting the transfer hose may be unnecessary where a gravity feed system is in place. It will however still be important to maintain a sound coupling at each end of the transfer hose.
    - Controlling potential leaks due to coupling devices by fairly simple systems such as drip trays, or by designated areas within the bund system. Rainwater falling over the rest of the bund area falls to a sump and, if uncontaminated, can be pumped to the site interceptor and discharge points. The bund areas are inspected, maintained and cleaned. Pollution of water discharges can occur but are minimised by design and management.
    - Good housekeeping practices requiring constant attention and cleaning.
f. Providing of routine maintenance, so that a more acute accident situation does not arise due to the failure of the plant or equipment. This may include the failure of a pump seal or the blockage of a filter pot commonly used at transfer points.
g. Having an emergency storage for leaking vehicles, to minimise an acute incident associated with the failure of the seal on the road tanker.
h. Back balancing the vapour system when loading road tankers.
i. Having measures in place to ensure that the correct waste is discharged to the correct transfer point and that the waste is then transferred to the correct storage point, e.g. ~~In order to prevent an unauthorised discharge,~~ by means of a lockable isolating valve ~~needs to be~~ fitted to the loading connection ~~This needs to be~~ that is kept locked during periods when there is no supervision of the unloading points.
j. Having in place systems and procedures to ensure that waste due to be transferred is packaged and transported in accordance with legislation concerning the safe carriage of dangerous goods.
k. Continuing the waste tracking system that began at the pre-acceptance stage, linked with acceptance, throughout the duration the waste is kept at the site (see Section 2.3.2.5).
l. Recording in the site diary any small spills ~~during decanting~~. Spills need to be retained within the bunded areas and then collected using adsorbents. If this is not done, the spillage will exit the site through the rainwater collection systems or may generate fugitive emissions (e.g. VOCs).
m. Ensuring that tankers are not used as reaction vessels as this is not their designed purpose.
n. Blending by bulking into tankers only needs to take place once suitable verification and compatibility testing has been carried out.
o. Technical and, if relevant, construction precautions are taken to protect human health and the environment when mixing or blending wastes, depending on the composition and consistency of the wastes to be mixed or blended (e.g. vacuuming dust-like wastes).

From ex-**Section 4.1.4.8 "Handling activities related to transfers into or from drums and Containers"**

p. Training forklift drivers in the handling of palletised goods, to minimise forklift truck damage to the integrity of drums.
q. Using rotary type pumps equipped with a pressure control system and safety valve.
r. Using pumping of sludges instead of open movement..
s. Keeping the container lidded/sealed as much as possible.
t. Transferring wastes in containers into storage vessels using a dip pipe.
u. During bulking to tankers, using vapour balance lines connected to appropriate abatement equipment .

WORKING DRAFT IN PROGRESS

v. Manipulating drums using mechanical means, for example a forklift truck with a rotating drum-handling fitting.
w. Securing the drums together with shrink wrap.

~~x. ensuring that bulking/mixing only takes place under instruction from, and under the direct supervision of a suitable manager/chemist and under local exhaust ventilation when appropriate~~
~~y. only moving drums and other mobile containers between different locations (or loaded for removal off site) under instructions from the appropriate manager; also then ensuring that the waste tracking system is amended to record these changes.~~
~~z. decanting larger individual containers of waste into IBCs or 205 litre drums and generally bunding these areas to protect site drainage~~
aa. ~~having a qualified chemist/person attend the site of the waste producer/holder to check the laboratory smalls, classifying the substances accordingly and packaging the containers into specific containers. In some cases, the individual packages are prevented from mechanical damage in the drum by the use of vermiculite. Some operators only deal with laboratory smalls if the customers use their packing service~~
~~bb. packing containers of chemicals into separate drums based on their hazard classification. Chemicals which are incompatible (e.g. oxidisers and flammable liquids) should are not be stored in the same drum~~
~~cc. having in place a system to ensure that the correct discharge point or storage area is used. Some options for this include ticket systems, supervision by site staff, keys or colour-coded points/hoses or fittings of a specific size~~
~~dd. utilising an impervious surface with self-contained drainage, to prevent any spillage entering the storage systems or escaping off site in the offloading and quarantine points~~
~~ee. ensuring that damaged hoses, valves and connections are not used. Hoses, valves and connections need to designed and maintained to be sure that they are suitable for the purpose to be used and that they are chemically stable towards what they are intended for~~
~~ff. selecting the adequate packaging material considering what material/waste is intended to be contained (e.g. dangerous material)~~
~~gg. taking suitable precautions against the hazards of static electricity when handling flammable liquids~~
~~hh. using sound and undamaged pallets~~
~~ii. replacing any damaged pallets on arrival and not transferring them into storage~~
~~jj. providing adequate space needs within drum storage areas~~

Achieved environmental benefits
The environmental benefits of this technique include prevention of unexpected releases or reactions and the associated emissions.

Environmental performance and operational data
Most sites have a full concrete base, with falls to internal site drainage systems leading to storage tanks or to interceptors that collect rainwater and any spillages. Interceptors with overflows to sewers usually have automatic monitoring systems, such as a check on pH, which can shut down the overflow.

Cross-media effects
None.

Technical considerations relevant to applicability
The systems and procedures are adapted to the characteristics of the waste (e.g. hazardous, non-hazardous, liquid, solid).

Economics
No information available.

Driving force for implementation

WORKING DRAFT IN PROGRESS

There is legislation concerning the safe carriage of dangerous goods.

Example plants

The larger solvent transfer stations reduce displacement losses from loading and unloading tankers and drums with balancing systems or VOC recovery systems. Many chemical treatment plants and solvent storage sites have pollution abatement equipment to minimise acidic and VOC emissions.

Sites storing organic wastes with a solvent content tend to utilise a carbon filter system to control discharges to air and to undertake some monitoring of the exit gas.
~~Many of the waste transfer stations storing and pumping larger quantities of VOCs have abatement equipment or balancing equipment to minimise losses to the air due to displacement or thermal effects.~~

Reference literature

[16, UK Environment Agency 1996] [28, Scori 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003] [78, Eucopro 2003][98, WT TWG 2004] [100, WT TWG 2004] [101, WT TWG 2005] [115, UBA Germany 2012]

Ex-Section **4.1.4.7 'Handling of solid waste'** deleted to avoid repetition.

Ex-Section **4.1.4.9 'Automatic unloading of drums'** moved to Section 2.1.2: process step description

Ex-**Section 4.1.4.10 'Techniques to improve stock control'** in storage moved to Section 2.3.13.2

2.3.14 Techniques for the decommissioning of the plant

From ex-**Section 4.1.9 "Techniques for decommissioning"**

Description

Set of organisational and technical measures to be taken throughout the plant lifetime to optimise the plant decommissioning and reduce ~~minimise de-commissioning problems and~~ any associated environmental impacts.

Technical description

~~Some~~ Techniques include the following:

a. Considering the decommissioning at the design stage, thereby making suitable plans to minimise risks during later decommissioning.
b. For existing plants where potential problems are identified, putting in place a programme of design improvements. These designs improvements need to ensure that:
    - underground tanks and pipework are avoided; if it is not economically possible to replace them, ~~then operators should~~ they are protected ~~them~~ by secondary containment or a suitable monitoring programme;
    - there is provision for the draining and clean-out of vessels and pipework prior to dismantling;
    - lagoons and landfills are designed with a view to their eventual clean-up;
    - insulation is provided which is readily dismantled without dust or hazard;
    - any materials used are recyclable (having regard for operational or other environmental objectives).
c. Maintaining a ~~site closure~~ decommissioning plan to demonstrate that, in its current state, the plant can be decommissioned to avoid any pollution risk and to return the site of operation

WORKING DRAFT IN PROGRESS

to a satisfactory state. The plan ~~should be~~ is kept updated as material changes occur. However, even at an early stage, the ~~closure~~ decommissioning plan can include details on:

- either the removal or the flushing out of pipelines and vessels where appropriate and their complete emptying of any potentially harmful contents;
- plans covering all the underground pipes and vessels;
- the method and resources necessary for the clearing of lagoons;
- the method of closure of any on-site landfills;
- the removal of asbestos or other potentially harmful materials, unless it has been agreed that it is reasonable to leave such liabilities to future owners;
- methods of dismantling buildings and other structures, for the protection of surface water and groundwater at construction and demolition sites;
- the required testing of the soil needed to ascertain the degree of any pollution caused by the site activities and information on what is needed for any remediation to return the site to a satisfactory state as defined by the initial site report;
- ~~describing~~ the measures proposed, upon definitive cessation of activities, to avoid any pollution risk and to return the site of operation to a satisfactory state (including, where appropriate, measures relating to the design and construction of the plant);
- ~~describing plans for~~ the clearing of deposited residues, waste and any contamination resulting from the waste treatment activities.

d. Ensuring that ~~plant and~~ equipment taken out of use is decontaminated and removed from the site.

Achieved environmental benefits
Prevention of environmental issues during decommissioning.

Environmental performance and operational data
No information.

Cross-media effects
None.

Technical considerations related to applicability
The techniques mentioned here are applicable to the plant's operation lifetime, the design and building stage of the activities and the site closure.

Driving force for implementation
~~Technique (e) (see description section above) is mandatory for current EU regulation on waste.~~
Environmental legislation

Example plants
The decommissioning of whole plants or parts of them occurs frequently in the sector.

Reference literature
[33, UK EA 2001] [73, Irish EPA 2003] [98, WT TWG 2004]

Ex-**Section 2.1.6 "Decommissioning"** deleted to avoid repetition.

WORKING DRAFT IN PROGRESS

3 MECHANICAL TREATMENT OF WASTE

This chapter covers the treatment in shredders of metal waste, including waste electrical and electronic equipment (WEEE) and end-of-life vehicles (EoLVs) and their components (Annex I to [122, Directive 2010/75/EU 2010]). It also covers the mechanical treatment in shredders of temperature exchange equipment, and the mechanical treatment of solid waste with calorific value.

3.1 Mechanical treatment in shredders of metal waste

[107, Mech. subgroup 2014]

3.1.1 Applied processes and techniques

Purpose and principle of operation

In shredders, the waste input is reduced into smaller material components by means of fragmentation and attrition. These components can then be separated from one another in a downstream sorting process. Large items of scrap can also be shredded.

The main output is quality steel scrap with a high density, high degree of purity and predominantly homogeneous size. This shredder steel scrap can be used directly in metal works to produce steel. The other end fractions are shredded non-ferrous fractions, containing other metallic products, and shredder residues. These other fractions can be recovered through further treatment or use.

Process description

The main plant areas and process steps in a shredder are:

1. delivery, reception and acceptance;
2. pre-sorting and pretreatment;
3. shredder technology;
4. post-shredder processes;
5. end-of-pipe abatement techniques.

Figure 3.1 shows an example of a shredder with typical feedstock (mixed EoLVs and scraps) and outputs (shredder light and heavy fractions).

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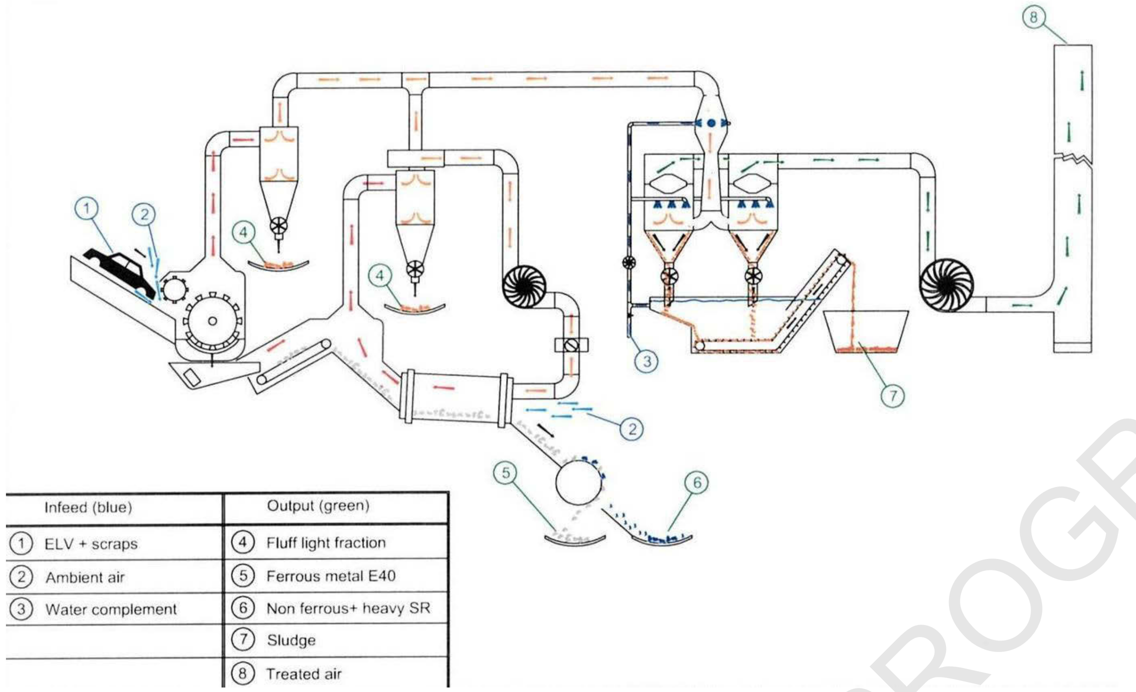


Source: [107, Mech. subgroup 2014]

Figure 3.1: Example of a mixed scrap shredder plant

Directive 2000/53/EC on end-of-life vehicles (EoLVs) and Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) prescribe certain pretreatments, including removal of hazardous material and components, before shredding. With these pretreatment requirements, shredders' waste input and output are generally considered non-hazardous waste.

Grabbers, excavators or front-end loaders can be used for the sorting and charging of the material. Feedstock is generally fed by grab crane to a ground-level conveyor which elevates the material to the shredder feed chute. The feed materials then fall by gravity into the shredder box. Within the shredder box is a heavy, fast-spinning rotor equipped with hammers which cut the material on anvils within the shredder box and then drive the cut (shredded) materials through sizing grates to further process the scrap to the desired state of liberation, size and density.

In Figure 3.1 the first air treatment step is carried out by a cyclone (red to orange) and the second step by a wet scrubber (orange to green). The shredder light fraction ④ and shredder heavy fraction ⑥ are then further treated. Non-ferrous metals recovered during the shredding process or in downstream plants (e.g. sink-float plants in heavy media plants) are used industrially for non-ferrous metal production.

The mixed shredded materials are then transported to a range of separation systems which separate the shredded materials into streams of ferrous and mixed non-ferrous scrap and residual, non-metallic materials. These residual non-metallic materials are then sent to other plants for subsequent use or treatment: for energy recovery in waste treatment plants or for material recovery in post-shredder technology (PST) plants including recycling of plastics. Final non-metallic fractions without a commercial market may also be disposed of to landfill.

The ferrous stream is a furnace-ready material. Individual operators may choose to improve the quality of the mixed non-ferrous output by further separation stages, for example eddy current separators and metal-sensing or colour-sorting machinery. This further processing can be carried out online as part of the shredder downstream equipment, but is generally carried out offline in purpose-built premises and so does not form a part of the shredder plant. It is therefore not discussed further in this document because BAT for differing items of downstream equipment will not be identical. Alternatively, the mixed non-ferrous materials may be separated by dense media separation, which is always an entirely separate process.

WORKING DRAFT IN PROGRESS

Delivery, reception and acceptance

The improvement of the metal shredder's environmental performance can be dealt with in two principal ways: one is to control outputs and emissions, the other is to control the quality and type of feed to the plant in the first place. In basic terms, what goes in to the fragmentiser will come out.

Scrap feed which contains dirt or other added non-metals, concealed items such as gas cylinders, or contaminated materials such as not depolluted or poorly depolluted EoLVs and contaminated drums is not acceptable. There are significant environmental and health and safety issues associated with the inadvertent processing of these types of poor quality material.

A material reception area is designed with trained staff controlling the inspection, reception and validation of materials at the plant; and quarantine areas established for materials that are prohibited, awaiting full inspection, testing or removal.

The delivery area of an industrial shredder plant consists of a sufficiently sized acceptance area, which, as a rule, is a paved surface with a weighing platform (weighbridge) and corresponding weighbridge office. The weights of all material input and output streams are recorded at the weighing station.

The delivery area offers the possibility to carry out an intake control, for both commercial and legal reasons with regard to the waste, and to make a preselection according to visually recognisable criteria.

The visual inspection can be done directly at the weighing station or during offloading in the delivery area. It serves to preselect waste into its main groups and detect elements containing harmful substances or impurities. This area can also be used for pricing.

Shredder feed is delivered in containers, walking-floor vehicles and normal lorries which are registered for the transport of waste. Sites with water or rail connections also use ships or trains for their input/output logistics.

The delivery area also includes means of checking the delivered materials for an increased level of radioactivity. The delivery vehicles (road or rail) need to pass through radiation monitoring at a very slow speed to ensure an accurate reading. Another possibility for measuring radioactivity is by detectors attached to the grab, magnetic plate or arm of the unloading equipment. This technique can be found when unloading ships or rail cars, for example.

After the acceptance check, the shredder feed goes into interim storage in the delivery area.

Pre-sorting and pretreatment

Pre-sorting is a part of integral stock management. The goal is to sort out impurities and homogenise or keep separate selected input materials in order to be able to produce the qualities the customer demands. Pre-sorting can be done manually or mechanically (e.g. with a grab/magnet).

Pre-sorting is an important way of increasing plant availability and throughput, homogenising the material input and reducing the ancillary costs of the plant operation. It also guards against deflagrations or unshreddable items.

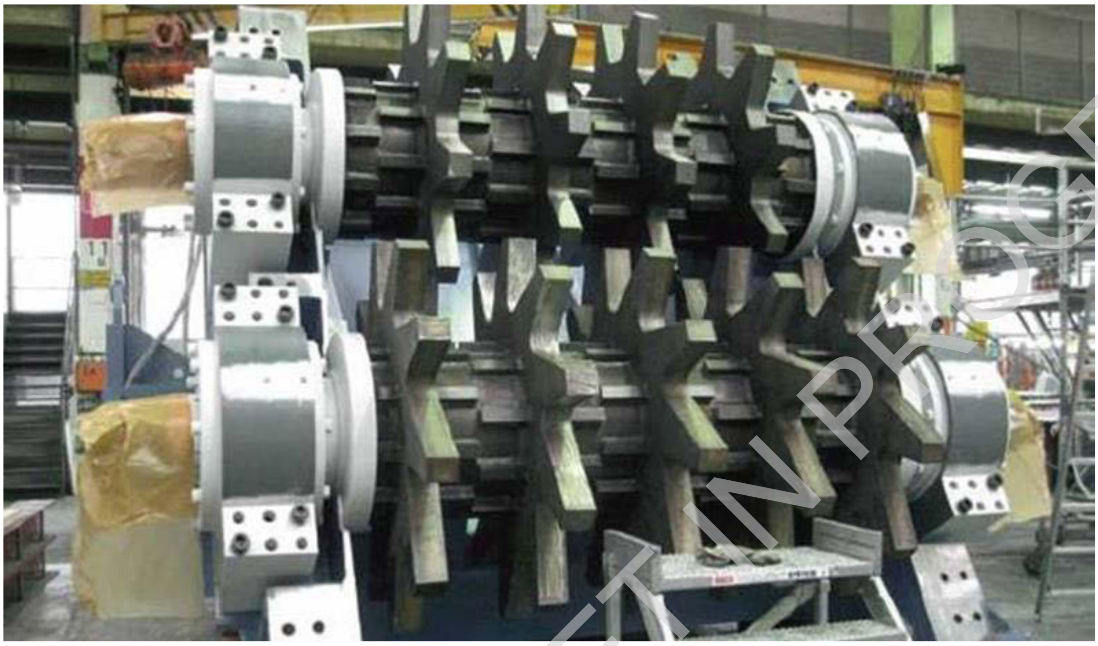
The shredder feed undergoes pretreatment before being sent to the shredder. In practice, there can be various types of pretreatment, depending on the operational requirements. The aim of the pretreatment processes is to maximise plant availability, minimise shredder downtime, and achieve an optimised composition of the input material from an economic point of view as regards the quantity and quality of the output streams.

With the exception of heavy scrap such as cast iron parts and bulky parts (rail tracks, sectional steels and girders), which usually undergo separate processing, most types of scrap can be shredded in shredder plants. Even scrap cars, which may make up an appreciable proportion of shredder feed, can be handled without any prior size reduction.

WORKING DRAFT IN PROGRESS

Pre-shredding

Another considerably more elaborate and costly pretreatment measure can be to reduce the size of the feed prior to shredding (prior size reduction, see Section 2.1.7). The equipment used may be shears or pre-shredders. A pre-shredder or ripper (see Figure 3.2) is a slow-running machine installed upstream from the main shredder. The pre-shredder rips up the material fed into the shredder thus ensuring a maximum size for the input materials. Pre-shredding can also reduce the risk of deflagrations. For reasons of space, the pre-shredder may not be available for larger shredders whose requisite throughput would need several such units.



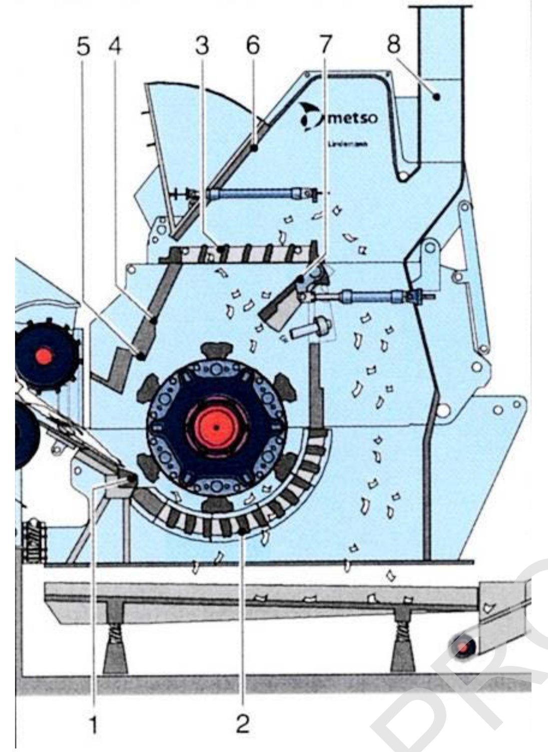
Source: [107, Mech. subgroup 2014]

Figure 3.2: Example of a pre-shredder

Shredding

The material pushed into the shredder box by the feed rollers (see Figure 3.3 is torn between the rotating hammers and the edge of the primary anvil (1). The torn pieces are then further shredded on the lower grid (2) and, once shredded to the requisite size, will exit the shredder box through the lower grid or upper grid (3).

WORKING DRAFT IN PROGRESS



Source: [107, Mech. subgroup 2014] METSO

Figure 3.3: Detail of shredding process

Any material which has not been shredded small enough on the first pass is flung against the rear wall of the shredder (4) and then torn again between the hammers and a secondary anvil (5), proceeding then to mix with new incoming feedstock for a second pass. This process of tearing and shredding continues until the material has passed through the grids. It is important to keep the shredder box filled with material to optimise shredding efficiency; this is generally achieved by the blending of different feedstock streams.

In order to achieve a particularly high density of shredded product, some shredders are equipped with a mechanism (6) to cover the upper grid and thus retain more material within the shredder box for a second or further passes.

Unshreddable materials are discharged through the hydraulically actuated ejection door (7).

The intake pipes (8) in the dedusting device aspirate the dust when the shredder box is fitted with an aspiration system. In a damp shredder this pipe will be blanked.

<u>*Mixed scrap (or conventional) shredder*</u>

Mixed scrap shredders have a drive power of up to 9200 hp (7000 Kw), or some 400 t/h. These plants are the largest and most common type of shredding plant in the EU, often misdescribed as car shredders. However, cars (in the form of depolluted end-of-life vehicles) usually form only a minority percentage of the material being processed by such plants. The remaining material feedstock is comprised of any light steel and, in the case of larger plants, sometimes heavier steel, suitable for shredding in either clean (e.g. cladding from buildings) or complex/composite (e.g. non-hazardous and depolluted waste electrical and electronic equipment) form.

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Source: [107, Mech. subgroup 2014]

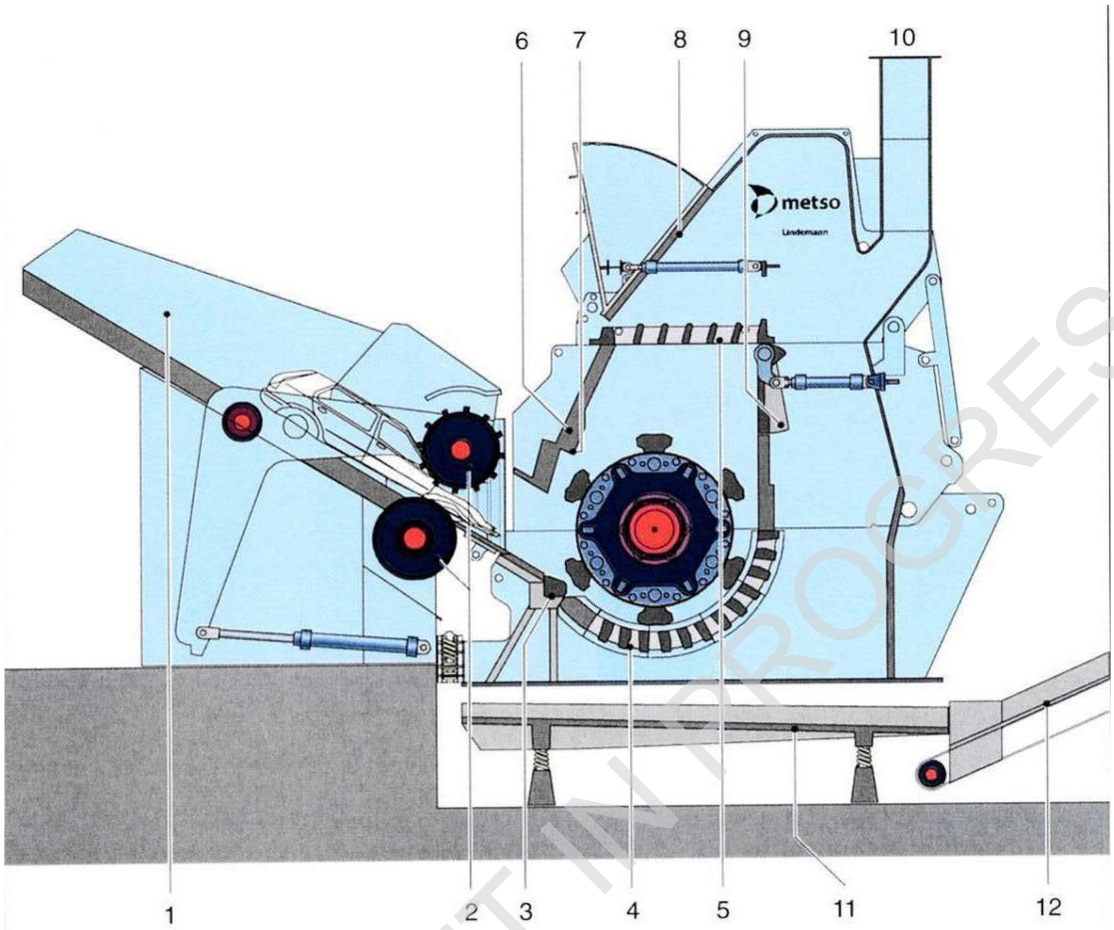
Figure 3.4: A typical EU mixed scrap shredder plant

The purpose of such plants is threefold: (1) to separate the materials in the feedstock from each other; (2) to ensure that the metals produced are sufficiently clean to facilitate their smelting into new metal products; and (3) to densify the metals so that they are of a furnace-size suitable for smelters.

Densification also increases logistical efficiency (and thus decreases the economic impact of transporting these product materials). For similar reasons, feedstock to these plants has often been pre-densified (by other operators in the supply chain) in the form of sheared or baled material.

Figure 3.5 illustrates how a conventional shredder plant works.

WORKING DRAFT IN PROGRESS



1. Chute
2. Drive pulleys
3. Anvil
4. Lower grid (optional)
5. Upper grid
6. Shredder wall
7. Secondary anvil
8. Upper grid cover
9. Ejection door
10. Intake pipe
11. Vibrating conveyor
12. Conveyor

Source: [107, Mech. subgroup 2014]

Figure 3.5: Conventional shredder plant mechanism

The shredders used to reduce mixed scrap are rotor hammer mills. The hammer mill consists of a rotor in which several hammers weighing between 70 kg and 260 kg are suspended. The rotor is driven by a motor with a rating of up to 7000 kW and rotates at 450–600 rpm. The hammers swing out as a result of the centripetal forces caused by the rotation.

Special shredders

Zerdirators have a drive power of between 500 kW and 4000 kW. Zerdirators are rotor mills for processing lightweight scrap. Material discharge from the rotor chamber is different from that of conventional shredders because the Zerdirator has a grid at the top and the bottom.

Kondirators have a drive power of between 750 kW and 3000 kW. Kondirators were developed to reprocess medium-heavy mixed scrap that is too heavy for conventional shredders. Compared with conventional shredders, the rotors rotate in the opposite direction and the process scrap discharge from the rotor chamber differs. In the Kondirator, bulky or long items of scrap can be separated from the remaining shredded material during the shredding process through a separate discharge outlet.

Damp or semi-wet shredders

WORKING DRAFT IN PROGRESS

In this type of shredders, an electronically controlled injection of water suppresses dust during the shredding process. The water is taken from a supply tank and injected into the rotor chamber at several places via a pump station and mist sprays. The small diameter of the water mist droplets facilitates the encapsulation of dust particles, thus directing them to co-mingling with the material stream leaving the plant for further downstream separation. Water addition also helps to minimise inadvertent deflagration events and cools the rotor and the pieces of scrap. The steam/mist that is produced escapes through the openings in the shredder, i.e. around the feed chute and the vibrating extraction conveyor. Most of this steam is captured by the soundproof housing of the shredder (if applicable).

Wet shredders

Wet shredders operate with pre-wetted shredder material. For this reason, material separation is different from that of other shredders. The fact that the shredder feed is wet reduces the proportion of low density materials as compared with dry processes and which later accumulate as shredder residue. However, a considerable quantity of sludge accumulates when the contaminated waste water is cleaned and this has to be disposed of. Scrap vehicles and light to medium-heavy scrap metal and industrial scrap are shredded in wet shredders. The scrap quality is that of customary shredder scrap.

Feed and output streams

The waste input material delivered to shredder plants (feed) comprises:

- pretreated scrap cars from dismantling facilities;
- scrap from municipal collections;
- scrap from commercial collections;
- industrial scrap from production or demolition;
- pretreated domestic appliances (usually excluding refrigerators);
- scrap from waste incineration plants;
- metal mixes (ferrous and non-ferrous) from processing and sorting plants;
- other metal scrap.

The proportion of each type of scrap in the total volume is difficult to calculate since the composition of the shredder feed varies from one plant to another and depends on the season and the region.

Irrespective of the type of shredder being used the following output fractions are the result of the average input from the shredder process. The size of the iron/steel fraction scrap (also called ‘Fe fraction’ or ‘shredder scrap’) is fairly homogeneous, ranging from 50 mm to 150 mm, and is over 98 % iron or steel. The recovery of this fraction is the main reason for operating a shredder plant. It is sold to steelworks globally. The iron/steel fraction corresponds to approximately 65 % to 75 % by weight of the shredder feed.

On average, the non-ferrous metal fraction (also called ‘shredder heavy fraction’/‘SHF’) makes up approximately 5 % to 10 % by weight of the shredder feed and mainly consists of aluminium, copper and zinc mixed with non-metals (e.g. rubber, plastics, glass or stones). These non-metals represent an impurity in terms of using the valuable non-ferrous metals.

Before further metallurgical reprocessing (e.g. in foundries), the non-metallic content of the non-ferrous fractions has to be removed. They are reprocessed in online or offline treatment stages until the non-metal content is removed and the non-ferrous metals are separated. Increasingly today (2015), the non-metallic materials are being further refined in order to extract recyclable plastics, aggregates and solid recovered fuel, while minimising the residual waste to landfill.

WORKING DRAFT IN PROGRESS

In the process of shredding, the input materials are separated and broken apart into small pieces. Heavy materials are discharged from the shredder, whereas the shredder light fraction (SLF, the remaining light components of the input material) is discharged by the forced air supply of the cyclone and air separator systems. The SLF mix thus also contains components of the input material in a shredded form. These are essentially:

- textiles (e.g. seat covers);
- foamed plastics (e.g. from seat cushioning);
- plastics and plastic sheeting (e.g. from trims);
- mineral components (e.g. adhesions in the wheelhouses and on the undercarriage);
- screws, nuts, NF pieces of metal, aluminium pieces, foils and rust;
- wood and elastomers.

Approximately 10 % to 20 % by weight of the shredder feed, depending on its composition, is shredder light fraction. Its material composition varies greatly and is largely influenced by the type of feed. The individual proportion of any type of scrap in the total volume is difficult to determine since the composition of the feed varies greatly from plant to plant and also according to the season and the region.

The fluctuations in the composition of the shredder feed are passed to the composition of the shredder light fraction. The shredding of scrap vehicles thus leads to a disproportionately high proportion of plastics in the shredder light fraction, just as the shredding of mixed scrap and industrial scrap (e.g. pipelines and light sectional sheet with concrete adhesions) causes a considerably lower proportion of plastics in the shredder light fraction.

Moreover, the type of air separation has a substantial impact on the composition of the SLF. With a weak air current the SLF contains fewer plastics and with a strong air current the SLF contains more plastics. Shredder operators will regularly monitor the SLF to ensure that metal inclusions are minimised and, if present, reprocessed.

Post-shredder processes

Post-shredder technology (PST) is the further reprocessing of shredder residues (SLF and/or SHF) and goes beyond the technologies described below. This can be done online with the shredder plant or offline on the same site or at another site. Online is the continuous feeding of the material stream from the place it (the SLF or SHF) is generated into a reprocessing facility, generally via a belt conveyor system. Offline is a discontinuous plant operation, e.g. in batches via a wheel loader.

Many industrial shredder operators have PST systems at either the shredder site or elsewhere. Their main goal is to recover materials from the SLF and SHF to comply with the basic legal requirements such as recycling quotas or any immediate landfill ban, etc. Consequently, the reprocessing extent of the PST may vary in accordance with the respective shredder process configuration and the local availability of economic disposal possibilities.

The summary below is not comprehensive and does not purport to be complete. The basic mixed scrap shredder plant can be taken as an elevating feed conveyor, shredder box (mill), windsifting system, rotary magnet(s), air extraction and classification systems, and vibrating and belt conveyors. The PST steps listed below could be carried out either within or outside the shredder plant. Most operators carry out these processes offline due to throughput constraints of these techniques and to facilitate smoother metering of materials to these techniques. The PST processes steps can be combined in different ways as regards the process.

Scrap cleaning step

The mixed shredded product is generally conveyed via vibrating and/or belt conveyors to a zigzag windshifter where light material (SLF) is aspirated from heavier materials.

The light air aspirated material (SLF) is then passed through an air classification system and deposited onto a stacking conveyor which conveys it to a bin, bunker/truck or rail car.

WORKING DRAFT IN PROGRESS

Cleaned materials fall on a vibrating conveyor installed under the air classifier cascade.

Separation of materials

The cleaned non-ferrous metals and steel scrap are continuously fed from the air classifier, generally via a vibrating conveyor, to a rotating magnetic drum separator. Steel scrap is attracted from the product flow and lifted up and over the rotating magnet onto a belt conveyor. Non-magnetic metals are not attracted and fall beneath the magnet onto a different conveyor. The steel scrap is agitated on the magnet drum to release any tramp pieces of non-magnetic material.

The steel scrap is then passed over a slow-moving sorting conveyor, where armatures (and other copper-bearing composites) and any tramp non-metallic materials are manually removed to a bin or bunker. The sorting conveyor generally discharges to a stacking conveyor which in turn discharges to a bin, bunker/truck or rail car.

Some non-ferrous metals may also be manually sorted from a conveyor and are then further mechanically separated, online and/or offline. Most operators will carry out the mechanical separation of non-ferrous metals offline due to throughput imbalances and to facilitate better metering.

See Section 2.3.2.8 for more detailed descriptions of the material separation steps listed below.

- Manual picking: manual sorting is widely used for the coarse fractions from shredder residues, particularly from SHF, to separate the larger residual metal parts.
- Screening/sifting.
- Air separation/density separation: usually after upstream shredding and screening steps for fractions that are separated according to their specific density with accurately adjustable separation equipment.
- Size reduction: for better fractioning, shredder residues are often reduced in size, i.e. the particle size is reduced to a homogeneous size suited to the subsequent reprocessing step.
- Eddy current separation.
- Induction sorting systems: usually employed to extract from non-metallic materials those metals which cannot be extracted using eddy current separators, e.g. lead and stainless steel.
- Magnet separator.
- Optical sorting systems: used to separate copper/brass from other heavy metals.
- X-ray systems: metal composites are sorted according to various material densities, halogen components or organic components with the aid of X-rays. Sorting can be according to light and heavy metals or plastics.
- Electrostatic sorting: use of the electrostatic properties of the various materials.
- Sink-float tanks: Dense media separation method of sorting to separate two solids by exploiting the different material densities.

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3.1.2 Current emission and consumption levels

3.1.2.1 Emissions to air

3.1.2.1.1 General overview

Emissions to air from a shredder plant are likely to be dust including metallic particles, VOCs, water vapour or, occasionally under other than normal operating conditions: smoke, dust and potentially dioxins in the event of a deflagration.

When the shredder separates the materials and sorts the magnetic fraction, these operations are conducted at a high throughput rate, commonly between 40 and 200 tonnes per hour. At this rate, even with a strict visual control of the input, it is impossible to avoid the entrance of some material capable of producing a deflagration in the shredder and, although the risk of an occurrence can be reduced, it cannot be completely eliminated. Therefore, the shredder itself cannot be equipped with a bag filter to suppress POPs, as this would inevitably be blown out by a deflagration in the shredder.

Consequently, the shredder has to be equipped with dust collection systems compatible with deflagrations, comprising cyclones and venturi scrubbers. Hence, the POPs emission at the clean air exhaust is determined by the efficiency of such abatement equipment. However, from company to company, and from sample to sample, there are variations in the measured emissions, which could be due to the infeed, the plant, or the process and procedures. Indeed, because of the deflagration risk, in some areas of the EU there is no dust collection in the shredding step; some operators preferring to use water injection for emission control (damp shredding) in the shredding step, and conventional emission control only in the second step.

Diffuse emissions can locally cause environment impacts and are reduced by the different technics described in this document (see Section 2.3.5). It is difficult to give a figure in unit per time or per tonnage of material processed, rather they represent a concentration in some areas of the shredder plant. **Figure 3.6** shows potential air emission sources at a shredding plant.

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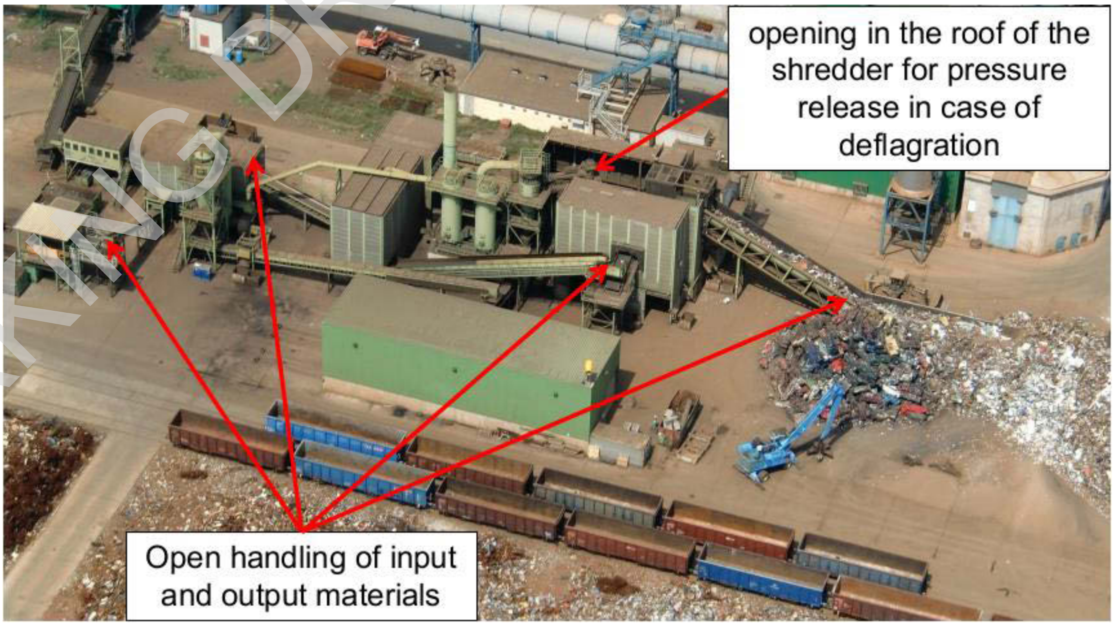

Source: [107, Mech. subgroup 2014]

Figure 3.6: Potential sources of air emission at a shredder plant

A further source of diffuse emissions from shredding plants are deflagrations. Deflagrations can be caused by residual fuel left in end-of-life vehicles. Analysis of the amount of dust that is emitted during a deflagration is not known. **Figure 3.7** shows the emission from a shredding plant in the case of a deflagration. This is considered as other than normal operating conditions (OTNOC).

Source: [107, Mech. subgroup 2014]

Figure 3.7: Emission from a shredding plant in the case of a deflagration

The number of deflagrations varies from one shredder site to another. An efficiently managed shredder has less than one deflagration per year.

3.1.2.1.2 Dust and particle-bound metals

Although the potential contamination of dust by heavy metals (e.g. lead) is considerably lowered by the implementation of the EoLV Directive (2000/53/EC) and its strict depollution requirement, particulate emissions to air from the shredding of metal waste (depolluted EoLVs, depolluted WEEE, ferrous and/or non-ferrous metals) include dust and particle-bound metals. The levels of dust and metals emission to air and the associated techniques reported through the data collection are given in Table 3.1 below.

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Table 3.1: Dust and metal emissions to air from mechanical treatment in shredders of metal waste – Periodic measurements

Plant code	Techniques used	Capacity (t/day)	Exhaust air flow rate (Nm^3/h)	Dust (mg/Nm^3)	Ni (mg/Nm^3)	Pb (mg/Nm^3)	Cd (mg/Nm^3)	As (mg/Nm^3)	Cu (mg/Nm^3)	Zn (mg/Nm^3)	Number of measurements in the three-year reference period (2010-2012)
136, 464-5	Cyclone alone	80 to 350	20 000 to 136 300	5.3–33(1)	0.08(1)	0.15(1)	0.013(1)	0.007(1)	0.056(1)	1.5(1)	Dust: up to 3 Ni: up to 3 Pb: up to 3 Cd: up to 3 As: up to 3 Cu: up to 3 Zn: up to 3
364-2, 464-4	Fabric filter	80 to 1120	15 000 to 65 000	1.1–2	0.008	0.003	0.0006	0.0006	0.003	0.6	Dust: up to 9 Ni: up to 9 Pb: up to 9 Cd: up to 9 As: up to 9 Cu: up to 9 Zn: up to 3
95, 441, 571	Venturi scrubber	480 to 1000	8 500 to 64 000	9.4–24.1	0.02–0.03	0.007–0.02	0.0006–0.14	0.001–0.02	0.001–0.29	0.2	Dust: up to 3 Ni: up to 3 Pb: up to 3 Cd: up to 3 As: up to 3 Cu: up to 3 Zn: up to 2
25, 26, 27-1, 28, 55, 455-1, 456	Cyclone & wet scrubber	200 to 1100	30 000 to 87 000	2.7–36.3(2)	0.004–2.4	0.002–0.02	0.00004–0.001	NI	0.02	NI	Dust: up to 9 Ni: up to 9 Pb: up to 9 Cd: up to 9 Cu: up to 9
29, 293, 294, 455, 464-1, 464-2, 464-3	Cyclone & fabric filter	70 to 4160	9 300 to 47 000	0.1-5	0.8	0.006	NI	NI	0.12	18	Dust: up to 3 Ni: 1 Pb: 1 Cu: 1 Zn: 1

WORKING DRAFT IN PROGRESS

54-1, 54-2	Cyclone, venturi scrubber, carbon adsorption	350	53 000	< 2.4	NI	< 0.007	< 0.0003	NI	0.008	0.16	Dust: 1 Pb: 1 Cd: 1 As: 1 Cu: 1 Zn: 1
282, 288-1, 288-2, 289, 290, 291	Cyclone & venturi scrubber	250 to 1660	21 000 to 100 000	0.1–12.8	NI	0.0044	0.0003	NI	0.002–0.008	NI	Dust: up to 3 Pb: 3 Cd: 3 Cu: up to 3
364-1	Fabric filter, venturi scrubber, carbon adsorption	1120	83 000	2.1	NI	0.02	NI	0.0008	0.02	0.6	Dust: 12 Pb: 6 As: 7 Cu: 6 Zn: up to 6
432-1, 432-2	Fabric filter & venturi scrubber	1440	43 000	2.1–7.2	0.007	NI	NI	NI	NI	NI	Dust: 6 Ni: 6
478	Cyclone. Water injection into the mill	800	128 400	1.1	0.0006	0.003	0.00005	/	0.002	0.02	Dust: 2 Ni: 1 Pb: 2 Cd: 2 Cu: 2 Zn: 2
285-1, 285-2, 286-1, 286-2	No information	1500	49 000 to 93 000	0.1–6	NI	NI	NI	NI	NI	NI	Dust: 1

NI: No information.

(1) Emission from Plant 136 equipped with a cyclone only.

(2) Measurement before air abatement. The value after abatement is 4.4 mg/Nm^3.

The values are the average over the three reference years.

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Figure 3.8 and **Figure 3.9** give the reported levels of dust and lead emissions to air, respectively, from mechanical treatment in shredders of metal waste.

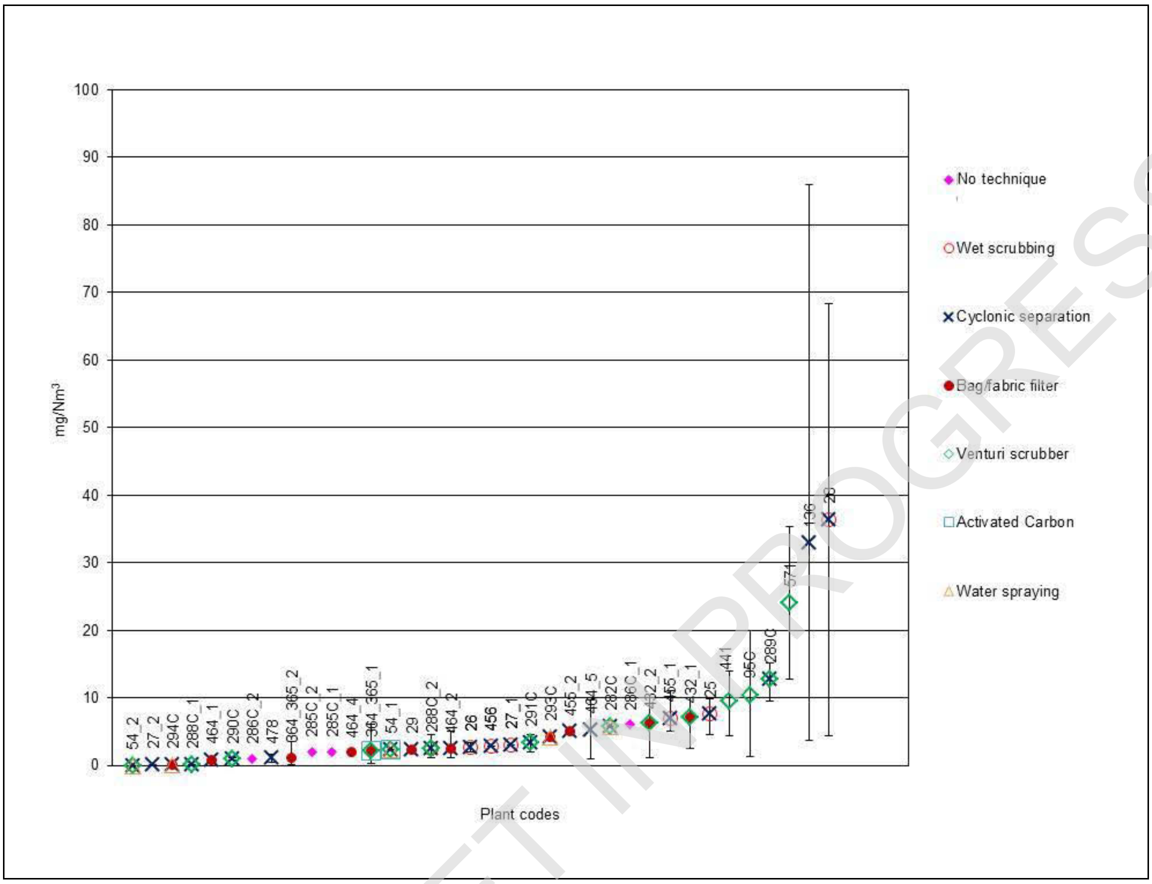

Figure 3.8: Dust emissions to air from mechanical treatment in shredders of metal waste

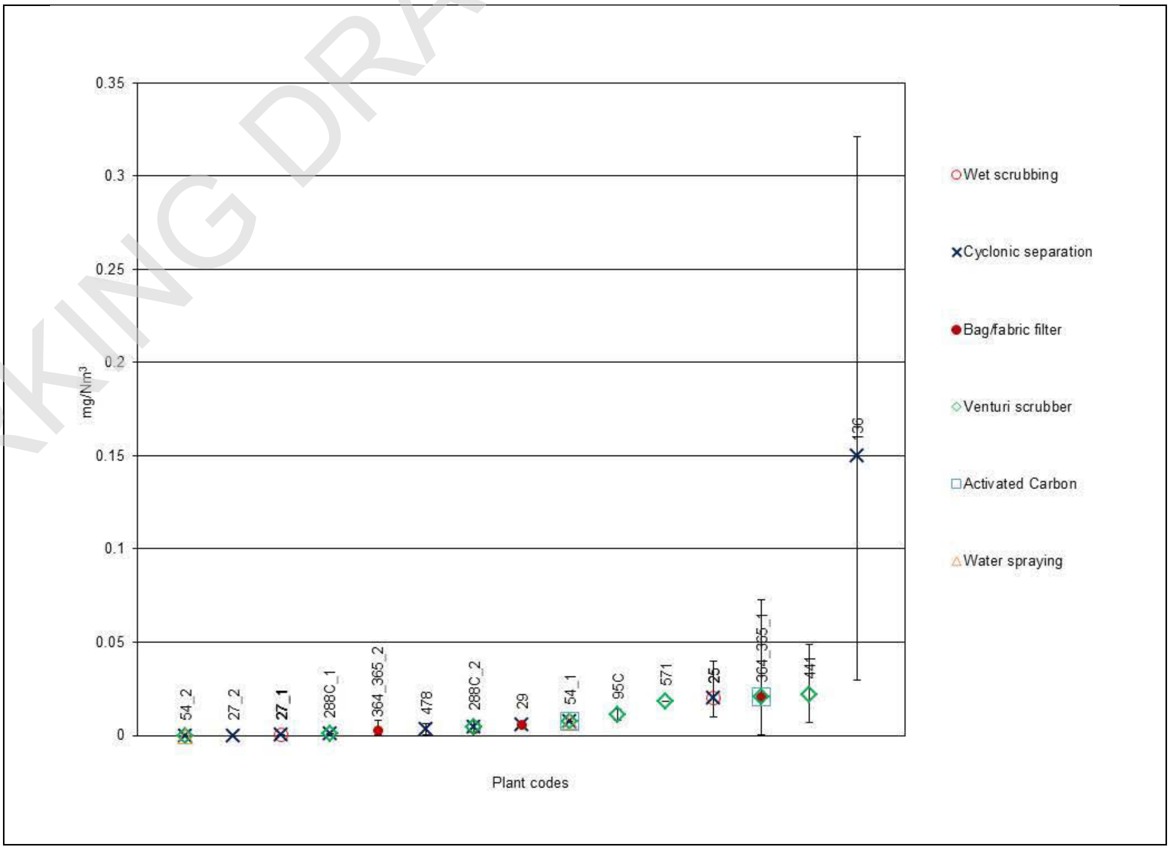

Figure 3.9: Lead emissions to air from mechanical treatment in shredders of metal waste

WORKING DRAFT IN PROGRESS

3.1.2.1.3 Volatile organic compounds (VOCs)

In general, the greatest concentrations of VOCs detected relate to those compounds associated with petrol and diesel fuels. These include, for example, xylene isomers, toluene and light hydrocarbons.

Gaseous organic contents in the exhaust air can be reduced to a certain extent with the commonly used combination of cyclones and wet scrubbers.

The End-of-life Vehicles Directive (2000/53/EC) and Waste Electrical & Electronic Equipment Directive (2012/19/EU) include specific depollution requirements to extract fuels and oils from vehicles, refrigerants, oils, and gases from refrigerator foam. This means that the infeed of shredders does not now include fuel or refrigerants and, consequently, VOCs are less likely to be emitted. [107, Mech. subgroup 2014]

Table 3.2 below gives the reported levels of TVOC and TOC emissions to air from mechanical treatment in shredders of metal waste.

Table 3.2: TVOC and TOC emissions to air from mechanical treatment in shredders of metal waste – Periodic measurements

Plant code	Techniques used	Capacity (t/day)	Exhaust air flow rate (Nm^3/h)	TVOC (mg/Nm^3)	TOC (mg/Nm^3)	Number of measurements during the three reference years
364-2	Fabric filter	80 to 1120	15 000 to 65 000	NI	3.5	5
95, 571	Venturi scrubber	480 to 1000	8 500 to 64 000	NI	30–39	
25, 27-1, 27-2	Cyclone & wet scrubber	200 to 1100	30 000 to 87 000	NI	2.1–166	
288-1, 289, 290, 291	Cyclone & venturi scrubber	250 to 1660	21 000 to 100 000	36.6	0.1–9.5	TVOC: up to 3 TOC: up to 3
364-1	Fabric filter, venturi scrubber, carbon adsorption	1120	83 000	NI	3.5	
288-2	Cyclone, wet scrubber and venturi scrubber	450	63 000	36.6	NI	3
NI: No information. The values are the average over the three reference years.						

When reported, the standard for TOC measurements is EN 12619, for which the monitoring method is a flame ionisation detector (FID). The reported values for TOC might therefore be considered as volatile compounds without the solid phase (particulate).

Figure 3.10 below shows the reported levels of TOC emissions to air from mechanical treatment in shredders of metal waste.

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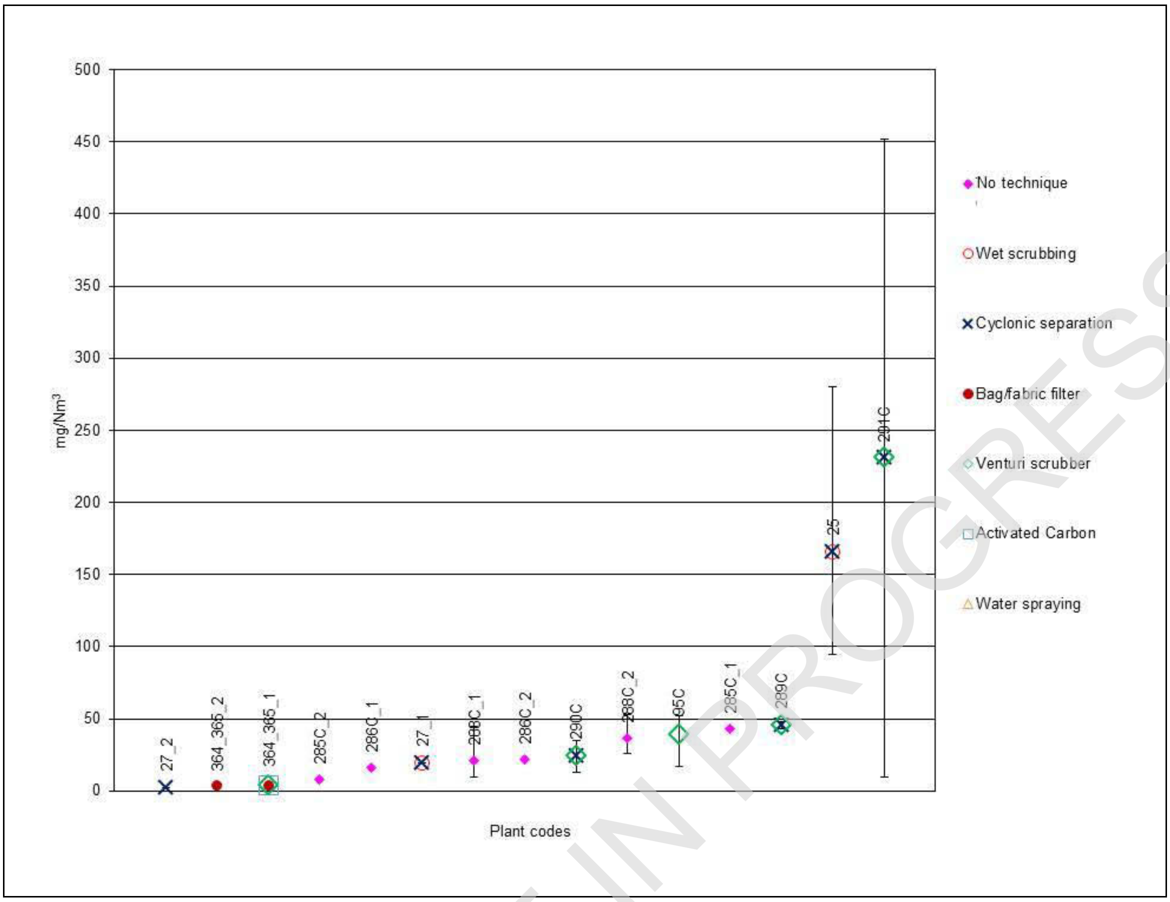

Figure 3.10: TOC emission to air from mechanical treatment in shredders of metal waste

One plant located in Austria (Plant 25) reported that the level of TOC emissions was reduced by decreasing the feeding rate of the shredder.

3.1.2.1.4 PCB and dioxins

Shredder plants for the treatment of end-of-life vehicles are mentioned in Annex C, Part III, of the Stockholm Convention on POPs (as amended in 2009), as one of the potential source categories for the unintentional formation and release of PCDD/F and PCB.

Regarding dioxins, company tests have shown that temperatures in the shredding chamber do not exceed 70 °C. Consequently, except under other than normal operating conditions, such as deflagration, which have to be further reduced as much as possible, the material composition of the products entering the plant is the same as that found at the different outlets of the plant. [125, EFR_ESG 2015]

However, PCB emissions may occur because end-of-life goods in which PCB has been widely utilised in the past are processed in shredder plants. Commercial PCB products always contained a small quantity of dl-PCB and less PCDD/F, and the measured emissions can be explained by re-emission of former used PCB.

End-of-life goods that may generate PCB emissions when processed include:

- PCB-containing capacitors and transformers;
- PCB-containing dip paints for copper windings in electric motors;
- PCB-containing parting compounds in electronic waste, e.g. coated papers, pulps and plastics;
- metal waste with PCB-containing coatings, e.g. tables, chairs, window frames, steel beams, support materials for sawtooth roofs.

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The shredding process, including the handling of scrap and residues, generates high amounts of dust containing pollutants such as heavy metals, PCDD/F and PCB, which are very susceptible to dispersion into the environment (channelled and diffuse emissions). Table 3.3 below gives the levels of PCDD/F and PCB emissions reported though the data collection. No measurement for dioxin-like PCB was reported.

Table 3.3: PCDD/F and PCB emissions from mechanical treatment in shredders of metal waste – Periodic measurements

Plant code	Techniques used	Exhaust air flow rate (Nm^3/h)	PCDD/F (ng^{I-TEQ}/Nm^3)	PCB (mg/Nm^3)	Number of measurements in the three-year reference period (2010-2012)
364-2	Fabric filter	65 000	NI	0.0003	PCB: 3
95	Venturi scrubber alone	64 000	0.013	0.004	PCDD/F: 3 PCB: 3
288-1	Cyclone & venturi scrubber	63 000	0.0002	0.002	PCDD/F: 1 PCB: up to 3
54-1	Cyclone & venturi scrubber, carbon adsorption	53 000	NI	0.009	PCB: 1
364-1	Fabric filter & venturi scrubber	100 000	NI	0.0004	PCB: 4
288-2	Cyclone, wet scrubber and venturi scrubber	63 000	0.003	0.01	PCDD/F: 1 PCB: 3
285-1	NI	NI	0.03	NI	PCDD/F: 1
NI: No information. The values are the average over the three reference years.					

Table 3.4 shows measured dust emissions at three Flemish shredding plants. These shredders have at least a cyclone filter system for dedusting the flue-gases. The flue-gas flow rates are typically about 75 000 Nm^3/h. All PCDD/F concentrations, except one, were below 0.1 ng TEQ/Nm^3. Concentrations of dioxin-like PCB varied significantly between the different shredders and measurement days. Differences in flue-gas cleaning and the type and PCB content of the material being shredded during the measurements are the reasons. During the measurements, no particular correlation could be found between dust emissions and PCDD/F or PCB emissions. [107, Mech. subgroup 2014] [124, Belgium 2007]

Table 3.4: Dust emissions at three Flemish shredder plants

Emission measurement	PCDD/F ng TEQ/Nm^3	Dioxin-like PCB (sum of 12) ng TEQ/Nm^3
Shredder 1	0.0098 0.012 0.0048 0.0004	0.048 0.41 0.073 0.025
Shredder 2	0.077 0.043 0.022	0.74 1.06 0.30
Shredder 3	0.0088 0.37 0.025	0.171 0.34 0.73

A Flemish study concluded that diffuse emission sources may have a major impact on the environmental contamination, especially for dioxin-like PCB, and therefore have to be taken into consideration for the environmental impact of the mechanical treatment in shredders of metal waste. [107, Mech. subgroup 2014]

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When high amounts of polluted dust are released via diffuse emissions this will also lead to a significantly high emission load. An overview of the average, minimum and maximum monthly deposition values, measured between April 2003 and April 2004 in the surroundings of four Flemish shredder plants is given in Table 3.5 below. The results show that the deposition levels of PCB-126 are generally higher than the PCDD/F ones, and that there is no clear correlation between both compounds. This could indicate that PCDD/F and PCB-126 have different sources and/or pathways to the environment. [107, Mech. subgroup 2014]

Table 3.5: Result of emission measurements near four Flemish shredder plants

Deposition measurements near	**PCDD/F (pg TEQ/m^2·day) average (min – max)**	**PCB – 126 (pg TEQ/m2 .day) Average (min – max)**
Shredder 1 (gauge 1)	16 (7 – 25)	43 (8 – 102)
Shredder 1 (gauge 2)	27 (12 – 41)	66 (23 – 123)
Shredder 2	29 (11 – 54)	52 (17 – 83)
Shredder 3	29 (10 – 45)	137 (21 – 223)
Shredder 4	27 (17 – 34)	86 (14 – 142)

Later results at different Flemish shredder plants confirmed the connection between scrap metal recycling activities and increased levels of dl-PCB in the surroundings. [107, Mech. subgroup 2014]

However, although the infeed of shredder plants may occasionally contain used equipment sold on the market before 1987, in which traces of PCB can be found, the amount of PCB entering shredders is decreasing and will continue to decrease in the future [107, Mech. subgroup 2014].

- The presence of PCB oil from electric heaters and some capacitors has been recognised as a potential source of PCB in metal waste. The implementation of both the WEEE Directive and the EoLV Directive over the past 10 years has imposed depollution before shredding, and the practice of this depollution step has been largely expanded.
- The prohibition, since 1987, of the use of PCBs in Europe has naturally led to a decrease of PCB in metal waste. In 2014, ECO-SYSTEMES in France established the absence of PCB in the WEEE entering the recycling market TWG, please provide the ECO-SYSTEMES document.

The information given above shows that the main ways to prevent PCB and dioxin emissions to air from mechanical treatment in shredders of metal waste are:

- to avoid the shredding of waste containing PCB, and
- to avoid incidents/accidents such as deflagrations and fires.

This is done by optimising the knowledge and control of the waste input (see Section 2.1.1).

3.1.2.1.5 Mercury

Mercury can arise in waste input, principally in the following material streams:

- mercury switches of some temperature exchange equipment such as fridges and freezers (Figure 3.11);

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Source: [107, Mech. subgroup 2014]

Figure 3.11: Mercury switch

- some LCD/LED flat-panel display backlights (Figure 3.12);

Source: [107, Mech. subgroup 2014]

Figure 3.12: Mercury blacklight lamp

- certain button cells, although mercury has been banned from this application in Europe since 2000 (**Figure 3.13**).

Source: [107, Mech. subgroup 2014]

Figure 3.13: Mercury button cells

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Treatment of these waste streams is covered by the WEEE Directive which requires strict depollution steps. Metal wastes known or suspected to contain these items are processed in dedicated plants, and normally not in mixed-metal shredders. [107, Mech. subgroup 2014]

Nevertheless, mercury can be present in emissions to air from mechanical treatment in shredders of metal waste, as shown in Table 3.6 and Figure 3.14 below.

Table 3.6: Mercury emissions to air from mechanical treatment in shredders of metal waste – Periodic measurements

Plant code	Techniques used	Exhaust air flow rate (Nm^3/h)	Hg ($\mu g/Nm^3$)	Number of measurements during the 3-year reference period (2010-2012)
136	Cyclone alone	20 000 to 136 300	< 0.9	3
364-2,	Fabric filter	15 000 to 65 000	6	3
95, 571	Venturi scrubber	8 500 to 64 000	6–20	up to 2
25, 27-1, 27-2	Cyclone & wet scrubber	30 000 to 87 000	< 0.0005–2.9	up to 9
29, 293, 294, 455,	Cyclone & fabric filter	9 300 to 47 000	< 0.6	1
54-1, 54-2	Cyclone, venturi scrubber, carbon adsorption	53 000	0	1
364-1	Fabric filter, venturi scrubber, carbon adsorption	83 000	7	3
288-1, 288-2	Cyclone and venturi scrubber	63 000	< 0.06	3
The levels are the average over the three reference years. NB: The limit of detection for the standard EN 13211 is 2.6 $\mu g/m^3$.				

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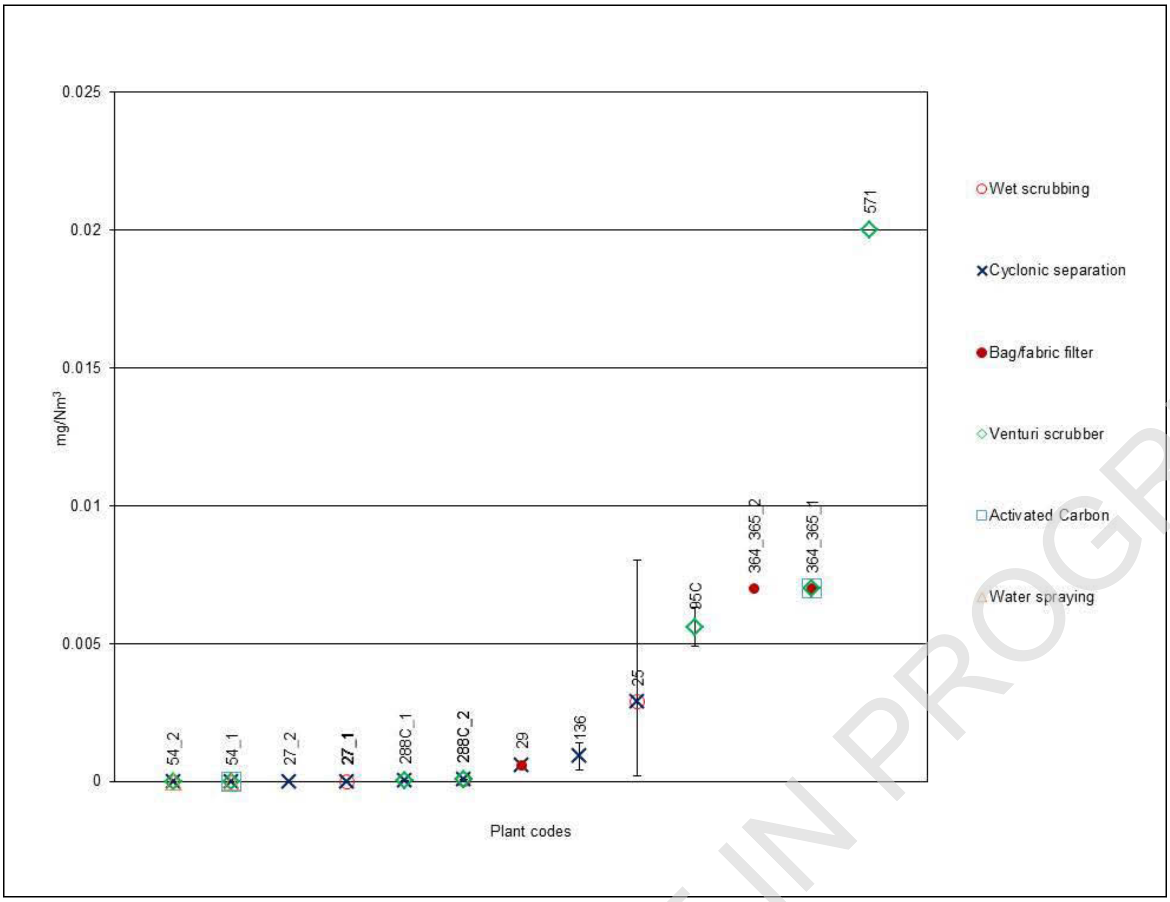

Figure 3.14: Mercury emissions to air from mechanical treatment in shredders of metal waste

Just as with PCB and dioxins, the main way to prevent mercury emissions to air from mechanical treatment in shredders of metal waste is to prevent such mercury-containing wastes from entering the process.

3.1.2.2 Emissions to water and water usage

3.1.2.2.1 Emissions to water

Rainwater run-off is collected and drained, as is any water released by processes on site, including water for damping down for dust suppression or process water releases. Surface water run-off also includes those waters which percolate through the stored waste input and output. During percolation, it is possible for the waters to leach soluble components and to suspend and carry insoluble materials into the drainage system.

Plants have sealed surfaces composed of concrete paving, which drain via grit traps or settlement tanks to oil/water interceptors and then to a discharge point.

The objectives are to reduce the quantity of any water to be discharged from the plant, and to reduce the degree to which this water is exposed to potential contaminants.

Where not reused, waste water is preferably discharged to a sewer. Only where locations or other engineering constraints prevent connection to a sewer should the discharge be connected to controlled water. Connection of discharge to controlled water may require additional treatment to meet the consent limits. [107, Mech. subgroup 2014]

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Table 3.7 below summarises the levels of emissions to water reported through the data collection. It should be read together with Table 3.8 which gives an indication of the applied techniques and the origin of the emissions to water.

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Table 3.7: Reported emissions to water from mechanical treatment in shredders of metal waste

Parameter measured	Monitoring	Plants concerned	Range (mg/l except for pH and flow)	Number of measurements during the 3-year reference period (2010-2012)
Flow (m^3/h)	Continuous	54, 441, 478,	6.8–13	NA
	24-hour flow-proportional composite sample	95, 455	9.7–36.9	NA
	Estimated	364-365	7	NA
pH	24-hour flow-proportional composite sample	455	8.2–8.4	NA
	Composite sample	54, 136	7.5-8.2	3 to 22
	Grab sample	95, 137, 282, 289, 293, 364-365, 441, 464, 478, 571	6.5–8.1	1 to 12
COD	24-hour flow-proportional composite sample	455	210–298	NA
	Composite sample	54, 136	59-174	3 to 35
	Grab sample	137, 364-365, 441, 478, 571	38–697	1 to 10
TOC	Grab sample	289, 293, 478	8.4–112	4 to 13
BOD_5	24-hour flow-proportional composite sample	455	35–98	NA
	Composite sample	54, 136	5.2-38	
	Grab sample	137, 293, 441, 571	16–280	1 to 10
Total N	Grab sample	293. 441, 478	5.4–51	4 to 7
Total P	Grab sample	293, 364-365, 441, 571	0.9–5.7	6 to 8
TSS	24-hour flow-proportional composite sample	455, 456	17–129	NA
	Composite sample	54, 136	9-41	3 to 32
	Grab sample	137, 282, 293, 364-365, 441, 464, 478, 571	0.1–49	1 to 10
THC	Composite sample	136	3.3	3
	Grab sample	28, 137, 282, 364-365, 441, 464, 478	0.2–8.7	3 to 7
HOI	Grab sample	441, 478	1.1–9.5	10 to 11
PAHs	Composite sample	136	0.002	1
	Grab sample	137	0.000004	1
Cd	24-hour flow-proportional composite sample	455	0.005–0.006	NA
	Composite sample	54	0.002	19
	Grab sample	95, 282, 293, 364-365, 478, 571	0.0008–0.05	1 to 13
Hg	24-hour flow-proportional composite sample	455	0.00007–0.002	NA
	Composite sample	54	0.00007	19
	Grab sample	95, 364-365, 478, 571	0.0001–0.004	1 to 13

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As	24-hour flow-proportional composite sample	455	0.005	NA
	Composite sample	54	0.001	17
	Grab sample	137, 364-365, 478, 571	0.001–0.01	1 to 13
Pb	24-hour flow-proportional composite sample	455, 456	0.06–0.3	NA
	Composite sample	54, 136	0.04-0.1	3 to 31
	Grab sample	28, 95, 137, 282, 289, 293, 364-365, 478, 571	0.01–0.3	1 to 13
Cr	24-hour flow-proportional composite sample	455, 456	0.02–0.03	NA
	Composite sample	54	0.0008	14
	Grab sample	95, 137, 282, 293, 364-365, 478, 571	0.005–0.13	1 to 13
Cr(VI)	24-hour flow-proportional composite sample	455	0.05	NA
	Grab sample	571	0.01	1
Cu	24-hour flow-proportional composite sample	455, 456	0.1–0.2	NA
	Composite sample	54, 136	0.07-0.1	3 to 32
	Grab sample	28, 95, 137, 282, 293, 364-365, 441, 478, 571	0.04–0.4	1 to 13
Mn	24-hour flow-proportional composite sample	455	0.11–0.14	NA
	Composite sample	136	0.2	3
	Grab sample	137, 364-365	0.006–0.1	1 to 6
Ni	24-hour flow-proportional composite sample	455, 456	0.01–0.03	NA
	Composite sample	54, 136	0.009-0.02	2 to 31
	Grab sample	95, 137, 282, 293, 364-365, 478	0.00001-0.09	1 to 13
V	Grab sample	478	0.008	2
Zn	24-hour flow-proportional composite sample	455, 456	0.6–1.5	NA
	Composite sample	54, 136	0.2-0.6	3 to 31
	Grab sample	28, 95, 137, 289, 282, 293, 364-365, 464, 478, 571	0.00007-2.2	1 to 13
Fe	24-hour flow-proportional composite sample	455, 456	0.8–7.6	NA
	Grab sample	282, 464, 441	1.4–2.4	6 to 12
PCB	Composite sample	54	0	3
	Grab sample	478	0.02	6
Chlorine	Grab sample	478	109	9
AOX	Composite sample	28, 54, 137, 282, 289	< 0.2	2 to 12
EOX	Grab sample	478	0.01	2
BTEX	Grab sample	478	0.02	2
Surfactant	Grab sample	571	0.1	1

NA: Not applicable.
Plant 455 reported emission levels as daily average. Averaging period not indicated for Plant 456.

WORKING DRAFT IN PROGRESS

Table 3.8: Mechanical treatment in shredder of metal waste – Techniques used, origin of emissions to water and point of release

Plant code	Techniques used	Origin of emissions to water	Point of release
25	NI	NI	NI
26	NI	NI	NI
27	NI	NI	NI
28	NI	Whole plant, including run-off water	Indirect discharge (off-site common WWT facilities)
29	NA	No emissions	NA
30	NI	NI	NI
54	Buffer tanks Sand filtration Biological treatment	Whole plant	Indirect discharge (off-site common WWT facilities)
55	Decantation Absorption Sand filtration	Water treatment on the scrap yard	Direct discharge via the on-site common WWT facilities
95	API separator system	Run-off water	Indirect discharge (off-site common WWT facilities)
100	NA	No emissions.	NA
136	Buffer tanks Decantation Parallel plate interceptor system	Run-off water	Direct discharge via the on-site common WWT facilities
137	Decantation Filtration	Shredding plant	NI
282	Retention basin with integrated sludge trap Coalescence separator	Run-off water	Indirect discharge (urban/municipal sewer system)
285	NI	Run-off water	Indirect discharge (urban/municipal sewer system)
286	NI	Run-off water	Indirect discharge (urban/municipal sewer system)
288	Sieving (sludge trap) Oil separation	Run-off water	Indirect discharge (urban/municipal sewer system)
289	Sieving (sludge trap) Oil separation	Run-off water	Indirect discharge (urban/municipal sewer system)
290	Sieving (sludge trap) Oil separation	Run-off water	Indirect discharge (urban/municipal sewer system)
291	Sieving (sludge trap) Oil separation	Run-off water	Indirect discharge (urban/municipal sewer system)
293	Coalescence separator with integrated sludge trap	Run-off water	Indirect discharge (urban/municipal sewer system)
294	Sedimentation (ponds)	NI	NI
364	Chemical oxidation Chemical precipitation Chemical reduction Coagulation Decantation Filtration	Whole plant	Indirect discharge (urban/municipal sewer system)
432	NI	Shredding plant	NI
441	Sedimentation (ponds) API separator system	Whole plant	Direct discharge via the on-site common WWT facilities
455	Decantation Oil separation	Storage and common steps	Indirect discharge (urban/municipal sewer system)
456	Decantation Oil separation	Storage and common steps	Indirect discharge (urban/municipal sewer system)
464	Decantation Oil separation	Storage	Direct discharge via the on-site common WWT

WORKING DRAFT IN PROGRESS

478	Sedimentation (ponds) API separator system	Shredding plant	Direct discharge via the on-site common WWT
516	NI	NI	NI
517	NI	NI	NI
571	Decantation Flotation Press filtering Hydrocarbon separation	Run-off water from the open air storage	Indirect discharge (off-site common WWT facilities)

NI: No information.
NA: Not applicable.

Of the 31 plants that participated in the data collection, five (Plants 55, 136, 441, 464 and 478) reported to have direct discharge to the environment. With the exception of plant 364 (indirect discharge to an urban/municipal sewer system), the reported implemented techniques aim to abate particulates (TSS) and hydrocarbons (oil).

Three plants (Plants 55, 136 and 464) indicated that the origin of emissions to water is rainwater, two (Plants 441 and 478) indicated that the origin of emissions to water is the whole installation. Table 3.9 below presents the reported concentration values for emissions to water directly discharged to the environment.

Table 3.9: Mechanical treatment in shredder of metal waste – Direct discharge to water

Parameter (mg/l)	Origin of emissions to water			
	Rainwater		Whole plant	
	Plant 136	Plant 464[(1)]	Plant 441	Plant 478
TSS	41	74	42	19.6
BOD5	38	NI	18.4	NI
COD	174	NI	105.8	328
TOC	NI	NI	NI	95.9
THC	3.3	3.9	8.7	0.2
HOI	NI	NI	9.5	1.1
PAHs	0.0023	NI	NI	NI
Total N	NI	NI	5.4	7.23
Total P	NI	NI	0.975	NI
Cd	NI	NI	NI	0.00083
Hg	0.0005	NI	NI	0.00013
Sb	NI	NI	NI	0.003
As	NI	NI	NI	0.002
Pb	0.13	NI	NI	0.03
Cr	NI	NI	NI	0.0063
Cr(VI)	NI	NI	NI	NI
Cu	0.073	NI	0.22	0.053
Ni	0.009	NI	NI	0.02
Zn	0.6	0.8	NI	0.5
Fe	NI	3	2	NI

(1) The figures are the maximum reported values (average over the three reference years) of the three release points indicated in the questionnaire.
NI: No information.
No data were provided by Plant 55.

WORKING DRAFT IN PROGRESS

3.1.2.2.2 Water usage

Metal waste shredders do not use much water, and many facilities run without water. However, water may be used for injection into the mill or for wet scrubbing. Then it is commonly reused in a closed circuit after cleaning. The input of fresh water is limited to water added to make up for losses due to evaporation or water remaining in the sludge tank. The use of newer methods, such as the addition of a foaming agent to the mill injection, reduces the quantity of water used. [107, Mech. subgroup 2014]

The reported amount of water used in semi-wet or wet shredder systems (either water injected into the mill or used for the wet (venturi) scrubber) is 1–10 litres per tonne of waste treated.

3.1.2.3 Noise and vibration

The operation of shredder plants results in noise emissions, caused by the machinery and material-handling technology, as well as by the delivery of the shredder feed and the transport of the output.

Monitoring has been carried out in some Member States of both shredder operational/processing levels and idle, non-processing levels, and levels associated with the plant when the mill was shut down. Such information indicates that the mill is the main source of noise on the site even though the other operations generate a significant contribution to the plant noise. It should be noted, however, that it is not just the level of noise which is significant, but the characteristics of how and when the noise is produced; so for the outfall conveyor, the noise tends to be more high-pitched. Furthermore, continuous noise tends to be less intrusive and less noticeable than irregular events. This may mean that tipping is a more noticeable disturbance than the continuous sound of the mill.

3.1.2.4 Consumption of energy

The energy input in the form of electrical power depends directly on the rotor power and the types of processes and technologies used. It is thus very specific to each individual case and is only comparable to a limited extent. Gross monitoring and reporting of total consumption may be undertaken for cost purposes, and, for example, the rate at which the mill draws current on site may be monitored live, but it is not always recorded.

There is limited detailed monitoring/metering by shredder operators of the power they use to run the plants, though the Bureau of International Recycling, the world federation of the recycling industry, has begun Shredder Energy Efficiency Benchmarking.

Manufacturer information suggests the power use estimates are based upon the size (infeed and mill box size) and power rating of the mill and its production capacity. A 2 200 kW (3000 hp) metal waste shredder could process around 100–130 tonnes/hour; therefore the power usage would be in the order of 17–22 kWh per tonne. This would produce 70–90 tonnes of ferrous product per hour. The actual use of power varies on a day-to-day basis and depending on the material. The average power consumption is around 27.2 kWh t^{-1}, with a range of 17–47 kWh t^{-1}. [107, Mech. subgroup 2014]

From the data collection, the average specific power consumption (electricity) is around 30 kWh.t^{-1}, with a range of 7–60 kWh.t^{-1}.

WORKING DRAFT IN PROGRESS

3.1.3 Techniques to consider in the determination of BAT

3.1.3.1 Techniques for the prevention or reduction of emissions to air

3.1.3.1.1 Reduction of dust and particle-bound metals emissions

Description

The equipment units used in the shredding plant (i.e. mill, windshifter drum, conveyors) are enclosed and connected by pipes. Exhaust air is collected from the mill and the windshifter drum, and treated before release.

Technical description

The air collection and treatment system depends on the type of shedder, namely:

1. shredder system with single cyclone;
2. shredder system with cyclone(s), venturi scrubber and one air exhaust;
3. shredder system with cyclone(s), venturi scrubber, bag filter and two exhausts;
4. shredder system with water injection into the mill.

In all types of systems, the air-classified materials (shredder light fraction) are discharged from cyclones/plenums via rotary valves onto covered belt conveyors, which carry the material to the bunker, bin, truck or rail car.

The technical descriptions of each individual technique for dust abatement, e.g. cyclone, venturi scrubber and fabric filter, are given in Section 2.3.4.

From ex-Section 4.1.6.1

The abatement system can be interlocked with the plant operation, so that the plant cannot operate unless the abatement system is working.

Achieved environmental benefits

The achieved environmental benefits of these techniques include:

- reduction of dust and metal emissions to air;
- improvement of the recycling rate by removing the shredded light fraction (SLF) from the desired shredded material.

Deflagrations can never be completely eliminated in a large shredder plant. In addition to the exhaust air dedusting and to the separation of the SLF from the shredded materials, a wet scrubber technique has the important advantage that it can withstand shockwaves of up to 3 bars. [107, Mech. subgroup 2014]

Water injection into the shredder box helps to suppress any deflagration events caused by the inadvertent feeding of flammable materials to the shredder.

TWG please clarify whether water injection prevents any deflagration in shredders or not

Environmental performance and operational data

See Table 3.1

Examples of the four types of shredder systems are given below.

1. Shredder system with single cyclone. Collection of the offtake from the mill and the air flow from the downstream material windshifter to a single cyclone and a single clean air exhaust (see Figure 3.15). This system is mostly found in old non-retrofitted plants.

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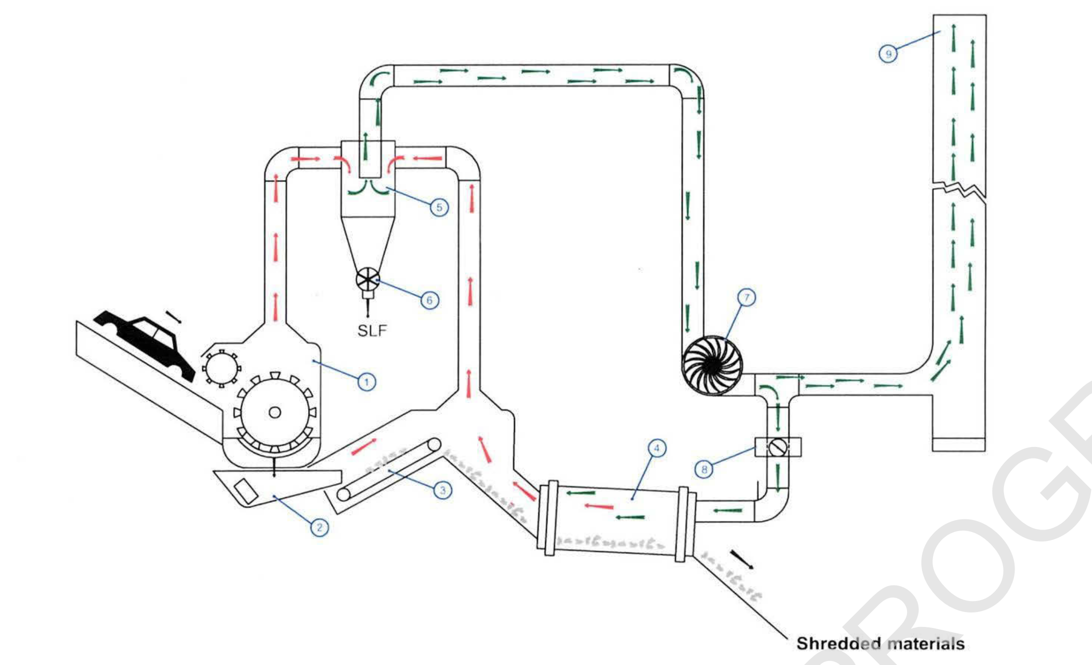

(1) Shredder chamber
(2) Vibrating conveyor
(3) Conveyor
(4) Windshifter drum
(5) Cyclone
(6) Rotary valve
(7) Ventilator
(8) Flap
(9) Treated air exhaust

Source: [107, Mech. subgroup 2014]

Figure 3.15: Shredder system with single cyclone

2. Shredder system with two cyclones, venturi scrubber and single exhaust: collection of the offtake from the mill and the air flow from the downstream material windshifter to two cyclones/plenums before directing air to a venturi scrubber and a single clean air exhaust (see Figure 3.16).

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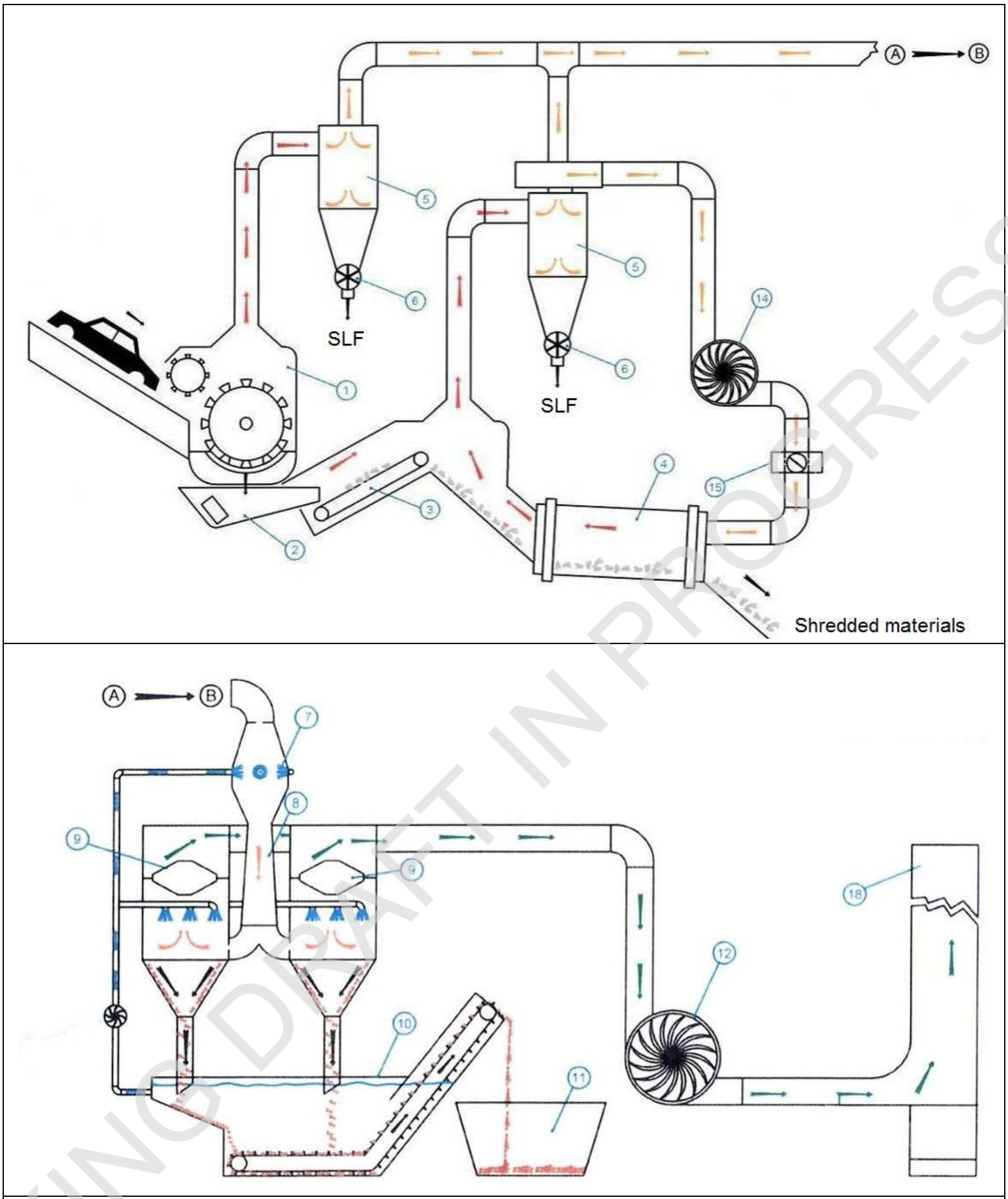


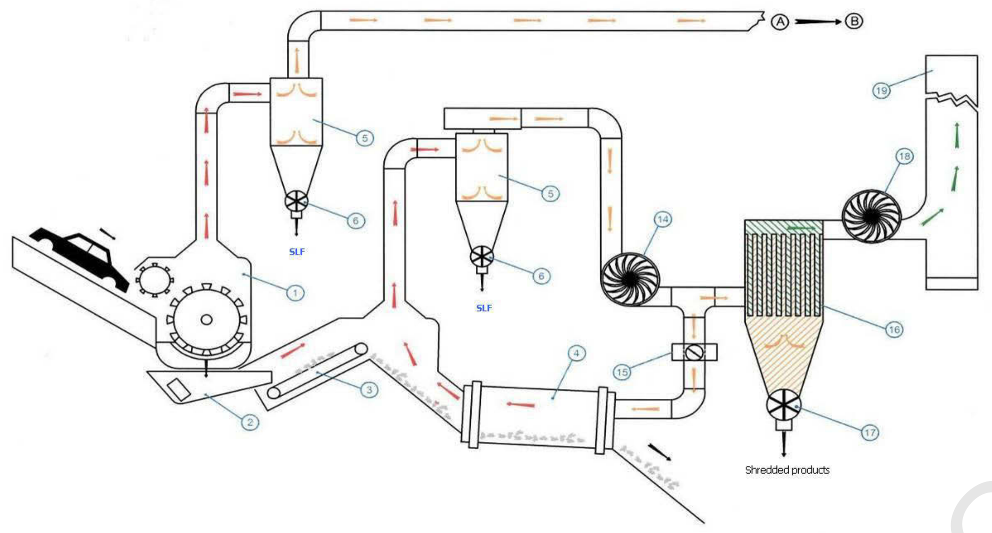
(1) Shredder chamber tank
(2) Vibrating conveyor
(3) Conveyor
(4) Windshifter drum
(5) Cyclone exhaust
(6) Rotary valve
(7) Water injection
(8) Venturi Tubes
(9) Droplet separator
(10) Settling tank
(11) Sludge tank
(12) Exhaust fan
(14) Ventilator
(15) Flap
(18) Clean air exhaust

Source: [107, Mech. subgroup 2014]

Figure 3.16: Shredder system with two cyclones, venturi scrubber and single exhaust

3. Shredder system with two cyclones, venturi scrubber, bag filter and two exhausts: collection of the offtake from the mill to a cyclone/plenum and then to a venturi scrubber, and collection of the air flow from the downstream windshifter to a separate cyclone followed by a bag filter; then two clean air exhausts (see Figure 3.17).

WORKING DRAFT IN PROGRESS



(1) Shredder chamber
(2) Vibrating conveyor
(3) Conveyor
(4) Windshifter drum
(5) Cyclone
(6) (17) Dust rotary valve
(14) Ventilator
(15) Flap
(16) Bag filter
(18) Exhaust Ventilator
(19) Clean air exhaust

Source: [107, Mech. subgroup 2014]

Figure 3.17: Shredder system with two cyclones, venturi scrubber, bag filter and two exhausts

The dust-laden air is pre-cleaned in a cyclone (5) before being reprocessed in a venturi scrubber (A ➔ B). The air from the windshifter is pre-cleaned in another cyclone (5) before being reprocessed in a bag filter (16).

Much of the pre-cleaned air from the second cyclone is returned to the air classifier (drum or cascade) by an air-recycling fan (14).

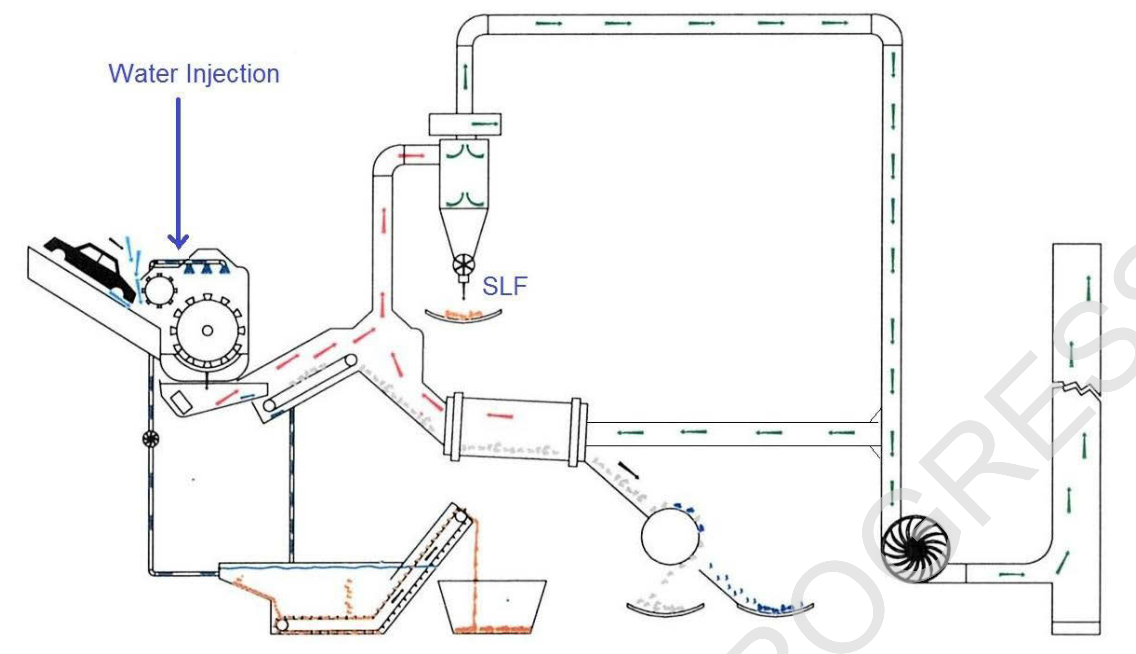
In the scrubber, the dust content of the exhaust air at the outlet of the cyclone is reduced to the prescribed value. This process is carried out by injection of water in the venturi neck (7) wherein the water is transformed into fine droplets, which absorb the particles of dust .

The polluted water is directed into a settling tank (10), in order to be purified. While purified cleaning water is returned to a venturi pump, solids are discharged into containers on a conveyor rake (dredge mud).

Apart from venturi scrubbers, other techniques (e.g. ring scrubbers) can be used for wet dust separation in large shredder plants. A common feature is their robustness and their ability to resist pressure shocks.

4. <u>Shredder system with water injection into the mill:</u> there is no air extraction from the mill – the preliminary dust suppression in the shredder box is achieved by water mist sprays. The airflow that contains residual dust can then be treated through cyclone(s) or a venturi scrubber. The injected water is mainly captured by the shredded light fraction (see Figure 3.19).

WORKING DRAFT IN PROGRESS



Source: [107, Mech. subgroup 2014]

Figure 3.18: Shredder system with water injection into the mill

Source: [107, Mech. subgroup 2014]

Figure 3.19: Water injection into the mill

The shredded material is made damp by injecting water into the mill (Figure 3.20). The amount of water is regulated in relation to the amount of energy consumed by the main motor. Downstream windshifter separation is not affected if the water mist is properly controlled. The air system works without filter systems, and the dust is separated from the air stream with cyclones.

In the winter period in northern Europe, the material can be wet enough (from snow, ice and rain) that no extra water need be injected into the shredder.

WORKING DRAFT IN PROGRESS

In some countries, the heating of certain components, such as the air locks and water injection piping, may be necessary.

According to the data collection, it seems that the implementation of the types of shredder systems described above is linked to the age of the plant. There are few examples of plants in Europe fitted with a shredder system with water injection into the mill (only one plant located in Sweden in the data collection). Figure 3.20 below shows the relationship between dust emissions and plant age.

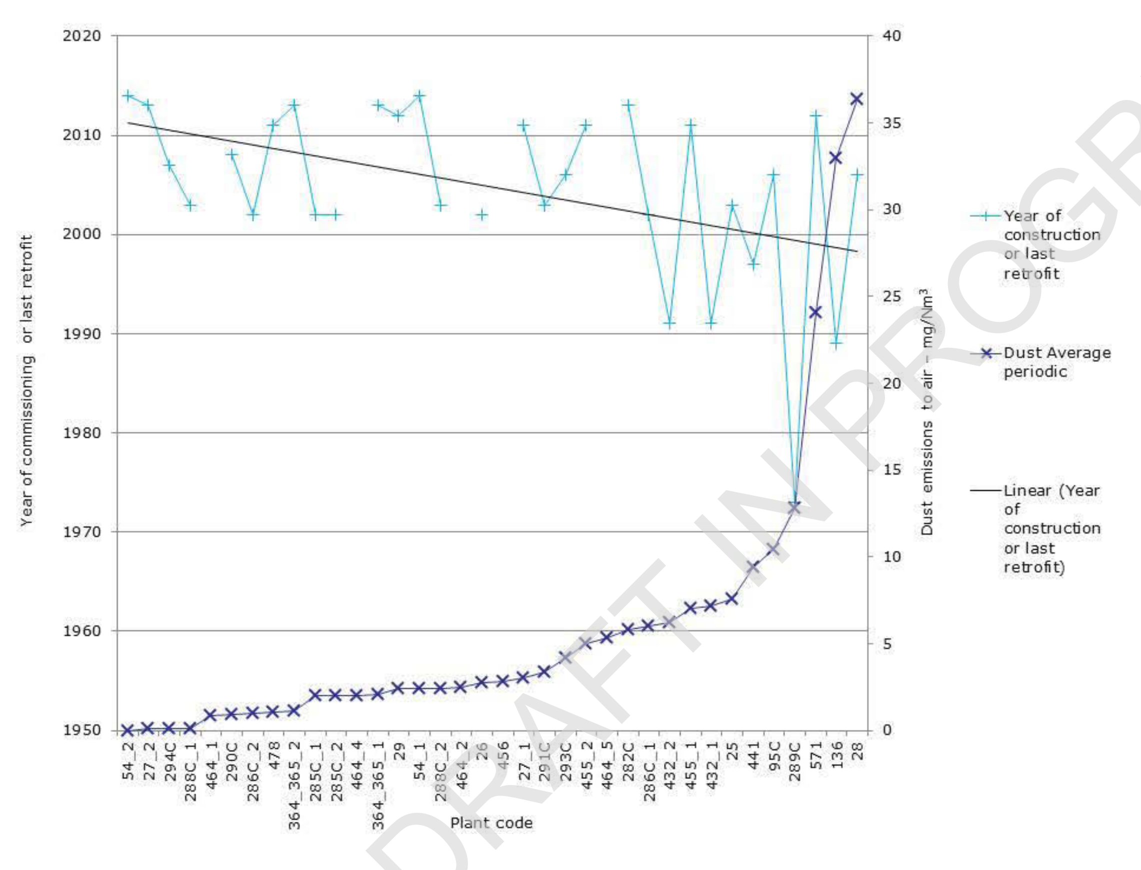


Figure 3.20: Mechanical treatment in shredder of metal waste – Relationship between plant age and dust emissions to air

The dust emission levels can be seen as an indicator for all other emissions since all essential emissions are directly connected to dust. With the reduction of dust, other emissions, particularly metal emissions, are simultaneously reduced. Therefore, an efficient dust abatement system also reduces metal emissions to air. Table 3.10 below shows the dust, lead and copper emissions to air from mechanical treatment in shredders of metal waste.

WORKING DRAFT IN PROGRESS

Table 3.10: **Dust, Pb, and Cu emissions to air from mechanical treatment in shredders of metal waste**

Type of shredder system	**Capacity (t/day)**	**Exhaust air flow rate (Nm^3/h)**	**Dust (mg/Nm^3)**	**Pb (mg/Nm^3)**	**Cu (mg/Nm^3)**	**Number of measurements during the three reference years**
Type 1 (single cyclone)	80	12 000	9.6	NI	NI	Dust: 1
Type 2 (cyclone, venturi scrubber)	220 to 1 100	16 000 to 106 000	0.1–10.4	<0.0002–0.02	0.008–0.02	Dust: up to 12 Pb: up to 9 Cu: up to 9
Type 3 (cyclone, venturi scrubber and bag filter)	70[(1)]	9 000 to 83 000	0.1-5	0.002-0.2	0.003-0.12	Dust: up to 9 Pb: up to 9 Cu: up to 9
Type 4 (water injection into the mill)	800	128 400	1.1	0.003	0.002	Dust: 2 Pb: 2 Cu: 2

Type 1: 464-5.
Types 2:: 25, 26, 27, 28, 54, 55, 95, 282, 285, 288, 290, 291, 441, 455-1, 456, 464-3.
Type 3: 29, 293, 294, 364, 455-2, 464-1, 464-2, 464-4
Type 4: 478.
NI: no information
(1) Only one plant (plant 29) indicated the daily capacity

Bag filters are usually found in newer shredder plants with separate exhaust air flows for the rotor and separator cycle and the appropriate separation technology (e.g. air classification).

Venturi scrubbers are established and field-tested technologies.

Scrubbers/wet systems are usually employed as a separation step. In general, these wet dust separation technologies are tested and usable in large shredder plants.

The used cleaning water from the wet scrubber can be recycled after conditioning with a drum screen and mud dredge.

Cross-media effects

- Water usage when water is injected into the mill.
- Depending on local conditions (e.g. winter period in northern countries), energy consumption for heating water injection piping.
- Mud can be generated when the water injection is not properly controlled.
- Thorough separation, increasing the amount of dust (bag filter) and slurry (wet scrubber) for disposal and incineration.

Technical considerations relevant to applicability

Shredder systems with water injection into the mill may not be applicable due to local conditions (e.g. low temperature in winter in northern countries).

Economics

Investment costs depend on the technique, but a cyclone and scrubber, with all facilities, costs EUR 1 000 000.

Operation and maintenance costs depend on the throughput, size and water usage, and vary between EUR 350 000 and EUR 500 000 a year.

WORKING DRAFT IN PROGRESS

Driving force for implementation
Environmental legislation.

Example plants
See Table 3.10.

Reference literature
[107, Mech. subgroup 2014] [160, WT TWG 2014]

3.1.3.1.2 Prevention or reduction of diffuse emissions

3.1.3.1.2.1 Generic techniques

Generic techniques to prevent diffusion emissions are described in Section 2.3.5.

From ex-**Section 4.1.6.1 "Techniques to reduce emissions from drum crushing and shredding activities"**

~~**Description**~~
~~Several techniques which can be applied to reduce emissions from drum crushing and shredding activities are:~~

~~a. making the drum crushing and shredding plant fully enclosed and fitting it with an extractive vent system linked to abatement equipment, e.g. an oil scrubber and activated carbon filter.~~
~~b. keeping skips for the storage of crushed/cut drums covered~~
~~c. using sealed system, e.g. chutes, for the containment of residues~~

~~In a shredding facility, the following techniques can also be applied:~~

~~d. providing a hall for conditioning hazardous waste before treatment; the entire treatment hall is kept permanently under negative pressure by the exhaust air treatment installation. Therefore, no emissions are released~~
~~e. storing of acids, bases, photographic chemicals, chemicals from households, pesticides and lab chemicals~~
~~f. storage for flammable liquids like waste solvents, with a flashpoint of <21 °C~~
~~g. decomposition of the aerosol cans into the following components: propellants, liquid ingredients, metals and plastics~~
~~h. suction cleaning of all emissions; an automatic control for the suction of the exhaust air from different processes can be applied and this suction can be reduced during the operation-free time to avoid consuming energy~~
~~i. treating the exhaust air with a dust filter and/or a regenerative post-combustion for a residue-free combustion. An upstream pre-coat filter (activated carbon and lime mixture) to collect the adhesive components can also be used.~~

~~When treating hazardous wastes in a shredding facility, the following techniques can also be applied:~~

~~j. pressure-surge-proof channel of 12 m high against damages~~
~~k. the facility is pressure resistant up to 10 bar~~
~~l. batch-wise operating of the shredder for minimising the exposure~~
~~m. using fire alarm systems and sprinkler installations; furthermore, boxes are equipped with a sprinkler installation for the reduction of dust~~
~~n. having an online connection to the rescue service; in case of a fire, the fire department is immediately notified~~
~~o. using explosion-proof switches, aggregates and machines in the entire hall~~

WORKING DRAFT IN PROGRESS

p. ~~using overpressurised cabins with activated carbon filters in all machines, for the safety of the workers~~
q. ~~fire water of 50 m^3 in a subsurface basin~~
r. ~~permanent nitrogen flooding of the work space inside the shredder, therefore under oxygen exclusion no reactions will take place (nitrogen purge device).~~

~~Finally, to protect the soil in a shredding facility, the following techniques can be applied:~~

s. ~~using a vacuum monitored laminated base for the identification of leaks; the base of the hall is bowl shaped so that liquid material cannot flow out~~
t. ~~retaining fire water of 450 m^3; this is possible through the bowl shaped base with a pump sump for pumping the fire water.~~

~~Achieved environmental benefits~~

~~Reduces VOC and PCB ? emissions to air and reduces contamination to water streams and to soil. Drum crushing/shredding units may vent directly to the air. One technique to reduce VOC emissions is to avoid venting directly to the air unless the emissions/vents have been washed and fully purged of their former contents. Some techniques, for example technique t (see description above), are carried out to prevent ignition.~~

~~Operational data~~

~~Inert atmospheres to avoid ignition can be generated by the use of inert gases, for example nitrogen or carbon dioxide.~~

~~In an aerosol can shredder, suction cleaning of 30000 m^3 hall air per hour over the dust filter is applied. Two separate exhaust air collecting and treatment systems are used. Alternately, controllable source suction in the boxes, shredder and aerosol can shredder with a maximal of 12000 m^3/h may be implemented. The exhaust combustion facility is used at more than 800 ºC for a complete destruction of the harmful substances.~~

~~Applicability~~

~~Such treatments of some wastes containing e.g. VOCs may create flammable atmospheres which can be a problem as there may also a possibility of static discharges with some types and mixes of wastes and reagents. In some specific cases, some drums containing volatile substances (see technique e in the description section above) may be crushed if the crusher incorporates a system that avoids flammable or explosion problems. When wastes handled do not generate emissions to air (e.g. odours, dust, VOCs) then extractive systems are typically not applied.~~

~~Economics~~

~~An example bin shredding installation in Germany. The capacity of the facility is 5000 Mg/a. The quantity of hazardous waste treated is 1000 t/yr. The investment needed for the treatment plant is EUR 325000.~~

~~An example aerosol can shredding installation in Germany. The capacity of the treatment facility is 500 t/yr. The investment needed for the treatment plant is EUR 500000.~~

~~Example plants~~

~~An example plant consists of a fume-extracted enclosure mounted on a raised platform and contains a hydraulically operated remotely controlled crushing head. Residues expelled from the drums during crushing are passed via an enclosed chute into a drum placed underneath the elevated platform. Vapours are extracted through an oil scrubber and two activated carbon filters in series, before discharge to the air. Interlocks prevent operation of the crusher when either the crusher door is open or the abatement system is not operating.~~

~~Reference literature~~

WORKING DRAFT IN PROGRESS

~~[33, UK EA 2001] [60, WT TWG 2003] [98, WT TWG 2004] [100, WT TWG 2004] [104, UBA Germany 2004]~~

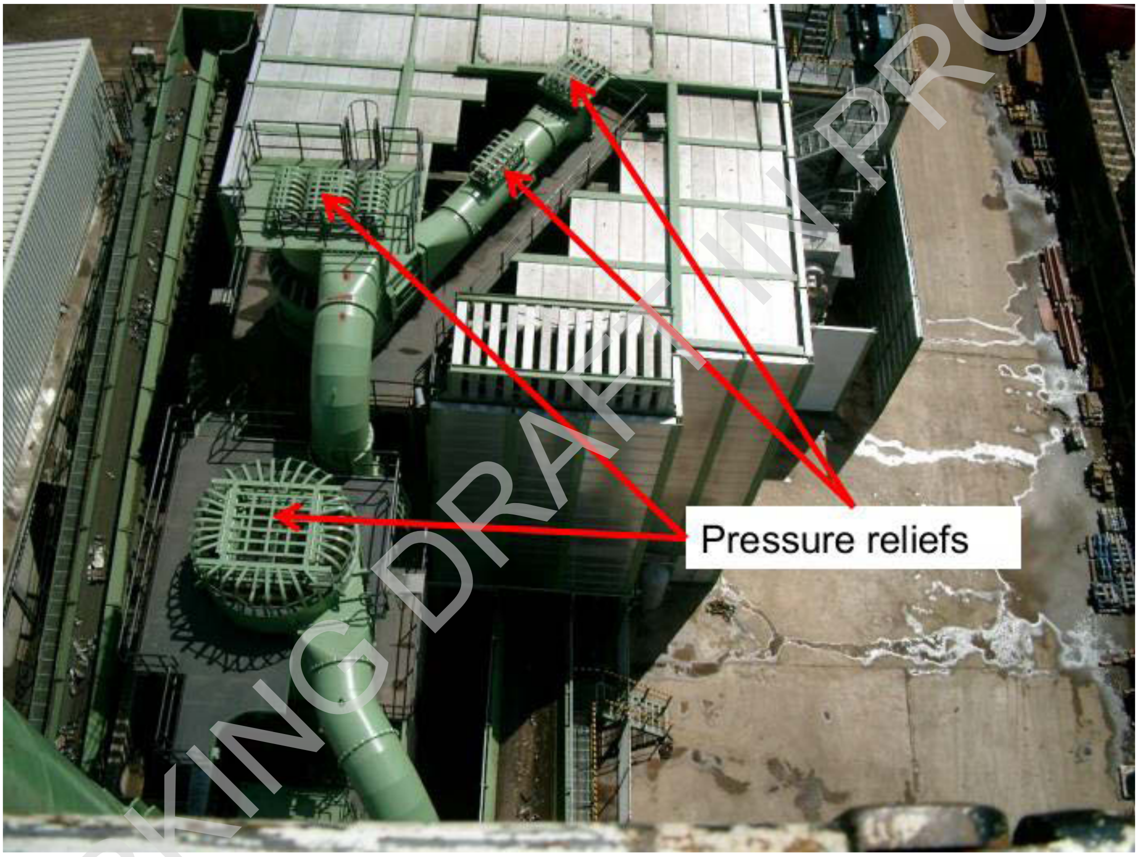
3.1.3.1.2.2 Pressure relief equipment

Description
Pressure relief dampers are equipped with rubber flaps.

Technical description
In the event of a deflagration, the rubber flaps release the pressure. By lying firmly on the openings, the flaps avoid the leakage of air during normal operating conditions.

Pressure relief devices, e.g. on side walls or on the roof, can minimise openings in the building which lead to the release of diffuse emissions.

Figure 3.21 below shows an example of pressure relief dampers at a shredding plant.



Souce: [107, Mech. subgroup 2014]

Figure 3.21: Bird's-eye view of pressure reliefs at a shredding plant

Achieved environmental benefits
Reduction of diffuse emissions.

Environmental performance and operational data
For pipes, the area for pressure relief dampers is generally calculated as 10 % of the volume of the pipe (e.g. for a pipe with a volume of 10 m^3, an area of 1 m^2 for the pressure relief damper is appropriate).

Cross-media effects
Not identified.

WORKING DRAFT IN PROGRESS

Technical considerations relevant to applicability
Generally applicable.

Economics

TWG members, please provide information

Driving force for implementation
Protection of the assets.

Example plants

TWG, please provide information

Reference literature
[107, Mech. subgroup 2014]

3.1.3.1.2.3 Deflagration reduction plan

Description
Implementation of a deflagration management plan, as part of the environmental management system (EMS) (see Section 2.3.1.1)

Technical description
A deflagration management plan includes:

- a protocol containing appropriate actions and timelines;
- a protocol for conducting deflagration monitoring;
- a protocol for response to identified deflagrations;
- a deflagration reduction programme designed to identify the source(s), and to implement elimination and/or reduction measures (e.g. inspection of waste input and management of prohibited materials);
- a review of historical deflagration incidents and remedies, and the dissemination of deflagration knowledge.

Achieved environmental benefits
Reduction of diffuse emissions (e.g. dust, VOCs, PCB and dioxins).

Environmental performance and operational data
The reported number of deflagrations at shredding plants participating in the data collection is given in Table 3.11 below.

WORKING DRAFT IN PROGRESS

Table 3.11: Mechanical treatment in shredders of metal waste – Number of deflagrations per year

Plant code	Number of deflagrations		
	2010	2011	2012
25	14	14	4
26	8	16	4
27	NI	70	47
28	NI	NI	9
29	0	0	0
54	0	0	0
95	NI	21	53
100	0	0	0
136	0	0	0
137	0	0	0
285	11	12	10
286	10	14	13
288	0	0	0
289	0	0	0
290	0	0	0
291	0	1	0
293	NI	42	43
294	22	6	4
364-365	0	0	0
432	NI	0	0
464	0	0	0
516(1)	60	30	220(2)
517(1)	50	NI	NI
571	NI	NI	0

NI: No information.
(1) Calculated on the basis of the reported number of deflagrations/tonnes of waste, and the reported waste input quantities.
(2) A specific receiving inspection process has been implemented in this plant, allowing the ratio to be decreased to 25 deflagrations/1000 tonnes of waste treated in 2014.

With the exception of Plant 516 in 2012, the number of deflagrations per year goes up to 70. As a maximum, the number of deflagrations per waste treated is around 25 deflagrations/1000 tonnes of waste treated.

Three plants (Plants 25, 28 and 516) reported that focusing on the receiving inspection of waste input, recording deflagrations and identifying their origin has improved deflagration figures (in 2013 for Plant 516).

Cross-media effects
Not identified.

Technical considerations relevant to applicability
Generally applicable.

Economics
No information available

Driving force for implementation
Protection of the assets.

Example plants
Plants 25, 28, 516.

Reference literature
[107, Mech. subgroup 2014] [160, WT TWG 2014]

WORKING DRAFT IN PROGRESS

3.1.3.2 Techniques for the prevention and control of noise and vibration emissions

3.1.3.2.1 Vibration management plan

Description
Implementation of a vibration management plan, as part of the environmental management system (EMS) (see Section 2.3.1.1).

Technical description
A vibration management plan includes:

- a protocol containing appropriate actions and timelines;
- a protocol for conducting vibration monitoring;
- a protocol for response to identified vibration incidents;
- a vibration reduction programme designed to identify the source(s), to measure vibration emissions, to measure/estimate vibration exposure, to characterise the contributions of the sources and to implement elimination and/or reduction measures (dampening adjustment and resonance assessment);
- a review of historical vibration incidents and remedies and the dissemination of vibration incident knowledge.

Achieved environmental benefits
Prevention and reduction of vibration emissions.

Environmental performance and operational data
Shredder plants install isolation elements (see Figure 3.22) that are adapted to their individual fields of use and conditions to prevent major vibrations from the operation of the plant.

Source: [107, Mech. subgroup 2014]

Figure 3.22: Isolation elements (circled) for vibration reduction

During loading and discharging of primary materials and finished goods, vibrations are detectable, but these are locally confined to the point of impact where the bulk material hits the ground plate.

WORKING DRAFT IN PROGRESS

Cross-media effects
Not identified.

Technical considerations relevant to applicability
The applicability is restricted to cases where a vibration nuisance in residential or other sensitive areas (e.g. recreational areas) can be expected and/or has been reported.

Economics

TWG, please provide information

Driving force for implementation
Environmental legislation.

Example plants

TWG, please provide information

Reference literature
[107, Mech. subgroup 2014]

3.1.3.2.2 Noise barriers

Description
Place noise barriers (non-reflective acoustic walls) between the source and the receptor.

Technical description
A shredder mill generates noise, the permissible levels of which are often stipulated in the permit for the operation. The main mitigation/attenuation measures for noise are distance and screening. It is important to consider all kinds of noise sources, including handling of the material, loading and unloading, the shredder itself, noise from fans, deflagrations, etc.
Noise barriers in form of the housing, soundproof walls, splitter silencers, etc. may be necessary in order to reduce noise levels (see examples in Figure 3.23 and Figure 3.24). A closed design of the shredder mill may be efficient for noise reduction.

Another alternative is to place screens between the site and sensitive receptors. These are made of a non-reflective material, located as close to the installation as possible, and of sufficient height to shield the operations. There are examples of this type of screening located along the entire length of shredders and enclosing whole metal recycling yards in order to control and mitigate noise levels.

Source:[107, Mech. subgroup 2014]

Figure 3.23: Protective screening at the Schrott-Bosch GmbH shredder, Germany

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Source: [107, Mech. subgroup 2014]

Figure 3.24: Splitter silencers at the roof of a shredding plant

Environmental performance and operational data

Local screening and localised noise barriers placed around particular activities or processes allow significant noise reductions to be achieved. With the use of the appropriate noise-absorbing materials, these could be up to 5–10dB reduction on the screened side.

Technical considerations relevant to applicability

Total enclosure of mixed scrap shredder plants is not appropriate due to possible deflagrations.

Achieved environmental benefits

The achieved environmental benefits of this technique include the reduction of noise emissions.

Cross-media effects

TWG, please provide information

Economics

TWG, please provide information

Driving force for implementation

Environmental legislation.

Example plants

TWG, please provide information

Reference literature

[107, Mech. subgroup 2014]

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3.1.3.3 Techniques to reduce energy consumption

3.1.3.3.1 Mill feeding regulation

Description

Reduction of consumption peaks and power losses and avoidance of unwanted shutdowns, by regulating the feed to ensure that the shredder load and rotor speed are as constant as possible.

Technical description

The key to controlling and minimising the power usage relates to the shredding operation. The process requires that the mill chamber/box is full and the feed is consistent. The mill under these circumstances would pull a consistent current. If the feed varies greatly in density or size then the rotor will slow down during heavy loading and speed up during light loading.

In the situation of periodic heavy loading, the rotor slows, losing momentum due to the greater resistance of the material. This requires more power from the motor to increase the rotor speed and replace the lost momentum. The efficiency of the mill is also reduced when it is left running empty, or when the load rate falls below the optimum.

Achieved environmental benefits

The environmental benefits of this technique include the efficient use of energy.

Environmental performance and operational data

TWG, please provide information

Cross-media effects

Not identified.

Technical considerations relevant to applicability

Generally applicable.

Economics

TWG, please provide information

Driving force for implementation

Savings in energy consumption costs.

Example plants

TWG, please provide information

Reference literature

[107, Mech. subgroup 2014]

3.1.3.4 Water management in mechanical treatment in shredder of metal waste

Description

Manage waste water in mechanical treatment in shredder of metal waste to reduce emissions to water and to reduce water usage.

Technical description

This include:

- Reusing in a closed circuit water injected into the mill
- Collecting rainwater run-off, and damping water for dust suppression
- Implement a suitable combination of abatement techniques, such as:
    - Oil-water separator (see Section 2.3.6.4.1)

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  - Sedimentation system (see Section 2.3.6.4.4)
  - Filtration system (see Section 2.3.6.4.6)

Achieved environmental benefits
The achieved environmental benefits of this technique include:

- Reduction of water usage
- Reduction of total suspended solids (TSS) and hydrocarbon (HOI) emissions to water

Environmental performance and operational data
See Table 3.9

Cross-media effect
See the CWW BREF [138, COM 2014]

Technical considerations relevant to applicability
See See the CWW BREF [138, COM 2014]

Economics
See See the CWW BREF [138, COM 2014]

Driving force for implementation
Environmental legislation

Example plants
See Table 3.8 and Table 3.9

Reference literature
[107, Mech. subgroup 2014] [138, COM 2014] [160, WT TWG 2014]

WORKING DRAFT IN PROGRESS

3.2 Mechanical treatment in shredders of equipment containing VFCs or VHCs

3.2.1 Applied processes and techniques

[126, Mech. subgroup 2014], [127, EERA 2015]

Purpose and principle of operation

In mechanical treatment in shredders of temperature exchange equipment, once the loose inner parts of the temperature exchange equipment are removed, and oil and volatile fluorocarbons (VFCs) and/or volatile hydrocarbons (VHCs) are properly extracted to be further treated (i.e. in accordance with Regulation EC/1005/2009), the devices are shredded into smaller material components. These components (ferrous scrap, mixed non-ferrous scrap, foam, and plastics) are separated from one another in a downstream sorting process.

Feed and output streams

A recycling unit for refrigeration devices accepts (as feed) household appliances, which contain CFC, HCFC, HC and HFC refrigerants and blowing agents. Household refrigerators and freezers manufactured before 1995 typically contain chlorofluorocarbon (CFC) refrigerants in the circuit and in the insulation as blowing agents. CFCs and HCFCs are ozone-depleting substances (ODS) and potent greenhouse gases. Refrigerators and freezers manufactured since 1995 contain ozone-friendly hydrofluorocarbon (HFC) refrigerants; however, these refrigerants still need to be carefully handled as they are greenhouse gases. Since the mid-1990s, producers also used hydrocarbons (HCs; e.g. R600a) as refrigerants, and cyclopentane or isopentane as blowing agents. Most air-conditioning units and dehumidifiers contain HCFCs and CFCs.

The shredder feed includes:

- fridges and freezer appliances;
- air-conditioning units;
- Dehumidifiers;
- water coolers;
- dispensers of cold products.

The following substances or materials result from the process:

- iron and steel scrap;
- non-ferrous scrap, aluminium and copper fractions;
- plastic fraction, mainly polystyrene and polyurethane;
- polyurethane foam (PUR foam) in pellets or powder (a refrigerator contains approximately 4.5 kg of PUR foam);
- shedder light fraction (SLF);
- oil, VFC/VHC refrigerants and blowing agents.

Process description

[126, Mech. subgroup 2014]

An outline of a two-stage automated mechanical treatment of temperature exchange equipment is given in Figure 3.25 below.

TWG, please provide the original file of the Figure below

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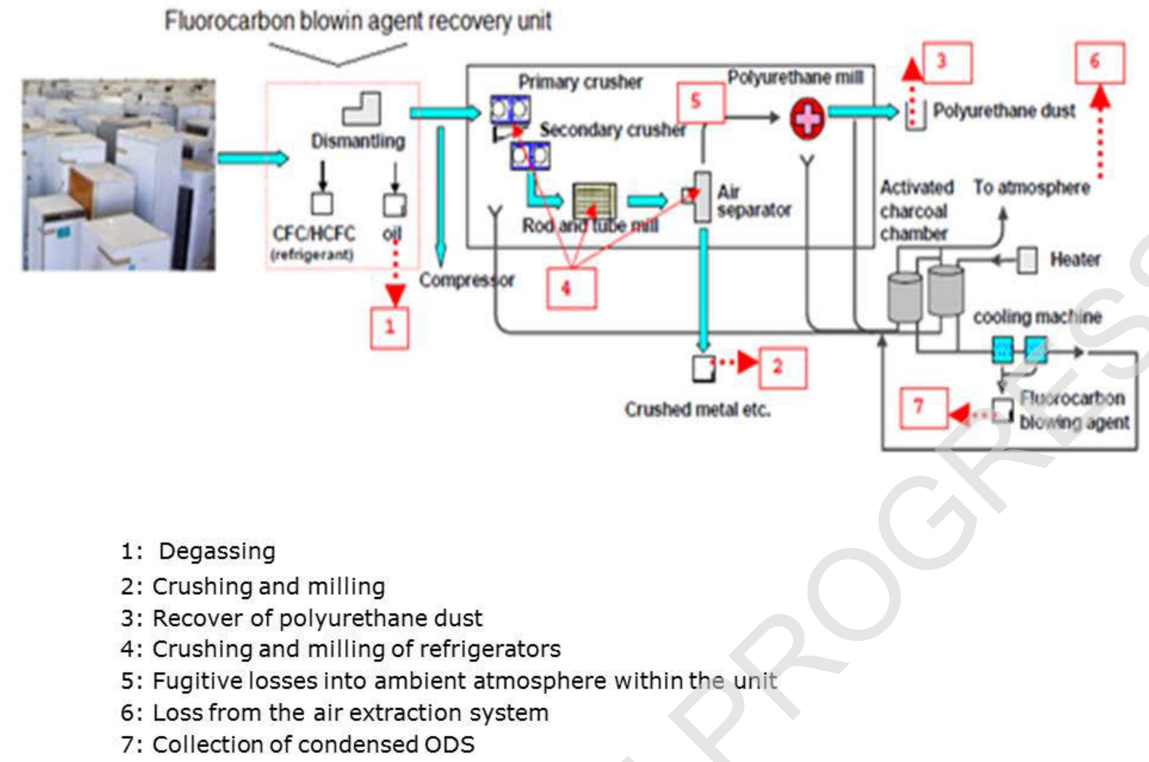

Source: [126, Mech. subgroup 2014],

Figure 3.25: Fluorocarbon blowing agent recovery unit

Before the temperature exchange equipment is broken up, external electrical cables, the loose inner parts including glass, plastic racks, etc. are taken out, and, if present, the capacitors and the mercury switches are removed.

Stage 1: extraction of the oil and refrigerants

The oil and the refrigerants are removed. Fluorocarbon and hydrocarbon refrigerants extracted from the temperature exchange equipment are recovered into recovery cylinders. Stationary units such as refrigerators and small air conditioners may not have a service hose access port (service valve). In such cases, the refrigerant recovery is achieved by using approved piercing pliers or a drill head. Once the line or compressor is pierced, a small valve prevents the flow of refrigerant. Service hoses fitted with 'ball' valves at one end prevent the accidental release of fluorocarbon or hydrocarbon refrigerants into the atmosphere, and assist in the safe removal of the service hoses.

Extracting oil and refrigerants in the same step by using vacuum suction allows the best possible outcome to be achieved.

Then the compressor is removed and the cooling device is automatically moved to the shredding system.

Stage 2: extraction of VFC and VHC blowing agents from the insulating material

After removing the compressor, the device is moved to the shredding system.

A typical fully automated plant will handle between 35 and 45 refrigeration devices per hour. The refrigerators are automatically moved by hydraulic lifting and/or belt conveyor to the shredding unit. The cutting operation takes place in a shredding chamber.

Degasification of the shredding area is performed before the shredded pieces are extracted from the shredder chamber (see below). The shredded materials are sent to a wind separator, for example, where the shredded pieces of PUR foam are separated. The PUR foam is then

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compressed to firm pellets in a pelleting press. In some cases, the polyurethane granulate foam is heated to around 110 °C in a closed heating spiral to extract the entire remaining expanding agent. The exhaust air from this process step is also pumped into the process gas cleaning system. Alternatively, the PUR foam is ground in a mill system. Degassing of the resulting PUR powder can be done during the shredding process by means of a thermal screw, or further heated in a vessel for about four hours.

Other recovery systems have been developed to ensure the recovery of VFC/VHC-containing insulation and blowing agents that are released from the insulation foam during shredding.
TWG, please provide additional information

Stage 3: separation step
The shredded ferrous, non-ferrous and plastic parts are separated following a classic sorting step, using a magnetic separator, eddy current separator, wind sifter, sieve, hydrocyclone, etc.

Treatment of gas released in the shredding stage
Degasification inside the shredding area is done by of one of the following techniques:

1. The cryogenic technique: the shredding area is under air suction, VFCs/VHCs are exhausted and N_2 is blown in to reduce the O_2 level to < 4 %, which prevents the risk of fire. The gas is then exhausted inside the cryogenic unit, where it is cooled down with liquid nitrogen to −90 °C, and liquefied. The liquefied gases are then stored in gauged tanks. N_2 is recovered and sent back into the shredding area, and the water is released.

2. The IC (impact catalyst) technique: the shredding area is supplied with air continuously, in order to keep the concentration of pentane constantly well below the lower explosive limit (LEL). In this case, inerting of the shredding area is no longer necessary. Gas purification takes place in two catalytic converters connected in series. The hydrocarbon compounds, such as isobutane and pentane, are oxidised in the first converter to form water and carbon dioxide. In the second reactor, the VFCs are converted into hydrogen chloride (HCl), hydrogen fluoride (HF), and carbon dioxide (CO_2). HCl and HF gases are converted via washer stages into a concentrated saline solution, which is disposed of externally.

3. The adsorption technique: the gases from the shredding area are pumped into adsorption filters. Cooling can be used prior to adsorption to reduce the amount of water in the process gas. VFCs and VHCs are captured by activated carbon or zeolite in the adsorption filters. VFC/VHC emissions after the filters are continuously monitored. An adsorption process consists of at least two filters which are switched in parallel so that at least one is adsorbing and one is regenerating. During the regeneration, heated air passes through the filter to evaporate trapped VFCs and VHCs. The regeneration gas is compressed and cooled in order to liquefy the VFCs and VHCs, which are then stored in tanks. The emitted gas is usually led back into the adsorbing filter in order to recover any residual VFCs or VHCs.

Explosion risk
VHC refrigerants and blowing agents are explosive. Treatment facilities that treat VHC-containing temperature exchange equipment comply with explosion protection measures (Directive 1999/92/EC and 94/9/EC).

The concentration of gases is controlled to prevent the risk of explosion (e.g. limiting the concentration of pentane). In most cases, nitrogen is constantly injected into the shredder, the crusher, and the dust collector. Figure 3.26 below shows an example of safety measures for explosion prevention.

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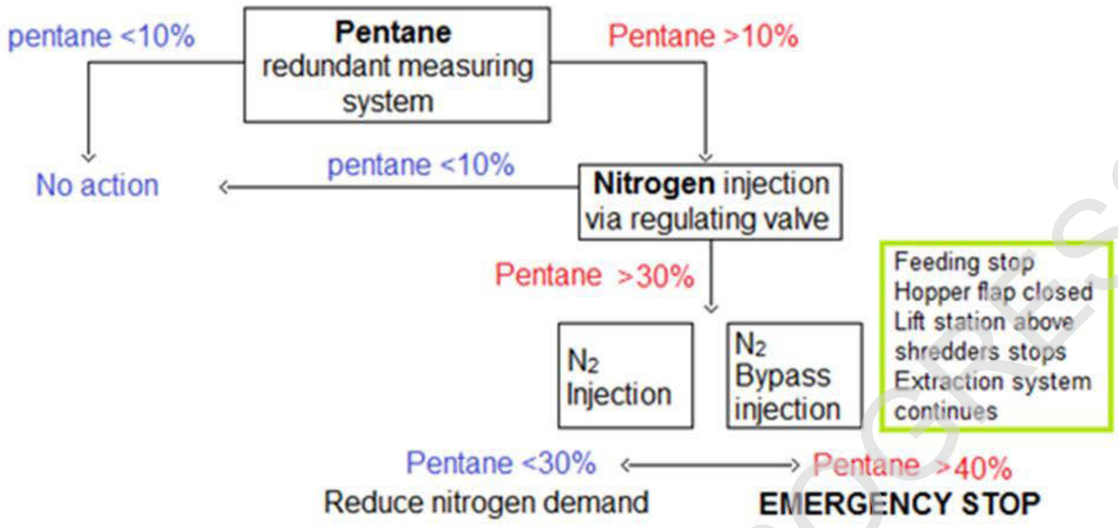


Source: 126 Mech. Subgroup 2014

Figure 3.26: Explosion protection measures

At the same time, water sprays are used to prevent high temperatures in the shredder and the crusher.

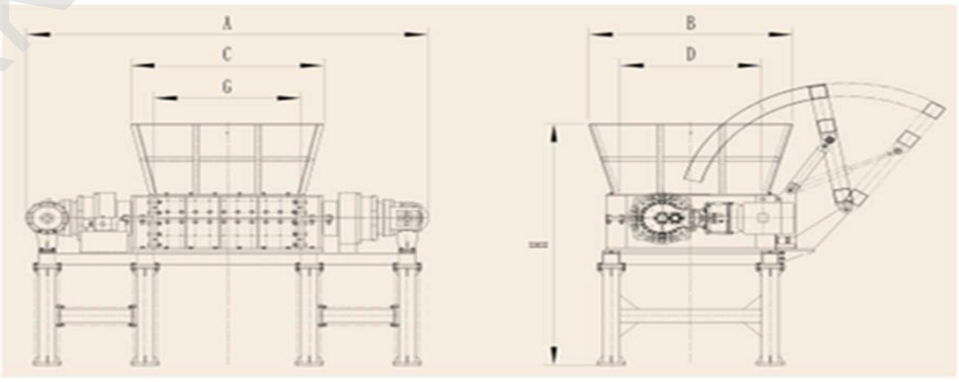
Types of shredders used

Pre-shredder

The pre-shredder is mainly used for the treatment of air-conditioning units, and large and professional cooling and freezing appliances. It is driven by a planetary gear box, usually with hydraulic motors. The rotors can be reversed when the shredder is blocked.

Twin-shaft rotor shear (see Figure 3.27)

The main focus of a twin-shaft shredder is shredding large-diameter and tough material, with an even and controllable output size. The twin-shaft shredding is characterised by a low speed and high torque, capable of high throughput rates. The two axes are operated differentially, with function of cutting. Small twin-shaft rotor shears are sometimes used for secondary size reduction to better separate residual insulation foam from shredded material. The rotor shear can be used with or without a screen under the knives.



Source: 126 Mech. Subgroup 2014

Figure 3.27: Twin-shaft rotor shear

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Four-shaft rotor shear (see Figure 3.28)
Four-shaft shredders have advantages in standardisation and modularisation design, and high interchangeability for their components. They have a low rotation speed, big torque and low noise levels. The four-shaft rotor shear can be used with or without a screen under the knives to reduce output sizes.

Source: 126 Mech. Subgroup 2014

Figure 3.28: Four-shaft rotor shear

Super chopper
Super choppers are heavy-duty pre-choppers designed as a first step in some refrigerator recycling processes.

Rotor shredder (see Figure 3.29 below)

These shredders can treat devices of up to 300 kg, depending on the feeding conditions. The chamber of the rotor shredder contains rotating hammers or chains fastened by articulated joints to a high-speed vertical shaft. They are arranged one above the other and are aligned horizontally and stabilised by centrifugal force. As the refrigeration units enter the range of the hammers or chains, they are subjected to intense impact, punching and shear forces, crushing them into small pieces. Once the crushed pieces have reached the desired size, they exit the chamber through a robust slotted gate. The material is crushed in a very short time and without interruption, resulting in a high degree of energy efficiency.

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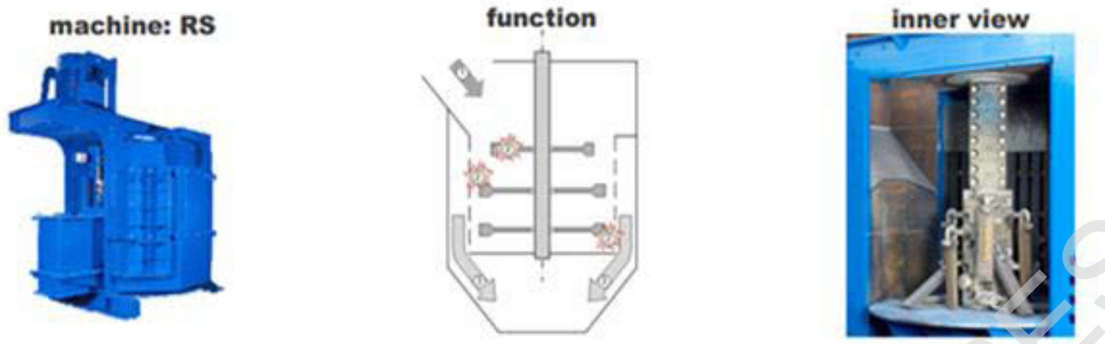

Source: 126 Mech. Subgroup 2014

Figure 3.29: Rotor shredder

Emissions to air are likely to be dust and VFCs/VHCs. The end-of-pipe techniques generally implemented are fabric (or bag) filters for dust emissions abatement, and activated carbon filters or condensation for the reduction of VFC/VHC emissions.

Water may be added to the shredder in order to prevent high temperatures. When it is not reused, the water is released to a sewer or to the environment after treatment. Catalyst processes produce saline solutions which are sent to an appropriate treatment before release.

TWG members, please provide information on the treatment of saline solutions

Users

From the data collection: Plants 38, 397, 458, 470, 629, 630, 636.

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3.2.2 Current emission and consumption levels

3.2.2.1 Emissions to air

3.2.2.1.1 Dust

Table 3.12 below gives the reported levels of dust emissions to air from mechanical treatment in shredders of equipment containing VFCs or VHCs, and the corresponding implemented abatement techniques.

Table 3.12: Dust emissions to air from mechanical treatment in shredders of equipment containing VFCs or VHCs

Plant code	Capacity (t/day)	Origin of emissions	Techniques used	Exhaust air flow rate (Nm^3/h)	Dust (mg/Nm^3)
458	20	Shredder	From the shredder process: activated carbon adsorption From the material transport: bag/fabric filter system	800	0.12 (1)
636	50	Recovery of blowing agents	Activated carbon adsorption Bag/fabric filter system	275	3 (2)
630_1	50	Recovery of blowing agent	Activated carbon adsorption Bag/fabric filter system	250	3 (2)
630_2	50	Separation of mixed plastics	Bag/fabric filter system	5500	0.2 (2)
630_3	50	Treatment of mixed metals	Bag/fabric filter system	5500	0.2 (2)

(1) Continuous measurements.
(2) Periodic measurements. One measurement over the three reference years.

3.2.2.1.2 CFCs, HFCs, and HCFCs

HFC emissions were reported by one plant (Plant 629), at a level of 10.6 mg/Nm^3 (one measurement during the three reference years).

No measurement of HCFC emissions was reported through the data collection.

Table 3.13 below gives the reported levels of CFC emissions to air from mechanical treatment in shredders of equipment containing VFCs or VHCs, and the corresponding implemented abatement techniques.

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Table 3.13: CFC emissions to air from mechanical treatment in shredders of equipment containing VFCs or VHCs

Plant code	Degasification technique	Capacity (t/day)	Origin of emissions	Techniques used	Exhaust air flow rate (Nm^3/h)	CFC (mg/Nm^3)		Number of measurements during the 3-year reference period (2010-2012)
						Continuous measurements	Periodic measurements	
458	Cryogenic condensation	20	Mechanical shredder	From the shredder process: activated carbon adsorption From the material transport: bag/fabric filter system Cryogenic condensation	800	1.5–12	NA	NA
470		35	Shredder	Cryogenic condensation	135	NA	139	1
629-1		40	Step 1: recovery of refrigerants (refrigerant filling container + skid)	Activated carbon adsorption	70	0	1.3	1
629-2		40	Step 2: recovery of blowing agents	Condensation Activated carbon adsorption	140	0.5–15.8	NA	NA
138	Activated carbon	50	Activated carbon batteries	Activated carbon adsorption	310	NA	11.3	3
630-1		50	Recovery of blowing agents	Activated carbon adsorption Bag/fabric filter system	250	3–20	NA	NA
636		50	Recovery of blowing agents	Activated carbon adsorption Bag/fabric filter system	270	NA	0.2	6
NA: Not applicable.								

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3.2.2.1.3 VOCs, NMVOC, and TOC

Data (graphs) on VOC emissions to air were provided by one plant (plant 636), ranging around 2-15 mg/Nm^3.

Data on TOC emissions to air were provided by one plant (Plant 629): 3.6 mg/Nm^3 - one measurement during the three reference years.

Data on NMVOC emissions were provided by the three plants using the activated carbon degasification technique (Plants 138, 630, and 636). They are given in Table 3.14 below, together with the corresponding implemented abatement techniques.

Table 3.14: NMVOC emissions to air from mechanical treatment in shredders of equipment containing VFCs or VHCs

Plant code	Degasification technique	Capacity (t/day)	Origin of emissions	Techniques used	Exhaust air flow rate (Nm^3/h)	NMVOC (mg/Nm^3)		Number of measurements during the 3-year reference period (2010-2012)
						Continuous measurements	Periodic measurements	
138	Activated carbon	50	Activated carbon batteries	Activated carbon adsorption	310	NA	17	3
630[(1)]		50	Recovery of blowing agents	Activated carbon adsorption Bag/fabric filter system	250	3–50	NA	NA
636[(2)]		50	Recovery of blowing agents	Activated carbon adsorption Bag/fabric filter system	270	3–20	NA	NA

NA: Not applicable.
(1) It is mentioned in the questionnaire that the real values are lower than the indicated ones.
(2) It is mentioned in the questionnaire that there is no recording of measured values. However, graphs have been provided on VOC emissions to air for the three reference years: 2–15 mg/m^3.

3.2.2.2 Emissions to water

The mechanical treatment in shredders of equipment containing VFCs or VHCs does not require a large amount of water (water may be added to the mill in order to prevent high temperatures in the shredder and the crusher), and therefore generates limited emissions to water.

Of the seven plants that participated in the data collection, three (Plants 138, 630 and 636, using the activated carbon degasification technique) reported having emissions to water.

- Plant 138: rainwater collected around the plant; there is no water emission from the process itself, and roof water is released directly to a nearby river.
- Plant 630:
  - condensed water from the recovery of blowing agents step (60 l/h; measured parameters: HOI and trichlorofluoromethane); the waste water is stored in a closed tank equipped with an activated carbon filter system, and sent to an off-site waste water treatment plant;

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  - separation step of mixed plastics (1 m^3/h; measured parameters: Cu, Zn and AOX); the waste water is filtered and sent to an off-site waste water treatment plant.
- Plant 636: condensed water from the recovery of blowing agents step (60 l/h; measured parameters: HOI, AOX and trichlorofluoromethane). The waste water is stored in a closed tank equipped with an activated carbon filter system, and sent to an off-site waste water treatment plant.

3.2.2.3 Energy consumption

The specific electrical energy consumption of mechanical treatment in shredders of equipment containing VFCs or VHCs t is given in Table 3.15 below.

Table 3.15: Specific electrical energy consumption of mechanical treatment in shredders of equipment containing VFCs or VHCs

Plant code	Degasification technique	Capacity (t/day)	Specific electrical energy consumption (MWh/t waste treated)
458	Cryogenic condensation	20	0.2
470		35	0.1
629		40	0.1
138	Activated carbon	50	0.2
630		50	0.7[1]
636		50	0.1

[1] The reported values include consumption of metal and mixed-plastics separation steps. The values are the average over the three reference years.

3.2.3 Techniques to consider in the determination of BAT

3.2.3.1 Techniques for the prevention or reduction of emissions to air

3.2.3.1.1 Degassing the shredding area

Description

Removal and treatment of VFCs/VHCs present in the shredding area by:

- cryogenic technique, or
- adsorption technique, or
- impact catalyst technique.

Technical description

The VFCs/VHCs are removed from the shredding area atmosphere using one of the following techniques.

- Cryogenic technique: gas containing VFCs/VHCs in the shredding area is sucked out, and inert gas (e.g. N_2) is blown in to reduce the O_2 concentration to below 4 %. The exhausted gas is sent to a cryogenic condensation unit where it is liquefied. The liquid gases are stored in tanks for further treatment. The inert gas is recovered and sent back to the shredding area, and the water is released.

  Figure 3.30 below gives an example of shredding area degasification by cryogenic condensation.

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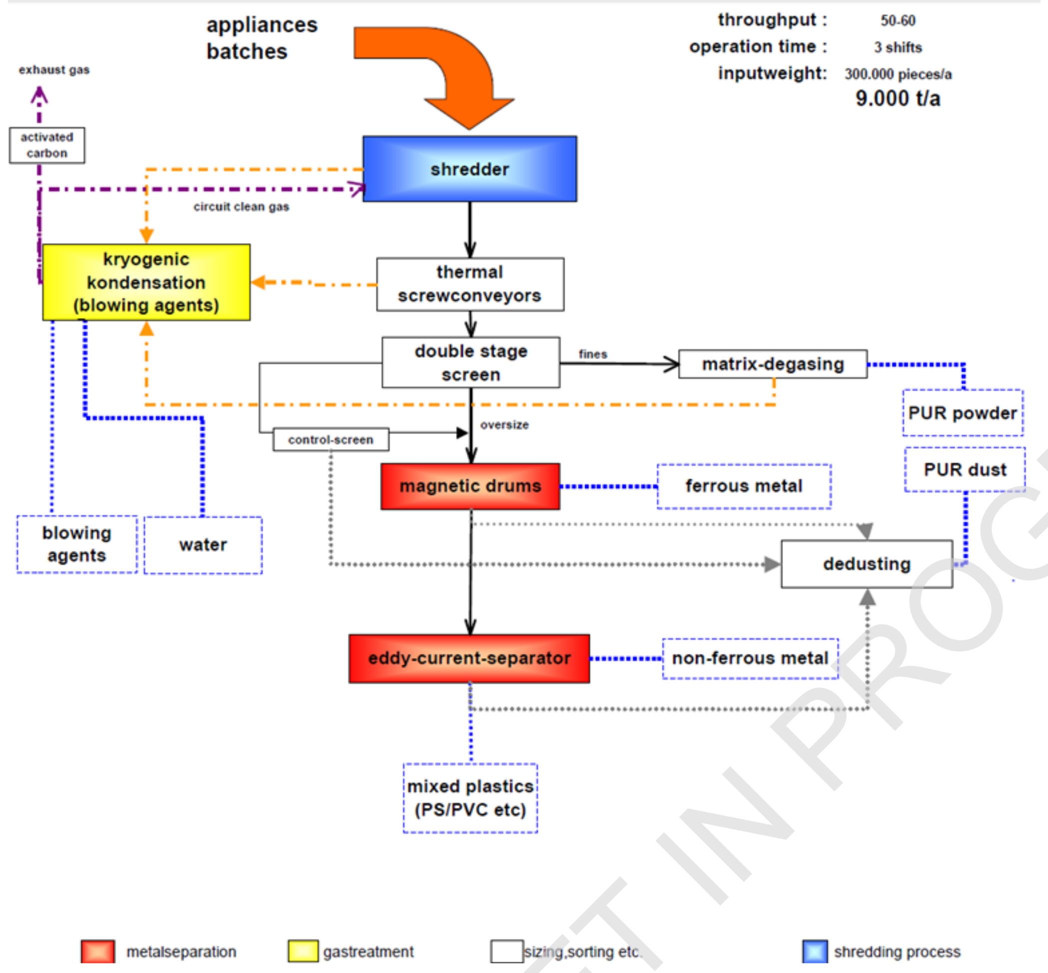

Source: plant #629

Figure 3.30: Degasification of the shredding area - Cryogenic condensation

A general description of the cryogenic condensation abatement technique can be found in the CWW BREF [118, COM 2003]

- Adsorption technique: the gases from the shredding area are pumped into adsorption filters. The used activated carbon is regenerated by means of heated air pumped into the filter to evaporate trapped VFCs and VHCs. After the filter, the gas is compressed and cooled in order to liquefy the VFCs and VHCs. The liquefied gases are then stored in tanks. The emitted gas is usually led back into the adsorbing filter in order to recover any residual VFCs or VHCs. Figure 3.31 below gives an example of degasification with activated carbon adsorption.

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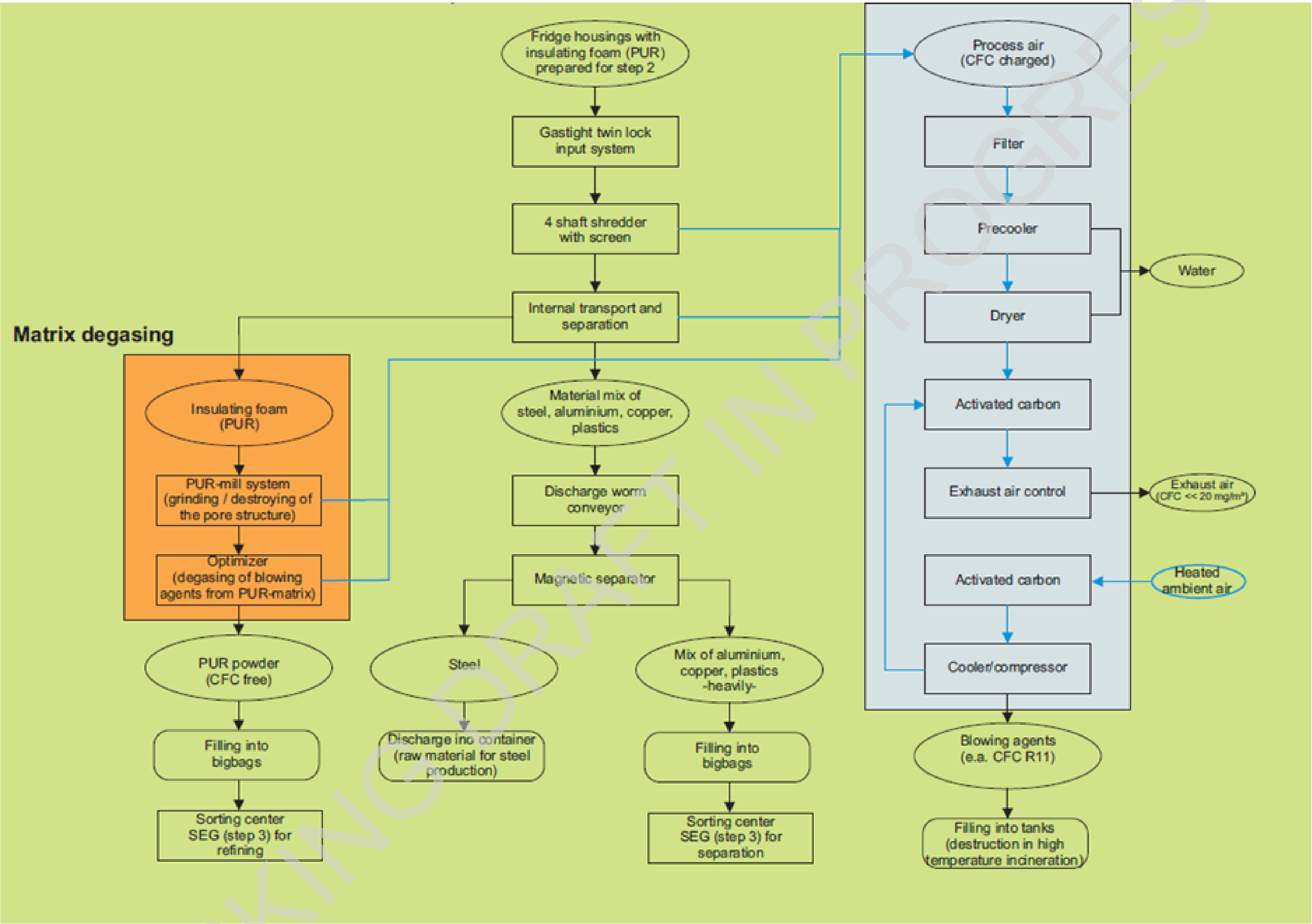

Source: Plant #636

Figure 3.31: Degasification of the shredding area - Activated carbon adsorption

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A general description of activated carbon adsorption can be found in the CWW BREF. [118, COM 2003]

- Impact catalyst (IC) technique: the shredding area is supplied with air continuously, so the concentration of pentane remains constantly well below the lower explosive limit (LEL). The gas is sent to catalytic converters where hydrocarbon compounds (e.g. isobutane, pentane) are converted to water and CO_2, and VFCs are converted to HCl, HF and CO_2. HCl and HF gases are washed and converted in saline solutions that are disposed of.

TWG members, this technique is also mentioned as emerging technique. Please confirm whether or not it is considered as emerging, and provide technical information.

Achieved environmental benefits
The achieved environmental benefits of this technique include:

- reduction of diffuse and channelled VFC/VHC emissions;
- reduction of diffuse and channelled VOC emissions;
- reduction of explosion risk and related uncontrolled emissions.

Environmental performance and operational data
Degassing step: All liquids that contribute to the contamination of separated fractions during or after the treatment process are removed. The maximum VFC/VHC concentration in oil is 0.2 % by weight. Degassing units are capable of removing more than 99 % of oil and refrigerant mix from the cooling circuit and compressor at typical temperatures of 5–10 °C. [107, Mech. subgroup 2014]

Cryogenic technique: The shredding chamber is encapsulated under suction, VFCs/VHCs are exhausted and N_2 is blown in to reduce the O_2 level to < 4 %. For a shredding chamber measuring 2000 x 1200 x 1000 mm, the total amount of air exhausted would be 400 m^3/hour. The VFCs/VHCs are then exhausted inside the unit, which cools them down with liquid nitrogen to −90 °C. At that freezing temperature the gases turn into liquids. The liquefied gases are then stored in tanks. The tank is placed on a scale, which makes it possible to see how much gas is recovered and when the tank has to be changed.

The specific consumption of N_2 reported via the data collection is around 0.06 t/tonne of waste treated. [107, Mech. subgroup 2014]

See also Section 3.2.2.1.2 for CFCs, HFCs and HCFCs in air emissions, and Section 3.2.2.1.3 for organic compounds in air emissions.

Adsorption technique: The gases from the shredding area are pumped into adsorption filters. Cooling can be used prior to adsorption to reduce the amount of water in the process gas. VFCs and VHCs are captured by activated carbon or zeolite in the adsorption filters. The 'clean' gas after the filters is monitored continually for VFC/VHC emissions. An adsorption process always consists of at least two filters which are switched in parallel so that at least one is adsorbing and one is regenerating. During the filter regeneration, heated outside air is pumped into the filter to evaporate trapped VFCs and VHCs.

The specific consumption of activated carbon reported via the data collection is below 0.5 kg/tonne of waste treated.

See also Section 3.2.2.1.2 for CFCs, HFCs and HCFCs in air emissions, and Section 3.2.2.1.3 for organic compounds in air emissions.

Cross-media effects

- Energy consumption.

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- Production of waste to be disposed of when using IC technique.

TWG members, please provide information

Technical considerations relevant to applicability

TWG members, please provide information

Economics

Generation and transportation costs if nitrogen is purchased in bottles, or generation cost if nitrogen is produced on site.

TWG, please provide information

In the current state of the art, the cost of the stage 1 (extraction of the oil and refrigerants)and stage 2 (extraction of VFC and VHC blowing agents from the insulating material) processes are higher than the price of recovered materials. In some Member States (e.g. France), cooling appliances are accepted with a negative price at the gate of dedicated plants. This is taken into account by a visible fee on new equipment such as fridges. [161, INERIS 2015]

Driving force for implementation

- Environmental legislation.
- Safety issues.
- Increase of recycling and usage rates.

Example plants

Cryogenic condensation: Plants 458, 470, 629.
Activated carbon adsorption: Plants 138, 630, 636.

Reference literature

[107, Mech. subgroup 2014] [126, Mech subgroup 2014] [127, EERA 2015] [160, WT TWG 2014]

3.2.3.1.2 Reduction of dust emissions

3.2.3.1.2.1 Fabric filter

Description

See Section 2.3.4.4.

Technical description

See the CWW BREF [138, COM 2014].

Achieved environmental benefits

The achieved environmental benefits of this technique include the reduction of dust emissions to air.

Environmental performance and operational data

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Table 3.16 below presents dust emissions to air from mechanical treatment in shredders of temperature exchange equipment equipped with a bag/fabric filter system.

Table 3.16: Dust emissions to air from mechanical treatment in shredders of equipment containing VFCs or VHCs equipped with a bag/fabric filter system

Plant code	Capacity (t/day)	Origin of emissions	Techniques used	Exhaust air flow rate (Nm^3/h)	Dust (mg/Nm^3)
458	20	Material handling	Bag/fabric filter system	800	0.12 (1)
636	50	Recovery of blowing agent	Activated carbon adsorption Bag/fabric filter system	275	3 (2)
630_1	50	Recovery of blowing agent	Activated carbon adsorption Bag/fabric filter system	250	3 (2)
630_2	50	Separation of mixed plastics	Bag/fabric filter system	5500	0.2 (2)
630_3	50	Treatment of mixed metals	Bag/fabric filter system	5500	0.2 (2)

(1) Continuous measurements.
(2) Periodic measurements. One measurement over the three reference years (2010-2012).

Cross-media effects
See the CWW BREF [138, COM 2014]

Technical considerations relevant to applicability
See the CWW BREF [138, COM 2014]

Economics
See the CWW BREF [138, COM 2014].

Driving force for implementation
Environmental legislation.

Example plants
See Table 3.16

Reference literature
[160, WT TWG 2014]

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3.3 Mechanical treatment of waste with calorific value

3.3.1 Overview

This section covers treatment methods and processes mainly used to obtain a material out of non-hazardous waste so that it can be used as fuel. However, some treatment methods may produce outputs that may be used for purposes other than fuel.

3.3.2 Applied processes and techniques

From ex-Section **2.5.1.1 Preparation of solid waste fuel by mechanical (and biological) treatment from non-hazardous wastes**

Purpose

The main purpose is to prepare a combustible material out of non-hazardous solid waste, in some cases municipal solid waste (MSW). This section also covers the preparation of solid fuels by blending/mixing.

The main function of the fuel preparation is to upgrade selected materials into a specified fuel. In the case of feedstock with no biodegradable fraction, the facility upgrades the feed mainly by removing non-combustible materials.

In the case of feedstock with a biodegradable fraction on which a biological treatment is performed additionally to the mechanical one, this is dealt with in Section 4.4 related to mechanical biological treatment (MBT).

Moved to Section 4.4

~~Broadly, it is possible to distinguish two types of MBTs:~~

- ~~'separation' facilities, which seek to split residual waste into non-combustible, biodegradable (that may be dried and used as fuel) and 'high calorific' fractions, and~~
- ~~'dry stabilisation' processes, which are less concerned with the splitting into fractions, and more aim towards the use of heat from a 'composting' process to dry the residual waste and increase its calorific value, therefore making it suitable for use as a fuel as well as to improve the separation of fractions.~~

Principle of operation

The waste input is ~~is manufactured by sorting wastes~~ sorted and shredded mainly to leave a more homogeneous combustible material, ~~by mainly removing~~ which does not contain wet putrescible materials ~~and~~ or heavy inert materials (stones, glass, scrap metals, etc.) ~~from the wastes~~. Other operations used are, for example, sieving, separators, crushers, screening and picking.

~~The processing of solid waste fuel is not a standardised process. The extent of processing carried out depends to a certain degree on the type of waste being received (input) and to the actual application of the solid waste fuel.~~

Solid fuel preparation technologies vary considerably depending on the source and type of waste, and on the user specifications ~~requirements~~ of the customer/combustion installation.

It is very important to bear in mind that waste is a heterogeneous mixture of materials, especially municipal solid wastes. Therefore, by processing the waste with a specific preparation technology when producing the fuel, the producer makes the fuel more homogeneous.

WORKING DRAFT IN PROGRESS

Feed and output streams

Feedstock

MSW, 'commercial' waste, and construction and demolition waste are the most common sources. ~~The most common waste materials are paper, plastic, wood and textiles.~~ ~~Another type of waste typically used is the paper fraction (paper + plastic + rubber) from oil filters. This contains a high calorific value.~~

From ex-**Section 3.5.1 "Waste IN for the preparation of waste fuels"**

Table 3.17 shows some characteristics of municipal solid waste, and some of its fractions which can be used as fuel.

Table 3.17: Important characteristics of MSW, and some of its fractions, for use as fuel

Municipal solid waste	Heating value (MJ/kg wet matter)	Other components
Generic municipal solid waste	5–8	Cl: 0.5–1.0 % The content of some metals may be high
Residual municipal solid waste	8–11	Cl: 0.5–1.0 % The content of some metals may be high
Paper	11–14	Cl: 0.5 % Pb: 33 ppm Cd: 0.3 ppm
Cellulose (20 w/w-% ash content and moisture of 5 %)	12.3	NI
Cellulose (20 w/w-% ash content and moisture of 40 %)	5.7	NI
Polyethylene (20 w/w-% ash content and moisture of 40 %)	16.5	NI
Polyethylene (0 w/w-% ash content and moisture of 40 %)	25.3	NI
Polyethylene (0 w/w-% ash content and moisture of 5 %)	41.5	NI
Polyethylene hard density (printed)	NI	Volatiles(1): 97 % Ash(2): 2 % Fixed carbon: 0.3 %
Polypropylene	NI	Volatiles: 100 % Ash: < 0.05 %
Polystyrene (white)	NI	Volatiles: 97 % Ash: 3 %
PVC	NI	Volatiles: 92 % Ash: < 0.05 % Fixed carbon: 8 %
Plastics	23.7–28.4	Cd: 0.7–72 ppm Cl: 1–4.5 % Cr: 48 ppm Hg: 1.3 ppm Pb: 98–739 ppm Tl: 0.3 ppm Zn: 550 ppm
Composites	13.3–16.2	Cd: 0.2–37 ppm Cl: 0.5–4.0 % Pb: 48–500 ppm
Textiles, leather and shoes	17.1	Cd: 2.2 ppm Cl: 1.2 % Pb: 96 ppm

NI: No information.

(1) Plastics volatilise after melting by depolymerisation.

(2) The pure polymer is ash-free, but ash comes from printing and pigments.

Source: [1, Langenkamp H. 1997] [5, Krajenbrink et al. 1999] [12, ÖWAV Working Commitee 2002] [58, VDI and Dechema 2002] [98, WT TWG 2004]

WORKING DRAFT IN PROGRESS

Waste plastic

The demonstration of energy recovery for specific waste plastic streams in full-scale tests has been going on over a sufficiently long time period to prove the repeatable and stable operating conditions; to document the effect the waste plastics have on the operation; and also to indicate what materials and emissions will arise. An overview of the APME (Association of Plastics Manufacturers in Europe) TEC programme is sketched out in Table 3.18 below.

Table 3.18: The use of waste plastics from different industrial sectors as fuel

Burning technology	**Energy use**	**Packaging**	**Com-mercial**	**Automotive**	**Electrical and electronics**	**Agricultural**	**Building and cons-truction**
Grate type	District heat and Heat/power	MPW	NI	SR	NI	NI	Foams
Fluidised bed (FB)	Heat/power	MPW, SR	NI	NI	NI	NI	NI
Pulverised coal	Power	MPW	NI	NI	NI	Films	NI
Rotary kiln	Cement	MPW	NI	NI	Foam	NI	NI
Industrial furnace	Non-ferrous	NI	NI	NI	ESR	NI	NI
Circulating FB	Pulp paper	MPW	Kerbside	SR	NI	NI	NI

NB: MPW: municipal plastic waste (sometimes needs to be shredded before use); SR: shredder residue; ESR: shredder residue from white goods.
NI: No information.
Source: [36, CEFIC 2002] [60, WT TWG 2003] [98, WT TWG 2004]

Output

The ~~treatment to produce solid waste fuel~~ process to derive fuel from solid wastes separates the ~~MSW~~ calorific fraction and the non-calorific fraction contained in the waste input. ~~into two fractions. The calorific value and the composition of these fractions are different and differ from the MSW treated~~. The non-calorific fraction that remains after ~~the extraction of the solid waste fuel~~ this operation may represent a high percentage of the ~~MSW~~ waste input (e.g. MSW) treated.

The output types include:

- Solid fuel, e.g.:
  - Solid recovered fuel (SRF), which is a solid fuel prepared from non-hazardous waste to be used for energy recovery in incineration or co-incineration plants, and which meets standardised classification and specification requirements (EN15359, elaborated by the CEN TC 343).
  - Refuse-derived fuel (RDF); RDF differs from SRF in that it is not produced in compliance with specific criteria. RDF includes high calorific fractions, which are coarser fractions from waste streams that contain materials with a high calorific value that have not been processed as extensively as fractions for power plants running on secondary fuels.
  - Solid biofuels; solid biofuels are divided into two categories, namely high calorific biodegradable waste, such as wood, paper, textiles and wet putrescible waste (which usually includes food), and garden and sludge wastes. Terminology, definitions and descriptions are given in EN 14588:2010 - Solid biofuels, drafted by the CEN TC 335.

  The solid fuel can either be shredded fluff-like materials, or densified in pellets, cubes and briquettes.

~~It is possible to distinguish two major fuel types: shredded or fluff-like material and densified fuels, such as pellets, cubes and briquettes.~~

WORKING DRAFT IN PROGRESS

~~Densified recovered solid fuel can have lower heating values (LHV) i.e. up to 30 MJ/kg depending on composition. The reported minimum calorific values vary from 3 to 40 MJ/kg. Other data report that the input, which may typically have a starting calorific value of c. 8.4 MJ/kg, can increase its calorific value to about c. 17 MJ/kg mainly by separating out the non-combustible fractions (e.g. inorganic materials and water).~~

- Waste plastic that can ~~be~~ substitute~~d for~~ other solid fuels, such as coal, peat, wood, petroleum coke, etc. There are a number of developments currently being carried out in fuel substitution, as well as some demonstration plants currently operating using solid waste plastic.
- Wood for reuse.
- Incombustible materials such as metals, stone, and glass, which can be sent to material recovery.

[162, Mech. Subgroup 2014]

From ex-**Section 3.5.4.1 "Solid waste fuel prepared from municipal solid waste"**

The range of compositions of solid waste fuel in Europe is shown in Table 3.19 below.

Table 3.19: Ranges from the analyses of solid waste fuel prepared from MSW in Europe

Property	Range	Unit
Dry matter	75.3–78.0	%
Humidity	1.6–50	%
Calorific value	10–40	MJ/kg
Ash	0.7–20	w/w-%
Composition of the ash		w/w-%
aluminium	6.9–9.2	
calcium	17.6–21.8	
iron	1.6–2.2	
potassium	1.9–2.2	
magnesium	1.4–1.7	
sodium	1.9–2.7	
silicon	17.9–20.8	
titanium	1.0–1.6	
Chlorine	< 0.01–1.77	w/w-%
Fluorine	0.001–0.02	w/w-%
Sulphur	0.02–0.6	w/w-%
Carbon	47.1–50.7	w/w-%
Hydrogen	6.6–7.0	w/w-%
Nitrogen	0.5–0.8	w/w-%
Oxygen	30.4–34.4	w/w-%
As	< 0.4–160	ppm
Be	0.2–0.3	ppm
Cd*	0.16–6	ppm
Cd + Hg	7	ppm
Co	0.4–7.4	ppm
Cr	2.5–226	ppm
Cu	6.8–1340	ppm
Hg	< 0.02–1	ppm
Mn	22–590	ppm
Ni	< 2.5–40	ppm
Pb	2.4–300	ppm
Sb	1–39	ppm
Se	0.8–1.7	ppm
Sn	2–27.6	ppm
Te	0.6–1.58	ppm
Tl	< 0.1–0.8	ppm
V	2.3–10.2	ppm
Zn	225–500	ppm
EOX	31–42	ppm

WORKING DRAFT IN PROGRESS

* Around 70 % of the Cd that may be present in the MSW is transferred to the combustible products.
Source: [1, Langenkamp H. 1997] [5, Krajenbrink et al. 1999] [15, Langenkamp, H. and Nieman, H. 2001] [58, VDI and Dechema 2002]

TWG members, please confirm whether these figures are still valid

Table 3.20: Solid waste fuel produced from the high calorific fraction of demolition waste

Parameter	**Unit**	**Median**	**80th percentile**	**Number of samples**
Net calorific value	MJ/kg	20.6	25.1	179
Moisture content	%	13.4	18.8	346
Ash content	% DM	13.8	20.6	151
Chlorine total	%	0.7	1.1	171
Fluorine total	mg/kg DM	100.0	400.0	55
Sulphur total	%	0.1	0.4	110
Antimony	mg/kg DM	10.8	42.4	284
Arsenic	mg/kg DM	1.0	2.0	257
Beryllium	mg/kg DM	0.2	0.3	230
Cadmium	mg/kg DM	2.2	4.9	266
Chromium	mg/kg DM	48.0	82.9	259
Cobalt	mg/kg DM	2.9	4.7	245
Copper	mg/kg DM	97.5	560.0	286
Lead	mg/kg DM	89.0	160.0	265
Manganese	mg/kg DM	61.0	94.0	229
Mercury	mg/kg DM	0.2	0.3	249
Nickel	mg/kg DM	13.1	26.3	243
Selenium	mg/kg DM	0.4	1.7	235
Tellurium	mg/kg DM	0.4	1.0	222
Thallium	mg/kg DM	0.4	0.5	241
Tin	mg/kg DM	4.0	12.2	192
Vanadium	mg/kg DM	3.6	5.3	241
PCB	Sum DIN 51527	0.2	0.5	21

NB: DM = dry matter.
All percentages are by mass.
The MSW used at this time did not include the high calorific fraction of household waste. It contained the high calorific fraction from construction and demolition waste and from commercial waste, which explains the stated net calorific value.
Source:[15, Langenkamp, H. and Nieman, H. 2001]

TWG members, please confirm whether these figures are still valid

WORKING DRAFT IN PROGRESS

Table 3.21: ~~Recovered fuel produced from source-separated fractions of MSW and other combustible waste (Finland)~~

~~**Parameter**~~	~~**Units**~~	~~**Source-separated raw materials from apartments, offices, etc.**~~[1]	~~**Source-separated raw materials from industries and companies**~~[2]
~~Moisture~~	~~%~~	~~33.6~~	~~16.6~~
~~Gross calorific value~~	~~MJ/kg DM~~	~~23.1~~	~~21.2~~
~~Net calorific value~~	~~MJ/kg DM~~	~~22.3~~	~~20.1~~
~~Net calorific value~~	~~MJ/kg~~	~~14.0~~	~~16.8~~
~~Energy content~~	~~MWh/tonne~~	~~3.9~~	~~4.7~~
~~Ash content~~	~~%~~	~~10.2~~	~~6.7~~
~~Volatile matter~~	~~%~~	~~74.8~~	~~78.3~~
~~Chlorine~~	~~%~~	~~0.4~~	~~0.3~~
~~Aluminium~~	~~%~~	~~0.6~~	~~0.2~~
~~Metallic aluminium~~	~~%~~		~~0.03~~
~~Sulphur~~	~~%~~	~~0.2~~	~~0.1~~
~~Nitrogen~~	~~%~~	~~1.5~~	~~1.4~~
~~Sodium~~	~~%~~	~~0.4~~	~~0.1~~
~~Sodium soluble~~	~~%~~	~~0.3~~	~~0.1~~
~~Potassium~~	~~%~~	~~0.3~~	~~0.1~~
~~Potassium soluble~~	~~%~~	~~0.2~~	~~0.1~~
~~Mercury~~	~~mg/kg DM~~	~~0.3~~	~~0.1~~
~~Cadmium~~	~~mg/kg DM~~	~~1.2~~	
~~Chromium~~	~~mg/kg DM~~	~~140~~	
~~Copper~~	~~mg/kg DM~~	~~80~~	
~~Nickel~~	~~mg/kg DM~~	~~20~~	
~~Zinc~~	~~mg/kg DM~~	~~340~~	
~~Manganese~~	~~mg/kg DM~~	~~210~~	
~~Arsenic~~	~~mg/kg DM~~	~~8.8~~	
~~Lead~~	~~mg/kg DM~~	~~52.4~~	

~~Notes: DM = dry matter~~
~~All percentages are by mass~~
[1] ~~Mean derived from 742 samples~~
[2] ~~Mean derived from 490 samples~~
~~*Source*:[15, Langenkamp, H. and Nieman, H. 2001]~~

WORKING DRAFT IN PROGRESS

Table 3.22: Recovered fuel produced from monostreams of commercial and industrial waste (data from one German company)

~~Parameter~~	~~Units~~	~~Median~~	~~80th percentile~~	~~Number of samples~~
~~Net calorific value~~	~~MJ/kg~~	~~22.9~~	~~25.3~~	~~1402~~
~~Moisture content~~	~~%~~	~~11.5~~	~~17.2~~	~~1849~~
~~Ash content~~	~~% DM~~	~~9.6~~	~~11.6~~	~~1308~~
~~Chlorine total~~	~~%~~	~~0.4~~	~~0.7~~	~~1475~~
~~Fluorine total~~	~~mg/kg DM~~	~~100~~	~~400~~	~~200~~
~~Sulphur total~~	~~%~~	~~0.1~~	~~0.1~~	~~307~~
~~Cadmium~~	~~mg/kg DM~~	~~0.8~~	~~3.2~~	~~443~~
~~Mercury~~	~~mg/kg DM~~	~~0.2~~	~~0.4~~	~~402~~
~~Thallium~~	~~mg/kg DM~~	~~0.5~~	~~1.5~~	~~410~~
~~Arsenic~~	~~mg/kg DM~~	~~1.5~~	~~1.7~~	~~394~~
~~Cobalt~~	~~mg/kg DM~~	~~2.0~~	~~3.8~~	~~383~~
~~Nickel~~	~~mg/kg DM~~	~~6.2~~	~~16.0~~	~~384~~
~~Selenium~~	~~mg/kg DM~~	~~1.0~~	~~2.5~~	~~318~~
~~Tellurium~~	~~mg/kg DM~~	~~1.0~~	~~5.0~~	~~322~~
~~Antimony~~	~~mg/kg DM~~	~~9.4~~	~~33.9~~	~~547~~
~~Beryllium~~	~~mg/kg DM~~	~~0.2~~	~~0.3~~	~~343~~
~~Lead~~	~~mg/kg DM~~	~~25.0~~	~~64.4~~	~~406~~
~~Chromium~~	~~mg/kg DM~~	~~20.0~~	~~43.9~~	~~417~~
~~Copper~~	~~mg/kg DM~~	~~48.0~~	~~118~~	~~504~~
~~Manganese~~	~~mg/kg DM~~	~~28.0~~	~~47.0~~	~~369~~
~~Vanadium~~	~~mg/kg DM~~	~~3.3~~	~~10.0~~	~~347~~
~~Tin~~	~~mg/kg DM~~	~~7.0~~	~~12.4~~	~~114~~
~~PCB~~	~~Sum DIN 51527~~	~~0.2~~	~~0.5~~	~~134~~

~~Notes: DM = dry matter~~
~~All percentages are by mass~~
~~*Source*:[15, Langenkamp, H. and Nieman, H. 2001]~~

Solid waste fuel to substitute coal

The main differences between coal and solid waste fuels are the contents of sulphur, chlorine and heavy metals. In many cases, for instance, if solid waste fuels with plastics are considered and compared to coal, the chlorine of the recovered fuels is higher (typically 0.5–1.0 %) and the sulphur is lower. Also, the heavy metals content will generally be in a similar range (ppm range) or may even increase. Solid waste fuel is sold in different physical forms. Table 3.23 gives an overview of the different physical forms of waste fuel.

Table 3.23: Overview of the different physical forms of the waste fuel (output)

Waste fuels	Determining physical and chemical characterisation
Fluffy	Particle size, bulk density, moisture content, net calorific value, ash content, chemical composition
Soft pellets	
Hard pellets	
Chips	
Powder	

Source:[82, Pretz et al. 2003] [100, WT TWG 2004]

The user requirements often define the product quality and the waste fuel characterisation. Power plants, cement and lime works, gasification plants, multifuel boilers, etc. have different standards for the use of solid waste fuel dependent on their technology, waste gas treatment and product specification.

Dried sewage sludge

Large volumes of dried sewage sludge with calorific values between 3 MJ/kg and <10 MJ/kg are used in power plants.

From ex-Section **4.5.1 To improve the knowledge of the waste fuel prepared**

WORKING DRAFT IN PROGRESS

The quality assurance of the preparation of waste to be used as fuel is driven by the need to meet the specifications set by the receiving facility. This ~~technique~~ is related to the waste composition characterisation ~~one described in~~ (see Section 2.3.2), and to the Quality Management System (QMS). Mixing and blending (see Section 2.3.2.7) also plays an important role in this issue.

Some ~~techniques~~ practices include:

a. delivering a report to the customer covering the main physical and chemical properties of the waste fuel, in particular:
   - origin and EWL number,
   - net calorific value,
   - ash content,
   - water content,
   - volatile matter content,
   - biomass content,
   - chemical composition (especially C, H, O, N, S, P, Cl, F, Al, K, Na, heavy metals);
b. limiting the amount of relevant parameters for any waste that is to be used as fuel in any co-incineration plant (e.g. chromium (VI), total chromium, lead, cadmium, mercury, thallium, PCB, sulphur and the total halogen content for use in cement kilns).

[10, Ministry for the Environment 2000] [33, UK EA 2001] [52, ENDS 2002] [60, WT TWG 2003] [98, WT TWG 2004] [100, WT TWG 2004]

~~Achieved environmental benefits~~

~~Passes on knowledge to the user of the fuel about the possible emissions and any operational problems that may be generated by the use of the material as fuel. The waste fuel user needs to provide sufficient specifications of the waste fuel to be used to reduce the possible impact on the emissions, quality of residues generated by waste fuel user, corrosion behaviour and the quality of products.~~

~~Operational data~~

~~Laboratory work is required (analyses).~~

~~Applicability~~

~~The actual blend of waste solvents in particular is set by a good knowledge of the constituents, to meet calorific values and limits on contaminants, for example, chlorine and heavy metals.~~

~~Driving force for implementation~~

~~CEN/TC 343 solid recovered fuels and WG 2 ‘Specifications and classes’. The use of waste fuels and the displacement of pollutants to residues or products increasingly becomes an important issue. Therefore the use of some waste fuels has to be restricted, depending on the subsequent treatment. New discussion or regulations limiting chromium (VI) in cement to no more than 2 ppm because of health and safety reasons may restrict the use of some wastes containing chromium. Some guidances is also available (e.g. North Rhine Westphalia in Germany).~~

~~Reference literature~~

Process description

~~See Section . Depending on the source and the use, these wastes are shredded, separated, blended and pelletized.~~

Depending on the source of the waste input and the requirements for the output ~~use~~, this waste~~s~~ is shredded, separated, blended and pelletised.

WORKING DRAFT IN PROGRESS

Source selection may be the first action to take into account for monostreams. Preselection may be incorporated into the collection system for mixed commercial wastes. The waste reception area is the first important facility with regard to the quality assurance management system and this is where the receiving inspection is carried out. All kinds of disturbance materials which might cause operational or quality problems ~~need to be~~ are removed at this early stage.

The ~~production of solid waste fuel~~ process for deriving fuel from solid waste can be divided into several steps which are listed below. However, this list only presents an overview of possible steps ~~techniques~~; each one ~~technique~~ is not necessarily part of each process:

- reception area/bunker;
- presorting/contaminants selection;
- feeding equipment - wheel loaders or cranes are usually applied for the feeding of the process;
- size reduction - comminution can be achieved by hammer mills, shear shredders, single-shaft shredders, rotary cutters, camshaft shredders and cascade mills;
- sorting (e.g. ferrous and non-ferrous metals separation, screening, air classification, NIR, picking); a general description of the sorting steps can be found in Section 2.3.2.8;
- ~~metal separation – to separate, for instance, ferrous metals out of the solid waste, it is possible to use a number of techniques based on the different properties of the material. The most important characteristics in waste treatment are density, shape, magnetic susceptibility and electric conductivity. The type of systems mostly used in this sector are magnetic separators (overband magnetic separators, magnetic drum separators, magnetic pulleys) or Eddy current separators (to separate out non-ferrous metals)~~
- ~~air classification (e.g. by air classifiers or aeroherds)~~
- ~~near infrared spectroscopy~~
- ~~automatic picking~~

Moved to Section 2.3.2.8

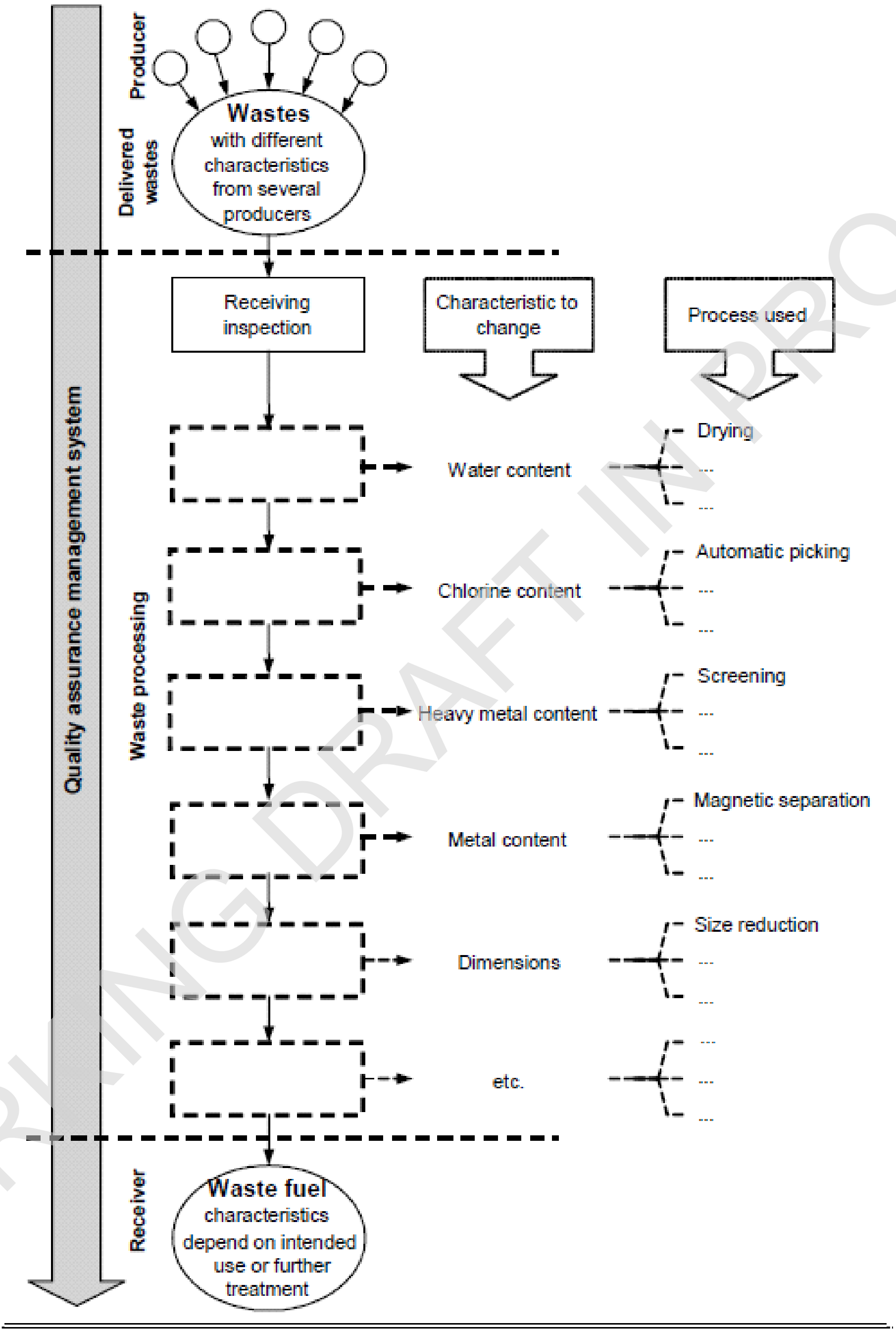
- ~~classification – classification can be carried out by drum screens, linear and circular oscillating screens, flip-flop screens, flat screen, tumbler screens and moving grates. A very important processing step, within classification is the screening step, before and after grinding. Screens are applied to allow mass and volume division by particle size. It is noticeable that in small particle size mixtures, the content of hazardous substances accumulates compared to the amount found in the screen overflow. A classification with sieves is applied in waste treatment processing when:~~
  - ~~materials from an upstream process need to undergo some kind of conversion to make them suitable for further processing steps, i.e. separation into defined size fractions~~
  - ~~a separation of coarse or fine particle sizes is required~~
  - ~~a comminution material has a high content of particles of the final particle size and only oversized particles should be reduced in size again~~
  - ~~certain materials need to be concentrated. In this case, the processing is called sorting classification. This also includes separation of the small size fractions, which often contains a high content of heavy metals substances~~
- compacting/pelletising can be carried out by flatbed presses, ring die presses, or disc agglomerators (see also Section 5.3);
- storage/storage area/hopper;

Moved to Section 4.4 (MBT)

- ~~biological degradation/thermal drying – If the water content has to be reduced to increase the calorific value, a drying process step is necessary. This can be implemented as a thermal or biological drying step. It may be necessary to dry the waste in order to achieve higher sorting/classification ratios of waste~~
- ~~exhaust gas collection and cleaning~~
- ~~waste water treatment~~
- loading and transportation.

WORKING DRAFT IN PROGRESS

~~A typical example of a flow sheet is: input (waste), mechanical transport (e.g. conveyer belt), separation (e.g. by drum sieves, air classifiers, handpicking, magnets, dryers), size reduction (e.g. by crushing, shredding), size increasing (e.g. baling, pelletizing), and finally output (fuel). Several examples applied in this process are known: reducing/removing/changing physical and/or chemical contaminants. only shows one main characteristic – automatic picking. Near infrared spectroscopy or metal separation also influences such properties as for example heavy metal contents.~~ Figure 3.33 ~~presents an overview of some common process units, which may be applied for solid waste fuel production. The number and kind of processing steps applied depend on the waste composition and the desired waste OUT qualities.~~

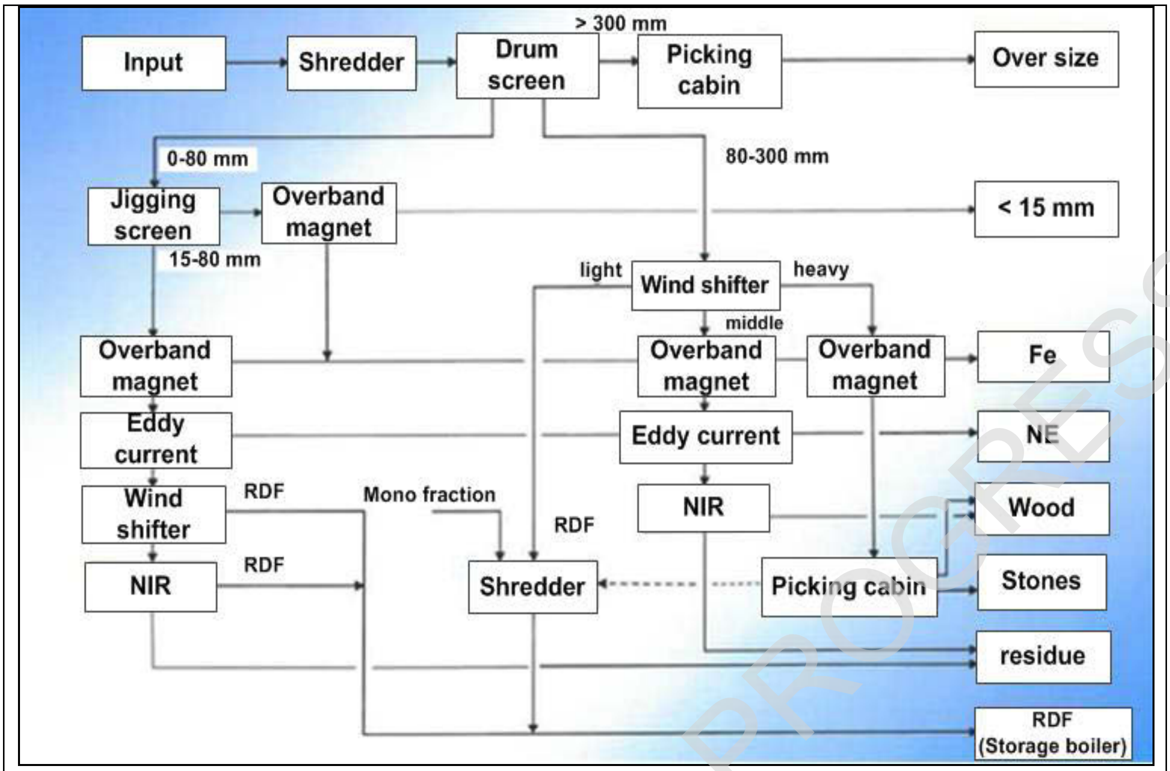


Source: ~~[82, Pretz et al. 2003]~~

Figure 3.32: Process scheme of solid waste fuel production

An ~~typical~~ example of a flow sheet for mechanical treatment of waste with calorific value with RDF output is shown in Figure 3.33 below.

WORKING DRAFT IN PROGRESS



Source: Plant #122

Figure 3.33: Flow sheet for mechanical treatment of waste with calorific value

After the final processing step, a solid waste fuel is obtained. In some cases, additional processing steps may be required to design the solid waste fuel according to the consumers' wishes. For example, further compacting or further size reduction may be requested. Table 3.24 shows the correlation between different fuel preparation processes and the end application for different purposes.

Table 3.24: Additional processing steps required according to the waste's physical characteristics, to deliver waste fuel to consumers' specifications

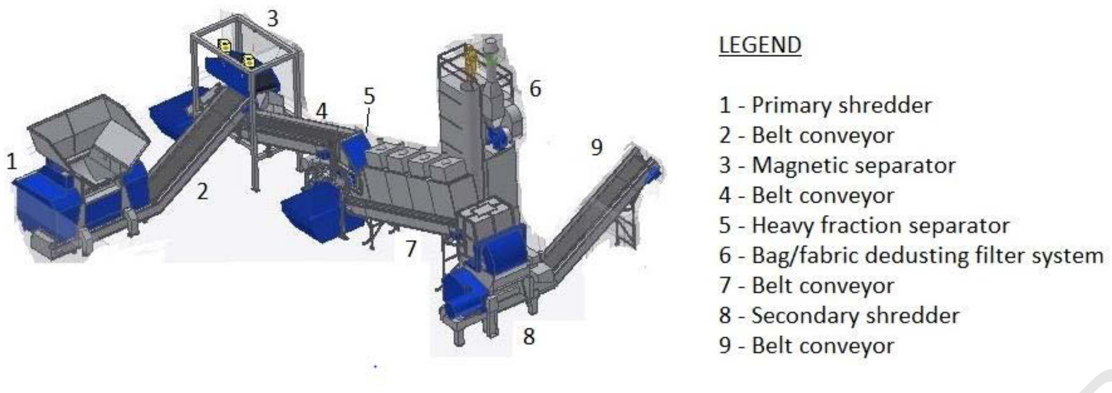
Prepared fuel in form of	Co-combustion process			
	Cement kiln	**Circulated fluidised bed**	**Pulverised coal power plant**	**Gasification and pulverised coal power plant**
Bales	Shredding (fluff), covered storage	Shredding (fluff), covered storage	Pelletising, storage, pulverisation	Shredding (fluff), covered storage
Soft pellets/fluff	Covered storage	Covered storage	Covered storage	Covered storage
Hard pellets	Covered storage, simple crushing	Covered storage	Covered storage, pulverisation	Covered storage
Source:[82, Pretz et al. 2003] [98, WT TWG 2004]				

Once the combustible material has been separated, it is then shredded and either sent to the customer, or pelletised before it is sent for combustion (this usually occurs when the material is burned off site, as a densified fuel reduces transport costs).

Emissions to air from mechanical treatment of waste with calorific value are likely to be dust. In some cases, the prevention/reduction of diffuse dust emissions from the waste input storage is done by water spraying. The reduction of channelled dust emissions is mostly done by means of a fabric filter.

Figure 3.34 below gives an example of a mechanical treatment of waste with calorific value equipped with a fabric filter.

WORKING DRAFT IN PROGRESS



Source: Plant #443

Figure 3.34: Mechanical treatment of waste with calorific value equipped with a bag/fabric filter

Users

The combustible material is typically incinerated in dedicated facilities or co-incinerated in plants where a combustion process is carried out. The major fuel application is in cement/limestone production and power generation. Depending on the end application, there are different requirements for waste fuels.

This type of plant can be found in the Netherlands, Italy, Germany, Austria and Belgium, and constitutes a basic template for some 'integrated facilities' planned in the UK. The blending of large volumes of solid wastes is common practice in a number of EUM countries (e.g. Belgium, France, Germany, Denmark).

Moved to Section 4.4 (MBT)

~~In mechanical biological treatment, the process used in the production of solid waste fuel is a kind of mechanical upstream facility, because the high calorific wastes are separated out before the rest of the material is fed into the biological degradation step to lower its organics content. In some cases, the biological degradation step is part of the production of solid waste fuel, with the main focus being on lowering the water content. In other cases, the biological degradation step is also arranged in the production of solid waste fuel, but the main focus may be on lowering the organics content, to maintain the respective disposal criteria for any material which is not part of the solid waste fuel and which needs to be disposed of. Depending on the applied process, different regulations for emissions may apply.~~

~~In some cases, the entire waste is dried by physical and biological processes for several days (e.g. in Germany, 7 days) under high aeration rates in a closed bio-reactor. Within this process, the organics content is reduced only slightly, and the separation behaviour is improved significantly. This is followed by a separation into a heavy and light fraction. The light fraction is used as RDF after further separation of the metals. The heavy fraction (about 15 %) is separated into metals, glass, batteries and mineral components for re-use.~~

~~Other purposes of MBTs are mentioned in Section~~

3.3.3 Current emission and consumption levels

[160, WT TWG 2014] [155, Umweltbundesamt 2015]

From ex-**Section 3.5.3 "Emissions from the preparation of waste fuel"**

~~**Emissions from the preparation of solid waste fuel from municipal solid waste**~~

~~The material balance of the production of a RDF is shown in the next table.~~

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Table 3.25: Examples of the emissions from the production of RDF from MSW

~~Combustable product (e.g. RDF)~~	~~Organic matter~~	~~Non-combustable waste with an inorganic base~~	~~Metals~~	~~Water evaporated and CO_2~~	~~Others~~
~~55 – 50~~	~~20~~		~~5~~	~~20 – 25~~	
~~53~~ [1]		~~Glass: 4~~ ~~White: 3~~ ~~Brown: 0.5~~ ~~Green: 0.5~~ ~~Minerals: 4~~ ~~Fine grain and dust to be disposed off: 4~~	~~Ferrous metals: 4~~ ~~Non-ferrous metals: 1~~		~~Batteries: 0.05~~
~~Values in kg/100 kg of waste entrance~~ [1] ~~calorific value 15 – 18 MJ/kg~~ ~~*Source*: [30, Ecodeco 2002] [58, VDI and Dechema 2002]~~					

~~gives an overview of the plants that have provided data for this section.~~

Table 3.26: Overview of some solid waste fuel production plants in the EU

~~Type of plant~~	~~Kind of solid waste fuel production~~	~~Capacity (kt/yr)~~	~~Amount of solid waste fuel products (t/yr)~~	~~% product/ waste~~	~~Amount of exhaust gas (m^3/h)~~	~~Dust (kg/yr)~~	~~Odour (OU/m^3)~~	~~Noise distance to the location of immission (m) Acoustic pressure level day/night as technical approval (dB(A))~~
~~MSW processing without biological decomposition step~~	~~Fluff~~	~~23~~	~~17400~~	~~76.7~~				
~~Commercial waste processing plants~~	~~Soft/hard pellets~~	~~40~~	~~15300~~	~~69.5~~	~~18000~~			~~<40/<40~~
~~Commercial waste processing plants~~	~~Soft pellets, fluff~~	~~65~~	~~31700~~	~~99.1~~	~~48000~~			~~10~~ ~~<70/<70~~
~~MSW processing without biological decomposition step~~	~~n.a.~~	~~80~~	~~16300~~	~~84.0~~				
~~Mechanical-biological waste treatment~~	~~Fluff~~	~~100~~	~~30700~~	~~48.7~~	~~45000~~	~~394~~		
~~High calorific fraction from MSW processing and commercial waste processing plant~~	~~Soft pellets, fluff~~	~~100~~	~~9000~~	~~90.0~~	~~48000~~			~~1000~~ ~~<50/<35~~

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~~Commercial waste processing plants~~	~~Soft pellets, fluff~~	~~100~~	~~27000~~	~~90.0~~	~~48000~~			~~1000~~ ~~<50/<35~~
~~Mechanical-biological waste treatment~~	~~High calorific fraction in bales~~	~~110~~	~~19500~~	~~17.7~~	~~120000~~		~~406~~	~~200~~ ~~50/39~~
~~MSW processing without biological decomposition step~~	~~Fluff~~	~~840~~	~~90000~~	~~11.5~~	~~90000~~		~~220~~	~~650~~ ~~38/37.5~~
~~*Source:* [82, Pretz et al. 2003]~~								

Table 3.27: Examples of air emissions from the preparation of fuel from non-hazardous waste

	~~**Units**~~	~~**Installation A**~~		~~**Installation B**~~		~~**Installation C**~~	
~~Capacity~~	~~kt/yr~~	~~65~~		~~86~~		~~98~~	
		~~**Conc.**~~	~~**Load**~~	~~**Conc.**~~	~~**Load**~~	~~**Conc.**~~	~~**Load**~~
~~Fumes~~	~~million Nm^3~~				~~394.2~~		
~~Oxygen~~	~~%~~	-		~~19~~		~~1.4~~	
~~CO^2~~	~~t/yr~~		~~11765~~		~~8428~~		
~~PM~~	~~mg/Nm^3 – kg/yr~~	~~0~~		~~1~~	~~394.2~~	-	
~~SO*~~	~~mg/Nm^3 – kg/yr~~	-	~~1820~~	~~18.6~~	~~7332~~	-	
~~NO*~~	~~mg/Nm^3 – kg/yr~~	~~80~~	~~4699.5~~	~~47~~	~~18527~~	~~12.5~~	
~~N^{2}O~~	~~mg/Nm^3 – kg/yr~~				~~0~~		
~~TOC~~	~~mg/Nm^3 – kg/yr~~	~~40~~	~~2340~~	~~1.7~~	~~670.14~~	-	
~~CH^4~~	~~kg/yr~~		~~26715~~				
~~CO~~	~~mg/Nm^3 – kg/yr~~	~~80~~	~~4699.5~~	~~8.4~~	~~3311.28~~	~~16~~	
~~HCl~~	~~mg/Nm^3 – kg/yr~~	-	~~78~~	-		-	
~~HF~~	~~mg/Nm^3 – kg/yr~~		~~26~~				
~~Total metals~~	~~mg/Nm^3 – kg/yr~~	-		~~0.4~~	~~197.1~~	-	
~~Hg~~	~~mg/Nm^3 – kg/yr~~	-		~~3.7~~	~~1.46~~	-	
~~Cd + Tl~~	~~mg/Nm^3 – kg/yr~~	-		~~0.4~~	~~0.197~~	~~0.08~~	
~~Chlorobenzenes~~	~~mg/Nm^3 – kg/yr~~	-		~~0~~	~~0.0047~~		
~~PCDD/PCDF~~	~~ngTEQ/Nm^3 – g/yr~~	-	~~0.0026~~	~~0.002~~	~~0.00079~~		
~~CFC~~	~~mg/Nm^3 – kg/yr~~	-		~~0.044~~	~~17.345~~	-	
~~Odour~~	~~EU O.U./Nm^3 – MGE/yr~~	~~0~~		~~110~~	~~43362~~	-	
~~NH^3~~	~~mg/Nm^3~~	~~0~~		-		-	
~~*Source:* [44, TWG 2003]~~							

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Table 3.28: Examples of water emissions from the preparation of fuel from non-hazardous waste

	~~**Units**~~	~~**Installation A**~~		~~**Installation B**~~		~~**Installation C**~~	
~~Capacity~~	~~kt/yr~~	~~65~~		~~86~~		~~160~~	
		~~**Conc.**~~	~~**Load**~~	~~**Conc.**~~	~~**Load**~~	~~**Conc.**~~	~~**Load**~~
~~WW generated~~	~~m^3/yr~~		~~16965~~		~~30100~~		~~8000~~
~~BOD^5~~	~~mg/l - kg/yr~~			~~21~~			
~~COD~~	~~mg/l - kg/yr~~		~~34450~~	~~40~~			
~~Total N (as N)~~	~~mg/l - kg/yr~~			~~230~~			
~~Nitrit~~	~~mg/l - kg/yr~~			~~1.8~~			
~~Nitrates~~	~~mg/l - kg/yr~~						
~~Ammonia~~	~~mg/l - kg/yr~~		~~10400~~				
~~Nitrates~~	~~mg/l - kg/yr~~		~~650~~				
~~Sulphates~~	~~mg/l - kg/yr~~		~~325~~				
~~*Source:*[44, TWG 2003]~~							

~~Depending on the type of plant a great difference can be found in the ratio between the amount of treated waste and the solid waste fuel products. This is explained by the fact that some plants treat commercial waste and other plants treat MSW. Additionally, the producers have different ways to produce their solid waste fuel. For instance, if the fine material is added to the solid waste fuel product and this is not disposed in a landfill, the amount of product increases but the quality decreases significantly. Other plants are building up their capacities by modifications of their operation or produce solid waste fuel in a combined production with MSW processing plants.~~

~~The declared values are taken from the technical approvals. The differences seen by the wide range of the values can be explained by the location of the processing plants, and their different input materials and operating times, e.g. in some cases one, two or three shift operations.~~
~~With reference to, the difference between the amount of input and the amount of product output must be adjusted taking into account the amount of potential recyclables such as ferrous and non-ferrous metals in the waste. The content of potential recyclables depends on each waste composition, which can vary widely. Furthermore, residues may accrue during the waste gas cleaning process.~~

~~Depending on the processing method, there may also be some by-products generated. Depending on the quality of the by-products they might be recycled directly or treated after a further processing. The current by-products are typically ferrous and non-ferrous metals and an inert fraction. The quality of the ferrous and non-ferrous metal product depends on the waste content and on the processing method applied. Higher quality products are applicable for material recycling.~~

~~The inert fraction is sometimes used as construction materials, e.g. as road construction material or for landfill. In rare cases, a recycling material may be produced which is used directly as a raw material, e.g. some kinds of plastics and glass. Furthermore, by application of an air separator a heavyweight fraction can accrue which is applied for energetic utilisation.~~

~~The composition of the waste that is not used as fuel is different than that of the waste IN and the waste OUT. It depends on the waste IN but also the type of treatment given. Material balances showing such differences as well as showing where the different components of the waste IN end up, have not been provided.~~

From ex-**Section 3.5.2 "Consumptions of preparation of waste fuel"**

~~**Consumptions in the preparation of waste fuel from municipal solid waste**~~
~~Table 3.29 below gives an overview of the plants that have provided data for this section.~~

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Table 3.29: Consumption examples for the preparation of fuels from MSW

~~Type of plant~~	~~Kind of solid waste fuel production~~	~~Capacity (kt/yr)~~	~~Energy consumption (MWh/yr)~~	~~Specific energy consumption (kWh/t input material)~~
~~Commercial waste processing plants~~	~~Soft/hard pellets~~	~~40~~	~~2400~~	~~109~~
~~Mechanical-biological waste treatment~~	~~Soft pellets, fluff~~	~~55~~	~~2300~~	~~38 – 56~~
~~Commercial waste processing plants~~	~~Soft pellets, fluff~~	~~65~~	~~1268 – 1902~~	~~40 – 59~~
~~MSW processing without a biological decomposition step~~		~~80~~	~~781~~	~~40~~
~~Mechanical-biological waste treatment~~	~~Fluff~~	~~100~~	~~5800~~	~~92~~
~~High calorific fraction from MSW processing and commercial waste processing plant~~	~~Soft pellets, fluff~~	~~100~~	~~315 – 405~~	~~32 – 41~~
~~Commercial waste processing plants~~	~~Soft pellets, fluff~~	~~100~~	~~1080 – 1620~~	~~36 – 54~~
~~Mechanical-biological waste treatment~~	~~High calorific fraction in bales~~	~~110~~	~~1870~~	~~17~~
~~Mechanical-biological waste treatment~~	~~Soft pellets, fluff~~	~~110~~	~~4000~~	~~33 – 40~~
~~Mechanical-biological waste treatment~~	~~Fluff~~	~~600~~	~~2760~~	
~~MSW processing without a biological decomposition step~~	~~Fluff~~	~~840~~	~~23650~~	~~30~~
~~Residual municipal solid waste treatment~~				~~60~~ ~~Separation: 8 – 15~~
~~Source~~~~: [30, Ecodeco 2002] [44, TWG 2003] [82, Pretz et al. 2003] [98, WT TWG 2004] [103, VROM 2004]~~				

Table 3.30: Consumption examples for the preparation of fuel from non-hazardous waste

~~Capacity (kt/yr)~~	~~Fuel consumption (GJ/yr)~~	~~Electricity consumption (MWh/yr)~~	~~Specific electricity consumption (kWh/t)~~	~~Specific water consumption (m^3/t)~~
~~65~~	~~38475~~	~~3575~~	~~55~~	~~0.078~~
~~86~~	~~0~~	~~5831~~	~~68~~	~~0.0019~~
~~100~~		~~1050~~	~~10.5~~	
~~Source:~~ ~~[44, TWG 2003]~~				

3.3.3.1 Emissions to air

Table 3.31 shows the different parameters measured at mechanical treatment plants of waste with calorific value. This table should be read together with Table 3.32 which shows, for each plant, the origin of the emissions and the associated abatement techniques.

The most commonly measured parameter is dust, which is treated mainly by means of a bag/fabric filter system. Some plants equipped with activated carbon adsorption and/or a biofilter also measure organic compounds (TOC, TVOC) and odour.

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Table 3.31: Emissions to air from mechanical treatment of waste with calorific value

Pollutant measured	Type of measurement	Plants concerned	Range (mg/Nm^3 except for flow and odour)	Number of measurements during the three reference years
Flow (Nm^3/h)	Continuous	35, 161, 280	17 000–125 000	NA
	Periodic	24, 32, 122, 269, 270, 277, 279-1, 278, 326, 361, 442, 615, 627, 632	1.8–190 000	Up to 6
	Estimated	133	NI	NA
Dust	Continuous$^{(1)}$	280	0.4–0.6	NA
	Periodic	24, 31, 32, 35, 122, 270, 273, 277, 279-1, 312, 326, 361, 442, 615, 627, 632	0.09–8.8$^{(2)}$	Up to 12
	Estimated	133	NI	NA
HCl	Periodic	277, 278	0.3–1.3	Up to 4
TVOC	Periodic	361	3.5	5
TOC	Continuous$^{(1)}$	280	31.9–34.5	NA
	Periodic	277, 278, 361,615	3.5–29	Up to 5
Odour (OU$_E$/m^3)	Periodic	32, 35, 278	274–1020	Up to 8
Cd	Periodic	24	0.003	6
Hg	Continuous$^{(1)}$	280	0.004–0.005	NA
	Periodic	24, 361	0.004–0.008	Up to 6
As	Periodic	24	0.004	6
Pb	Periodic	24	0.07	6
Cr	Periodic	24	0.006	6
Co (cobalt)	Periodic	24	0.005	6
Ni	Periodic	24	0.003	6
Zn	Periodic	24	0.09	6

(1) Yearly average.
(2) For this value of 8.8 mg/Nm^3, nine of the twelve provided values are estimated values at 10 mg/Nm^3. The average of the three real measurements is 5.3 mg/Nm^3.
For periodic measurements, the values are the average over the three reference years.
NA: not applicable
NI: no informtion

WORKING DRAFT IN PROGRESS

Table 3.32: Mechanical treatment of waste with calorific value – Origin of emissions to air and associated abatement techniques

Plant code	Origin of emissions to air	Abatement techniques
24	Mechanical process	Bag/fabric filter system
31	Mechanical process	Bag/fabric filter system
32	Mechanical process	Activated carbon adsorption
	Mechanical process	Biofiltering
34	Mechanical process	Bag/fabric filter system
35	Storage & Mechanical process	Bag/fabric filter system Activated carbon adsorption Exhaust air is used as combustion air for incineration
115	No emissions to air from the mechanical process	NA
116	Mechanical process	Water spraying (dust)
117	NI	NI
122	NI	Bag/fabric filter system
133	Mechanical process	Bag/fabric filter system Cyclonic separation Water spraying (dust)
219	No emissions to air	High pressure fog system
269	Storage & Mechanical process	Bag/fabric filter system
270	Storage & Mechanical process	Bag/fabric filter system Water spraying (dust)
273	Storage & Mechanical process	Exhaust air is directed to a combustion plant
277	Storage & Mechanical process	Activated carbon adsorption Bag/fabric filter system
278	Storage & Mechanical process	Bag/fabric filter system Biofiltering Wet scrubbing
279-1	Mechanical process	Bag/fabric filter system
280	Mechanical process	Biofiltering Activated carbon adsorption Cyclonic separation Bag/fabric filter system
312	Mechanical process	Water spraying (dust) Bag/fabric filter system
325	No emissions to air	NA
326	Mechanical process	Bag/fabric filter system
361	Mechanical process	Bag/fabric filter system
442	Mechanical process, output sorting, transport and storage steps	Bag/fabric filter system
443	Mixed-waste shredder NA	Bag/fabric filter system
472	NI	NI
493	No emissions to air	NA
574	No emissions to air	NA
615	Storage & Mechanical process	Bag/fabric filter system
627	Storage & Mechanical process	Bag/fabric filter system Water spraying (dust)
632	Mechanical process	Bag/fabric filter system
633	NI	NI
NI: No information. NA: Not applicable.		

Figure 3.35 below shows the level of dust in air emissions from mechanical treatment of waste with calorific value.

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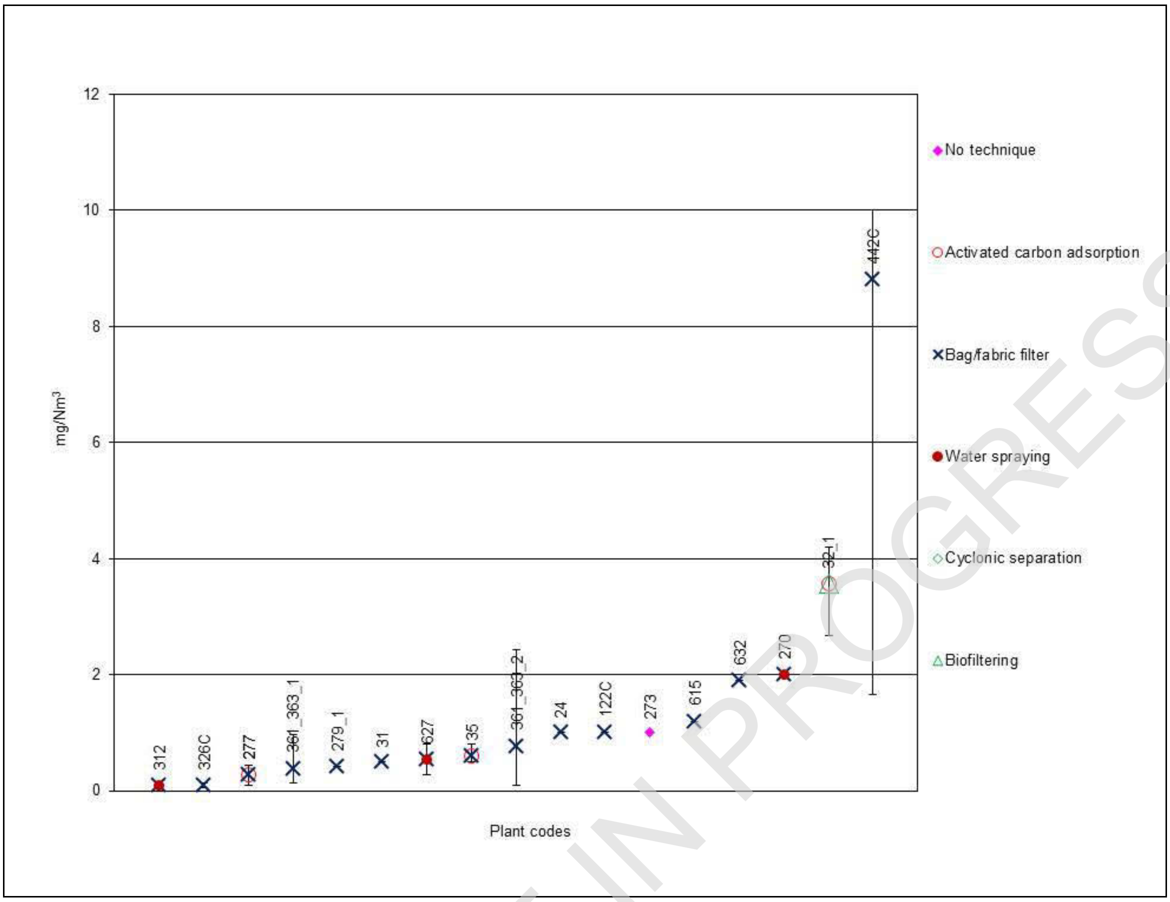

Figure 3.35: Dust emissions to air from mechanical treatment of waste with calorific value

3.3.3.2 Emissions to water

Table 3.33 shows the different parameters measured at mechanical treatment plants of waste with calorific value. This table should be read together with Table 3.34 which shows, for each plant, the origin of the emissions, the associated abatement techniques, and the point of release (direct or indirect discharge).

Out of 31 plants that participated in the data collection, 17 reported having no emissions to water from the mechanical process. Among 10 plants that reported having emissions to water (from the mechanical process and/or from storage or other common process steps), 9 reported releasing to a sewer system (indirect discharge). One plant (Plant 31) reported having direct discharge to the environment, which monitor THC (reported average concentration: 0.24 mg/l). Globally, the most measured parameters are pH, TSS and COD.

WORKING DRAFT IN PROGRESS

Table 3.33: Emissions to water from mechanical treatment of waste with calorific value

Pollutant measured	Monitoring	Plants concerned	Range (mg/l except for pH and flow)	Number of measurements
Flow (m^3/h)	Estimated	278, 361	0.07–7	3
pH	Grab sample	280, 361, 632	7.3–8.1	5 to 29
TSS	Grab sample	280, 361, 632	19–58	6 to 30
BOD_5	Grab sample	632	25	26
COD	Grab sample	280, 361, 632	38.3–95.7	6 to 30
THC	Grab sample	31, 361	0.2–1.3	3 to 6
Total P	Grab sample	361	2.9	6
Cd	Grab sample	361	0.006	6
Hg	Grab sample	361	0.0005	6
As	Grab sample	361	0.01	6
Pb	Grab sample	361	0.01	6
Cr	Grab sample	361	0.005	6
Cu	Grab sample	361	0.04	6
Mn	Grab sample	361	0.1	6
Ni	Grab sample	361	0.006	6
Zn	Grab sample	361	0.1	6
NB: The values are the minimum and maximum reported average of the measurements over the three reference years.				

WORKING DRAFT IN PROGRESS

Table 3.34: Mechanical treatment of waste with calorific value - Origin of emissions to water, abatement techniques used, and point of release

Plant code	Origin of emissions to water	Techniques used	Point of release
24	No emissions to water from the process	The used water is recirculated	NA
31	Storage and common steps	Oil separator	Direct discharge from the on-site common WWT facilities
32	No emissions to water from the process	NA	NA
34	No emissions to water from the process	NA	NA
35	NI	NI	NI
115	NI	No technique specific to the mechanical treatment of waste with calorific value	Indirect discharge from the WT plant to an on-site common WWTP
116	Storage and mechanical process	No technique	Indirect discharge (urban/municipal sewer system)
117	No emissions to water from the process. Leachate from storage is transported by truck to a municipal WWTP	NA	Indirect discharge (urban/municipal sewer system)
122	No emissions to water from the process	NA	NA
133	Mechanical process	API separator system	NI
219	No emissions to water from the process	NA	NA
269	No emissions to water from the process	NA	NA
270	NI	NI	NI
273	No emissions to water from the process	NA	NA
277	NI	NI	NI
278	Wet scrubbing No emissions to water from the process		Indirect discharge (urban/municipal sewer system)
279	NI	NI	NI
280	Segregated drainage system	Sedimentation (ponds)	Indirect discharge (urban/municipal sewer system)
312	No emissions to water from the process, only rainwater	NI	Indirect discharge (urban/municipal sewer system)
325	No emissions to water from the process	NA	NA
326	No emissions to water from the process	NA	NA
361	Storage and mechanical process	Chemical oxidation Chemical precipitation Chemical reduction Coagulation Decantation Filtration	Indirect discharge (urban/municipal sewer system)
442	No emissions to water from the process	NA	NA

WORKING DRAFT IN PROGRESS

443	Storage	Decantation	Indirect discharge from the WT plant to an on-site common WWTP
472	NI	NI	NI
493	No emissions to water from the process	NA	NA
574	No emissions to water from the process	NA	NA
615	No emissions to water from the process	NA	NA
627	No emissions to water from the process	NA	NA
632	Road water, roof water	NI	Indirect discharge (urban/municipal sewer system)
633	NI	NI	NI
NI: No information. NA: Not applicable.			

3.3.3.3 Water usage

Mechanical treatment of waste with calorific value is a dry process. Water may be used for cleaning, and for wet scrubbing or water spraying (dust abatement). The annual amount of water used, according to the data collection, ranges from 22 m^3 to 16 400 m^3 (of which 5000 m^3/year is recycled).

This corresponds to a specific water usage ranging from 2 litres to 800 litres per tonne of waste treated.

3.3.3.4 Energy consumption

Electricity is the main energy source. Some plants also provided information on the use of energy from fossil fuels. From the provided data, the range of energy consumption is from around 700 MWh/year to 12 000 MWh/year, with an average of around 3000 MWh/year.

The specific energy consumption varies strongly, from 11.7 kWh to 260 kWh per tonne of waste treated, with an average of around 54 kWh/t.

The specific electricity consumption varies from 6.3 kWh/t to 152 kWh/t, with an average of around 43 kWh/t.

3.3.3.5 Raw material consumption

The data collection gives the following information on raw material consumption.

- Activated carbon (air emissions treatment):
  - Plant 32 provides an estimate of the annual use of activated carbon of 5.5 m^3;
  - Plant 280 indicates the use of 15 t/year;
  - Plant 35 indicates that a complete exchange of the activated carbon represents 40 tonnes, and is expected three times a year.
- Other:
  - Plant 472 indicates the use of 1 tonne of oils in 2011, and 5 tonnes of oils in 2012;
  - Plant 574 indicates the use of 10 litres of chemicals for odour reduction;
  - Plant 24 indicates the use of 488 t/year (average over the three reference years) of lime powder for the density separation process step.

WORKING DRAFT IN PROGRESS

3.3.4 Techniques to consider in the determination of BAT

From ex-Section **4.5.3 Techniques for preparation of solid waste fuel**

~~This section contains techniques applied to the preparation of solid waste fuel from hazardous and non-hazardous waste. The applicability sections for these techniques give more guidance as to where the techniques are applied. However, techniques in Sections to are relevant for any type of waste. Techniques in Sections to 5.3.2.1.2 are mainly applicable to non-hazardous waste. Only one technique specifically for hazardous waste has been included and is in Section~~

Ex-Section 4.5.3.1 **Selection of techniques used for the preparation of solid waste** deleted as the general techniques are mentioned in Section 2.3

~~**Description**~~
~~Some techniques include:~~

~~a. classifying solid waste (e.g. household waste) and crushing the bulky fraction waste before the sorting operation~~
~~b. applying a magnetic separator~~
~~c. carrying out the mixing and sieving operations in closed areas~~
~~d. using nitrogen mixing devices to make the atmosphere inert when there is risk of explosion.~~

~~**Achieved environmental benefits**~~
~~Classifying and crushing operations are essential to achieve satisfactory sorting results and to facilitate the subsequent thermal treatment. Other reasons are that these techniques may also prevent indirectly fugitive emissions of dust and VOC.~~

~~**Operational data**~~
~~Size reduction requires much energy at high costs but maybe inevitable in cases with bulky material.~~

~~**Applicability**~~
~~Hazardous and non-hazardous waste. Technique a in the description section above is not adapted to the production of waste fuel from hazardous waste. This technique might be advantageous but there are other strategies which work as well. Technique d is applied to hazardous waste with risk of explosion.~~

~~Some special wastes from non-hazardous waste preparation may not need some of the special techniques mentioned above. Some examples identified are the installations which produce waste fuels from source separated streams e.g. waste from cuttings from plastic manufacturing or wastes from the processing of waste paper. However, this exception depends on the experience of the WT operator with the specific waste. That means that the WT operator should know the customer(s) quite well, the composition of waste processed and the way the customer collects the waste. Only in this way can parts which may otherwise cause problems in the WT installation or in the quality of the waste fuel produced be avoided.~~

~~**Driving force for implementation**~~
~~Technique d from the description section above is typically regulated by legislation addressed to prevent accidents.~~

~~**Example plants**~~
~~The safety of the mixing device can be ensured by adding nitrogen to make the waste inert. The resultant reduction of the oxygen content (working conditions between 6 to 8 % of oxygen) is by the addition of nitrogen to make the atmosphere inert. For example, such a technique allows waste with a flashpoint of lower than 0 °C to be mixed.~~

~~**Reference literature**~~
~~[78, Eucopro 2003] [82, Pretz et al. 2003][98, WT TWG 2004] [100, WT TWG 2004]~~

WORKING DRAFT IN PROGRESS

3.3.4.1 Techniques for the prevention or reduction of emissions to air

3.3.4.1.1 Reduction of dust emissions

3.3.4.1.1.1 Fabric filter

Description
See Section 2.3.4.4.

Technical description
See the CWW BREF [138, COM 2014]

Achieved environmental benefits
The achieved environmental benefits of this technique include the reduction of dust emissions to air.

Environmental performance and operational data
Table 3.35 below presents dust emissions to air from mechanical treatment of waste with calorific value equipped with a bag/fabric filter system.

WORKING DRAFT IN PROGRESS

Table 3.35: Dust emissions to air from mechanical treatment of waste with calorific value equipped with a bag/fabric filter system

Plant code	Capacity (t/day)	Origin of emissions to air	Air flow (Nm^3/h) Average over the three reference years	Dust emission concentration (mg/Nm^3) Average over the three reference years	Number of measurements during the three reference years	Waste input	Output type
24	300	Mechanical process	68 000	1	6	Shredder light fraction Shredder heavy fraction	Ferrous metal Non-ferrous metal Mixed plastics Fluff Residues from sorting
31	450	Mechanical process	NI	0.5	1	Mixed municipal waste, plastics, wood, etc.	SRF Residues from shredding Ferrous metal Non-ferrous metal
35	1200	Storage & Mechanical process	NI	0.6	6	Household waste; industrial waste; bulk waste	RDF Ferrous metal Non-ferrous metal
122	400	NI	19 000	1	2	Construction and demolition wastes	Ferrous metal SRF Wood Non-ferrous metal Residues from sorting Fine fraction
270	320	Storage & Mechanical process	50 000	2	1	Bulky waste, mixed plastics, sorting residues	SRF Residues from sorting Ferrous metal
277	280	Storage & Mechanical process	45 000	0.3	4	Mixed plastics, plastics, mixed package	SRF Residues from sorting Ferrous metal Non-ferrous metal
279	250	Mechanical process	36 000	0.4	1	Waste pretreated in sorting plant: high calorific fractions from MSW and bulky waste, wastes directly delivered to the plant	SRF Ferrous metal Non-ferrous metal Residues from sorting

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280	800	Mechanical process	NI	0.6[(1)]	NA	Municipal Wastes (household waste and similar commercial wastes)	RDF Ferrous metal Non-ferrous metal Immobilised solid waste
312	320	Mechanical process	NI	0.1	3	Hazardous and non-hazardous wood waste	Wood Ferrous metal Other
326	120	Mechanical process	1.7	0.1	3	Wastes from mechanical treatment of waste (e.g. sorting, crushing, compacting, palletising), construction and demolition wastes	RDF Residues from sorting
361	1120	Mechanical process	32 000	0.4	9	Mixed waste containing plastic, rubber, wood, etc.	Other (waste with calorific value)
	1120	Mechanical process, output sorting, transport and storage steps	190 000	0.7	9	Mixed waste containing plastic, rubber, wood, etc.	
615	400	Storage & Mechanical process	45 000	1.2	1	High calorific waste from mechanical treatment, mixed plastics from packaging sorting	SRF
627	450	Mechanical process	16 000	0.5	3	Waste wood	Wood Non-ferrous metal Ferrous metal
632	300	Mechanical process	45 000	1.9	3	Mixed municipal waste, sorting residues of selective collection, sorting residues of paper activity	RDF Ferrous metal Paper Wood Residues from sorting

(1) Continuous measurement. Yearly average.
NA: not applicable

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Cross-media effects
See the CWW BREF [138, COM 2014]

Technical considerations relevant to applicability
See the CWW BREF [138, COM 2014]

Economics
See the CWW BREF [138, COM 2014]

Driving force for implementation
Environmental legislation.

Example plants
See Table 3.35.

Reference literature
[160, WT TWG 2014]

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4 BIOLOGICAL TREATMENTS OF WASTE

From ex-Section **3.2.1 Emissions and consumptions from biological treatments**

~~[20, ETSU 1998] [29, Inertec; dechets, F. and Sita 2002] [32, Vrancken et al. 2001] [33, UK EA 2001] [1, Langenkamp H. 1997] [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [44, TWG 2003] [54, EEA 2003] [58, VDI and Dechema 2002] [60, WT TWG 2003] [71, COWI A/S 2002] [92, Lanfranchi, B. 2003] [98, WT TWG 2004]~~

~~This section discusses the emissions and consumptions of the biological treatments mentioned in Section 3.3.3. Each section of this Section 3.2 is structured in the same way as Section 3.3.3, namely the treatments follow the order of: emissions and consumptions of anaerobic digestion, mechanical biological treatments and lastly biological treatments applied to contaminated soil. Emissions associated with an ancillary treatment, e.g. transfer station operation, are covered in Section 3.1.~~

From **ex-Section 2.2.** The aerobic treatment of contaminated soil (only three plants are in the reference list) is dealt with in PCT.

[18, Greenpeace 2001], [19, DETR and DTI 2001], [20, ETSU 1998], [29, Inertec; dechets, F. and Sita 2002], [31, LaGrega et al. 1994], [32, Vrancken et al. 2001], [33, UK EA 2001], [34, Babtie Group Ltd 2002], [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002], [57, Petts, J. and Eduljee, G. 1994], [58, VDI and Dechema 2002], [60, WT TWG 2003], [72, Hogg, D. 2001], [74, EC DG ENV 2001], [88, UBA Germany 2003], [92, Lanfranchi, B. 2003], [98, WT TWG 2004].

4.1 General overview

Biological treatments use~~s~~ living microorganisms to decompose organic wastes~~s~~ into either water, CO_2 and simple inorganics or into simpler organics such as aldehydes and acids. There are several biological treatments used for the treatment of waste~~s~~, however, not all are included in the Scope of this document.

Table 4.1, together with information included in the Scope section, tries to clarify which treatments are included in this document.

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Table 4.1: Biological treatments of waste

Biological treatment	Brief description	Included in this document?
Aerobic treatment (including composting)	Reduction of the organic content of wastes. Applied to solid waste, non-continuous waste waters, bioremediation and to sludge and soil contaminated with oil. Composting consists of building ~~‘engineered’~~ mounds of waste ~~are built~~ to encourage the ~~biological breakdown~~ aerobic digestion of organic solids, producing a humic substance valuable as a soil conditioner	~~Not included in this document~~ See Section 4.2. Only *ex situ* bioremediation of contaminated soil is covered in this document (see Section 5.6)
~~Aerobic digestion~~	~~Reduction of the organic content of waste. Applied to solid waste, non-continuous waste waters, bioremediation and to sludge and soil contaminated with oil~~	~~Mechanical biological treatment~~ ~~Only ex-situ bioremediation covered in this document~~
Anaerobic treatment (or anaerobic digestion - AD)	Decomposes organic ~~matter~~ content of wastes in closed vessels in the absence of air. Uses two forms of bacteria: acid-forming and methane- forming. Applied to solid-liquid wastes, highly contaminated waste waters (e.g. chlorinated compounds), bioremediation and in the production of biogas to be used as a fuel	See Section 4.2.2.2.5. ~~and~~ Only ~~covered the~~ *ex situ* bioremediation is covered (see Section 5.6)
Mechanical biological treatment (MBT)	Combination of mechanical and biological (aerobic and/or anaerobic) treatments	See Section 4.4
Biodrying	A typical biodrying reactor includes a series of discrete, enclosed containers coupled with an aeration system or a large biodrying hall where batches of waste are progressively moved through the hall by a mechanical load crane (wandering heap)	See Section 4.2.1
Activated sludge	Decomposes organic wastes in water by exposing them to biological growth. Water is recycled and aerated to facilitate biological action and a sludge is generated. Two commonly applied systems: suspended growth systems and attached growth systems	Included as a waste water treatment (see Section 2.3.6)
Aerated lagoons	Large lagoons containing high concentrations of microorganisms. The lagoon is aerated to encourage bacterial growth and decomposition of waste	Included as a waste water treatment (see Section 2.3.6)

Biological treatments of waste water are dealt with in Section 2.3.6.6 and Section 5.6.

As the three processes addressed in this chapter (aerobic treatment, anaerobic treatment and MBT) have many commonalities and in order to avoid repetitions, the structure of chapter 4 is sligthly different than the structures of Chapters 3 and 5: the techniques to consider in the determination of BAT are not presented in each subsection dedictated to one of the three processes mentioned before but at the very end of the chapter.

From ex-Section 4.2.

~~This section contains techniques considered to have a good environmental operating performance (e.g use of a good energy system) or that can help lead to a good environmental performance (e.g. environmental management systems). These techniques are applied with biological treatments typically used as part of a whole waste treatment. Biological treatments of waste waters are covered in Section~~

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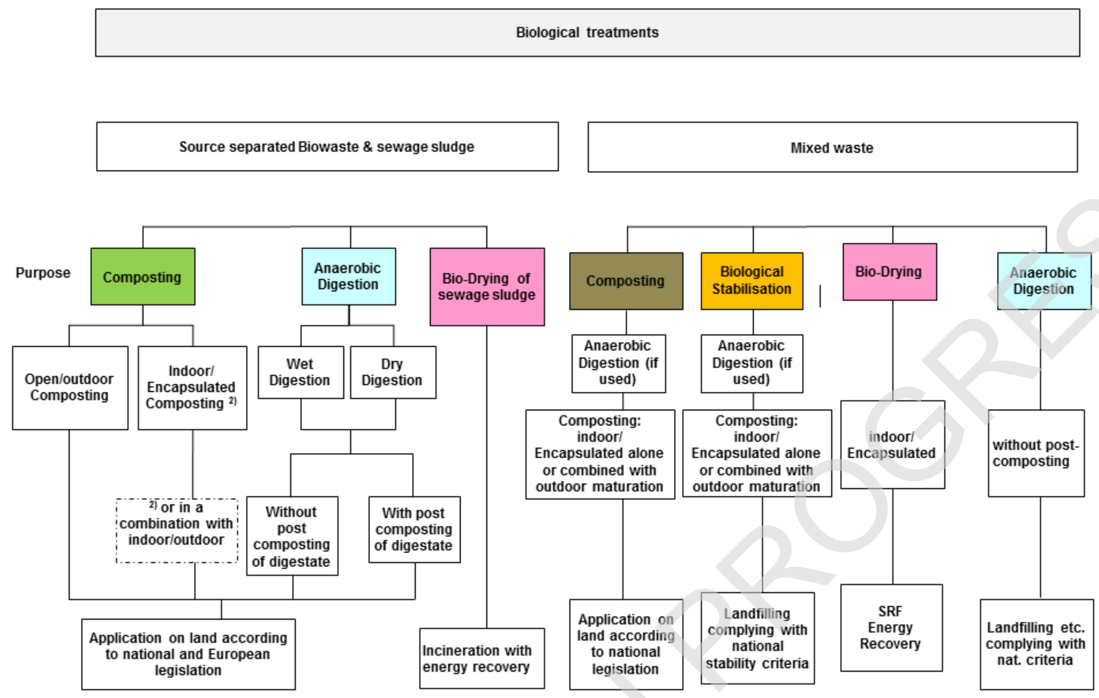
Figure 4.1 below gives a scheme of the biological treatment route.



Source: [110, Bio. Subgroup 2014]

Figure 4.1: Biological treatment route

From ex-Section 3.2.1

Generally, ~~successful~~ biological treatment ~~only occurs~~ is successful only when the waste is non-toxic (although microorganisms can acclimatise to some extent and to certain wastes), within the relatively narrow pH range of pH 4–8, and with a C:N:P ratio of around 100:5:1. Biological treatment is, if well prepared, able to be adapted to a great variety of organic compounds which can be found in wastes or contaminated ground.

From ex-Section 3.2.3 Emissions from biological treatments.

The specific emissions from biological treatments depend on:

1. the volatile components ~~already being a content of the~~ present in the feedstock,
2. the amount and type of waste being treated, and
3. ~~on~~ the type of treatment.

~~For example, wastes derived from biological sources (such as rendering or food industry effluents) are less likely to produce high emission loads. Thus, e.g. the emissions (loads of TOC, methane, N_2O, ammonia, etc.) from the biological treatment of separately collected biowaste (not covered in this document) are comparable to the emissions from the biological treatment of MSW and sludge except for some volatile VOC ingredients from MSW (e.g. fluorinated chlorinated hydrocarbons).~~

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~~heavy metals in the original material will be well mixed with the rest of the material, by dissolution, extraction or simply by being torn into small pieces during the operation.~~

A common characteristic of biological treatments of wastes is that heavy metals and other non-biodegradable components are subjected to dilution by mixing, and dissolution in the aqueous phase, and therefore become part of the body of the microorganisms~~, concentration by loss of moisture and weight and so on.~~ In general, heavy metal compounds are not selectively separated from the waste and not selectively concentrated ~~to~~ in a target output material.

Volatile chemical constituents are the most likely to result in fugitive air emissions, together with ammonia. Municipal wastes ~~tend to produce~~ are more likely to lead to the presence of metals in the effluent or sludge.

WORKING DRAFT IN PROGRESS

4.2 Aerobic treatment (including composting)

4.2.1 Applied processes and techniques

Purpose

To convert biodegradable waste into compost that is safe for humans, animals and plants, and that is recyclable mainly as a fertiliser or, in a lower proportion, recovered as a fuel.

Exothermic biochemical decomposition helps to sanitise compost, killing off seeds, spores and pathogenic microorganisms.

Principle of operation

Aerobic digestion of waste is the natural biological degradation and purification process in which bacteria that thrive in oxygen-rich environments break down and digest the waste.

During the oxidation process, pollutants are broken down into carbon dioxide (CO_2), water (H_2O), nitrates, sulphates and biomass (microorganisms).

For decomposition to take place in the shortest possible time, input materials must be a mixture of easily degradable, wet organic substances and structure-improving organic matter. Structure-improving materials are needed to create structure with adequate air-filled porosity and a high number of pores in the pile when air conductivity is low [136, Bidlingmaier et al. 1998]. The water content is at least 25–35 % up to a maximum of 75 %. As a rule, water contents between 50 % and 65 % are particularly beneficial, although this depends on the type of feedstock and its structure.

C:N ratios of 10:1 and 35:1 are considered favourable to supply microorganisms with nutrients. Bulk density is an indicator of the quality of the input material's structure.

Feed and output stream

Separately collected organic waste and green waste (garden and park waste) are the main feedstock entering aerobic treatment plants.

Operating materials used in composting plants are: water, sulphuric acid, sulphurous acid, lubricants and oils, and gas oil. Water is also used as an additive (process water).

As an example, **Table 4.2** below shows the average composition of the feedstock entering German composting plants in 2009, depending on the plant capacities.

Table 4.2: Average input to German composting plants by size

Type of waste	Proportion of input	
	Plant size 10–30 t/year	Plant size > 30 t/year
Separately collected organic waste	52 %	68 %
Green waste (garden and park waste)	37 %	26 %
Commercial catering waste	0 %	0 %
Waste from the food industry	1 %	1 %
Animal by-products	0 %	0 %
Auxiliary agents and additives	2 %	0 %
Sewage sludge	6 %	2 %
Renewable raw materials or their residues	0 %	1 %
Production waste	1 %	0 %
Other	0 %	2 %

Source: [111, UBA Germany 2013]

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The output of the plants is mainly compost (fresh or mature), but also fuel.

Process description

A basic design for composting plants involves four main steps: reception, preparation, composting, and finalisation.

- Reception: weighing and monitoring the waste input

  The characteristics and quantity of the waste input are recorded in the reception area or by the supplier by means of above-ground or flush-mounted floor scales, or by flow-rate meters. Quality checks consist of visual inspections or of reference samples analysis.
  The design of the reception area (e.g. way of discharging the feedstock, encapsulation of the reception area) depends on the type of substrate, on air pollution control, and on hygiene requirements. Flat or recessed bunkers and tanks provide a buffer.

- Preparation:
  - Manual sorting

  If necessary, unwanted large non-biodegradable materials are removed by hand.
  - Shredding

  The purpose of shredding is to better prepare the organic waste input for biological treatment: breaking open packaging, homogenising the feedstock, etc. Shredders are fed by wheel loader, crane and other conveying systems, or by means of belt and auger conveyors. Depending on the feedstock, the shredding can take place either before or after the sorting step.
  - Automatic sorting and homogenising

  Drum screens are frequently used to classify and homogenise material. When necessary, metals, plastic, and other non-biodegradable materials are removed, by means of magnetic and eddy current separators and air classifiers respectively.

- Composting:
  - Intensive decomposition

  Intensive decomposition occurs during the first two to three weeks of the process, when the degradation curve is very steep. Most of the emissions are linked to this phase: aerobic degradation releases carbon dioxide, water, ammonia and heat. The temperature of the rotting material climbs to up 70 °C in the pile.
  Water content, aeration, and temperature are the key composting process control parameters. Enclosing or encapsulating the intensive decomposition process step reduces emissions from composting plants.

  Aeration
  Oxygen availability is crucial to maintain aerobic degradation and for preventing the formation of anaerobic zones releasing methane. Furthermore, the aeration system simultaneously removes heat and moisture from the windrow. This prevents the windrow from overheating, but also dries out the material.

  By operating the oxygen supply with aerators**,** the process can be significantly accelerated. Due to the high oxygen demand, active aeration is typically required during intensive decomposition. Active aeration can be done by blowing or by suction through slatted floors.

  Although blowing generally leads to a quicker and better decomposition, it blows the exhaust air to the surroundings and/or into the composting hall. Suction eases the emissions collection, the protection against corrosion in the hall, and, except in the case of tunnel composting where workers do not enter, facilitates maintenance of the required working conditions.

  - Maturation

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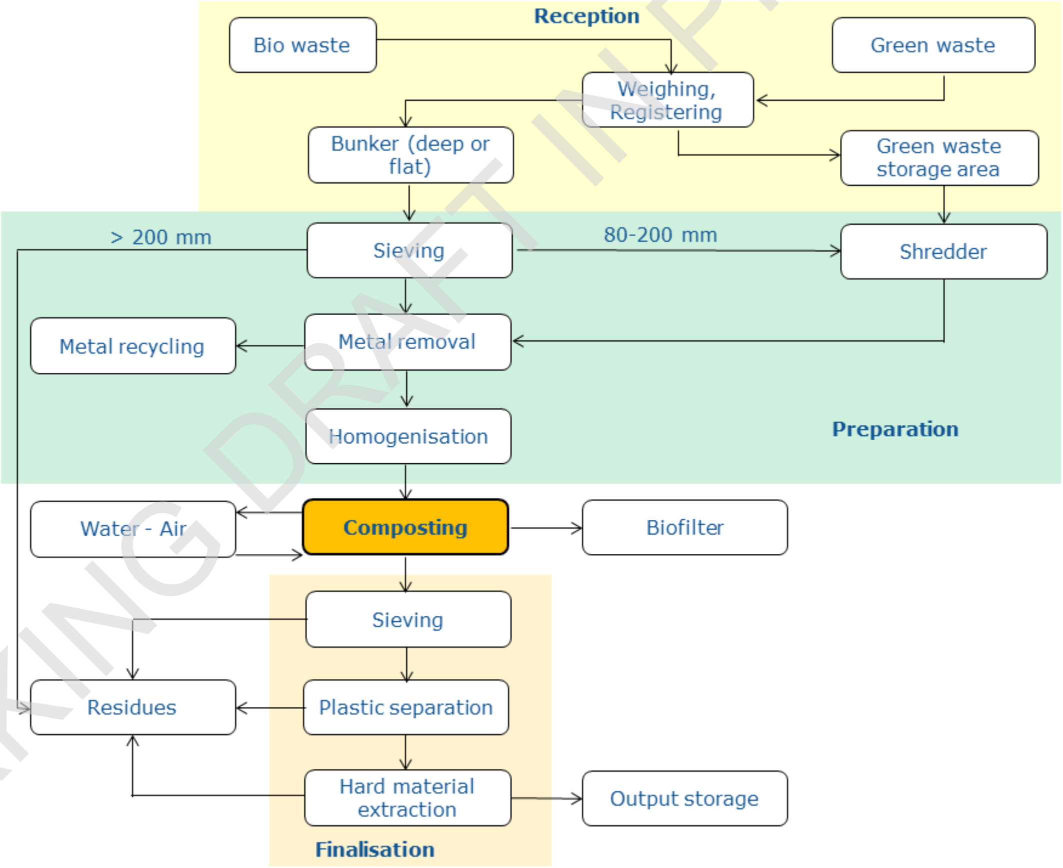
Depending on the process, the feedstock, and the expected output quality, a maturation step may be needed. This step lasts from six to twelve weeks. Maturation generally takes place in table or triangular windrows. Undecomposed materials remaining after the intensive decomposition release humic substances during the maturation phase. Macro-organisms (e.g. earthworms and enchytraeids) that mix and reduce the size of the compost move in as the temperature is now lower.

- Finalisation
  When required, the compost is sent to a final treatment. This step includes size classification and removal of any remaining impurities (e.g. glass and plastics), by means of drum screens and air classifiers.

  Composting plants do not have a separate sanitation stage because self-heating within the windrows ensures sanitation. Measures to prevent any possible cross-contamination of the sanitised compost include: having strictly separate clean and dirty areas (this also applies to the use of technology, e.g. wheel loaders with exchangeable buckets), banning the addition of fresh material after the main composting stage, and only irrigating windrows with percolation water during thermophilic composting (around 55 °C).

Figure 4.2 below illustrates these main steps.



Source: [111, UBA Germany 2013]

Figure 4.2: **Basic design of composting plant**

Types of composting process
The key distinction between the different composting processes relates to the construction of the biological stage in which decomposition is the most intense. A further distinction is to be made with regards to how the composting plant and the windrow itself are built.

The second distinguishing feature relates to the way that the composting plant operates. Plants can have active or passive ventilation systems, dynamic windrows (continuously turning, as in

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composting drums), semi-dynamic windrows (rotting material is turned or mixed by machines) and static windrows (no turning).

- 'Brikollare' system

The Brikollare technique presses shredded feedstock into small briquettes and transfers them on pallets to a composting hall. These mouldings have a water content of 50 % to a maximum of 62 %. The capillary motion expels water inside the briquettes. At the same time, aerobic decomposition processes begin, leading to strong fungal growth and warming the rotting material to almost 70 °C. Biological decomposition and desiccation occur simultaneously and result in a stable, water-repellent product with a residual moisture content of around 20 % after three to six weeks. [128, Kern et al. 2010]

- Drum composting

A few plants start the biological treatment in a steel drum that rotates very slowly. The feedstock is shredded and homogenised, improving the bioavailability and aeration of the mixture. Integrated nozzles can also inject moisture when necessary. The residence time stands at one to seven days. Material then undergoes additional composting using other technologies. Just a few plants use composting drums because of their high operating costs.

- Box, container and tunnel composting

These technologies perform intensive decomposition in an enclosed space with forced aeration that captures all exhaust air. Fresh compost is typically produced once the intensive decomposition stage ends (decomposition grade I or II). Material can then undergo maturation in a triangular or table windrow or be returned to the bioreactor (tunnel, box or container) if additional processing is desired (decomposition grade III to V). [128, Kern et al. 2010]

- Linear composting

This technology consists of fortified open-air composting lines, each of them being individually actively aerated. Special turning machinery turns the windrows line by line. The composting process takes from two weeks (producing solely fresh compost) to twelve weeks. Linear composting is used for both intensive decomposition and maturation.

- Table windrows

Table windrows are oversized windrows, typically set up throughout almost an entire hall. Automatic turning machinery (bucket wheel or screw system) turns these windrows. A ventilation floor provides active aeration. The aeration floor is divided into segments, allowing the aeration intensity to be adjusted based on the material decomposition.

- Triangular windrows

Triangular windrows are laid out in elongated lines in a hall, or in an enclosure covered by a roof, or in the open air. Material is stacked, e.g. by a wheel loader, and turned by a wheel loader or a windrow turner. Triangular windrows mostly employ passive aeration and are largely used for maturation when the oxygen demand is no longer too high.

- Triangular and linear windrows under a semipermeable membrane

Semipermeable membrane covers are a hybrid form of tunnel or in-vessel composting and covered windrow composting. The semipermeable membrane cover, which is water-resistant but also permeable to gas and steam, protects against water-logging. The cover and the active aeration it provides create composting conditions under which odours, VOCs and other emissions are largely contained.

TWG please provide photos or figures of the different types of composting

- Biodrying

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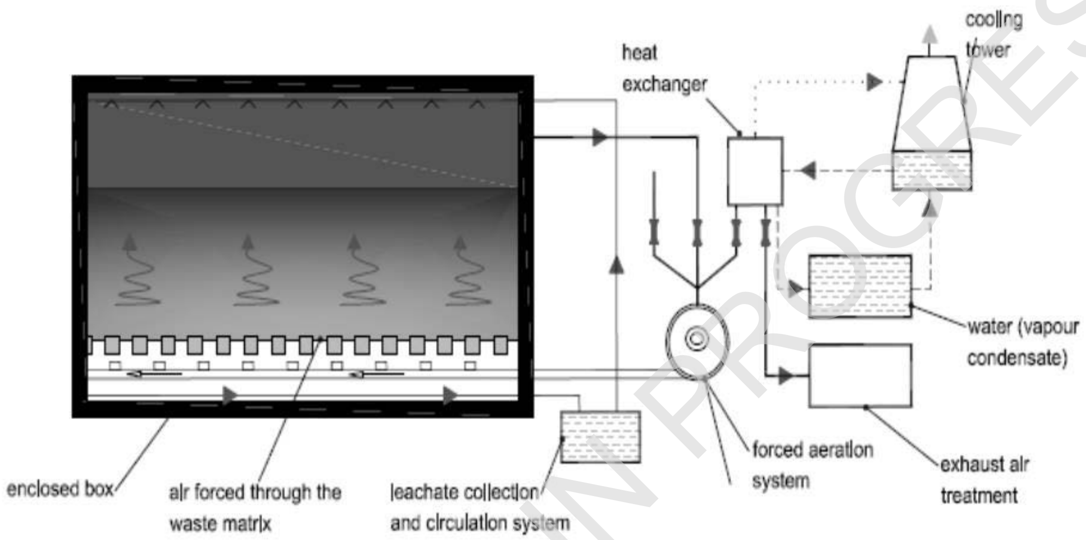
A typical biodrying reactor will include a series of discrete, enclosed containers coupled with an aeration system or a large biodrying hall where batches of waste are progressively moved through the hall by a mechanical load crane (wandering heap). Each of the containers used will require an aeration and emissions management system to achieve optimum drying conditions and reduce the potential for emissions.

A typical configuration for a biodrying reactor is shown in Figure 4.3 below.



Source: [113, UK 2013]

Figure 4.3: Biodrying process schematic

Biodrying uses the heat released during the aerobic decomposition of the readily degradable organic material to drive moisture out of the organic waste pile in combination with the application of excess aeration to the waste mass. By removing the moisture inherent in the waste, an RDF material can be produced.

Moisture loss can be controlled through the air flow rate, which should coincide with the temperature profiles. The specific humidity of air (i.e. the amount of water in the gas phase) will increase with the temperature. Evaporation of water from the organic waste pile will increase at increased air flow rates, leading to a significant loss of energy in the form of heat from the waste mass.

The process will also deplete the energy content of the wastes. The process of drying can also be accelerated by introducing supplementary heat from gas or biogas burners or waste heat from gas engine exhausts where AD units are a combined treatment option.

Gas and air offtake treatment from process areas needs special consideration as the air flow is acidic and usually hot.
[113, UK 2013]

Potential emissions
Potential emissions from composting are:

- Odourous emissions due to the degradation of organic primary substances;
- dust and bioaerosols during handling of the materials;
- further gaseous emissions (VOCs, NH_3, N_2O, CH_4);
- noise caused by aeration and turning devices;
- material drifting during manipulation;
- liquids (e.g. process, condensate, run-off water).

WORKING DRAFT IN PROGRESS

Abatement techniques used to reduce emissions to air are open or enclosed biofilters, dust filters, or acidic scrubbers.

Users
See list of plants in Table 4.5 and Table 4.11.

Reference literature
[111, UBA Germany 2013] [109, Bio. subgroup 2014] [128, Kern et al. 2010] [154, Umweltbundesamt 2015]

~~**Aerobic digestion of slurries**~~

4.2.2 Current emission and consumption levels

4.2.2.1 Outdoor aerobic treatment

4.2.2.1.1 Emissions to air

In open/outdoor aerobic treatment plants, emissions to air are diffuse emissions, inherently providing little or no options for direct regular monitoring of channelled emission components. This is confirmed by
Table 4.3: only 7 out of 28 plants for which data have been collected measure emissions to air. All plants measuring bioaerosols are located in the UK.

Table 4.3: Parameters measured in emissions to air at outdoor aerobic treatment plants

Parameter measured	Type of measurement	Plants concerned
Odour	Periodic	110, 125, 262, 544, 548
NH_3	Periodic	410_411_2
Bioaerosols	Periodic	544, 546, 548
Other: specific types of bioaerosols (e.g. Aspergilus Fumigatus)	Periodic	544, 548

As there are no end-of-pipe abatement techniques, quality and operational process management aiming at the minimisation of emissions to air, specifically in the case of odour, dust and bioaerosols, as well as the selection of a suitable location for the outdoor composting plant are of utmost importance.

Regarding bioaerosols, there is currently no international consensus on the method or indicator that can be used as the preferred metric to assess the health risk of bioaerosol emissions. As a consequence, there is also no consensus as to whether bioaerosol monitoring can be used to effectively check that environmental limits are being achieved and control measures are operating. Within the EU, only the UK and Germany have implemented additional monitoring requirements related to bioaerosols, for which national guidelines have been established.

Figure 4.4 shows the emissions of odour at the plants mentioned in Table 4.3. It should be noted that:

- there are no abatement techniques in these cases ('other' refers to the control of waste input and maintain of aerobic conditions);
- it is not possible to compare the emissions as the results are highly dependent on the sampling method (location, distance, etc.)

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;

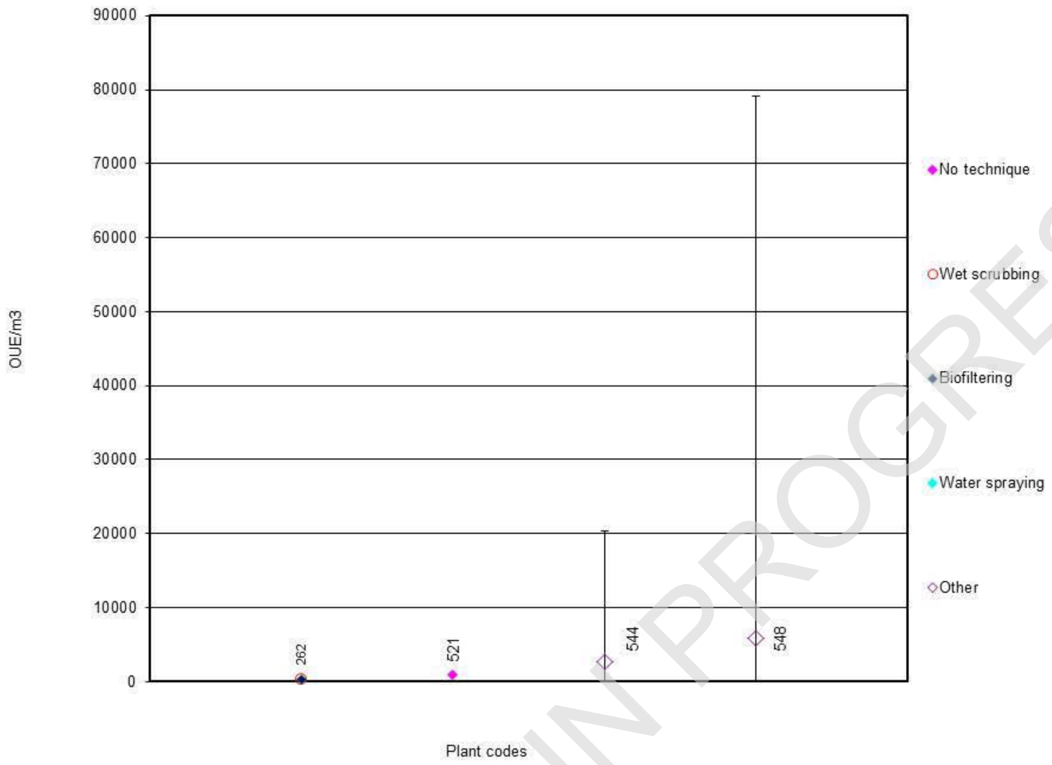

Figure 4.4: Odour emissions in outdoor aerobic treatment plants

4.2.2.1.2 Emissions to water

Composting can generate leachate as a result of high moisture levels in bio-waste and putrescible waste, and from natural precipitation seeping through active or curing compost piles. Waste water also consists of run-off water that has fallen on storage and/or treatment areas, and of washing water that is used to clean plant/equipment and surfaces.

Run-off water from roofs or from areas that are not used for storing and treating waste are considered ‘clean’ water and may be discharged directly to the environment.

Table 4.4 shows the measurements of emissions to water performed by outdoor composting plants.

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Table 4.4: Parameters measured in emissions to water at outdoor composting plants

Parameter measured	Monitoring	Plants concerned	Range (mg/l except for pH and flow)	Number of measurements during the 3-year reference period (2010-2012)
Flow (m^3/h)	Continuous	021, 110, 410_411, 418, 521, 572	2.7-26	NA
	Grab sample	417	NI	NI
	Estimated	419	2	NI
pH	Continuous	419	7	NA
	24-hours proportional composite sample	418	7	NA
	Composite sample	110	8	NI
	Grab sample	021, 104, 125, 417, 521, 572	7.1-8.6	4-36
COD	24-hours proportional composite sample	418	4620	NA
	Composite sample	110	361	NI
	Grab sample	104, 417, 521, 572	175-948	1-12
	Estimated	419	2167	NI
Total N	24-hours proportional composite sample	418	420	NA
	Composite sample	110	171	NI
	Grab sample	104, 417, 521, 572	5.2-225	1-23
	Estimated	419	217	NI
Total P	24-hours proportional composite sample	418	26	NA
	Composite sample	110	1.7	NI
	Grab sample	104, 417, 572	4.8-5.8	6-26
TSS	Grab sample	104, 125, 521, 572	7.7-235	1-26
Pb	Composite sample	110	0.0031	NI
	Grab sample	021, 104, 572	0.0033-0.075	6-26
Cr	Composite sample	110	0.010	NI
	Grab sample	021, 104, 572	0.0002-0.024	6-26
BOD_5	Composite sample	110	32	NI
	Grab sample	104, 521	8-117	1-11
Cd	Composite sample	110	0.00008	NI
	Grab sample	021, 572	0.0002-0.024	6-26
Hg	Composite sample	110	0.0001	NI
	Grab sample	021, 572	0.0001-0.0006	6-26
Cu	Composite sample	110	0.03	NI
	Grab sample	021, 104, 572	0.01-0.09	6-26
Ni	Composite sample	110	0.04	NI
	Grab sample	021, 104, 572	0.02-0.03	6-26
TOC	Grab sample	021, 104	0.1-253.9	6-8
BOD_7	Grab sample	572	77.3	26
NH3-N	Composite sample	110	120	NI
	Grab sample	021	11.5	12
Zn	Grab sample	021, 104, 572	0.02-0.16	6-26
Co	Grab sample	021	NI	NI

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Mn	Grab sample	021	NI	NI
Sum metals	Grab sample	021	NI	NI
THC	Grab sample	021	1.6	12
Tl	Grab sample	021	NI	NI
Cd+Tl	Grab sample	021	NI	NI
Sb	Grab sample	021	NI	NI
As	Grab sample	021	NI	NI
Cr(VI)	Grab sample	021	NI	NI
V	Grab sample	021	NI	NI
Fe	Grab sample	021	NI	NI
Chlorine	Grab sample	021	NI	NI
Phenols	Grab sample	021	NI	NI
AOX	Grab sample	021	0.22	8

NA: Not applicable.
NI: No information

These measurements should be analysed in correlation with the types of emissions to water of each plant. Table 4.5 shows that not all plants release waste water and therefore measure emissions to water. For these plants, waste water may be reused in the process, or tankered for further treatment off site.

As far as plants with water release are concerned, the water is generally released to an urban/municipal sewer system or to a waste water treatment plant on site. There are only one case where the water is released directly to the environment, and three cases where waste waster is used for landspreading.

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Table 4.5: Origin of emissions to water and associated abatement techniques at outdoor composting plants

Plant code	Origin of emissions to water	Point of discharge	Abatement techniques
21	Biological process	Indirect discharge (urban/municipal sewer system)	NI
38	Biological process	NI	NI
69	NI	NI	NI
73	No emission to water: potentially polluted rainwater is collected, stored in a buffer tank and reused in the process	NA	NA
74	NI	NI	NI
104	Batch discharge of excess collected leachate from sedimentation basin	Indirect discharge (urban/municipal sewer system)	Sedimentation (ponds)
110	Run-off water collected from all areas (storage of input materials, processing and storage of final products)	Indirect discharge (urban/municipal sewer system)	Nitrification/denitrification
124	NI	NI	NI
125	Run-off water collected from storage, common steps and biological process areas	Landspreading	Aeration (rotation speed depending on oxygen rate) and extraction (silt storage and oil separator)
129	NI	NI	NI
262	NI	NI	NI
331	NI	NI	NI
410_411_2	First biodegradation Final dry maturation	Indirect discharge (urban/municipal sewer system)	NI
417	First biodegradation	Indirect discharge (urban/municipal sewer system)	Buffer tanks
418	First biodegradation	Indirect discharge (urban/municipal sewer system)	Aeration buffer tanks
419	First biodegradation	Indirect discharge (urban/municipal sewer system)	Aeration buffer tanks
521	Reed bed output	Direct discharge from the on-site common facility to the environment	Reed bed systems
525	No emissions to water	NA	NA
531	No emissions to water	NA	NA
544	All potentially contaminated water is collected	Landspreading	NA
546	All potentially contaminated water is collected	Landspreading	NA
547	All potentially contaminated water is collected and tankered away	NI	NA
548	All potentially contaminated water is collected and tankered away	NI	NA

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572	Biological process, final dry maturation (leachate water collected from the whole site)	Indirect discharge (urban/municipal sewer system)	NI
606	Run-off water from whole site	Indirect discharge (on-site common facilities mainly influenced by waste water streams coming from activities other than the aerobic treatment plant)	NI
622	Run-off water from whole site - tankering off site	Indirect discharge (urban/municipal sewer system)	NI
631	NI	NI	NI
635	NI	NI	NI
NI: No information. NA: Not applicable.			

The analysis of emissions to water from Plant 521 discharging directly to a water body after treatment is dealt with in Section 2.3.6.7.

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4.2.2.1.3 Water usage

Figure 4.5 shows the water usage per tonne of waste treated for different plants. It is difficult to draw any conclusions from this figure as the quantity of water used also depends in this case on the meteorological conditions.

The reported average water usage per tonne of waste treated is around 150 l/t, with a range of 10–730 l/t.

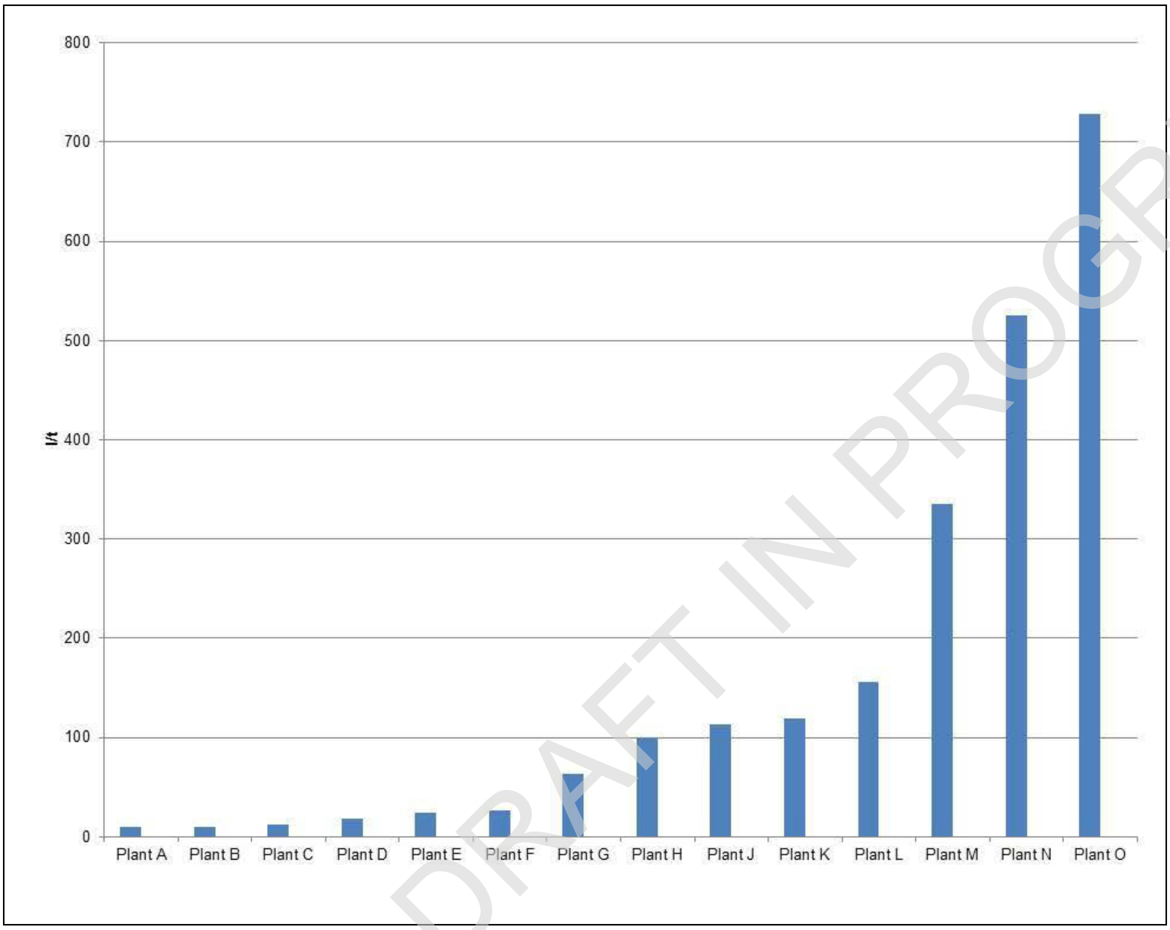

Figure 4.5: Water usage per tonne of waste treated in outdoor aerobic treatment plants

4.2.2.1.4 Energy consumption

Figure 4.6 shows the energy consumption per tonne of waste treated in outdoor aerobic treatment plants for different plants.

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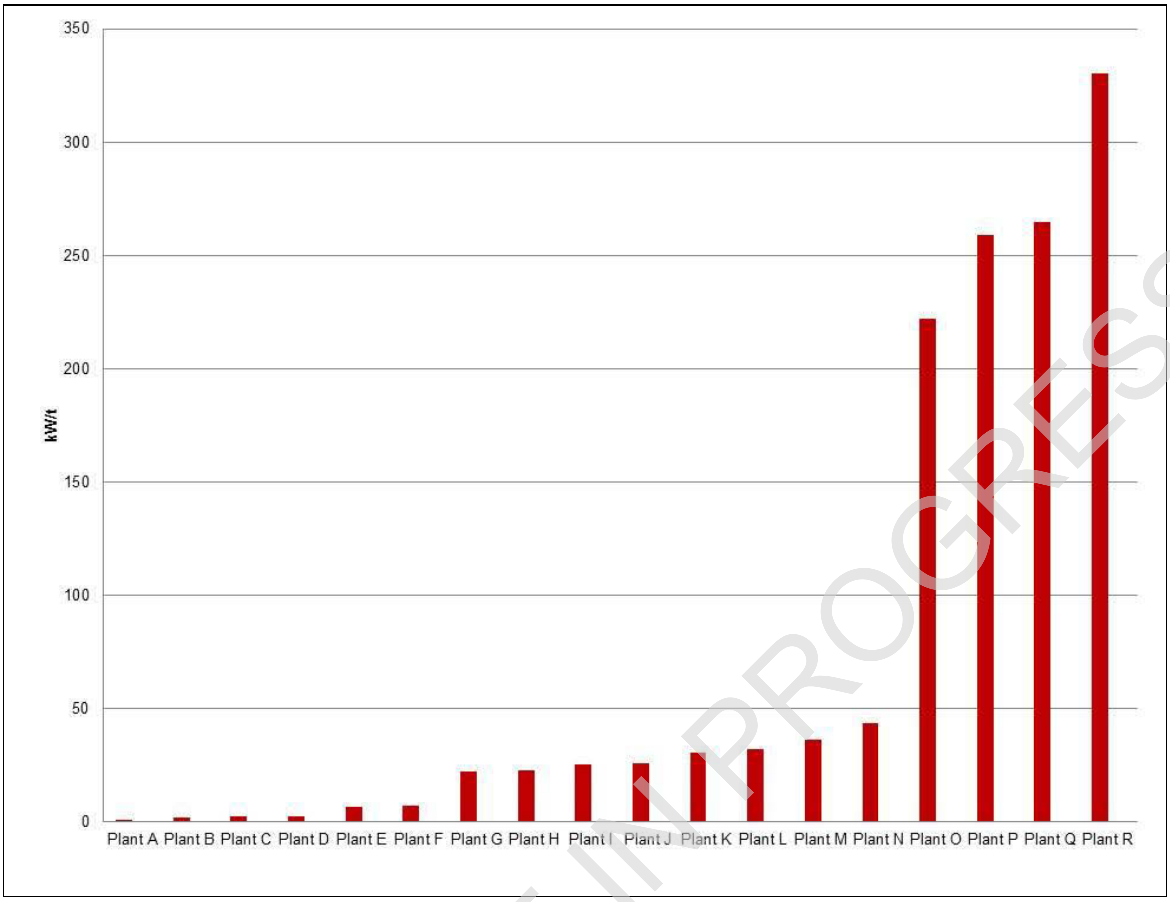

Figure 4.6: Energy consumption per tonne of waste treated in outdoor aerobic tretament plants

From the data reported, the specific energy consumption is around 74 kWh/t, with a range of 1–330 kWh/t.
The highest values were provided by plants where electricity is provided by a diesel engine generator.

4.2.2.1.5 Raw material consumption

Table 4.6 gives an illustration of the raw materials used in the outdoor aerobic treatment plants that took part in the data collection.

Table 4.6: Raw materials used by outdoor aerobic treatment plants

Auxiliary material	Amount used in waste treatment (t/year) Average over the three reference years
Straw	2749
Odour suppressant chemical with water spray system	2.1
Peat used in composting	95 530 m^3/year
Sand used in refining compost	30 683
Biotite used in refining compost	506
Adsorbent for H_2S	80

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4.2.2.2 Indoor aerobic treatment

4.2.2.2.1 Emissions to air

Table 4.7 shows the different parameters measured at indoor aerobic treatment plants as well as the type of measurement (periodic/continuous). This table should be read together with Table 4.8 which shows, for each plant, the origin of emissions to air, the associated abatement techniques and the flow of the emissions to air.

The most measured parameters are odour and NH_3 which are measured by plants equipped only with a biofilter, or a combination of a biofilter and a wet scrubber, or a combination of a biofilter and an acid scrubber. Some plants use only wet scrubbers (e.g. Plant 126 for the ambient air of the composting halls) or cyclones (e.g. Plant 460 for the waste reception hall). Finally, two plants (Plants 579 and 580) use semipermeable membranes as abatement techniques. In these cases, no information has been reported about measurement of emissions to air.

Concerning the measurement of bioaerosols, seven plants reported such monitoring, but for one of them (Plant 372) bioaerosols are measured inside the composting hall. It should be noted that the six other plants are all located in the UK.

Table 4.7: Parameters measured in emissions to air at indoor aerobic treatment plants

Parameter measured	Type of measurement	Plants concerned
Odour	Periodic	114, 126_1, 126_2, 126_3, 126_4, 126_5, 261, 372, 406_407_2, 414_1, 414_2, 416, 460_1, 518, 520, 537, 542, 543, 608, 621, 634
NH_3	Periodic	062, 114, 126_1, 126_2, 126_3, 126_4, 126_5, 328, 372, 406_407_2, 460_1, 621, 634
Bioaerosols	Periodic	372*, 518, 520, 537, 542, 543, 608
Other: specific types of bioaerosols (e.g. Aspergilus Fumigatus)	Periodic	518, 520, 542, 608
H_2S	Periodic	328, 372, 460_1, 634
TOC	Periodic	460_1
Dust	Periodic	372
SO_X	Periodic	406_407_1**
NO_X	Periodic	406_407_1**
CH_4	Periodic	634
* Total bacteria count in biooxidation hall. ** Emission from biogas combustion.		

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Table 4.8: Origin of emissions to air and associated abatement techniques at indoor aerobic treatment plants

Plant code	Origin of emissions to air	Abatement techniques
62	Mixer, sieving, windshifter, ballistic separation, first biodegradation and post-treatment	• Biofiltering • Injection of odour neutralisers • Water spraying (dust) • Fast-closing curtains
114	Pre-shredder, mixer, screening, first biodegradation	• Acid scrubber system • Biofiltering
126_1 (composting boxes)	First biodegradation, acid and alkaline oxidative scrubber system	• Acid scrubber system • Alkaline oxidative scrubber system
126_2 (hall ambient air)	First biodegradation, water scrubber 1	Wet scrubbing
126_3 (hall ambient air)	First biodegradation, water scrubber 2	Wet scrubbing
126_4 (hall ambient air)	First biodegradation, water scrubber 3	Wet scrubbing
126_5 (hall ambient air)	First biodegradation, water scrubber 4	Wet scrubbing
128	NI	NI
260	Whole plant - biofilter	• Absolute filter system • Acid scrubber system • Activated carbon adsorption • Alkaline oxidative scrubber system • Bag/fabric filter system • Basic scrubber system • Biofiltering • Bioscrubbing • Biotrickling • Catalytic oxidation • Cyclonic separation • Dry electrostatic precipitation (ESP) • Flaring
261	Whole plant - biofilter	Biofiltering
328	Biological treatment of bio-waste - biofilter	• Acid scrubber system • Biofiltering
372	Reception, storage and handling, segregation, wheel-load mixer, sorting step, aerobic process	• Wet scrubbing • Biofiltering
406_407_1	Anaerobic process - gas engine**	NI
406_407_2	Aerobic process - biofilter	Biofiltering
412_1	First biodegradation - biofilter	Biofiltering
413_1	First biodegradation - biofilter	Biofiltering
414_1	Aerobic process - filter 1	Biofiltering

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414_2	Aerobic process - filter 2	Biofiltering
416	First biodegradation and final dry maturation	- Acid scrubber system - Biofiltering (with cooling of process air to ensure proper operation of the biofilters)
460_1	Reception area, pretreatment, first biodegradation, final maturation in tunnels and, in general, enclosed buildings - acid scrubber and biofilter	- Acid scrubber system - Biofiltering - Forced aeration - Water spraying (dust)
460_2	Cyclonic separation	Cyclonic separation
511	NI	Biofiltering
518	First biodegradation and final dry maturation	Biofiltering
520	First biodegradation and final dry maturation	Biofiltering
530	Complete plant	Thermal profiling started 2014, gas and flow analysis installed in 2012
537	Complete plant	Biofiltering
542	Complete plant	Biofiltering
543	NI	Biofiltering
579	Biological step	Gore cover system
580	NI	Semipermeable membranes
608	Biological step	- Wet scrubbing - Biofiltering
609	NI	Biofiltering
621	Complete plant	Biofiltering
623	In-vessel composting (IVC) and aerated pad (one biofilter for each step)	Biofiltering
634	Aerobic process	- Biofiltering - Tower water scrubber

** Emission from biogas combustion.
NI: No information.

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Figure 4.7 and **Figure 4.8** show the odour and NH_3 concentrations, respectively, in emissions to air.

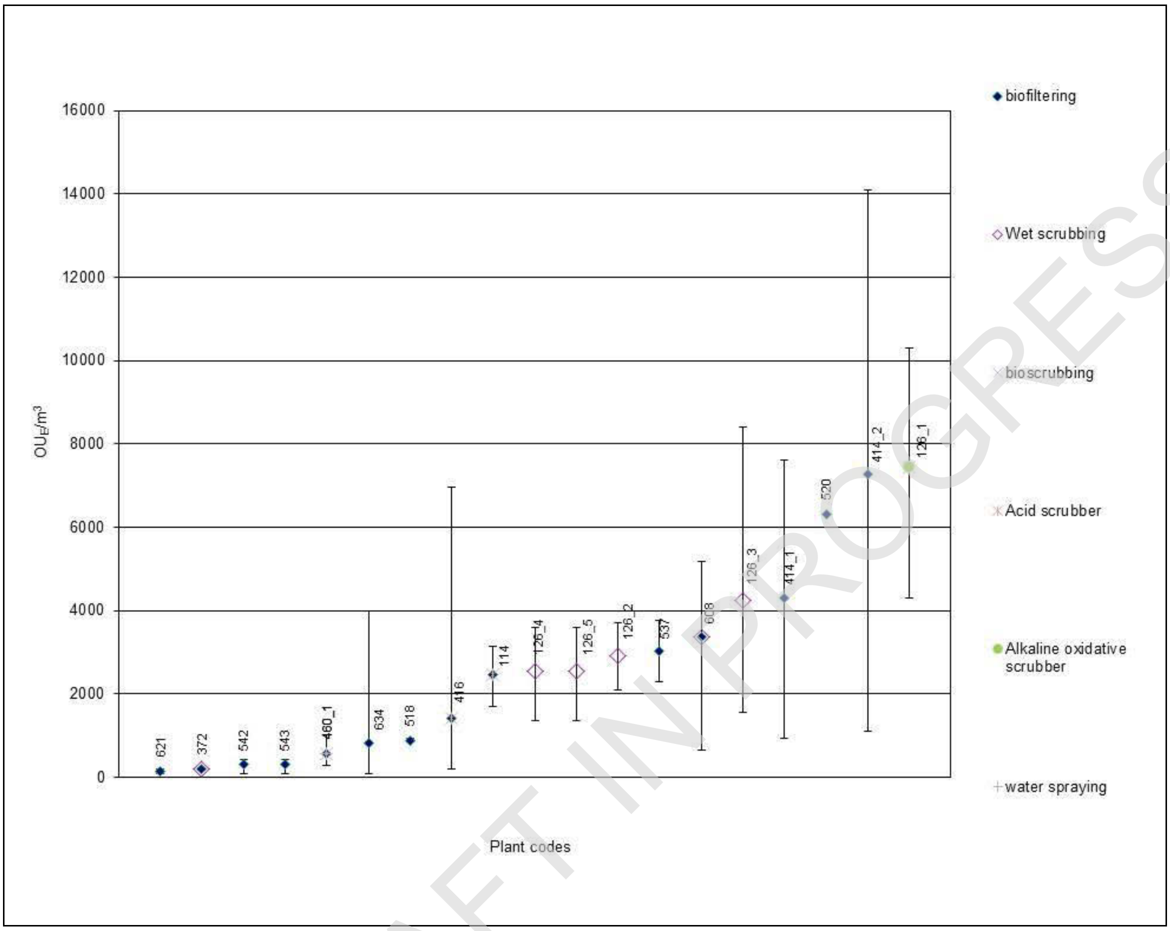

Figure 4.7: Odour concentrations at indoor aerobic treatment plants

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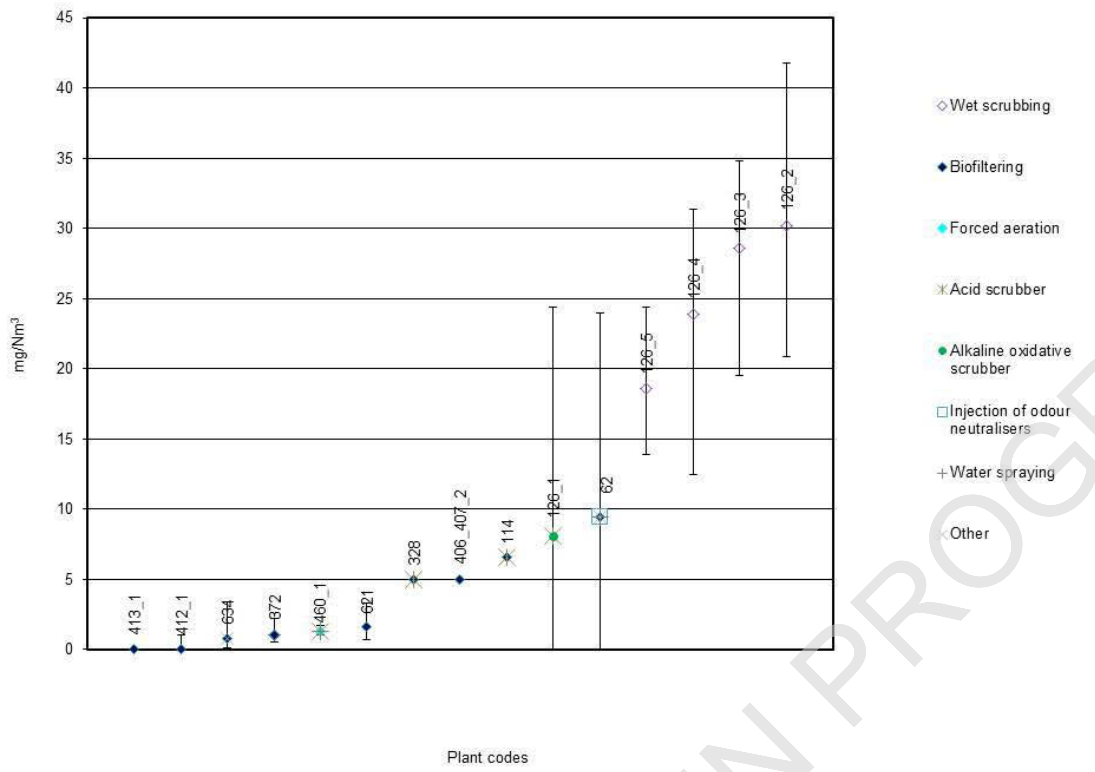

NB: The value for Plant 114 is given considering correction to an O_2 reference concentration.

Figure 4.8: **NH_3 concentrations at indoor aerobic treatment plants**

Table 4.9 shows the number of periodic measurements of NH3 concentration in emissions to air.

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Table 4.9: Number of periodic measurements of NH_3 concentration in emissions to air

Plant code	Number of NH_3 measurements over the three reference years
62	30
114	3
126_1	3
126_2	3
126_3	3
126_4	3
126_5	3
328	36
372	3
406_407_2	3
412_1	33
413_1	33
460_1	3
621	7
634	4

4.2.2.2.2 Emissions to water

Table 4.10 shows the different parameters measured at indoor aerobic treatment plants as well as the type of measurement (periodic/continuous). This table should be read together with Table 4.11 which shows, for each plant, the origin of emissions to water, the associated abatement techniques and the flow of the emissions to water.

The most measured parameters in emissions to water are TSS, pH, COD, Total N and BOD_5. There are five plants (Plants 372, 580, 609, 623, 634) which report releasing waste water directly to the environment. All the other plants release waste water to an on-site waste water treatment plant or to an off-site waste water treatment plant via the sewage system or via intermediate tankering of waste water. Two plants (Plants 579 and 621) report not having emissions to water.

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Table 4.10: Parameters measured in emissions to water at indoor aerobic treatment plants

Parameter measured	**Monitoring**	**Plants concerned**	**Range (mg/l except for pH and flow)**	**Number of measurements during the 3-year reference period (2010-2012)**
Flow (m^3/h)	Continuous	062, 114, 126_1, 372, 416	0.055-15 000 m^3/h	NA
	Composite sample	623$^{(1)}$	15 779 m^3/year	By tank
	Grab sample	412_1, 609	20-55 m^3/h	1-36
	Estimated	412_2, 413_2	700 m^3/year	NI
pH	Composite sample	372, 623$^{(1)}$	6.2-8	3
	Grab sample	062, 114, 126_1, 412_1, 608	5.9-8.8	3-23
TSS	24-hours proportional composite sample	416	63	NA
	Composite sample	372, 623$^{(1)}$	899-1255	3
	Grab sample	062, 114, 126_1, 412_1, 608, 609	26-4143	1-31
COD	Composite sample	372, 623$^{(1)}$	3180-20 382	3
	Grab sample	062, 114, 126_1, 412_1, 608	300-20 983	1-23
Total N	24-hours proportional composite sample	416	69	NA
	Composite sample	372, 623$^{(1)}$	3-557	3
	Grab sample	062, 114, 412_1, 609	0.3-2915	1-29
BOD5	Composite sample	372, 623	1150-8687	3
	Grab sample	062, 114, 126_1, 609	3.3-15 667	3-33
Total P	Continuous	260	NI	NI
	Composite sample	372	37.8	3
	Grab sample	062, 114, 126_1	3.4-105.7	1-6
TOC	Composite sample	372	NI	NI
	Grab sample	062, 126_1	223-1290	2-5
Cl^-	Grab sample	126_1, 412_1	24-515	1-3
Sulphates	Grab sample	126_1, 412_1	50-9420	1-2
NH_3-N	Grab sample	126_1	3094	2
	Estimated	260	NI	NI
Cd	Grab sample	126_1, 412_1	0.0005-0.001	1
Hg	Grab sample	126_1, 412_1	0.0001	1
As	Grab sample	126_1, 412_1	0.005-0.014	1-3
Pb	Grab sample	126_1, 412_1	0.009-0.029	1-2
Cr	Grab sample	126_1, 412_1	0.0045-0.009	1-2
Cu	Grab sample	126_1, 412_1	0.03-0.19	1-2
Ni	Grab sample	126_1, 412_1	0.009	1
Zn	Grab sample	126_1, 412_1	0.218-0.228	1-2
EOX	Grab sample	126_1, 412_1	0.13-0.9	1-2
F^-	Grab sample	126_1	0.17	2
TKN	Grab sample	126_1	3820	3
Cr(VI)	Grab sample	126_1	<0.05	1
Mn	Grab sample	126_1	0.243	2
Fe	Grab sample	126_1	3.535	2
Phenols	Grab sample	126_1	0.59	1

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AOX	Grab sample	126_1	3	2
PCB	Grab sample	126_1	<0.01	1
NA: Not applicable. NI: No information (1)Plant 623: measurements are made by tank.				

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Table 4.11: Origin of emissions to water and associated abatement techniques at indoor aerobic treatment plants

Plant code	Origin of emissions to water	Point of discharge	Receiving water body	Abatement techniques
62	• Mixer • Oversized bodies separation - screening • Ferromagnetic separation • Sieving • Wind shifter • Ballistic separation • Sieving • First biodegradation • Post-treatment	Indirect discharge (on-site common facilities mainly influenced by waste water streams coming from activities other than the waste treatment plant)	River/Stream	NI
114	• Handling, loading, unloading • Waste input storage • Pre-shredder • Mixer • Oversized bodies separation - screening • First biodegradation • Post-treatment	Indirect discharge (urban/municipal sewer system)	Coastal water (sea/ocean)	NI
126_1	Sludge and green waste composting process and air treatment	Indirect discharge (on-site common facilities mainly influenced by waste water streams coming from activities other than the waste treatment plant)	NI	The waste water generated by the plant is stored before being used as a reagent for the hazardous waste stabilisation process
128	No emissions to water	NA	NA	NI
260	Whole plant	Indirect discharge (urban/municipal sewer system)	NI	NI
261	NI	Indirect discharge (urban/municipal sewer system)	NI	NI
328	NI	NI	NI	NI

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372	• Reception • Handling, loading, unloading • Waste input storage • Unpacking • Output storage • Open air • Segregation and compatibility procedure • Wheel loader mixing • Squeezing machine for separating plastics from food waste • Final dry maturation • First biodegradation	Discharge from the WT plant to the environment without treatment	Groundwater	NI
406_407_2	NI	NI	NI	NI
412_1	First biodegradation - run-off water from concrete surface	Indirect discharge (urban/municipal sewer system)	River/Stream	Precipitation Flotation
412_2	First biodegradation - continuously flow of condensed water to the sewer system	Indirect discharge (urban/municipal sewer system)	River/Stream	NI
413_1	First biodegradation - Run of water from concrete surface	Indirect discharge (urban/municipal sewer system)	Transitional waters (i.e. surface water in the vicinity of river mouths)	Precipitation
413_2	NI	NI	NI	NI
414_1	Aerobic process	Indirect discharge (urban/municipal sewer system)	NI	NI
416	Aerobic process	Indirect discharge (off-site common waste water treatment facilities)	NI	NI
460_1	NI	NI	NI	Nitrification/denitrification Ultrafiltration
511	NI	NI	NI	NI
518	NI	Indirect discharge (urban/municipal sewer system)	River/Stream	NI
520	NI	Indirect discharge (urban/municipal sewer system)	NI	NI
530	Complete plant	Indirect discharge (urban/municipal sewer system)	NI	NI
537	All potentially contaminated water is collected and tankered away for treatment	NI	NI	NI
542	All potentially contaminated is collected and tankered away for treatment	NI	NI	NI
543	NI	NI	NI	NI
579	No emissions to water: waste water is used throughout the process	NA	NA	NA
580	Surface water from driving areas and other uncovered areas	Direct discharge from the on-site common waste water facilities to the environment	River/Stream	Combination of ultrafiltration and reverse osmosis

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608	Biological step	Indirect discharge (urban/municipal sewer system)	NI	NI
609	Waste treatment plant	Direct discharge from the on-site common waste water facilities to the environment	River / Stream	NI
621	No emissions to water	NA	NA	Automated waste water recirculation
623	Run-off from tanks to tankers	Direct discharge from the on-site common waste water facilities to the environment	River/Stream	Off-site tankering to a sewage treatment works
634	Aerobic process	Direct discharge from the on-site common waste water facilities to the environment	River/Stream	NI
NI: No information. NA: Not applicable.				

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Figure 4.9 to **Figure 4.13** show measurements of TSS, pH, COD, Total N and BOD_5 in emissions to water.

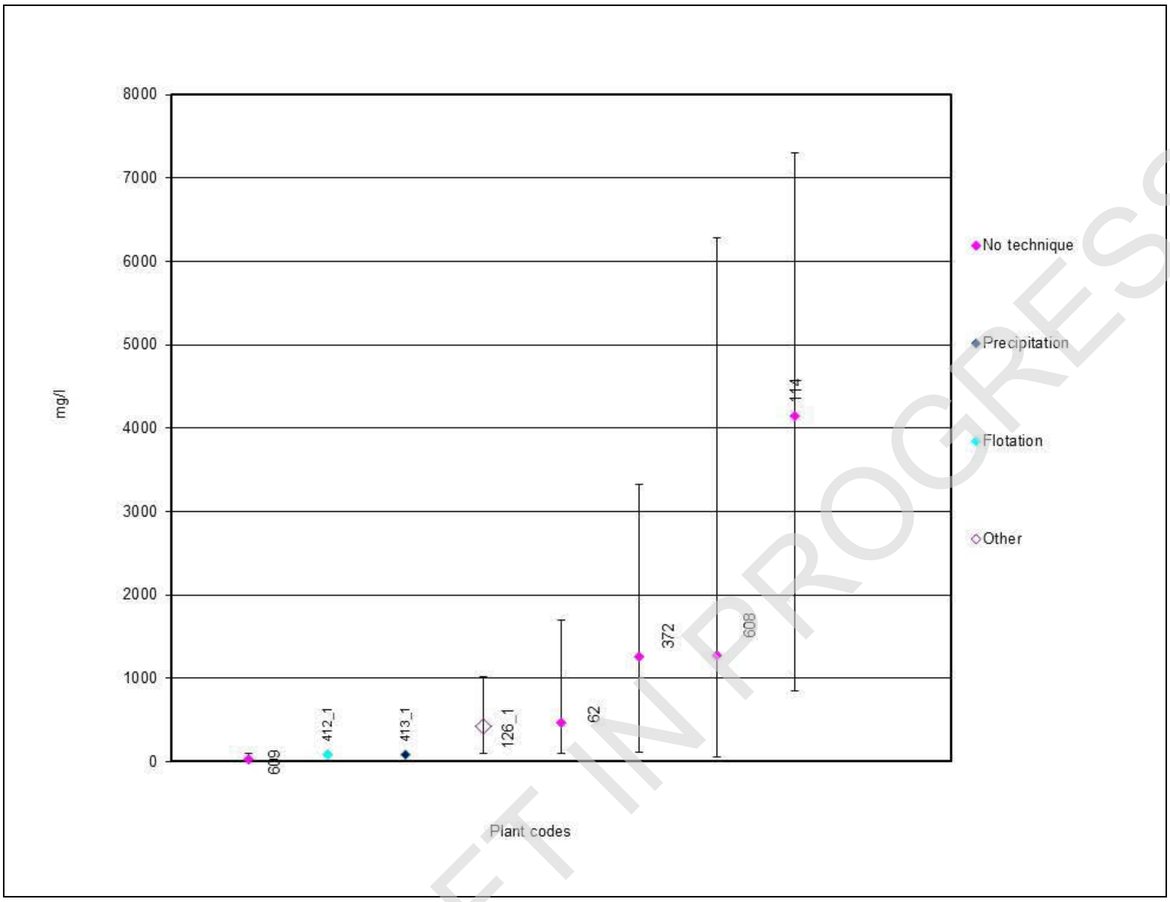

Figure 4.9: Periodic measurements of TSS concentration in emissions to water

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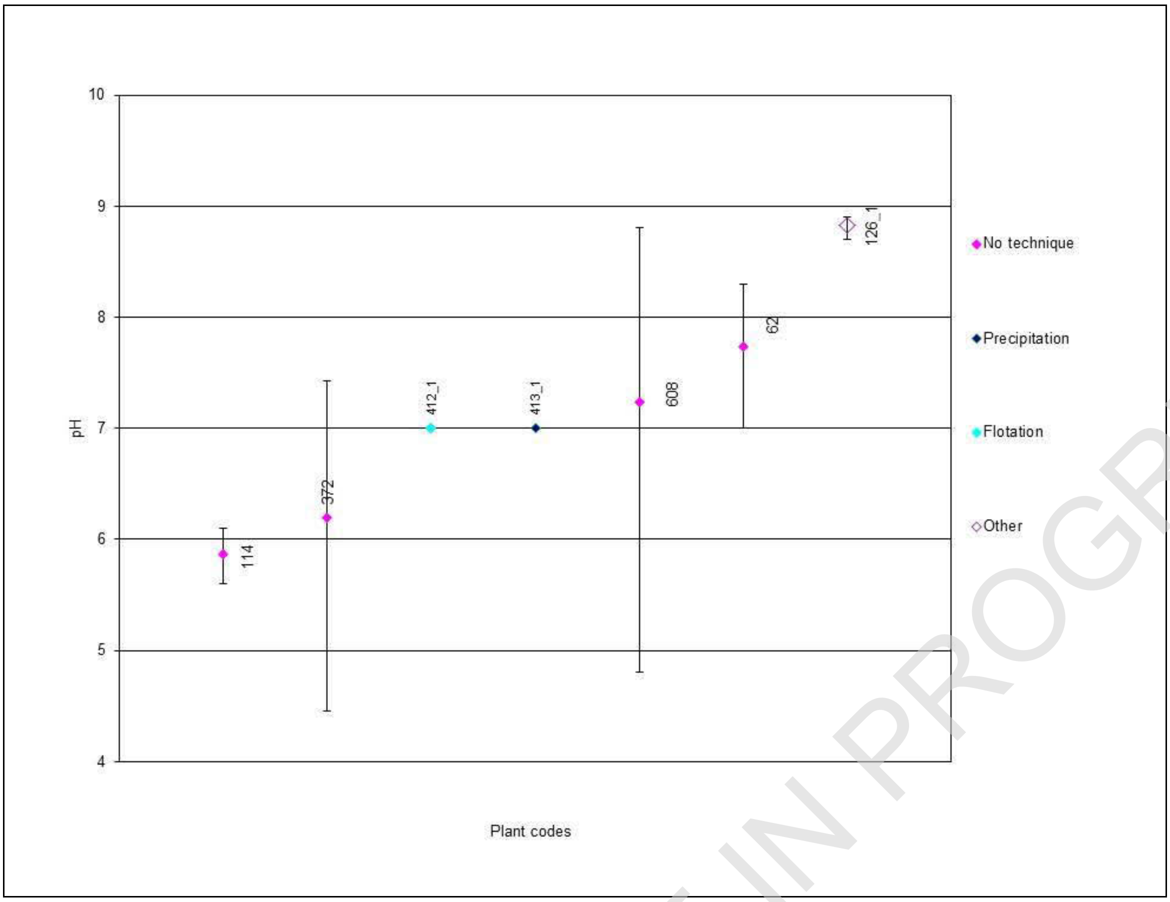

Figure 4.10: Periodic measurements of pH in emissions to water

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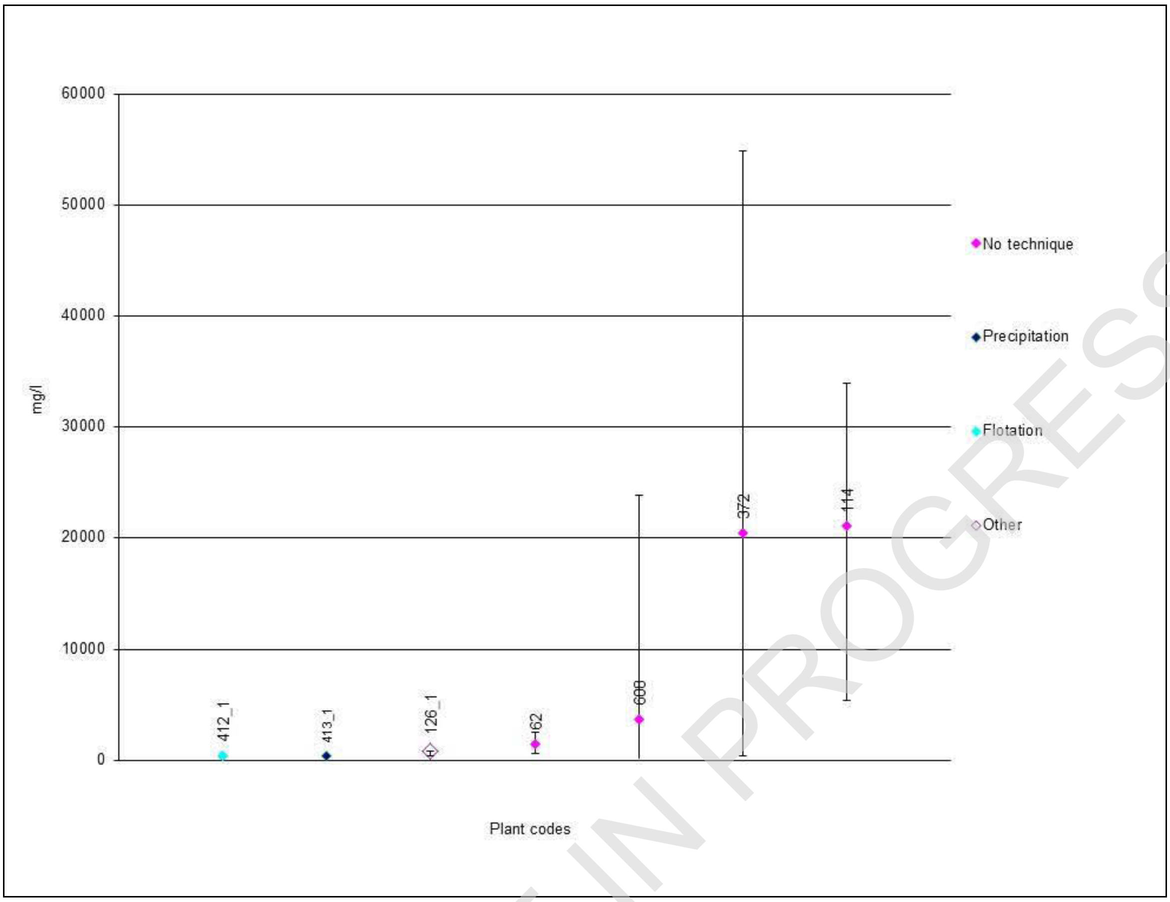

Figure 4.11: Periodic measurements of COD concentration in emissions to water

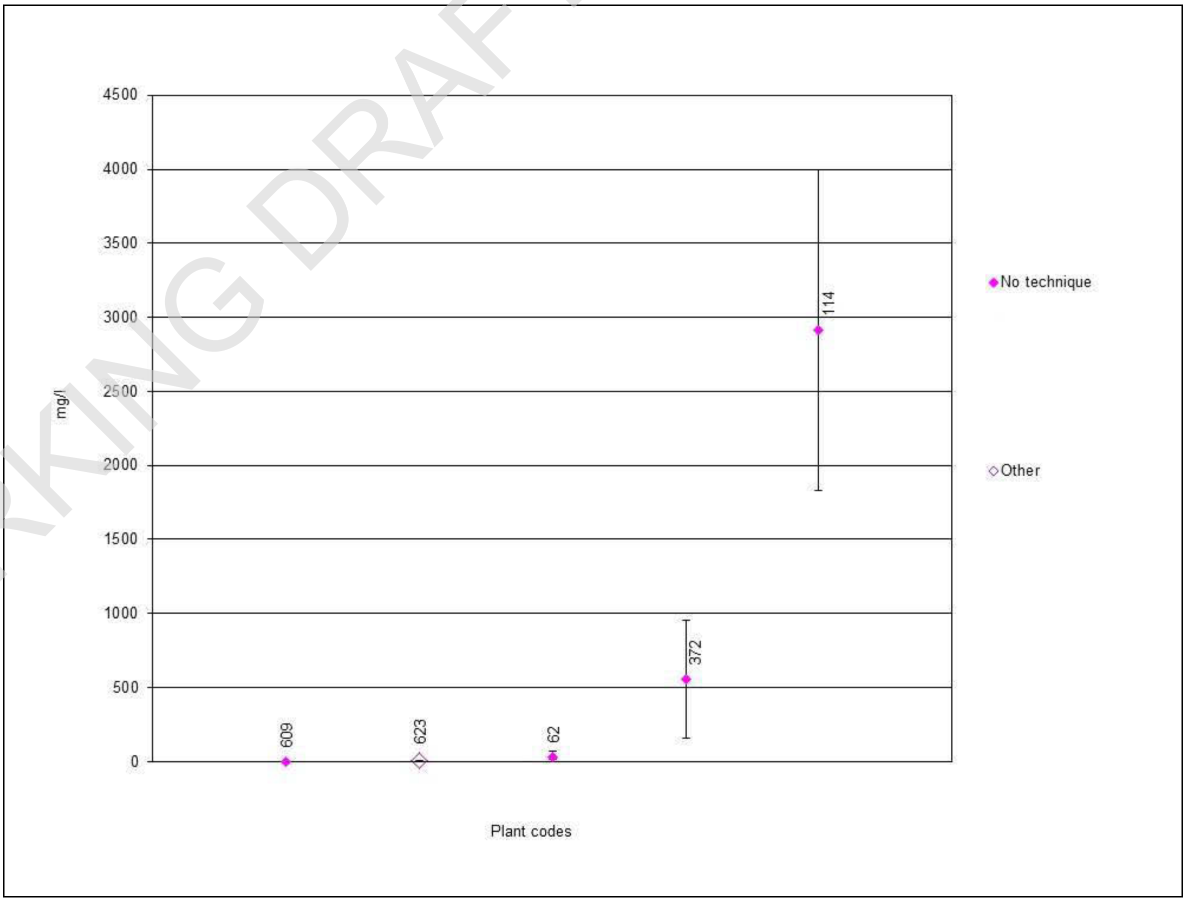

Figure 4.12: Periodic measurements of Total N concentration in emissions to water

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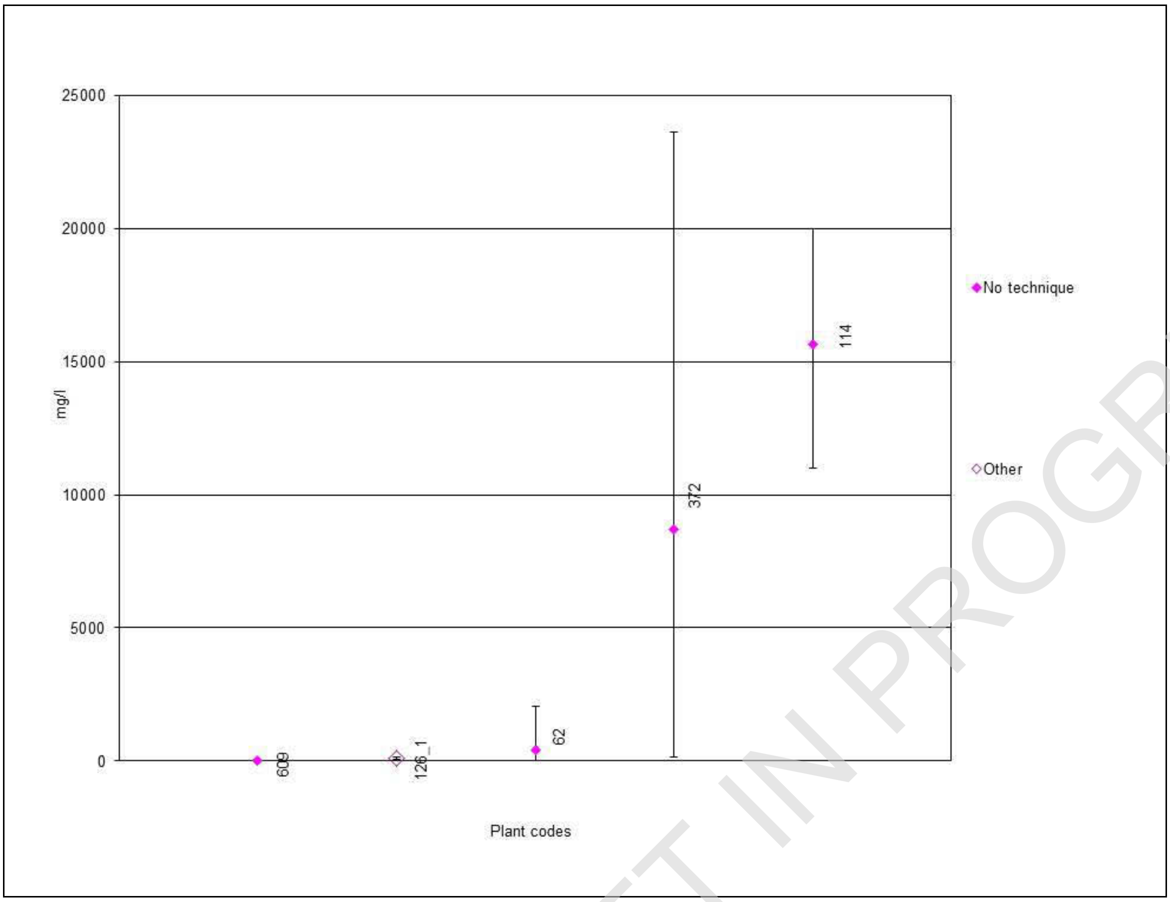

Figure 4.13: Periodic measurements of BOD_5 concentration in emissions to water

The analysis of emissions to water from plants 580, 609, 623 and 634 discharging directly to a water body after treatment is dealt with in Section 2.3.6.7.

4.2.2.2.3 Water usage

Figure 4.14, shows the amount of water used per tonne of waste treated at indoor aerobic treatment plants for different plants.

The reported average water usage per tonne of waste treated is around 1 400 l/t, with a range of 10–5 500 l/t.

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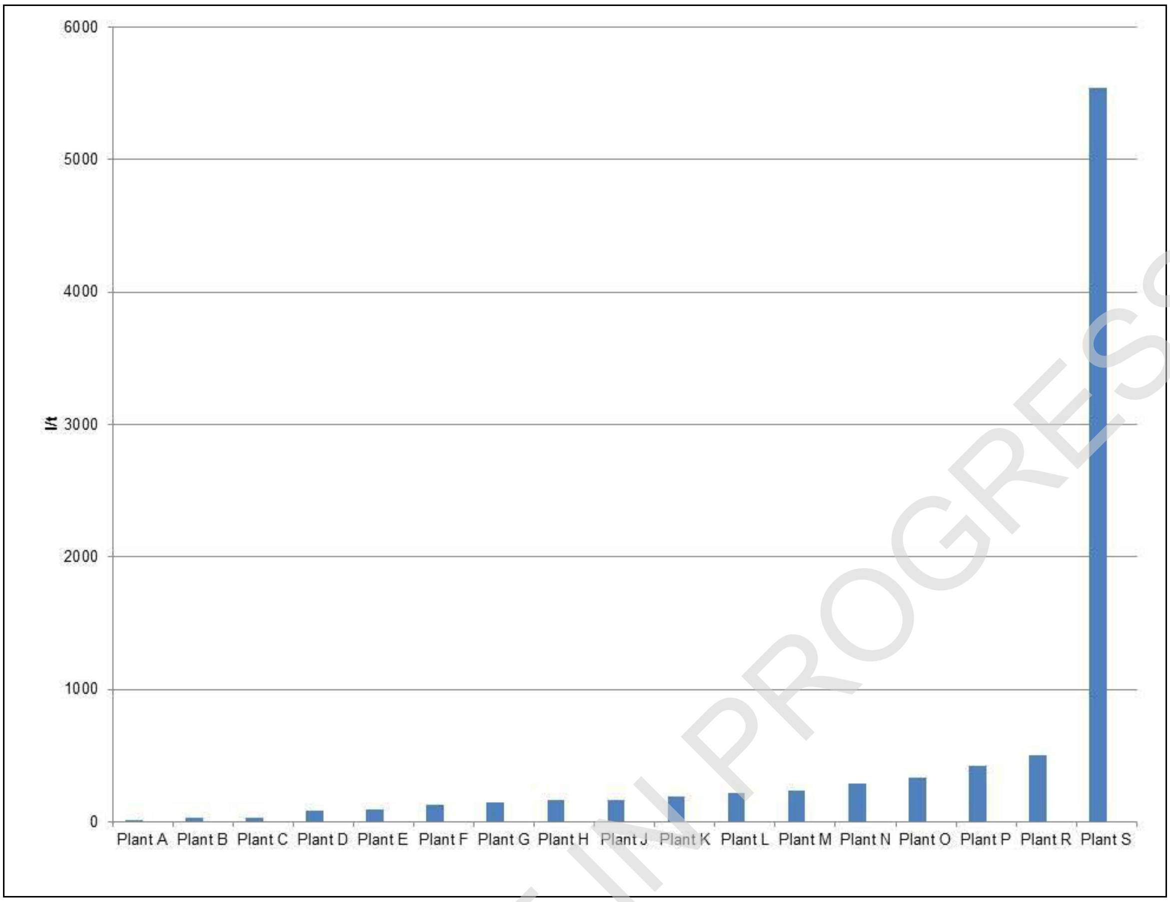

Figure 4.14: **Water usage per tonne of waste treated in indoor aerobic treatment plants**

4.2.2.2.4 Energy consumption

From ex-Section **3.2.2 Consumption of biological treatment**

Table 4.12: **Specific energy consumption of aerobic digestion processes**

~~**Aerobic process**~~	~~**Electricity (kWh/t)**~~	~~**Diesel oil (kJ/kg)**~~
~~Enclosed aerobic digestion~~	~~27 – 65~~ [2]	~~5~~
~~Windrows~~	~~0~~	~~15~~
~~Range~~[1]	~~4 – 72~~ [2]	~~5 – 132~~ [3]
[1] ~~Range contains different types of installations with more or less sophisticated gas treatments and without gas treatments~~ [2] ~~Higher end of the range typically corresponds to process with advanced purification of exhaust gases~~ [3] ~~Higher diesel consumptions are associated with a lower electricity consumptions~~		

~~[37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [44, TWG 2003] [98, WT TWG 2004]~~

Figure 4.15 shows the energy consumed per tonne of waste treated by indoor aerobic treatment plants.

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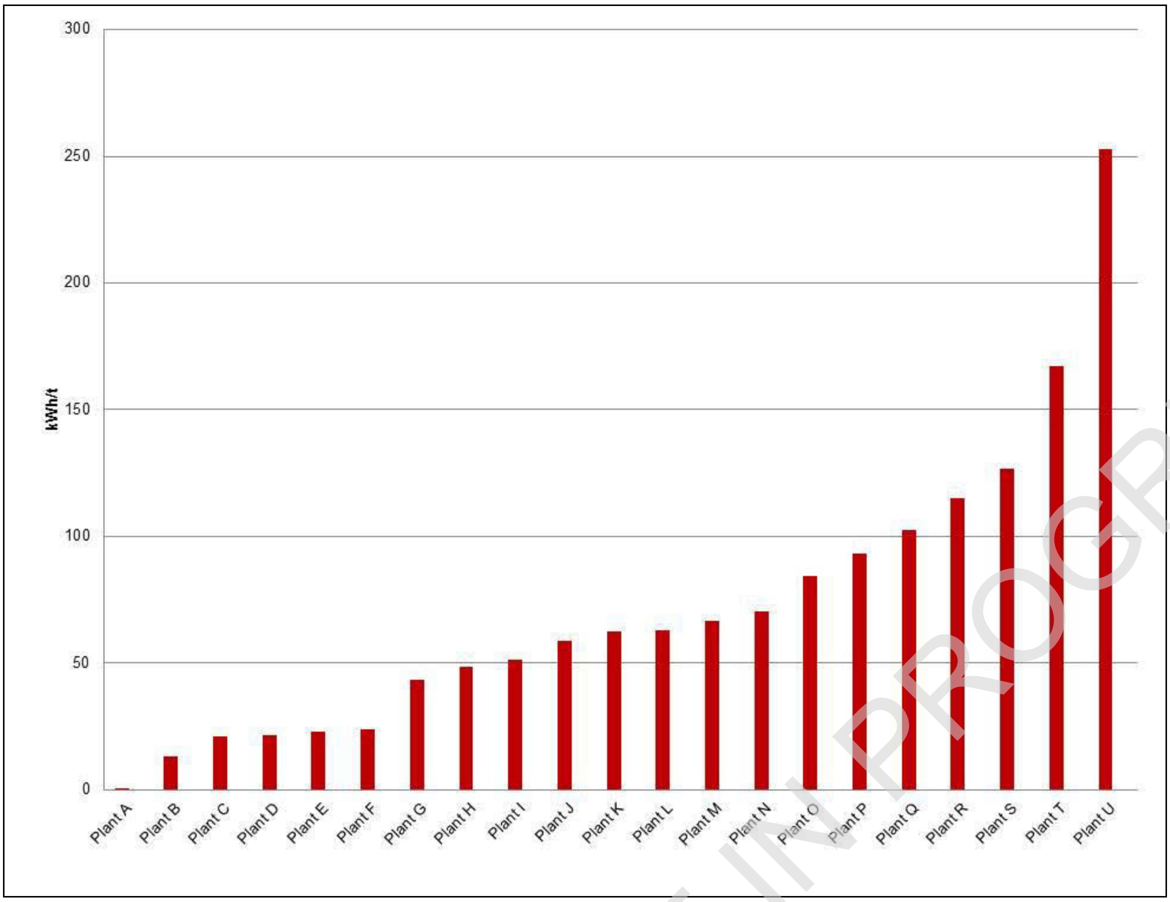

Figure 4.15: Energy consumption per tonne of waste treated in indoor aerobic treatment plants

From the reported data, the average energy consumption is around 69 kWh/t, with a range of 0.1–253 kWh/t.

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4.2.2.2.5 Raw material consumption

Table 4.13 gives an illustration of the raw materials used in the indoor aerobic treatment plants that took part in the data collection.

Table 4.13: Raw materials used by indoor aerobic treatment plants

Auxiliary material	Amount used in waste treatment (t/year) Average over the three reference years
Acid for acid scrubber	44–2389
Wood chips for biofilter	26 864
Wood	1000
NaClO for alkaline scrubber	56
NaOH for alkaline scrubber	19
Shredded wooden pallets	398
Acid for water treatment	7
Lime	34
Lubricant	4
Flocculants	2

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4.3 Anaerobic treatment (or Anaerobic Digestion – AD)

4.3.1 Applied processes and techniques

From ex-**Section 2.2.1 "Anaerobic digestion"**

Purpose

The treatment of biodegradable waste by controlled anaerobic treatment (also called anaerobic digestion – AD) is used to transform the organic matter contained in the waste into biogas and digestate.

Anaerobic digestion is used in industry to handle wastes very high in COD, and as a treatment process for sewage sludge after an aerobic waste water treatment.

The production of biogas from controlled anaerobic digestion is one of the principal advantages of the process: it is a renewable energy source which can be used for the production of electricity, heat, and fuel (gaseous or liquefied).

Principle of operation

Anaerobic digestion involves the bacterial decomposition of biomass (biogenic organic material) in the ~~(relative)~~ absence of free oxygen.

The conversion of biomass to biogas and digestate is a complex biochemical process. Four phases can be distinguished as follows (see Figure 4.16 below).

1. In the first step, the **hydrolysis**, polymer components of the feedstock (e.g. carbohydrates, proteins, fat) are disassembled into lower molecular organic compounds (inter alia amino acids, sugar and fatty acids). The hydrolytic microorganisms involved release hydrolytic enzymes, which decompose the material biochemically outside the microbial cells. During hydrolysis some hydrogen is formed which can be directly used for methane formation.
2. The intermediates produced are degraded during **acidogenesis** (fermentation) by acidogenic bacteria to lower fatty acids (acetic acids, propionic and butyric acid) as well as to carbon dioxide and hydrogen. Also, lactic acid and alcohols are produced in small quantities.
3. The intermediates are subsequently transformed during **acetogenesis** by acetogenic bacteria to acetic acid, hydrogen and carbon dioxide.
4. In the last phase, the **methanogenesis**, methane and carbon dioxide are formed, by archaea.

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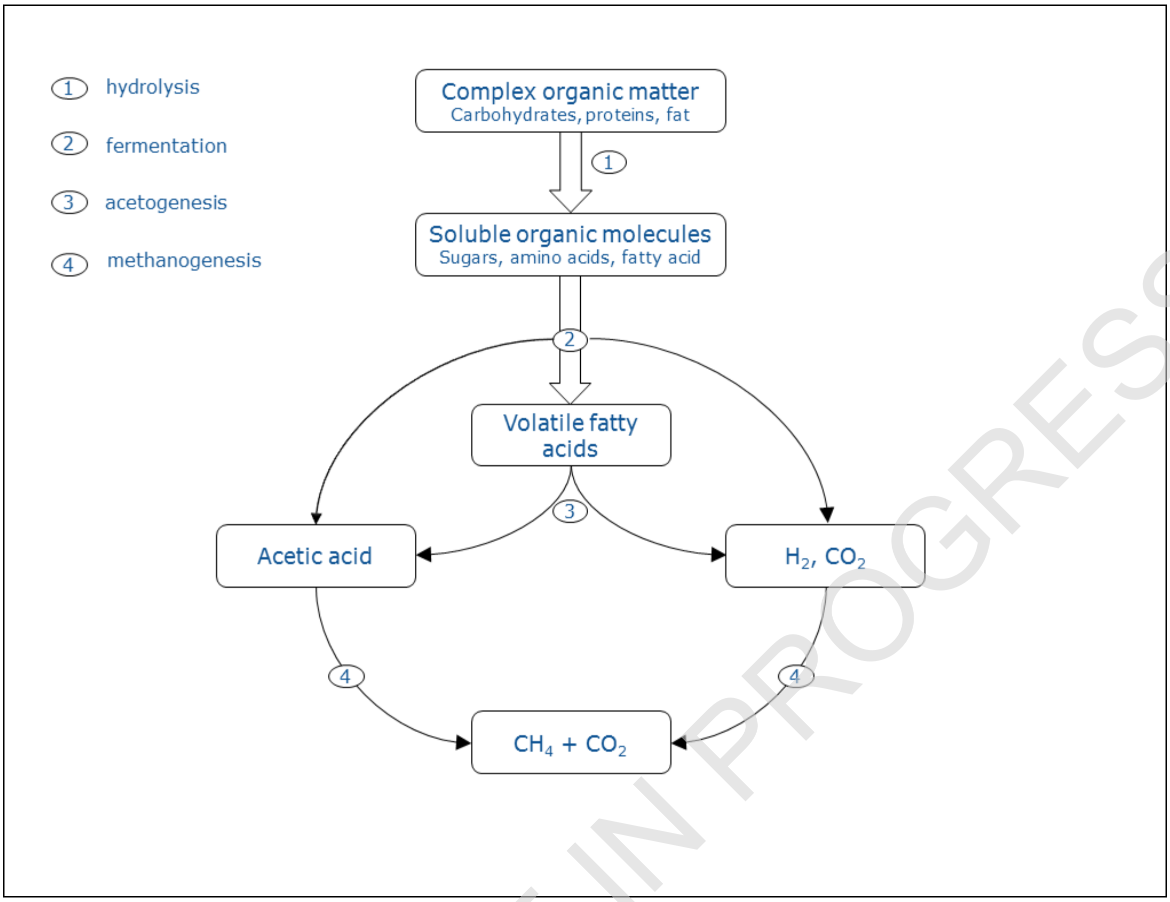

Figure 4.16: Path of Anaerobic Digestion

In the process, carbon from incoming organics is mostly converted to methane and carbon dioxide, and then released as biogas~~, which is capable of being combusted to generate energy or be used as a fuel to abate VOC emissions for example~~. The biogas can be combusted in boilers to produce heat or in combined heat and power units (CHP). It can also be upgraded to biomethane by removal of the carbon dioxide content, and be injected into the natural gas grid or used as a fuel for vehicles.

The proportion of methane to carbon dioxide varies with the waste stream and the temperature of the system. The system needs to have a balanced feed to maximise methane production. Installations usually target carbon-rich wastes that will make use of the available nitrogen ~~(and probably the extra required through bioaugmentation)~~.

Feed and output streams

A great variety of organic materials are suitable as feedstock, for instance:

- agricultural wastes,
- separately collected household bio-waste,
- organic fraction of mixed waste,
- garden and park waste,
- fat separator contents,
- food leftovers from kitchens, hotels and restaurants,
- expired food from retail markets,
- agricultural by-products like manure and other animal by-products,
- industrial slurries and sewage sludge from municipal waste water treatment.

One of the main limits of AD is its inability to degrade lignin (a major component of wood). This is in contrast with the process of aerobic ~~biodegradation~~ treatment.

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From ex-Section 3.2.1

~~Anaerobic digestion may be used to treat liquid or solid wastes directly (e.g. MSW), or to treat the biological sludge generated by an earlier aerobic stage. There are a number of possible feedstocks which can be used in anaerobic digestion. These include the following: source separated food waste, sludge (e.g. sewage sludge from municipal waste water treatment), agro-industrial by-products, manure, slurries, some fractions of the MSW, and yard waste.~~

Anaerobic digestion (AD) is better suited to waste with a higher moisture content than aerobic treatment. The process of AD can occur in waste with a moisture content of between 60 % and 99 %. ~~Moisture content is also important~~. Low ~~value~~ moisture content increases both the ammonium inhibition of the AD process and the salt toxicity. Therefore, kitchen waste and other putrescible wastes, which ~~by themselves~~ may be too wet and lacking in structure to be properly treated by aerobic treatment ~~digestion~~, can provide an excellent feedstock for AD. Liquids are often added to the AD processes (either water or recycled effluent) to maintain a high moisture content.

The characteristics of the feedstock have very important effects on the AD process and therefore on the biogas yield and on the digestate quality. ~~A high quality feedstock will increase the quality of the digestate~~. High heavy metal concentrations in the feedstock can be toxic to methanogenic bacteria, in the following order (of increasing severity): iron<cadmium<zinc<chromium<lead<copper<nickel. The volatile solids content will affect the extent to which the process needs to be monitored to avoid the damaging effect of overloading.

~~The type of waste accepted in this type of treatment is, principally, source separated biodegradable waste, since matter and nutrients are to be recovered with minimal contamination, composting of residual waste or separated fractions thereof is becoming increasingly uncommon. Therefore, the types of waste typically used are the wet organic fractions from kitchen waste and from hotels and restaurants. Garden and park waste and paper and board are not usually processed. Some waste fractions excluded are metals, plastic, glass, animal waste, which is undesirable at plants without hygienisation due to the degradation of lignin which requires post-digestion composting.~~

There are two main alternatives for waste separation. The choice between them has an important bearing on the anaerobic digestion feedstock quality.

- Source separation (not covered under the scope of this document) – this is actively encouraged in a number of Member States. It includes separation of the putrescible organic fraction (bio-waste). It is generally accepted that source separation provides the best quality feedstock for both AD and composting, offering both a maximum organic content and minimum contamination with heavy metals, glass and plastics. After digestion of this source-separated waste in a reliable process, the end result will be the formation of a quality digestate and a high volume of biogas.
- Centralised separation – this is the only route for obtaining a digestible fraction from residual waste. The techniques involved include mechanical processing, optical processing and hand-picking. The digestible fraction obtained tends to be more contaminated than source-separated bio-waste, with inevitable consequences for the digestate's ultimate utilisation (there is some evidence that where pulping is used as a pre-process sorting phase, liquid separation can lead to the removal of some of the more hazardous elements). There is also the risk of larger, non-separated components of the waste being carried over and then causing physical damage to treatment plants further downstream (by abrasion, blockages or tangling).

Anaerobic processes may be used to directly treat liquid wastes, the biological sludge generated by an earlier aerobic stage, organic solids and sludges. The inclusion of other feedstocks, such as sewage sludge, alters the resulting digestate. However, it is important to note that the mixing of household waste with these feedstocks can improve both the environmental and economic

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aspects of the process and has already been adopted in a number of plants (particularly, co-digestion with slurries and manure at small-scale farm-based plants).

From ex-Section 3.2.4

An overview of the expected output ~~waste OUT~~ (based on the source-separated MSW input) is given in **Table 4.14**.

Table 4.14: Expected waste output (based on the standard composition of waste input) from the plant

Fractions suitable for energy recovery	Specific amounts (kg per tonne MSW)	Heating value (MJ/kg)	
		Lower	Higher
Biogas (1)	117.5 (75–364 Nm^3)	15.4	16.8
Light residue	37.3	12.4	21.5
RDF	257.2	17	25.8
Wood-like fraction	14	4.9	10.0

(1) This lower yield is mainly explained by the higher content of non-degradable material (sand). Yields may vary from season to season (higher yields during autumn/winter).

Source: [32, Vrancken et al. 2001] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002]

Biogas

The anaerobic digestion process leads to the production of methane, with a theoretical production level of 348 Nm^3/tonne of COD. Dry biogas has a typical composition of 55–70 % methane, 30–45 % carbon dioxide and 50–4000 ppm hydrogen sulphide alongside other traces of volatile elements. The biogas yield and the proportion of methane to carbon dioxide will vary with the feedstock and the temperature of the system. [109, Bio. subgroup 2014]

From ex-Section 3.2.4

~~*Biogas*~~

~~In the biogas, there are also other constituents in smaller concentrations including carbon monoxide, hydrogen, nitrogen and oxygen. A larger proportion of inorganics and polluting substances in the process will lead to smaller amounts of a 'dirtier' biogas. The constituents of biogas (other than carbon dioxide and methane) can be quite important in its end-use. Table 4.15 shows such the typical composition of a biogas generated by anaerobic digestion.~~

Table 4.15: Composition of biogas generated by anaerobic digestion

~~**Component**~~	~~**Biogas concentration (vol-%)**~~	~~**Specific production (g/tonne of waste)**~~	~~**Specific emissions (g/MJ of methane)**~~
~~CO_2~~	~~25 – 50~~	~~181000 – 520000~~	~~85~~
~~Methane~~	~~50 – 75~~	~~0 – 411~~	~~0.1~~
~~Water (biogas)~~	~~6 – 6.5~~	~~/~~	~~/~~
~~O_2~~	~~0.9 – 1.1~~	~~/~~	~~/~~
~~N_2~~	~~3.9 – 4.1~~	~~/~~	~~/~~
~~H_2~~			
~~H_2S~~	~~<0.1 – 0.8~~	~~/~~	~~/~~
~~Ammonia~~	~~<0.1 – 1~~	~~/~~	~~/~~
~~Mercaptan~~	~~In spores~~	~~/~~	~~/~~
~~Low molecular fatty acids~~			
~~Higher molecular substances~~	~~traces~~	~~/~~	~~/~~

~~*Source:* [20, ETSU 1998] [32, Vrancken et al. 2001] [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002]~~

~~The biogas may be partly used for the production of power and/or heat (e.g. electricity, building heating, vehicles powered with biogas) by combusting it in a biogas engine. When biogas is~~

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~~used to generate energy, it is possible to generate from 20 to near to 300 kWh of net energy per tonne of waste. Several references have been enclosed in Table 4.16.~~

Table 4.16: Net energy production figures from different sources

~~**Study/process**~~	~~**Net energy production (kWh/tonne of waste)**~~		
	~~Minimum*~~	~~Average*~~	~~Maximum*~~
~~AN-Anaerob~~	~~38~~	~~49~~	~~60~~
~~DBA~~	~~45~~	~~53~~	~~60~~
~~Kompo~~	~~85~~	~~88~~	~~90~~
~~NOVEM~~	~~21~~	~~88~~	~~154~~
~~Plaunener-Verfahren~~	~~85~~	~~98~~	~~110~~
~~Waterman BBT~~	~~/~~	~~100~~	~~/~~
~~DHV study~~	~~/~~	~~102~~	~~/~~
~~White et al~~	~~/~~	~~110~~	~~/~~
~~Prethane-Biopaq~~	~~80~~	~~110~~	~~140~~
~~IEA Bioenergy~~	~~75~~	~~113~~	~~150~~
~~BTA~~	~~100~~	~~115~~	~~130~~
~~Dranco~~	~~105~~	~~131~~	~~157~~
~~Vrancken~~	~~/~~	~~140~~	~~/~~
~~WAASA~~	~~120~~	~~145~~	~~170~~
~~IWM~~	~~100~~	~~150~~	~~200~~
~~Schwarting-UHDE~~	~~/~~	~~154~~	~~/~~
~~D.U.T~~	~~254~~	~~273~~	~~292~~
~~* If only one figure is quoted, the reference in question did not provide a range~~			

~~[37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [32, Vrancken et al. 2001] [98, WT TWG 2004]~~

In general, anaerobic digestion produces 100–200 Nm^3 of ~~COD~~ biogas per tonne of biological municipal waste processed. Biogas generation is very sensitive to the feedstock and can vary, e.g. in one plant, volumes ranged ~~found volumes ranging~~ from 80 Nm^3 to 120 Nm^3 per tonne depending on the waste input. Biogas can be used to produce electricity (for internal consumption and/or for export), ~~it can be~~ burnt in boilers to produce hot water and steam for industrial purposes, ~~and it can also be~~ used as an alternative fuel in light and heavy-duty vehicles, or injected into the natural gas grid (see Figure 4.17).

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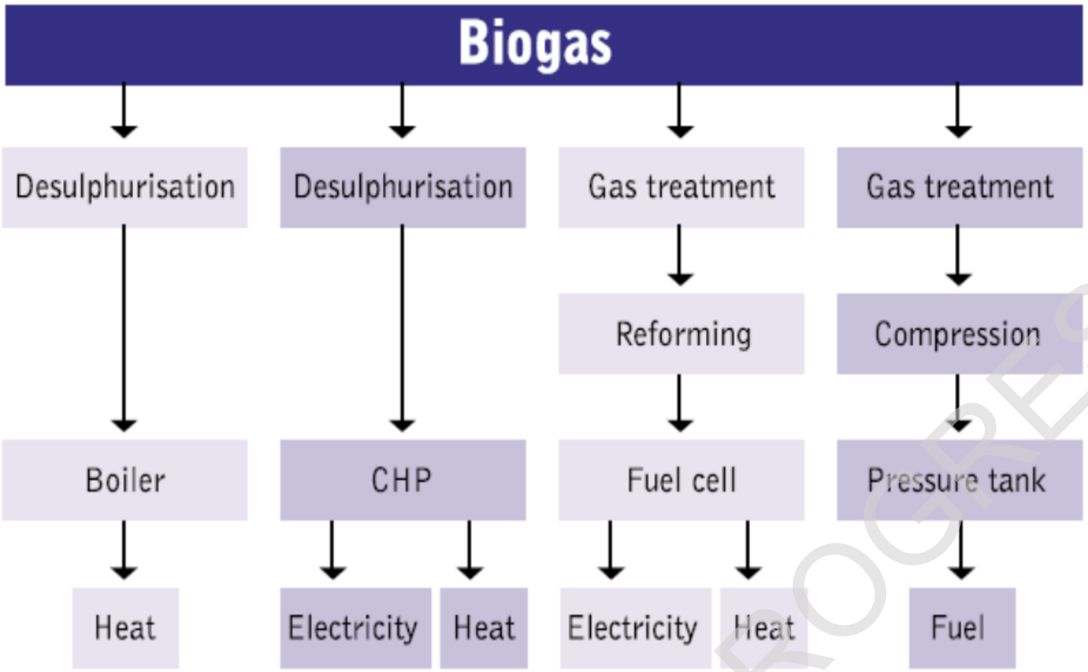

Source: [163, UK 2013]

Figure 4.17: Options for biogas utilisation

End uses for biogas include burning in a simple boiler to generate heat, or use in an engine with a generator to produce power. The most common biogas use is combined heat and power (CHP) generation to produce both heat and power. Heat is most effectively used on site or locally whereas power can be used on site or connected to the main electricity grid.

Alternatively, biogas can be upgraded, which requires the removal of carbon dioxide and other contaminant gases, in order to generate biomethane. The addition of propane to biomethane may also be required in order to achieve the required gas Calorific Value (CV). Biomethane can be injected into the natural gas distribution network, for conversion to heat or power at the point of offtake, or used as a transport fuel in a similar way to LPG or CNG. Whilst biogas upgrading may be more efficient in terms of energy utilisation, it is also significantly more costly and biogas upgrading options are not generally viewed as viable for a small-scale AD application.

~~The semi-solid residue, referred to as a digestate, is further treated normally through aerobic digestion. Some countries allow direct application of the digestate onto farmlands in certain circumstances (e.g. Sweden, Denmark). The risk of digestate application onto soil, mainly due to the heavy metals is typically controlled by national legislation in the different EU countries. As well as the main product from the process, i.e. a solid digestate, small quantities of surplus liquor are also available which can be dewatered to provide liquid fertiliser or sent to a waste water treatment plant (often following some separation of the solids).~~

Biogas from the digester is dehumidified and cleaned to remove siloxanes and hydrogen sulphide before it is used as fuel (either for external or internal use), by means of the following techniques:

- sulphide precipitation inside the digester:
    - adding metal salts into the digester,
    - controlled addition of oxygen into the digester;
- biogas scrubbing;
- activated carbon filtration.

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According to the data collection, all but one anaerobic digestion plants reported having a biogas pretreatment step. The techniques mainly used are:

- activated carbon filtration;
- sulphide precipitation;
- water scrubbing.

The biogas is used for cogeneration (reciprocating engines, turbines) in 21 plants, in boilers in 4 plants, and 2 plants are upgrading the biogas for use in vehicles.

Table 4.17 below summarises the applied techniques and the biogas utilisation in anaerobic digestion plants.

Table 4.17: Biogas pretreatment and utilisation

Plant code	Biogas pretreatmene	Biogas utilisation
20	No information	Cogeneration
71	Sulphide precipitation	Cogeneration
72	Sulphide precipitation, water removal, compression	Cogeneration
111	Water scrubbing	Heating
113	Water removal	Cogeneration
131	Sulphide precipitation, water removal	Cogeneration Power
132	Activated carbon filter, compression, water removal	Cogeneration
251	Water removal	Cogeneration
255	Activated carbon filters	Cogeneration
256	Sulphide precipitation, activated carbon filters, compression, water removal	Cogeneration
259	Activated carbon filters	Power
265	Activated carbon filters	Cogeneration
268	Water removal, sulphide precipitation, activated carbon filters	Cogeneration
319	Water removal	Cogeneration
339	Activated carbon filters	Cogeneration
341	Water scrubbing	Cogeneration
377	Water removal, compression, activated carbon filter	Cogeneration
382	Water scrubbing	Cogeneration
459	Sulphide precipitation, water removal	Cogeneration Heating
484	CO_2 removal	Gas distribution for transport fuel
485	CO_2 removal	Gas distribution for transport fuel
526	Ferric dosing	Cogeneration
528	Ferric dosing	Cogeneration
529	Ferric dosing	Cogeneration
534	Sulphide precipitation	Power
541	Sulphide precipitation, activated carbon filters, compression	Power
592	Compression	Power
638	Compression	Cogeneration

Digestate

A clean biodegradable feedstock will increase the quality of the digestate, which – if complying with national and European legislations and voluntary product specifications – can be used as an organic fertiliser or soil improver in agriculture, either in a liquid form (about 5–15 % dry matter) like manure, in a semi-solid form (10–30 %) like peat, or be further upgraded, e.g. by

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composting, drying and/or pelletising in landscaping and horticulture as well as in private gardens.

In Germany, Belgium, the Netherlands and other Member States (MS), digestates are commonly post-composted if the feedstock is mainly based on household bio-waste. In the UK and Sweden, source-separated bio-waste from households is mainly digested in liquid systems, and even when separation into a liquid and a solid fraction occurs, the solid fraction is usually not post-composted. Liquid or separated solid digestate produced from industrial and agricultural bio-waste are commonly not composted but used directly as fertiliser.

The nutrients previously contained in the feedstock remain in the digestate. Only carbon, hydrogen, oxygen (as part of CO_2), and in marginal quantities nitrogen and sulphur, can leave the process within the gas phase. Therefore, the feedstocks used directly determine the composition of the generated digestate. The nutrient content is predominantly described by nitrogen, phosphorus, potassium and the organic carbon content. When the digestate cannot be used as fertiliser due to high contents of impurities and other contaminants (e.g. heavy metals), the energetic recovery of the digestate is a possible alternative.

From ex-Section 3.2.3 Emissions from biological treatment

~~*Digested matter and waste*~~

~~Concerning anaerobic digestion,~~ The sludge or digestate is usually dewatered. The content of heavy metals may be leached out to soil or washed off into watercourses if the digestate is used as compost, as soil cover or landfilled. In the event that the content of heavy metals is too high to allow a land application, the compost/sludge may be used for daily covering at landfills. In this aspect, the Groundwater Directive may be applied.

As the resulting anaerobic sludges are generated in a reducing environment, such sludges may contain concentrations of some compounds such as metal sulphides and some organics (e.g. insoluble intractable organics). The sludges processed from MSW or sewage sludge with an industrial feed will have a metal content in the waste intake, which will be deposited in the sludge.

The sludge cake, generated in the waste water treatment plant, can undergo further chemical purification. If no purification is carried out, the sludge cake needs to be disposed of by landfill or can be (co-)incinerated. The residue of the sand washing is probably not suitable for thermal treatment, due to its low calorific value, and thus is disposed of by landfill.

From ex-Section 3.2.4

~~*Digestate*~~

~~The amount of digestate generated ranges from 100 – 500 kilograms per tonne of waste IN. This range is due to an extention of biodegradation, the moisture content of waste IN, the extent of process water recirculation, the way in which the digestate is used and the degree to which steam is used to heat biomass.~~ The digestate composition varies as shown in Table 4.18.

Table 4.18: Chemical characteristics of anaerobic digestate

Feedstock	Units	N	P	K	Mg	Ca
Bio-waste/RDF	% of TS	1.2	0.68	0.74	NI	0
Source-sep. MSW	% of DM	1.90	0.66	0.63	NI	NI
Source-sep. MSW	ppm	20.0	11.9	14.7	11.6	49.7
Source-sep. MSW	ppm	11	8	10	NI	NI
Organic fraction MSW	ppm	1–1.3	6–12	8–12	17–26	60–110
Fruit/veg from market	ppm	21.9	9.5	10.5	4.7	NI
Unsorted MSW	ppm	11	8	10	NI	NI
Unsorted MSW	ppm	19	13	15	3.67	NI

Source:[37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002][98, WT TWG 2004]
NI: No information.

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Solid waste fuel to be used as fuel

More information on this matter can be found in Section 3.3. The solid fuel prepared is a presorted mixture of paper and plastics. Washing of the digestion product yields two additional streams: a residue and a wood-like fraction, with a residual calorific value that allows thermal treatment. The three streams added together give 308.5 kg solid fuel mix for thermal usage. The solid fuel mix has a lower heating value of 16.5 MJ/kg and a dry solids content of 66 %.

Table 4.19 gives an example of the composition of slid waste prepared.

Table 4.19: Composition of the solid waste prepared

Type of waste	%
Organic waste	45
Others	31
Paper/cardboard	13
Plastics	9
Textile	2
Source: [32, Vrancken et al. 2001] [98, WT TWG 2004]	

Other products/waste

Table 4.20 gives an Overview of outputs from anaerobic treatment of biodegradable municipal waste.

Table 4.20: Overview of outputs from anaerobic treatment of biodegradable municipal waste

Recovered product	Specific production (~~tonnes~~ per tonne of waste treated)
Nutrient recovery	4.0–4.5 kg N 0.5–1 kg P 2.5–3 kg K
Energy recovery	0.4–0.9 MJ electricity. In addition, CHP plants may generate a similar quantity of heat
Total solid residuals depending on waste	0.3–0.6
Quality products for recycling (recovery)	Fibres (0.07–0.3) (for composting)
Other residuals ~~possible for~~ able to be reused with restrictions	Fluids (0.6) Inerts (0.05) Sand (0.08)
Residuals for landfilling or other waste treatment	Overflow sieving (0.02–0.1)
Metals (~~containing~~ including ferrous)	0.043
Ferrous metals	0.032
NB: The separation and washing of the digested material yields fractions of inert materials, sand and a fibrous fraction. The inert materials and the sand fraction can be used as a building material. Another output corresponds to the fibrous fraction. *Source:* [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [32, Vrancken et al. 2001]	

Process description

The primary process variables are the methods of contacting the waste with the biomass (microbes), the moisture content of the waste (e.g. liquid, slurry or solid), and the method and degree of aeration. Anaerobic digestion generally involves the ~~following~~ stages shown in Figure 4.18 below.

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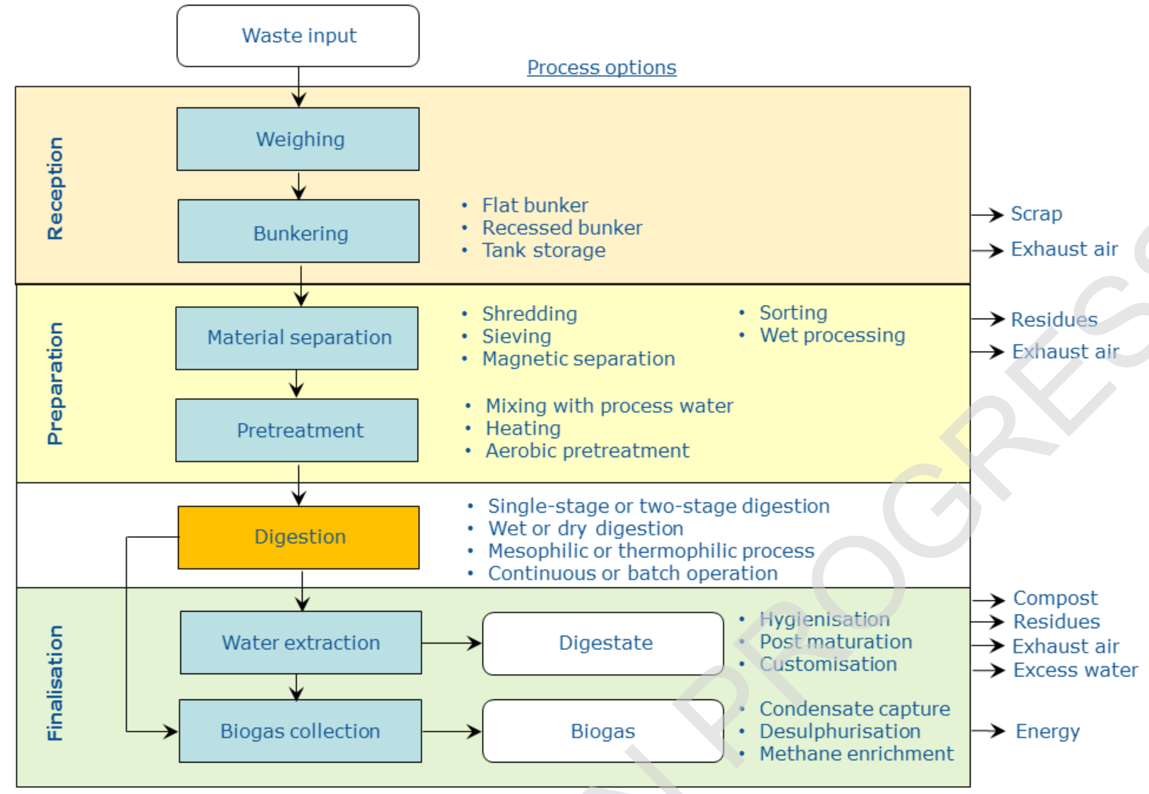

Source: [111, UBA Germany 2013]

Figure 4.18: **Anaerobic digestion plant design**

Reception: the reception step is similar to the one described in Section 4.2.1 above.

Preparation

Material separation: in order to improve the digestion process, materials, such as plastics, metals and oversized components, are removed from the waste to be treated. Separation can be carried out under wet or dry conditions. Following this, a further process of size reduction is used to create a more homogeneous material, which aids fermentation and facilitates processing. The size reduction could be brought about by screw-cutting, milling, drumming, pulping or shredding machines.

Pretreatment:

Preliminary aerobic decomposition can be performed over a period of two to four days in order to improve material breakdown and warm the digestate. This step takes place directly in box fermenters, or in separate preliminary digestion units (e.g. composting tunnels). The heated material reduces the consumption of energy needed to heat the digestion container. Preliminary digestion breaks down some biomass, which is then no longer available for anaerobic process stages. However, a better digestion increases the gas yield. [111, UBA Germany 2013]

Thermal disintegration can be used as an interim step between mechanical processing and material being fed into the fermenter. Cell breakdown, which takes place with thermal input, aims to improve the substrate's degradability and also increase the biogas yield. This process is primarily chosen for substrate with high fibre and lignin levels that resists degradation. Upstream sanitation stages also bring about thermal disintegration. Ultrasound disintegration is another process in the same area of application. Only a very small number of plants intentionally utilise cell breakdown processes. [111, UBA Germany 2013]

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Digestion
There are a number of different operating conditions used in digestion processes. They are usually distinguished on the basis of the operating temperature and on the percentage of dry matter in the feedstock:

1. thermophilic plants operate at around 55 °C;
2. mesophilic plants operate at around 40 °C;
3. dry (or high-solid) systems when the feedstock contains 15–40 % dry matter; and
4. wet systems when the feedstock contains less than 15 % dry matter.

In principle, the higher the temperature, the faster the process. Nevertheless, the thermophilic process may be harder to control and will need more energy for heating due to higher heat losses from the tanks.

The moisture content and degradability of feedstock are very important for the choice of technology. For instance, kitchen waste and other putrescible wastes, which may be too wet and lacking in structure for composting, can provide an excellent feedstock for Anaerobic Digestion.

In pretreatment, liquids are added to control the dry matter content. For digestion, liquids are added to control ammonia in particular and sometimes salt concentrations. Viscosity control is managed by the recycling of liquid digestate.

~~Some~~ The most common existing anaerobic digestion technologies ~~currently available~~ are listed in Table 4.21

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Table 4.21: Anaerobic digestion technologies

~~Technique~~ Technology	Description	Input
Wet ~~single-step~~ digestion	Solid bio-waste is ~~slurried~~ mixed with ~~the~~ process water or with liquid waste to provide a diluted feedstock for feeding into ~~a mixing tank~~ the digester. Liquid bio-waste can be used directly	The process can be used for household, industrial, commercial and agricultural bio-waste as well as animal manure and energy crops. ~~MSW on its own, but the wet process lends itself to co-digestion with diluted feedstocks, such as animal manure and organic industrial wastes~~
~~Wet multi-step~~	~~Solid waste is slurried and fermented by hydrolytic and fermentative bacteria to release volatile fatty acids which are then converted to biogas in a high rate industrial waste water anaerobic digester~~	~~The system lends itself to the digestion of MSW and to the wet organic waste from food processors~~
Dry continuous digestion	The digestion vessel is continuously fed with a material with ~~20–~~15–40 % dry matter via ~~through batch loading~~ semi-continuous feeding. In both mixed and plug-flow variants, the heat balance is favourable for thermophilic digestion. There are vertical and horizontal digesters.	The process can be used for household, industrial, commercial and agricultural bio-waste and the organic fraction of mixed household waste of overall limited degradation
Dry batch digestion	A batch is inoculated with digestate from another reactor and left to digest ~~naturally~~ without further mixing. Leachate is recirculated to ~~maintain moisture content and to redistribute methane bacteria throughout the vessel~~ improve the contact between locally formed organic acids and methane-forming bacteria.	The process is commonly used for commingled kitchen and garden waste with a considerable content from structural material. Other applications are solid manure and energy crops.
~~Sequencing batch~~	~~Essentially a variant of the dry batch process, in which leachate is exchanged between established and new batches to facilitate start up, inoculation and removal of the volatile materials from the active reactor. After digestion becomes established, the digester is uncoupled from the established batch and coupled to a new batch in another vessel~~	
~~Heap bioreactor~~		

Source:[31, LaGrega et al. 1994], [33, UK EA 2001], [34, Babtie Group Ltd 2002], [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002]. [109, Bio. subgroup 2014]

Types of fermenters

The main types of fermenters are:

- vertical fermenters with an agitator (typically used in wet digestion facilities);
- horizontal fermenters with a slow transport agitator using plug-flow technology (used in dry digestion facilities);
- vertical fermenters without mixing using plug-flow technology (used in dry digestion facilities);
- box or percolation fermenters (used in batch dry digestion facilities).

The mixing systems used in the fermenters can be as follows:

- Mechanical. In this case, the agitators consume a significant amount of the electricity used by the plant.
- Hydraulic, by means of pumps that recirculate the substrate.
- Pneumatic. This method tends to favour the formation of surface scum.

[111, UBA Germany 2013]

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Finalisation

Sanitation: the sanitation stage can be considered complete during the fermentation phase performed by the thermophilic digestion process (e.g. in Germany). On the contrary, mesophilic digestion requires a separate sanitation stage (70 °C, one hour). In addition, sanitation occurs when thermal disintegration is used as a pretreatment prior to fermentation.
[111, UBA Germany 2013]

Maturation: ~~Anaerobic treatment steps therefore need to be followed by~~ A subsequent aerobic degradation step may be needed in order to lead organic material to a full mineralisation.

Maturation is an aerobic stage (also named post-composting) that produces compost, reduces water content, and prevents methane formation in solid digestate products. Boxes or tunnels with forced aeration systems are preferably used for maturation. This phase lasts between two and six weeks, depending upon the desired degree of maturation and sanitation.
[111, UBA Germany 2013]

Biogas

The following Table 4.22 provides an indicative overview of the requirements for biogas treatment in relation to the intended use.

Table 4.22: Indicative overview of the requirements for biogas treatment in relation to the intended use

Application	**H_2S**	**CO_2 removal (upgrading)**	**H_2O removal**
Gas heater (boiler)	< 1000 ppm	No	No
Kitchen stove	Yes	No	No
Stationary engine (CHP)	< 500 ppm	No	Moisture removal
Vehicle fuel	Yes	Yes	Yes
Natural gas grid	Yes	Yes	Yes

Water removal techniques include:

- cooling/condensation,
- compression,
- adsorption,
- absorption.

H_2S removal techniques include:

- Precipitation by addition of ferric ions, or FeCl2, or $FeCl_3$, or $FeSO_4$ in the digester. The precipitate iron sulphide can then be removed with the digestate.
- Chemical absorption by means of sodium hydroxide or iron oxide adsorption, or activated carbon absorption.

CO_2 removal techniques include:

- pressure swing adsorption (PSA), i.e. adsorption by activated carbon or zeolite under elevated pressure;
- water scrubbing;
- organic solvent scrubbing, e.g. with polyethylene glycol;
- chemical scrubbing, e.g. with amine solutions;
- membrane separation.

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From ex-Section **4.2.4 Generic techniques for anaerobic digestion optimisation**

~~However, not all compounds derived by the anaerobic breakdown of aromatic rings (e.g. xenobiotica) can be mineralised under anaerobic conditions~~

Users

~~Anaerobic digesters are currently used for municipal waste (specifically biowaste separated at source) but have been tested for hazardous waste disposal as well. In some anaerobic digesters at sewage treatment works, spare capacity is being used for a range of industrial non-hazardous organic wastes. The anaerobic digestion of MSW has been commercially available for approximately 10 years and is utilised in Germany, the Netherlands and Denmark. There are developments in Spain, Portugal and Belgium, and it is used to a limited extent in other countries such as Sweden, the UK and France.~~

Anaerobic Digestion is a common treatment for a wide range of biodegradable wastes (feedstock) in all European Member States. The feedstock and the applied processes and techniques can vary widely among Member States due to different legal requirements and local situations. The recovery of energy and fertiliser from bio-waste, including sewage sludge and the organic fraction of mixed household waste, has become very attractive due to European legislation (Waste Framework Directive 2008/98/EC, Landfill Directive 1999/31/EC, Renewable Energy Directive 2009/28/EC, Animal By-Product Regulation 1069/2009/EC, etc.)

Reference literature

[109, Bio. subgroup 2014] [111, UBA Germany 2013] [154] [163, UK 2013]

From ex-Section **4.2.4 Generic techniques for anaerobic digestion optimisation**

~~Although anaerobic systems can be operated in stages to reduce overall COD in the effluent, they are generally operated for efficient methane production and the liquid effluent tends to be more concentrated than effluent from aerobic systems, and requires an aerobic final treatment stage. This could be via a discharge to sewer, or through a second stage on site process.~~

4.3.2 Current emission and consumption levels

From ex-Section **3.2.3 Emissions from biological treatments**

~~Note: Brown arrows represent solid materials~~

~~Blue Arrows represent emissions~~
~~Green Arrows represent waste OUT with some use~~
~~*Source*: [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [98, WT TWG 2004]~~

~~Figure 4.19 shows the relevant emissions from anaerobic digestion processes.~~

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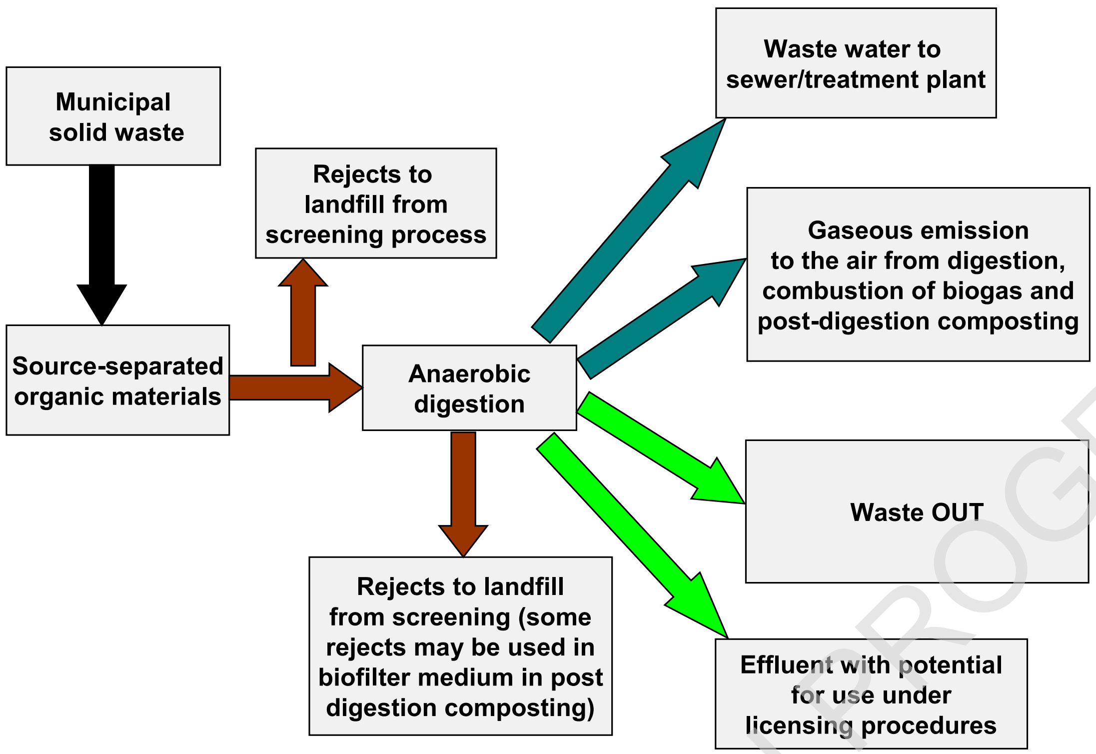

~~Note: Brown arrows represent solid materials~~

~~Blue Arrows represent emissions~~
~~Green Arrows represent waste OUT with some use~~
~~*Source*: [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [98, WT TWG 2004]~~

Figure 4.19: **Schematic representation of anaerobic digestion inputs and outputs**

4.3.2.1 Emissions to air

From ex-Section **3.2.3 Emissions from biological treatments**

~~This process is enclosed and air emissions are unlikely to occur except during transfer to and from the digester. Anaerobic systems generate less emissions than aerobic systems per kilogram of waste, since the principal gaseous emission (methane) is a desired product. However emissions related to the delivery of waste and mechanical treatment may cause emissions of odours and dust and the aerobic digestion of the digestate may cause a significant odour problem if not properly treated. The emissions generated by the combustion of the biogas are typically higher than the emissions generated during the biogas production process.~~

~~A simple mass balance would suggest that, if the input material has a moisture content of 70 %, and if the volatiles solids content of the remainder is 80 %, then the input waste must contain 240 kg of volatile solids. Unscreened stabilised biomass might account for 40 % of the initial weight, of which 40 % might be moisture with the remainder having a volatile solid content of 40 %. This implies a loss of 144 kg, volatile solids, if the incoming material has a moisture content of 70 %.~~

~~As already stated, since the digestion process is enclosed, air emissions are unlikely, except during transfer to and from the digester. However, fugitive emissions of biogas are possible from emergency vent valves and from poorly sealed water traps. This can result in a range of hazards, including the risk of fire or explosion, as well as toxicity from contaminant gases such as H_2S and mercaptans (generating odour). Nitrogen gases also are possible.~~

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~~Particulate emissions are also less likely than from aerobic digestion because the process is enclosed, but there will probably be some waste preparation units which may have larger particulate emissions.~~

Table 4.23: Examples of gaseous emissions from anaerobic plants

~~**Component**~~	~~**Emissions concentration**~~	~~**Unit**~~	~~**Specific emission (g/tonne of waste)**~~	~~**Specific emissions (g/MJ of methane)**~~
~~Flue-gas~~				~~11000 Nm^3/t~~
~~Methane~~	~~Fugitive~~	~~vol-%~~	~~0 – 411~~	~~0.1~~
~~CO^2~~	~~31 – 35.2~~	~~vol-%~~	~~181000 – 520000~~	~~85~~
~~CO~~			~~72.3~~	~~0.25~~
~~NO^x~~			~~10 – 72.3~~	
~~NH^3~~	~~Fugitive~~			
~~N^2O~~			~~0~~	~~0.2~~
~~SO^x~~			~~2.5 – 30~~	~~0.15~~
~~H^2S~~	~~284 – 289~~	~~mg/Nm^3~~	~~0.033~~	
~~TOC (VOC)~~			~~0.0023~~	
~~PM (e.g. bioaerosol)~~				
~~Odour~~	~~626~~	~~GE/Nm^3~~		
~~Chloroform~~	~~2~~	~~µg/Nm^3~~		
~~Benzene~~	~~50 – 70~~	~~µg/Nm^3~~		
~~Toluene~~	~~220 – 250~~	~~µg/Nm^3~~		
~~Ethylbenzene~~	~~610 – 630~~	~~µg/Nm^3~~		
~~m+p+o xylene~~	~~290 – 360~~	~~µg/Nm^3~~		
~~Halogenated HC and PCBs~~			~~0.00073~~	
~~Dioxins/furans (TEQ)~~			~~$(0.4 – 4) \cdot 10^{-8}$~~	
~~Total chlorine~~	~~1.5~~	~~µg/Nm^3~~		
~~HCl~~			~~0.011~~	
~~HF~~			~~0.0021~~	
~~Cd~~			~~$9.4.10^{-7}$~~	
~~Cr~~			~~$1.1.10^{-7}$~~	
~~Hg~~			~~$6.9.10^{-7}$~~	
~~Pb~~			~~$8.5.10^{-7}$~~	
~~Zn~~			~~$1.3.10^{-7}$~~	

~~Fugitive means that fugitive emissions of these components occur but no data have been provided to quantify it~~

~~*Source*:[20, ETSU 1998] [32, Vrancken et al. 2001] [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [98, WT TWG 2004]~~

The AD process itself is enclosed but emissions to air, including odour emissions, can occur for example from:

- handling of waste input;
- transfer to and from the digester;
- open storage;
- separation, pretreatment and mixing of waste (e.g. with digestate);
- open reactors or tanks;
- digestate conditioning;
- post-treatment.

The principal gaseous emission (methane) is a desired product of the AD process, which, used as a renewable energy source, maximises profits and reduces greenhouse gas emissions.

However, fugitive emissions of biogas can arise from pressure-relief valves, poorly sealed water traps or condensate handling. This can result in a range of hazards, including the risk of fire or

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explosion, as well as toxicity from contaminant gases such as H_2S. H_2S, nitrogen compounds and mercaptans present in biogas can be extremely odorous as well.

Table 4.24 below summaries the parameters measured for emissions to air by AD plants, and the corresponding emission levels (average of periodic measurements over the three reference years). Two distinctions are made: first between plants performing only anaerobic digestion and those also performing aerobic treatment, and second between emissions other than from biogas combustion (receiving hall, sorting, mechanical pretreatment, etc.) and those from biogas combustion equipment (engines, CHP). This table is to be read together with Table 4.25 which gives an indication of the abatement techniques applied and origin of channelled emissions to air.

Most of the measurements are related to emissions from biogas combustion (SO_X, NO_X, CO). As the emissions from biogas combustion are dealt with by the Medium Combustion Plant Directive 2015/2193/EU and therefore are not in the scope of the WT BREF, the reported values are given only for information purposes.

The parameters most commonly monitored for emissions from biological steps of the process (i.e. not considering the combustion of biogas) are NH_3, NMVOC and odour.

WORKING DRAFT IN PROGRESS

Table 4.24: Emissions to air from anaerobic digestion (AD)

Pollutant measured	Type of measurement	Plants concerned		Ranges (mg/Nm^3 except for flow and odour)			
		AD only	AD & aerobic	AD only		AD & aerobic	
				From biotreatment	From biogas combustion	From biotreatment	From biogas combustion
Flow (Nm^3/h)	Continuous	71, 592⁽¹⁾	255, 256	57 000	/	16 000–53 000	/
	Periodic	72, 111, 131, 132, 484, 485, 528, 529, 534, 541, 592	251, 341, 377, 382, 459	480–90 000	25.8–48 600	12 000–99 500	500–8900
Dust	Periodic	72, 113, 131, 132, 529	255, 341, 377, 382	/	0.21–21	0.3 – 2.1	1.7–4.3
SO_X	Periodic	132, 528, 529, 534, 541, 592	341, 377, 459	/	0.7–436	/	0.5–114
NO_X	Periodic	72, 113, 131, 132, 534, 541, 528, 529, 592	341, 377, 382, 459	/	60–822	/	236–444
CO	Periodic	72, 131, 132, 528, 529, 534, 541, 592	341, 377, 382, 459	/	0.7–1816	/	39–655
HCl	Periodic	/	341, 377, 382	/	/	/	0–3.3
HF	Periodic	/	341, 377, 382	/	/	/	0–0.5
H_2S	Periodic	528, 541, 592	251, 377, 459	/	0.14–0.75	0.0007–1.15	/
NH_3	Periodic	111, 339	256, 339, 341, 377, 459	0.46–83	/	0.3–265	/
CH_4	Periodic	111, 131, 484, 485	/	0–895	0.004–681	/	/
TVOC	Periodic	131, 528, 529, 534, 541, 592	/	/	599–2900	/	/
NMVOC	Periodic	113⁽²⁾, 131, 132, 528, 529, 534, 541, 592	377, 382	/	0.6–93	/	28–134
TOC	Periodic	/	377, 459	/	/	0.2–16	654
Odour (OU$_E$/m^3)	Periodic	111, 113, 339, 485, 592	20, 251, 255, 268, 339, 377, 459	29.5–12 967	7190⁽³⁾	107–663	/

NB: For periodic measurements, the values are the average over the three reference years.

(1) Flow not indicated.

(2) Estimated value: 2 t/year based on material balance calculation.

(3) Odour emissions from biogas upgrading unit.

WORKING DRAFT IN PROGRESS

The origin of channelled emissions to air and abatement techniques are given in Table 4.25 below. The applied techniques include mainly biofiltering and scrubber systems.

Table 4.25: Anaerobic digestion - Abatement techniques and origin of channelled emissions to air

Plant code	Techniques for emissions to air	Origin of channelled emissions	Type of biological waste treatment	Type of anaerobic process (mesophilic/thermophilic)
20	NI	Biological process	AD & aerobic outdoor	Mesophilic
71	Acid scrubber system Biofiltering	Mechanical pretreatment and AD	AD only	Mesophilic
72	NA	After post-combustion (Regenerative Thermal Oxidiser)	AD only	Mesophilic
111	Basic scrubber system Biofiltering	Exhaust air from process and buildings	AD only	Mesophilic
113	NA	CHP, solid fuel-fired boiler	AD and PCT (hydrolysis, evaporation, distillation for producing bioethanol)	Mesophilic
131	NA	Biogas combustion (Reciprocating engine) - Flare	AD only	Mesophilic
132	NA	Biogas combustion (CHP) - Flare Biofilter	AD only	Mesophilic
251	Acid scrubber system Biofiltering Flaring	Complete plant Biofilter	AD & aerobic indoor	Thermophilic
255	Biofiltering Wet scrubbing	Complete plant Biofilter	AD & aerobic indoor	Thermophilic
256	Biofiltering	Biological process	AD & aerobic indoor	Mesophilic
259	NI	NI	AD & aerobic indoor	Thermophilic
265	Biofiltering	Receiving hall and process	AD only	Mesophilic

WORKING DRAFT IN PROGRESS

268	Wet scrubbing Biofiltering	In-house sector of plant - digestate tanks - Biofilter	AD & aerobic indoor	Thermophilic
319	NI	No air emission measured	AD only	Mesophilic
339	Biofiltering	Common steps – Homogeniser	AD only	Mesophilic
341	Biofiltering	Common steps - Rotary screener - 2 Biofilters Biogas combustion – CHP - Flare	AD & aerobic indoor	Thermophilic
349	Biofiltering	Anaerobic digestion followed by digestate composting	AD & aerobic indoor	Mesophilic
377	Wet scrubbing Biofiltering	Anaerobic digestion followed by digestate composting 4 Biofilters Biogas combustion - 2 CHPs	AD & aerobic indoor	Mesophilic
382	Biofiltering	Biological process – 4 biofilters Biogas combustion - 3 CHPs	AD & aerobic indoor	Thermophilic
459	Sulphide removal at digester Wet scrubbing – Biofiltering – Forced aeration – Water spraying	Biogas combustion (reciprocating engine) Enclosed buildings – Waste input storage – Sorting process steps	AD & aerobic indoor	Mesophilic
484	Biofiltering Activated carbon adsorption	Receiving hall, receiving and substrate buffer tank, sanitation tanks Upgrading biogas unit	AD only	Thermophilic
485	Bag/fabric filter system – Biofiltering - Activated carbon adsorption	Buffer tanks – Receiving hall Enclosed buildings - Upgrading biogas unit	AD only	Thermophilic
526	Biofiltering Activated carbon adsorption	Common steps and biological process	AD only	Mesophilic
528	Biofiltering Flaring Activated carbon adsorption	Biological process Biogas combustion – 2 CHPs	AD only	Mesophilic
529	Biofiltering Flaring	Biological process Biogas combustion – 3 CHPs	AD only	Mesophilic
534	NA	Biogas combustion - CHP	AD only	Mesophilic

WORKING DRAFT IN PROGRESS

541	Biofiltering Flaring	Biogas combustion - CHP	AD only	Mesophilic
592	Biofiltering	Biological process - Biofilter stack Biogas combustion – 2 CHPs - Flare	AD only	Mesophilic
638	NI	NI	AD only	Mesophilic

NI: No information.
NA: Not applicable.

WORKING DRAFT IN PROGRESS

Levels of dust in air emissions from the biological step are given in **Figure 4.20** below.

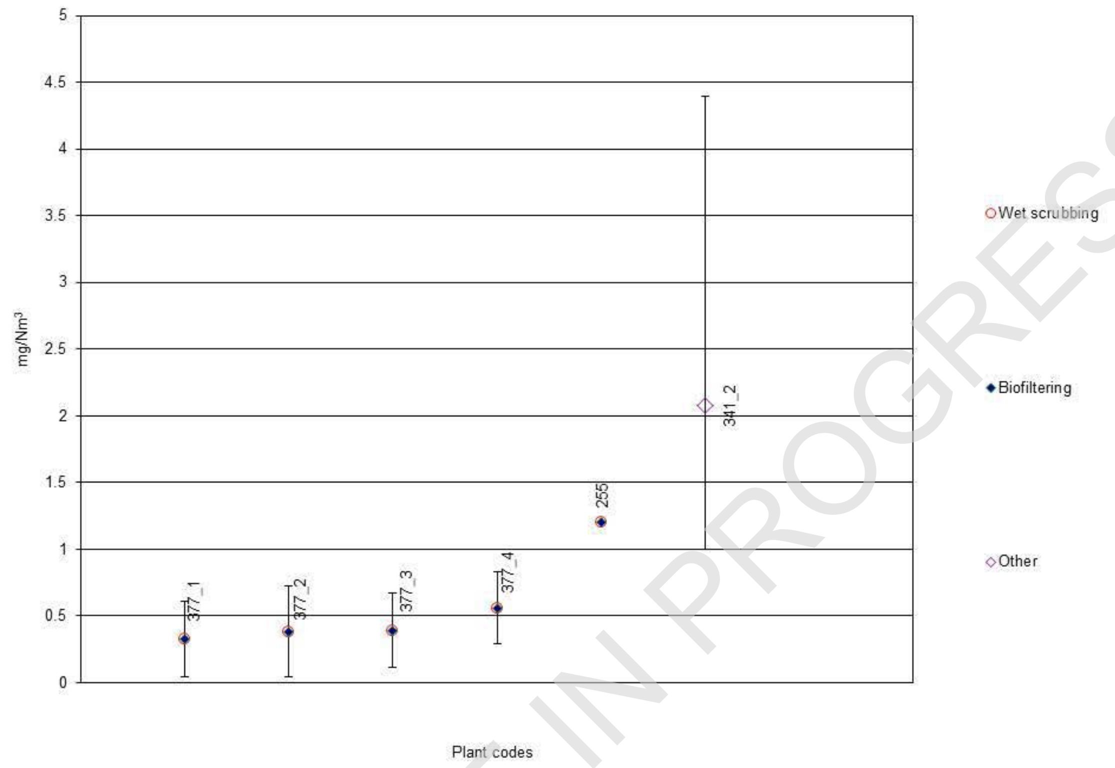

Figure 4.20: Dust emissions to air from the biological step of Anaerobic Digestion

4.3.2.2 Emissions to water and water usage

4.3.2.2.1 Emissions to water

From ex-Section **3.2.3 Emissions from biological treatments**

Although anaerobic systems can be operated in stages to reduce the overall COD in the effluent, they are generally operated for efficient methane production, and the liquid effluent thus tends to be more concentrated than the effluent from aerobic systems. During the AD process itself, there is no excess water; however during storage, pre- and post-treatment and side-activities (like cleaning or condensation from biogas) this can be important. Run-off water can be collected and used in the AD process or for composting plants.

The emission species will be similar to those from aerobic systems, but the volume of liquid is much higher and measurements will be needed to calculate emissions (e.g. TOC). The aqueous fraction may be discharged to a sewer, or ~~it may go through an~~ treated in an aerobic waste water treatment plant prior to discharge. ~~TOC, total nitrogen, total phosphorus and chloride levels will need to be monitored at the plant inlet and outlet to optimise plant performance, and are probably the most relevant indicators for such optimum performance.~~

Those units processing biological wastes from the food industries or agriculture are unlikely to ~~produce~~ release metals in the liquid emissions. Moreover, the metal content in a discharge may be lower than for an equivalent aerobic system because metal compounds are precipitated and leave with the solid fraction. However, a small amount can appear in the ~~liquid~~ effluent as suspended solids.

WORKING DRAFT IN PROGRESS

The quantity of waste or excess water generated depends upon a number of factors (the extent of biodegradation, the moisture content of input wastes and the extent to which the process water is recirculated, the way in which digestate is used –in some cases it is directly applied to land as slurry– and the degree to which steam is used to heat the biomass). Most processes seek to extract excess water from the digestate prior to aerobic digestion of the remaining biomass. ~~In some countries, however, little or no attempt is made to do this and the digestate is used on land as a soil conditioner. Some site studies state 100 – 500 kg per tonne of waste (wet weight). The excess waters are likely to be more polluted from dry systems, since more water is recirculated in the wet systems. Figures for wet and dry systems are given~~

~~The figures on dry and wet systems in relate to the waste water before removal of the suspended solids. In the post-treatment phase, the liquor from the digestate may be subjected to a process of denitrification, or filtered and/or fed to a decanter, with solids potentially being added to the digestate and the excess water being delivered to sewer.~~

Table 4.26: Typical waste water characteristics from anaerobic digestion

~~**Components**~~	~~**Units**~~	~~**Dry systems**~~	~~**Wet systems**~~	~~Amount (g)~~ ~~[1]~~
~~Waste water flow~~	~~m^3/t~~			~~0.47~~
~~COD~~	~~mg O^2/l~~	~~20000 – 40000~~	~~6000 – 24000~~	~~20 - 530~~
~~BOD~~	~~mg O^2/l~~	~~5000 – 10000~~	~~2500 – 5000~~	
~~Ammonia~~				~~1 – 160~~
~~Nitrate~~				~~1 – 10~~
~~Total N~~	~~mg N/l~~	~~2000 – 4000~~	~~800 – 1200~~	
~~Total P~~				
~~Cl~~				
~~Sulphate~~				~~1 – 5~~
~~As~~				
~~Cd~~				
~~Cr~~				
~~Cu~~				
~~Hg~~				
~~Ni~~				
~~Pb~~				
~~Zn~~				

~~[1] Based on 261 litres of waste water/tonne waste (possibly to be reduced to 211 litres by means of a partial re-use of the water used for the production of polymer solution). The range depends on the type of waste water treatment applied~~

~~Source:~~ ~~[37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [20, ETSU 1998] [34, Babtie Group Ltd 2002] [44, TWG 2003]~~

Table 4.27 below summarises the measures of emissions to water performed by plants performing anaerobic digestion, and the corresponding levels of emissions. The controlled parameters are mostly pH, TSS, COD, total N, and BOD_5. However, Table 4.28 shows that approximately a third of the plants that participated in the data collection did not report emissions to water, and, when there are emissions, those are mainly sent to a sewer or to an off-site waste water treatment plant.

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Table 4.27: Emissions to water from anaerobic digestion

Pollutant measured	Monitoring	Plants concerned	Range (mg/l except for flow, pH and conductivity)
Flow (m^3/h)	Continuous	20, 71, 111, 255, 382	1.25–470
	Estimated	341	1.3
pH	Continuous	111	Hourly average: 7–7.3 Monthly average: 7.8–7.9
	Composite sample	382	7.95
	Grab sample	20, 71, 113, 132, 341	7.1–7.2
TSS	24-hour flow-proportional composite sample	111	Hourly average: 300–1200
	Composite sample	382	1924
	Grab sample	71, 132, 341, 592	< 415
BOD$_5$	24-hour flow-proportional composite sample	111	Daily average: 70–370
	Composite sample	341, 382	1.5–1538
	Grab sample	20, 71, 132, 592	102–208
COD	24-hour flow-proportional composite sample	111	Daily average: 620–2900
	Composite sample	341, 382	9–3274
	Grab sample	20, 71, 113, 132	1260–2702
TOC	Grab sample	132	NI
THC	Composite sample	382	53
Cl$^-$	Composite sample	341, 382	10.5–537
F$^-$	Grab sample	341	0.009
S^{2-}	Composite sample	382	0
	Grab sample	341	0.095
SO$_3^{2-}$	Composite sample	382	1
	Grab sample	341	0.085
CN$^-$	Composite sample	382	0.2
Sulphates	Composite sample	382	12
	Grab sample	71, 113, 341	12–321
Total N	24-hour flow-proportional composite sample	111	Daily average: 130–440
	Composite sample	382	616
	Grab sample	20, 71, 341, 592	5.7–432
NO^{2-}/NO^{3-}	Grab sample	71, 341	0.25–116
NH$_3$-N	24-hour flow-proportional composite sample	111	Daily average: 40–170
	Composite sample	382	578
	Grab sample	71, 341	0.01–69
Total P	24-hour flow-proportional composite sample	111	Daily average: 10–14
	Composite sample	382	578
	Grab sample	71, 113, 341	0.3–35

Cd	Composite sample	382	0
Hg	Composite sample	382	0.01
As	Composite sample	382	0.004
	Grab sample	341	< 0.00005
Pb	Composite sample	382	1.9
	Grab sample	341	0.001
Cr	Composite sample	382	0.065
	Grab sample	341	0.002
Cr(VI)	Composite sample	382	0
Cu	Composite sample	382	0.3
	Grab sample	341	0.002
Mn	Composite sample	382	1.03
	Grab sample	341	0.04
Ni	Composite sample	382	0.35
	Grab sample	341	0.004
V	Grab sample	341	0.0002
Zn	Composite sample	382	1.4
	Grab sample	341	0.001
Fe	Composite sample	382	20.7
	Grab sample	341	0.07
Phenols	Composite sample	382	2.6
	Grab sample	341	0.004
BTEX	Composite sample	382	0
Surfactant	Composite sample	382	2.9
Toxicity (1)	Grab sample	341	0

NB: When the measurement method is composite sample or grab sample, the values in the table are the average of the measurements over the three reference years.
No emissions to water or no information: 71, 72, 97, 255, 256, 265, 268, 319, 339, 459, 526, 528, 529, 534, 592, 638 (see Table 4.28 below).
NI: No information.
(1) Reported toxicity: number of bodies built after 24 h – Standard: APAT CNR IRSA 7030 D Man 29 2003.

WORKING DRAFT IN PROGRESS

Table 4.28: Anaerobic digestion - Abatement techniques and origin of emissions to water

Plant code	Origin of emissions to water	Techniques used	Points of discharge	Dry/wet digestion	Type of plant
20	Biological process	Nitrification/denitrification	Indirect discharge (urban/municipal sewer system)	Wet digestion	AD & aerobic outdoor
71	Biological process	Aerobic Sequence Batch Reactor (SBR) – Vacuum evaporation – Recycling in process (91 %)	Indirect discharge (off-site common WWT facilities)	Wet digestion	AD only
72	Biological process	Recycling in process	No release	NI	AD only
97	Biological process	Recycling in process	No release	NI	AD & aerobic indoor
111	All processes, one waste water piping	Active sludge systems - SBR	Indirect discharge (urban/municipal sewer system)	Wet digestion	AD only
113	PCT (hydrolysis, evaporation, distillation for producing bioethanol)	Evaporation	Indirect discharge (off-site common WWT facilities)	Wet digestion	AD and PCT (hydrolysis, evaporation, distillation for producing bioethanol)
131	Rainwater	NI	Indirect discharge (urban/municipal sewer system)	Wet digestion	AD only
132	Rainwater	NI	Direct discharge from the on-site common WWT facilities to the environment	Wet digestion	AD only
251	All processes	Decantation	Indirect discharge (urban/municipal sewer system)	Dry digestion	AD & aerobic indoor
255	No release: all waste water (cleaning water, percolating water and condensate) is reused in the process	Recycling in process	No release	Dry digestion	AD & aerobic indoor
256	NI	NI	NI	Dry digestion	AD & aerobic indoor
259	Storage and common steps	NA	No release	Dry digestion	AD & aerobic indoor
265	NI	NI	NI	Wet digestion	AD only
268	NI	NI	NI	Dry digestion	Below IED threshold AD & aerobic indoor
319	No waste water	NA	No release	Wet digestion	AD only
339	NA	NA	No release	Wet digestion	AD only
341	Biological treatment of digestate	Equalisation - Active sludge systems SBR - Evaporation	Direct discharge from the on-site common WWT facilities to the environment	Wet digestion	AD & aerobic indoor
377	Biological process	NA	Direct discharge from the WT plant to the environment without treatment	Dry digestion	AD & aerobic indoor
382	All processes. Aerobic composting and anaerobic phase have separate points of release	NI	Indirect discharge from the WT plant to the on-site common WWT facilities	Wet digestion	AD & aerobic indoor

WORKING DRAFT IN PROGRESS

459	NI	Nitrification/denitrification Ultrafiltration	No external points of release	Wet digestion	AD & aerobic indoor
484	Waste water management: All incoming water, except the amount used as sanitary water, is reused in the process.	Incoming water is mainly used for washing trucks/tanks after unloading manure and sent to the substrate tank. Condensate from the biogas upgrading unit is sent to the digestion tank.	No process water is discharged from the plant, only storm water	Wet digestion	AD only
485	All incoming water, except the amount used as sanitary water, is reused in the process.	Incoming water is mainly used for washing trucks/tanks after unloading manure and sent in the substrate tank. Condensate from the biogas upgrading unit is sent to the digestion tank.	No process water is discharged from the plant, only storm water	Wet digestion	AD only
526	NI	NA	No release	Wet digestion	AD only
528	When containing ammonia, the collected water is used in the process, otherwise it is discharged into an on-site water lagoon. All the rainwater harvested on site is collected and eventually used within the process.	NA	No release	Wet digestion	AD only
529	When containing ammonia, the collected water is used in the process, otherwise it is discharged off site	NA	NI	Wet digestion	AD only
534	None	NA	No release	Wet digestion	AD only
541	All potentially contaminated water is collected and recycled into the AD process or sent off site for treatment	NA	No release	Wet digestion	AD only
592	Discharge consent available but at the moment there are no emissions to water from site	Anaerobic biological waste water treatment	No release	Wet digestion	AD only
638	NI	NI	NI	Wet digestion	AD only

NI: No information.
NA: Not applicable.

The analysis of emissions to water from Plants 132 and 341 discharging directly to a water body after treatment is dealt with in Section 2.3.6.7

WORKING DRAFT IN PROGRESS

4.3.2.2.2 Water usage

From ex-Section **3.2.2 Consumption of biological treatment**

~~The total water consumption for treatment of 1 tonne of waste is 78 litres. This treatment uses either tap or groundwater. Water is consumed in the following process steps:~~

- ~~steam production: 22 litres per tonne waste~~
- ~~production of polymer solution: 56 litres per tonne waste.~~

The reported water usage at anaerobic treatment plants is up to around 200 000 m^3/year. The reported average water usage per tonne of waste treated is 563 l/t, with a range of 6.4–3 100 l/t.

Figure 4.21 below shows the reported water usage per tonne of waste treated at anaerobic treatment plants.

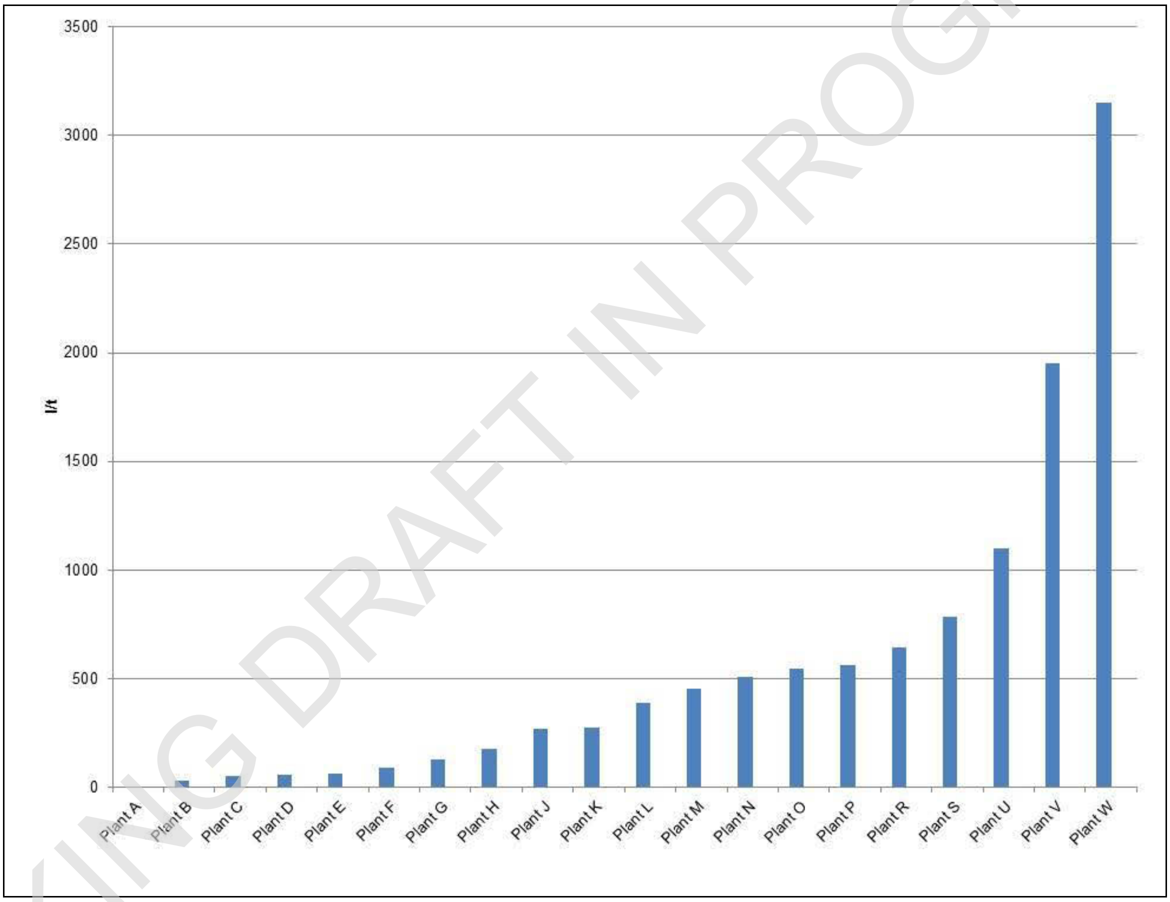

Figure 4.21: Water usage per tonne of waste treated in anaerobic treatment plants

The lowest specific water usage values were reported by plants with a dry digestion process (up to 270 l/tonne of waste treated). Water is used mostly in the process, while the lowest amount is used for cleaning and for air treatment. Some plants indicated using recycled water, e.g. from an adjacent waste water treatment plant.

4.3.2.3 Energy consumption

From ex-Section **3.2.2 Consumption of biological treatment**

The ~~only~~ energy sources which are used during the normal operation of anaerobic digestion ~~the installation, is~~ are electricity, which could be generated on site, and heat, which may be needed for possible drying and/or heating processes and for heating the buildings. The reported average

WORKING DRAFT IN PROGRESS

electricity use per tonne of waste is around 45 kWh$_e$, with a range of 2–150 kWh/t. This electricity could be generated at the plant itself by the combustion of biogas in a biogas engine (efficiency: 35 %). ~~The biogas consumption for electricity production is 29.1 Nm³ biogas containing 55 vol-% CH_4 (i.e. 37 kg). The electricity production and the energy use is given in Table 4.29 below.~~

~~**Table 4.29: Electricity consumption and production**~~

~~**Energy type**~~	~~**kWh per tonne MSW**~~	~~**Source**~~
~~Electricity input~~	~~50 – 55~~	~~Own production (biogas engine)~~
~~*Source*: [32, Vrancken et al. 2001] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [44, TWG 2003]~~		

~~Up to one third of the biogas produced is needed to heat the digester itself, since the process requires warm conditions.~~

Estimates concerning the utilisation of electricity by the plant vary a great deal. In rural AD plants, approximately 20 % of the electricity produced in the process is required for the plant operation, while urban plants may utilise two thirds of the electricity produced.

The reported specific energy consumption (kWh/tonne of waste treated – all types of energy sources) at anaerobic treatment plants is shown by **Figure 4.22** below. As some operators have claimed confidentiality issues, e.g. on waste input and/or output quantities, the data have been anonymised.

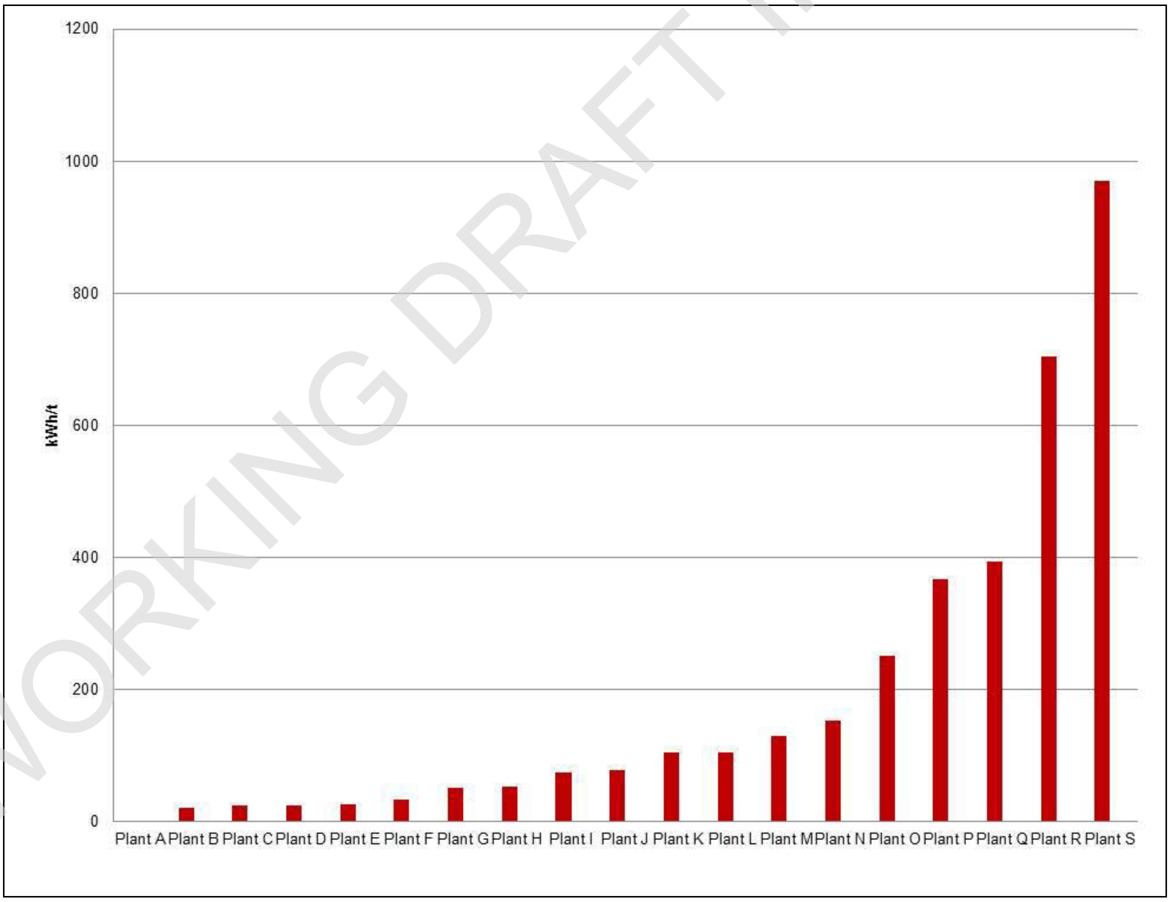

Figure 4.22: Energy consumption per tonne of waste treated in anaerobic treatment plants

The levels of energy consumption (all types of energy sources, i.e. including electricity, gas oil, gas, biogas) are up to 970 kWh/tonne of waste treated.

WORKING DRAFT IN PROGRESS

Some plants reported that only a renewable energy source (biogas) is used in the anaerobic digestion process, either for heating the digester, drying the digestate, or for generating the required electricity (CHP).

4.3.2.4 Raw material consumption

Auxiliary materials
The following products (delivered by truck) are used as auxiliary materials:

- anionic polymeric flocculants (polyacrylamide powder): 60 grams per tonne of waste;
- iron chloride solution (40 w/w-%): 3 kilograms per tonne of waste;
- anti-foaming products (polyalkylene glycol solution in water): 50 grams per tonne of waste

Table 4.30 below shows the reported amount of raw materials used in anaerobic plants.

Table 4.30: Raw materials used in anaerobic plants

Auxiliary material	Amount used in waste treatment (t/year) Average over the three reference years
Flocculants	0.2–140
Acids	13–360
Anti-foaming products	0.2–50
Activated carbon	4.4–800
Alkalis	480
Catalysts	92
Flocculants	1–141

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4.4 Mechanical biological treatment (MBT)

In this section, only specific techniques related to MBT are described. When necessary, cross references are made to related mechanical and/or biological sections.

4.4.1 Applied processes and techniques

From ex-Section **2.2.2**

Purpose

Mechanical biological treatment (MBT) is usually designed to recover materials for one or more purposes and to stabilise the organic fraction of the residual waste. The practical advantages of MBT plants are, above all, the reduction of:

- the volumes of waste;
- the organic matter content of the waste, which is ~~are~~ sent to final disposal (landfill or incineration).

Another purpose of MBT is ~~material splitting~~ to break down the material for further processing (e.g. preparation of solid waste fuels). Biological digestion is intended to reduce the weight, and to render inert any biologically active organic materials (typically called 'stabilised residue'). Typical values for the combined loss of water and biodegradable materials may be in the range of between 20 % and 35 %, mainly depending on ~~time~~ the duration of treatment ~~occurs~~. Further reductions of the waste volume sent to landfill may be achieved ~~due to~~ by mechanical separation of the output and can ~~then~~ be ~~finally~~ even higher ~~at~~ than 60 %.

Users

Mechanical biological treatment is a tool for pretreating wastes prior to landfilling or for preparing solid wastes (typically municipal solid waste) to be used as fuels. ~~Although the popularity of mixed waste composting is declining, it is currently still carried out in Greece, Spain, and Portugal, whilst in Italy, Germany and Austria, it is being progressively or totally 'converted' to MBT of residual waste. These types of treatments are also emerging in the Netherlands and Belgium. There is currently a lot of interest in this technology in the UK with some plants currently being constructed and the UK Government sponsoring trials of such new technologies.~~

~~These plants tend to have large capacities because they treat large volumes of mixed waste. An average capacity of 50 – 100 kt/yr is quite normal, but they can be as large as 700 kt/yr, as is one in Milan in Italy and can be as small as 7 kt/yr. At least four examples exist in Europe with the purpose of achieving complete recovery of MSW in the form of recycling materials and energy recovery~~

Principle of operation

MBT plants significantly reduce humidity by extracting, reducing and stabilising the organic content in the waste. These treatments involve a mechanical separation of the waste, biological treatment (anaerobic and/or aerobic digestion) of the organic fraction, and a further mechanical separation if required.

~~MBT has to lead to a reduction of the contents of biodegradable organic substances, volume, water content, gas formation potential and respiration activity of the waste, as well as having a significant improvement in leaching and settlement behaviour.~~

The biological steps of the mechanical biological residual waste treatment process are for the most part identical to those employed for the composting and anaerobic digestion of separately collected organic waste. However, MBT has tougher requirements with regards to mechanical treatment and some biological treatment machinery due to its broader input spectrum and more heterogeneous feedstock. MBT also necessitates more mechanical effort to extract a significant

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amount of material which does not endure biological treatment, for example the high calorific coarse fraction, and ferrous and non-ferrous metals. Where possible, the coarse fraction undergoes additional processing and differentiation. Residual waste also normally tends to have a much higher potential risk from spots of contamination and a significantly higher level of contaminants than separately collected organic waste. [123, UBA Germany 2013]

Feed and output streams

In principle, many types of waste materials can be accepted at a MBT plant. The materials broken down and digested in the biological stage include paper and board, green/kitchen organics, and the organic content contained within nappies, packaging, textiles, some types of sewage sludge, etc. Generally, only mixed, unsorted waste enters the plant. However, some European legislation and alterations in the treatment processes exclude or restrict some types of waste. Some examples are hazardous waste, waste for which a special treatment is obligatory because of EC legislation (e.g. Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption), waste for which a biological treatment is not appropriate and waste causing inhibition of ~~the~~ biological activity.

From ex-Section 3.2.1

~~The types of waste that may be accepted by this treatment are non-source separated municipal waste, sludge (e.g. sewage sludge from municipal waste water treatment plants) and commercial solid waste. Technically speaking, there is no restriction in also treating a wet organic fraction (e.g. kitchen wastes), garden and park waste, organic waste from hotels and restaurants or paper and board. However typically these last types of waste are not usually treated by these treatments.~~

The moisture content of ~~intake~~ waste intake is extremely variable, but it would be expected that green wastes and household wastes have a moisture content of at least 40–50 %.

The output from MBT plants is greatly reduced in weight and stabilised (emission releases from the ~~product~~ output compared with the untreated material could be reduced approximately 90–98 % under landfill conditions). Such figures are very variable and greatly depend on how the reduction of emissions is calculated (e.g. gas generation and respiration activity) and can typically have significant variations in quality. In some countries, the ~~waste OUT~~ output may be used as landfill cover if contamination is low enough ~~(low grade compost, grey compost or stabilised biodegradable waste)~~, or it may be landfilled. The quality of the ~~waste OUT~~ output ~~produced~~ is generally not acceptable for widespread use because of the contaminants ~~within~~ related to both the inert content (glass, plastic, etc.) and also to the heavy metals content arising from other wastes entering the stream (batteries, etc.). Other outputs are combustible fractions and recyclable materials (e.g. metals, plastic). Table 4.31 below gives an overview of the output from MBT processes, depending on the process configuration.

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Table 4.31: Overview of output from different MBT process configuration

Process configuration	Output
Aerobic biodrying	Recyclable materials (vary depending on configuration) but generally ferrous and non-ferrous metals, plastic polymers
	RDF or SRF
	Inorganic fines and inerts
Aerobic biostabilisation	Recyclable materials (vary depending on configuration) but generally ferrous and non-ferrous metals, plastic polymers
	Plastics and other inorganic residues not suitable for biostabilisation and production of separated and treated organic fraction
	Separated and treated organic fraction or biostabilised waste
	Inorganic fines and inerts
Aerobic biostabilisation producing an RDF	Recyclable materials (vary depending on configuration) but generally ferrous and non-ferrous metals, plastic polymers
	Inorganic material
	Biostabilised waste suitable for RDF or landfill
	Inorganic fines and inerts
Anaerobic Digestion	Biogas
	Digestate with possible use as a low calorific value (CV) RDF additive or landfill restoration additive
	Recyclable materials (vary depending on configuration) but generally ferrous and non-ferrous metals, plastic polymers
	Plastics and other inorganic residues not suitable for anaerobic digestion
	Inorganic fines and inerts
Source:[113, UK 2013]	

Figure 4.23 below shows a flow diagram for a typical MBT process.

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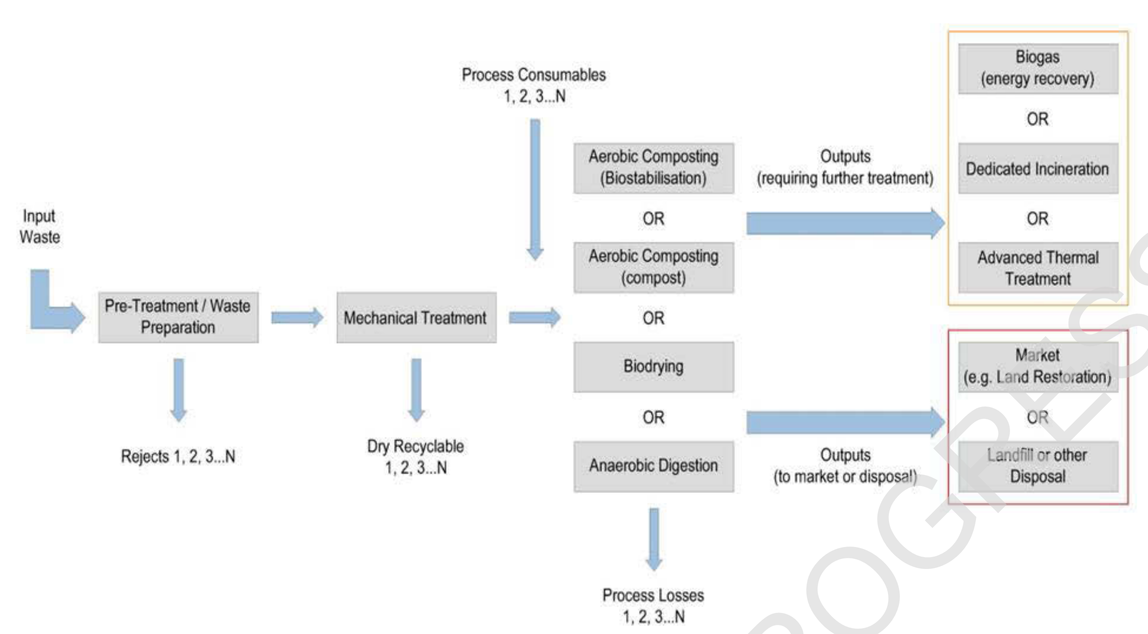

Source: [113, UK 2013]

Figure 4.23: Material flow diagram for a MBT process

From ex-Section 3.2.4

~~The aerobic treatments reduce the tonnage of input materials by the conversion of part of the biomass to carbon dioxide and water through microbial actions.~~ **Table 4.32** below gives an indication of the specific amount, destination and properties of output from MBT.

Table 4.32: Specific amount, destination and properties of output from MBT

Fractions suitable for energy recovery	**Specific amount (kg per tonne MSW)**	**Heating value (MJ/kg)**	
		Lower	**Higher**
RDF	300 460	16.6	19.9
Fractions not suitable for energy recovery		**Destination and properties**	
Ferrous	32–40: 24 ferrous 1 8 ferrous 2	Scrap trade (2 fractions) Pre-separation Post-separation	
Inerts	48.6 < 40 glass	Reuse	
Non-ferrous	8–10	Recovery	
Organics-rich material (to biological treatment)	550 • process losses: 200 • treated waste for landfilling: 350	TOC 18 w/w-% Upper heating value of 6 MJ/kg Density > 1.5 t/m^3 (wet) Hydraulic conductivity $k^f < 10^{-8}$ m/s	
Source:[32, Vrancken et al. 2001][37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [58, VDI and Dechema 2002]			

~~Grey compost~~ Separated and treated organic fraction

Copper and zinc can be expected to be found in any compost as they are plant micronutrients. Other heavy metals will be associated with whole aerobic digestion only or ~~by~~ with the addition of hazardous waste streams. In general, metals will be retained in the solid fraction. Metals will bioaccumulate in the compost fraction. Some products recovered by this treatment are shown in ~~the~~ Table 4.33

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Table 4.33: Overview of MBT outputs from the treatment of biodegradable municipal waste

Recovered product	Value (tonnes/tonne of waste treated)
Nutrient recovery	2.5–10 kg N/tonne of bio-waste recovered 0.5–1 kg P/tonne of bio-waste recovered 1–2 kg K/tonne of bio-waste recovered
Energy recovery	Likely (e.g. through dry stabilisation/separation processes to manufacture RDF). Depending on the configuration, RDF may be (typically) 0.2–0.5 tonnes, with a calorific value of around 15–20 MJ/kg (sometimes higher). In addition, in some configurations, digestion processes can recover energy from degradation of the biodegradable fraction (can be > 100 kWh depending on composition)
Total solid residuals depending on waste ~~(tonnes/tonne of waste)~~	0.7–0.9
Quality products for recycling (recovery)	0.05 (Metals)
Other residuals possible for reuse with restrictions	0.3–0.4 (RDF) 0.07–0.2 (Stabilised organic fraction) ▪ respiration activity (AT^4): < 5–7 mg O^2/g TS ▪ gas formation: GB21 < 20 mg/g TS
Residuals for landfilling or other waste treatment	0.2–0.4 (Heavy and light rejects)
Source:[37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [98, WT TWG 2004]	

The ~~characteristics of the~~ aerobic digested product has the following characteristics: one kilogram of treated waste potentially releases a total load of 1–3 g COD, 0.5–1.5 g TOC and 0.1–0.2 g NH_4-N into the leachates. The real numbers clearly depend on the respective intensity ~~respective~~ and the duration of the treatment. Table 4.34 shows the potential emissions from ~~grey compost~~ the separated and treated organic fraction by gas and leachate.

Table 4.34: Range of organic carbon, nitrogen and chlorine transfer by gas and leachate

Emission potential	Unit	Untreated MSW	MSW treated in a MBT plant ~~Mechanical biological treated MSW~~
By gas: carbon	litre/kg of dry matter	134–233	12–50
	g C_{org}/kg of dry matter	71.7–124.7	6.4–26.8
By leachate: TOC	g/kg of dry matter	8–16	0.3–3.3
N	g/kg of dry matter	4–6	0.6–2.4
Cl	g/kg of dry matter	4–5	4–6
NB: Minimum values represent the stabilisation degree reached by more modern MBTs. *Source*:[58, VDI and Dechema 2002]			

Process description

MBT plants are very flexible and can be built on a modular basis. For example, the mechanical treatment may be carried out before or after the biological treatment (see Figure 4.24 below).

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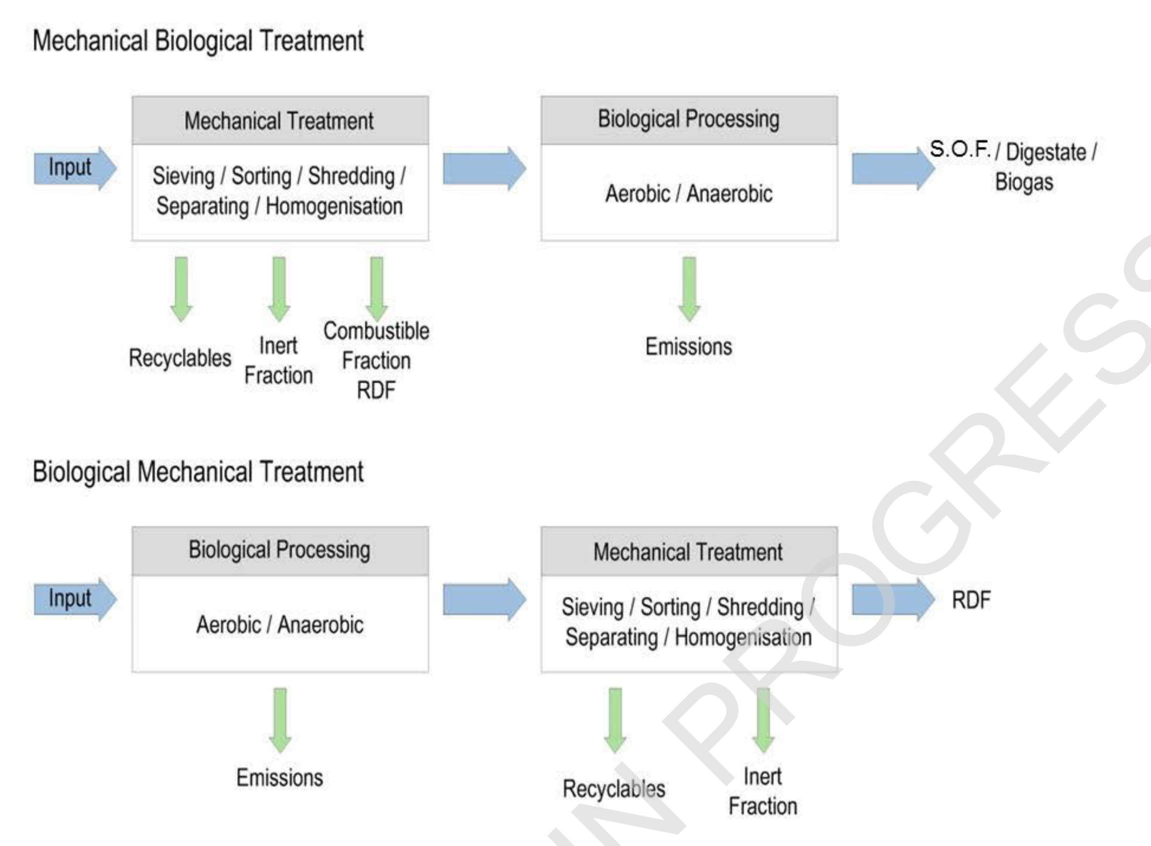

NB: S.O.F.: Separated organic fraction
Source: [113, UK 2013]

Figure 4.24: Schematic representation of MBT and BMT configurations

Mechanical treatment (see also Section 2.3.2.8 and Section 3.3)
The mechanical treatment phase involves segregating and conditioning the wastes. The processes that may be involved are as follows.

- Opening of waste bags (where necessary) (e.g. shredders).
- Extraction of undesirable components that might obstruct the subsequent processing (e.g. metal separators).
- Optimisation of the particle size for subsequent processing (e.g. by sieves, or shredders).
- Segregation of biodegradable materials in the underflows of primary screening, so that they can be sent to the biological treatment process (e.g. by sieves).
- Segregation of materials with a high calorific value, such as textiles, paper and plastics, in the overflows of primary screening, so that they can be sent for use in the production of fuel. Also, segregation of those materials suitable for further material recovery (e.g. by air separation).
- Homogenisation of materials destined for biological treatment.

Apart from these ~~elements~~ processes, the plant may include equipment for the recovery of metals and for the extraction of mineral fractions. The permutations regarding the design of an MBT plant are many and varied. Some plants are designed to separate and biologically treat the residual waste from MSW prior to landfill. ~~A scheme of a MBT process is shown in Figure 4.25.~~

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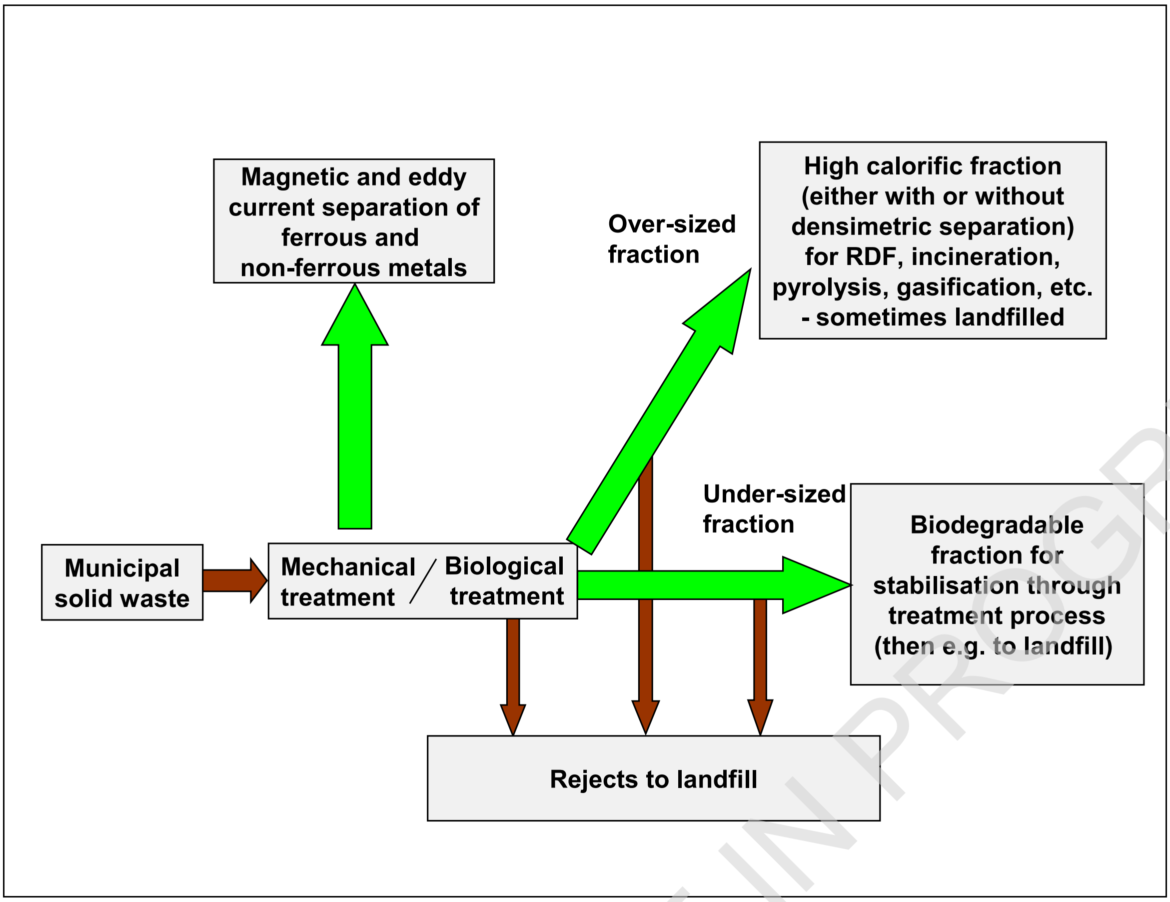

Figure 4.25: Schematic representation of mechanical/biological treatment inputs and outputs

~~Note: Brown arrows represent residual materials~~
~~Green arrows represent processed outputs~~
~~[13, Eunomia Research & Consulting 2002], [98, WT TWG 2004]~~.

The biological treatments that are used in an MBT facility are either aerobic treatment (see Section 4.2) or anaerobic digestion (see Section 4.3).

Already mentioned in "aerobic" section

~~Two types of MBT systems exist: encapsulated and housed.~~
~~*Encapsulated systems* (container, tunnel) are usually operated only under pressure with circulating air. Control is exercised through the parameters of temperature and oxygen content in the circulating air. The heat has to be led off from the system by cooling the circulating air. The condensate that is created may be used for watering the heaps or has to be disposed of as waste water.~~

~~*Housed systems* (wandering heap process) are operated both with pressure and with suction, in some plants both aeration methods are used alternatively. Circulating air systems are only possible to a limited extent in housed systems. In the suction operation, at least repeated re-use of the heap exhaust air is feasible. The heat generated can only be led off through water evaporation and exhaust air. In addition to specific aeration control, the periodic turnover of the biologically degraded material is of decisive importance for the progress of biological treatment. It serves the purpose of:~~

- ~~mixing the material and making new surfaces accessible for the micro-organisms~~
- ~~activating the biological degradation~~
- ~~minimising the biological degradation times~~
- ~~watering the heap evenly and compensating evaporation losses~~
- ~~compensating for the volume loss of the biological degradation~~

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- ~~leading off heat from the heap.~~

~~So the biological process is optimised and the existing biological treatment capacities are cost-effectively utilised. In MBT plants with quasi-dynamical biological treatments according to the moving heaps process or the tunnel process, turnover usually occurs in weekly intervals. Some biological processes require two turnover cycles per week during the first three weeks. After this period, the material is turned over every five to seven days.~~

From ex-Section **3.2.2 Consumption of biological treatment** – Aeration is addressed in Aerobic treatment

~~In quasi-dynamic biological systems the major part of organic waste contents is degraded within the first four weeks of biological degradation. During this period, the highest aeration rates are needed and up to 60 or 70 % of the total heap air supply is consumed. In the case of process interruptions in the pre-biological degradation, biological degradation is deferred towards the later biological degradation phases/aeration fields. The same holds for static processes without turnover. In the case of upstream fermentation, the intensive degradation of the easily degradable organic components occurs in the closed fermenter. Thus the exhaust gas quantities from the after-degradation are strongly reduced compared to fully aerobic degradation processes.~~

Table 4.35: Aeration rates

~~MBT technique~~	**~~Aeration rate~~ ~~(Nm^3 air/(m^3 of waste.h)~~**
~~Tunnel:~~	~~40 – 60~~
~~Moving heap~~ ~~pre-degradation~~ ~~after degradation~~	 ~~5 – 10~~ ~~1 – 5~~
~~Heap~~	~~10~~
~~*Source*:[88, UBA Germany 2003]~~	

The potential emissions from MBT processes are summarised in Table 4.26 below.

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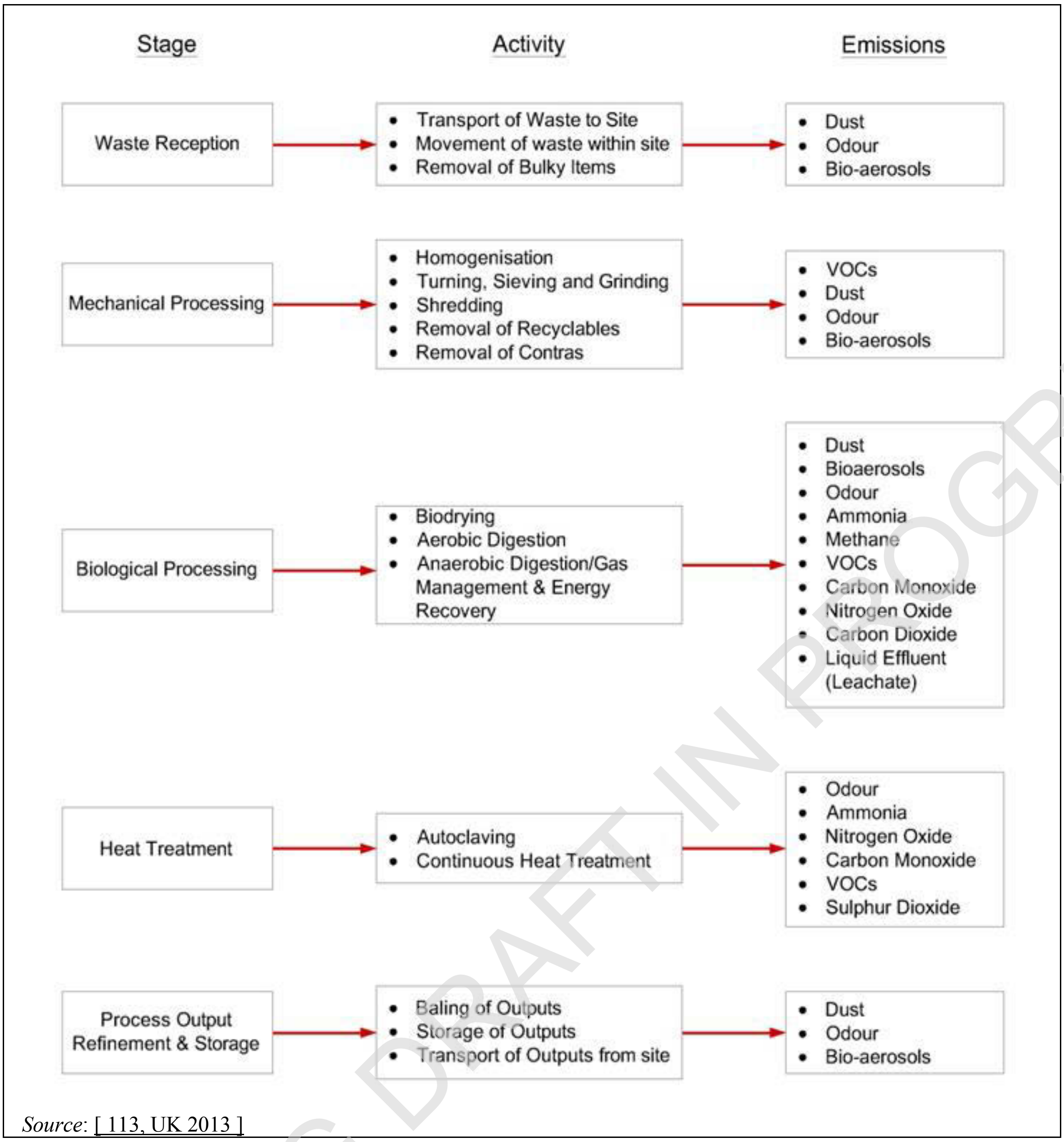

Source: [113, UK 2013]

Figure 4.26: Potential emission sources from MBT processes

Reference literature

[154, Umweltbundesamt 2015]

4.4.2 Current emission and consumption levels

From ex-Section 3.2.3 Emissions from biological treatment

The loss of weight during the aerobic process is about 10–20 % of the dry substance matter of the input waste, equivalent to 30–40 % loss ~~referred to~~ of the total weight. However, these data do not differentiate between moisture loss and carbon dioxide production. Aerobic systems operated in the open are more likely to create a wide range of emissions because the temperature and moisture content of the process is harder to control. There is much more chance that the material will saturate and produce a liquid emission, and a higher chance of the process turning anaerobic with subsequent emissions of methane.

Various companies co-digest hazardous organic waste streams with municipal or green wastes and low concentrations of halogenated organics with aqueous organic wastes. In both cases, it is reasonable to expect the biomass to adapt to a new food source, but it is also reasonable to

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expect that the temperature rise in composting, or agitation of the tanks in activated sludge systems, will create a discharge to the air of new species.

By contrast to composting plants treating green waste and separately collected bio-waste, the material treated in MBT plants may exhibit a broad range of emissions (municipal waste). MBT exhaust gas may contain fluorinated chlorinated hydrocarbons, ammonia, mercury, methane, N_2O and other compounds.

The MBT exhaust gas is partially produced during the mechanical treatment, but mostly is related to the biological process in which heat is released. Depending on the process, ~~management~~ temperatures from 30 °C up to 90 °C may be reached. Thus a great part of the moisture contained in the waste is driven out. Furthermore, the remains of solvents and of mineral oil carbohydrates can be driven out. Under these boundary conditions, the MBT exhaust gas contains at least the following material groups:

- water in the form of water vapour-saturated process exhaust air which is not likely to be below saturation level unless unsaturated hall air is added;
- degradation products of organic decomposition which are also known to result from alcoholic fermentation, such as acetone, acetaldehyde, ethanol, methanol, butanol and other short-chained compounds;
- solvents, especially benzene, toluene, xylene;
- odorous terpenes, mainly limonene and alpha- and beta-pinene;
- traces of mineral oil carbohydrates.

From ex-**Section 3.2.2 "Consumptions of biological treatments"**

~~**Anaerobic digestion**~~

A mechanical biological treatment (MBT) containing separation and anaerobic digestion typically consumes water, auxiliary materials and energy.

4.4.2.1 Emissions to air

From ex-Section 3.2.3 Emissions from biological treatment

~~There is a limited amount of information available on emissions from aerobic operations.~~ The emissions to ~~of~~ air of pollutants and odorous substances of MBT plants are:

- waste-specific (type, composition, age);
- treatment-specific (aerobic degradation, fermentation);
- process-specific (type of aeration);
- dependent on operational management;
- influenced meteorologically (weather conditions) in the case of open reactors.

In addition to the release of odorous substances at delivery and during mechanical treatment, the emissions of the plant are mainly determined by the following sources:

- aerobic degradation,
- fermentation,
- exhaust air/exhaust gas treatment.

~~Microbiological degradation releases are from 30 to 50 MJ of heat per kg of organic substance in the waste. This heat leads to the desired self-warming of the material. The surplus heat that exceeds the quantity necessary for maintaining the process temperature is dissipated through evaporation of the water. The water thus fulfils the important function of the heat carrier.~~

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Table 4.36: Examples of air parameters from some MBT

~~Capacity MBT~~	~~Part of the facility~~	~~Air renewal, temperature~~[1]~~, process conditions~~	~~TOC (FID)~~	~~Concentration of odour~~		~~Odour~~
~~kt/yr~~			~~mg/m^3 and g/t respect~~	~~spectrum GE/m^3~~	~~average GE/m^3~~	~~10^6 GE/h~~
~~30~~	~~Mechanical treatment and low bunker~~	~~Forced ventilation, approx. 2-fold air renewal, 5 – 10 °C during the measurement~~	~~40 mg/m^3~~ ~~20 – 25 g/t~~	-	-	-
~~200~~	~~Mechanical treatment and low bunker~~	~~Forced ventilation, approx. 1.5-fold air renewal, 10 – 13 °C during the measurement~~	~~15 – 25 mg/m^3~~ ~~25 – 55 g/t~~	~~150 - 630~~	~~390~~	~~38~~
~~30~~	~~Total exhaust air of MBT (2 weeks biological degradation)~~	~~Mixture of exhaust air from halls and heaps, approx. 3-fold air renewal, 25 – 30 °C during the measurement~~	~~60 – 130 mg/m^3~~ ~~500 – 720 g/t without methane~~ ~~10 - 30 mg/m^3~~ ~~approx. 700 g/t methane~~			
~~50~~	~~Total exhaust air of MBT (16 weeks biological degradation)~~	~~Mixture of exhaust air from halls and heaps, approx. 1-fold air renewal, 20 – 30 °C during the measurement~~	~~700 – 880 g/t~~ ~~200 – 700 mg/m^3~~ ~~up to 12000 g/t methane~~			
~~70~~	~~Exhaust air from biological degradation (fermentation with 8 weeks of biological degradation)~~	~~Mixture of exhaust air from halls and heaps, approx. single air renewal, 25 – 30 °C during the measurement~~	~~50 – 180 mg/m^3~~ ~~590 – 720 g/t without methane~~ ~~approx. 80 mg/m^3~~ ~~approx. 1100 g/t methane~~	~~8000 – 20000~~	~~15000~~	~~1200 to bio-filter~~

[1] ~~There are some systems (air suction systems) where temperatures can reach up to 40°C~~

~~*Source*:[88, UBA Germany 2003] [98, WT TWG 2004]~~

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~~Some data on air emissions from aerobic operations is shown below.~~

Table 4.37: Relevant emissions for MBT operations

~~**Parameters/ pollutants**~~	~~**Emission to air**~~ ~~(values in g/tonne of waste digested)~~ [6]
~~Flow~~	~~Exhaust air: 2500 – 30000 Nm^3/t~~
~~Ammonia~~[3]	~~5 – 3700~~ ~~Other data:~~ ~~0.12 times intake tonnage~~[1] ~~20 – 40 mg/Nm^3~~ [4]
~~Carbon dioxide~~	~~98 – 563 kg/tonne of MSW~~ ~~482 – 566 kg/tonne of MSW if machinery, energy system and construction are included~~ ~~Other data:~~ ~~10 – 20 % intake tonnage of waste x 1000~~ ~~20 % of the intake dry solids~~
~~N_2O~~	~~11 – 110~~
~~NO_x~~	~~100~~
~~Methane~~	~~411 – 2000~~
~~Particulate matter~~[2]	~~163 – 186~~
~~PM^{10}s~~	~~e.g. bioaerosols~~
~~Odour~~	~~50 – 500 GE/m^3~~
~~TOC (VOC)~~[5]	~~0.7 – 600~~
~~AOX~~	
~~CFC~~	
~~Dioxins/furans~~	~~0.1 ng/m^3~~
~~Microbes~~	
~~Mercury~~	

[1] ~~Reduce emission factor by 50 % if the system uses forced air or another method to ensure aerobic conditions throughout; increased emission factor if high nitrogen wastes received.~~

[2] ~~Filter systems on the exit air will reduce general particulate emissions, but not PM$_{10}$.~~

[3] ~~If treatment process conditions move away from the range of pH 4 – 8 and with a C:N:P ratio of out of 100:5:1, then larger quantities of other gases may evolve; larger quantities of ammonia may become particularly prevalent if there is too much nitrogen in the feedstock.~~

[4] ~~Equals 545 - 1090 grams per tonne before any abatement of ammonia (e.g. biofilter).~~

[5] ~~Methane may represent 1/6 of the TOC amount.~~

[6] ~~In some cases several ways of calculation or different types of emission data are presented.~~

~~*Source:* [32, Vrancken et al. 2001] [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [44, TWG 2003] [53, UNECE Task force on Emission Inventories 1999] [58, VDI and Dechema 2002] [88, UBA Germany 2003] [104, UBA Germany 2004]~~

From ex-**Section 3.2.3 "Emissions from biological treatments"**

~~**Mechanical biological treatments**~~

~~*Ammonia emissions*~~

~~Nitrogen in the waste can easily be converted to ammonia, and this is more likely to happen if the C:N ratios are unbalanced (too much nitrogen), or the mass becomes anoxic. For green wastes, this is more likely in the summer months with high levels of grass mowings in the waste and insufficient woody material as a bulking agent. Enclosed aerobic digestion or biodegradation systems with a high forced air injection providing an excess of oxygen produce less ammonia than standard windrows. The ammonia load of the crude gas of MBT plants amounts to between 10 to 560 mg/Nm^3 depending on the process variant, specific exhaust air~~

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~~quantity, etc. With upstream fermentation, up to 1000 mg/Nm^3 may be found in the pre-biological degradation. In addition to its effect of polluting the air, a high ammonia concentration in the crude gas damages the biofilters often used in MBT plants. Therefore, the aim has to be to keep the ammonia load of the crude gas prior to entry into the biofilter as low as possible. Upstream pH controlled acid scrubbers can reliably keep NH_3 concentrations below 10 mg/Nm^3.~~

~~Sites undertake a range of riddling, sieving, grinding and turning operations. *Particulate* emissions occur, but there are no data to quantify them. It is known that most aerobic digestion operations generate a range of fungi, particularly aspergillus. Filters on the exit air will minimise particulate emissions. PM_{10} emissions are a possibility.~~

~~*Bioaerosols*~~

~~These are micro-organisms and other tiny biological particles that are suspended in air. They are respirable and generally invisible. Bioaerosols can be produced by the aerobic process. Surveys have drawn particular attention to a fungus called Aspergillus fumigatus. It is found all over the world, especially in soils and in forest litter. It is particularly associated with the aerobic digestion process as it is capable of degrading cellulose (a carbohydrate found in plant material) and is capable of surviving at high temperatures (up to 65 °C). As part of its lifecycle, Aspergillus fumigatus produces tiny spores.~~

~~*Odour emissions*~~

~~They may come from anaerobic conditions. Odours are emitted from the surface of open piles, windrows, maturation piles, storage piles and stockpiles. Exhaust gases from controlled aeration systems also contain odourous compounds. Typically the most problematic odorous compounds at aerobic digestion facilities include ammonia, hydrogen sulphide, mercaptans, alkyl sulphides such as dimethyl sulphide, dimethyl disulphide and terpenes. These compounds are present in many feedstocks or are formed during the process through aerobic or anaerobic actions.~~

~~*Some pesticide*~~

~~They may be broken down by photolysis, plant metabolisms or microbial action. Others are persistent.~~

~~*Methane*~~

~~Methane will also be an issue, although the plant will usually be run in such a way so as to minimise this production. Methane emissions may range from 10 to 2000 mg/Nm^3.~~

~~*VOCs*~~

~~Any volatiles in the feedstock will tend to be emitted to the air due to the temperature rises. The crude gas from MBT plants contains a large number of single organic compounds in relatively high but fluctuating concentrations. The TOC concentration (total organic carbon) that records all organic contents is a parameter suitable for monitoring. The MBT crude gas contains TOC concentrations of between 10 to 2000 mg/Nm^3, but up to 7500 mg/Nm^3 have been measured. Open-air heaps have TOC concentrations above 1000 mg/m^3 due to inevitable anaerobic conditions within the core of the heap. Carbon concentrations of more than 10000 mg/Nm^3 have been recorded at the surface of non-aerated open-air heaps especially with anaerobic conditions within the heap. The main outflow of the TOC occurs during the first hot biological degradation phase, i.e. in the first one or two weeks of biological degradation. Next~~

Table 4.38~~ shows the list of organic compounds identified in MBTs.~~

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Table 4.38: Organic compounds which were verified within the scope of four screening inquiries of exhaust air (three aerobic tests with intensive and after-biological degradation, one anaerobic plant)

~~Alkanes~~		
~~1,1-dimethylcyclopentane~~	~~4-methylnonane~~	~~n-dodecane~~
~~1,3-dimethylcyclohexane~~	~~5 ratified alkane~~	~~n-heptane~~
~~1,4-dimethylcyclohexane~~	~~5-methylundecane~~	~~n-hexane~~
~~10 ratified alkane~~	~~6 alkylcyclohexane~~	~~n-nonane~~
~~11 ratified alkane~~	~~butylcyclohexane~~	~~n-pentadecane~~
~~2 ratified ektane~~	~~2 C^3-cyclohexane~~	~~n-pentane~~
~~2 ratified undecane~~	~~C^4- cyclohexane~~	~~n-tetradecane~~
~~2,3-dimethylpentane~~	~~cyclohexane~~	~~n-tridecane~~
~~2,4-diphenyl-4-methyl-2-pentene~~	~~decane~~	~~n-undecane~~
~~2-methyldekane~~	~~dimethylcyclohexane~~	~~nonadecane~~
~~2-methylheptane~~	~~dodecane~~	~~propylcyclohexane~~
~~2-methylhexane~~	~~ethylcyclohexane~~	~~tridecane~~
~~2-methylnonane~~	~~ethylcyclopentane~~	~~trimethylbenzol~~
~~2-methylundecane~~	~~hexadecane~~	~~trimethylcyclohexane~~
~~3-methyldecane~~	~~methylcyclopentane~~	~~undecane~~
~~3-methylheptane~~	~~methylbutane~~	~~3 ratified heptane~~
~~3-methylhexane~~	~~methylcyclohexane~~	~~7 ratified nonane~~
~~3-methylnonane~~	~~methyloctane~~	~~2 ratified octane~~
~~4-methylheptane~~	~~n-decane~~	~~ratified dodecane~~
~~PAHs~~		
~~1,2,3,4-tetrahydromethyl-naphthaline~~	~~naphthaline~~	~~acenaphthene~~
~~1,2,3,4-tetrahydronaphthaline (tetraline)~~	~~dimethylnaphthaline~~	~~methyldecaline~~
~~ethylnaphthaline (vinylnaphthaline)~~	~~1-methylnaphthaline~~	~~2 -methylnaphthaline~~
~~decahydromethyl- naphthaline~~	~~methyltetraline~~	
~~Acids and esters~~		
~~2-butene acidethylester~~	~~butyric acidmethylester~~	~~hexanal~~
~~2-methylbutyric acidethylester~~	~~2 carbonacidester~~	~~hexanacidethylester~~
~~3-methylbutyric acidethylester~~	~~6 carbonacid~~	~~fattyacidethylester~~
~~alkanacidethylester~~	~~acetic acid~~	~~myristinacidisopropylester~~
~~alkanacidethylester (acid >C^7)~~	~~2 alkanacid~~	~~pentanacidmethylester~~
~~aceticacid -1-methylethylester~~	~~aceticacidalkylester~~	~~propanacidethylester~~
~~benzoacid~~	~~aceticacidbutylester~~	~~propanacidmethylester~~
~~benzoacidbenzylester~~	~~aceticacidethylester~~	~~hetradecane acid~~
~~butyricacid~~	~~aceticacidmethylester~~	~~hexadecane acid~~
~~butyricacidethylester~~		
~~Terpene~~		
~~α-pinene~~	~~β-pinene~~	~~β-myrcene~~
~~pinene~~	~~D-limonene~~	~~3-carene~~
~~myrcene~~	~~camphor~~	
~~Aldehydes/ketones~~		
~~1,2-diphenylethanone~~	~~3-buten-2-one~~	~~hexanal~~
~~2,3-butandione~~	~~3-hydroxy-2-butanone~~	~~methyl-2-butanone~~
~~5 2-alkanone~~	~~3-pentanone~~	~~methylisobutylketone~~
~~2-butanone~~	~~Acetaldehyde~~	~~nonanal~~
~~2-heptanone~~	~~Acetone~~	~~octanol~~
~~2-hexanone~~	~~acetophenone~~	~~pentanal~~
~~2-methylpropanal~~	~~decanal~~	~~ramified 2-heptanone~~
~~2-pentanone~~	~~diphenylethandione~~	~~dodecanal~~
~~2-undecanone~~		
~~Alcohols~~		
~~1-butanol~~	~~2-methyl-1-propanol~~	~~isopropanol~~
~~1-pentanol~~	~~2-methylbutanol~~	~~ramified alcanol~~
~~2-butanol~~	~~3-Methyl-1-butanol~~	~~ramified pentanol~~

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~~2-ethyl-1-hexanol~~	~~butanol~~	~~ethanol~~
~~2-methyl-1-butanol~~		
~~Benzenes/alkylbenzenes~~		
~~benzene~~	~~2 C^6-benzene~~	~~methylpropylbenzene~~
~~5 C^3-benzene~~	~~3-dimethylethylbenzene~~	~~propylbenzene~~
~~C^4-benzene~~	~~ethylbenzene~~	~~styrol~~
~~1-methylpropylbenzene~~	~~ethylmethylbenzene~~	~~toluene~~
~~15 C^4-benzene~~	~~o/m/p-xylene~~	~~3-trimethylbenzoene~~
~~7 C^5-benzene~~	~~methylisopropylbenzole~~	
~~Halogenic compounds~~		
~~1,1,1-trichlorethane~~	~~dichlormethane~~	~~tetrachlorethylene~~
~~dichlorbenzene~~	~~fluorethylene~~	~~trichlorethylene~~
~~Sulphur compounds~~		
~~2-butanthiol~~	~~dimethylsulphide~~	~~sulphur dioxide~~
~~dimethyldisulphide~~	~~methanthiol~~	~~carbon disulphide~~
~~Siloxanes~~		
~~cyclohexasiloxane~~	~~cyclotetrasiloxane~~	~~cyclosiloxane~~
~~cyclopentasiloxane~~	~~hexamethyldisiloxane~~	~~siloxane~~
~~octamethylcyclotetra-disiloxane~~		
~~Phthalates~~		
~~diethylphthalate~~	~~dimethylphthalate~~	
~~Ethers~~		
~~tetrahydrofurane~~		

~~[88, UBA Germany 2003]~~

~~Chlorofluorocarbons~~ ~~(CFC)~~

~~The few available data shows that in MBT plants CFC loads of more than 10 grams per tonne input material may be released depending on the processed waste type (~~Table 4.39~~). Leading substances are CFC R11 (trichlorofluoromethane) and R12 (dichlorofluoromethane) which were used frequently in the past.~~

Table 4.39: CFC emissions from MBT (raw gas)

~~Parameter (g/tonne)~~	**~~Facility A (exhaust air from tunnel)~~**	**~~Facility B (exhaust air from biological degradation trommel)~~**	**~~Facility B (exhaust air from biological degradation trommel)~~**	**~~Facility B (exhaust air from halls)~~**	**~~Facility C (exhaust air from biological degradation module)~~**
~~Probe spring~~	~~Winter~~	~~Summer~~	~~Winter~~	~~Summer~~	~~(estimated)~~
~~R11~~	~~n.d.~~	~~8.5~~	~~4.1~~	~~0.4~~	~~2.2 – 2.3~~
~~R12~~	~~n.d.~~	~~11.3~~	~~0.2~~	~~0.4~~	~~1.3 – 1.4~~
~~R21~~	~~n.d.~~	~~n.d.~~	-	~~n.d.~~	~~n.d.~~
~~R113~~	~~n.d.~~	~~n.d.~~	~~<0.05~~	~~n.d.~~	~~1.9~~
~~R114~~	~~n.d.~~	~~n.d.~~	~~0.2~~	~~0.4~~	~~1.2 – 1.4~~
~~n.d. = not detectable~~					

~~[88, UBA Germany 2003]~~

~~Waste water~~

~~Sites are unlikely to produce a surplus of liquid because the aerobic digestion process emits large volumes of water to the air and generally requires additional liquids as 'top-ups'. If they do, then these will be occasional intermittent flows. Although it is known that some sites have had problems with waste water, the quantities of liquid emissions are likely to be small since aerobic digestion is an exothermic process~~.

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Table 4.40: Leachate from aerobic digestion

~~**Water parameter**~~	~~**Specific emissions (kg/tonne of MSW)**~~	~~**Concentration of the waste water (mg/l)**~~
~~Waste water flow~~	~~260 – 470~~	
~~TOC~~		~~40~~
~~COD~~	~~0.457~~	~~120 – 200~~
~~BOD^5~~		~~20 – 25~~
~~HC~~		~~10 – 20~~
~~BTEX~~		~~0.1~~
~~AOX~~		~~0.5~~
~~Chloride~~	~~0.152~~	
~~Total N~~		~~70~~
~~Total P~~		~~1 – 3~~
~~CN~~	~~$7.28\cdot10^{-5}$~~	~~0.2~~
~~Sulphide~~		~~0.1 – 1~~
~~Cd~~	~~0~~	
~~Cr~~	~~0~~	~~0.5~~
~~Cr (VI)~~		~~0.1~~
~~Cu~~	~~0~~	
~~Hg~~	~~0~~	
~~Mg~~	~~0~~	
~~Ni~~	~~$7.94\cdot10^{-4}$~~	
~~Pb~~	~~$5.96\cdot10^{-4}$~~	
~~Zn~~	~~$2.38\cdot10^{-4}$~~	
~~Copper and zinc would be expected in any aerobic digestion leachate as they are plant micronutrients. There is a possibility of toxic metals in the effluent although most metals will remain in the aerobic digestion product.~~		

~~[32, Vrancken et al. 2001] [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [44, TWG 2003] [53, UNECE Task force on Emission Inventories 1999] [58, VDI and Dechema 2002] [88, UBA Germany 2003]~~
~~[98, WT TWG 2004]~~

~~*Emissions to land*~~

~~Aerobic digestion sites should make certain whether or not there are liquid emissions to land, even if they have a concrete base underneath the windrows, as the concrete basement may not be non-continuous, and part of the operation may be on a permeable surface. If the base is impermeable, then there will be a discharge to surface waters or sewer or a collection in sumps. If the aerobic digestion sites are on the landfill, liquid discharges will go to the landfill treatment plant.~~

~~There is also a possible problem if excess rainwater falling on the windrows is not evaporated by the heat of the aerobic digestion process. Surplus water would pick up fatty acids and humic acids and solids from the aerobic digestion process and then transfer the discharge to land, surface water or sewer.~~

~~Sludge and/or digestate for onward disposal to landfill typically have organic compounds, nitrogen and phosphorous compounds, chloride and chromium.~~

Table 4.41 shows the different parameters measured at mechanical biological treatment plants as well as the type of measurement (periodic/continuous). This table should be read together with Table 4.42 which shows, for each plant, the origin of emissions to air as well as the associated abatement techniques.

The most measured parameters are NH_3, odour, dust, H_2S and TOC from plants equipped mainly with a scrubber system and a biofilter. Abatement of dust emissions is sometimes carried out with a bag filter. Some plants are equipped with a biofilter only. Four plants (243, 267, 279 and 628) are equipped with a regenerative thermal oxidation system.

WORKING DRAFT IN PROGRESS

Table 4.41: Parameters measured in emissions to air from MBT plants (excluding biogas combustion)

Parameter measured	Type of measurement	Plants concerned	Ranges (mg/Nm^3 except for flow, odour and air O_2 content)
Flow	Continuous	017_1, 037, 239, 243, 244, 257_1, 257_2, 266, 267, 573, 628	720–134 000
	Periodic	017_2, 017_3, 019, 127, 279_1, 279_2, 337_1, 337_2, 338, 349_1, 349_2, 349_3, 349_4, 350_1, 350_2, 350_3, 452_1, 452_2, 452_3, 452_4, 452_5, 452_6, 454, 566	
Dust	Continuous	239, 243, 244, 257_1, 257_2, 266, 267, 279_2, 628	< 19
	Periodic	017_3, 019, 037, 127, 279_1, 337_1, 337_2, 349_1, 349_2, 349_3, 349_4, 350_1, 350_2, 350_3, 452_1, 452_2, 452_3, 452_4, 452_5, 452_6, 573	
Odour	Periodic	017_1, 017_2, 019, 037, 127, 239, 243, 244, 257_1, 257_2, 266, 267, 279_2, 338, 349_1, 349_2, 415_1, 434_1, 434_2, 628	74–5550
NH_3	Periodic	017_1, 019, 037, 127, 243, 337_1, 338, 349_1, 349_2, 350_1, 350_2, 350_3, 415_1, 452_1, 452_2, 452_3, 566, 573	0.12–48$^{(1)}$
TVOC$^{(2)}$	Continuous	239, 243, 244, 257_1, 257_2, 266, 267, 628	3–21
	Periodic	017_1, 017_2, 019, 037, 337_1, 349_1, 349_2, 350_1, 350_2, 350_3452_1, 452_2, 452_3, 452_4, 452_5,	
H_2S	Periodic	127, 337_1, 349_1, 349_2, 350_1, 350_2, 350_3, 452_1, 452_2, 452_3, 452_4, 452_5, 566, 573,	0–4.25
NO_X	Periodic	019, 349_3, 349_4, 415_2, 415_3, 452_4, 452_5, 452_6, 566, 573	0.95–405
N_2O	Continuous	239, 243, 244, 257_1, 257_2, 266	0–14.99
	Periodic	017_1	
HCl	Periodic	349_3, 349_4, 452_1, 452_2, 452_3, 452_4, 452_5	0.06–3.23
HF	Periodic	349_3, 349_4, 452_1, 452_2, 452_3, 452_4, 452_5	0–0.33
SO_X	Periodic	415_2, 415_3, 452_4, 452_5, 452_6	5.5–15.20
CO	Periodic	349_3, 349_4, 452_4, 452_5, 452_6	3.9–94.97
PCDD/PCDF	Continuous	266	0–0.0019
	Periodic	239, 243, 257_1, 257_2	
CH_4	Periodic	017_1, 037	5.79–22
NMVOC	Periodic	349_3, 349_4	17–19
Hg	Continuous	628	0–9.09
	Periodic	573	
Bioaerosols	Periodic	37	41.5 (cfu/Nm^3)

(1) Value for NH_3 before treatment. The emission concentration is below 1 mg/Nm^3 after treatment.

(2) TVOC is measured by 2 plants (349 and 350), and TOC by 11 plants (17, 19, 37, 239, 243, 244, 257, 267, 337, 452, 628). For TOC, the reported standard EN 12619 and corresponding measuring method (FID) allows plants to measure the volatile fraction only.

WORKING DRAFT IN PROGRESS

Table 4.42: Abatement techniques for emissions to air and origin of emissions at MBT plants

Plant code	Origin of emissions to air	Techniques used
17_1	Biological process	Heat exchanger before biofilter Biofiltering
17_2	Mechanical process: Waste-receiving hall	Biofiltering
17_3	Mechanical process: Loading hall	Bag/fabric filter system
19	Biological process	Biofiltering Wet scrubbing
37	Whole plant	Other Bioscrubbing Biofiltering Wet scrubbing
89	No monitoring is performed	NI
127	Mechanical and biological process phases	Wet scrubbing Biofiltering Bag/fabric filter system Biofiltering
130	Biofilter	Biofiltering
239	Aerobic process	Acid scrubber system Regenerative thermal oxidation
243	Mechanical biological treatment of mixed solid waste containing bio-waste one stack	Wet scrubbing with sorbent injection Bag/fabric filter system Biofiltering Regenerative thermal oxidation
244	Whole plant	Biofiltering Regenerative thermal oxidation Wet scrubbing with sorbent injection Bag/fabric filter system Activated carbon
257_1	Biological process	Regenerative thermal oxidation
257_2	Mechanical process	Bag/fabric filter system
266	Discharged air of the composting tunnels	Biofiltering Air humidifier conditioning the delivery air to the biological filter Recirculation of air for tunnel ventilation
267	Mechanical and biological treatment	Bag/fabric filter system Wet scrubbing with sorbent injection Biofiltering Regenerative thermal oxidation
279_1	SRF plant	Bag/fabric filter system
279_2	Biological process	Biofiltering Regenerative thermal oxidation
337_1	Biodryer E1+E2	Biofiltering Wet scrubbing with sorbent injection
337_2	Preparation of SRF for incineration or co-incineration E3	Bag/fabric filter system
338	Mechanical biological treatment (MBT) of mixed solid waste containing bio-waste	Biofiltering

WORKING DRAFT IN PROGRESS

349_1	Anaerobic digestion followed by digestate composting E1	Biofiltering
349_2	Anaerobic digestion followed by digestate composting E2	Biofiltering
349_3	Anaerobic digestion followed by digestate composting post-combustion E4	Post-combustion
349_4	Anaerobic digestion followed by digestate composting post-combustion E4	Post-combustion
350_1	Mechanical separation activity E1	Biofiltering
350_2	Waste stabilisation E3	Biofiltering
350_3	Composting activity E4	Biofiltering
415_1	Common steps	Biofiltering
415_2	Biogas – gas engine	NI
415_3	Biogas - heating	NI
415_4	Biogas – gas purification	NI
415_5	Biogas - flare	NI
434_1	Biological treatment, mechanical treatment	Cover membrane
434_2	Biological treatment, mechanical treatment,	Forced aeration Activated carbon adsorption
452_1	Reception biofilter	Biofiltering
452_2	Sorting-anaerobic process biofilter	Biofiltering
452_3	Composting biofilter	Biofiltering
452_4	Biogas motor 1	NI
452_5	Biogas motor 2	NI
452_6	Cauldron for heating digester	NI
453	NI	NI
454	Composting	Biofiltering
519	Aerobic treatment	NI
566	Biological process	Acid scrubber system Biofiltering
573	Biological process	Biofiltering Wet scrubbing
594	No points of channelled air emissions from the facility	NI
628	Whole plant	Regenerative thermal oxidation Bag/fabric filter system
NI: No information.		

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Figure 4.27 to Figure 4.31 below illustrate the emissions to air from MBT plants for dust and TVOC.

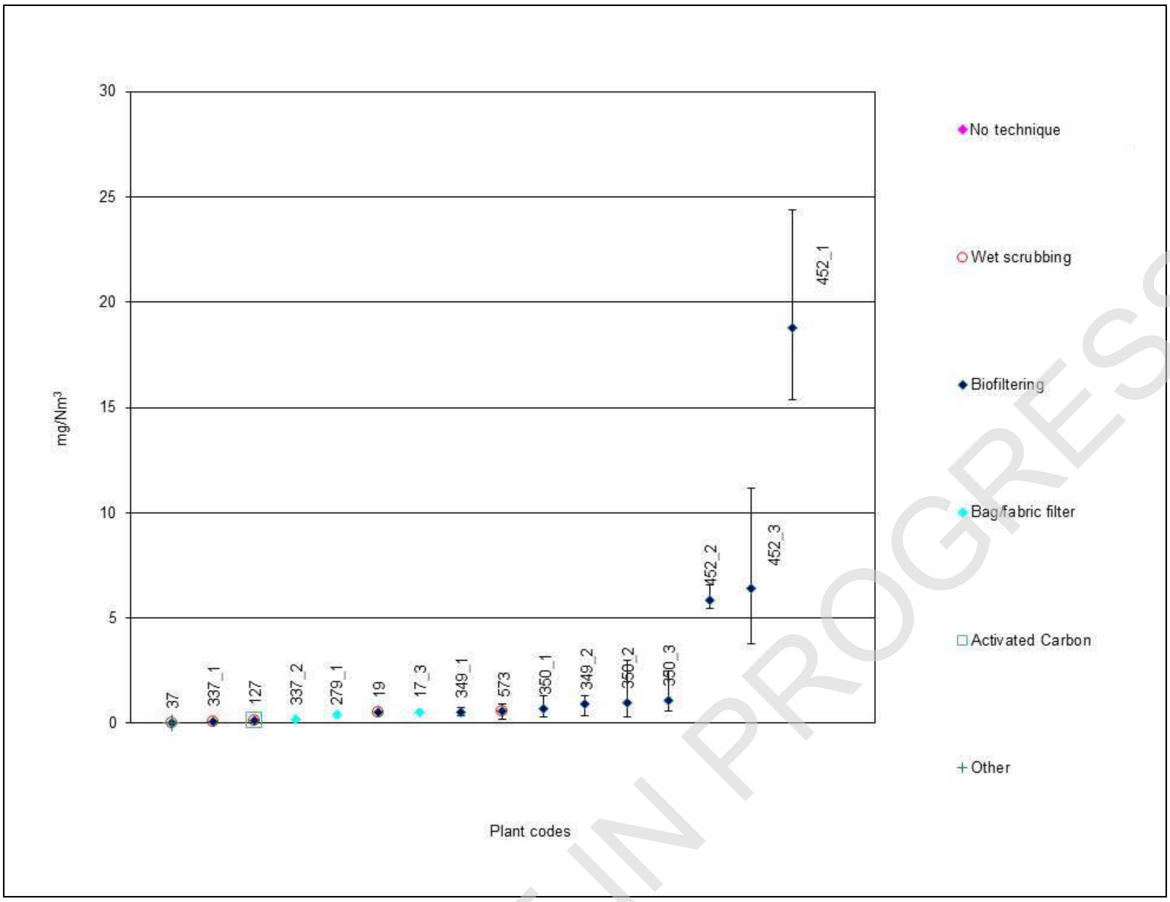

Figure 4.27: Dust emissions to air from MBT plants – Periodic measurements

Table 4.28 below gives the comparison of the levels of dust emissions to air from MBT plants measured periodically or continuously.

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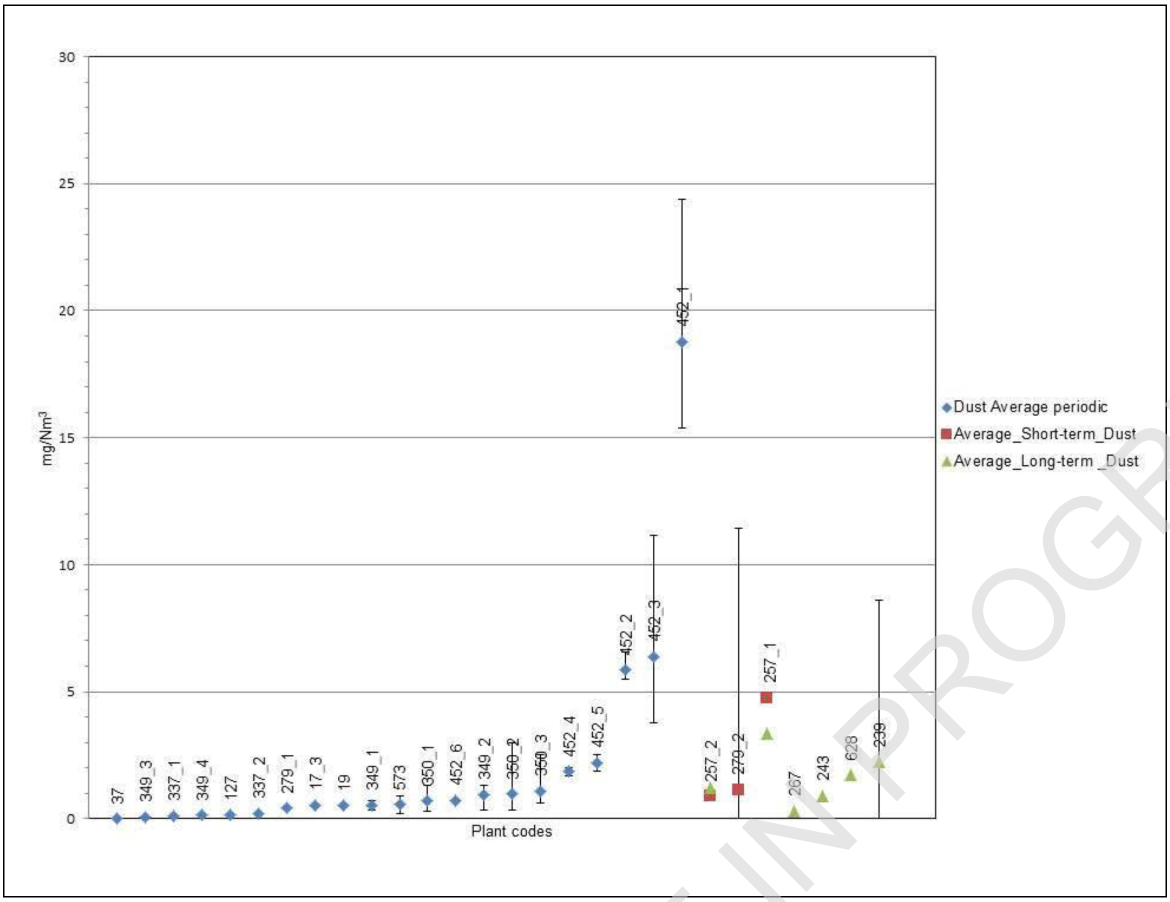

Figure 4.28: Dust emissions to air from MBT plants – All types of measurements

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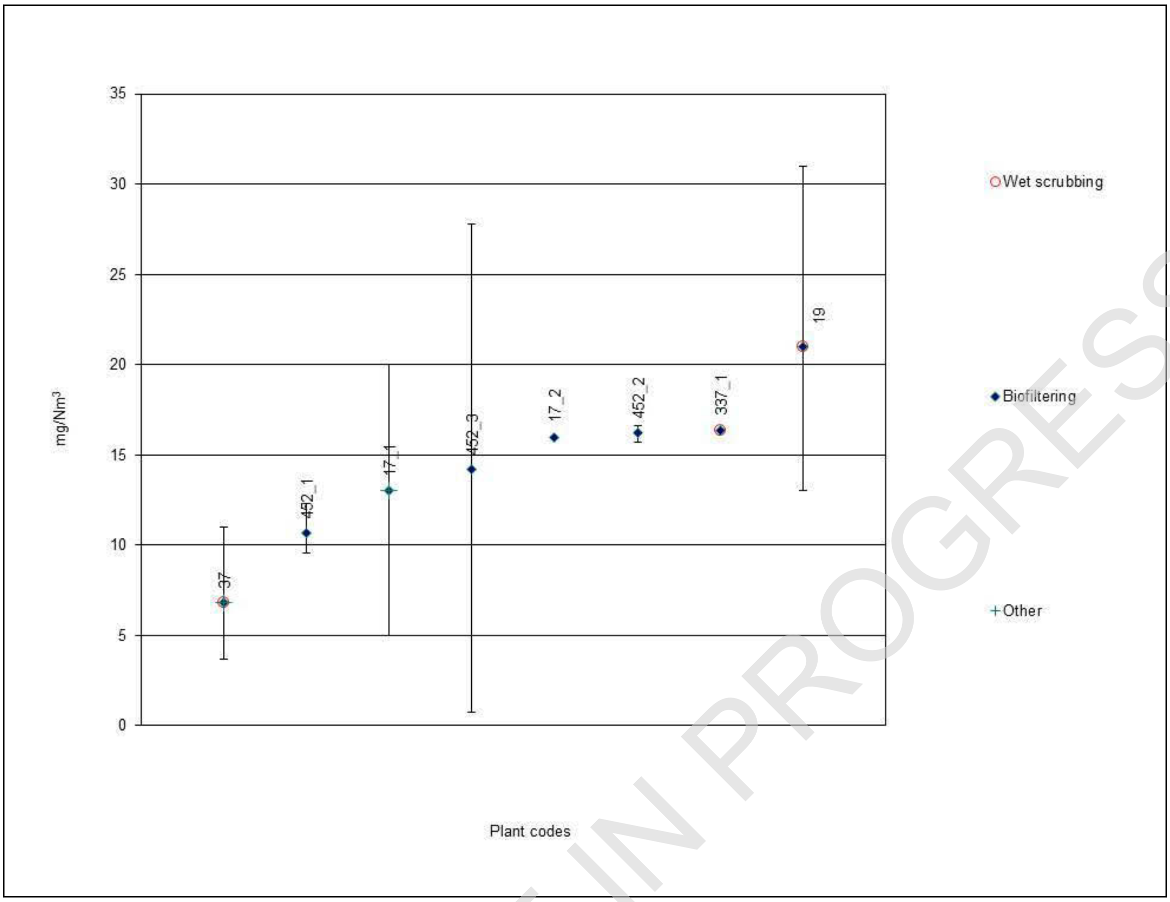

Figure 4.29: TVOC emissions to air from MBT plants – Periodic measurements

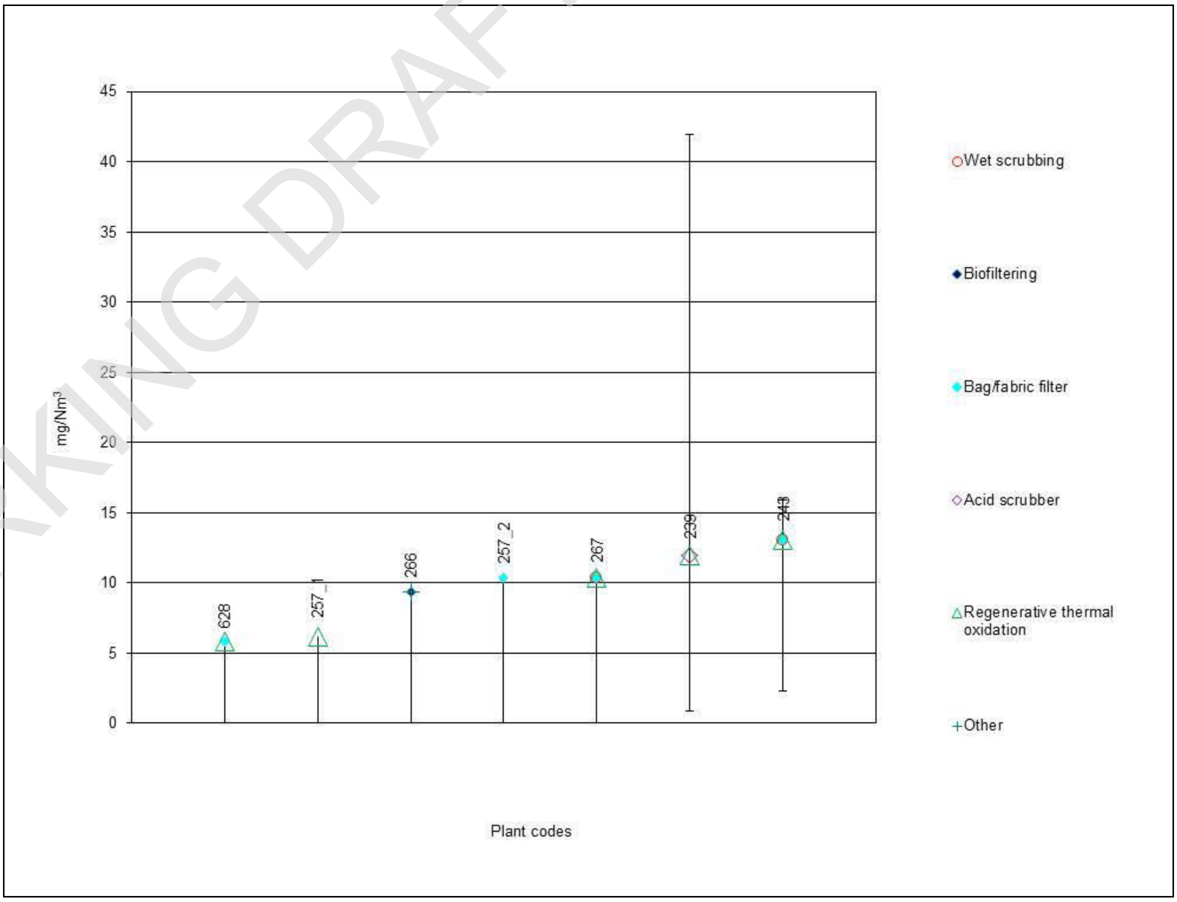

Figure 4.30: Average long-term TVOC emissions to air from MBT plants – Continuous measurements

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Figure 4.31 below gives the comparison of the levels of TVOC emissions to air from MBT plants measured periodically or continuously.

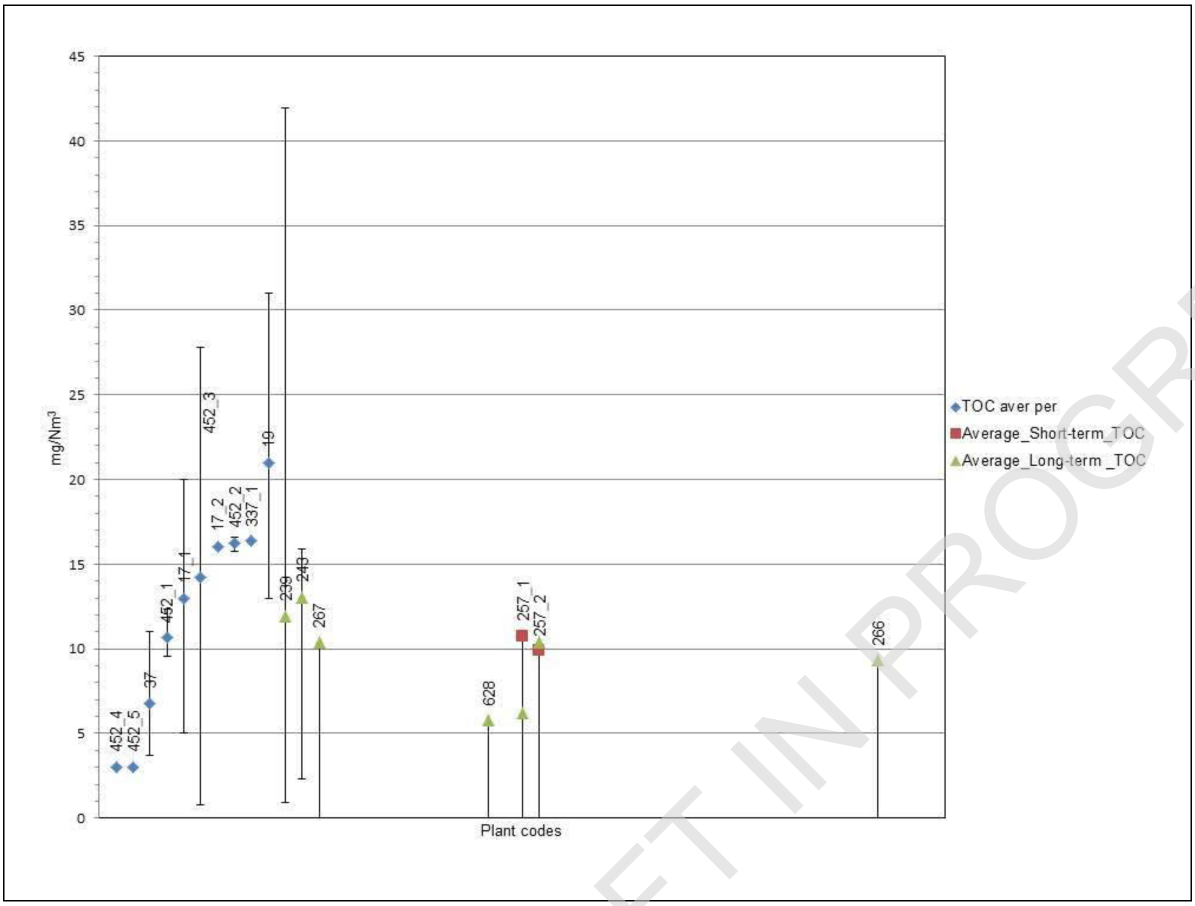

Figure 4.31: TVOC emissions to air from MBT plants – All types of measurements

4.4.2.2 Emissions to water and water usage

4.4.2.2.1 Emissions to water

Table 4.43 below shows the main measured pollutants at MBT plants, and the type of measurements (continuous/periodic). It should be read together with Table 4.44 which summarises the applied abatement techniques and point of release of emissions to water.

The most measured parameters are pH, COD, BOD_5, NH_3-N, and some metals such as Cd, Pb, Cr, Ni and Zn. Around half of the plants reported to have indirect discharge to water. Three plants reported to have direct discharge to the environment without treatment.

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Table 4.43: Emissions to water from MBT plants

Parameter measured	Type of measurement	Plants concerned	Range (mg/l except for flow, temperature and pH)	Number of measurements during the 3-year reference period (2010-2012)
Flow (m^3/h)	Continuous	243, 244, 257, 415, 434, 566, 628	0.4–10	NA
	Grab sample	127	0.06-2.3	1 to 3
Temperature (°C)	Continuous	244	37	NA
	Grab sample	17, 243, 519	20-30	1 to 36
pH	Grab sample	17, 19, 127, 243, 244, 257, 349, 350, 434	6.9–8.6	1 to 36
COD	Grab sample	127, 244, 279, 350, 519	30–88 809	1 to 36
TOC	Grab sample	17, 434	317-382	1
BOD_5	Grab sample	127, 243, 244, 350, 519	2.75–36 347	1 to 36
Total N	Grab sample	127, 244, 279, 350	171–8449	1 to 33
NH_3-N	Grab sample	17, 19, 350, 519	1–487	1 to 11
Total P	Grab sample	127, 519, 566	45-638	1 to 3
TSS	Grab sample	127, 349, 350	16–1360	1 to 11
THC	Grab sample	19	1.5	1
Cl^-	Grab sample	350, 519, 566	31.3-254	3 to 11
F^-	Grab sample	350, 566	0.8	11
S^{2-}	Grab sample	19, 244, 350, 519, 566	0.01-0.4	1 to 33
SO_3^{2-}	Grab sample	350, 566	0.1	8
CN^-	Grab sample	244, 350, 566	0.006-0.03	11 to 36
Sulphate	Grab sample	350, 519, 566	31.2-633	3 to 11
Cd	Grab sample	19, 243, 244, 257, 349, 350, 434	0.001–0.01	1 to 36
Hg	Grab sample	19, 243, 244, 257, 350, 434_1	0.0001–0.0009	1 to 36
As	Grab sample	243, 244, 257, 349, 350	0.009–0.05	1 to 36
Pb	Grab sample	19, 243, 244, 257, 279, 349, 350, 434	0.004–0.07	1 to 36
Cr	Grab sample	19, 243, 244, 257, 279, 349, 350_1	0.009–0.2	1 to 36
Cr(VI)	Grab sample	244, 257, 350, 566	0.01-0.04	3 to 36
Co	Grab sample	244, 566	0.02	36
Cu	Grab sample	19, 127, 243, 244, 257, 279, 349, 350, 434, 566	0.01–0.1	1 to 36
Mn	Grab sample	244, 350	0.09-0.13	11 to 36
Ni	Grab sample	19, 243, 244, 257, 279, 349, 350	0.046–0.45	1 to 36
Zn	Grab sample	19, 127, 243, 244, 257, 279, 350, 434	0.02–2.4	1 to 36
Fe	Grab sample	350, 566	0.15	11
Chlorine	Grab sample	519, 566	254	3
Phenols	Grab sample	19-566	0.1	1
AOX	Grab sample	19, 243, 244, 257, 350	0.03–0.36	1 to 36
BTEX	Grab sample	19, 566	0.6	1
Toxicity	Grab sample	257	0.01	3

Note 1: the highest concentration values for COD, BOD_5, Total N and TSS were reported by Plant 127 (leachate directed to an on-site WWTP – see **Table 4.44** below).
Note 2: the figures provided by plant 566 are the limit values set in the permit. They are not reported in this table.
Note 3: other parameters (for example conductivity, NO_2-N, NO_3-N) have been reported each by one plant. They are not reported in this table

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Table 4.44 below gives an overview of abatement techniques for emissions to water used in MBT plants.

Table 4.44: Abatement techniques for emissions to water in MBT plants

Plant code	Origin of emissions to water	Point of release	Techniques used
17	Biological process (air management, waste water is only released from heat exchanger before biofilter)	Indirect discharge (off-site common WWT facilities)	NI
19	Biological process	Indirect discharge (urban/municipal sewer system)	NI
37	No emissions to water (all water is reused, emission only evaporated via biofilter)	NA	NA
89	No emissions to water from composting. Rainwater and process water are collected separately and reused in the process. Surpluses (a small part) are transported to the WWTP by road tanks.	Indirect discharge (off-site common WWT facilities)	NA
127	Leachate production in excess coming from composting tunnels and waste water in excess coming from treatment of emissions to air treatment	Indirect discharge to an on-site common WWT facility (the WWT facility is mainly influenced by waste water streams coming from activities other than the WT plant)	Active sludge systems - conventional Biological nutrient removal (nitrification) Ultrafiltration Absorption Treated water is stored in 3 storage basins and spread on land
130	Water from outdoor platform	Indirect discharge to an on-site common WWT facility (the WWT facility is mainly influenced by waste water streams coming from activities other than the WT plant)	NA
239	Drainage digestate Excess water	Indirect discharge (off-site common WWT facilities)	NA
243	Mechanical biological treatment	Indirect discharge (urban/municipal sewer system)	Nitrification/denitrification
244	Complete plant	Indirect discharge (urban/municipal sewer system)	Absorption Nitrification/denitrification Ultrafiltration
257	Biological process (biological drying	Indirect discharge (urban/municipal sewer system)	Nitrification/denitrification Ultrafiltration
266	Final dry maturation of the biological waste	Discharge from the WT plant to the environment without treatment	Sieving Buffer tanks Evaporation
267	Usually waste water-free operation	NA	NA
279	Biological process	Indirect discharge (off-site common WWT facilities)	NI
337	No points of emission to water; all the leachate is sent to an external waste water treatment plant	NA	NA
338	Leachate is sent to an external waste water treatment plant	NA	Wet air oxidation
349	Biological process S1A	Discharge from the WT plant to the environment without treatment	NI
	Biological process S1B	Discharge from the WT plant to the environment without treatment	NI
350	Biological process S1	Discharge from the WT plant to the environment without treatment	NI
415	Shredding	Indirect discharge (off-site common WWT facilities)	Buffer tanks
434	Biological process, storage yards, transportation areas	Indirect discharge (urban/municipal sewer system)	Buffer tanks

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452	No emission to water	NA	NA
453	No emission to water	NA	NA
454	The used water is collected in a tank and is sent in an external waste water treatment plant.	NI	NI
519	NI	Indirect discharge (urban/municipal sewer system)	NI
566	NI	Indirect discharge (urban/municipal sewer system)	Waste water is routed after the pretreatment to a sewer (around 10 m^3 per day)
573	Industrial waste water is transferred to the waste water treatment plant	NI	NI
594	No emission to water	NA	NA
628	All processes	Indirect discharge: the excess process water is treated in an external WWTP	NA
NI: no information NA: not applicable			

Figure 4.32 to Figure 4.36 below show the levels of emissions to water from MBT plants for COD, Ni, Pb, Zn and Cu.

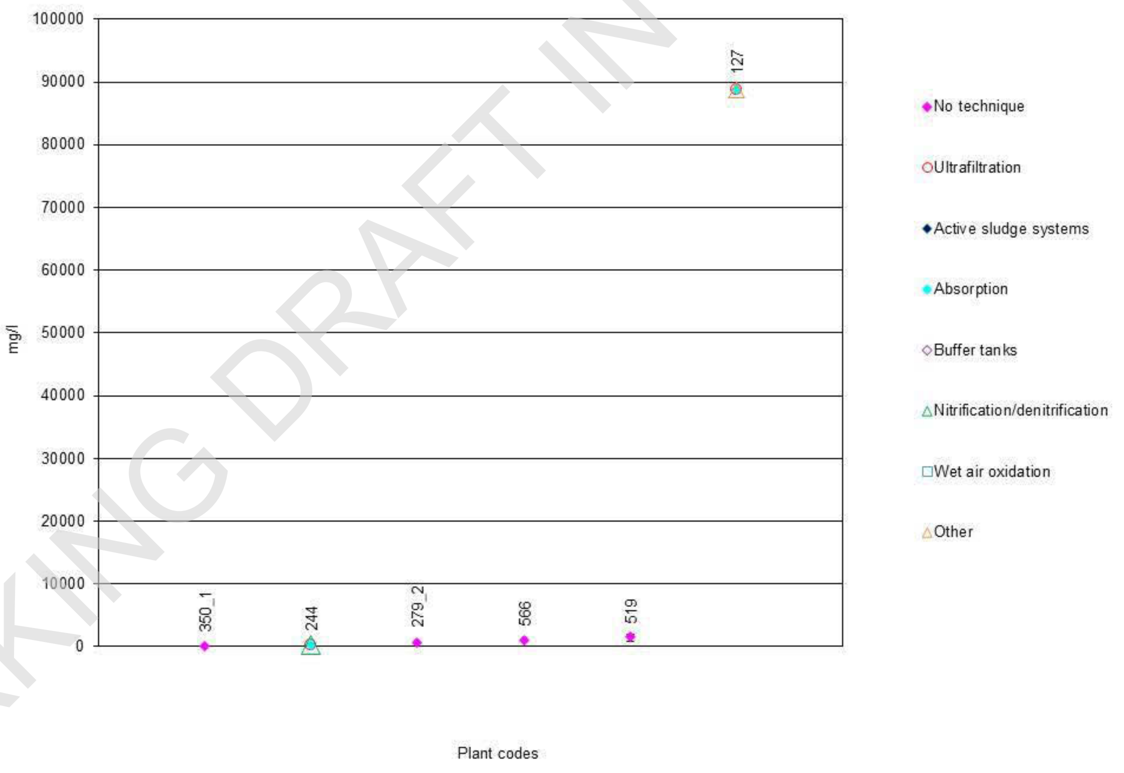

Figure 4.32: COD in emissions to water from MBT plants – Periodic measurements

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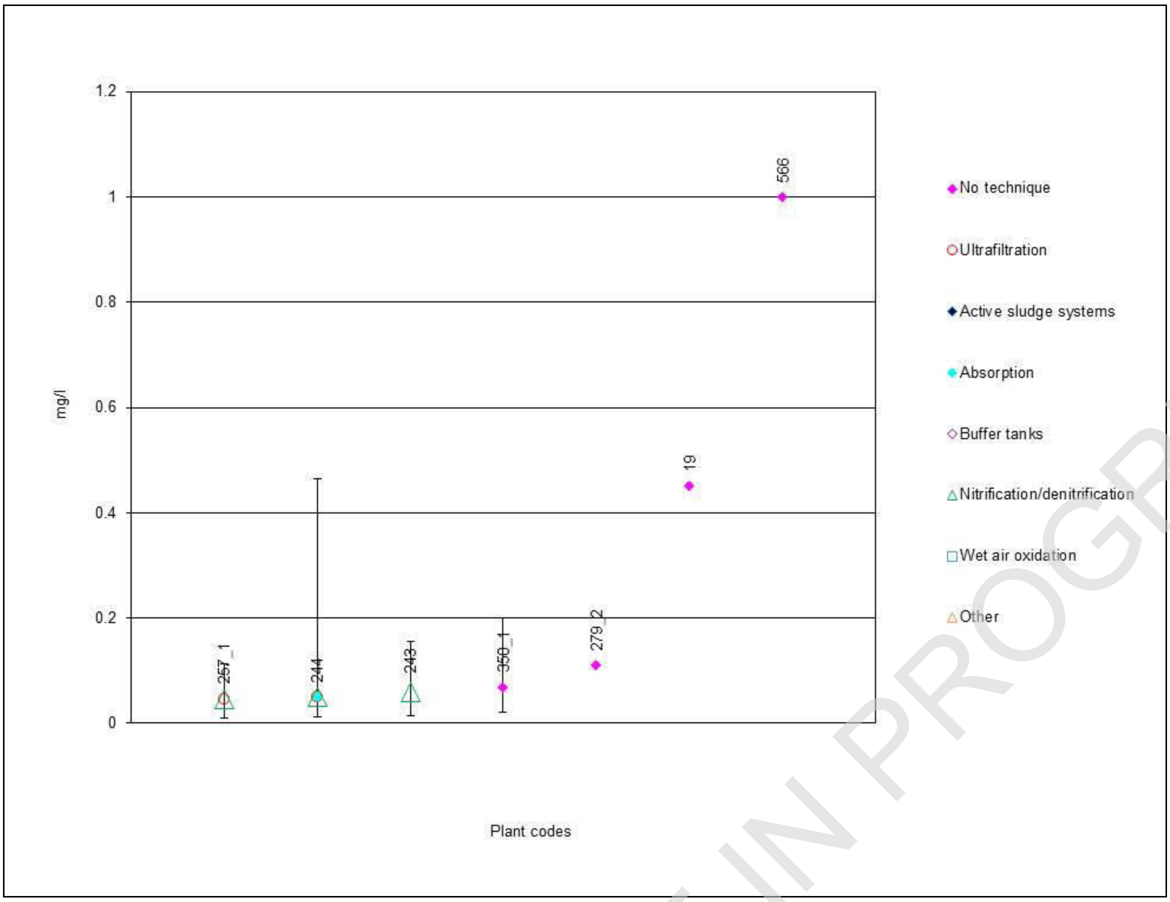

Figure 4.33: Ni in emissions to water from MBT plants – Periodic measurements

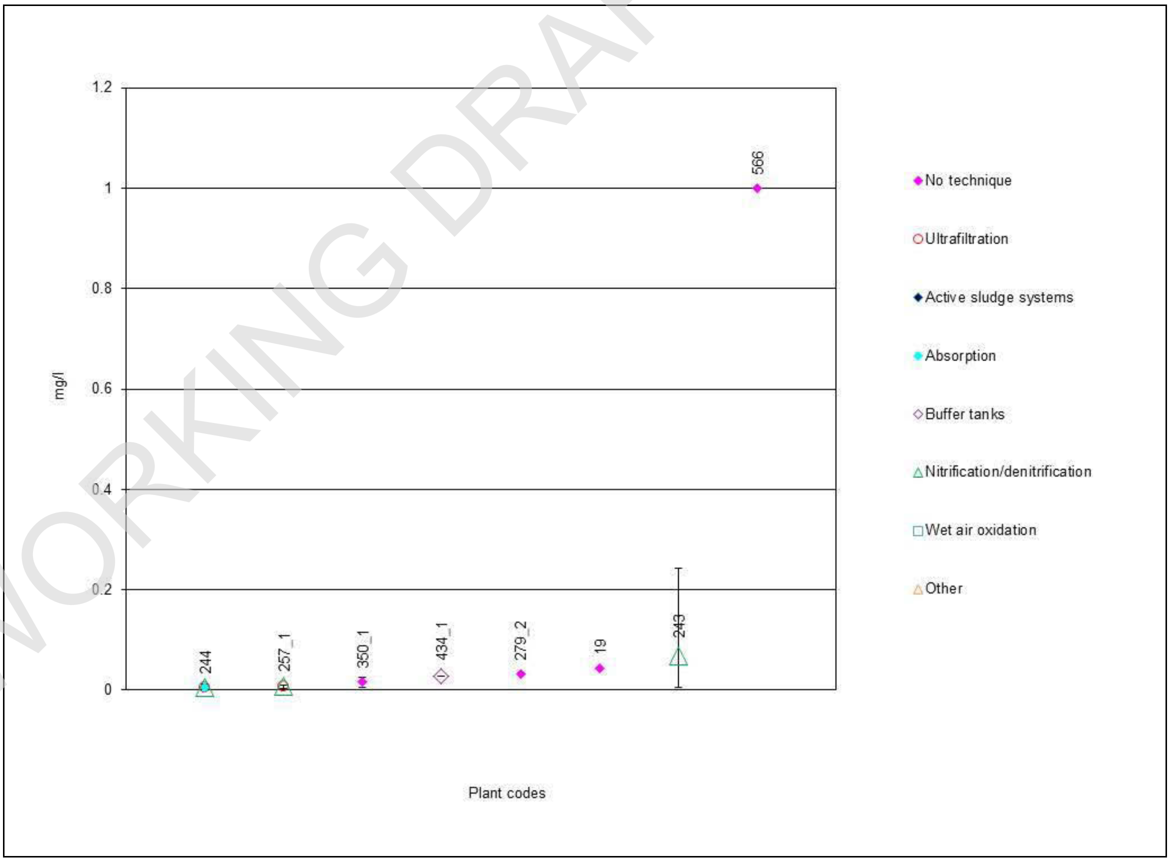

Figure 4.34: Pb in emissions to water from MBT plants – Periodic measurements

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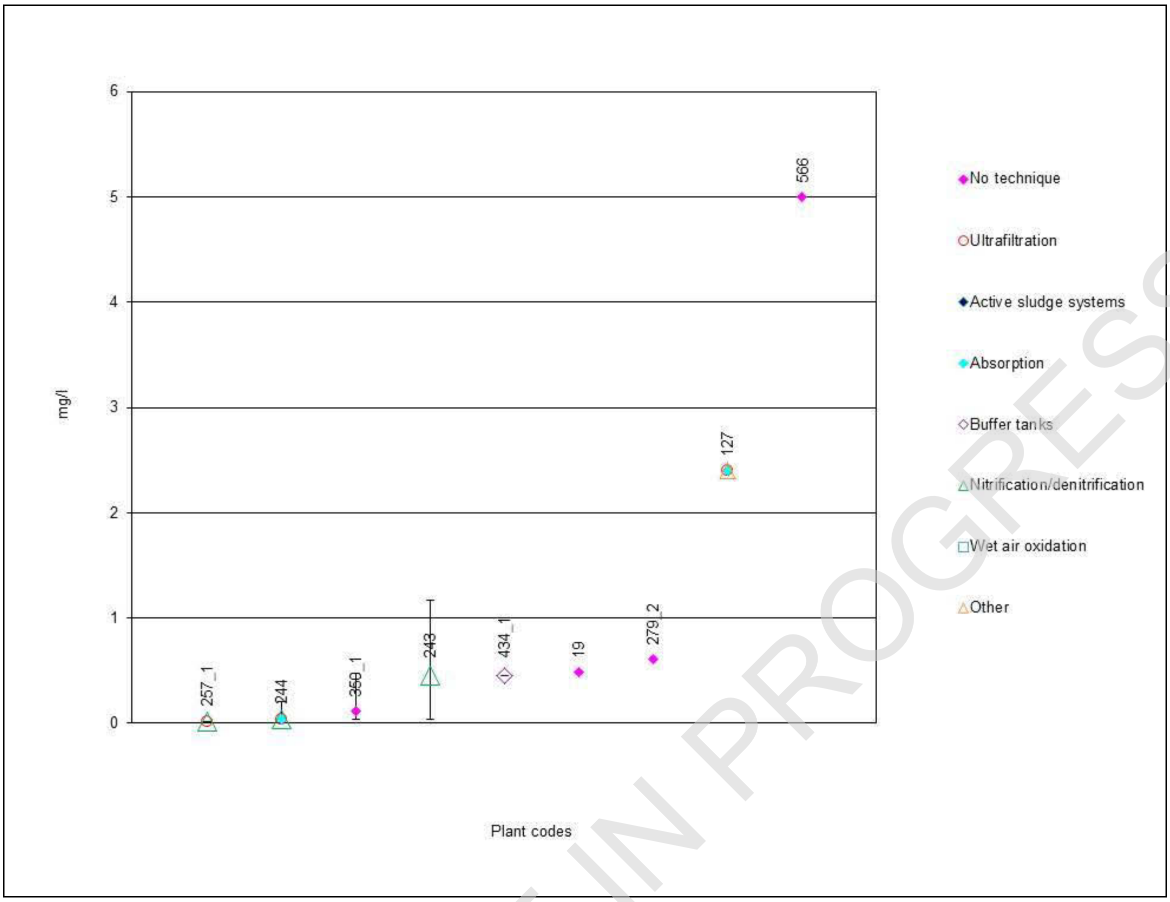

Figure 4.35: Zn in emissions to water from MBT plants – Periodic measurements

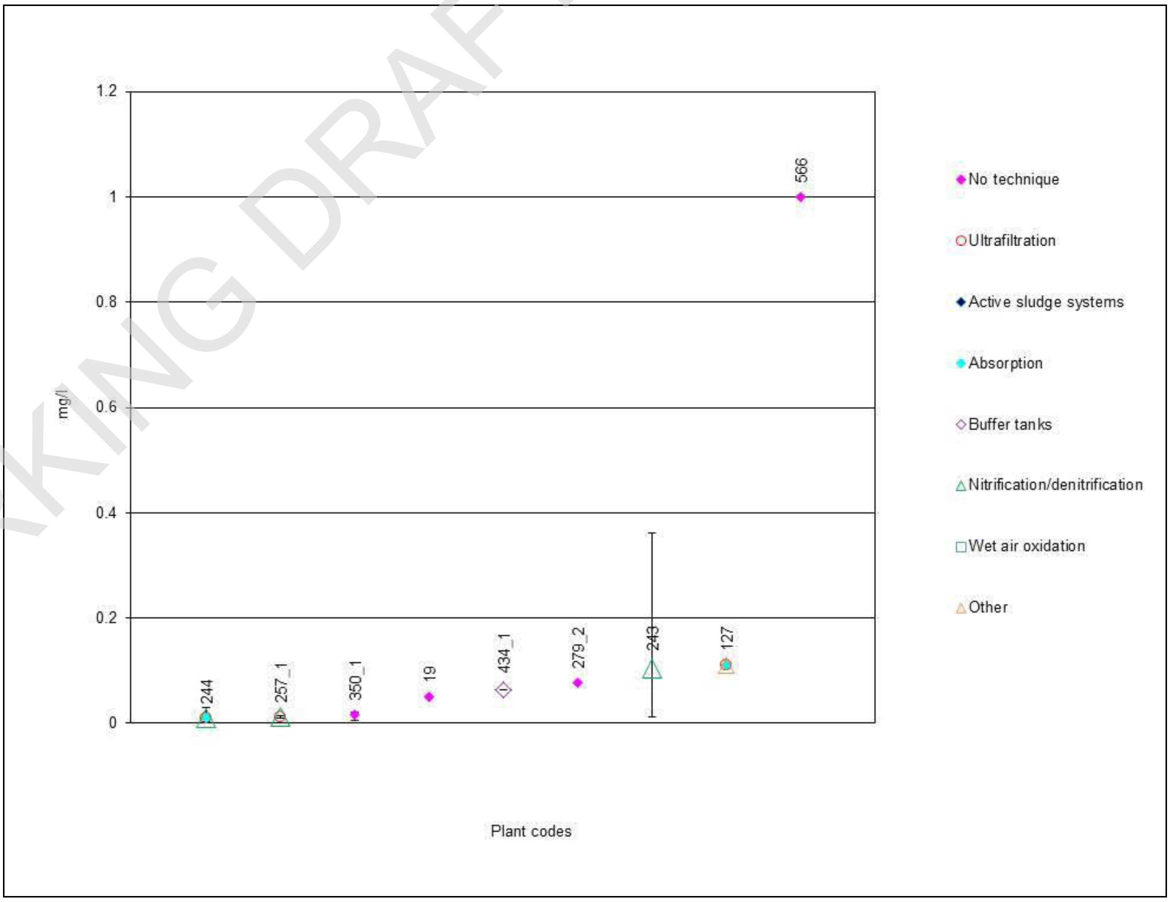

Figure 4.36: Cu in emissions to water from MBT plants – Periodic measurements

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4.4.2.2.2 Water usage

From ex-Section **3.2.2 Consumption of biological treatment**

MBT plants sometimes add water to the windrows, as moisture is lost during aerobic digestion, which could otherwise lead to a shortage of water and halt the aerobic digestion process. This typically occurs during summer and winter months.

In some cases, there is no net water consumption in the process. In the drying process, water is produced (350 litres -in vapour form- per tonne waste). During aerobic digestion, temperatures of 50–60 °C are reached. Thus, water lost from the feedstock becomes water vapour (about 90 %) and is typically released to the air. However, in some cases, some of this water is condensed. The treatment of this condensation water is quite complex. The purified waste water (permeate) is used as process water in the cooling circuit. It is evaporated in the cooling tower. Tap water is only used in the cooling tower as make-up water (10 litres per tonne of waste). ~~However, other sources reported that the water consumption range from 260 - 470 litres per tonne of waste treated.~~

The reported average water usage per tonne of waste treated is 132 l/t, with a range of 6–860 l/t.

Figure 4.37 below shows the reported specific water usage, expressed as litres per tonne of waste treated, for different plants.

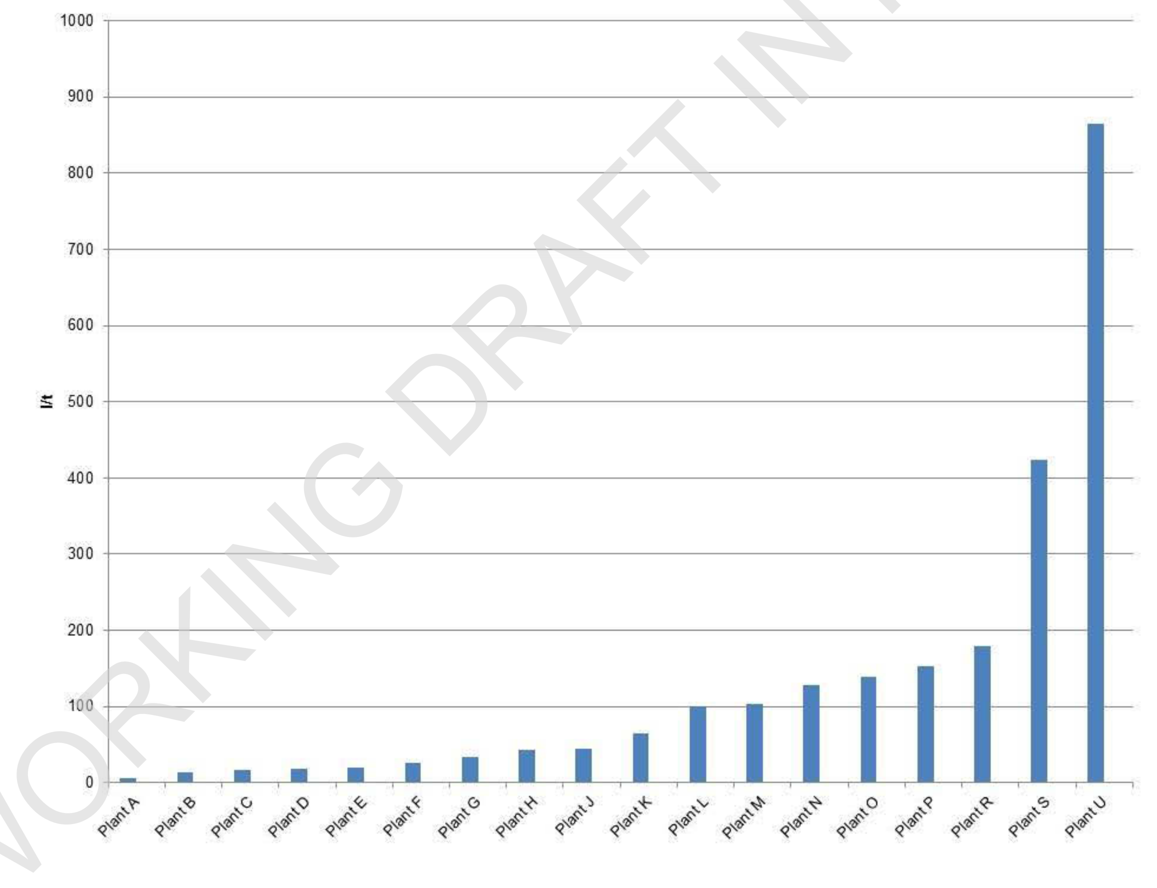

Figure 4.37: Water usage per tonne of waste treated in MBT plants

Some plants reported using recycled water, e.g. from an adjacent waste water treatment plant.

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4.4.2.3 Energy consumption

Figure 4.38 below shows the energy consumption per tonne of waste treated at MBT plants for different plants.

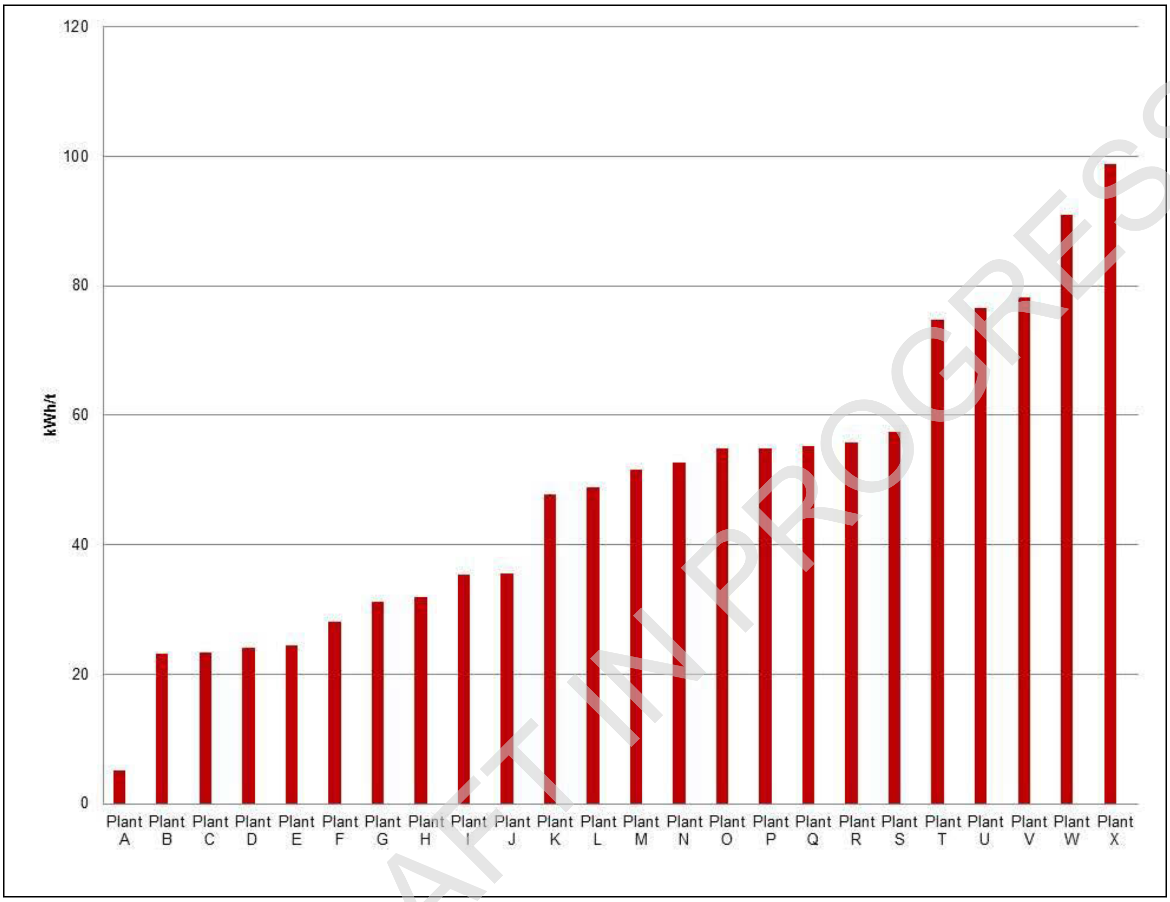

Figure 4.38: Energy consumption per tonne of waste treated in MBT plants

The reported average energy consumption per tonne of waste treated at mechanical biological treatment plants, including for example fuel consumption for machines and wheel loaders, ranges from 5 kW/t to around 100 kW/t, with an average of approximately 50 kW/t.

The reported average electricity consumption per tonne of waste treated ranges from 1 kWh_e/t to 86 kWhe/t, with an average of around 37 kWh_e/t.

Figure 4.39 below shows the electricity consumption per tonne of waste treated at MBT plants for different plants.

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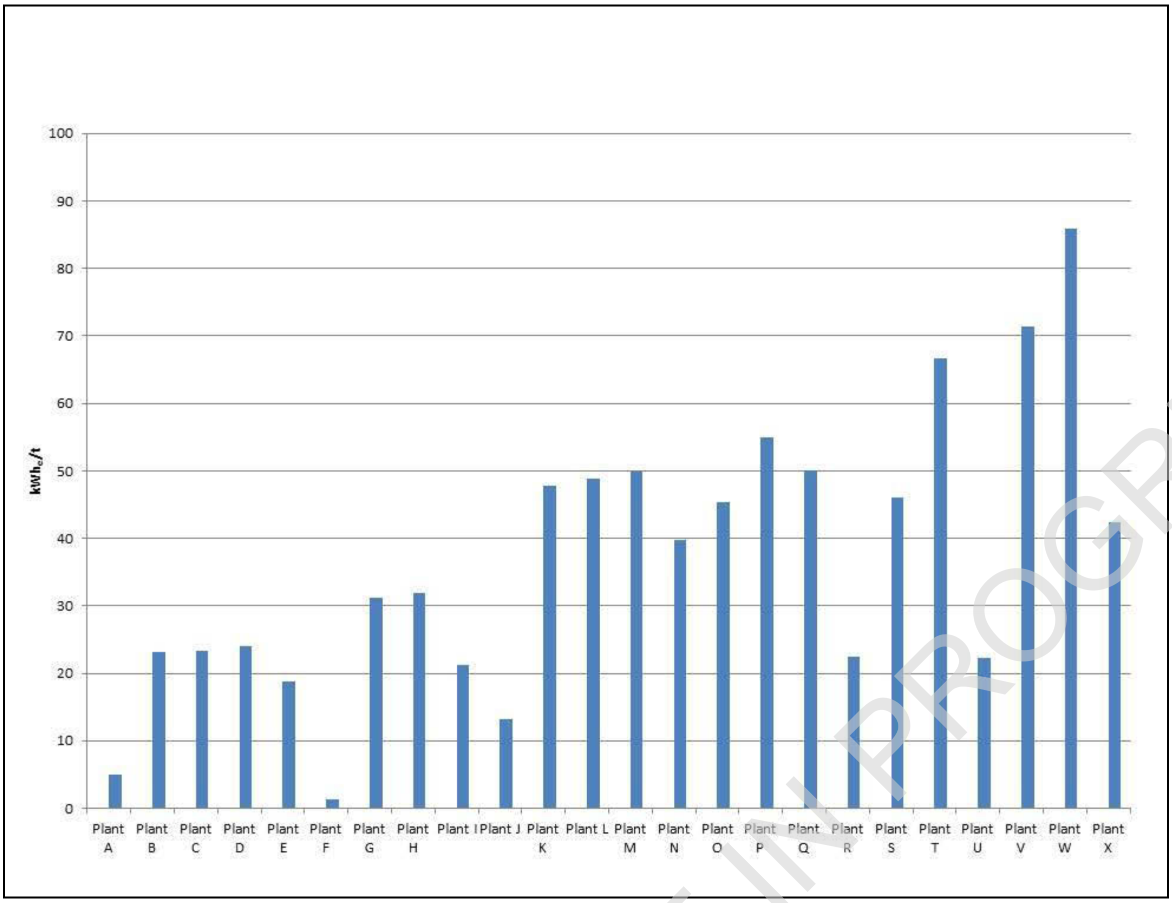

Figure 4.39: Electricity consumption per tonne of waste treated in MBT plants

4.4.2.4 Raw material consumption

~~*Auxiliary products*~~

~~As reported, no auxiliary materials are used in the process, except for the plastic foil used to bale the waste solid fuel.~~

Table 4.45 gives an illustration of the raw materials used in the MBT plants which took part in the data collection.

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Table 4.45: Raw materials used in MBT plants

Auxiliary material	Amount used in waste treatment (t/year) Average over the three reference years
Acid for acid scrubber	2.8–2403
Activated carbon	3–58
Anti-foaming product	0.002–16.5
Acid in waste treatment	1.2–43
Wood	148
Alkali	4
Ferric chloride	516–576
Ferric oxide	255–1207
Reducing agents	120
Flocculants	0.027–101
Detergents	0.14
Trisodium phosphate	0.5

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4.5 Techniques to consider in the determination of BAT

4.5.1 Techniques for all types of biological treatment

4.5.1.1 ~~Relation bio-waste / biological treatments~~ Selection of biological treatment and associated feedstock

From ex-Section 4.2.1 and 4.2.3.

Description
~~**Purpose**~~
~~Selecting~~ Selection of the appropriate biological treatment for the waste to be treated, which helps to avoid operational problems ~~as well as to extract the major benefit from the waste (e.g. use as fuel)~~.

Selection of the feedstock to enable an appropriate nutrient balance, and avoid toxic compounds (i.e. toxic in terms of reducing biological activity) entering the biological systems. This is also in relation to the pre-acceptance, acceptance, and sorting procedures described in Section 2.3.2.

Technical description

~~**Principle of operation**~~
A key technical factor for selecting the appropriate system is its capability to provide proper contact between the organic constituents of the waste and the microbial population. This capability primarily depends on the state of the waste and its organic carbon concentration. An approximate schematic of the system offering the most capability as a function of these two variables is shown in Figure 4.40 below.

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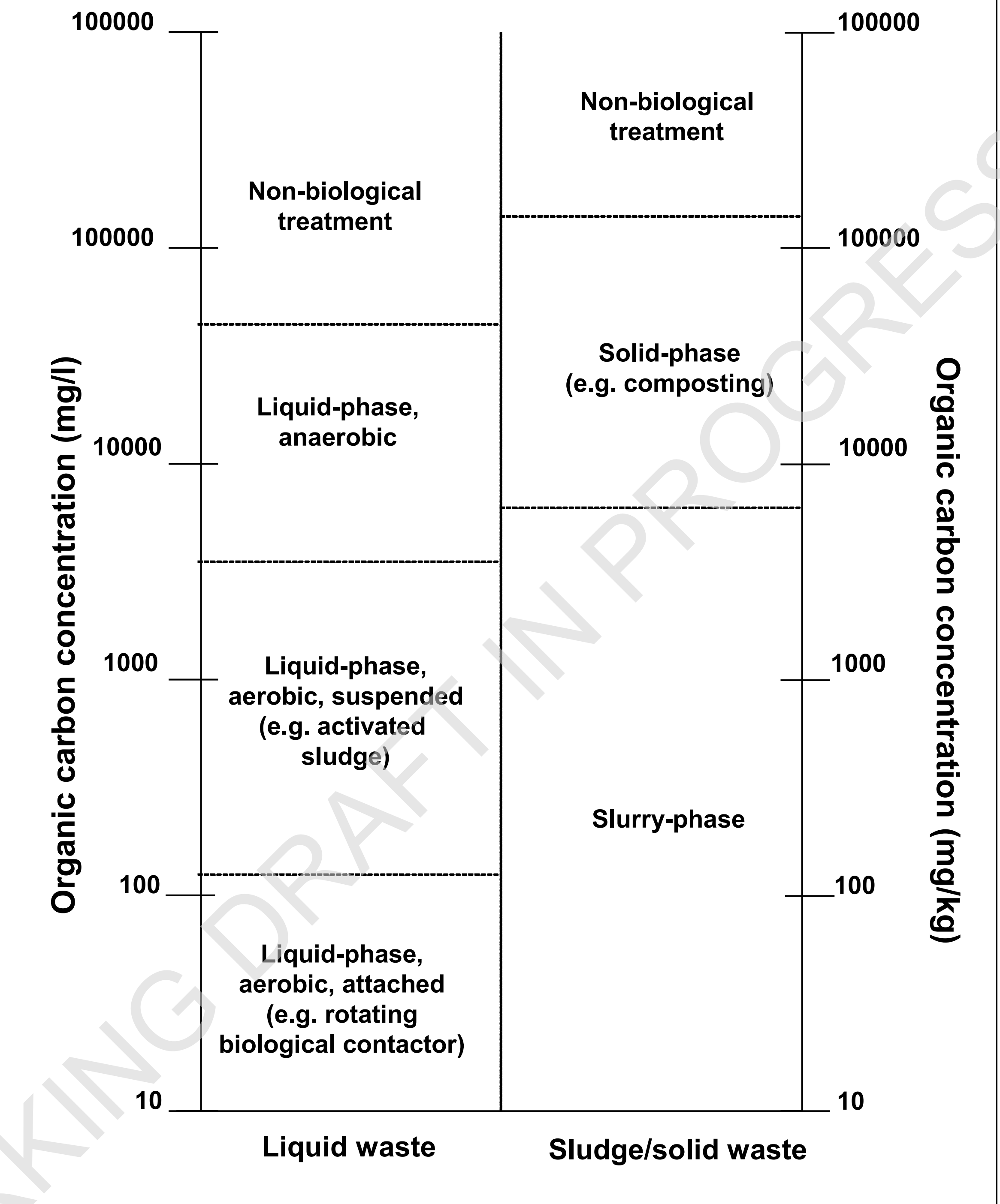

Source: [31, LaGrega et al. 1994]

Figure 4.40: Selection of an appropriate biological treatment system as a function of organic carbon concentration and the form of waste

Important features, for consideration, of the selected biological system are the uniform distribution of the nutrients and the moisture of the waste to be treated (homogeneity) as well as the availability of the treatment selected.

The waste hierarchy may give some guidance on what type of treatments can be used. However, it may be that when applying the waste hierarchy without a suitable underlying analysis, a good result may not be achieved. It has been reported that in the case of sewage sludge treatment, because of the low energy content of biologically treated sewage sludge in relation to thermally

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dried sewage sludge, a good option may be to ~~either~~ select anaerobic digestion and thermic drying and/or incineration for different wastes.

~~In addition, fully enclosed or encapsulated bioreactors help to better control the biological treatment and avoidance of fugitive emissions (e.g. VOC, odours, dust).~~

Other ~~Some~~ issues to consider are:

a. ~~whilst the process itself is an important aspect,~~ Maximising the quality of the feedstock in line with the treatment ~~probably has the biggest effect and so it is vital to maximise its quality~~. Both admissible waste types and separation steps ~~processes~~ (see information on pre-acceptance, acceptance and sorting techniques in Sections 2.3.2.1, 2.3.2.3 and 2.3.2.8) are important here. Techniques include:
    - Ensuring the right balance of the nutrient content (e.g. nitrogen vs carbon content).
    - Minimising the presence of toxic and unwanted materials (including heavy metals, pathogens and inert materials).
    - Recognising that any non-biodegradable components of waste which are fed into an anaerobic digester, and will not be affected by the process, simply take up unnecessary space. It could also damage the process and the equipment. To maximise the benefit of using the technique (both environmental and economic) and to minimise the cost, it is important to minimise the presence of these components in the feedstock.

b. Increasing the nutrient level of the feedstock by adding sewage for example to the organic fraction of municipal solid waste, as well as adding moisture ~~content~~. When proved to be appropriate (see Section 2.3.2.7), other wastes that ~~can~~ may also have benefits are: organic industrial wastes, food processing wastes and agricultural wastes.

c. Not mixing different types of waste if not proved to be appropriate. This is related to Section 2.3.2.7

d. Continuous learning about the influence of the waste characteristics on the operational settings such as aggregates, mass flow, volumes, biological degradation variables (e.g. temperature, CO_2) as well as measured (gaseous) emissions (e.g. use of continuously acquired emission data (raw gas and/or clean gas), VOCs, methane, for the adjustment of settings, i.e. automatic control of biological processes).

~~e. the presence of substances which are not subject to beneficial treatment such as, toxic metals need to be limited for entering into the biological processes. For example, some mechanical treatment may help to accomplish such limitations~~

Achieved environmental benefits

The achieved environmental benefits of this technique include:

- prevention of emissions, e.g. of nitrogen compounds; ~~good balance of the nutrient content avoids emissions, for example of nitrogen compounds.~~
- improvement of the reuse/recycling rate by separating non-biological active parts (e.g. glass, metals) from the feedstock.

Environmental performance and operational data

~~In the case of technique c (see description section above)~~ An integral biological drying of municipal waste is undertaken, as typically the presence of plastics and other non-biodegradable materials can represent an advantage for aeration, preventing anaerobic zones, which leads to lower emissions.

Cross-media effects

The addition of sewage sludge to the organic fraction of MSW may have ~~bad~~ adverse effects on the biological treatment itself, the exhaust gas quality that is generated during the biological treatment ~~or~~ and the quality of the output.

Technical considerations relevant to applicability

Generally applicable to all treatments.

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Economics
No information available.

Driving force for implementation
Quality of the end product.

Example plants
No information available.

Reference literature
[31, LaGrega et al. 1994] [98, WT TWG 2004]
[33, UK EA 2001] [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [98, WT TWG 2004] [100, WT TWG 2004][101, WT TWG 2005]

~~If non-biological active parts of the feedstock are separated from the feedstock, such streams can be easily re-used or recycled (e.g. glass, metals)~~

~~Abatement techniques for biological treatments~~

From ex **Section 4.2.12.** Deleted because information has been updated via the data collection and is present in the relevant subsection.

~~Table 4.46 shows air abatement techniques reported to be applied in biological treatment plants. These are described in detail in Section~~

Table 4.46: Air abatement techniques used in biological treatment plants

~~**Technique**~~	~~**Section number where it is covered**~~
~~Generic prevention~~	~~Section~~
~~Adsorption~~	~~Section~~
~~Biofilters~~	~~Section~~
~~Chemical scrubbing~~	~~Section~~
~~Low-oxidative processes~~	~~Section~~
~~Incineration~~	~~Section~~
~~Catalytic combustion~~	~~Section~~
~~Regenerative thermal oxidiser~~	~~Section~~
~~Non-thermal plasma treatment~~	~~Section~~

4.5.1.2 Storage management of putrescible waste input

Description
Management and optimisation of the storage of putrescible waste input, in terms of duration, location, and size.

From ex-Section 4.2.2

Technical description

a. The storage area for putrescible, non-woody feedstock is designed to allow complete emptying and cleaning including drainage (when needed at this stage) to allow appropriate leachate and washing water collection, transfer and discharge into gullies via a sump for use within the process, discharge into sewers where required, tankering to a WWTP or other authorised waste treatment plant or use on land where this is allowed.

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b. Some input woody materials (bulky bush and tree cuttings) are stored in a dedicated area for blending with other incoming bio-wastes and sludges. These are stored in such a way to mitigate fugitive emissions and fires.

c. The level of protection measures is proportional to the risk of surface water and/or groundwater pollution. All storage areas for putrescible, non-woody feedstock have an impermeable surface with a sealed drainage system, to prevent any spillage entering the storage systems or escaping off site. The design prevents the contamination of clean surface water (see section 2.3.11).

d. Waste is stored under appropriate conditions in a designated area to manage putrefaction, odour generation, the attraction of vermin and any other nuisance or objectionable condition. This can be achieved by ensuring that waste is processed quickly and waste storage time is minimised.

e. Depending on the feedstock type (C:N ratio, degradability, etc.), the capacity for optimal residence time for feedstock material stored prior to processing is an important factor in a site's potential for odour generation. Untreated and improperly mixed material can increase the generation of odours. The separate storage of different waste types may be useful to create specified compost products (e.g. green waste compost, bio-waste compost, bark compost, sludge compost).

f. Storage of putrescible wastes is preferably carried out in an enclosed area. If not:

  - freshly delivered grass and leaves are treated ('treated' can also mean mixed, covered or made silage, etc.) within a maximum of 72 hours;
  - other putrescible waste (e.g. food waste, kitchen waste, waste from the food industry) are treated ('treated' can also mean mixed, covered or made silage, etc.) within a maximum of 24 hours.

g. When enclosed buildings are used, fast-acting doors are provided for access and egress for delivery and other vehicles. Buildings are sized so offloading can be carried out within the building with the doors shut. ~~using a combination of automated and rapid action doors with so-called air curtain installations, which in practice could also act as a lock, with the opening times of the doors being kept to a minimun~~. This can be helped by the insertion of sensor-controlled rolling shutter gates or flap gates and by sufficient dimensioning of the manoeuvring area in front of the hall. It needs to be recognised that the discipline of the hall and vehicle fleet staff is at least equally important to actually realise the short opening times. ~~It also needs to be ensured that sufficient maintenance of the doors is carried out as required and stick to the appropriate operation.~~ ~~Installing an air curtain creates a curtain of surrounding air in the open door that prevents the ingress of air from the hall.~~ For an underground bunker, which the vehicles approach backwards and then tip their load ~~over~~ into, the installation of a curtain with the vehicle outline behind the actual door may be a way to minimise air exchange during unloading as far as possible.

h. Where the waste storage area is required to be in an enclosed building, it includes a building ventilation system and an emission abatement system that maintains the building under negative air pressure in order to minimise fugitive odour and dust release from the building. Exhaust air is captured and can be reused to aerate the composting piles before discharge and treatment.

i. In the case of intermediate storage of source-separated green waste and food waste from households (in countries where this is allowed outdoors), physical protection against wind drifting of light fractions (contaminants such as plastics) is installed (fences, walls, fleece coverage) or light fractions are removed from the surface.

Deleted because transfer stations are outside the scope

~~a. anaerobic decomposition in the storage of waste materials from a civic amenity site/transfer station comprising high levels of grass mowing during warm wet periods should be actively avoided. Typically grass has a high moisture content, and mats together to prevent ingress of oxygen. If the waste has been piled up in a transfer station for a day or so, then bulked into a container and stored in a pile in wet weather, anaerobic conditions will set in. Another~~

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~~possibility for moisture ingress is through unprotected windrows after prolonged wet weather causing aerobic decomposition to cease, so these should be suitably protected or covered~~

From ex-Section 4.2.2

~~a. having reception pits or equalisation tanks~~
~~b. housing and equipping the waste treatment installation (including acceptance area and bunker), mechanical treatment, storage facilities and all biological treatment steps) with an exhaust air collection device (containing dust, TOC, ammonia, odours, germs), and where applicable, a removal facility. Air exchanges three or four times per hour are common~~
~~c. closing feed bunkers constructed with a vehicle sluice; in open warehouses and during unloading of waste vehicles, the bunker waste gas is removed by suction and fed into a waste gas treatment facility.~~

Achieved environmental benefits
The achieved environmental benefits of this technique include:

- minimisation of odour generation;
- prevention of uncontrolled release of waste water and leachate.

From ex-Section 4.2.2

~~It is important in liquid waste biotreatment systems that the flow of substrate is relatively constant to maintain correct operation, otherwise unexpected emissions can be caused. Some techniques are focused on preventing emissions into the air. For example, temperature rises in waste heaps containing organic matter due to increased biological activity, may occur within short periods of time and may result in air emissions (total C, odour).~~

~~Due to the higher temperatures inside the hall, in winter an airflow profile develops at the hall gates, with warm air leaving the hall in the upper part of the opening and cool air entering at the bottom.~~

~~Residual wastes may contain large amounts of small-grained particles. Therefore, in the bunker considerable dust emissions can be expected due to the tipping and loading processes with mobile tools, which should be retrieved or deposited as close to the source as possible.~~

Environmental performance and operational data

Table 4.47 shows the type of storage for the input waste as well as the associated capacity for the different types of biological treatments of waste.

Table 4.47: Biological treatment plants equipped with a closed hall, and associated storage capacities

Type of biological treatment plant	Number of plants equipped with closed halls for waste input storage (out of those which participated in the data collection)	Range of storage capacity of the closed halls (t)
Outdoor aerobic treatment plants	3 out of 27	198–1000
Indoor aerobic treatment plants	22 out of 28	50–2000
Anaerobic treatment plants	23 out of 29	50–1000
MBT plants	17 out of 27	200–2000

Cross-media effects
No effect identified.

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Technical considerations relevant to applicability

Adequate provision must be made for the acceptance of seasonal peak volumes of delivery such as those occurring during spring and autumn. In addition, space needs to be made available for the storage of additive for use in blending feedstocks prior to shredding.

~~Due to the wide range of biological treatment procedures covered here as well as types of wastes (e.g. containing volatile components, odour), there are some techniques that may be not be applicable to some biological treatments (e.g. activated sludge, aerated lagoons, MBT, in-situ bioremediation, oil contaminated soil und sludge, production of biogas to be used as fuel,...). Some applicability exceptions identified in the techniques below which can be found in the description section above are the following:~~

- ~~technique b for the last steps of biological treatment or after treatment~~
- ~~technique e is typically applied to waste no so odours are emitted~~
- ~~technique f is typically applied to high odour waste.~~

From ex-Section 4.2.2

~~**Operational data**~~

~~The storage areas are usually filled from road tankers or from a pipe to the source.~~

Economics

TWG, please provide information

Driving force for implementation

Reduced local nuisance and therefore less complaints from the neighbourhood.

From ex-Section 4.2.2

~~Related to technique b from the description section above, three or four air exchanges where operators work is applicable by Italian regional law. In areas where operators do not work, two exchanges per hour are typically applied. Technique f comes from a special requirement of TA Luft for fermentation plants and a general provision of the 30 BlmSchV german regulation. Technique m is also a general provision of the 30 BlmSchV German regulation.~~

Example plants

In Plant 125, the oxygen concentration of input waste is controlled as well as the rotating speed of the input waste mixer. This waste is permanently either mixed with a low rotative speed or aired with a higher speed when it is necessary to increase the oxygen rate.

In Plant 635, the air from the input waste shredding area is pumped out and injected under the heaps which work as a biofilter. This reduces odour emission and improves air supply to the compost heaps (instead of periodically turning the heaps). The heaps are covered by a semipermeable membrane.

Reference literature

[56, Babtie Group Ltd, 2002], [132, UBA, 2003], [150, TWG, 2004],[109, Bio. subgroup 2014] [160, WT TWG 2014]

TWG, please provide this document: *EA 2013. Draft Sector guidance note 'How to comply with your environmental permit. Additional technical guidance for: composting and aerobic treatment sector. LIT 8705, Report version 1.0'*

4.5.1.3 Odour management plan

More information can be found in Section 2.3.5.1.

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From ex-Section 4.6.23

Description

An 'odour management plan' identifies the appropriate measures to mitigate odours at the site, including:

- operational measures;
- management of complaints;
- monitoring of odour emissions.

Technical description

Operational measures

The odour management plan identifies operational measures to mitigate odours. These operational measures are described in 'Sections 4.5.2.1 and 4.5.3.1.

Complaints

In addition, as part of the odour management plan, the 'complaints management' in the case of single odour emission events includes:

- name, address and telephone number of the complainant;
- date and time of the complaint;
- subject of the complaint;
- operations carried out at the time of the complaint;
- weather conditions (e.g. temperature, wind direction, rainfall);
- operational measures due to the complaint;
- communication with the complainant: an immediate reply is given to the complainant.

The odour management plan also includes operational measures such as monitoring of odour emissions.

Monitoring of odour emissions

The odour management plan identifies the need for monitoring of odour emissions and, if relevant, the frequency and location of the measurements as well as the measurement method.

Achieved environmental benefits

The achieved environmental benefits of this technique include:

- reduction of odour emissions;
- reduction of number of complaints from the neighbourhood.

Environmental performance and operational data

Table 4.48 shows the odour emissions measured at biological treatment plants.

Table 4.48: Ranges of measured odour emissions at biological treatment plants

Type of biological treatment	Ranges of odour emissions measured (OU_E/m^3)
Aerobic outdoor (see Figure 4.4)	303–5916
Aerobic indoor (see Figure 4.7)	139–7433
Anaerobic (see Table 4.24)	29–12 967
MBT (see Table 4.41)	74–5550

Cross-media effects

None recorded

Technical considerations relevant to applicability

Generally applicable. The need for monitoring of odour emissions depends on the potential nuisance for the neighbourhood.

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~~Environmental performance and operational data~~

~~When applying technique ‘n’ (see Description section above), the airflow to maintain a negative air pressure, is sometimes given in how many hours are necessary to exchange the air inside the building. The high this value is, the higher the odour concentrations are achieved inside.~~

~~Technical considerations relevant to applicability~~

~~In encapsulated systems such as tunnel, box or container, aeration of the biologically degraded products occurs under pressure and by circulating air operation. In the housed hall systems both pressure and suction systems are used.~~

Economics

No information provided.

Driving force for implementation

Reduced number of complaints from the neighbourhood.

Example plants

A good number of facilities across Europe currently employ technologies that help in the running of aerobic digestion activities even in ~~most~~ more crowded areas, provided the design and management of the plant consider odour problems with the proper care.

Reference literature

[109, Bio. subgroup 2014] [160, WT TWG 2014]

4.5.1.4 Reduction of channelled emissions of odorous subtances, H_2S and NH_3

From ex-Section 4.2.4 **Generic techniques for anaerobic digestion**

~~Odour emissions of 500 – 1000 GE/m³from anaerobic treatment can be reached by using an appropriate combination of biofilter and scrubber if the~~ ~~NH_3~~ ~~content is higher than 30 mg/Nm³.~~

Description

~~‘Biofilter’ is the generic term covering all biological oxidation processes taking place in a packed system. This includes conventional trickling filters, bioscrubbers (microbial population supported in scrubber liquor) or biobeds (packed system using soil, peat and bark (~~

A biofilter is used to reduce the channelled emissions to air.

Technical description

See Section 2.3.4.7 and CWW BREF [138, COM 2014] for the description of a biofilter.

Achieved environmental benefits

The achieved environmental benefits of this technique include:

- reduction of odourous emissions;
- reduction of H_2S emissions;
- reduction of NH_3 emissions;
- reduction of VOC and inorganic compound emissions.

Cross-media effects

See CWW BREF [138, COM 2014].

Environmental performance and operational data

Because ammonia has an inhibiting effect on biofilters, a combination of wet scrubbing (see Section 2.3.4.10) followed by treatment in a biofilter may work best. Moreover, an acid

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scrubber is an effective system to limit competition between H_2S and NH_3 in the biofilter and ensure that the biofilter would treat H_2S efficiently.

Figure 4.41 to Figure 4.43 below summarise the data provided via the data collection for NH_3 and H_2S emissions to air from biological treatments of waste.

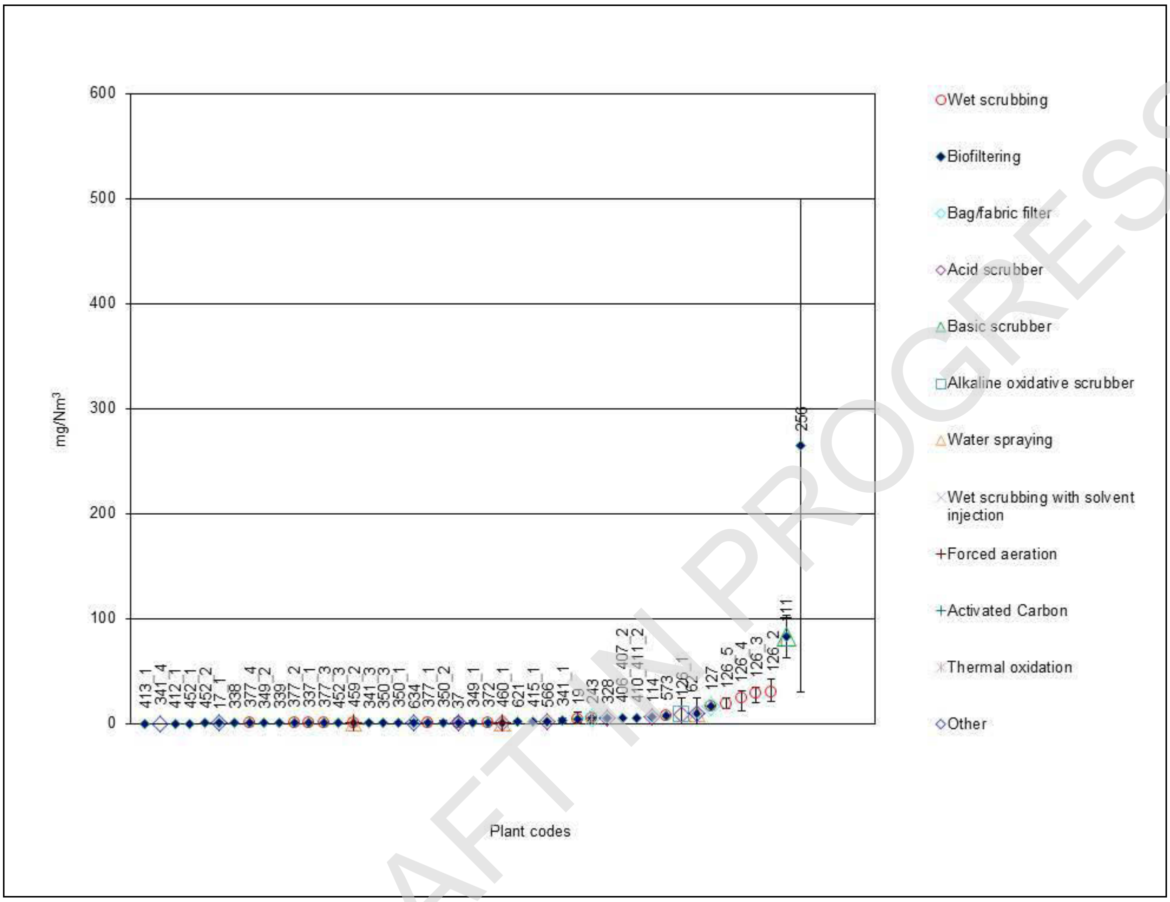

Figure 4.41: NH_3 emissions to air from all plants performing biological treatments

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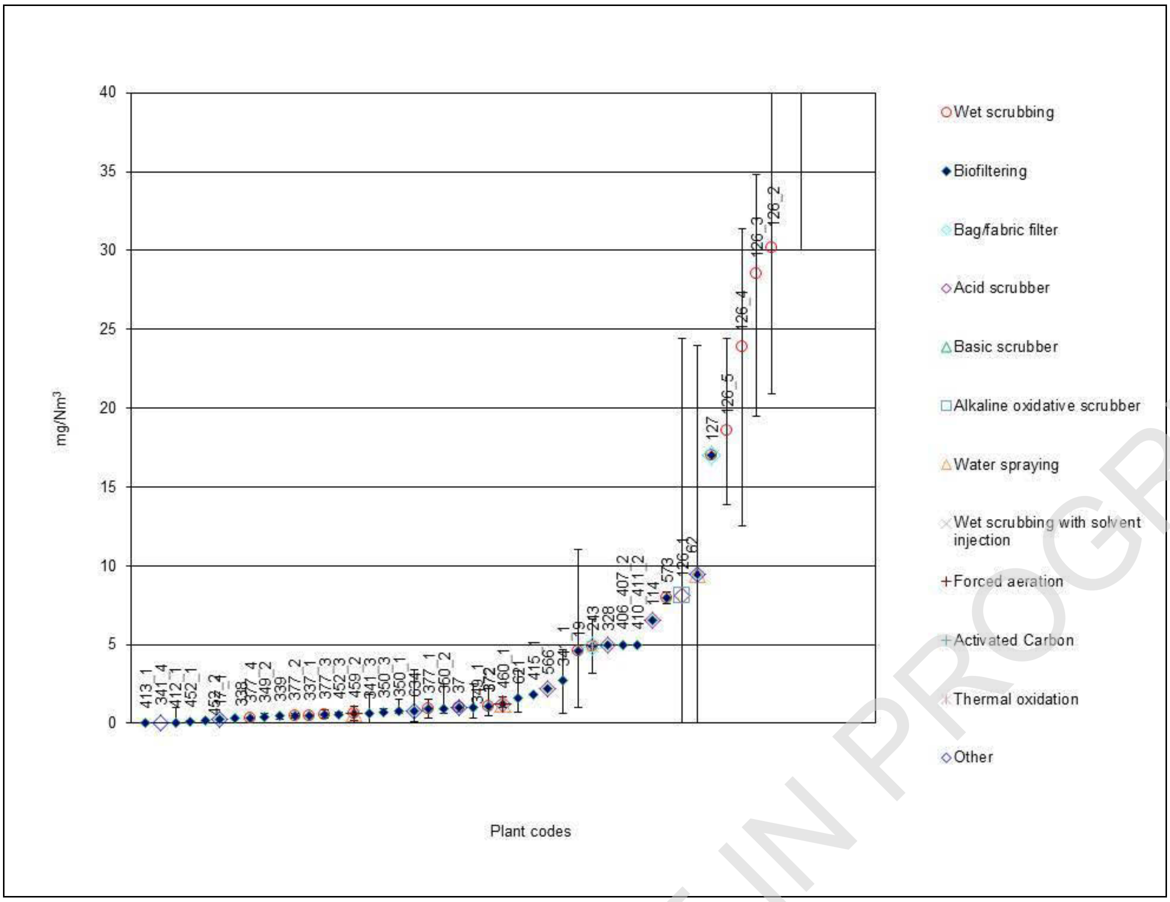

Figure 4.42: NH_3 emissions to air from all plants performing biological treatments (range 0-40 mg/Nm^3)

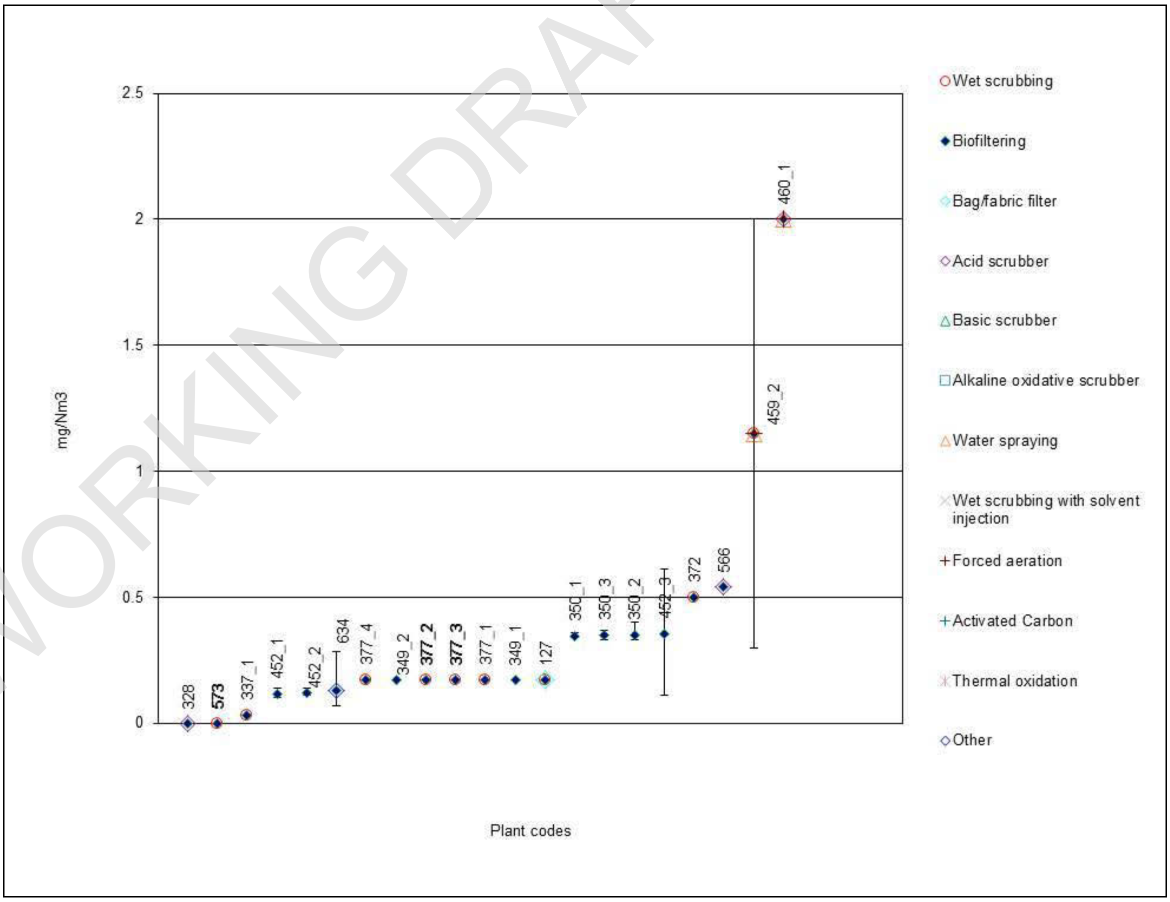

Figure 4.43: H2S emissions to air from all plants performing biological treatments

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Table 4.49 shows the methods of standards used for monitoring NH_3 and H_2S and Figure 4.44 and Figure 4.45 give an overview of how often the measurements are carried out.

Table 4.49: Standards used for monitoring NH_3 and H_2S emissions to air

Monitoring methods/ standards used for NH_3	Monitoring methods / standards used for H_2S
Spectrophotometric Ion chromatography Gas detection tube Colorimetric tubes EPA CTM - 027 EPA CTM - 029 EPA CTM - 030 EPA CTM - 031 MX 6i Brid 400 UNE EN 13284 KJ-I-5.4.-198 VDI 3496, Blatt 1 M.U 632 + APATCNR IRSA 4030 A1MAN 29/2003 Metodo UNICHIM 634:1984 Man. 122, Parte II UNICHIM 632 Mu 632: 94 NTP-62	Spectrophotometric Colorimetric tubes USEPA METHOD 11 DIN - VDI 2454 & EPA 11 DIN - VDI 2454 & EPA 13 DIN - VDI 2454 & EPA 14 DIN - VDI 2454 & EPA 15 UNI 634 MAN. 122 DIN EN 13725 UNE EN 13284 KJ-I-5.4.-198 Metodo UNICHIM 634:1984 Man. 122, Parte II UNICHIM 634 M.U. 634

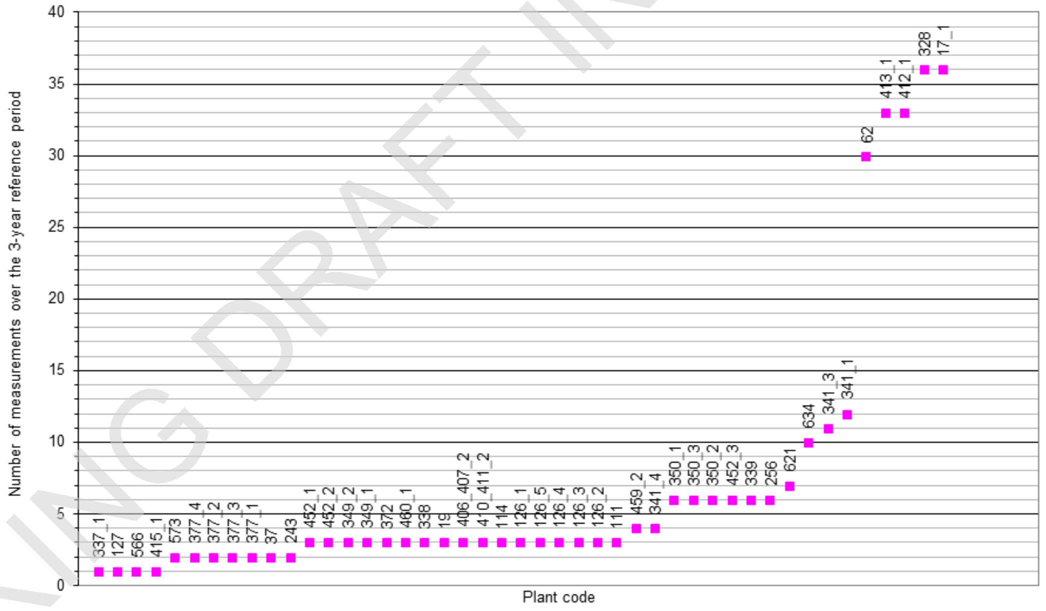

Figure 4.44: Measurement periodicity of NH_3 emissions to air

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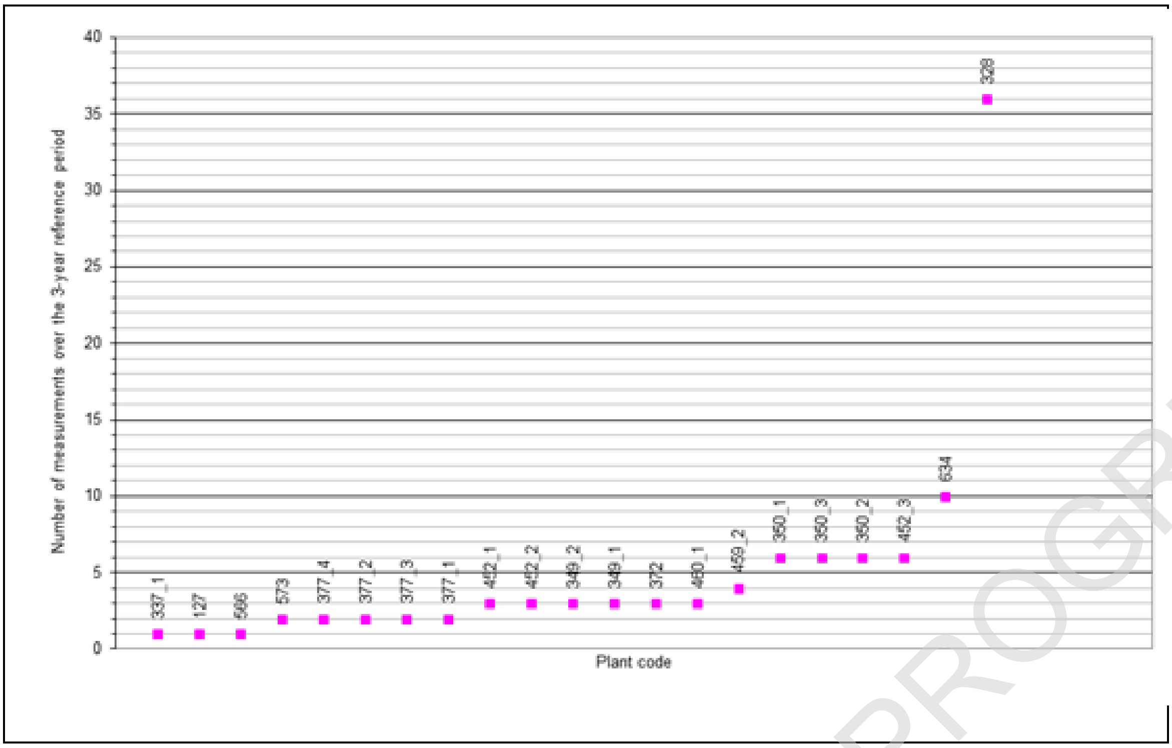

Figure 4.45: Measurement periodicity of H_2S emissions to air

Technical considerations relevant to applicability
These end-of-pipe abatement techniques are generally applicable in biological processes where air emissions are channelled. See also CWW BREF [138, COM 2014].

Economics
See CWW BREF [138, COM 2014].

Driving force for implementation

- Environmental legislation.
- Odour complaints.

Example plants
See Figure 4.41 to Figure 4.43
Reference literature
.

TWG, please provide this document: *Cré-Composting and Anaerobic Digestion Association of Ireland (2011) Certificate in Compost Facility Operation Manual. Dundalk, Louth, Ireland*

[129, Jacobs et al. 2007] [109, Bio. subgroup 2014] [160, WT TWG 2014]

4.5.1.5 Minimization of waste water generation and water usage and prevention of contamination of ground and surface waters

Description
Management of water and leachate on site ~~aims to avoid the comtamination of ground or surface waters in the vicinity of the site~~. This technique includes:

From ex-Section 4.2.8

a. recycling process waters (e.g. from dewatering of liquid digestate in case of anaerobic treatment) or muddy residues, or using alternative sources of water as much as possible, e.g.

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condensed water, rinsing water, run-off water, within the ~~aerobic treatment~~ process to ~~completely avoid~~ minimise water emissions;

b. efficient balancing of water to minimise the production of leachates;

c. segregation of leachate seeping from compost piles and windrows, surface water arising from roads and uncontaminated run-off water from buildings;

d. on-site treatment of waste water before discharge when water cannot be completely recirculated to the process or applied on land (if allowed), and depending on the receiving body.

~~e. making provisions for leachate collection with recirculation systems, in order to feed the leachate back into the windrows to maintain the optimum moisture content and also to facilitate the leachate treatment~~

See also Section 2.3.7.

From ex-Section **4.2.4 Generic techniques for anaerobic digestion optimisation**

~~a. having a close integration between waste management and water management. This would be helpful for further developments and for management to make improvements and gather data for keeping full control of the water consumption~~

~~b. recycling the maximum amount of waste water to the reactor, to facilitate any dissolved organic material being converted to biogas~~

~~c. re-using the condensed water vapours arising from ventilation of the windrows (maturing process) and the accumulated water only in the case of open aerobic digestion treatments in order to humidify the solid waste and in the case that olfactory nuisances may be avoided.~~

- ~~Re-using the condensed and accumulated water may lead to odour emissions~~

Technical description

Dirty waters

Leachate typically has a high content of organic substances, which has the potential to cause eutrophication in surface water, groundwater and flora and can cause soil contamination. It also has a high potential for generating odour.

The site is designed to have sufficient collection and storage of dirty run-off, leachate and washing water (dirty waters) from any impermeable paved areas of the site. Storage areas and lagoons are constructed according to available construction design standards. Underground tanks are checked at regular intervals for integrity~~. introducing~~ A highly permeable drainage layer, such as wood chips, is introduced in the windrow construction to allow leachate drainage and airflow into the windrows.

To comply with local, national and European water quality standards, dirty waters are minimised and collected. Then they are either reused within the composting process, disposed of properly for treatment in a waste water treatment plant, treated at another authorised waste treatment plant (e.g. AD plant) or applied to land when allowed by the relevant competent authority.

Once collected, dirty waters may be reused in the beginning of the composting process for wetting fresh feedstock materials in the facility's mixing procedure, when moisture assessment warrants the adjustment, or later in the composting process if allowed by the regulatory regime and provided the dirty waters do not contain a significant amount of contaminants that may compromise the quality of the compost produced.

Treatment of the leachate on site by approved means prior to discharge may also be implemented (e.g. in the form of reed beds, aerated lagoons or on-site waste water treatment plants).

Leachate can also be generated during the outdoor curing process. All curing pads are graded so that leachate can be collected with the use of a catchment system to intercept and direct the liquid to a catch basin and underground storage tank or a storage lagoon.

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Clean surface water

Clean surface waters are collected and stored separately from dirty water or leachate, to reduce the volume of dirty water to be treated.

Proper surface water design management will be important to protect nearby watercourses. The entire site is graded and bunded or kerbed to facilitate the collection and drainage of surface water to catch basins that direct this water to a storage lagoon or tank for reuse in the composting process.

Surface water can be managed or used effectively on site in the following ways:

- sprayed on working surfaces on the site for dust control;
- moisture control at the start of and during the active composting phase and curing stages;
- uncontaminated surface water can also be stored in settling ponds to let the sediment settle to the bottom of the pond before being discharged to local watercourses; and
- it can also be treated in constructed wetlands to reduce the pollution potential before discharge to local watercourses.

Further considerations

a. The appropriate dimensioning of the intermediate waste water tank(s) takes into account the site size and rainfall in order to hold dirty waters from all paved areas where compost or raw material is stored or treated in open, unroofed areas.

b. The impermeable area covers the following areas of the composting plant:
   - the tipping and intermediate feedstock storage area for all input materials with the possible exception of woody materials (tree and bush cuttings), straw, or similar biologically inactive, carbon-rich, dry feedstock (if allowed by the regulatory regime) or finished compost;
   - the storage area for non-woody materials (food and kitchen waste, sludge, food processing waste, all materials with high water content and a high fermentability potential);
   - the preprocessing area where feedstocks are mixed, with the exception of the area where woody materials (tree and bush cuttings) only are shredded;
   - the active decomposition area, irrespective of whether it is roofed or not;
   - the maturation area, irrespective of whether it is roofed or not; and
   - the storage area for matured compost with any possible exception to be approved by the competent authority and taking into account at least:
     - local precipitation,
     - ground and surface water protection,
     - coverage by water-repellent fleece or roof.

c. In the case of areas of heavy rainfall or high precipitation, covering small triangular windrows with geo-textiles or composting under a roofed structure reduces the formation and the organic contamination of waste water and helps improve run-off management.

d. All storage and treatment areas allow for the controlled drainage of all liquids to avoid water-logging at the windrow or feedstock base. This is achieved by constructing the composting pad on a slope to avoid water stagnating. The minimum slope of the site is determined by the windrow height, the annual precipitation, the existence of roofing, the method of aeration and the presence of drainage/aeration tubes.

From ex-**Section 4.2.8**

~~e.~~ When relevant, ~~thermally insulating~~ the hall ceiling of the biological degradation hall in aerobic processes is thermally insulated in order to minimise the generation of condensate.

Water usage

Quality management measures aimed at reducing the quantity of water used and to manage dirty waters are:

WORKING DRAFT IN PROGRESS

  - including in the initial composting mixture feedstocks that provide a good structure and water-holding capacity (e.g. shredded wood, bark, straw, oversize screenings, sawdust, leaves and compost at an appropriate rate);
  - adjusting the initial moisture content of the feedstock to adapt it as much as possible to the water-holding capacity;
  - assessing the need for water addition and ensuring the correct addition of water as the composting process progresses and the total water-holding capacity decreases.

Achieved environmental benefits

The achieved environmental benefits of this technique include:

- prevention of the contamination of groundwater or surface water; ~~in the vicinity of the site.~~
- reduction of water usage and leachate production;
- reduction of waste water to be treated before release.

Environmental performance and operational data

For examples of plants using recycling water, See Table 4.50 below presents the reported emissions to water from biological treatments of waste directly discharging to a water body.

Table 4.50: Biological treatments of waste –Direct discharge to water

Plant code	Process type	Parameter (mg/l)			
		TSS	BOD_5	COD	Total N
521	Aerobic outdoor	36	8.3	175	5.3
580	Aerobic indoor	No information			
609		25.6	3.3	NI	0.3
623		NI	NI	NI	3.2
634		No information			
132	Anaerobic	No information			
341		0	1.5	9	5.75
266	MBT	No information			
349		40	NI	30	NI
350		16.2	12.6	30.4	NI
NI: no information					

Additionally plants 341, 349 and 350 provided concentration values listed in Table 4.51 below

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Table 4.51: Reported emissions to water from plants 341 (anaerobic digestion), 349 and 350 (MBT)

Parameter	Concentration value (mg/l)		
	Plant 341	Plant 349	Plant 350
Cl^-	10.5	NI	31.3
F^-	0.009	NI	0.8
S^{2-}	0.095	NI	0.4
SO_3^{2-}	0.09	NI	0.1
Sulphate	11.9	NI	31.2
NO^{2-}/NO^{3-}	0.25	NI	NI
NH_3-N	0.01	NI	1.5
Total P	0.3	NI	NI
As	0.00005	0.03	0.03
Pb	0.001	0.01	0.02
Cr	0.002	0.1	0.07
Cr (VI)	NI	NI	0.03
Cu	0.002	0.05	0.02
Mn	0.04	0.1	0.09
Ni	0.004	0.1	0.07
V	0.0002	NI	NI
Zn	0.001	NI	0.11
Fe	0.065	NI	0.15
Phenols	0.004	NI	NI
Toxicity (number of bodies built after 24 h [%])	0	NI	NI

NI: no information

Cross-media effects

Reuse of leachate water may generate odorous emissions and reintroduce pathogens into sanitised compost.

Moreover, recycling of waste water ~~(technique b in the description section above)~~ may result in an increase in the concentration of toxic/inhibiting compounds which may have negative effects on the biological treatment. Also making these water sources available induces costs (e.g. water treatment).

Technical considerations relevant to applicability

Specific collection system for clean surface waters, as well as grading of the site, may be applicable for new sites only.

The recirculation into the process is limited by potential contents of impurities (heavy metals, salts, pathogens, etc.)

The waste water treatment to be carried out depends principally on the type of discharge to the environment, whether it is direct or indirect, and in the case of indirect discharge whether the receiving WWTP is designed to treat the waste water (for example, if the latter contains metals).

Economics

TWG, please provide information

Reduction of water expenses.

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Driving force for implementation
Legislation on water pollution.

Example plants
The data collection shows that 21 plants use recycled water (see Table 4.52). The reported recycled water to water used ratio (as an average over the three reference years) ranges from 20 % to 100 %. The recycled water is used as washing water, as well as process water. The source of recycled water is mainly rainwater, and also leachate and waste water after treatment.

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Table 4.52: Examples of plants using recycled water

Type of biological treatment	Plant code	Ratio of water used coming from recycling (%)	Comment
Anaerobic	097	100	Rainwater from roofs is used for washing of machinery
Anaerobic	255	70	Used for mixing the bio-waste for the fermentation unit
Anaerobic	377	50	NI
Anaerobic	113	26	Based on material balance calculation, cleaning and dilution water
Anaerobic	382	61	This refers to the direct recycled and the part after the waste water treatment plant
Anaerobic	459	78	Rainwater + treated waste water + Wet pretreatment: (pulpers)
Anaerobic	541	100	Rainwater is harvested and used in the AD process and also for biofilter irrigation
Indoor aerobic	062	78	Maximise the use of rainwater in the composting process and further reduction of the waste water sent to WWT
Indoor aerobic	518	58	Harvesting rainwater
Indoor aerobic	520	23	Harvesting rainwater
Indoor aerobic	621	100	Estimated value of recycled rainfall water
Indoor aerobic	460	78	Air emission abatement. Scrubber. Rainwater + treated waste water for cleaning and plant washdowns, scrubbers, other process
MBT	349	47	NI
MBT	415	51	NI
Outdoor aerobic	069	100	Rainwater/leachate
Outdoor aerobic	073	100	Run-off and leachate
Outdoor aerobic	104	100	Recycled water/leachate is primarily used to prevent dust nuisances
Outdoor aerobic	124	98	Water collected in the plant (leachate + rainwater) used in the process
Outdoor aerobic	417	100	NI
Outdoor aerobic	418	100	NI
Outdoor aerobic	419	50	NI
NI: No information.			

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Reference literature

TWG, please provide these documents: *Composting and Anaerobic Digestion Association of Ireland (2011) Certificate in Compost Facility Operation Manual. Dundalk, Louth, Ireland.* And *The BAT study (manure) co-digestion (VITO), 2006 Waste Treatment BREF*

[130, Sauer et al. 2013] [109, Bio. subgroup 2014] [160, WT TWG 2014]

4.5.2 Techniques for aerobic treatment

4.5.2.1 Monitoring of aerobic process to improve the environmental performance

From ex-Section 4.2.8

~~**Environmental performance and operational data**~~

~~Aerobic biological systems are generally more robust than anaerobic systems, and are less sensitive to chlorinated and sulphur compounds, pH and temperature fluctuations and do not require a pre-acidification stage.~~
~~Good operational practice will determine whether or not the site remains aerobic. It is in the operator's best interest to maintain aerobic conditions, to avoid odour problems and to speed up aerobic digestion rates. Anaerobic conditions may lead to occasional problems, i.e. not a regular event, which still need to be recorded in the site diary.~~

~~When the relative humidity of the exhaust air is high (more than 90 %), the emission of particulates is low.~~

Description
Proper monitoring and control of key process parameters to reduce emissions of odour, including:

- control of waste input characteristics (e.g. C:N ratio, particle size);
- control of water content;
- control of air diffusion through the waste;
- control of temperature.

Technical description
Waste input characteristics
Proper preparation of waste contributes to the reduction of odours. It includes the following:
~~Effective operational management can help control the formation of odours. This includes:~~

Deleted: already in Section 4.5.1.2

~~a. processing incoming feedstock as soon as possible~~

a. Identification of odourous waste at the site as quickly as possible upon delivery.
b. Ensuring proper stabilisation of the biomass within the retention time in enclosed buildings, so as to ensure that only odourless materials are present in the open curing stage
c. Optimal particle size which can be achieved by shredding the feedstocks, in order to create the ideal habitat for composting microbes and to enhance biodegradation.
d. Avoiding an early refining step to reduce the particle size too far, which would hinder the diffusion of air through the material that still has to complete its biochemical transformation (a smaller particle size could cause the ~~aerobic digestion~~ bio-waste to lose its structure and make anaerobic decomposition more likely).
e. Mixing input materials in order to achieve an optimal balanced C:N ratio in the batch. Within a low C:N ratio, the NH_3 emissions increase as the composting temperature increases. A C:N ratio of > 25 minimises NH_3 formation. However, as the ratio increases (to above 35) the rate of composting will slow down, as N will be rate-limiting.

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f. The accepted load is assessed to identify the processing requirements and any potential problems. Any moist or wet loads accepted are routinely blended with other woody or dry inputs or oversize compost material (compost screenings) upon discharge to reduce the possibility of anaerobic conditions developing and causing an odour release.
g. Addition of mature compost may be beneficial in order to facilitate the efficient formation of humic substances (humification) and the incorporation of volatile carbon and nitrogen compounds into more complex compounds.
h. Composting process additives (e.g. mineral-based or bio-based inoculants or activators) may be added at this stage of the process or at later stages to enhance the process, or ensure the necessary diversity of bacteria species to guarantee consistency in plant operation. They are only applied if they are intended to confer a benefit to the composting process or reduce emissions, without any significant adverse effects on compost characteristics.
i. Preventing the formation of leakage puddles (e.g. ensuring proper slopes to paved surfaces).
j. Avoiding the external stockpiling of coarse rejects from pre-process screening steps, as these would also contain a certain percentage of fermentable materials.
k. Using surfactant reagents.

From ex-Section 4.2.2

From ex-Section **4.2.10**

~~**Description**~~

~~Some techniques include:~~

~~a. applying overpressure operation~~
- ~~this has the following advantages:~~
    - ~~lower risk of wetting and compaction of the aeration floor~~
    - ~~rectified flows of air and natural heat emission~~
    - ~~low requirements for the construction of the aeration floor~~
- ~~however, there are also disadvantages:~~
    - ~~mixing of heap air and hall air~~
    - ~~intake of air saturated with water vapour into the hall~~
    - ~~limited accessibility of the hall~~
    - ~~high corrosion of the constructive elements and machines with increased abrasion and maintenance costs~~
    - ~~it is not possible to determine the process parameters of the exhaust air~~
    - ~~biological degradation can only be controlled through indirect measurements and experience~~
    - ~~separate treatment and purification of heap and hall exhaust air is not possible~~

~~b. applying suction (under pressure) operation~~
- ~~suction operation by contrast to overpressure operation has the following advantages:~~
    - ~~only minor pollution of the hall air with heap air~~
    - ~~low corrosion of the constructive elements and machines~~
    - ~~hall is accessible during heap aeration~~
    - ~~possible to determine the process parameters in the heap exhaust air~~
    - ~~separate collection and treatment of heap air possible~~
- ~~the disadvantages of suction operation are:~~
    - ~~higher requirements for the construction of the aeration floor~~
    - ~~danger of wetting the distance and diffuse air layer~~

~~c. having aeration floor with slitted plates and a basement cellar to ensure an even aeration of the complete moving/turning~~
~~d. adapting aeration to the biodegradation activity of the material by segmentation of the biological degradation area in separately controllable aeration fields. Also by regulating the air quantity per aeration field depending on the temperature and oxygen content, by frequency-controlled ventilators or by alternating the cyclic operation~~
~~e. ensuring that there is an even flow through the biodegraded material in tunnel system floors, by using embedded punched pipes and relatively high pressures~~

WORKING DRAFT IN PROGRESS

~~f. using heat-exchangers to lower the exhaust gas temperature and humidity, in order to ensure a heat discharge in circulating air systems.~~
~~l. ensuring proper maintenance of odour abatement technologies is carried out~~
~~m. purifying the exhaust air or re-using it, e.g. as supply air for biological degradation~~

~~Achieved environmental benefits~~
~~The aims of aeration are to:~~

- ~~ensure a sufficient oxygen content in the heap~~
- ~~prevent methane formation in anaerobic areas~~
- ~~discharge any methane generated~~
- ~~lead off the released reaction heat~~
- ~~allow biogenic drying (in MBT plants with dry stabilisation).~~

~~Cross-media effects~~
~~The aims mentioned above have to be balanced against the competing aim of minimising the air quantity and evaporation losses.~~

~~Operational data~~
~~In static biological systems, there is no turnover. Generally the rule holds that the shorter the turnover intervals (with simultaneous watering), the greater is the danger of the heap running dry. Watering the heap without turning often only humidifies the layers near the surface.~~

~~Applicability~~
~~In encapsulated systems such as tunnel, box or container, aeration of the biologically degraded products occurs under pressure and by circulating air operation. In the housed hall systems both pressure and suction systems are used.~~

~~Economics~~
~~The construction investment costs of an aeration floor with slitted plates and basement cellar are 40 to 50 % higher than those of other available systems (e.g. aeration tubes or channels in the bottom of the hall).~~

~~Reference literature~~
~~[88, UBA Germany 2003]~~

Water content
The ideal moisture content at the start of the composting process is below 65–70 % (mass/mass), and between 50 % and 60 % (mass/mass) during the process. The following information is recorded:

- moisture assessment (when carried out; in indoor composting this is not always possible);
- watering date;
- origin of water used (e.g. well water; roof water; leachate water from intensive decomposition and tipping area; leachate water from maturation and compost storage area).

Moisture is controlled during the entire composting process. This can be done by means of visual control combined with one of the following methods:

- o A ‘squeeze or fist test’, which is the most commonly used by operators. It entails grasping and clenching the sample in a gloved hand for approximately ten seconds, then opening and assessing the moisture content using Table 4.53 below. This is a subjective test but is regarded as reliable when carried out by an experienced operator.
- o A moisture monitoring device with read-out or connectivity to a data capture system.

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- A more accurate drying in an oven method, which is followed by calculating the change of mass having weighed the sample before and after 'drying and cooling of the sample'.

Since results from the squeeze test and moisture probe techniques are less accurate, when possible these can be verified at regular, stated intervals by comparison with quantitative results (% mass/mass) obtained using the drying in an oven method.

Table 4.53: Moisture assessment index

Index	Sample moisture behaviour	Interpretation
1	Water seeps out	Too wet
2	More than one droplet appears	Too wet
3	One droplet appears	OK
4	Compost particles remain packed together and no droplets appear	OK
5	Compost particles fall away from each other	Too dry

Aeration

Aeration monitoring aims at ensuring that aerobic conditions are maintained. Furthermore, a high temperature for prolonged periods of time after thermal sanitisation leads to the formation of odorous substances and ammonia. The following parameters are recorded:

- Turning frequency (e.g. for open windrow composting), or oxygen and/or CO_2.
- In the case of indoor composting systems, the air supply can also be controlled by monitoring the temperature of the process air, via temperature sensors within the inlet- and/or exhaust-air pipes of forced aerated systems. The air flow rate will be regulated on the basis of the temperature values measured.

Table 4.54 below summarises measures to prevent oxygen deficiency and water surplus during composting.

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Table 4.54: **Measures to prevent oxygen deficiency during composting**

Measures against water surplus	Reduce water input: • Choose dry feedstock with a high water retention capacity • Add high C:N input materials (chopped/shredded wood, bark, sawdust, dry compost etc.) • In case of heavy rainfalls: Cover open triangular windrows with a geo-textile (drains off 80–90 % of rainwater) • Shape windrow to shed water Increase water release: • Ensure initial 'mix' of materials is balanced and that porosity is maximised • Uncover the windrows on days with high evaporation potential
Measures to improve structure	• Mix additional bulking agents if required (shredded bush cuttings) • Increase bulking agents especially in the bottom of the heap, if required. Create a basic layer with structure-forming shredded wood. • Use oversize elements when required to 'open' the feedstock texture. • Porosity is a key factor in the generation of odours. The density of the material can be optimised from the beginning by effective blending and mixing of feedstocks. This will enable adequate air flow throughput the pile.

Windrow structure	• Set up loose, well-structured windrows for the initial intensive degradation phase
	• The maximum height of a pile/windrow depends on:
	  • decomposition age (the more mature, the higher the piles can be)
	  • structural stability of the whole mixture
	  • installation of a forced aeration system (alternating positive [blowing] and/or negative [sucking])
	• Through mechanical agitation (turning), new accessible surfaces are created and air exchange rates are increased.

Adapted from [Bidlingmaier & Müsken, 1997, 131]	

Table 4.55 gives an indication of the advantages and disadvantages of positive and negative aeration.

From ex-**Section 4.2.10 "Aeration control of biological degradation"** (text changed into table)

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Table 4.55: Advantages/disadvantages of overpressure and suction systems

	Advantages	Disadvantages
Overpressure (positive aeration system)	• Lower risk of wetting and compaction of the aeration floor • ~~Rectified flows of~~ Control of air flow and natural heat emission • ~~Low~~ Limited constraints ~~requirements~~ for the construction of the aeration floor	• Mixing of heap air and hall air • Intake of air saturated with water vapour into the hall • Limited accessibility of the hall • High corrosion of the constructive elements and machines with increased abrasion and maintenance costs • It is not possible to determine the process parameters of the exhaust air • Biological degradation can only be controlled through indirect measurements and experience • Separate treatment and purification of heap and hall exhaust air is not possible
Suction (negative aeration system)	• Only minor pollution of the hall air with heap air • Low corrosion of the constructive elements and machines • Hall is accessible during heap aeration • Possible to determine the process parameters in the heap exhaust air • Separate collection and treatment of heap air possible	• ~~Higher requirements~~ More constraints for the construction of the aeration floor ~~• Danger~~ Higher risk of wetting ~~the distance and diffuse air layer~~

An aeration floor with slitted plates and a basement cellar allows a uniform aeration of the complete moving/turning space.

Aeration is adapted to the biodegradation activity of the material by segmentation of the biological degradation area into separately controllable aeration fields, and by regulating the air quantity per aeration field depending on the temperature and oxygen content, by frequency-controlled ventilators or by alternating the cyclic operation.
An even flow through the biodegraded material in tunnel system floors is ensured by using embedded punched pipes and relatively high pressures.

Natural aeration in open windrow systems is based on the *principle of natural convection* and, during the preliminary decomposition stages, mechanical agitation can cause short-term increased odour emissions. Therefore in open windrow systems, the site-specific conditions are considered together with the feedstock properties and daily process management operations.

Specific operational measures to reduce odour emissions from open windrow composting systems are:

- the immediate and efficient processing of delivered waste material with a high potential for formation of odorous substances (e.g. food waste, fresh grass cuttings);
- mixing with well shredded and structured woody garden and park waste (maintaining sufficient storage /supply of bulking agents to address the C:N ratio and porosity);
- regular turning to avoid anaerobic zones forming in windrows;
- limiting the size of the windrows; and

WORKING DRAFT IN PROGRESS

- keeping the facility clean (regular cleaning of surfaces, equipment and all traffic routes etc.); and
- turning the windrows only when there is an advantageous wind direction relative to the potentially affected neighbourhood where possible.

Temperature
Apart from its effects on the output quality, temperature control is useful to ensure an optimal abatement system efficiency (e.g. biofilter, bioscrubber). Furthermore, high temperatures for prolonged periods of time after thermal hygienisation may lead to an increase in the formation of odorous substances and ammonia. Temperature monitoring can also be used for controlling aeration.

More sophisticated compost management software enabling integrated monitoring of oxygen, moisture, temperature, and carbon dioxide is also available for process control purposes and can assist the operator to understand more accurately the conditions actually occurring within the compost mass.

More specifically, the technique includes the following:

a. temperature is monitored at an appropriate frequency during the intensive composting phase (for thermal hygienisation) as required by the regulator;
b. the temperature is recorded at representative points intermittently or continuously, as defined in the operator's quality management system, usually at least once per working day during the entire hygienisation period;
c. in order to reduce the formation of odorous substances and ammonia, it is recommended to avoid very high temperatures for prolonged periods of time after thermal hygienisation.

Achieved environmental benefits

- Reduced emissions of ammonia, VOCs and odour.
- Reduced number of complaints from the neighbourhood.

Environmental performance and operational data
See Section 4.5.1.3 for information on odour emissions.

Cross-media effects
~~The use of surfactant reagents will not completely eliminate odour, especially if the choice of reagent is based on a characterisation of the compounds in the odour-causing aerosol.~~

The negative pressure works 'against gravity' – the energy consumption is much higher as in the case of positive pressure. This must be taken into consideration.

Technical considerations relevant to applicability
Water content
It is normally challenging to monitor moisture during the composting process inside an enclosed building or vessel, due to health and safety issues. Regular measurement of moisture content in the material inside closed systems is technically not feasible. Moisture can be assessed before loading the material into the enclosed composting reactor and amended and adjusted when it comes out of the indoor composting stage. An optimal moisture content can be maintained inside the enclosed composting unit based on the operator's experience. In addition, the assessment of the water balance can be determined if the initial moisture content is analysed and the water loss is estimated by calculating the air flow rate and the water content of the exhaust air.

~~Besides prevention, often aerobic facilities have to tackle odour issues through the treatment of the exhaust air, above all where they feature high capacities and/or involve short distances from dwellings.~~

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Note that in some cases – e.g. winter months, typically characterised by high C:N feedstocks – it may be difficult for the operator to get hold of feedstocks with the desired C:N ratio.

~~Environmental performance and operational data~~

~~When applying technique 'n' (see Description section above), the airflow to maintain a negative air pressure, is sometimes given in how many hours are necessary to exchange the air inside the building. The high this value is, the higher the odour concentrations are achieved inside.~~

~~Technical considerations relevant to applicability~~

~~In encapsulated systems such as tunnel, box or container, aeration of the biologically degraded products occurs under pressure and by circulating air operation. In the housed hall systems both pressure and suction systems are used.~~

Economics

The construction investment costs of an aeration floor with slitted plates and a basement cellar are 40–50 % higher than those of other available systems (e.g. aeration tubes or channels in the bottom of the hall).

Driving force for implementation

- ~~Prevents or decreases odour emissions~~.
- Reduced number of complaints from the neighbourhood.
- Improvement of product quality.

Example plants

~~A good number of facilities across Europe are currently employing technologies that help in the running of aerobic digestion activities even in most crowded areas, provided design and management of the plant consider odour problems with the proper care.~~

Plants 544, 546, 547, 548, 622.

Reference literature

[88, UBA Germany 2003] [109, Bio. subgroup 2014] [112, Amlinger et al. 2009]

[129, Jacobs et al. 2007], [130, Sauer et al. 2013] [156] [160, WT TWG 2014]
Composting and Anaerobic Digestion Association of Ireland (2011) Certificate in Compost Facility Operation Manual. Dundalk, Louth, Ireland.
[37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [34, Babtie Group Ltd 2002] [73, Irish EPA 2003] [88, UBA Germany 2003] [98, WT TWG 2004]
Example plants section containing lists of techniques applied in several types of combination process/waste have been moved and merged into Chapter 2

Items of ex-Section **4.2.2 'Specific storage and handling techniques for biological treatments'** moved to Section 2.3.13

4.5.2.2 Techniques to limit diffuse dust and bioaerosol emissions

Description

To identify site activities and meteorological conditions that could potentially generate dust and bioaerosols and to take measures to mitigate and manage emissions.

Technical description

The following activities/events can generate dust and/or bioaerosols and odour:

WORKING DRAFT IN PROGRESS

- vehicle and equipment movement around the site;
- shredding of feedstock or bulking materials;
- formation and turning of compost piles/windrows and filling of vessels;
- forced aeration of outdoor windrows without covers;
- screening of finished compost;
- spraying of leachate when it is reused in the composting process, in particular when sprinklers are used (resulting primarily in the generation of bioaerosols;
- strong wind.

Specific management measures to reduce dust and bioaerosol emissions are listed below. These control measures are covered by a facility's diffuse emissions management plan (see 2.3.5.3), unless evidence is provided that these measures are not feasible, effective or useful in a specific situation.

a. Covering of skips in transit to and from site and in storage.
b. Regular housekeeping (e.g. keeping the site, moving machines and loaders in order and clean).
c. Site surfaces such as roads and tracks are regularly dampened down and/or swept to suppress dust and bioaerosols. Binders can be used to prolong dust suppression.
d. The plant and machinery are well maintained to avoid generation of dust or particulates.
e. Effective management of moisture, temperature and air supply of all material liable to generate dust and bioaerosols.
f. Maintenance of adequate moisture content throughout the composting process to avoid the input feedstocks, composting materials and finished compost drying out and potentially generating dust and bioaerosols when handled.
g. Batch irrigation is undertaken when the parameters for moisture content fall below the critical limits. Water is applied evenly.
h. Weather conditions and wind direction are monitored and taken into account when undertaking major process activities.
i. The formation or turning of windrows or piles is avoided if possible on windy days.
j. Screening and shredding are also undertaken when wind speed is calm or wind direction is away from sensitive receptors.
k. Windrows are orientated to take into account the direction of the prevailing wind. The smallest possible area of composting mass is exposed to the prevailing winds to avoid 'stripping' of the windrow surface and preferably at the lowest elevation within the overall site layout.
l. Physical barriers such as earth banks or walls or a tree boundary can reduce dust and bioaerosol emissions leaving a site. The use of enclosures for screens and hoppers can be useful in reducing dust and bioaerosol dispersal.

Achieved environmental benefits
To minimise diffuse dust and bioaerosol emissions to air from composting activities.

Environmental performance and operational data
Not identified at this stage.

Cross-media effects
Dust control means higher water usage. A higher ventilation rate also means higher energy consumption.

Technical considerations relevant to applicability
No limitations identified.

Economics
Not identified at this stage.

Driving force for implementation

WORKING DRAFT IN PROGRESS

Not identified at this stage.

Example plants
Not identified at this stage.

Reference literature
Composting and Anaerobic Digestion Association of Ireland (2011) Certificate in Compost Facility Operation Manual. Dundalk, Louth, Ireland.

4.5.2.3 Encapsulation with semipermeable membrane covers

Description

Encapsulated, positively aerated facilities covered and sealed with semipermeable membrane covers are a common method of treating emissions, such as odours, ammonia, VOCs, dust and bioaerosols from an active composting heap.

Technical description
In contrast to the end-of-pipe techniques, these systems realise the emission abatement at the point of the source. The cover is formed by a textile laminate with the membrane being the middle layer as the functional component. The emission retention is based on the combination of a liquid condensate layer being generated on the inner surface of the cover, which acts as a kind of bio washer layer dissolving the majority of the gaseous substances, and the semipermeable behaviour of the membrane.
Following the force of gravity, droplets are formed and drip off thus maintaining a steady exchange with unsaturated water which in turn ensures the odour retention capability.

Another important function of the semipermeable membrane cover as a system component is to provide for optimum moisture management during the abovementioned biological treatment processes.

An installation with a semipermeable membrane cover is designed so that the cover is sealed to the installation interfaces to facilitate a slight back pressure and to ensure the exhaust air's passage through the membrane. The back pressure provides for a homogeneous air supply in the heap formation to facilitate good biological treatment processes.

The water repellency as well as the air and moisture transmission characteristics of the laminate in combination with a sensor-controlled process (temperature and/or oxygen) avoid water-logging or the excessively rapid drying out of the input material.

Encapsulation with semipermeable membrane covers and laminates can be realised by different designs according to the needs with regards to the siting of a plant. The following list describes a representative design spectrum:

1. Designs requiring devices to move a cover:
   - ***a.*** *heap version with cover sealed to the ground;*
   - ***b.*** *sidewall version with cover sealed to the sidewall as well as to the pushwall.*
2. Structural designs with semipermeable membrane laminates mounted to a moveable frame construction:
   - ***a.*** *butterfly version (pitched roof with two hinged halves which can be opened) with a common wall;*
   - ***b.*** *lifting roof version with a common wall.*
3. Combined designs:

WORKING DRAFT IN PROGRESS

a. *closed flexible encapsulation connected to a negatively aerated building (feeding tunnel).*

The structural design versions 2 and 3 are constructed in such a way that the cover/roof can be lifted to provide trafficability of loading vehicles.

The design versions 1a and 1b require winding devices for the covering, as well as for the uncovering of a heap. Those devices can, for example, take the form of mobile winders in the case of 1a or a mounted version, e.g. to the push wall, in the case of version 1b.

All versions are designed so that the connections between the cover laminate and the installation, like the interfaces between the ground (1a) or sidewall and pushwall (1b) or the common wall (2) to the cover, are sealed to avoid bypass streams.

Heap versions (1a) can be sealed to the ground by loading the framing edge strip of a cover made from a non-permeable material with weights or in the case of sidewall versions (1b) utilising flexible ropes threaded through an eyelet pattern in the edge strip which fix and thus seal the cover edge to the top of the sidewall.

For the other designs (2 and 3) the connection can, for example, be designed:

- so that moveable components, like roofs or front doors, are equipped with appropriate means like rubber lips or profiles to provide the necessary sealability when the installation is closed;
- through a fixation of the cover to a wall while the cover itself is tailored to form a buffer to compensate for the elevated height difference when lifted.

Achieved environmental benefits

- Low energy consumption: 1.5–4 kWh/t of input material (depending on the design and type of aerobic biological treatment).
- Emission reduction without further exchange of media (no depletion) like in the case of biofilters.
- No inherent odours generated by the semipermeable membrane cover.
- Lowest carbon dioxide equivalent compared to other technologies for composting operations.

Environmental performance and operational data

The capacity range in which encapsulation with semipermeable membrane covers has been realised ranges from 2 000 t/y up to 620 000 t/y. Roughly 200 sites have been installed over the course of the last 20 years in the EU.

The following Table 4.56 describes the emission abatement performance for the mentioned pollutants, exemplarily utilising the Cover Efficiency which is a relative comparison of the atmosphere above and underneath the cover:

- based on two actual measurements above and underneath the cover;
- as well as, in the case of ammonia, a relative comparison of one actual measurement above the cover to a so-called Baseline Factor which is described as a standardised emission from an open, non-aerated composting windrow

WORKING DRAFT IN PROGRESS

Table 4.56: Emission abatement as Cover Efficiency and vs Baseline Factor of semipermeable membrane covers

Emission type	Cover Efficiency	vs Baseline Factor
Odour	90–97 % (1, 2, 3)	
Bioaerosols	99.99 % (1,3)	
Dust/particulate matter (4)	99.99% (4) (undetectable)	
Ammonia		80 % (5,6)
VOCs	90–95 % + (7)	90–98 % (7)

(1) [132, Kühner 2001].
(2) [149,Kühner 2000.]
(3) Input: Bio-waste; measurements carried out with the same product as (6).
(4) PM 2.5 Particle Filtration efficiency according to 'VDI 3926, Part 2 Testing of Filter Media fo Cleanable Filters under Operational Conditions from December 1994'. This test was carried out o GORE® L3650 which is a Dry Filtration Media with an ePTFE membrane with a much wide porous structure. This is only for indication purposes. The performance of the GORE® ePTF membrane of GORE® Heap Cover is supposedly much better due to the tighter pore structure an the fact that a dry filtration test represents a worst case scenario. The trapping effect of the aqueou condensate film for fine particles cannot be considered with this test.
Source:
(5) [133, Schmidt et al. 2009].
(6) Input: BioSolids/Sewage Sludge; measurements carried out with GORE® Heap Cover wit semipermeable GORE® ePTFE membrane.
(7) Measurements with different input materials in the framework of a project to prove GORE Heap Cover as BACT (Best Available Control Technology) according to SJVAPCD (San Joaqui Valley Air Pollution Control District; CA) Rule 4565 and Rule 4566 and SCAQMD (Souther California Air Quality Management District; CA) Rule 1133.

The performance of encapsulation with semipermeable membrane covers, in the respective case design version 1b, achieved odour control similar to or better than conventional tunnel composting systems with a biofilter and subsequent maturation for a site with an annual capacity of 60 000 tonnes of a mixed waste input of 70 % bio-waste and 30 % green waste. [134, BRUYN]

Cross-media effects

None identified.

Technical considerations relevant to applicability

Generally applicable to aerobic treatment.

Economics

Designs for the encapsulation with semipermeable membrane covers usually have lower capital and operational costs compared to building designs. Capital costs might increase with the grade of structural components (with design version 1a as the lowest to 3 as the highest), however structural design versions might simplify the operational practice.

With regards to the emission abatement performance, no depletion of any media occurs since no chemical or biochemical processes with involvement of the cover materials take place. The focus here is on conserving the integrity of the cover laminate which consists of the membrane plus the back and front fabric. This is secured through good practice as well as utilising the appropriate handling devices for designs which require the cover to move for the opening and closing of the encapsulated reactor (1a and 1b). In the designs in which the laminate is mounted to a frame the risk of damage is, due to the nature of the design, unlikely. For example, experience with semipermeable membrane covers shows, when applying best practice, average service life times of around five to seven years.

WORKING DRAFT IN PROGRESS

[135, Peche et al. 2014]

Driving force for implementation

- Simple and robust technology.
- Significantly lower capital costs compared to conventional building technologies.
- Low maintenance and operational costs.
- No end-of-pipe technology necessary except for the design version 3 a. However, this version allows a significantly smaller end-of-pipe treatment design due to the fact that only air from the connected feeding tunnel requires treatment. The process air from the biological treatment is handled by 'encapsulation with semipermeable membrane cover'.

Example plants

Plants 579, 580, 635.

Reference literature

[132, Kühner 2001] [133, Schmidt et al. 2009] [134, Bruyn 2011] [135, Peche et al. 2014] [137, Bio. Subgroup 2015] [160, WT TWG 2014]

4.5.3 Techniques for anaerobic treatment

From ex-Section **4.2.4 Generic techniques for anaerobic digestion optimisation.** A large part of ex-Section 4.2.4 does not deal with techniques for preventing or reducing emissions but with techniques for optimising the anaerobic process on the performance point of view. This part has been deleted.

~~**Description**~~

~~An optimisation of the anaerobic digestion that amount of biogas, biogas quality and quality of digestate needs to be carried out.An increases in the biogas production typically has an effect on and thus the quality of the digestate and biogas.~~

~~Some techniques include:~~

~~**Technical description**~~

~~d. controlling relevant parameters in digestion water, digestion residue and waste water in regular intervals in order to ensure good operation of the installation~~

~~e. having closed feed bunkers constructed with a vehicle sluice. In open warehouses and during unloading of waste vehicles, the bunker waste gas is to be removed by suction and fed into a waste gas treatment facility~~

~~f. having adequate space particularly for the storage area on the basis of the estimated monthly utilisation~~

~~g. designing, constructing and operating the facility in order to prevent soil contamination due to sewage water~~

~~**Achieved environmental benefits**~~

- ~~Increases the efficiency of anaerobic digestion and allows better use of their products.~~

~~Minimising the quantity of potentially toxic materials is also an important consideration for the quality of the end product. Anaerobic systems are effective at breaking down ring compounds (for example, phenols) and generate methane that can be utilised as a fuel~~

~~**Environmental performance and operational data**~~

~~The high degree of flexibility associated with anaerobic digestion is claimed to be one of the most important advantages of the method, since it can treat several types of waste, ranging from wet to dry and from clean organics to grey waste. The suitability of the method for very wet materials, for instance, has been addressed as an important feature in those scenarios where~~

WORKING DRAFT IN PROGRESS

~~source separated food waste cannot be mixed up with enough quantities of bulking agents such as yard waste (namely, waste from many metropolitan districts).~~
~~Anaerobic biological systems are sensitive to chlorinated and sulphur compounds, pH and to temperature fluctuations and may require a pre-acidification stage.~~

~~In certain circumstances, it is necessary to control relevant parameters in digestion water, digestion residue and waste water, at regular intervals in order to ensure a good operational mode of the installation (technique d in the description section above). In these cases the parameters mentioned are not sufficient for process control. According to the aim of the treatment (landfilling, fertilisers), parameters for the control of the output have to be fixed according to further use.~~

~~Cross-media effects~~
~~The use of sludge in anaerobic digestion needs to be decided on a case-by-case basis, since the heavy metal concentration in sludge may present difficulties for the operator to meet the tight limit values for quality composted products which exist in some EU countries.~~

~~Technical considerations relevant to applicability~~
~~The main area of concern in anaerobic digestion is the guarantee of the long term performance of a plant, which is of course key to its economic feasibility. This risk can be reduced through technological developments but the associated costs of these can affect the economics in the short term. The building of more plants in the future will further operating knowledge and this may increase confidence (see Section).~~

~~Technique e in the description section above is appropriate to reduce odour emissions.~~

~~Thermophilic digestion conditions (technique c in the description section above) may not be useful or possible for all applications (e.g. adaptations of micro-organisms communities for the degradation of chlorinated aromatic compounds or dechlorination of specific xenobiotica cannot be achieved under thermophilic conditions, no thermophilic microbial population can be adapted to the compounds to be treated).~~

~~Economics~~
~~Specific investment costs are generally much higher than with aerobic digestion. Having a close integration between waste management and water management would be helpful for further development. This would reduce the extra costs related to the discharge of excess waters from anaerobic digestion to a waste water treatment plant. However, in reality this occurs only rarely across Europe, most often where water utilities are involved in the process.~~

~~Driving force for implementation~~
~~Better management of the process and requirements of the Landfill Directive. Techniques from e to h in the description section above are requirements under the German TA Luft regulations and technique e is necessary for odour reduction.~~

~~Example plants~~
~~This treatment method is relatively rare at present (it is only part of waste management strategies in four countries, Germany, Austria, Belgium and Denmark, although some applications are also found on mixed or residual wastes in France, Spain and Italy, and a small-scale plant is also known to be in operation in the UK). Recent developments in source separation schemes in Italy and Spain suggest an optimistic view for the future availability of quality feedstock.~~

~~It is also worth mentioning that anaerobic digestion is experiencing the fastest growth take-up across Europe in Spain, thanks to public funding of facilities through EU programmes. Such funding reduces the overall management costs, since depreciation is one of main cost factors.~~

~~Reference literature~~

WORKING DRAFT IN PROGRESS

~~[20, ETSU 1998][33, UK EA 2001] [34, Babtie Group Ltd 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [72, Hogg, D. 2001] [98, WT TWG 2004] [98, WT TWG 2004][101, WT TWG 2005]~~

Ex-Section **4.2.5 'Increase the retention time in the anaerobic digestion processes'** deleted

4.5.3.1 Anaerobic process monitoring

From ex-Section **4.2.4 Generic techniques for anaerobic digestion optimisation**

~~h. operating the system under thermophilic digestion conditions, in order to increases the pathogen destruction, and the biogas production rate (hence higher energy recovery) and the retention time~~
~~i. measuring TOC, COD, N, P and Cl levels in inlet and outlet flows, in order to balance feeds and to ensure good methane production~~
~~j. Optimising the digestate retention time under biological degradation conditions. Having a high enough temperature and a long enough retention time will ensure that the material is mature, free from pathogenic bacteria and seeds and generate lower odour emissions.~~

Description
Process monitoring system, both manual and instrumental, to:

- ensure a stable reactor operation;
- minimise operational difficulties, such as foaming, which may lead to odour problems;
- provide sufficient early warning of system failures which may lead to loss of containment and potentially explosions.

Technical description
Process monitoring and control is the main preventative action on reducing emissions to air as well as producing a stable digestate. Depending on the feedstock, the anaerobic digestion system adopted and the use of digestate, the key factors of the digestion process itself to be monitored, having better control to optimise the process or to shorten the time of recovery after a problem has occurred, include:

- pH and alkalinity;
- temperature and temperature distribution;
- hydraulic loading rate;
- organic loading rate including total solids and volatile solids fractions;
- concentration of volatile fatty acids (VFA);
- ammonia;
- C:N ratio;
- gas production and composition;
- gas pressure;
- gas H_2S concentrations;
- liquid and foam levels.

The monitoring system is designed so that the required sampling of digester feed, substrate within the digester, digestate and biogas at key points in the process, and periodic digester capacity testing are possible. At large-scale AD facilities, provision for on-site laboratory facilities performing sample analysis may be considered:

Some additional techniques for anaerobic digestion may include:

WORKING DRAFT IN PROGRESS

a. Storing insufficiently stabilised liquid digestate in closed storage with gas collection or exhaust air treatment to minimise methane and ammonia emissions (see section 2.3.5.3).
b. Avoiding emissions from uncontrolled anaerobic processes during post-composting by an adequate aeration step (see section 4.5.2.1). Implementing a leak dection and repair programme (LDAR), e.g. with an IR camera, identifying significant fugitive emissions to air. Undertaking maintenance activities for fixing any detected leaks of methane, e.g. replacing valve (see section 2.3.5.4).

Achieved environmental benefits
The achieved environmental benefits of this technique include:

- improvement of the process efficiency;
- prevention of odorous emissions.

Environmental performance and operational data
In all circumstances, it is necessary to control and monitor relevant parameters in the feedstock, digester and digestate at regular intervals in order to ensure the good operation of the plant. Monitoring includes logging, checking and acting upon the data at frequent intervals, influenced by the rate of change in the process.

An increase in biogas production relating to the amount of feed is typically correlated with an increased stability of the produced digestate having been better digested microbiologically if the feedstock is unchanged. Also, there is a correlation between hygienic status and biogas production because a higher amount of methane-forming microorganisms displace pathogenic bacteria. These are indirect effects on the quality of the digestate.

Cross-media effects
None identified.

Technical considerations relevant to applicability
Generally applicable.

Economics
The higher the organic load the higher the gas potential. However, the longer the retention time the less material can be processed. If there is a gate fee for the waste, this will impact on the economy of the plant. All parameters need to be optimised in conjunction with each other.
Driving force for implementation

- Environmental legislation.
- Improvement of biogas quality and production.
- Improvement of digestate quality.

Example plants
No information available.

Reference literature
[109, Bio. subgroup 2014] [160, WT TWG 2014] [163, UK 2013]

ex-Section **4.2.6 Techniques for the reduction of emissions when biogas is used as fuel."** is deleted because outside scope

Ex-Section **4.2.7 Increasing the energy efficiency of the electricity generators and anaerobic digestion systems** is deleted because it is not related to a technique associated with energy-saving during the production of biogas by AD but to optimisation of energy production with biogas.

WORKING DRAFT IN PROGRESS

4.5.4 Techniques for MBT

Given that MBT is a combination of mechanical and biological treatments, techniques described in Sections 3.3, 4.5.1, 4.5.2, and 4.5.3 are partially or fully relevant for MBT, depending on the subprocesses involved (for instance, aerobic or anaerobic).

4.5.4.1 Measures to reduce emissions to air and associated monitoring

~~f. the pretreatment of the biological treatment feedstock to optimise the biological treatment. This may include mechanical techniques like: separating substances which are rather unsuitable for biological treatment, interfering substances and pollutants, as well as optimising the biological degradation of remaining wastes by increasing both availability and homogeneity~~

Ex-Section **4.2.11 Management of exhaust gas in MBTs partially deleted: covered by relevant section in "Mechanical" and "Biological treatment"**

Description
This technique includes:

- limitation of diffuse emissions to air;
- separate collection of air flows;
- partial reuse of exhaust air in the biological process.

The air is dedusted before reuse, e.g. by means of a bag filter, and treated before release by an appropriate combination of a bag filter, biofilter, scrubber and/or regenerative thermal oxidiser.

Technical description
Limitation of diffuse emissions

~~a.~~ ~~installation in closed rooms with locks or equivalent facilities of the unloading sites,~~ Unloading areas in enclosed buildings with negative air pressure and equipped with air locks, as well as use of feed bunkers and receiving bunkers or other equipment for delivery, transport and storage of the input substances. ~~The aim of this measure is the minimisation of diffuse emissions. In locks this is achieved by suction of the airlock area so as to keep the ambient pressure below atmospheric pressure~~

~~b.~~ ~~for machines, apparatus or other equipment used for mechanical treatment or for physical separation of the waste, e.g. by crushing, classing, sorting, mixing, homogenising, dewatering, drying, pelletising or pressing, the management system needs to ensure that potential diffuse emissions are minimised through~~ Encapsulation or air suction (focal point suction) measures for ~~of the individual aggregates~~ sources of diffuse emissions such as mechanical treatment of waste or ~~for~~ physical separation of ~~the~~ waste, e.g. ~~by~~ crushing, classing, sorting, mixing, homogenising, dewatering, drying, pelletising or pressing.

c. Use of closed containers for the removal of dust-emitting goods.

d. Used of encapsulated or housed systems for the conveyance and treatment of fermentation residues. The exhaust air from these systems is ~~to be~~ collected (hall and source suction), preferably so it can be reused within the process or for it to be treated

Separate collection of exhaust air partial flows

~~e.~~ Splitting of the total ~~volume~~ air flow that is to be treated into heavily polluted exhaust gas and lightly polluted exhaust air. ~~Therefore, the choice of a suitable system for the treatment of the lightly polluted but odour prone exhaust air plays a key role in MBT plants with long term biological degradation. However, the system is completed by further components, such as an acid scrubber (absorption of ammonia), a dust filter and an oxidation facility for the treatment of higher polluted streams mainly from the pre-biological degradation stage. The type of the oxidation facility (thermal, chemical, physical) and the exhaust gas quantity~~

WORKING DRAFT IN PROGRESS

~~from the pre-biological degradation that has to be treated have to be adapted to the chosen process concept and fixed in each individual case~~

Partial reuse of exhaust air

f. Minimisation of the exhaust gas through multiple use/cascade use.~~, circular guidance~~

~~g. minimisation of the exhaust gas through anaerobic degradation of organic substances (fermentation with utilisation of biogas instead of aerobic digestion)~~

~~h.~~ Reuse of the exhaust air as far as possible. ~~The remaining air needs to be treated before being disposed of to the air~~

From ex-Section **4.2.8 Techniques to improve MBTs**

The ~~using~~ use of air re-circulation ~~in order to~~ increases the concentration of carbon compounds in the air~~, This~~ which makes thermal afterburning a feasible alternative for a biological filter. ~~Under these conditions only, e.g. 2500 – 8000 Nm^3 of air per tonne waste need to be treated (related with Section 4.5.4.1)~~

i. ~~Treatment of~~ For instance, the exhausted gas from the delivery area, such as low bunkers and underground bunkers, with or without mechanical treatment of the delivered wastes, or the recycling of the gas are used as the air supply (process air) for biological degradation.

Abatement techniques

j. Treatment of partial flows with a suitable combination of ~~biological, chemical, physical and thermal treatment components~~ bag filters, biofilters, wet scrubbers and RTO (see the CWW BREF [138, COM 2014] for additional information on each of these techniques).

~~k. monitoring exhaust gas emissions on line and using data for the adjustment of biological processes~~

~~l. reduction of specific exhaust air emissions to between 2500 and 8000 Nm^3 per tonne of waste by installing circular guidance across heat exchangers and by discharging the excess heat as a precondition for an effective circular guidance~~

g. ~~using of absorption/desorption and combustion systems in case the concentration of the carbon compounds is low.~~

~~h.~~ Controlling the air emissions of organic compounds, ~~particulate matter~~ dust and ~~odour,~~ ammonia. ~~mercury, nitrous oxide (N_2O) and dioxins~~. ~~Some techniques for this are mentioned in Section~~

Achieved environmental benefits

Reduction of ~~utilisation and exhaust air~~ emissions to air.

Environmental performance and operational data

See Figure **4.27**, Figure **4.28**, Figure **4.29** and Figure **4.31**

The ranges of NH_3, dust and organic compounds concentrations in air emissions are summarised in Table 4.57 below.

WORKING DRAFT IN PROGRESS

Table 4.57: NH3, dust and organic compounds concentration in air emissions in MBT plants

Abatement techniques used for emissions to air	**Range of NH_3 concentration in air emissions (mg/Nm^3)**	**Range of dust concentration in air emissions (mg/Nm^3)**	**Range of TVOC concentration in air emissions (mg/Nm^3)**
Bag filter	NI	0.2–1.24	9.89
Biofilter	0.12–1.8	0.52–18.78	0.38–16.24
Biofilter and wet scrubbing	0.5–7.98	0–0.56	6.8–21
Biofilter and acid scrubbing	2.21	NI	NI
Wet scrubbing, Biofiltering and activated carbon	17	0.15	NI
Wet scrubbing with sorbent injection, bag/fabric filter system, biofiltering and regenerative thermal oxidation (RTO)	4.9	0.31–0.90	10.4–13.06
RTO	NI	3.35–4.75	6.19–10.76
Bag filter and RTO	NI	1.73	5.8
Acid scrubbing and RTO	NI	2.22	11.96
Biofilter and RTO	NI	1.12	NI
NI: No information.			

Table 4.58 and Table 4.59 below show the types of measurements of dust and organic compounds in air emissions respectively.

WORKING DRAFT IN PROGRESS

Table 4.58: MBT - Types of dust measurement in air emissions

Plant code	Periodic measurements	Continuous measurements		Standard/method
	Number of measurements over the three reference years	Short-term	Long-term	
017_3	1	NA	NA	ÖNORM EN 13284-1
019	3	NA	NA	ÖNORM M 5861-1
037	3	NA	NA	ÖNORM M 5861
127	1	NA	NA	NI
239(1)	NA	NA	Long-term	NI
243	NA	NA	Yearly	AMS
244(1)	NA	NA	Long-term	NI
257_1	NA	Monthly	Yearly	NI
257_2	NA	Monthly	Yearly	NI
266	NA	Daily	NA	NI
267(1)	NA	NA	Long-term	NI
279_1	1	NA	NA	DIN EN 13284
279_2(1)	NA	Short-term	NA	DIN EN 13284
337_1	1	NA	NA	UNI 10263:93
337_2	1	NA	NA	UNI 10263:93
349_1	3	NA	NA	UNI EN 13284-1:2003
349_2	3	NA	NA	UNI EN 13284-1:2003
350_1	6	NA	NA	NI
350_2	6	NA	NA	NI
350_3	6	NA	NA	NI
452_1	3	NA	NA	UNE EN 13284
452_2	3	NA	NA	UNE EN 13284
452_3	6	NA	NA	UNE EN 13284
573	2	NA	NA	Electrochemical
628(1)	NA	NA	Long-term	NI

(1): no information on the averaging period.
NI: No information.
NA: not applicable.

WORKING DRAFT IN PROGRESS

Table 4.59: MBT - Type of measurement of organic compounds in air emissions

Plant code	Periodic measurements	Continuous measurements		Standard/method
	Number of measurements over the three reference years	Short-term	Long-term	
17_1	3	NA	NA	EN 12619
17_2	1	NA	NA	EN 12619
19	3	NA	NA	FID
37	3	NA	NA	EN 12619
239 (1)	NA	NI	Long-term	NI
243	NA	NA	Yearly	AMS
244 (1)	NA	Short-term	Long-term	NI
257_1	NA	Monthly	Yearly	NI
257_2	NA	Monthly	Yearly	NI
266	NA	Monthly	NA	NI
267(1)	NA	NA	Long-term	NI
337_1	1	NA	NA	NI
349_1	3	NA	NA	UNI EN 13526:2002 (2)
349_2	3	NA	NA	UNI EN 13526:2002(2)
350_1	2	NA	NA	NI
350_2	2	NA	NA	NI
350_3	2	NA	NA	NI
452_1	3	NA	NA	UNE EN 12619
452_2	3	NA	NA	UNE EN 12619
452_3	6	NA	NA	UNE EN 13526(1)
628(1)	NA	NA	Long-term	NI

(1): no information on the averaging period.
(2) EN 13526 cancelled and replaced by EN 12619.
NI: No information.
NA: not applicable.

Cross-media effects

~~Related to e from description section above,~~ When the recirculating air is very humid, the treatment of the exhaust air may cause problems. In such cases, it is necessary to condense water vapour, ~~and thus~~ which implies air cooling through heat exchangers ~~is necessary to condensate the water~~ and the treatment of condensate water ~~needs to be treated~~.

Technical considerations relevant to applicability

~~Mechanical biological treatments (MBT)~~
The exhaust gas management affects both the construction and process engineering of the facility. Indeed, the following factors play key roles in any exhaust gas management strategy:

- minimisation of hall volume;
- segmentation of the operation units;
- close-to-source measures for the active and passive minimisation of emissions.

For abatement techniques (i.e.fabric filter, regenerative thermal oxidiser, biofilter), see the CWW BREF [138, COM 2014].

Economics

TWG members, please provide information on separate collection of air flows

For abatement techniques (i.e.fabric filter, regenerative thermal oxidiser, biofilter), see the CWW BREF [138, COM 2014].

Driving force for implementation

Regulations on air pollution.

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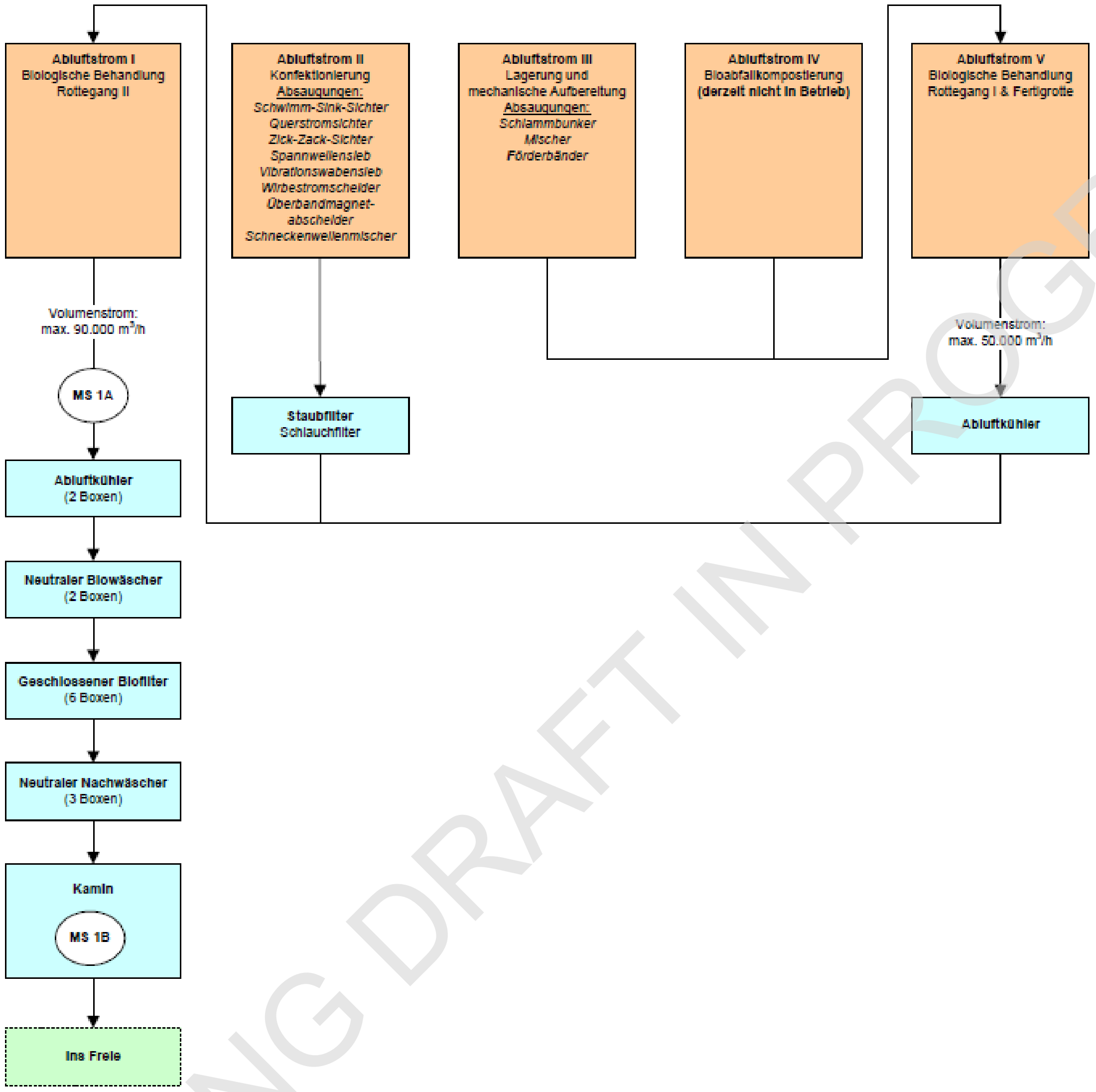
Example plants

The following plants reuse air from waste sorting and preparation and/or from mechanical treatment processes, after dedusting with bag filters, in the biological process: 17, 19, 37, 239, 267. Figure 4.46 gives an example of a possible configuration of an exhaust air collection system.



Source: [88, UBA Germany 2003] [98, WT TWG 2004] [109, Bio. subgroup 2014]

Figure 4.46: Configuration of the exhaust air collection system at Plant 37

Reference literature

[18, Greenpeace 2001][32, Vrancken et al. 2001] [33, UK EA 2001] [34, Babtie Group Ltd 2002][37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [72, Hogg, D. 2001] [73, Irish EPA 2003][88, UBA Germany 2003] [98, WT TWG 2004] [101, WT TWG 2005] [109, Bio. subgroup 2014] [160, WT TWG 2014]

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From ex-Section **4.2.8** **Techniques to improve MBT**

~~VOC emissions from MBTs cannot be avoided because of VOC already in the waste IN and the VOC generated by the biological process. Thus, requirements like housing / fully enclosed bioreactors, collection of exhaust air and effective treatment of exhaust air (limit values for the emissions) reduce such emissions. Aerobic systems (MBT) are suitable for treating wastes containing VOCs. In addition, anaerobic systems may result in well pretreated wastes but still may have a high potential for emissions (ammonia and other compounds generated during anaerobic treatment) and a high biological reactivity (under subsequent aerobic conditions). Therefore, a combination of anaerobic (pretreatment) and aerobic treatment steps are typically required.~~

~~reducing emissions of nitrogen compounds by optimising the C:N ratio and using acid scrubbers~~

From ex-Section **4.2.8**

~~Technical description~~

~~i. a controlled amount of anaerobic conditions obtained in well regulated processes may be of interest in aerobic treatment due to the production of methane, which can be used as an energy input for thermal-regenerative exhaust gas treatment (and if in addition the quality of the waste OUT still fulfils the requirements, the exhaust gas treatment is optimised, and security arrangements (prevention of explosion and security for employees) are sufficient~~

~~j. using as a solid fuel the filter cake generated on the dust filters of the air treatment system~~

~~k. treating the condensation water by buffer, bioreactors and ultrafiltration. The purified waste water (permeate) can then be used as process water in the cooling circuit that it is evaporated in the cooling tower~~

Deleted: already part of techniques in aerobic treatment

~~l. avoiding anaerobic conditions in aerobic treatment installations (where the waste gets starved of oxygen, usually due to it being saturated) by:~~
  - ~~introducing sufficient woody materials to the mixture (e.g. wood chips), and keeping the structure open. This also helps to reduce the impact of excess nitrogen~~
  - ~~avoiding waste materials that have both a high water content and limited interstices between the waste materials for water to drain down through the waste under gravity~~

Partially deleted: already part of techniques in aerobic treatment

m. ~~controlling the air supply using a stabilised air circuit. A good adjustment of the aeration can be carried out by controlling the CO_2 concentration per segment or by on line measurements of certain parameters (e.g. O_2, temperature, moisture, methane, VOC, CO_2) of the air supply/exhaust air. This guarantees a sufficient air supply, irrespective of the composition of the waste.~~

Deleted: already part of techniques in biological treatment

~~n. fully establishing the feedstock specifications~~
~~o. carefully positioning the windrows to enable proper access for forming and turning~~
~~p. efficient balancing of water to minimise the production of leachates~~
~~q. providing impermeable hard standing over a sufficient area to allow machinery movements to turn windrows and also to provide space for leachate collection drainage~~
~~r. introducing a high permeability drainage layer, such as wood chips, in the windrow construction to allow leachate drainage and airflow into the windrows~~
~~s. making provisions for leachate collection with recirculation systems, in order to feed the leachate back into the windrows to maintain the optimum moisture content and also to facilitate the leachate treatment~~
~~t. recycling process waters or muddy residues within the aerobic treatment process to completely avoid water emissions~~

~~Achieved environmental benefits~~

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~~MBT plants are very flexible. They can be built on a modular basis. Some of the above techniques avoid.~~

~~Optimised biological processes combine a reduction of emissions to water and air during treatment in the treatment plant.~~

Deleted: related to process

~~Furthermore, another environmental benefit is that mechanically biologically pretreated waste is characterised by a marked reduction in volume, water content and gas formation potential, as well as having a significant improvement in leaching and settlement behaviour in landfills. Another benefit is that a high calorific waste stream is separated which can be incinerated with energy recovery~~.

Deleted: already in preparation of waste for aerobic treatment

~~Mechanical and physical treatments used as a pretreatment to optimise the conditions for the subsequent biological treatment (e.g. mixing, homogenising, moistening) are adjusted to enhance the separation of valuable materials (e.g. ferrous materials), inhibiting materials or materials for which a biological treatment is not suitable. Sometimes the separation enhances more than one type of material mentioned above~~.

Moved to 'Technical description'

~~Related with technique c (see description section above), however, a controlled amount of anaerobic conditions obtained in well regulated processes may be of interest in aerobic treatment due to the production of methane, which can be used as an energy input for thermal-regenerative exhaust gas treatment (and if in addition the quality of the waste OUT still fulfils the requirements, the exhaust gas treatment is optimised, and security arrangements (prevention of explosion and security for employees) are sufficient.~~

~~Cross-media effects~~

~~VOC emissions from MBTs cannot be avoided because of VOC already in the waste IN and the VOC generated by the biological process. Thus, requirements like housing / fully enclosed bioreactors, collection of exhaust air and effective treatment of exhaust air (limit values for the emissions) reduce such emissions. Aerobic systems (MBT) are suitable for treating wastes containing VOCs. In addition, anaerobic systems may result in well pretreated wastes but still may have a high potential for emissions (ammonia and other compounds generated during anaerobic treatment) and a high biological reactivity (under subsequent aerobic conditions). Therefore, a combination of anaerobic (pretreatment) and aerobic treatment steps are typically required.~~

~~Concerning technique c from the description section above on introduction of sufficient woody materials, generally in MBTs there is enough structural material given by the feedstock (MSW). Input of woody materials can cause problems in meeting landfill criteria (e.g. TOC).~~

Deleted: related to process

~~Related to technique o from the description section above, the aerobic treatment has to take into account that accumulation of recycled substances can result in undesired effects (salinisation --> inhibitory effects, recycling of N-compounds --> higher air emissions of N-compounds (e.g. ammonia, laughing gas).~~

Deleted: already in aerobic treatment

~~Technical considerations relevant to applicability~~

~~MBT is widely used for the treatment of MSW, sludges and other types of waste. Aerobic systems may be unsuitable for treating wastes containing VOCs, which may be emitted to the air. Aerobic systems are less effective at breaking down ring compounds (for example, phenols) than anaerobic systems.~~

Deleted: related to process

~~Economics~~

WORKING DRAFT IN PROGRESS

~~**Driving force for implementation**~~

~~The Landfill Directive's acceptance criteria for biodegradable waste. These criteria aim to decrease the biodegradable content of the waste, thereby leading to a significant reduction of gas and leachate emissions from landfill.~~

Deleted: related to process

~~**Example plants**~~

~~Widely used throughout Europe. Aerobic systems are used to reduce the putrescible and moisture content of whole waste prior to landfill or for the production of waste derived fuels enclosed. This is a common practice prior to landfill in Europe.~~

Deleted: related to process

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5 PHYSICO-CHEMICAL TREATMENT OF WASTE

From ex-Section 2.3 **Physico-chemical treatments of waste**

~~[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997] [29, Inertec; dechets, F. and Sita 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [61, UBA Germany 2003] [65, USA DoE 2002] [68, Fons-Esteve et al. 2002] [69, UNEP 2000] [70, Greenpeace 1998] [77, Schmidt et al. 2002] [79, Perseo, P. 2003] [89, UBA Germany 2003] [97, Germany 2003] [98, WT TWG 2004] [100, WT TWG 2004] [102, UNEP 2004] [103, VROM 2004] [104, UBA Germany 2004]~~

~~This section contains the emissions and consumptions of physico-chemical (Ph-c) treatments discussed in Section 5. Chemical treatment processes cover a wide range of unit operations and a wide range of wastes. This section also applies to chemical treatment plants operating neutralisation processes. The following sections highlight information available to site operators from their current record systems and the areas where emissions are likely to occur. Most sites are on a totally enclosed base with all liquids entering or generated on-site (including rainfall) returned to the process. This sector is very diverse, but also one of the best monitored sectors, as was observed in site visits.~~

~~The structure of each of the following sections in this section is the same as the one followed in Section 2.3. Emissions associated with an ancillary treatment, e.g. transfer station operation are covered in Section 3.1.~~

From ex-**Section 3.4 Emissions and consumptions from waste treatments applied mainly to recover the materials from waste**

~~[3, Silver Springs Oil Recovery Inc. 2000] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [10, Ministry for the Environment 2000] [16, UK Environment Agency 1996] [25, UK Department of the Environment 1991] [26, UK, H. 1995] [34, Babtie Group Ltd 2002] [44, TWG 2003] [60, WT TWG 2003] [67, Straetmans, B. 2003] [81, Ruiz, C. 2002] [85, Cruz Gomez, M. J. 2002] [97, Germany 2003] [98, WT TWG 2004] [103, VROM 2004] [104, UBA Germany 2004]~~

~~This section contains the emissions and consumptions of treatments mentioned in Section 2.4. The following sections (Sections 3.4.X) details information available to site WT operators from their current recording systems and highlights areas where emissions are likely to occur. The structure of each of the following sections in this section is the same as the one followed in Section 2.4. Emissions associated with ancillary treatments, e.g. transfer station operations, are covered in Section 3.1.~~

From ex-**Section 3.4.2 "Consumptions of waste treatments to obtain a recycled material"**

Solid photographic waste deleted in accordance with conclusions of PCT workshop

~~**Consumptions in treatment of solid photographic waste**~~

~~The electricity consumption for shredding, washing/rinsing and electrolysis amounts to 100 to 300 kWh/t film waste. Depending on the process of desilvering, auxiliary materials are used. These are shown~~

Table 5.1: Used amounts of auxiliary materials for desilvering film waste

~~**Desilvering with bleach-fix**~~	~~**Desilvering with iron chloride**~~
~~Sodium hydroxide (20 %): 6 l/t film~~	~~Iron chloride (40 %): 11 l/t film~~
~~Sulphuric acid: 6 l/t film~~	~~Hydrochloric acid (36 %): 8 l/t film~~
~~Sodium bisulphite: 12 l/t film~~	~~Sodium sulphite: 12 l/t film~~
	~~Hydrogen peroxide (35 %): 4 l/t film~~

~~**[103, VROM 2004]**~~

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From ex-**Section 3.4.3.7 "Emissions from the treatment of photographic waste"**

~~Treatment of solid photographic waste~~

~~In shredding, emissions of dust occur. These are treated with a dust filter. The emission of dust to the air ranges from 2 to 5 mg/Nm^3. The amount is estimated to be 29 g/t film waste.~~

From ex-**Section 3.4.4 "Waste OUT from re-recycling/regeneration treatments"**

~~In some cases the materials obtained by these treatments are commercial products with only minor differences compared to virgin products.~~

WORKING DRAFT IN PROGRESS

5.1 Physico-chemical treatments of solid and/or pasty waste

From **ex-Section 2.3 Physico-chemical treatment of waste**

[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997], [29, Inertec; dechets, F. and Sita 2002], [31, LaGrega et al. 1994], [33, UK EA 2001], [34, Babtie Group Ltd 2002], [60, WT TWG 2003], [61, UBA Germany 2003], [69, UNEP 2000], [70, Greenpeace 1998], [77, Schmidt et al. 2002], [79, Perseo, P. 2003], [80, Iswa 2003], [91, Straetmans, B. 2003], [96, Galambos et al. 2003], [98, WT TWG 2004], [100, WT TWG 2004], [103, VROM 2004], [104, UBA Germany 2004].

5.1.1 Overview

This section details the physico-chemical ~~(Ph-c)~~ treatments of solid and/or pasty waste. ~~Treatments such as precipitation, decanting and centrifuging, and Thermal treatments not included in WI BREF are included here.~~ ~~Due to the fact that many of these treatments are common unit operations, the description of some operations will only be mentioned briefly in this section. For those techniques considered less common and that need extra explanations, an independent section within this section has been created.~~ Two main processes for physico-chemical treatment of solid and/or pasty waste are described: immobilisation of solid and/or pasty waste (Section 5.1.2.1), which includes stabilisation and solidification, and physico-chemical treatment of solid and/or pasty waste before backfilling (Section 5.1.2.2). Techniques for the abatement of emissions are covered in Sections 2.3.4 and 2.3.6. Common activities carried out in these plants (e.g. storage, handling) are covered in Section 2.1.

~~The structure of this section relates to the physical conditions of the type of waste.~~ ~~Treatments carried out on liquids and solids differ a lot and it has been suggested that considering these separately may give a good structure to such a long section. At the end of the section, some special physico-chemical treatments carried out on special wastes (e.g. destruction of POPs) have also been included.~~

~~Some of the techniques for the treatment of waste may make use, for example, of the acidic solution from the first scrubber in a wet air pollution control system when air pollution control waste treatment is being considered. Some techniques involve the return of the treated residues to the combustion chamber for sintering with bottom ash. These techniques are not included in this document because they are integrated measures of the combustion technologies. These issues can be found in other BREF documents.~~

Introduction of ex-Section **2.3.3 "Physico-chemical treatment of waste solid and waste sludges"**

The main goal in the physico-chemical treatment of solid and/or pasty waste ~~solids and waste sludge~~ is to minimise the long-term release by leaching out ~~the~~ primarily heavy metals and poorly biodegradable compounds. The available treatment options act to prolong the leaching time period by releasing, for example, heavy metals at lower and more environmentally acceptable concentrations for an extended period of time.

In principle, all treatment options can be applied to solid and/or pasty waste ~~waste solids and waste sludges~~. However, the characteristics of the treated material and the effectiveness of a treatment technology can vary greatly depending on the specific properties of the original waste input ~~IN~~ and on the type of cleaning system applied.
~~The treatment options has been sub-grouped according to the following types:~~

- ~~extraction and separation~~
- ~~thermal treatment~~
- ~~mechanical separation~~
- ~~conditioning~~
- ~~immobilisation (this treatment covers solidification and stabilisation)~~
- ~~dewatering~~

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- ~~drying~~
- ~~thermal desorption~~
- ~~vapour extraction from excavated soil~~
- ~~solvent extraction from solid waste (e.g. excavated soil)~~
- ~~excavation and removal of excavated soil~~
- ~~soil washing.~~

Ex-Section **2.3.3.1 "Extraction and separation"** moved to Section 5.5.1.5.

Ex-Section **2.3.3.3 "Mechanical separation"** Deleted and replaced by Section 2.3.2.8

Ex-Section **4.3.3.2 Thermochemical conversion of waste asbestos** deleted as it is not an applied process (see conclusion 3 of PCT workshop)

~~Waste contaminated with asbestos are actually landfilled in the EU, however new techniques are appearing in order to treat them prior to landfill disposal.~~

From ex-**Section 3.3.1 "Waste IN in physico-chemical treatments"**

~~*Asbestos*~~

~~Table 5.2 below shows ranges found in the composition of different asbestos types.~~

~~**Table 5.2: Asbestos composition**~~

~~**Value in %**~~	~~**Friable asbestos**~~	~~**Transite asbestos**~~
~~Al_2O_3~~	~~0.16 – 1.57~~	~~1.08 – 2.60~~
~~CaO~~	~~2.86 – 3.89~~	~~7.53 – 36.20~~
~~Fe_2O_3~~	~~5.43 – 8.17~~	~~0.55 – 11.85~~
~~FeO~~	~~0.00~~	~~0.00~~
~~K_2O~~	~~0.02 – 0.26~~	~~0.39 – 0.43~~
~~MgO~~	~~69.00 - 78.49~~	~~1.22 – 56.13~~
~~MnO~~	~~0.04 – 0.18~~	~~0.01 – 0.2~~
~~Na_2O~~	~~0.41 – 0.73~~	~~0.01 – 0.14~~
~~P_2O_5~~	~~0.16 – 0.22~~	~~0.02 – 0.20~~
~~SiO_2~~	~~12.04 – 16.10~~	~~20.87 - 60.01~~
~~TiO_2~~	~~0.02 – 0.06~~	~~0.09 – 0.23~~
~~Loss on ignition~~ [1]	~~48.47 – 51.53~~	~~17.96 – 44.35~~

[1] ~~Indicator of the organic content of the sample.~~

~~*Source*: [65, USA DoE 2002]~~

~~Thermochemical conversion technology uses a combination of chemical treatment and heat to bring about a re-mineralisation of asbestos and other silicate materials. The re-mineralisation process accomplishes several goals including:~~

- ~~conversion of asbestos minerals into non-asbestos minerals, without the need for melting~~
- ~~destruction of organic compounds, through pyrolysis and/or oxidation~~
- ~~immobilisation of metals and radionuclides.~~

~~The technology provides treatment effectiveness equivalent to that of vitrification without the requirement for melting the waste. In particular it:~~

- ~~converts asbestos materials into inert material~~

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- ~~results in a significant volume reduction of the waste. The volume of the treated product can be significantly reduced from the original waste (up to 90 %), but may ultimately require landfill disposal depending on the contaminants present.~~

~~The process also results in the destruction of organics, including PCBs to 99.9999 % destruction removal efficiency. Toxic metals are stabilised in the sintered product through molecular bonding and the technology developer believes that, based on preliminary testing, the process will also be effective for radionuclides.~~

~~The process is also effective on other types of waste including demolition debris and predominantly organic waste. The technology is applicable to liquid and solid wastes that are reasonably homogeneous or that can be made so without excessive expense. The process can treat wastes contaminated with a variety of contaminants including organic contaminants such as VOCs; semi-volatile organic compounds; PCBs and dioxins; inorganic contaminants such as asbestos and cyanide; metals including arsenic, lead, chromium, barium, zinc, selenium, cadmium; radionuclides that can be vitrified such as transuranic elements, caesium, thorium and uranium; and mixtures of these contaminants.~~

~~Wastes for which there are limited data or for which it is believed that the technology is not economically viable or technically compatible include mercury, gaseous radionuclides such as ^{14}C, explosives and some chemical agents (although here it is believed that the technology may be applicable, but there are no data to support such a claim).~~

~~The process involves shredding and then mixing material containing asbestos with fluxing agents and heating the fluxed mixture. The presence of the fluxing agents at elevated temperatures (approximately 1200 °C) results in the rapid re-mineralisation of asbestos fibres, which are converted into non-asbestos minerals such as diopside, wollastonite, olivine and glass.~~

~~The processing equipment consists of four primary systems which are feed preparation, rotary hearth converter, off-gas treatment, and product removal.~~

~~Pyrolysis of the organic compounds takes place in the rotary hearth. The pyrolysis products are directed via an induced draft to a thermal oxidation unit that destroys any residual organic contamination that might be present in the off-gas. From the thermal oxidiser, the off-gases are cooled and scrubbed of any particulates and acid components that might be present. The presence of demineralising agents accelerates molecular diffusion in inorganic waste during heating, which destroys inorganic compounds such as asbestos and causes a simultaneous oxidation and molecular bonding of metals and radionuclides within the waste media. This results in the immobilisation of metals and radionuclides. The process also results in significant volume reduction of the waste. The amount of volume reduction is dependent upon the type of material being treated and can range from 10 % for soils to over 90 % for materials containing asbestos or primarily organic materials.~~

~~Achieved environmental benefits~~
~~Applicability~~

~~Economics~~
~~The technology provides treatment effectiveness equivalent to that of vitrification without the requirement for melting the waste. This makes the technology less expensive and more versatile than vitrification for certain wastes. The capital cost for the 37 tonnes per day unit is approximately USD 3 million. Using the assumptions presented at the end of this section, a 37 tonne/day system can treat material containing asbestos for approximately USD 175 – 225 per tonne.~~
~~The three largest most significant contributors to the overall cost are fuel, equipment, and labour. Fuel makes up approximately 36 % of the total cost, equipment makes up 30 %, and~~

WORKING DRAFT IN PROGRESS

~~labour about 22 %. Other items such as reagents, maintenance, water, electricity, personal protection equipment and filters make up the remaining 12 % of the overall cost.~~

~~The cost estimates presented in this section are based on the following assumptions:~~

- ~~system description: 37 tonne/day system, direct fired with heat recovery, with dry lime scrubber~~
- ~~capital cost: based on a 7 year capital recovery period at a real discount rate of 3.0 % (2002)~~
- ~~operating conditions: 24 h/day operation, 80 % operating efficiency, 9 person crew~~
- ~~cost includes fuel (kerosene), electricity, process chemicals, personal protection equipment, regular maintenance, and HEPA filters~~
- ~~overheads and profits are also included~~
- ~~disposal of treated materials is not included~~
- ~~transportation to the treatment facility is not included.~~

~~Driving force for implementation~~
~~Users~~
~~Waste asbestos is typically disposed of in landfills. However, some of the asbestos can be contaminated with radionuclides, PCBs, metals. For this reason, those materials may require pretreatment prior to landfill disposal.~~

~~Example plants~~
~~A new plant is currently proposed in Ireland.~~

~~Reference literature~~
~~[65, USA DoE 2002][98, WT TWG 2004]~~

From ex-Sections **2.3.3.2 Thermal treatment** and **4.3.2.7 Thermal treatments of solid waste.** Deleted as they are not applied processes

~~Purpose~~
~~Thermal treatment of FGT waste from combustion processes is used extensively in a few countries, mainly to reduce the volume and to improve their leaching properties.~~

~~Thermal treatment is used for the treatment of bottom ashes, as well as for combinations of bottom ash and FGT waste. Due to the typically high contents of salts and heavy metals in the FGT waste, the separate treatment of FGT waste may necessitate a requirement for extensive off-gas treatment, thus reducing the overall benefits of separately treating these materials.~~

~~These techniques includes vitrification, melting and fusion of solid wastes . Its application to solid waste from waste incinerators is covered in the WI BREF.~~
~~A major drawback to these techniques is that they require substantial amounts of energy input.~~

~~Principle of operation~~
~~High temperature treatments use heat in order to melt waste and initiate vitrification and ceramisation processes. Thermal treatments can be grouped into three categories: vitrification, smelting and sintering. The differences between these processes chiefly relate to the characteristics and properties of the final material:~~

- ~~vitrification is a process where wastes are mixed with glass precursor materials and then combined at high temperatures into a single-phase amorphous, glassy output. Typical vitrification temperatures are 1300 to 1500 °C. The retention mechanisms are chemical bonding of inorganic species in the waste with glass-forming materials, such as silica, and encapsulation of the constituents by a layer of glassy material~~
- ~~melting is similar to vitrifying, but this process does not include the addition of glass materials and results in a multiple-phased product. Often several molten metal phases are~~

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~~generated. It is possible to separate specific metal phases from the melted output and recycle these metals, possibly after refinement. Temperatures are similar to those used in vitrifying~~

- ~~sintering involves heating the waste to a level where a bonding of the particles occurs and chemical phases in the wastes reconfigure. This leads to a denser output with less porosity and a higher strength than the original waste. Typical temperatures are around 900 °C. Temperatures for sintering bottom ash from MSW incinerators can be up to 1200 °C.~~

~~**Feed and output streams**~~
~~Most commonly, FGT wastes are treated thermally in combination with bottom ashes. Usually, the waste Input should comply with certain requirements, for example: water content <5 %, unburned contents <3 %, metal content <20 % by weight, and ash size <100 mm.~~

~~Depending on the melting system, metal alloys may be recovered from the reaction chamber. Depending on the temperatures in the reaction chamber and the state of oxidation or reduction of the gas phase, heavy metals (especially Cd and Pb) may be volatised and removed with the off-gas. All process configurations need off-gas treatment systems to minimise emissions.~~

~~An inherent advantage of these processes is the resulting destruction of organic pollutants, i.e. dioxins. Thermal treatment facilities in general reduce the volume to about 30 – 50 % of the input volume. Melting increases the density of the products to typically 2.4 – 2.9 tonnes/m^3.~~

~~Melted and vitrified products generally have very good retention properties, but Swiss studies show that sintered products also reach about the same level of stability with regard to retention. Vitrification typically yields the most stable and dense products.~~

~~**Process description**~~
~~Several systems can be used for heating the solid wastes: electrical melting systems, fuel fired burner systems or blast melting. These differ only in the way the energy is transferred to the solid material. Generally processes are inspired from furnaces used in iron and steel production. Regardless of the process, the thermal treatment of FGT waste in most cases results in a more homogeneous, denser product with improved leaching properties. Vitrifying also adds the benefits of the physical encapsulation of contaminants in the glass matrix. Additionally, the processes produce solid residues from the off-gas treatment. On the other hand, metals can be recovered from the process and, in some cases, even the vitrified product can be recycled~~

~~The thermal treatment of FGT waste requires substantial off gas treatment, thus creating a new solid residue to be treated. Also the high salts concentrations in FGT waste can cause corrosion problems in off-gas treatment systems. Thermal treatment processes also use substantial amounts of energy. Typically in the order of about 700 – 1200 kWh energy is used per tonne of treated material to reach and maintain the elevated temperatures, althought figures of up to about 8000 kWh/tonne have been reported. Energy consumption and operation varies with the furnace type and plant design. The technique is typically rather expensive compared to other treatment options. Treatment costs are reported to be in the order of EUR 100 – 500/tonne of input. Investment costs could be about EUR 20 million for a plant with a capacity to deal with 1 – 1.5 tonne/hour~~
~~Vitrification and melting result in a mobilisation of volatile elements such as Hg, Pb and Zn during the treatment process, which in some processes is used in combination with other parameters to produce a recyclable product low in heavy metals. Due to the release of vaporised heavy metals from the process, thermal treatment requires the additional of a flue-gas treatment system.~~

~~The main reason for implementing the technique is the good retention properties of the final product, especially in the case of vitrifying, and the significant reduction in volume. In densely populated areas, such as Japan, landfill capacity can be a scarce resource and landfilling can thus be relatively costly. Organic compounds such as dioxins and furans are almost completely destroyed.~~

WORKING DRAFT IN PROGRESS

~~Users~~
~~Sintering is not used as a dedicated treatment option for FGT waste, however some combined treatment methods may involve sintering. There are 30 – 40 melting and vitrification plants in Japan and there are also plants operating in Europe and the US.~~

Table 5.3: Thermal treatment plants

~~Country~~	~~Characteristics~~			
~~US~~	~~A vitrification process includes initial steps such as water extraction, dewatering and drying at 500 °C before the addition of glass forming additives and melting. The initial washing and drying is carried out to remove chlorides and residual organic carbon~~			
~~Japan~~	~~Plants for the thermal treatment of both bottom ash and FGT waste:~~			
		~~In operation~~	~~Planned~~	~~Capacity (tonne/day)~~
	~~Electric melting:~~			
	~~Electric arc~~	~~4~~	~~2~~	~~655~~
	~~Plasma arc~~	~~4~~	~~2~~	~~183~~
	~~Electric resistance~~	~~2~~	~~3~~	~~148~~
	~~Burner:~~			
	~~Reflecting surface~~	~~12~~		~~209~~
	~~Rotating surface~~	~~5~~		~~84~~
	~~Blast melting:~~			
	~~Coke bed~~	~~3~~		~~170~~
	~~Residual carbon combustion~~	~~1~~		~~15~~
	~~Total~~	~~31~~	~~7~~	~~1464~~

~~[80, Iswa 2003]~~

~~Reference literature~~
~~[80, Iswa 2003] [98, WT TWG 2004]~~

Ex-**Section 2.3.3.7 High temperature drying.** No questionnaire via the data collection

~~Purpose~~
~~The aims of the process are the following:~~

- ~~removal of the water content from the wastes; making recycling economically viable~~
- ~~concentration of the waste components (e.g. metal compounds); the heating value is considerably raised~~
- ~~elimination of the problems with handling paste-like substances, as drying the waste transforms it into granulate material~~
- ~~use of the waste heat in other processes, e.g. distillation~~
- ~~the dissipated plume gives the necessary moisture to the biofilter.~~

~~Principle of operation~~

From ex-**Section 3.3.1 "Waste IN in physico-chemical treatments"**

~~High temperature drying~~
~~The drying facility performs the pretreatment of aqueous paste-like wastes such as metal hydroxide sludges or coagulated lacquer and paint sludges.~~

~~The input substances that are to be dried are provided by the gathering chain conveyor and put into the revolving tube drum in single portions. The residence time of the input substances in the drier and thus the dryness of the granulated product can be regulated by hydraulic adjustment of the tube angle. The energy required for the drying process is drawn from the waste heat of the incinerator. The air needed for cooling the flue-gases is cooled down to 150 °C in air-air heat exchangers.~~

~~For instance, up to 30000 m^3/h drying air (maximum 100 °C) flow through the revolving tube countercurrently to the moist input. The heat is used for the evaporation of the water. The plume is extracted by suction via a dust filter and directly transferred to the biofilter. Hereby, a slight~~

WORKING DRAFT IN PROGRESS

~~negative pressure is created in the dryer who prevents effectively the leakage of dust into the environment. The granulated dry product is discharged automatically by the rotation of the drum and filled into big bags or other containers.~~

~~**Feed and output streams**~~
~~Sludges are dried and transformed into granulated material.~~

~~**Process description**~~
~~Drying consists of the following processes:~~

- ~~warm air supply controlled by temperature and differential pressure~~
- ~~hydraulically adjustable revolving tube drum~~
- ~~gathering chain conveyor for charging~~
- ~~dust filter with 300 m^2 filter area~~
- ~~plume dissipation towards biofilter by means of induced draft fan~~
- ~~measurement technique (e.g. dust, temperature, pressure, volume flow and moisture)~~
- ~~process control system.~~

From ex-**Section 2.3.3.8 Thermal distillative drying plants**~~-~~Deleted. No questionnaire via the data collection

~~**Purpose**~~
~~To process materials which cannot be accepted by hazardous waste incineration plants or hazardous waste landfill sites without complex prior conditioning.~~

~~**Principle of operation**~~
~~The input material is first crushed in the plant under inert conditions and bunkered. The released propellants are transferred to the high temperature incineration plant or to the biofilter. Afterwards, treatment is carried out in order to distillate the fluids from the input material~~
~~**Feed and output streams**~~
~~Solid/paste like hazardous wastes which contain considerable amounts of free or bound fluids are treated. Both the solid and the fluid products that leave this facility may be recycled, thermally used, incinerated or landfilled.~~

From ex-**Section 3.3.1 "Waste IN in physico-chemical treatments"**

~~*Thermal distillative drying*~~
~~Solid/paste like hazardous wastes which contain considerable amounts of free or bound fluids are treated. They are processed in order to recover solvents, to produce defined solid products or for drying in the facility.~~

~~In addition, heat cost allocator tubes or aerosol cans may also be treated. Heat cost allocator tubes are used for measuring heat energy consumption. They consist mainly of a glass tube and methyl benzoate as the evaporative medium. The drying residue (cullet) of the heat cost allocator tubes can be smelted in the corresponding steel mills or used in road construction. The condensate from the drying process can be recycled, i.e. it is re-used for the production of heat cost allocator tubes.~~

From ex-**section 3.3.4 "Waste OUT from physico-chemical treatments"**

~~*Waste OUT from thermal distillative drying*~~
~~The dry residue of the treatment of aerosol cans is separated into steel and waste aluminium before smelting. These metal fractions fulfil all acceptance criteria of the steel mill operations. The condensates from the drying process consist of complex solvent mixtures that may only be used thermally or have to be incinerated. When unused faulty aerosol cans are treated, it may be discussed in advance with the producer if recycling of the contained solvents is also possible.~~

~~**Process description**~~
~~The process consists of two parts: materials handling and crushing; and thermal distillation.~~

WORKING DRAFT IN PROGRESS

- ~~Material handling and crushing:~~
    - ~~lift-tilt installation for containers~~
    - ~~inertable crusher~~
    - ~~gathering conveyor~~
    - ~~CO_2 fire extinguisher and inerting facility~~
    - ~~discharge of solids with load container and carrying chain conveyor.~~

- ~~Thermal distillation:~~
    - ~~reactor and vacuum slider~~
    - ~~plume filter and circulation fan~~
    - ~~plume superheater~~
    - ~~condensers, product coolers, product containers and phase separation~~
    - ~~vacuum pump station~~
    - ~~vapour, inert gas and cooling water distribution~~
    - ~~exhaustive security measures~~
    - ~~control system with two work places and one computer for data collection.~~

~~The containers are transported from the high rack storage area to the facility and individually emptied into the feeding hopper of the crusher. After crushing, the input material is stored under a CO_2 atmosphere on an inerted gathering conveyor. This is carried out until the quantity necessary for processing is reached in the mixing reactor (maximum 3 m^3) and the reactor is prepared for take-up of the next load. The waste solvent vapours released at the crusher are specifically drawn off in order to prevent the production of explosive mixtures in the hall. The drawn off air is fed to the biofilter as well as the exhaust air from the vacuum pumps.~~

~~If the mixing reactor has been re-inerted after emptying of the previous load, it can be charged by the gathering conveyor. After charging, the mixing reactor and the pipe system are pressurised by the vacuum pumps to 400 mbar. Then, the circulation fan is powered up. The nitrogen from inerting and the created plumes can then be run over the superheater where they are heated up to 450 ºC. Afterwards, they flow into the reactor where they heat up and dry the input material. The heating period may, if necessary, be supported by fresh vapour from a boiler. Vacuum control keeps the maximum pressure in the facility approximately at 100 mbar, below that of the ambient air.~~

~~At the end of the drying process; i.e. when the maximum temperature of 180 to 200 ºC is reached in the reactor, in the plume filter or in the circulation fan; the facility is evacuated to a pressure of <100 mbar. This is carried out in order to evaporate the remaining solvent residues and to cool the dried material. To keep the emissions of the dried material low at discharge, cooling water is added directly to the dried material. Here, it immediately evaporates under vacuum and thus cools the dry product down to the discharge temperature of 50 to 60 ºC. The condensate is recovered by the in-house distillation facility directly after phase separation or after treatment. Solvent fractions that cannot be recycled may be thermally utilised or incinerated in the in-house high temperature incineration facility.~~

Ex-Section **2.4.7 Treatment of solid photographic waste** deleted as it is not an applied process

~~**Purpose**~~
~~Separate the waste in two main streams: one containing some valuable components (e.g. Ag) and the other to be used as fuel.~~

~~**Principle of operation**~~
~~The silver containing fixer is desilvered by means of electrolysis on treatment of liquid photographic waste). The chemical reaction for dissolving silver from film is: $Ag + Fe^{3+} \leftrightarrow Ag^{+} + Fe^{2+}$.~~

~~**Feed and output streams**~~
~~Silver and energy.~~

~~**Process description**~~

WORKING DRAFT IN PROGRESS

~~The film waste is cut into little pieces by a shredder. The shreds are washed with a desilvering liquid and rinsed with water. Possible desilvering agents are desilvered bleach-fix (contains iron) or iron chloride. When desilvered bleach-fix is used, the consumption of raw materials is reduced. When iron chloride is used, silver chloride is separated and then dissolved again by means of a fixer. The plastic shreds are dried, after which they can be incinerated with energy recovery or used as a secondary fuel in a cement kiln.~~

~~**Users**~~
~~Photographic industries.~~

Ex-**Section 2.3.4 Unit operations used in the physico-chemical processing of waste solids and sludges** deleted: these common operations are described in Sections 2.3.6 and 5.6

~~This section contains common physico-chemical techniques used in the waste treatment sector. They are mainly common unit operations. They have been tabulated in Table 5.4, which gives the purpose and principle of the treatments and their main users.~~

WORKING DRAFT IN PROGRESS

~~**Table 5.4: Common unit operations used in physico-chemical treatments**~~

~~**Technique**~~	~~**Purpose and principle of operation**~~	~~**Users**~~
~~Adsorption~~	~~See~~	
~~Centrifuging~~	~~See~~	~~Applied to liquid waste. Centrifuging is typically used together with recovery of the organic phase~~
~~Decanting~~	~~The principle of operation is the density difference of the different components to separate~~	~~Applied to liquid waste (e.g. separation of two inmiscible liquids, recovery of liquid layers after separation of suspended solids or biological/chemical flocs)~~
~~Drying~~	~~Thermal drying as evaporation~~	~~Applied to contaminated soils, sludges~~
~~Extraction~~	~~See~~	
~~Filtration~~	~~See~~	
~~Flotation~~	~~See~~	~~Flotation is used on liquid waste when gravity settlement is not appropriate. It occurs when:~~ • ~~the density difference between the suspended particles and water is too low~~ • ~~there is a space constraint at the site~~ • ~~the waste contains oil or grease that needs to be removed before treatment~~ • ~~recovery of the sludge is required~~
~~Metal recovery~~		
~~Oil separation processes~~	~~See~~	~~Gravity separation of soluble oils and oil/water mixtures~~
~~Oxidation~~	~~See~~	~~The chemical oxidation of wastes is a well-established technology that is capable of destroying a wide range of organic molecules, including chlorinated organic carbons, VOCs, mercaptans, phenols, and inorganics such as cyanide. The most common oxidising agents used for hazardous waste treatments are ozone, hydrogen peroxide, and chlorine. Ultraviolet (UV) light is usually added along with ozone and/or hydrogen peroxide to accelerate the oxidation of chlorinated VOCs.~~ ~~It is a very common pretreatment operation at many plants, but has a variety of technologies~~
~~Scrubbing~~	~~Air scrubbing~~	
~~Sedimentation (settlement)~~	~~See~~	~~Applied to liquid waste. Sludges liberated from a settlement stage are typically around 1 % dry solids content~~
~~Stripping~~	~~See~~	~~*Air stripping* is one of the most commonly used processes for separation of waste water contaminated with VOCs, such as solvents. It can be used to remove the halogenated or non-halogenated hydrocarbons from dilute aqueous solution. Solutions high in ammonia can also undergo such pretreatment to reduce the concentration of ammonia.~~ ~~*Steam stripping* is utilised for the removal of volatile and sometimes semi-volatile compounds from waste water.~~

WORKING DRAFT IN PROGRESS

~~**Technique**~~	~~**Purpose and principle of operation**~~	~~**Users**~~
~~Supercritical treatments~~	~~Extraction and/or oxidation of pollutants from contaminated water or sediments. Supercritical fluids (e.g. carbon dioxide, water, ammonia, cyclohexane) are materials at elevated temperature and pressure that have properties between those of a gas and a liquid. In extraction, the organics in soils, sediment or water are dissolved in the fluid at elevated temperatures and pressure conditions and are then released from the extraction at lower temperatures and pressures. In supercritical water oxidation, air and contaminated water are brought together above the critical point of water and the complete oxidation of organic compounds occurs rapidly~~	~~Treatment of POPs~~
~~Water reactive chemicals pretreatment~~	~~These are scrubbed in a caustic solution and both treated liquors and scrubber liquors are treated in the main plant~~	~~The pretreatment of materials such as thionyl chloride, acetyl chloride, silicon tetrachloride with water to liberate acid gases~~
~~* The thermal treatments covered are those not included in the WI BREF~~		

~~[31, LaGrega et al. 1994] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [98, WT TWG 2004]~~

5.1.2 Applied processes and techniques

5.1.2.1 Immobilisation of solid and/or pasty waste

From ex-**Section 2.3.3.5 "Immobilisation"**

Purpose

~~The aim of immobilisation is~~ Immobilisation aims at minimising the rate of contaminant migration to the environment and/or reducing the level of toxicity of contaminants, in order to alter or improve the characteristics of the waste so that it can be disposed of. The objective encompasses both a reduction in the waste toxicity and mobility as well as an improvement in the engineering properties of the stabilised material.

From ex-Section 4.3.2.3 (Cross-media effect)

Immobilisation only changes the chemical composition by some chemical reactions and ~~is~~ does not ~~fit to~~ reduce the content of any contaminant in the waste input. Organic wastes are typically not immobilised by stabilisation/solidification, but are adsorbed by the solid matter.

See also the information given in Section 2.3.2.7 on compatibility to mix or blend waste.

Principle of operation

Immobilisation relies on the properties of the reagent to produce an immobilised output ~~waste product~~, even when this output ~~the waste product~~ does not have a solid form.

Stabilisation and solidification are the two main process types for immobilisation:

- Stabilisation (see Section 5.1.2.1.1) changes the chemical state of the constituent of the waste input. With complete stabilisation, a hazardous waste can be transformed into a non-hazardous waste by means of specific chemical reactions that:
  - destroy organic hazardous contents;
  - convert inorganic hazardous substances into non-hazardous compounds (for instance, the reduction of chromium VI into chromium III or the oxidation of cyanide).
- Solidification (see Section 5.1.2.1.2) changes the physical properties of the waste input (e.g. liquid into solid) by using additives. Partial stabilisation or solidification processes do

WORKING DRAFT IN PROGRESS

not change the hazardous nature of wastes, and the classification of waste with regards to pollutant parameters is therefore not modified.

These processes retain substance(s) adsorbed to, or trapped within, a solid matrix. ~~Some of these processes are reversible (i.e. the immobilised substances can be released), due to both poor process control and to subsequent mixing with other waste types.~~ Attention must be paid to process control and to potential subsequent mixing of the output with other waste types in order to limit the risk of release of immobilised substances after treatment.

Feed and output stream

From ex-**Section 3.3.1 "Waste IN in physico-chemical treatments"**

Waste input

Some solid and/or pasty waste ~~solids and sludges~~ treated by physico-chemical treatments are listed below.

- Asbestos.
- slag or bottom ash from combustion processes (excluded from the scope of this WT BREF).
- FGT waste (e.g. incineration ashes from MSW, hospital waste or industrial waste incinerators).
- Sludge to be stabilised. Sludges from chemical industry may contain sulphates and organic salts.
- Stable waste.
- Sludge from waste water processing (municipal or industrial).
- Residues from the metallurgical industry (dusts, sludge, ~~slags~~). These may have high contents of Cr(VI).
- Spent catalysts.
- Paint residues.
- Mineral residues from chemical processing.
- Wastes containing acid and soluble compounds.
- High arsenic content residues from the chemical, metallurgical or ore industries.
- Contaminated soil (see Section 5.6).

~~The following text gives some information about some of these types of waste.~~

Deleted from ex-Section **3.3.1 Waste IN in physico-chemical treatments**: treatment of bottom ash as it is outside the WT BREF scope (see KOM Conclusion 1.5b)

~~*Bottom ash and FGT wastes from combustion processes*~~

~~Some wastes from combustion processes are bottom ashes, FGT waste and filter cakes. Table 5.5 shows the physico-chemical characteristics of such waste from MSW incinerators:~~

~~**Table 5.5: Characterisation of residues from MSW incinerators**~~

~~**Properties**~~	~~**Compounds**~~	~~**Values**~~
~~pH~~		~~11 – 12.5 – 13~~
~~Soluble salts content~~	~~Cl, sulphates~~	~~Up to 70 % (Conductivity 15000 – 27000 – 37000 µS/cm)~~
~~Heavy metals~~	~~Pb, Zn, Cd, Cr~~	~~Up to several %~~
~~Inert compounds~~	~~Silica, alumina, lime~~	
~~Fine particulates~~		~~<100 µm~~
~~Density~~		~~Low (0.4 – 0.6)~~
~~Hygroscopic material~~	~~Salts, excess lime content~~	
~~Leaching test before treatment~~	~~Solubles~~	~~10 – 80 %~~
	~~Cr~~	~~1.5 – 8 ppm~~
	~~Cd~~	~~1 – 500 ppm~~
	~~Pb~~	~~1 – 1400 ppm~~
	~~Zn~~	~~1 – 10000 ppm~~
	~~As~~	~~1 – 50000 ppm~~

~~Middle number in ranges corresponds to averages.~~
~~*Source*: [29, Inertec; dechets, F. and Sita 2002]~~

WORKING DRAFT IN PROGRESS

~~The general components of slag/bottom ash from household incineration are silicates, alkaline earth, chloride, sulphates, non-ferrous metals (e.g. As, Cd, Cu, Pb), ferrous metals and heavy metals. The main components are the mineral fraction, the non-incinerated fraction and the scrap metal.~~

Table 5.6: ~~Main components of slag/bottom ash~~

~~**Categories**~~	~~**Percentage by weight (%)**~~
~~Mineral fraction~~	~~85 – 90~~
~~Non-incinerated fraction~~	~~1 – 5~~
~~Metal scrap~~	~~7 – 10~~
~~*Source*: [61, UBA Germany 2003]~~	

~~**Table 5.7: Chemical composition of bottom ash after the household incineration plant**~~

~~**Values in %-wt**~~	~~**Slag/bottom ash (fresh)**~~			~~**Slag/bottom ash after storage (ageing time of 3 months)**~~		
~~**Parameter**~~	~~**Min.**~~	~~**Average**~~	~~**Max.**~~	~~**Min.**~~	~~**Average**~~	~~**Max.**~~
~~SiO^2~~	~~42.91~~	~~49.2~~	~~64.84~~	~~39.66~~	~~49.2~~	~~60.39~~
~~Fe^2O^3~~	~~9.74~~	~~12~~	~~13.71~~	~~8.41~~	~~12.7~~	~~17.81~~
~~CaO~~	~~10.45~~	~~15.3~~	~~21.77~~	~~10.42~~	~~15.1~~	~~23.27~~
~~K^2O~~	~~0.83~~	~~1.05~~	~~1.36~~	~~0.84~~	~~0.91~~	~~1.42~~
~~TiO^2~~	~~0.65~~	~~1.03~~	~~1.33~~	~~0.65~~	~~0.88~~	~~1.12~~
~~MnO~~	~~0.06~~	~~0.14~~	~~0.22~~	~~0.1~~	~~0.17~~	~~0.26~~
~~Al^2O^3~~	~~6.58~~	~~8.5~~	~~10.79~~	~~7.43~~	~~8.83~~	~~10.45~~
~~P^2O^5~~	~~0.55~~	~~0.91~~	~~1.49~~	~~0.5~~	~~1.04~~	~~2.61~~
~~MgO~~	~~1.79~~	~~2.69~~	~~3.4~~	~~1.84~~	~~2.59~~	~~3.51~~
~~Na^2O~~	~~1.86~~	~~4.3~~	~~5.81~~	~~2.05~~	~~4.15~~	~~7.49~~
~~Carbonates~~	~~2.56~~	~~5.91~~	~~10.96~~	~~5.59~~	~~5.83~~	~~7.62~~
~~Sulphates~~	~~2.5~~	~~15.3~~	~~28.3~~	~~5.8~~	~~12.5~~	~~22.5~~
~~Cl~~	~~1.3~~	~~3.01~~	~~7~~	~~1.5~~	~~2.71~~	~~4.6~~
~~Cr (ppm)~~	~~174~~	~~648~~	~~1035~~	~~295~~	~~655~~	~~1.617~~
~~Ni (ppm)~~	~~55~~	~~215~~	~~316~~	~~90~~	~~165~~	~~260.2~~
~~Cu (ppm)~~	~~935~~	~~2151~~	~~6240~~	~~1245~~	~~2510~~	~~5823~~
~~Zn (ppm)~~	~~1200~~	~~2383~~	~~4001~~	~~1795~~	~~3132~~	~~5255~~
~~Pb (ppm)~~	~~497~~	~~1655~~	~~3245~~	~~1108~~	~~2245~~	~~3900~~
~~*Source*: [98, WT TWG 2004]~~						

~~The following Table 5.8 and~~

~~-describe some general values of bottom ash parameters after the incineration process, with data from two different treatment plants.~~

~~**Table 5.8: General bottom ash values after the household waste incineration process**~~

~~**Values**~~	~~**Pb**~~	~~**Cr**~~	~~**Cu**~~	~~**Cd**~~	~~**As**~~	~~**Zn**~~	~~**Hg**~~	~~**Ni**~~
~~Minimum~~	~~0.6~~	~~0.1~~	~~0.2~~	~~0.0001~~	~~0.003~~	~~0.5~~	~~0.07~~	
~~Average~~	~~1.6~~	~~0.5~~	~~2.2~~	~~0.021~~	~~0.012~~	~~4.8~~	~~0.7~~	
~~Maximum~~	~~5.2 – 6~~	~~2 – 9.6~~	~~7~~	~~0.02 – 0.08~~	~~0.022~~	~~10 – 21~~	~~2~~	~~0.5~~
~~Values in g/kg of bottom ash~~ ~~*Source*: [61, UBA Germany 2003]~~								

WORKING DRAFT IN PROGRESS

~~**Table 5.9: Metals in bottom and fly ashes of municipal solid waste incinerators**~~

~~**Metal**~~	~~**Bottom ashes (slag) (ppm)**~~	~~Bottom ashes[1] (slag) (ppm)~~	~~Fly ash and residues from dry and semi-dry processes (ppm)[1]~~	~~Mixture of fly ash and sludge from wet scrubbing process (ppm)[1]~~
~~Cd~~	~~0.3 – 70.5~~	~~0.01 – 0.1~~	~~1 – 10~~	~~<0.001~~
~~Cr~~	~~23 – 3170~~	~~0.001 – 0.01~~	~~1 – 10~~	~~0.01 – 0.1~~
~~Hg~~	~~0.02 – 7.75~~	~~0.001 – 0.01~~	~~<0.001~~	~~<0.001~~
~~Pb~~	~~98 – 13700~~	~~1 – 10~~	~~10000 – 100000~~	~~0.001 – 0.01~~

~~[1] Values correspond to concentration ranges in initial leachates~~
~~Some more information on incinerators can be found in the waste incineration BREF.~~
~~*Source*: [71, COWI A/S 2002] [98, WT TWG 2004]~~

~~During the combustion of coal, two types of coal ashes are generated. Classic fly ashes are mainly composed of non-combustible elements and non-burned particulates, and contain, on average, 50 % silica, 25 – 30 % alumina, 8 % iron oxides (containing Ca, K, Mg, Na, Ti and traces of As, Cd, Cr, Cu, Ni, Pb, Se, Zn). The other type of fly ash is composed of silico-calcareous ashes that are generated from the particulate abatement techniques and sulphur oxide abatement techniques. These ashes are rich in calcium sulphate. More information can be found in the Large Combustion Plant BREF.~~

~~The ashes from heavy fuel oil typically contain sulphur, vanadium and nickel. They are also characterised by high percentages of non-burned carbon, typically 60 % but can reach up to 80 %. More information can be found in the Large Combustion Plant BREF.~~

From ex-**Section 4.3.2.3 "Applicability of immobilisation"**

Although a large range of waste can be treated (liquids, solids, many chemical pollutants, ashes, etc.), immobilisation is most likely to be effective in the treatment of inorganic wastes where solubility is already quite low. Waste containing chromates, amphoteric metals such as lead and zinc, and waste with some soluble salts content, need pretreatment before the immobilisation process. Some wastes not suitable for immobilisation include the following:

- Flammable and highly flammable wastes (e.g. low flashpoint solvents).
- Wastes containing volatile substances. Sometimes very low concentrations of VOCs may be accepted.
- Oxidising agents. Sometimes very low concentrations of oxidising agents may be accepted.
- Odorous wastes. Sometimes materials with very little odourous substances may be accepted.
- Waste containing highly soluble organic waste and with a high COD content.
- Waste containing molybdenum.
- Waste containing soluble inorganic salts.
- Solid cyanides. Sometimes very low concentrations of cyanides may be accepted.
- Chelating agents. Sometimes very low concentrations of chelating agents may be accepted.

Some of the wastes mentioned above may be treated by some specific reagents. For example, cement (as shown in Table 5.10 below) and lime reagents are compatible with oxidising agents.

From ex-**Section 4.3.2.5 "Use of other reagents in the immobilisation process"**

WORKING DRAFT IN PROGRESS

Table 5.10: Reagent applicability for immobilisation of waste

Waste component	Cement-based reagent	Pozzolan-based reagent	Thermoplastic reagent	Organic polymer reagent
Non-polar organics such as: - oil and grease - aromatic hydrocarbons - halogenated hydrocarbons - PCBs	May impede setting. Decreased durability over a long time period. Volatiles may escape upon mixing. Demonstrated effectiveness under certain conditions	May impede setting. Decreased durability over a long time period. Volatiles may escape upon mixing. Demonstrated effectiveness under certain conditions	Organics may vaporise upon heating. Demonstrated effectiveness under certain conditions	May impede setting. Demonstrated effectiveness under certain conditions
Polar organics such as: - alcohols - phenols - organic acids - glycols	Phenol will significantly retard setting and will decrease the durability in the short run and over a long time period	Phenol will significantly retard setting and will decrease the durability in the short run and over a long time period. Alcohols may retard setting.	Organics may vaporise upon heating	No significant effect on setting
Acids: - hydrochloric acid - hydrofluoric acid	No significant effect on setting. Cement will neutralise acids. Portland cement Types II and IV give better durability characteristics than Type I. Demonstrated effectiveness	No significant effect on setting. Compatible, will neutralise acids. Demonstrated effectiveness	Can be neutralised before incorporation	Can be neutralised before incorporation. Urea-formaldehyde demonstrated to be effective
Oxidisers such as: - sodium hypochlorite - potassium permanganate - nitric acid - potassium dichromate	Compatible	Compatible	May cause matrix breakdown. Fire risk	May cause matrix breakdown. Fire risk
Salts such as: - sulphates - halides - nitrates - cyanides	Increased setting times. Decreased durability. Sulphates may retard setting and cause spalling unless special cement is used. Sulphates accelerate other reactions	Halides are easily leached and retard setting. Sulphates can retard or accelerate reactions	Sulphates and halides may dehydrate and then rehydrate, causing splitting	Compatible
Heavy metals such as: - arsenic - cadmium - chromium - lead - mercury	Compatible. Can increase setting time. Demonstrated effectiveness under certain conditions	Compatible. Demonstrated effectiveness on certain species (lead, cadmium, chromium)	Compatible. Demonstrated effectiveness on certain species (copper, arsenic, chromium)	Compatible. Demonstrated effectiveness with arsenic

Source: [31, LaGrega et al. 1994]

From ex-Section **3.3.4 Waste OUT from physico-chemical treatments**

WORKING DRAFT IN PROGRESS

Output

The final material after stabilisation/solidification will have a similar composition in terms of metals and organic content to the original waste. However, the final material has a reduced toxicity and solubility of metals and organic compounds compared to the original waste.

The annex of the Landfill Directive (EC 33/2003) contains the criteria and procedures for the acceptance of waste at landfills. The criteria contain some limit values for hazardous waste acceptable at different types of landfills. These are based on leaching limit values and restrict some metals, some anions and organic compound parameters.

The water permeability of stabilised waste depends on many parameters (e.g. nature of the waste, nature and amount of added reagent, objectives) so permeability values may vary from 10^{-9} m/s to 10^{-12} m/s.

From ex-Section **3.3.4 Waste OUT from physico-chemical treatments.** Deleted: the treatment of slag and bottom ash is excluded from the WT BREF scope (KOM conclusion 1.5b)

~~*Immobilised bottom ash/slag*~~

~~In general, there are several possibilities employed for the re-use of bottom ash, after treatment. When the slag values do not meet defined parameters, a slag re-use with defined technical safety measures is possible. Some examples of re-use options are described below and are shown in~~

- ~~used in road and street construction. The bottom ash is used as a solid base for at the construction of, e.g. parking places, airports and harbour areas. However, there is a need for an impermeable layer which coaches over the bottom ash layer to avoid leaching, this can be asphalt or perhaps concrete~~
- ~~used in soil constructions, e.g. road embankments or noise protection walls. It is important that the area where bottom ash will be used has to be a hydrogeologically favourable land. This means that there has to be a layer of 2 meters of clay or loam which protects the groundwater from adverse effects. Furthermore, there has to be a mineral surface which is impermeable (d >0.5 m and~~ ~~$k_f < 10^{-8}$ m/s)~~
- ~~used in important water management zones and in hydrogeologically sensitive areas and is subject to exception for individual case inspections.~~

Table 5.11: Recycling paths of the mineral fraction of treated bottom ash in Germany

~~Recycling paths of treated bottom ash/slag~~	~~%~~
~~Anti-freeze course~~	~~27~~
~~Filling material~~	~~22~~
~~Ballast substructure~~	~~11~~
~~Improvement of land~~	~~9~~
~~Base frame/dam construction~~	~~5~~
~~Land consolidation~~	~~5~~
~~Noise protection wal~~	~~3~~
~~Landscaping~~	~~1~~
~~Unbound street and road construction~~	~~1~~
~~Others~~	~~16~~

~~[98, WT TWG 2004]~~

~~The following and below characterise the important bottom ash parameters after a physico-chemical treatment process.~~

WORKING DRAFT IN PROGRESS

Table 5.12: Metal composition of treated bottom ash after treatment (solid analyses)

~~Metals~~	~~**Minimum**~~	~~**Average**~~	~~**Maximum**~~
~~As~~	~~0~~	~~0.074 0.15~~	~~0.187~~
~~Cd~~	~~0.0008~~	~~0.0037 0.01~~	~~0.0167~~
~~Cr~~	~~0.067~~	~~0.172 0.6~~	~~0.726~~
~~Cu~~	~~0.150~~	~~0.6 6.826~~	~~29.781~~
~~Hg~~	~~0~~	~~0.01 0.07~~	~~0.37~~
~~Ni~~	~~0.023~~	~~0.165 0.6~~	~~0.661~~
~~Pb~~	~~0.19~~	~~1 1.222~~	~~4.063~~
~~Tl~~	~~0~~		
~~Zn~~	~~0.470~~	~~1.5 2.970~~	~~14.356~~
~~Units: in g/kg, except Hg that is in mg/kg~~ ~~Zero in this table means below analysis detection limit~~			

~~[61, UBA Germany 2003] [98, WT TWG 2004]~~

Table 5.13: Eluate analysis of bottom ash quality after treatment

~~Chemicals~~	~~**Minimum**~~	~~**Average**~~	~~**Maximum**~~
~~Cl~~	~~29~~		
~~Sulphates~~	~~43~~		
~~CN total~~	~~0~~		
~~Phenol index~~	~~0~~		
~~As~~	~~1.3~~	~~5.3~~	~~16.1~~
~~Cd~~	~~0~~	~~0.8~~	~~5~~
~~Cr~~	~~0~~	~~15.2~~	~~200~~
~~Cu~~	~~0~~	~~60.7~~	~~300~~
~~Hg~~	~~0~~	~~<0.2~~	~~1~~
~~Ni~~	~~0~~	~~2.9~~	~~40~~
~~Pb~~	~~0~~	~~11.4~~	~~59.0~~
~~Tl~~	~~2~~		
~~Zn~~	~~0~~	~~19.4~~	~~300~~
~~Units in µg/l~~ ~~Zero in this table means below analysis detection limit~~			

~~[61, UBA Germany 2003] [98, WT TWG 2004]~~

From ex-**Section 4.3.2.3 "Immobilisation"** (Cross-media effect)

~~Waste OUT/waste IN~~ Output/waste input ratios range between 1.2 and 2.4 in weight and generally between 0.9 and 1.4 in volume (due to the typical increase of the density of the ~~waste OUT~~ output compared with the waste input ~~IN~~). Thus, the process leads to an increase in weight and a minor change in volume.

From ex-Section 4.3.2.3 Environmental benefit

The following measures enhance the ~~environmental~~ performance ~~quality~~ of the ~~output from~~ immobilisation processes (e.g. reduction of permeability, reduction of specific surface area, chemical buffering of the output):

From ex-Section 4.3.2.3 Items r to u

- Guaranteeing that solid phase neutralisation reactions have been carried out to the completion of the reaction.
- using hydraulic binders complemented by specific chemical reagents, especially for:
    - mercury fixation as HgS and $Hg_3(SO_4)O_2$
    - fixation of metals as metallic hydroxide sludge (e.g. Zn, Pb, Cu, Cr, Cd) as insoluble compounds and by solidification
    - reduction of hexavalent chromium in basic conditions (e.g. by $FeSO_4$), followed by precipitation and solidification
    - fixation of organic compounds from ~~that~~ sludge ~~from the chemical industry~~ containing sulphates and organic salts, followed by precipitation of sulphates to

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  ensure the structure durability, for example by adding clay to adsorb organic compounds
  - a high arsenic content ~~(e.g. from the chemical or metallurgical industry, or from ore treatment)~~ by oxidation of As (III), followed by stabilisation and solidification
- Considering the possibility of improving the final product quality by using additives (for example, hydrophobic reactants).
- Not relying solely on stabilisation processes for the disposal of intractable wastes which are difficult to treat and expensive to incinerate. These include solid cyanides, oxidising agents, chelating agents, high TOC wastes, wastes containing low flashpoint solvents and gas cylinders.

Whatever the stabilisation/solidification finally reached, it is considered that the output is not stable for a long period of time and that its compounds may escape (e.g. leaching).

For example, the probable increase in the pH and alkaline capacity of the mixture due to this treatment can lead to an increase in the leaching properties for the amphoteric metals (e.g. lead, cadmium for pH above 12.5), and for species sensitive to pH such as arsenic and cyanides as well as some organic components.

From ex-Section 4.3.2.2

Cement- or lime-based systems may take years to stabilise and decades/centuries or even longer to achieve equilibrium with the local environment. Because of this, full stability may be technically unrealistic.

From ex-Section 4.3.2.3 Economics

Reagents/binders are used when possible to lower the treatment costs (fly ashes from power stations, slag from steel mills, the residues of cement furnaces) and to limit the consumption of raw materials. Operators are not always in a position (because of regulations, local availability, interest in a specific waste, etc.) to use wastes as reagents, although it is of course generally economically viable.

Process description

The process typically comprises storage of the reagents, a reaction vessel and in some cases the addition of water. Figure 5.1 shows a representation of a typical immobilisation process.

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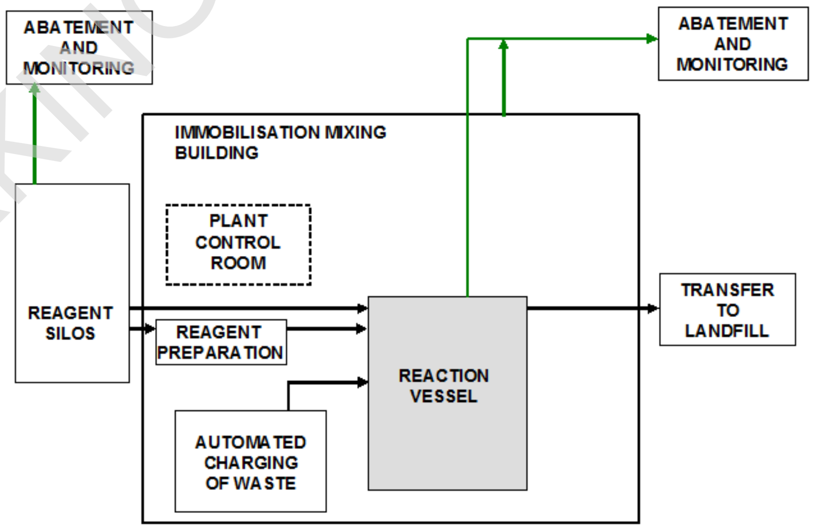

Source: [33, UK EA 2001]

Figure 5.1: Representation of an immobilisation process

From ex-Section 4.3.2.3 **Immobilisation**

~~a. using suitably designed reaction vessels for all immobilisation processes~~
~~b. performing these processes within controlled reaction vessels. Given the degree of process control that is needed to ensure the correct ratios of waste and reagent/binder entering the process and that sufficient mixing (and residence time) is achieved, it is essential that such vessels achieve these objectives. Automated loading, charging and mixing devices which can be monitored and controlled, will also be required~~
~~c. using suitable process monitoring within enclosed and abated systems~~
~~d. replacing the need to decant liquid wastes from drums and containers by utilising separate 'make-up' tanks to premix liquids and pumpable sludges~~
~~e. carrying out physico-chemical treatments, such as neutralisation reactions in the liquid phase, in order to enhance mixing and process control~~

Reaction vessels are suitably designed, and the process is performed within controlled reaction vessels to ensure the correct waste/reagent ratio, as well as the correct mixing and residence time.

Washing step
Several of the stabilisation methods have an initial washing step, where a major part of the soluble salts and, to some extent, the metals are extracted before chemical binding of the remaining metals (see also Section 5.6.3.2).

From ex-Section 4.3.2.1. Included here as a process step before immobilisation. Could also be considered as a common step

Waste containing chromates and amphoteric metals, such as lead and zinc, and waste with some soluble salts content typically need pretreatment before being subjected to the immobilisation process.

Pretreatment before immobilisation basically consists of the washing/leaching of salts with water, and the physico-chemical pretreatment of metals (especially insolubilisation of the amphoteric metals). ~~The subsequent treatment, solidification, is not covered in this Section~~.

This pretreatment allows the treatment of fly ashes and salts arising from the dechlorination of fumes in household waste incineration. It can also be applied to the fly ash resulting from both the lime treatment of the fumes and from the bicarbonate of soda treatment. In the latter case (sodium bicarbonate), it dissociates the soluble and insoluble solid components, and reduces the amount of disposal in landfills by recycling the soluble salts in a soda ash factory.

The outputs consist of a filter cake with a reduced toxicity and solubility, and salty water. ~~It~~ This pretreatment helps ~~to~~ reduce the leachability of the output and therefore the risk of contamination by the leaching out of soluble compounds. The process is more sophisticated than the simple solidification one described below.
[91, Straetmans, B. 2003][98, WT TWG 2004]

Dewatering step
~~These methods are finalised by dewatering the stabilised product, which will then be ready for landfilling~~.

From ex-**Section 2.3.3.6 Dewatering**

Sludge dewatering increases the dry solids content of sludge, producing a 'solid' waste. It is a grey area as to when a liquid sludge becomes a solid waste; however, any sludge typically over 10 % dry solids becomes difficult and expensive to pump.
Dewatering at ratios typically higher than 10 % will first require some form of chemical conditioning to assist in the separation of the bound and entrained water from within the sludge.

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There is a wide range of high molecular weight polymeric flocculants that are particularly effective at improving dewatering performance.

Dewatering produces a sludge ‘cake’, which may be between 20 % and 50 % dry solids, and an aqueous waste stream. Overall disposal costs would be expected to be reduced in cases where the aqueous waste stream requires no, or minimal, additional processing to remove contaminants.

A number of sludge dewatering processes exist and selection depends upon the nature and frequency of the solids produced, and the sludge cake required, for example:

- Filter (or plate) presses, which are batch processes and can be manually intensive. A filter press can produce up to ~~40 %~~ 20–65% dry solids cake.
- The belt press, which is a continuous process with the filter cloth continually running through rollers that forcefully dewater the sludge. A belt press can produce up to 35 % dry solids cake.
- Centrifuges, also continuous processes that can produce a cake of up to 40 % dry solids for certain sludge. Because of the shear forces, it can break up the solid particulates.
- Filter drums.

The majority of sites use filter presses on the sludge from the treatment plant and then send the aqueous fraction through clarification or DAF units prior to sewer discharge. Excess solids are returned to the treatment tanks.

Stabilisation and solidification processes are described in Sections 5.1.2.1.1 and 5.1.2.1.2 respectively.

Users

Immobilisation treatments (both stabilisation and solidification) are applied to:

- remediation of hazardous waste sites;
- treatments of waste from other treatment processes (e.g. ash from thermal treatments, residues from end-of-pipe techniques);
- treatment of contaminated land where large quantities of soil containing contaminants are encountered.

~~In several EU countries, stabilisation/solidification is not an issue at all due to their national legislation. In these cases, a lot of wastes do not need any such treatments to respect the parameters of the annexes of the EU Landfill Directive or national legislation.~~

~~Radioactive wastes have been encapsulated using cement/pulverised fuel ash and bottom ash (slag) for more than 30 years. However, radioactive materials are explicitely excluded from the IPPC Directive.~~

~~**Example plants**~~

~~13 plants stabilise around 400 kilotonnes of hazardous waste before landfilling, according to the French regulation and, from 2004 – 2005, to the EC regulation. Mobile units are also available to treat some waste spots on industrial sites.~~

~~In Portugal, one plant stabilise MSW incineration fly ashes before they are landfilled.~~

Reference literature

[29, Inertec; dechets, F. and Sita 2002] [30, Ecodeco 2002] [31, LaGrega et al. 1994] [33, UK EA 2001] [91, Straetmans, B. 2003] [98, WT TWG 2004] [106, UBA Germany 2013] [108, Physico-Chem. Subgroup 2014]

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5.1.2.1.1 Stabilisation

Purpose
This is a process by which contaminants (e.g. heavy metals) are fully or partially bound by the addition of supporting media, binders, or other modifiers.

Principle of operation
Stabilisation is accomplished by mixing the waste with a reagent (depending on the type of waste and reaction planned, this can be, for example, clay particles; humic organic substances, such as peat; activated carbon; oxidisers; reductors; precipitating reagents) to minimise the rate of contamination migration from the waste, thereby reducing the toxicity of the waste and improving the handling properties of the waste at the landfill. To achieve this, the process ~~should~~ includes a physico-chemical interaction between the reagent and waste, rather than just a dilution.

These stabilisation methods make use of both the precipitation of metals in new minerals as well as the binding of metals to minerals by sorption. The process includes some form of solubilisation of the heavy metals in the material and a subsequent precipitation in or sorption to new minerals.

The physical mechanisms used in stabilisation are: macro-encapsulation, micro-encapsulation, absorption, adsorption, precipitation and detoxification. There is an extensive range of sorbents and binders available for such purposes. Some of the most commonly used are: cement, pozzolans (alumino-silicious material that reacts with lime and water), lime, soluble silicates, organically modified clays or lime, thermosetting organic polymers, thermoplastic materials and vitrification (*in situ* or in-plant).

In many cases, both types of reagents (chemical reagents as mentioned three paragraphs above) and sorbents and binders (as mentioned in the above paragraph) are used simultaneously.

Process description
Phosphate stabilisation **[31, LaGrega et al. 1994][80, Iswa 2003] [98, WT TWG 2004]**

From ex-Section **4.3.2.6 Phosphate stabilisation**

Phosphate stabilisation ~~It~~ is a chemical stabilisation using phosphate as the stabilisation agent. Depending on the characteristics of the waste input, other additives, such as lime, are used. Reaction kinetics are fast and the material is considered fully treated without further curing. Sometimes phosphate addition is used together with carbonation in order to bind some metals in the waste input (e.g. lead).

The specific amounts of water and phosphate, as well as other additives, are likely to vary according to the properties of the waste input. However, no quantification of this has been made available.

~~**Achieved environmental benefits**~~
The process retains salts in the output. Compared to other similar processes, relatively small amounts of water are added along with the phosphate and no waste water is generated ~~produced~~.

There are currently no suggestions for utilisation of the output TWG, please confirm ~~treated product~~.

A substantial leaching is possible after landfilling, as is the case with some heavy metals due to increased solubility (e.g. cadmium). The release of salt and heavy metals in the landfill is expected to be higher than with other treatments. Phosphate stabilisation may enhance the phosphorus compound mobility of deposited waste. In one case, it has been shown that the total phosphate availability increased from 2 mg/kg (before treatment) to 4900 mg/kg (after treatment).

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The treatment process ~~is relatively simple, and~~ consists of:

- a mixing device (such as a pug mill) into which the waste input is fed at a controlled rate and mixed with a proprietary form of soluble phosphate;
- a conveyor at the end of the mixer which removes the treated output.

~~**Applicability**~~
~~The process is in all but one case implemented as an integrated unit at the incinerator, but it could also be set up to act as a centralised plant treating residues from more than one incinerator. The process was originally developed to treat MSW incinerator residues, however several other waste types (e.g. contaminated soil, slags, sludges, etc.) have been tried and tested.~~

~~**Economics**~~
~~The treatment cost is about EUR 15 per tonne of FGT waste. In addition to this, a royalty is charged for the use of the patented process amounting to EUR 5 – 10 per tonne. Investment costs are in the order of about EUR 150000 – 500000 per installation depending on existing equipment.~~

~~**Driving force for implementation**~~
~~The main reason for implementation of this technique is its simplicity of operation.~~

~~**Example plants**~~
~~The process is currently used in the United States, Japan and Taiwan~~

~~**Reference literature**~~
Lime stabilisation [106, UBA Germany 2013]
Liming is used to stabilise a wide range of sludge and waste types. This includes:

- neutralisation of acidic inorganic sludge;
- combined neutralisation and solidification of petrochemical sludge where suitable sorbents or solid combustible substances are added; their types vary depending on the final destination of the output (combustion, landfilling);
- stabilisation and hygienisation of sewage sludge and biological waste;
- stabilisation and solidification of soils polluted by hydrocarbons.

Lime is composed of calcium, (and magnesium in the case of dolomitic lime), which gives it flocculation properties; the hydroxyl ions provide basicity. These properties are used for inorganic and organic sludge treatment. Quicklime is hydrated in contact with water, reducing the original water content in sludge, and promoting an exothermic reaction which has a disinfectant action on the sludge and prevents odours.

Lime stabilisation brings the following benefits:

- Lime provides a high pH and as such neutralises acidity in industrial sludge.
- Calcium ions in lime promote sludge dewatering in filter presses or centrifuges (flocculation property).
- Treatment of sludge with lime, combined with mechanical dewatering (press filter, centrifuge, belt filter, etc.), can achieve 25 % to 45% dry solids and significantly reduce the total volume of waste to be landfilled.
- The combined action of the high pH and the quicklime reaction heat controls odours during sewage sludge and biological waste treatment.
- The combined action of the high pH and the quicklime reaction heat sanitises (eliminates growth of pathogens) sewage sludge and biological waste and enables their safe reuse in agriculture.
- Due to lime’s high pH value, most metallic trace elements (Pb, Ni, Fe, Zn, Cr) are kept in insoluble forms and immobilised in treated sludge and contaminated sediments.

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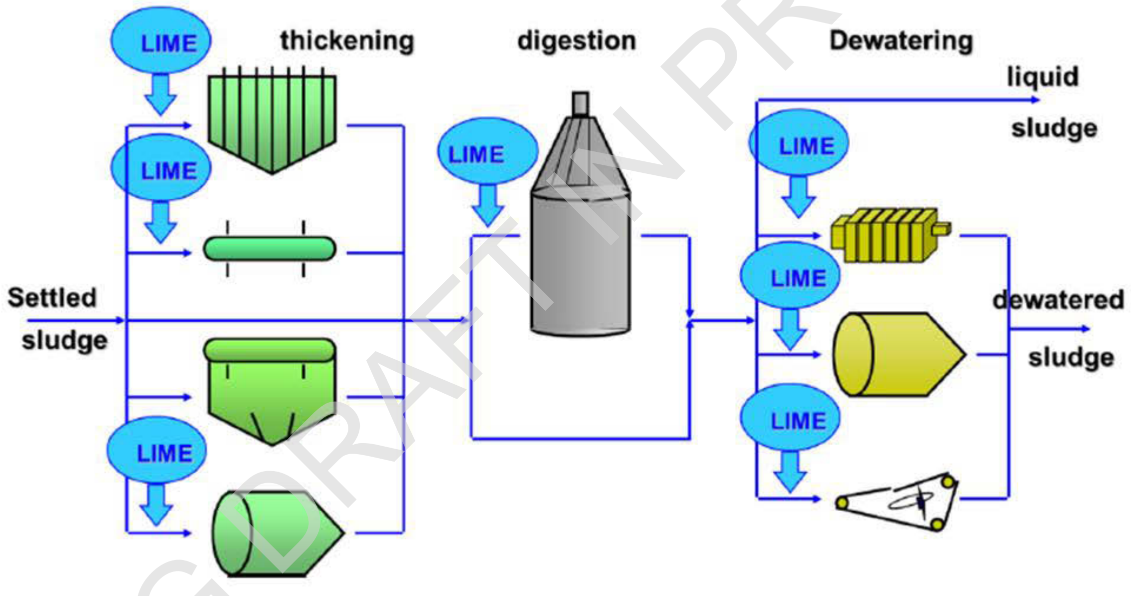
- Calcium ions in lime react with clay minerals and organic matter (ion exchange) and convert the matrix soil from plastic to friable. Further reactions with active silica or alumina in soils (pozzolanic reaction) form new, long-term stable compounds. These compounds encapsulate pollutants which cannot be immobilised by reactions with lime.
- The exothermic hydration reaction and chemical binding of water by quicklime promote the dewatering and drying of various soils.

The output/waste input ratios vary widely, depending on the initial water content of the treated sludge or waste and the absolute lime dosage. The lowest ratios are observed in processes where the flocculation, dewatering and drying by reaction heat are achieved simultaneously.

Two basic processes are used for lime application:

- Pre-liming, where lime is used preferably as milk of lime (liquid dispersion of $Ca(OH)_2$ particles in water), prior to further treatment steps. An example of a pre-liming system is shown in Figure 5.2 below.



Source: [106, UBA Germany 2013]

Figure 5.2: Example of pre-liming system in organic sludge treatment

- Post-liming, where lime is used preferably in some form of quicklime (having CaO as the main constituent). An example of a post-liming system is shown in Figure 5.3 below.

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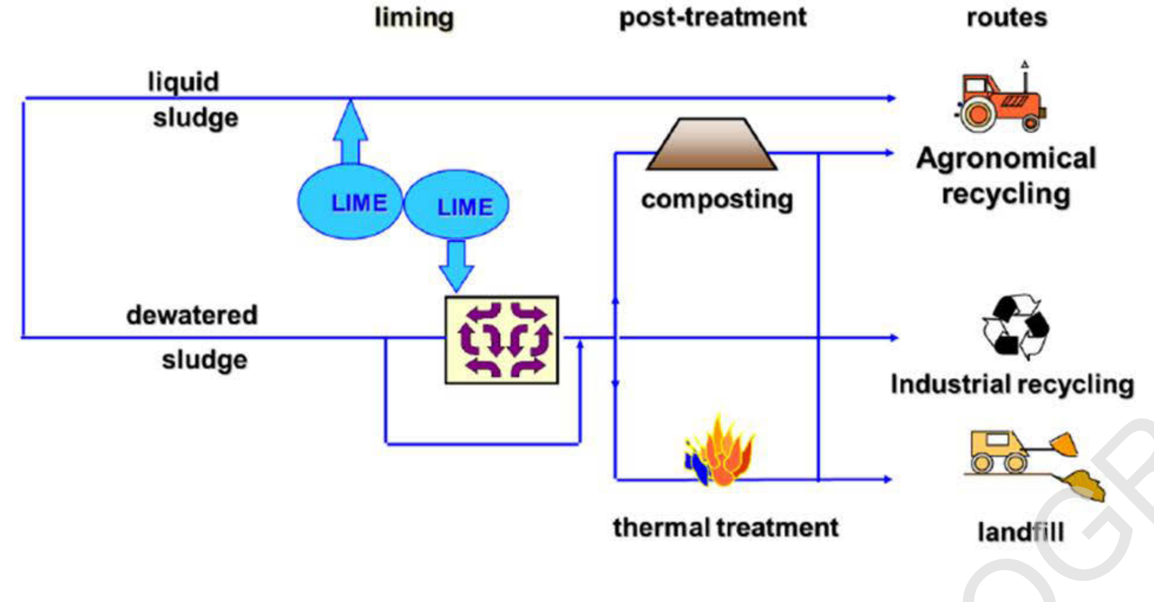

Source: [106, UBA Germany 2013]

Figure 5.3: Example of post-liming system in organic sludge treatment

In the case of sticky or pasty sludge, mixing/dispersion of lime with the sludge is a key element for success, the difficulty consisting of integrating a powder into a pasty matter. One state-of-the-art mixer is a ploughshare type, which permits good mixing without destroying the sludge structure, although it could be difficult to operate. The other common equipment is a screw pump mixer, which brings a well dispersed mix but destroys the sludge structure.

~~Emissions from stabilisation methods~~

Several of the stabilisation methods have an initial washing step, where a major part of the soluble salts and, to some extent, the metals are extracted before chemical binding of the remaining metals. These methods are finalised by dewatering the stabilised product, which will then be ready for landfilling. Then, the washing of solid waste generates waste water that needs some sort of treatment because of the content of some components. However, depending on the local conditions ~~authorities~~, such generated waste water may be discharged into the environment or treated in the chemical industry to recover some salts (e.g. sodium salts).

Users

Currently, ~~this process~~ phosphate stabilisation finds extensive commercial use in the United States, Japan and Taiwan at about 90 MSW incinerator facilities, treating over 2 million tonnes of bottom ash and FGT waste per year. The output is generally accepted as suitable for landfilling in these countries.

TWG, please confirm

5.1.2.1.2 Solidification

Purpose

Solidification changes the physical properties of the waste input (e.g. liquid into solid) by using additives. Partial stabilisation or solidification processes do not change the hazardous nature of wastes, and the classification of waste with regards to pollutant parameters is therefore not modified.

Two solidification processes are widely used: a) cement solidification (the most prevalent solidification technique), based on mixing waste with cement, and b) special hydraulic binder processes, which are chemical processes, aimed at developing bonds between the binder and the

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waste. Another technique, also in large-scale use, involves the curing of fly ash waste for example with aqueous neutral or acidic liquors to give a granular output prior to landfill.

Principle of operation

From ex-Section 4.3.2.4 Cement solidification

~~The main advantage of~~ Cement solidification ~~is the~~ reduces the contact between the water and the waste input, and to some extent the formation of less soluble metal hydroxides or carbonates. Amphoteric metals can also be treated. The solidified output is relatively easy to handle, and the risk of dust formation is very low. The release of heavy metals from the products in the short term is typically relatively low. The technique does, in some cases, facilitate utilisation of the output as backfilling or construction material in the mining industry.

Feed and output stream

The ~~technique~~ process can be used on all types of FGT wastes. Solidification with cement has also been used on many other types of hazardous wastes, including for the disposal of low level radioactive waste.

More information on the applicability use of the cement for solidification technique can be found in Table 5.10

The solidified output is landfilled in either surface level or underground deposits. In some countries, it may be utilised as a backfilling material in old salt mines.

Most studies have focused on the possible short-term releases of contaminants from the output. The long-term behaviour of the output is much less understood. It must be expected that the leaching of lime over time will change the chemical properties of the output and also that increased leaching may occur as the pH decreases. The time required for a complete release from stabilised ~~waste OUT~~ output can, however, be expected to be in the range of several hundred to a thousand years. The high pH level of cement-based systems can result in a significant leaching of amphoteric metals (lead and zinc).

Process description

Generally, wastes are mixed with Portland cement and additives to control the properties of the cement, and enough water to ensure that hydration reactions will take place to bind the cement. Both stabilisation and solidification processes take place. Cement-based solidification ~~techniques~~ relies on the use of equipment that is typically readily available. The mixing and handling associated with the processes are well developed and the technique is robust with respect to variations in waste input characteristics.

The wastes are thereby incorporated into the cement matrix. Typically, the waste input will react with water and the cement to form, to some extent, metal hydroxides or carbonates which are usually less soluble than the original metal compounds in the waste matrix.

Recent developments in this technology have been undertaken by incorporating additives to bind difficult contaminants before encapsulation. Difficult contaminants are considered to be arsenic, lead, phenols (including PCP), PCBs and dioxins. There is also evidence that cement can catalyse or participate in the reductive dechlorination of TCE.

From ex-Section 4.3.2.3 **Immobilisation**

Water permeability of $3.7 \cdot 10^{-11}$ m/s can be achieved in the final product when cement is used as an immobiliser. ~~When cement is used as a stabilisation material~~ The ratio of waste to be treated to ~~the~~ cement used is between 1:3 and 1:4, depending on the type of waste.

The drawbacks of this method are that the leaching of soluble salts is not hampered and that this can eventually result in the physical disintegration of the solidified product, thus allowing further leaching. In this case, the entry of air may result in some carbonation, partially rectifying the increase in porosity and loss of strength.

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If the heavy metals are not recovered from the residues, which is potentially possible but a costly and energy-intensive process, the contaminants will sooner or later be released. It should be emphasised that the time perspectives mean that the dominant part of the metals in question will be released at a time when all leachate collection activities from the landfills will probably have been discontinued for many years. In addition, the location of the deposit may have been forgotten, as the area in question will by then most probably have been used for other purposes for a long time.

Cement may contain some toxic components such as pulverised fuel ash, cement kiln dust, blast furnace slag and bitumen.

The addition of cement and additives increases the amount of waste to be handled; typically about 30–50 % of the waste input dry weight is added as cement and additives, and 30–100 % of the total dry weight is added as water. Thus, the output is typically increased from 20–30 kg/tonne of waste input to about 40–60 kg/tonne of waste input, including an addition of water corresponding to 50 % of the total dry weight.

Energy and water usage varies and is not quantified. The operation and control of equipment used by the technique is considered relatively simple and comparable with standard practices in the concrete industry.

Solidification is typically performed at dedicated plants located near the end destination of the final material; thus individual incinerators have no need to install solidification equipment.

In most cases, the waste input ~~IN~~ can be delivered to existing plants. Treatment costs for cement solidification alone is estimated to be about EUR 25 per tonne of waste input ~~IN~~.

Users

The ~~technique~~ process is relatively simple to use and the necessary technical knowledge is widely available. The leaching characteristics of the solidified product can be improved considerably compared to the untreated waste input ~~IN~~. Stabilisation of FGT wastes by cement solidification has long been, and is still considered, acceptable by authorities in many countries worldwide. The main reason for implementing this technology in Holland has been the lack of hazardous waste landfill capacity TWG, please confirm.

The technique is probably the most commonly used method for the treatment of FGT wastes, and is widely used in Europe and Japan. ~~Some examples of cement solidification are listed below:~~

~~**Country**~~	~~**Characteristics**~~
~~Austria~~	~~A plant for cement solidification for slag and ashes from MSW incineration is in operation in Vienna~~
~~Germany~~	~~Several salt mining companies accept several types of wastes (e.g. FGT waste, slags, demolition material from buildings) and perform cement solidification on these by using residues as filler material. The solidified wastes OUT are chiefly utilised as backfilling material or for reinforcement. Cement solidification is for some mines performed at one central plant using varying recipes according to final destination and requests. From the central solidification plant, the product is transported to the recipient mine~~
~~Sweden~~	~~At one landfill site in Sweden (Hogdalan) cement solidified FGT waste are cast into blocks and placed at a surface level landfill after hardening~~
~~Switzerland~~	~~A variation of cement solidification is used in Switzerland (initially funded by the Swiss government and Sulzer) where waste IN are washed with water at liquid solid ratio of 2:1 and dewatered prior to mixing with cement. This has the benefit of removing most of the soluble salts from the waste IN, thus improving the longevity of the solidified product. After solidification, the waste OUT is deposited~~

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	~~at surface level landfills before hardening. In some plants, the mixture is cast into moulds to produce blocks, that are then transported to surface landfills~~
~~*Source*:~~ ~~[80, Iswa 2003] [98, WT TWG 2004]~~	

Reference literature
[71, COWI A/S 2002][80, Iswa 2003] [98, WT TWG 2004] [100, WT TWG 2004]

~~In general, there are several possibilities employed for the re-use of bottom ash, after treatment. When the slag values do not meet defined parameters, a slag re-use with defined technical safety measures is possible. Some examples of re-use options are described below and are shown in~~

~~Recycling paths of treated bottom ash/slag~~	~~%~~
~~Anti-freeze course~~	~~27~~
~~Filling material~~	~~22~~
~~Ballast substructure~~	~~11~~
~~Improvement of land~~	~~9~~
~~Base frame/dam construction~~	~~5~~
~~Land consolidation~~	~~5~~
~~Noise protection wal~~	~~3~~
~~Landscaping~~	~~1~~
~~Unbound street and road construction~~	~~1~~
~~Others~~	~~16~~

~~[98, WT TWG 2004]~~

~~The following below characterise the important bottom ash parameters after a physico-chemical treatment process.~~

Table 5.14: Metal composition of treated bottom ash after treatment (solid analyses)

~~Metals~~	~~**Minimum**~~	~~**Average**~~	~~**Maximum**~~
~~As~~	~~0~~	~~0.074 – 0.15~~	~~0.187~~
~~Cd~~	~~0.0008~~	~~0.0037 – 0.01~~	~~0.0167~~
~~Cr~~	~~0.067~~	~~0.172 – 0.6~~	~~0.726~~
~~Cu~~	~~0.150~~	~~0.6 – 6.826~~	~~29.781~~
~~Hg~~	~~0~~	~~0.01 – 0.07~~	~~0.37~~
~~Ni~~	~~0.023~~	~~0.165 – 0.6~~	~~0.661~~
~~Pb~~	~~0.19~~	~~1 – 1.222~~	~~4.063~~
~~Tl~~	~~0~~		
~~Zn~~	~~0.470~~	~~1.5 – 2.970~~	~~14.356~~
~~Units: in g/kg, except Hg that is in mg/kg~~ ~~Zero in this table means below analysis detection limit~~			

~~[61, UBA Germany 2003] [98, WT TWG 2004]~~

Table 5.15: Eluate analysis of bottom ash quality after treatment

~~Chemicals~~	~~**Minimum**~~	~~**Average**~~	~~**Maximum**~~
~~Cl~~	~~29~~		
~~Sulphates~~	~~43~~		
~~CN total~~	~~0~~		
~~Phenol index~~	~~0~~		
~~As~~	~~1.3~~	~~5.3~~	~~16.1~~
~~Cd~~	~~0~~	~~0.8~~	~~5~~
~~Cr~~	~~0~~	~~15.2~~	~~200~~
~~Cu~~	~~0~~	~~60.7~~	~~300~~
~~Hg~~	~~0~~	~~<0.2~~	~~1~~
~~Ni~~	~~0~~	~~2.9~~	~~40~~
~~Pb~~	~~0~~	~~11.4~~	~~59.0~~
~~Tl~~	~~2~~		
~~Zn~~	~~0~~	~~19.4~~	~~300~~
~~Units in µg/l~~ ~~Zero in this table means below analysis detection limit~~			

~~[61, UBA Germany 2003] [98, WT TWG 2004]~~

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5.1.2.2 Physico-chemical treatment of solid and/or pasty waste before backfilling

Purpose

Physico-chemical treatment of waste prior to backfilling consists of adapting the structural and physical characteristics of the waste input (mainly fly ashes) in accordance with local conditions for long-term storage in the mine. If wastes cannot be used directly as backfilling material, they are treated in dedicated physico-chemical treatment plants.

Principle of operation

The physico-chemical treatment includes the blending of wastes with liquid solutions and, if necessary, additional binding agents. Some wastes are treated in a dry process using compacting processes (e.g. vibration).

The process takes place mostly above ground; in special cases, the backfilling material is generated underground.

Feed and output streams

The waste input is mainly flue-gas treatment residues from incineration or combustion plants (fly ashes).

The output is the material achieving adequate structural and physical characteristics for backfilling.

Process description

Figure 5.4 below presents an example of physico-chemical treatment of waste before backfilling.

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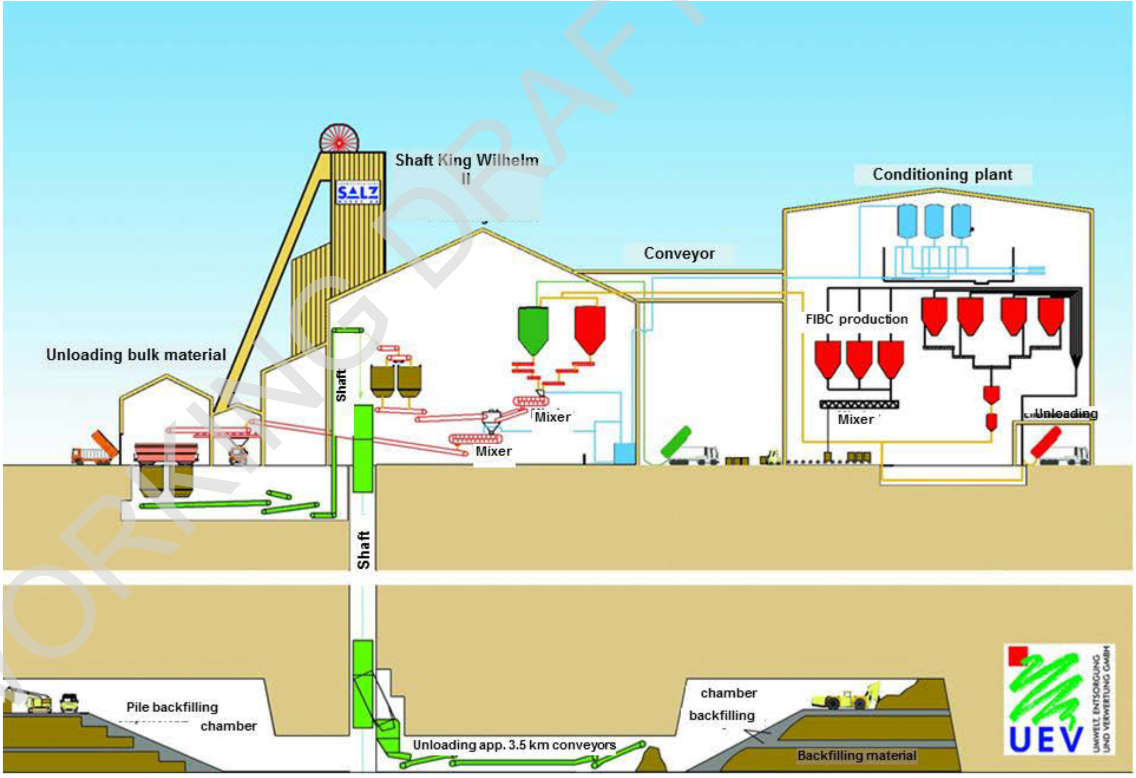

Source: [146, PCT]

Figure 5.4: Example of physico-chemical treatment before backfilling

The following operations are carried out before unloading the waste:

- check of the accompanying documents for completeness and correctness;
- sampling of waste;
- comparison of the waste with the details of the declaration;
- extraction of retained samples.

The waste is then treated by means of one or a combination of the following process steps:

- Compaction, using gravity as well as vibration methods. Generally, this is done without adding water. It can take place either above or below ground.
- Blending of different waste input and/or additives.
- Addition of liquids and/or binding agents. The physical properties of granulated wastes (ashes, dusts and sludge) are used for the production of backfilling mixtures. By mixing with liquids (e.g. brine and/or $MgCl_2$ brine), the waste input is converted to a pumpable, pasty, backfilling material mixture for example.

When liquids are added, the lower explosive limit (LEL) is continuously monitored during the process. In this case, one or a combination of the following gases is analysed:

- hydrogen,
- propane,
- methane,
- carbon monoxide,
- acetylene,
- ethanol.

Specific procedures are put in place which define the measures to be applied when the LEL is reached, such as:

- intensification of aeration and ventilation (e.g. opening of all gates in the hall and turning up of all vents);
- interruption of physico-chemical treatment;
- disconnection of the system from the power supply.

Users

Plants for physico-chemical treatment of wastes as a pretreatment before backfilling in salt and potash mines are found in Germany. [146, PCT]

From ex-Section **4.3.2.5 Use of other reagents for immobilisation process**. Deleted as it is no longer an applied process

~~**Description**~~

~~Some techniques are:~~

~~a. encapsulation by bitumen~~

~~Fly ash particles can be encapsulated by bitumen, and potential contact with water is thus restricted. This improves the leaching properties of the fly ash; probably allowing less heavy metals to be released than in the case of cement solidification. Bitumen encapsulation has been used on fly ash only and not for the residues from dry and semi-dry FGT systems, indicating that these may present problems. On bitumen encapsulation, no information on the possible leaching of dioxins from the solidified ash particles has been found, but it is noted that the solidification method itself does not reduce the original content. Solidification treatment by bitumen has been practised in the Netherlands~~

~~b. carbonation using CO_2~~

~~Waste incineration residues may be stabilised by carbonation (using CO_2), rather than hydration (with or without cement addition). Carbonation has a dramatic influence on the leaching of Pb and Zn and results in a lower pH product (around 9) but without loss of acid neutralisation capacity. Carbonisation of waste incineration residues have been practised in the UK~~

WORKING DRAFT IN PROGRESS

~~immobilisation with clay minerals.~~
~~Immobilisation by clay minerals have been practised in Austria~~

~~**[31, LaGrega et al. 1994][80, Iswa 2003] [98, WT TWG 2004]**~~

5.1.3 Current emission and consumption levels

5.1.3.1 Overview

From ex-Section **3.3.3.2 Emissions from the physico-chemical treatment of waste solids and sludge**

The emissions listed in Table 5.16 below can be expected to occur from most treatment plants. The scale of the emission depends on the plant throughput and on the abatement systems applied.

Table 5.16: Emissions from physico-chemical treatment of solids and pasty waste

Physico-chemical activity	Air	Water	Residues/Soil
Filtration/pressing	Ammonia and, if there is a high organic content in the waste streams, VOCs	NI	NI
Immobilisation mixing	Emissions of e.g. dust, VOC, via roof vents. Emissions occur during transfer from the mixing pit to removal off site; and via access doors from during charging of the reaction vessels (spillages/leaks)	NI	NI
Sludge blending	~~Particulate matter~~ Dust and VOCs, particularly if an exothermic reaction occurs	NI	NI
Sludge management (e.g. pressing or sludge storage)	VOCs as fugitive emissions. Gases from solutions	NI	NI
Solidification	There is potential for ~~particulate~~ dust emissions from this operation	NI	NI
Automated charging of waste	VOCs, dust, odour during the transfer of wastes and reagent	NI	NI
Reaction vessel	Emissions occur due to the reaction of incompatible substances. Uncontrollable reactions due to incorrect dosing of reactants or the formation of hot spots through poor mixing	Leakage through badly maintained or damaged equipment	Leakage through badly maintained or damaged equipment
Reagent silo	Dust arises from the overfilling of reagent silos. Also, fugitive dust emissions from silo connections and dust from reagent stockpiles	NI	NI

NI: No information.
Source: [33, UK EA 2001] [34, Babtie Group Ltd 2002]

~~The fugitive emissions from material handling operations for *ex situ* processes are often overlooked or ignored, but they may represent a significant fraction of the total emissions from the soil treatment.~~
~~**Emission from treatments of FGT waste**~~

WORKING DRAFT IN PROGRESS

The main environmental concern related to the handling, utilisation and disposal of combustion wastes is the potential emission of heavy metals, organic pollutants and salts. The main pathways for this are leaching and airborne dust emission. As airborne emissions can be controlled relatively easily, leaching is an environmentally more important issue. It should also be noted that hydrogen gas generation from FGT waste in contact with water has been documented and can potentially cause considerable problems. Its generation is dependent on intermediate FGT waste storage and the type, design and operation of the landfill that may be developed.

~~Emissions from solvent extraction~~

~~Up to five waste streams may result from the solvent extraction process: concentrated contaminants; solids; waste water; oversized rejects; and treated air emissions.~~

~~Solvent extraction units will be of a closed loop design in which the solvent is recycled and reused. Typically, solvent extraction units are designed to produce negligible air emissions, but some solvents have been detected in the off-gas vent system. In addition, significant levels of emissions (both vapour phase and particulate matter) may occur during waste preparation activities such as excavation and material handling.~~

~~Emission from asbestos treatments~~

~~The fibrous nature and the size of the fibres are the main parameters that make asbestos dangerous. During treatment some emissions may be generated.~~

5.1.3.2 Emissions to air

Table 5.17 below presents the reported emissions to air from the physico-chemical treatment of solid and/or pasty waste. It should be read together with Table 5.18 which presents the reported techniques to abate air emissions, origin of emissions to air, and exhaust air flow.

WORKING DRAFT IN PROGRESS

Table 5.17: Emissions to air from physico-chemical treatment of solid and/or pasty waste

Pollutant measured	Monitoring	Plants concerned	Ranges (mg/Nm^3 except for odour)	Number of measurements during the three reference years
Dust	Continuous	425	Average[(1)]: 0.4–5.5	NA
	Periodic	15, 221, 222, 223, 224, 225, 226, 228, 229, 399, 427, 475, 613, 614	0.5–18	1 to 12
SO_X	Periodic	427	532	9
NO_X	Periodic		5.7	9
HCl	Continuous	425	Average[(1)]: 0.1–0.2	NA
H_2S	Periodic	348	2.9	6
NH_3	Periodic	15, 340, 348, 551	0.000002–31[(2)]	1 to 36
TOC	Continuous	425	Average[(1)]: 6.6–11.5	NA
TVOC	Periodic	495	484–490 ppm	36
Odour (OU_E)	Periodic	340	74	2
Cd	Periodic	221, 399	0.0004–0.01	2 to 9
Hg	Periodic	399, 427	0.003–0.01	3 to 9
Sb	Periodic	399	0.01	9
As	Periodic	399	0.01	9
Pb	Periodic	221, 399	0.009–0.01	2 to 9
Cr	Periodic	221, 399	0.003–0.01	2 to 9
Cu	Periodic	221	0.002	2
Mn	Periodic	221	0.004	2
Ni	Periodic	399	0.01	9
Zn	Periodic	399	0.5	9
PCDD/F	Periodic	399	0.01	9

NA: Not applicable.

NB: For periodic measurements, the values are the average over the three reference years.

(1) Long-term average. Averaging period not indicated.

(2) Low end of the range from Plant 551; 36 measurements from mixing process step. High end of the range from Plant 15; two measurements in 2014 at storage facility during waste input delivery.

WORKING DRAFT IN PROGRESS

Table 5.18: Physico-chemical treatment of solid and/or pasty waste – Abatement techniques used and origin of emissions to air

Plant code	Techniques used	Origin of emissions	Waste input description	Air exhaust flow (Nm^3/h)
15	Venturi scrubber system Bag/fabric filter system	Storage facility	Pollution abatement component Fly ash Contaminated soil Sludge	14 000
	Membrane separation Wet scrubbing	Immobilisation process		
58	Rotation scrubber	Immobilisation/solidification plant is operated in underpressure; dust and NH_3 abatement from the extracted air	Pollution abatement component Sludge Filter cake	NI
176	No channelled emission, but good practices, e.g. for the venting devices of the silos (see below):		Contaminated soil Fly ash	NI
	Bag/fabric filter system	Stabilisation unit/silos and hoppers, e.g. silo venting filters which consist of a cylindrically shaped dust collector for venting of pneumatically filled silos		
	Water spraying (dust)	Stabilisation unit/pond		
	Activated carbon adsorption	Biological treatment of contaminated soil. The activated carbon is changed for each new 'biopile'		
181	Bag/fabric filter system	Stabilisation unit/silos and hoppers	Contaminated soil Fly ash Sludge Pollution abatement component	NA
	Activated carbon adsorption	Biopile. Treatment of contaminated soil		
187	Absolute filter system	Mixer process step	Fly ash Sludge	NI
	Bag/fabric filter system	Vent of the silos		NA
221	Air separator	Mixing and processing part	Contaminated soil Fly ash Brine	40
	Filter	Vent of the silo		
222	Bag/fabric filter system (first dedusting and additional security filter)	Storage and material handling. Above-ground silo for bulk input material	Flue-gas treatment residues (fly ash and other treatment residues)	5 000
		Storage and material handling. Underground silo for material to mixer		5 800

WORKING DRAFT IN PROGRESS

223	Bag/fabric filter system (first dedusting and additional security filter)	Storage and material handling - Silo for bulk input material	Flue-gas treatment residues (fly ash and other treatment residues)	3 600
224	Bag/fabric filter system (first dedusting and additional security filter)	Storage and material handling - Silo for bulk input material	Flue-gas treatment residues (fly ash and other treatment residues)	3 500
225	Bag/fabric filter system (first dedusting and additional security filter)	Storage and material handling - Silo for bulk input material	Flue-gas treatment residues (fly ash and other treatment residues)	4 200
226	Bag/fabric filter system (first dedusting and additional security filter)	Storage and material handling - Silo for bulk input material	Flue-gas treatment residues (fly ash and other treatment residues) Waste from power plants Waste from iron and steel casting, Waste from casting non-ferrous metals Waste from cement production Waste from physico-chemical treatment Waste from waste water treatment Waste from soil reclamation	3 400
228	Bag/fabric filter system (first dedusting and additional security filter)	Silo for bulk input material	Flue-gas treatment residues (fly ash and other treatment residues) Waste from power plants Waste from iron and steel industries Waste from glass industries Waste from physico- chemical treatment of waste	2 000
		Big bag input handling		2 800
		Material preparation Mixing of suspension liquid		2 700
		Material preparation Mixing of suspension liquid - Degassing conveyor		2 500
229	Bag/fabric filter system (first dedusting and additional security filter)	Silo for bulk input material	Flue-gas treatment residues (fly ash and other treatment residues) Mineral fraction from shredded material, mixed waste, demolition waste) Sludge with contamination	3 600
336	NI	NI	Street-cleaning residues Waste from sewage cleaning Screening material from WWT Waste from desanding Minerals (e.g. sand, stones)	NI

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

340	Bag/fabric filter system	Insolubilisation	Fly ash Sludge	17 000
	Wet scrubbing	Insolubilisation - air after wet scrubbing is entirely directed to biofilter		
	Biofiltering	Insolubilisation		
348	Acid scrubber system	Stabilisation and solidification processes	Off-shore drilling waste Pasty waste from diverse industries	19 000
		Filter press		5 500
		Storage hall		60 000
399	Bag/fabric filter system	Immobilisation process	Fly ash Sludge	10 000
	Wet scrubbing			
	Water spraying (dust)			
	Basic scrubber system			
425	Bag/fabric filter system	Shredder, granulator, mixer	Mixed hazardous waste Sludge Spent activated carbons Spent solvent Used resins Waste containing POPs	11 600
	Activated carbon adsorption			
	Thermal oxidation			
	Acid scrubber system			
427	NI	Neutralisation plant	Acid Fly ash Liquid waste from galvanic industry Metal hydroxide-containing sludge	3 500
475	Wet scrubbing	Immobilisation of organic waste	Fly ash Metal waste Pollution abatement component Sludge Fly ash Catalyst Contaminated soil	13 300
		Immobilisation of other waste		300
495	Biofiltering	Enclosed process and output storage building (low flow biofilter system)	Pollution abatement component Acid	480
	Wet scrubbing	Enclosed process and output storage building (high velocity extraction system)		36 500

	Activated carbon adsorption	Enclosed process and output storage building (high velocity extraction system)		
497	Activated carbon adsorption	Bulk storage tanks vent	Pollution abatement components Acid	NI
551	NI	Mixing step	Pollution abatement component Acid	NI
613	Bag/fabric filter system (first dedusting and additional security filter)	Storage and material handling - Big bag unloading	Flue-gas treatment residues (fly ash and other treatment residues) Bulk material/Sludge Waste from casting non-ferrous metals Waste from cement production Waste from physico-chemical treatment Waste from waste water treatment Waste from soil reclamation	6 400
		Storage and material handling - Mixing aggregate - Silo for bulk input material		
614	Bag/fabric filter system (first dedusting and additional security filter)	Storage and material handling - Big bag handling	Flue-gas treatment residues (fly ash and other treatment residues) Waste from casting non-ferrous metals Waste from cement production Waste from physico-chemical treatment Waste from waste water treatment Waste from soil reclamation	3 300
618	NA	No channelled emissions to air (wet process)	Foundries metallurgical sludge Undersize part from dusting of raw iron and from secondary metallurgy Undersize waste from coke transport Waste from production of isolating wool for building industry	NA
NI: No information. NA: Not applicable.				

WORKING DRAFT IN PROGRESS

Dust

Of the 26 plants performing physico-chemical treatment of solid and/or pasty waste, 13 reported dust concentration levels in emissions to air, some of them having more than one point of release. The reported average dust concentration is around 3 mg/Nm^3, with a range of 0.2–18 mg/Nm^3.

Figure 5.5 below presents the reported dust concentration in air emissions from immobilisation of solid and/or pasty waste (periodic measurements).

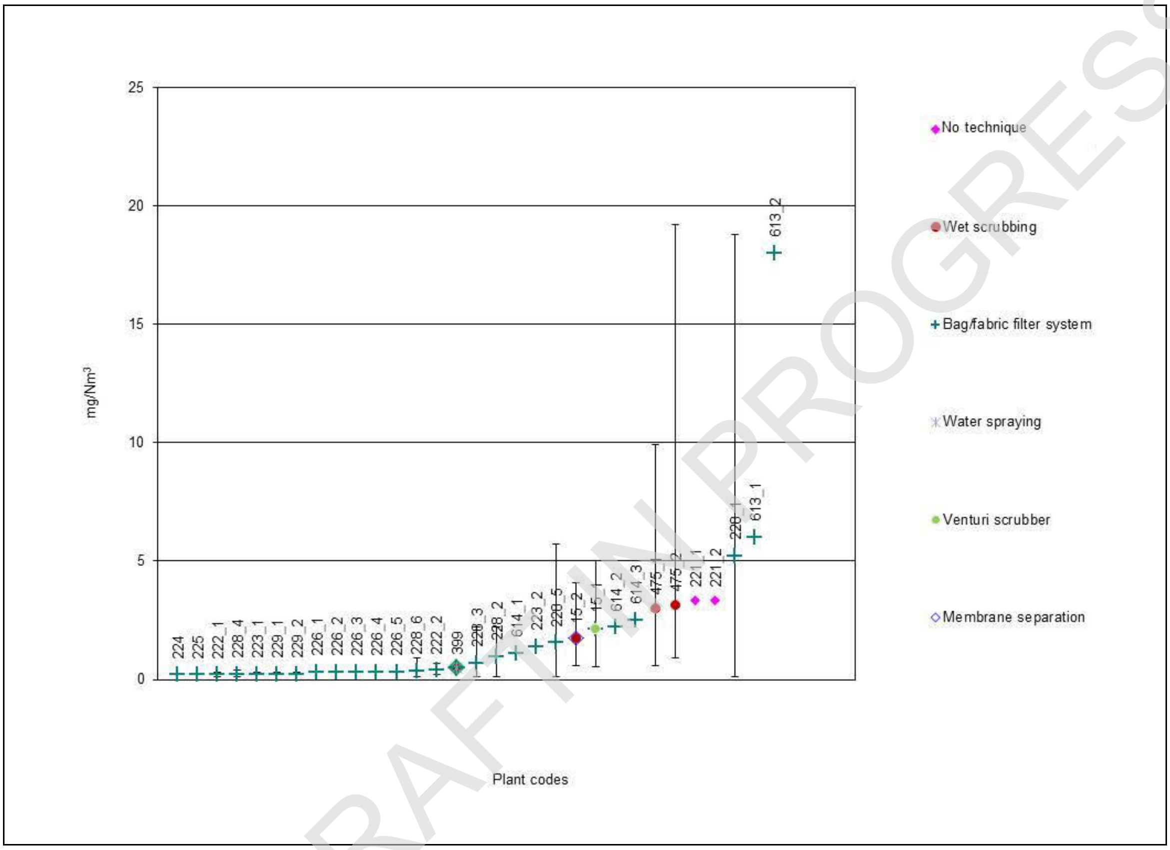

Figure 5.5: **Dust in air emissions from physico-chemical treatment of solid and/or pasty waste**

Ammonia (NH_3)

Of the 26 plants performing physico-chemical treatment of solid and/or pasty waste, 4 plants reported NH_3 concentration levels in emissions to air, some of them having more than one point of release. The reported average NH_3 concentration is around 5 mg/Nm^3, with a range of 2^{E-6}–31 mg/Nm^3. NH_3 emissions are mainly linked to the waste input to be treated (e.g. sludge).

Figure 5.6 below presents the reported NH_3 concentration in air emissions from physico-chemical treatment of solid and/or pasty waste (periodic measurements).

WORKING DRAFT IN PROGRESS

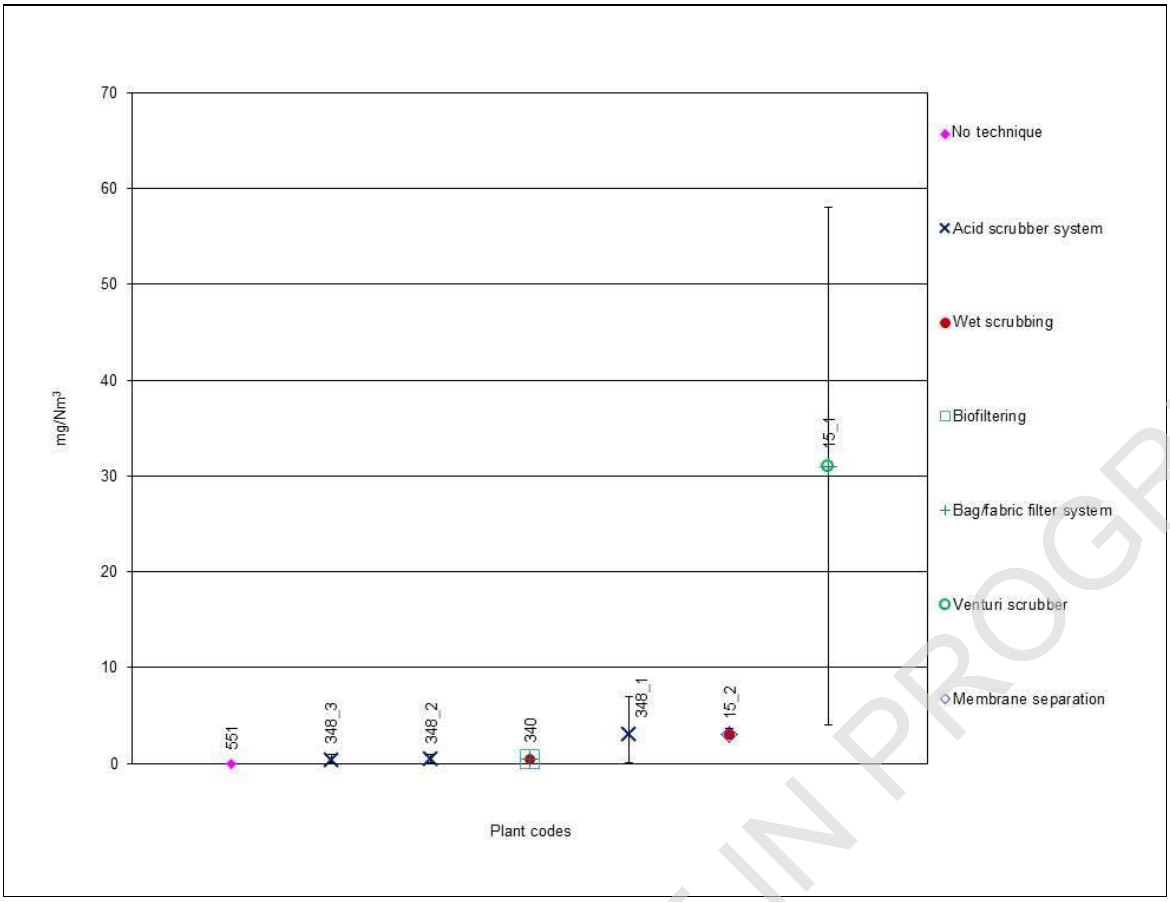

Figure 5.6: NH_3 in emissions to air from immobilisation of solid and/or pasty waste

Volatile organic compounds (VOCs)

Among the 26 plants performing physico-chemical treatment of solid and/or pasty waste, 3 plants reported VOC concentration levels in emissions to air, some of them having more than one point of release. The average reported VOC concentrations were expressed in mg/Nm^3 or ppm of TOC or TVOC.

Table 5.19 below presents the reported VOC concentration levels in emissions to air from physico-chemical treatment of solid and/or pasty waste.

WORKING DRAFT IN PROGRESS

Table 5.19: **Volatile organic compound emissions to air** from physico-chemical treatment **of solid and/or pasty waste**

Plant code	**Capacity (t/day)**	**Origin of emissions to air**	**Technique used**	**Air flow (Nm^3/h)**	**Organic compounds emission concentration**	**Number of measurements during the three reference years**	**Standard used for monitoring**
425	210	Shredder, granulator, mixer	Bag/fabric filter Activated carbon adsorption Thermal oxidation Acid scrubber	10 800	TOC: 6.6–11.5 mg/Nm^3	Continuous monitoring Long-term average	NI
475	400	Immobilisation of organic waste	Wet scrubbing	13 300	TOC: 1.7 mg/Nm^3	3	NI
		Immobilisation of solid and/or pasty waste	Wet scrubbing	340	TOC: 2.7 mg/Nm^3	3	
495	400	Output storage	Biofiltering	480	TVOC: 490 ppm	36	FID
		Conditioning	Wet scrubbing Activated carbon adsorption	36 000	TVOC: 484 ppm	36	

5.1.3.3 Emissions to water and water usage

The Table 5.20 below presents the reported techniques for abatement of emissions to water, the origin of emissions, and the point of release (direct/indirect discharge).

WORKING DRAFT IN PROGRESS

Table 5.20: Physico-chemical treatment of solid and/or pasty waste – Origin of emissions to water, abatement techniques used, and point of release

Plant code	Origin of emissions to water	Techniques used	Point of release
15	No emissions to water	NA	NA
58	No emissions to water	NA	NA
176	No emissions to water	NA	NA
181	No emissions to water	NA	NA
187	No emissions to water	NA	NA
221	Whole process	NI	NI
222	No emissions to water	NA	NA
223	No emissions to water	NA	NA
224	No emissions to water	NA	NA
225	No emissions to water	NA	NA
226	No emissions to water	NA	NA
228	No emissions to water	NA	NA
229	No emissions to water	NA	NA
336	Mechanical	NI	Indirect discharge (urban/municipal sewer system)
340	No emissions to water	NA	NA
348	Process water (filter press, scrubber) Rainwater	NI	Indirect discharge (off-site common WWT facility)
399	No emissions to water	NA	NA
425	NI	NI	NI
427	Neutralisation process	Chemical precipitation Sedimentation Filtration Adsorption	Direct discharge (on-site common WWT facility)
475	No emissions to water.	NA	NA
495	No emissions to water	NA	NA
497	NI	NI	NI
551	No emissions to water	NA	NA
613	No emissions to water	NA	NA
614	No emissions to water	NA	NA
618	No emissions to water	NA	NA
NI: No information. NA: Not applicable.			

Of the 26 plants performing physico-chemical treatment of solid and/or pasty waste that participated in the data collection, 20 plants (77 %) reported having no emissions to water from the process.

Of the six plants that reported having emissions to water, one (Plant 427) reported discharging to the environment via a common on-site WWT facility, two (Plants 336 and 348) discharge to a sewer system or to an off-site WTTP, and three (Plants 221, 425, and 497) provided no indication of the point of discharge.

The analysis of emissions to water from Plant 427 discharging directly to a water body after treatment is dealt with in Section 5.7.2.3.2.

WORKING DRAFT IN PROGRESS

Water usage
The reported average water usage per tonne of waste treated is around 410 l/t, with a range of 6–1800 l/t.

The high end of the range is achieved by plants with washing and/or cleaning steps, which is the main use of water; in most cases, water is recycled in the process.

5.1.3.4 Energy consumption

The main source of energy in physico-chemical treatment of solid and/or pasty waste is electricity.

The reported average energy consumption is 30 kWh/t, with a range of 3–112 kWh/t. This includes other energy sources, such as fossil fuel, e.g. for the wheel loader, whose use was reported by eight plants, and represents an average of around 8 kWh/t.

5.1.4 Techniques to consider in the determination of BAT

From ex-Section **4.3.2 Techniques for the physico-chemical treatments of solids and sludges**

In this section, only specific techniques to prevent and/or reduce consumption and emissions to air and to water from the physico-chemical treatment of solid and/or pasty waste are described.

5.1.4.1 Treatment efficiency optimisation

5.1.4.1.1 Specific procedures to control the waste input properties

Description
Implementation of specific procedures in order to control:

- the waste input content, e.g. of:
  - organics,
  - solid cyanides,
  - oxidising agents,
  - mercury;
- hydrogen (H_2) generation when mixing fly ashes (or air pollution control (APC) residues) with water.

Technical description
The specific procedures to control the waste input properties include in particular:

- Measurement of the waste input organic content (TOC). (TOC concentration < 6 % is commonly adopted). The potential effect of a high organic content in the waste input includes:
  - disturbance of the chemical reactions during the period of curing (pozzolanic and/or hydraulic reaction);
  - in the long term, biodegradation of organic compounds involves destruction of the concrete-like bulk waste and the disturbance of the physico-chemical equilibrium of the intraporosity liquid phase of the concrete-like waste with a potential release of heavy metals and salts.
- Measurement of the waste input mercury content. Mercury remains available in the waste and can involve contamination in the long term. Even if the mercury is in a sulphide form, the co-disposal with concrete-like waste will destroy sulphide mercury because of the alkaline pH.
- Regular test of hydrogen (H_2) generation when APC residues containing carbonate are mixed with water. Physico-chemical conditions when fly ashes or APC residues are mixed with water involve hydrolysis of e.g. aluminium, which generates hydrogen emissions. This reaction is catalysed in the presence of carbonate (which is the case, for example, of APC

WORKING DRAFT IN PROGRESS

residues generated by dry flue-gas cleaning using sodium bicarbonate). This leads to a risk of explosion in closed or confined areas where the limit of explosivity can be easily met. [146, PCT]

Achieved environmental benefits
The achieved environmental benefits of this technique include:

- optimisation of the overall treatment efficiency:
    - ensuring the compatibility of the waste input to be treated with the applied process;
    - preventing uncontrolled emissions;
- prevention of incident/accident, and associated emissions.

Environmental performance and operational data
Table 5.21 below presents the implemented procedures in physico-chemical treatment of solid and/or pasty waste, which aim to ensure the compatibility of the waste input and the treatment process.

Table 5.21: Immobilisation of solid and/or pasty waste – Implemented procedures related to ensure the compatibility of the waste input and the treatment process

Implemented procedure	**Plants concerned**
Pre-acceptance/acceptance	15, 58, 176, 181, 187, 222, 223, 224, 225, 226, 228, 229, 340, 348, 399, 425, 427, 475, 494, 495, 551. 569, 613, 614
Segregation and compatibility	348, 425, 427, 494, 495, 569
Waste input characterisation	15, 176, 181, 187, 222, 223, 224, 225, 226, 228, 229, 348, 399, 425, 427, 475, 495, 613, 614
Waste tracking system	176, 181, 187, 222, 223, 224, 225, 226, 228, 229, 425, 427, 475, 494, 495, 551, 613, 614
Process and risk management	176,181, 187, 222, 223, 224, 225, 226, 228, 229, 340, 348, 425,, 427, 494, 495, 613, 614, 618

Cross-media effects
Not identified.

Technical considerations relevant to applicability
Regular test of H_2 emissions is applicable when mixing carbonate-containing fly ashes with water.

Economics

TWG members, please provide information

Driving force for implementation

- Environmental legislation.
- Risk prevention.

Example plants
See Table 5.21.

Reference literature
[146, PCT] [160, WT TWG 2014]

Ex-Section **4.3.2.1 "Pretreatment before immobilisation"** moved to Section 5.1.2 (washing step in process description)

WORKING DRAFT IN PROGRESS

5.1.4.2 Techniques for the prevention or reduction of emissions to air

Description
Implement an appropriate combination of techniques such as:

- bag/fabric filter;
- wet scrubber,
- biofilter,
- adsorption.

Technical description
The technical descriptions of the techniques are given in Section 2.3.4.4 (bag/fabric filter) and Section 2.3.4.10 (wet scrubber).

Achieved environmental benefits
The achieved environmental benefits of this technique include:

- reduction of dust emissions to air;
- reduction of ammonia (NH_3) emissions to air;
- reduction of volatile organic compounds (VOC) emissions to air.

Environmental performance and operational data
Information on the environmental performance of each technique can be found in the CWW BREF [138, COM 2014].

Table 5.22 and Table 5.23 below present the reported dust and NH_3 concentration levels in emissions to air from the physico-chemical treatment of solid and/or pasty waste.

Table 5.22: **Dust emissions to air from physico-chemical treatment of solid and/or pasty waste**

Plant code	Capacity (t/day)	Origin of emissions to air	Techniques used	Air flow (Nm^3/h)	Dust emission concentration (mg/Nm^3)	Number of measurements during the three reference years	Standard used for monitoring
15	480	Storage facility	Venturi scrubber system Bag/fabric filter system	14 000	2.1	3	Gravimetric
		Immobilisation process	Wet scrubbing	6 200	1.8		
221	2 000	Mixing and processing (silo filter)	NI	40	3.4	2	TA Luft
222	430	Storage and material handling: above-ground silo for bulk input material	Bag/fabric filter system	5 000	0.2–0.4	3	NI
		Storage and material handling: underground silo for material to mixer	Bag/fabric filter system	5 800		3	

WORKING DRAFT IN PROGRESS

223	500	Storage and material handling. Silo for bulk input material 1	Bag/fabric filter system	3 600	0.2	3	VDI 2066-1
		Storage and material handling. Silo for bulk input material 2	Bag/fabric filter system		1.4	1	
224	400	Storage and material handling - Silo for bulk input material	Bag/fabric filter system	3 500	0.2	1	VDI 2066-1
225	200	Storage and material handling - Silo for bulk input material	Bag/fabric filter system	4 200	0.2	3	NI
226	1 300	Storage and material handling - Silo for bulk input material	Bag/fabric filter system	3 400	0.3	1	VDI 2066-1
228	850	Silo for bulk material	Bag/fabric filter system	2 000	0.2–5	4	NI
		Big Bag input handling	Bag/fabric filter system	2 800			
		Material preparation Mixing of suspension liquid	Bag/fabric filter system	2 700			
		Material preparation Mixing of suspension liquid - Degassing conveyor	Bag/fabric filter system	2 500			
229	2 000	Silo for bulk input material	Bag/fabric filter system	3 600	0.2	3	VDI 2066-1
		Treatment process	Bag/fabric filter system				
399	600	Immobilisation process	Bag/fabric filter system Wet scrubbing Basic scrubber system Water spraying	10 000	0.5	9	NI

WORKING DRAFT IN PROGRESS

425	210	Shredder, granulator, mixer	Bag/fabric filter system Activated carbon adsorption Thermal oxidation Acid scrubber system	11 600	Min–max: 0.2–0.4	Continuous measurements – Long-term average	NI
475	400	Immobilisation of organic waste	Wet scrubbing	13 300	3	12	NI
		Immobilisation of solid and/or pasty waste	Wet scrubbing	340	3.2	12	
614	400	Storage and material handling - Big bag handling	Bag/fabric filter system	3 300	1.1	1	VDI 2066-1
		Storage and material handling - Bulk material ramp	Bag/fabric filter system	9 000	2.2	2	
		Storage and material handling - Container feed	Bag/fabric filter system	4 200	2.5	2	
NI: No information.							

Table 5.23: NH_3 emissions to air from physico-chemical treatment of solid and/or pasty waste

Plant code	Capacity (t/day)	Origin of emissions to air	Techniques used	Air flow (Nm^3/h)	NH_3 concentration (mg/Nm^3)	Number of measurements during the three reference years	Standard used for monitoring
15	480	Immobilisation process	Wet scrubbing	6 200	3.1	3	Dräger Tube
340	240	Insolubilisation step	Bag/fabric filter system Wet scrubbing Biofiltering	17 000	0.5	1	UNICHIM 632
348	150	Storage hall	Acid scrubber system	19 000	3	6	NI
		Filter press		60 500	0.4	6	
551	450	Mixing step	NI	NI	0.000002	36	NI
NI: No information.							

Cross-media effects

See CWW BREF [138, COM 2014].

Technical considerations relevant to applicability

See CWW BREF [138, COM 2014].

Determining an appropriate combination of abatement techniques is generally applicable.

Economics

See CWW BREF [138, COM 2014].

WORKING DRAFT IN PROGRESS

Driving force for implementation
Environmental legislation.

Example plants
See Table 5.22 and Table 5.23

Reference literature
[138, COM 2014] [160, WT TWG 2014]

Ex-Section **4.3.2.4 "Cement solidification"** moved to Section 5.1.2.1.2: refer to process; see KOM conclusion 2.2f

Ex-Section **4.3.2.5 "Use of other reagents in the immobilisation process"** moved to Section 5.1.2.1: refer to process; see KOM conclusion 2.2f

Ex-Section **4.3.2.6 "Phosphate stabilisation"** moved to Section 5.1: refer to process; see KOM conclusion 2.2f

Ex-Section **4.3.2.7 "Thermal treatments of solid waste"** removed: refers to quality of output, excluded from BAT scope according to KOM conclusion 1.4a
Ex-Section **4.3.2.8 'Recovery of salts by solution/evaporation'** moved to Section 5.5.1.4.2

Ex-Section **4.3.2.10 "Excavation and removal of contaminated soil"** removed: excluded from scope; see KOM conclusion 1.2d

WORKING DRAFT IN PROGRESS

5.2 [~~The]~~ Re-refining of waste oils

Introduction of ex-Section **2.4 "Treatments applied mainly to recover the materials from waste"**

~~This sections includes those treatments and processes mainly designed to recover the materials or portions of materials contained in waste. Typically these processes are very dependent on the type of waste treated and the materials that are wanted or that need to be produced. The materials produced from these treatments are materials that can be re-used for the same purpose (e.g. lubricant oils) or recovery for other non-energy purposes (e.g. recovery of metals from catalysts). When the material is treated to be used subsequently as fuel, this is included in the Section~~

~~'Regeneration' is the term used in this document to describe these treatments except in the case of regeneration of waste oils where the term 're-refining' is used. This is not an attempt to make any kind of definition. This should be taken only as a convention to aid reading this document.~~

From ex-Section **3.4.1 Waste IN treated to obtain a recycled material**

~~When the aim is to obtain useable materials and not just material to be disposed of, the treatment given to each type of waste will typically be very specific, and will target the conversion of the waste into the useable end-product required.~~

From ex-Section **4.4 Techniques to consider for treatments applied mainly to recover the materials from waste**

~~This section contains techniques considered to have a good environmental operating performance (e.g use of a good energy system) or that can help lead to a good environmental performance (e.g. environmental management systems). They relate to treatments to recover mainly materials from waste.~~

5.2.1 Applied processes and techniques

From ex-Section 2.4.1

[2, Concawe 1996] [4, Monier, V. and Labouze, E. 2001] [7, Jacobs, A. and Dijkmans, R. 2001] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [34, Babtie Group Ltd 2002] [60, WT TWG 2003][67, Straetmans, B. 2003] [98, WT TWG 2004] [100, WT TWG 2004] [7, Jacobs, A. and Dijkmans, R. 2001]

There are two main options for the treatment of waste oils:

- ~~One is the treatment of~~ The recovery of waste oil ~~to produce a material that will be used mainly~~ to be used as a fuel ~~or for other uses (e.g. absorbant, mould release oil, flotation oil). These~~ This includes treatments such as ~~cleaning of waste oil,~~ thermal cracking and gasification ~~for example~~ ~~and~~ which are covered in Section **5.3.2.4**.
- The ~~other way is to~~ treatment of ~~the~~ waste oil to reconvert it into a material that can be used as a base oil to produce lubricants. This ~~latter way~~ is referred to as 're-refining' in this document. This section details the different treatments that are actually applied to waste oils for its clean-up and re-refining. ~~As it is the case in the whole document,~~ this classification has been adopted for this document and it is not intended to ~~provide any~~ attempt to define any of the 'R' codes from EC waste legislation.

A lot of treatment processes exist ~~(or are currently under development)~~ today in Europe. The most significant ones are listed below in Figure 5.7. This figure also gives an overview of how these treatments have been included in this document.

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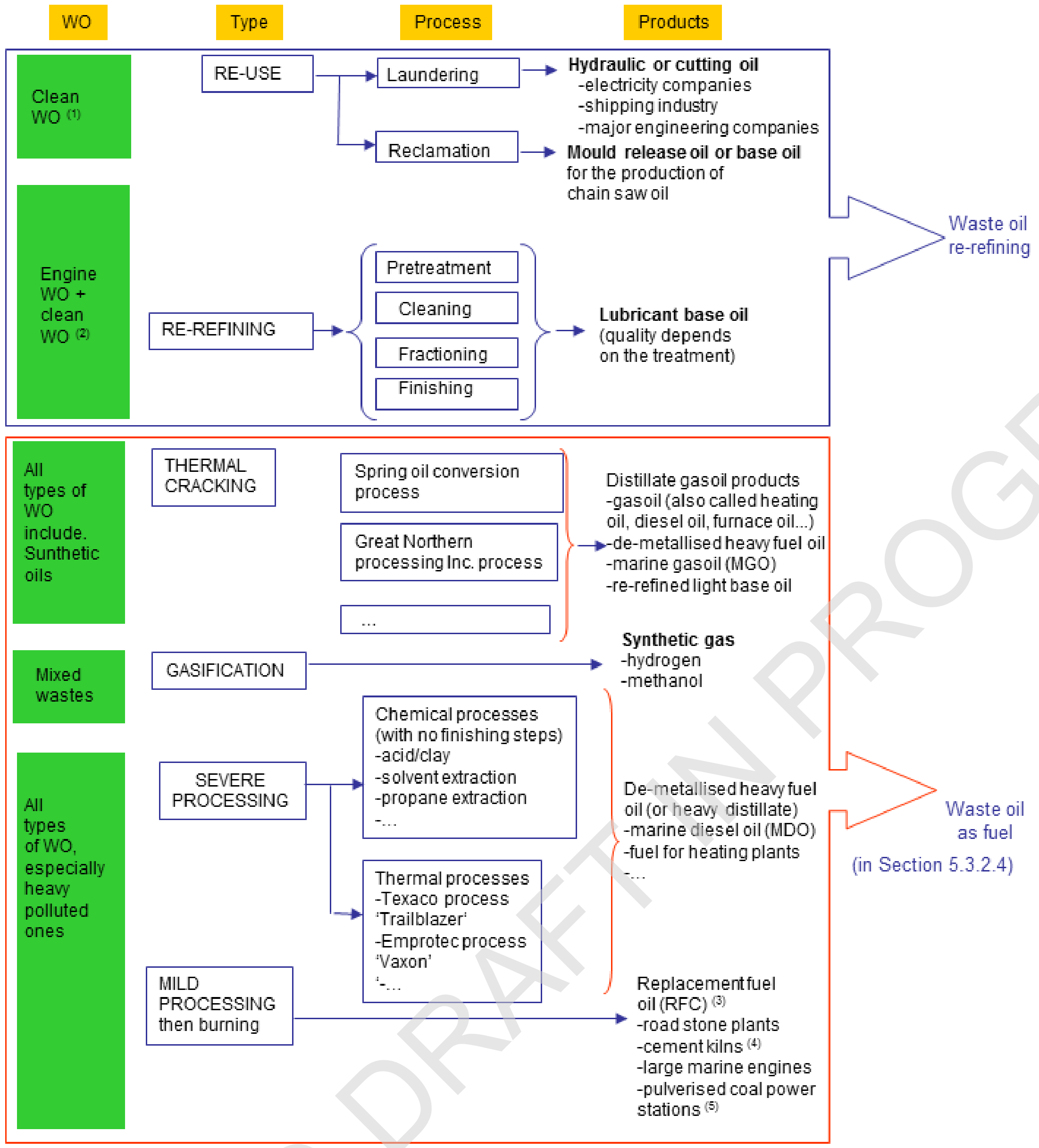

NB: (1) Especially hydraulic or cutting oil.
(2) Engine oils without chlorine + hydraulic oils without chlorine + hydraulic mineral oils + mineral diathermic oils (according to the API classification).
(3) Treated oil still containing the heavy metals, halogen and sulphur contained in the original waste oil (WO).
(4) Substitutes other secondary liquid fuel (SLF) or heavy fuel or coal or petroleum coke.
(5) As a furnace start-up fuel.

Source: [4, Monier, V. and Labouze, E. 2001] [60, WT TWG 2003] [98, WT TWG 2004]

Figure 5.7: Waste oil treatments and division approach used in this document

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Purpose

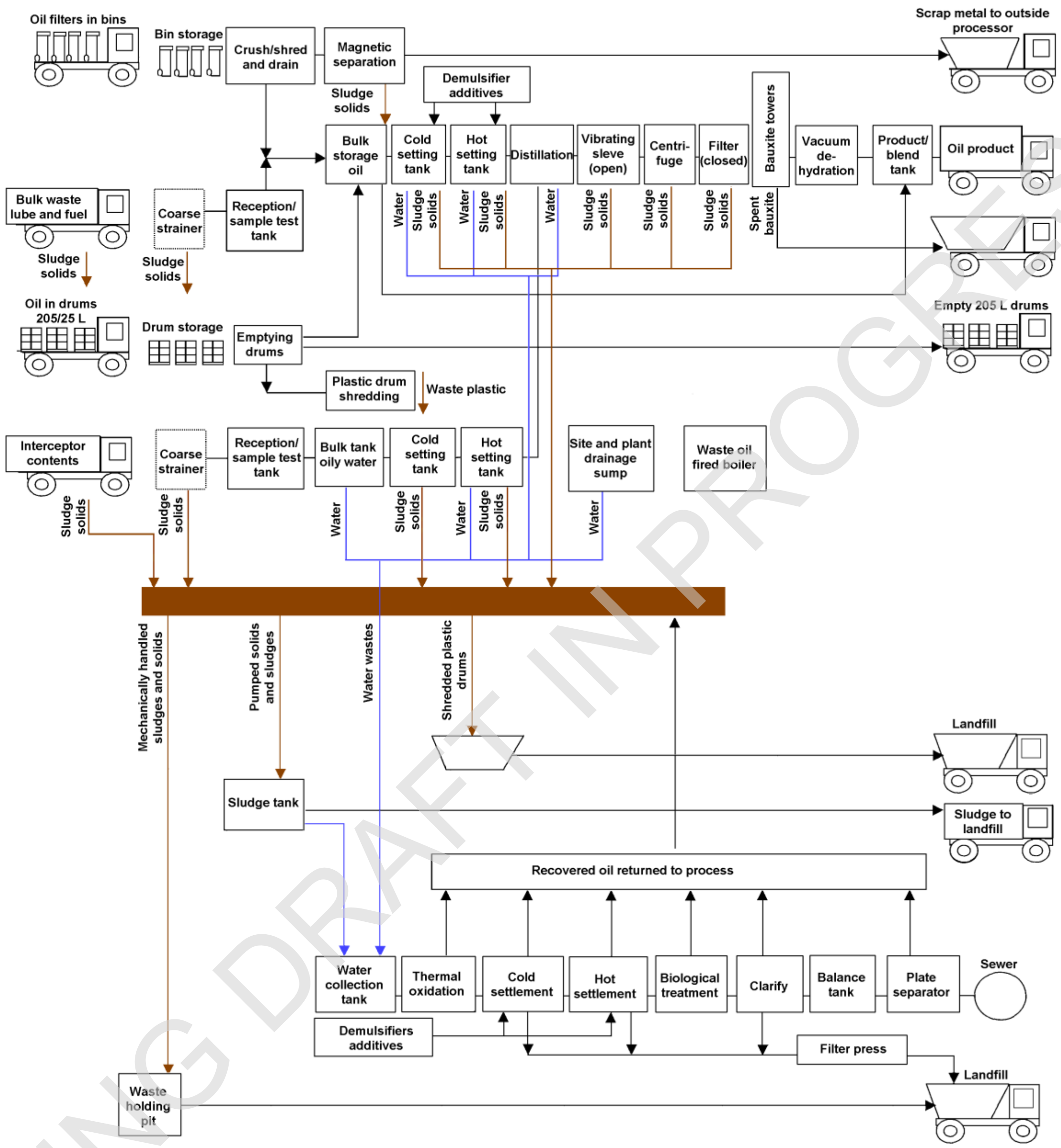
To reuse a waste oil to make a lubricant. It requires cleaning or re-refining in order to ~~make it into~~ obtain an output ~~product~~ suitable to be reused as a base oil to produce a lubricant.

Principle of operation

The~~se~~ processes involve the removal of impurities, defects and any leftover products from its ~~old~~ former use. ~~Generally, this type of process removes all impurities and additives and only base oil then remains~~. Subsequently, lubricant producers add substances to attain the specifications of a virgin product.

The main processes used in oil recovery plants are shown in Figure 5.8

This is an amalgamation of unit operations. Not all operations are applied in every plant. In practice, most plants only use a few of the processes shown, and usually there are two or more parallel streams from each process.



NB: The diagram indicates common treatment elements. Some of these are alternatives and not all occur in a single plant. Brown lines correspond to waste or sludges and blue lines to waste water.
Source:[34, Babtie Group Ltd 2002]

Figure 5.8: Generic flow diagram of waste oil treatment plant processes

Process description

Re-refining treatments may differ depending on the technology used for one or several of the following operations:

- pretreatment ,
- cleaning,
- fractionation, and
- finishing.

Each of these ~~processes~~ unit operations are briefly described ~~in the following sections.~~below.

Pretreatment of waste oil

WORKING DRAFT IN PROGRESS

From ex-**Section 2.4.1.1**

~~**Purpose**~~
~~To dewater (removal of water), de-fuel (removal of light ends and fuel traces such as naphtha, etc.) and remove sediments. This pretreatment process is not compared with the other oil treatment systems because it does not yield an end-product, nor does it achieve the final aim of treatment.~~

~~**Principle of operation**~~
Water and sediments are removed from the waste oil by a simple physical/mechanical treatment. Settling is used in some cases to remove water and sludge from waste oil and in the effluent treatment systems for removing oil and solids from the effluent. Generally, settling takes place using the gravity effect in settling tanks, clarifiers or plate separators, but centrifuges or distillation can also be used.

This pretreatment process is not compared with the other oil treatment systems because it does not yield an end product, nor does it achieve the final aim of the treatment.

~~**Feed and output streams**~~
~~The typical feed is collected waste oil. The product is cleaned waste oil. After this treatment the cleaned oil can be used in one of the options described below~~

~~**Process description**~~
~~The main techniques used are settling, sedimentation, filtering, and centrifuging.~~

~~*Settling*~~
~~A tank is filled and left until it settles, the upper oil strata is skimmed off and similarly the water layer is drawn off. Depending on how dirty the feedstock is, the sludge might be left at the bottom of the tank to accumulate over several settlement cycles before it is removed. The settling process is often aided by heating, to reduce the viscosity. In many cases, an interface layer of an oil/water emulsion remains. This can be encouraged to separate by the addition of heat and chemicals. Further settling processes applied to the 'water' layer can separate the oil/water phase even better.~~

~~*Sedimentation*~~

~~*Filtering/straining*~~
~~Particulates are removed by strainers, filters or sieves.~~

~~*Centrifuging*~~

~~*Distillation*~~
~~Water may be removed by this technique.~~
~~**Users**~~
~~Used in many of the waste oil re-refining technologies (see Table 5.25)~~

Cleaning of waste oil

From ex-**Section 2.4.1.2**

~~**Purpose**~~
Cleaning includes deasphalting and the removal of asphaltic residues: heavy metals, polymers, additives, and other degradation compounds.
~~**Principle of operation**~~
This is mostly done by distillation and ~~the~~ addition of acids. ~~are the most typical ways to achieve the above results~~.

~~**Feed and output streams**~~

WORKING DRAFT IN PROGRESS

~~**Process description**~~
Acid cleaning consists of additives, polymers, and oxidation and degradation products ~~are~~ being removed by contact with sulphuric acid or precipitated as sulphates (e.g. metals). ~~Clay cleaning is also considered, where the~~ Clarified oil ~~is~~ can also be mixed with clay ~~by absorption~~ to remove by absorption any polar and undesirable compounds still present.

~~**Users**~~
~~Used in many of the waste oil re-refining technologies (see Table 5.25).~~

Fractionation of waste oil

From ex-**Section 2.4.1.3**

~~**Purpose**~~
This involves the separation of the base oils using their different boiling temperatures, to produce two or three cuts (distillation fractions).

~~**Principle of operation**~~
~~This physical separation process utilises the boiling point differences of components.~~

~~**Feed and output streams**~~
~~Typically pretreated waste oil.~~

~~**Process description**~~
Vacuum distillation units can range in complexity from a simple splitting column to a full fractional distillation column, as used in mineral oil refineries.

~~**Users**~~
~~Used in many waste oil re-refining technologies (see Table 5.25).~~

Finishing of waste oil

From ex-**Section 2.4.1.4 "Finishing of waste oil"**

~~**Purpose**~~
This is mainly the final cleaning of the different cuts (distillation fractions) ~~is carried out~~ to achieve specific product specifications (e.g. improve colour, smell, thermal and oxidation stability, viscosity). Finishing may also include the removal of PAHs in the case of severe ~~(high temperature and high pressure)~~ hydrofinishing (high temperature and high pressure) or solvent extraction (low temperature and low pressure).

Table 5.24 below shows different finishing techniques.

~~**Principle of operation and feed and output streams**~~

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Table 5.24: Finishing techniques used for the treatment of waste oils

Technique	Principle of operation	~~Feed and output streams~~ Comments
Alkali treatment	KOH or NaOH is used	Colour properties are enhanced
Bleaching earth	This is a tertiary treatment, to remove the black colour from the oil (caused by the carbon breakdown from the additives), so it can visually be compared with virgin base oil	The new goals, set by the implementation of upcoming specifications for passenger car motor oils, cannot be achieved. In particular, the colour of the produced oils is darker than required
Clay polishing	This is a process similar to the acid/clay process but acid is not used. Bentonite is the clay typically used. The clay is then separated from the oil using a filter press	Generally, clay polishing does not produce the high quality base oils of solvent extraction or hydrotreatment
Hydrotreatment (1)	Chlorine and sulphur are removed from the waste oil fraction at a high temperature under a hydrogen atmosphere and in contact with a catalyst, being converted into HCl and H_2S. Phosphorus, lead and zinc are also removed in this process. PAHs can be removed by severe hydrofinishing (high temperature and with hydrogen under high pressure)	The quality of the distillates is very high and the petroleum fractions are immediately marketable. Hydrogen is needed for the process. Hydrogen sulphide is formed, which can later be reduced to sulphur
Solvent cleaning	PAHs are removed from the base oils by extracting them into the solvent (~~into ppb range~~). The solvent extraction also improves the colour and viscosity index	The feed into the extraction must be a good quality base oil with all heavy metals, etc. removed and already fractioned into wanted cuts. The products are a high quality base oil, the used solvent which is regenerated, and a small stream of base oil (around 3 % of the total base oil stream) with a high PAH concentration, which is used as a fuel product

(1) The hydrotreatment process can be found in the Refinery BREF.
Source: [4, Monier, V. and Labouze, E. 2001] [60, WT TWG 2003] [93, UBA Germany 2003]

~~**Process description**~~
~~The hydrotreatment process can be found in the Refinery BREF.~~

~~**Users**~~
~~Used in many waste oil re-refining technologies (see Table 5.25)~~

Table 5.25 summarises the different technologies used for the regeneration of waste oil.

Table from ex-**Section 2.4.1.5** completed by information from ex-**Sections 4.4.1.3 to 4.4.1.13**

WORKING DRAFT IN PROGRESS

Table 5.25: Waste oil re-refining technologies

Process technology	Feed and output streams	Process description				Yield	Usual plant capacity
		Pretreatment	Cleaning	Fractionation	Finishing		
Laundering	Feed: Transformer oils, industrial lubricants (e.g. hydraulic and cutting). ~~Product~~ Output: clean industrial lubricant returned to users	Adsorption Heating Filtration Vacuum dewatering	/	/	/	NI	NI
Reclamation	Feed: Industrial oils (especially hydraulic oils). ~~Product~~ Output: clean industrial lubricant returned to users	Centrifugation and/or filtering	/	/	/	NI	NI
Clay processing	~~Product~~ Output presents poor characteristics in terms of viscosity and volatility. It can only be employed in the formulation of a limited type of industrial lubricant	*Pre-flash unit* Atmospheric vacuum stripping	*Clay treatment* By contact with a large quantity of adsorption clay	/	/	NI	NI
Acid/clay + distillation	Feed: pretreated waste oils	*Atmospheric or vacuum flash stripping*	*Acid or clay treatment* Removal of waste oil contaminants (e.g. heavy metals, additives, polymers, oxidation and degradation compounds) by acid treatment (typically sulphuric acid) or clay treatment	*Distillation* The cleaned oil is then distilled to recover two or three cuts, plus an overhead gas oil	*Neutralisation and filtration* The lubricating oil cuts, along with the gas oil, are neutralised with calcium hydroxide and filtered	50 %	NI
~~Acid surfactant flocculation~~							
Distillation~~/~~ and chemical treatment or solvent extraction: series of vacuum cyclone evaporators followed by a chemical treatment of the lubricating oil cuts obtained [2, Concawe 1996] [60, WT TWG 2003]	Output: Adequate process selection can lead to the removal of virtually all PAHs, for instance by utilising solvent extraction. Some processes of this type do not generate residues because they transform the residues into products (e.g. production of a fertiliser by reutilisation of the reaction waters)	*Vacuum distillation* The 1st stage removes the water, naphtha and light end. The 2nd stage removes the gas oil, spindle oil or light fuel oil	*Vacuum distillation* The 3rd/4th stages separate the different lubricating oil cuts from the residue (in which all the metals, additives and degradation products are concentrated)		*Chemical treatment* is carried out in a blocked operation, followed by a distillation/stripper to correct volatility and the flashpoint. Alternatively, a *solvent extraction stage* can be supplied to remove the PAHs	65–70 % on dry basis	25 kt/year
Distillation and solvent extraction (Vaxon process)	Does not result in polluted clay as a waste product. Only 98 % of the solvent is		*Vacuum distillation*		*Solvent extraction*	NI	NI

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

	regenerated after extraction of the base oil						
Solvent extraction and distillation (Sener-Interline process) [2, Concawe 1996] [7, Jacobs, A. and Dijkmans, R. 2001] [60, WT TWG 2003] [98, WT TWG 2004]	The recovered base oils have a good quality. The process does not produce solid waste. The chemical treatment of the resulting oil fraction with a mixture of chemicals converts the organically bound chlorine into NaCl. After further distillation, all end products have a low ~~reduced~~ chlorine content (less than 10 ppm). The chemical reactor removes contaminants and virtually all chlorine down to less than 5 ppm. Emissions to air can be reduced by directing the vent streams and gas phase of the distillation units to a thermal oxidiser where pollutants are oxidised at 850 °C for a residence time of two seconds	*Chemical pretreatment with reagents and catalysts*	*Extraction with propane* Liquid propane extracts the base oils and rejects water, asphalt, additives, and other insoluble contaminants	*Atmospheric and vacuum distillation* The extracted oil is firstly distilled in an atmospheric distillation column to separate light hydrocarbons and some propane. The remaining oil is fractioned in a vacuum distillation column to recover lubricant base oils	*No finishing step is required*	79 % on dry basis or 72–74 % of base oils and 21–22 % asphalts on dry basis	25–30 kt/year
Propane deasphalting and hydrofinishing **[4, Monier, V. and Labouze, E. 2001] [60, WT TWG 2003]**	~~The technology produces good quality base oils and an asphaltic residue (suitable as bitumen)~~ From ex-Section 2.5.2.4.3 ~~The base oil produced is only suitable as a diesel extender because they produce unfinished lube basestocks which are not marketable.~~ The 'bottoms' produced are suitable as bitumen. This process yields more marketable materials than regeneration by chemical treatment or by hydrogenation. This is the reason why this process sometimes under certain ~~operational~~ operating conditions may be seen as a re-refining process because a high percentage of base oils are produced. More or less expensive according to the number of stages for the PDA.	*Pre-flash* In a distillation column	*Extraction with propane and fractionation and vacuum column* ~~Propane deasphalting~~ From ex-Section 2.5.2.4.3 Asphalt is separated by extracting the recoverable fractions of the used oil with liquid propane. Two versions exist: 1) Single stage: downstream of the PDA extraction unit, the clarified oil is separated from the propane and fed to the hydrotreatment. Finally, fractionation in a vacuum column produces the desired lubricating oil cuts. 2) Two-stage: the clarified oil ~~coming~~ from the first PDA unit is distilled and fractionated in a vacuum column. The bottom fraction, still containing impurities, is fed to a second PDA unit; the resulting asphaltic fraction is recycled back to the first PDA unit. The oil fractions ~~coming~~ from the side cuts of the vacuum column, along with the heavy cut clarified in the second PDA stage, are hydrogenated separately in the hydrotreatment.		*Hydrofinishing with a NiMo catalyst* From ex-Section 2.5.2.4.3 Clay or hydrotreatment: after the subsequent distillation steps, the chlorine content of the distillates is lowered by treatment with metallic sodium	From ex-Section 2.5.2.4.3 74 % in dry basis for IFP process (97 % dewatering defueling, 80 % deasphalting), 95 % hydrofinishing (medium pressure) 80 % in dry basis for the Snamprogetti. 5 % fuel, 9 % gas oil and 6 % residue	NI

	Significant amount of residues to be disposed of		The two-stage process, compared to the single stage, provides an extended life for the hydrotreating catalyst, but has higher investment and operating costs				
Distillation and alkali treatment (Vaxon - C.F.T. – Cator)	Motor and industrial waste oils, all types of synthetic lubricants except PAG water-soluble, silicon oils and some type of esters. Base oils and asphaltic residue are the main products. Impurities and sediments remain in the final solid waste, which has an asphaltic nature	*Distillation* Throughout the process, pretreatment forms part of the same process, since the first phase produces dewatering throughout the whole distillation with all oil types used			*Alkali treatment*	NI	NI
Thin film evaporators (TFE) and different finishing processes *: physical separation process (distillation) under high vacuum conditions [2, Concawe 1996] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [93, UBA Germany 2003] [98, WT TWG 2004]	Heavy metals, polymers, additives and other degradation products are removed as an asphaltic residue. TFE installations without further treatment produce a dark coloured oil, which is suitable for a diesel extender but not as a base oil suitable for blending into lubricants. Experience reported so far suggests odour problems may occur. Liquid waste effluents consist of process water from ejector sets and oily water	*Pre-flash and chemical treatment (1st)* Water, light ends and fuel traces contained in the used oil are removed. Atmospheric vacuum stripping + chemical treatment (optional) to minimise the corrosion and fouling of downstream equipment	*TFE (2nd)* Performed at very high temperatures and vacuums. The thin film evaporator consists of a vertical cylindrical surface enclosed in a heating jacket and an internal rotor which distributes a thin layer of oil on the heated wall, by means of rotating blades. By the action of the rotor (electrically driven), a high turbulence and back mixing occur in the thin layer of the oil film	*Distillation (4th)* The lubricating oil fraction is separated into different oil cuts in a vacuum column	*One of the following (3rd)* *a) Hydrotreatment* *b) Clay treatments* *c) Solvent extraction* *d) Solvent extraction + hydrotreatment*	With a): 72 % on dry basis With b): 54–73 % With c): 50–67 % With d): 91 %	25–160 kt/year
Thermal deasphalting process (TDA) [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [21, Viscolube 2002] [60, WT TWG 2003][98, WT TWG 2004]		*Pre-flash* Atmospheric vacuum stripping + chemical treatment. The last treatment is used to minimise the corrosion and fouling of downstream equipment and to facilitate the subsequent deasphalting step	*Settling + TDA* Deasphalted by settling. Residue removal is achieved by flashing at the bottom of the distillation column, which performs the fractionation of the different lubricating oil cuts		*a) Clay* *b) Hydrotreatment*	With a): 74 % With b): 77 %	a) 100–180 kt/year b) 40–100 kt/year
Direct contact	Waste oil and hot hydrogen gas	*Pretreatment*	*Guard hydrogenation*	*Fractionation (3rd)*	*Hydrotreatment (2nd)*	NI	100–160 kt/year

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hydrogenation process (DCH) [2, Concawe 1996] [4, Monier, V. and Labouze, E. 2001] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999][21, Viscolube 2002] [33, UK EA 2001] [60, WT TWG 2003] [98, WT TWG 2004] [106, UBA Germany 2013]	~~pass~~ enters the process as a mixture. The process produces good quality base oils (Group II): very efficient at separating contaminants from waste oil; halogenated and oxygenated compounds are destroyed; clean products (e.g. lower sulphur (<0.03 w/w-%) fuels) generated; toxic sulphide compounds are further catalytically converted to non-toxic sulphates. The waste oil is treated in a reducing environment that exhibits the formation of polymeric and carbonaceous by-products. Acid gases generated in the conversion reactor are neutralised with caustic solution. The only residues are spent catalysts. Waste water requires treatment. Hydrogen ~~needs to be generated~~ is either produced or purchased. Hydrogen-rich gas is recycled. Hydrotreatment typically increases the safety risks (due to the need for the handling of hydrogen ~~being~~ under pressure and at an elevated temperature).	Not necessary	*reactor (1st)* Hydrogen and oil vapour are routed to a two-stage fixed bed catalytic reactor. The guard reactor removes any trace metal contaminants, followed by the cracking of any sulphur, nitrogen, halogen compounds in the conversion reactor	The lubricating oil fraction is separated into different oil cuts in a vacuum column	High pressure flash separator. Fixed bed catalytic reactor. Hydrotreatment: • reduces or removes the remaining metals and metalloids of the waste oil • reduces the Conradson carbon (measurement of the tendency of a hydrocarbon to form coke) • reduces the organic acids and compounds containing chloride, sulphur and nitrogen • restores the colour, UV and thermal properties • reduces PAHs when operating under high pressure and at high temperatures • allows a viscosity index equal to or better than the original feed.		
Caustic soda and bleaching earth treatment (ENTRA) [2, Concawe 1996] [98, WT TWG 2004]	Feed: Waste oil and caustic soda. Output: the base oil produced is of good quality (Group II) with good yields: same quality and characteristics as virgin oils, Group I base oil with low sulphur and phosphorus, low aromatic content, high viscosity index and oxidation stability. Only 25 % of clay and acid is used compared to the usual clay/acid amount.	*Pre-flash* Dewatering. Feed with the addition of caustic soda (3 % referred to dry used oils) and bleaching earth (2 % referred to dry used oil)	*Tubular reactor* The breakdown of the undesired ~~metalorganic~~ organometallic, sulphur, nitrogen and halogen compounds takes place. An advanced control of temperature and retention time in a linear tubular reactor minimises the breakdown of those organic molecules which are still viable as lubricating oil components	*Fractionation* The lubricating oil fraction is separated into different oil cuts in the linear tubular reactor	*Neutralisation* Neutralisation with acid and clay treatment	NI	NI

WORKING DRAFT IN PROGRESS

Integration in the base oil production of a refinery [2, Concawe 1996] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999]	The oil produced represents a good quality of re-refined base oil. This technology improves the quality of the re-refined oil, when compared with existing re-refining plants using pre-flash, deasphalting and clay finishing. Moreover, the oil quality is claimed to be even higher in some respects compared to the conventional mineral oil produced on the same production run.	a) Pre-flash in a distillation column b) Atmospheric vacuum stripping	*TFE*	*Aromatic extraction unit* of the refinery to remove PAHs and other undesirable compounds	*Hydrofinishing*	65–70 %	NI
~~Integration in a refinery after pretreatment~~	~~Waste oil is reprocessed in a refinery to allow blending into fuel products. Contaminants within waste oils normally preclude their use as catalytic cracker feedstock or in lubricant oil production.~~	~~Water and sediments are removed from the waste oil by a pre-flash step~~	~~The pre-flashed waste oil is directly blended with the regular atmospheric residue of a refinery.~~				
* *1st, 2nd, 3rd, 4th* ~~stands for~~ represents the sequence of ~~when~~ the operations ~~are~~ being carried out within the process. When no such numbers are present, the sequence is the most common one, i.e. pretreatment, cleaning, fractionation and finishing. NI: No information							
Source: [2, Concawe 1996] [4, Monier, V. and Labouze, E. 2001] [93, UBA Germany 2003][98, WT TWG 2004]							

WORKING DRAFT IN PROGRESS

From ex-Section 2.5.2.4.3

~~**Users**~~

~~Single-stage: IFP was the first company to apply this technology in 1968 at Pieve Fissiraga in Italy (Viscolube plant). One plant in Italy producing 57 kt/yr~~
~~Two-stages: Snamprogetti installed this technology in 1982 at the Ceccano plant (Viscolube) in Italy.~~

Feed and output streams

From ex-**Section 3.4.1 "Waste IN treated to obtain a recycled material"**

Waste oils

Oils have many uses, e.g. they are used as a fuel, as lubricants, as a heat transfer medium, as cutting fluids, and as hydraulic fluids. Each has its own specification, usually based upon the hydrocarbons occurring within a specific boiling point range from the distillation of crude oil. Oils that need to be stable at high temperatures will not include large quantities of low boiling point hydrocarbons whereas oils used as fuel are more likely to include these lower boiling point hydrocarbon mixtures.

Before marketing, most base oils produced in mineral oil refineries are blended with a variety of additives to give them the required properties. Typical additive packages comprise between 5 % and 25 % of the base oil. However, probably at least half of the additive package is base oil used as solvent. Lubricating oils contain large numbers of additives, but the actual formulae are in most cases trade secrets. Data on the components and additives in new oils are given in the Safety Data Sheet which accompanies fresh products as supplied, however precise details of the formulations are company property. Hydraulic oils contain very few additives.

Some general classes of additives have been identified and are shown in Table 5.26 below. The information is not specific, but suggests that a number of metal additives, some chlorinated organic compounds, aromatic hydrocarbons, phenolic compounds and different kinds of polymers are used.

Table 5.26: Types of additives used in lubricants

Additive	Compounds used
Anti-corrosion	Zinc dithiophosphates, metal phenolates, fatty acids and amines
Anti-foam	Silicone polymers, organic copolymers
Antioxidant	Zinc dithiophosphates, hindered phenols, aromatic amines, sulphurised phenols
Anti-wear	Zinc dithiophosphates, acid phosphates, organic sulphur and chlorine compounds, sulphurised fats, sulphides and disulphides
Detergent	Organometallic compounds of sodium, calcium and magnesium phenolates, phosphonates and sulphonates
Dispersant	Alkylsuccinimides, alkylsuccinic esters
Friction modifier	Organic fatty acids, lard oil, phosphorus
Metal deactivator	Organic complexes containing nitrogen and sulphur amines, sulphides and phosphites
Pour-point depressant	Alkylated naphthalene and phenolic polymers, polymethacrylates
Seal swell agent	Organic phosphates, aromatic hydrocarbons
Viscosity modifier	Polymers of olefins, methacrylates, dienes or alkylated styrenes
Source:[45, DETR 2001]	

Additives need to be retained in the oil over its whole useful life. This means that even if the individual substance would be expected to be driven off at normal engine operating

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temperatures, there must be another additive incorporated that binds it within the oil formulation.

This requirement to keep additives in circulation, and to keep breakdown products in circulation to increase the longevity of the oil, creates one of the discussion points for emissions of waste oil. Although a number of components are solid at ambient temperatures and could be expected to settle out of the oil and into the sludge layer, dispersants in the oil will tend to keep them within the oil layer. Larger solids are taken out of the engines by the oil filters.

During use, the composition of the oil will change markedly, due to the breakdown of the additives, the formation of additional products of combustion and unburnt fuels, the addition of metals from wear and tear on the engine and from the breakdown of the base oil itself.

Large treatment sites recognise that there will be a range of species in waste oil and thus screen the incoming waste for flashpoint, metal and chlorine levels; whereas smaller sites will typically just accept the oil waste. There is a distinct shortage of analysis data for incoming wastes, although the screening activities of a few sites show that industry anticipates high metal levels and contamination by flammable solvents, giving a measurable flashpoint.

Used oils collected by high volume users can be more tightly controlled and may hence be more consistent in composition. Table 5.27 shows examples of waste containing waste oils.

Table 5.27: Type of waste containing waste oils

Type of waste containing waste oils	Comment
Oil filters	No specific analysis has been found but these are known to contain waste engine oils plus the residues of larger solids formed in the engine and that have been trapped in the filter. In addition, there are the plastic and metals of the filter. Metals tend to be sent for recycling
205-litre steel drums	Waste oil and steel
25-litre drums	Waste oil and plastics
Bulk used engine oil	Used engine oil is the main waste stream processed at licensed waste management sites. Most of the emissions will be due to this material
Source:[34, Babtie Group Ltd 2002]	

There are no comprehensive analyses available of the waste oils entering oil treatment plants. Instead the next couple of tables (Table 5.28 and Table 5.29) ~~show the data gathered~~ give an indication of the chemical components that typically exist in the different types of waste oils. It is not expected that in reality all waste oils will be covered by the lower or top ends of the ranges mentioned in these two tables.

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Table 5.28: Indicative list of components present in used oils

Waste oil components	Concentration range (ppm)	Origin/comments
Al	4–1112	Bearing wear or engine
Alkyl benzenes	900	Petroleum base oils
Aromatic compounds	14–30 w/w-%	For used motor oil, these arise from the lubricant base oil
Aliphatic compounds	65.4 w/w-%	N-alkanes are about 0.4 % waste oil, but the distribution is slanted towards the longer molecules that are less likely to evaporate: tetralin 0.0012 % dodecane 0.014 % tridecane 0.014 % octadecane 0.07 % nonadecane 0.2 %
Antifreeze	NI	NI
As	< 0.5–67	NI
Ash content	0.4–0.64 (1)	NI
Ba	50–690	Detergent additives, additive package
BTEX	300–700	A composite analysis shows a high level of short chain hydrocarbons (benzene (0.096–0.1 %), xylenes (0.3–0.34 %), toluene (0.22–0.25 %)), with boiling points below 150 °C.
Ca	900–3000	Detergent additives
Cd	0.4–22	NI
Cl	184–1500(2)	Chlorine in used oils arises from: contamination (either accidental or deliberate) with chlorinated solvents and transformer oils, both of which are now more closely controlled lubricating oil additives the lead scavengers added to leaded gasoline it is used as a cold-flow additive
Chlorinated hydrocarbons	37 6300 18–2800 18–2600 3–1300	dichlorodifluoromethane trichlorotrifluoroethane trichloroethanes trichloroethylene perchloroethylene Used oils can have a significant, but variable, chlorine content, including organochlorines such as PCB, dichlorodifluoromethane, trichlorotrifluoroethane, 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene. They may be formed chemically during the use of contaminated oil
Cr	2–89	Engine wear
Cu	< 11–250	Bearing wear
Engine blowback	8–10 w/w-%	Absorbed gas, gasoline and diesel fuel. A variety of 'thermal breakdown products' are also included in the composition of waste oil
Fe	100–500	Engine wear
Halides	Up to 500	NI
Heavy hydrocarbons		They arise from polymerisation and from the incomplete combustion of the fuel
Hg	0.05– < 11	NI
Light hydrocarbons	5–10 w/w-%	A certain amount of unburnt fuel (gasoline or diesel) dissolves in the oil and also arises from the breakdown of the oil
Lubricant base oil	Up to 95 w/w-%	Major components are aliphatic and naphthenic hydrocarbons and/or olefin polymers (e.g. polybutenes and poly-alpha-olefins in some lube base oils). Smaller amounts of aromatic and polyaromatic hydrocarbons are also present. The heavy metal content is less than 500 ppm. Phenols may be present at a few ppm

WORKING DRAFT IN PROGRESS

Waste oil components	Concentration range (ppm)	Origin/comments
Metals such as Al, As, Ba, B, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, P, Pb, Sb, Si, Sr, Ti, V, Zn	Up to 10 000 combined	These originate from the lube oil additives, engine wear and foreign sources. They appear in waste oils as additives within lubricating oil, from wear and tear on engines and with machining oils. Additives (particularly the metals) typically remain in the oil after use
Mg	100–500	Detergent additives
Ni	10	Engine wear
Naphthalenes	9.7–470–2300 (4)	From base oils
Nitrogen compounds		From the addition of nitrogen compounds
Non-lubricant-related compounds		Used oil often becomes contaminated by all kinds of materials, usually because of bad collection/segregation. Materials that may appear are brake fluid and antifreeze, vegetable oils, cigarette packets, solvents, etc.
P	6–1000	Antioxidant/anti-wear additives
PAHs	30.3–204– < 1000 (4) Sum of 26 individual PAHs represented 0.17 % of the oil or 1.2 % of the aromatic fraction	The aromatics also include a huge range of PAHs in concentrations of up to 700ppm for an individual species. They appear from base oils and from incomplete combustion. Examples are benz(a)anthracene (0.87–30 ppm), benzo(a)pyrene (0.36–62 ppm), pyrene (1.67–33 ppm), naphthalene (47 ppm), biphenyl (6.4 ppm) and also chlorinated polyaromatics
PCB	<0.5–11– < 50	Under the Waste Oil Directive, the maximum content of PCB allowed in used oils to be treated for disposal is 50 ppm. It occurs due to contamination with transformer oils
Pb	8–1200 Up to 14 000 when leaded gasoline is used	Leaded gasoline/bearing wear
S	0.1–2.8 w/w-%	From base oil and combustion products.
Sediments	0.5–2 w/w-%	Soot and sediment from the combustion chamber, free metals and dirt. Sediment formation is aggravated by the mixing of used oils from several manufacturers' additive packages, and collection sources
Si	50–100	Additives/water
Sn	Trace amounts	Bearing wear
Tl	0.1	
V	300	From base oil
Water	5–10 w/w-% (3)	Combustion
Zn	6–4080	Antioxidant/anti-wear additives

NB: Additions of figures cannot be made to fit perfectly because they correspond to different sets of data.

(1) Both parameter limits are average values.

(2) Up to 8452 ppm in collected used oil due to contamination with chlorinated solvents and sea salt from ship slops.

(3) Up to 30 %.

(4) When three numbers appear in a range, the middle number corresponds to the average.

NI: No information

Source:[1, Langenkamp H. 1997] [2, Concawe 1996] [3, Silver Springs Oil Recovery Inc. 2000] [10, Ministry for the Environment 2000][22, Woodward-Clyde 2000] [34, Babtie Group Ltd 2002] [26, UK, H. 1995] [98, WT TWG 2004]

WORKING DRAFT IN PROGRESS

Used industrial oils

A variety of oils are used in industry including soluble oils and some halogenated oils, although these are becoming less common. Oil is used as hydraulic oil, as lubrication, as a heat transfer medium, as an electrical medium and as a cutting fluid.

Soluble oils/machining oils are very common, but there is no information so far about their composition. Many of these industrial oils undergo intensive in-house recycling to extend their useful life, and the majority of any metal contaminants associated with grinding operations are removed by in-house systems and recovered. In the absence of other data, the following assumptions have been made:

- These oils are used in open systems. Their formulations do not include very low boiling point/volatile hydrocarbons because of the fire risk and health risks during use and the need to retain the product characteristics during use. They are agitated during use, and take away excess heat from machining surfaces, thus in operation they are heated above the ambient temperature. Therefore, VOC emissions during waste treatment are typically very small.
- The metal content will vary considerably from source to source. The main metals worked with will be copper, zinc, nickel and chromium.

Table 5.29: Estimated metal concentrations in industrial waste oils

	Concentration	**Reason**
Cadmium	50 % of concentration in lubricating oil or 0.000155 %	Cadmium is currently being phased out from the manufacture of lubricating oil
Chromium	100 % of concentration in lubricating oil or 0.0028 %	Common: typically used at the same level as in engine oil
Copper	100 % of concentration in lubricating oil or 0.025 %	Common: typically used at the same level as in engine oil
Lead	0	No particular reason to machine this
Naphthalene	0.0042 %	No data at all, naphthalene is in all oils, but one would expect the formulation to have the lowest amount possible (taken from fuel oil n^{o}6 content) because it would be a solid at room temperature and does not seem to add anything chemically useful to the formulation
Nickel	0.0028 %	No data for lubricating oils
PCB		Found in transformer coolant oils
Xylenes	0.22 %	
Zinc	50 % of concentration in lubricating oil or 0.029 %	Common machining component, but zinc appears to be a major additive in lubricating oils
Source: [34, Babtie Group Ltd 2002] [60, WT TWG 2003]		

Electrical oils are specialist oils which undergo a laundering process, so very little waste arises from them. The main concern with these oils is the risk of PCB contamination. Typically waste treatment facilities do analyse for PCBs.

Oily water from interceptors

Most waste from interceptors comes from car parks and vehicle service areas. It is therefore reasonable to assume that it is similar in content to used engine oil but that it will contain additional silt, possibly vehicle tyre wear particles, fuel combustion products and road-making tars. Spilt fuel will also be collected at the interceptor, but any materials that are capable of evaporating to the air at ambient temperatures will have done so before the interceptor waste is collected.

A proportion of oil interceptors arises from manufacturing sites and collected industrial waste oils. These will have far lower concentrations of combustion products, but might have higher metal concentrations, depending on the industrial application.

WORKING DRAFT IN PROGRESS

From ex-**Section 3.4.4 "Waste OUT from re-recycling/regeneration treatments"**

Re-refined waste oil

The quality of the base oil obtained is dependent upon the level of treatment applied. For example, severe processing involving hydrotreatment will be required in order to significantly remove PAHs.

Used oils vary according to the origin and type of oil collected. These variations are reflected in the base oil products from acid/clay treatment plants, in terms of their density, viscosity, viscosity index, sulphur level, etc. Less variation occurs in these parameters in the base oil products from vacuum distillation/hydrotreating units, with the exception of the sulphur content. Re-refined base oils from different processes and production plants vary greatly in their characteristics.

Some re-refining technologies allow the production of premium quality base oils: i.e. at least Group I according to the API base oils classification; and, when resorting to a severe hydrotreatment or solvent finishing, Group II base oils (e.g. topping purpose). The base stocks produced by the European re-refining industry today belong to Group I. Group I base stocks are solvent-refined mineral oils. They contain the most saturates and sulphur and have the lowest viscosity indexes. They define the bottom tier of lubricant performance. Group I stocks are the least expensive to produce. They currently account for about 75 % of all base stocks, comprising the bulk of the 'conventional' base stocks.

Almost all waste oil re-refining plants test for chlorine content and water content, and usually for PCBs. The final recovered oil is analysed because it has to satisfy specifications from the end user, but not all oil treatment plants blend a final product for sale or carry out such analyses. Table 5.30 shows an example of an analysis of the product made in an oil recovery plant, where several degrees of hydrotreatment are carried out on three different types of base oil (spindle, light and heavy lube oil).

WORKING DRAFT IN PROGRESS

Table 5.30: Effect of hydrotreatment on the pollutants of the feed after deasphalting

Type of feed	Spindle lube oil	Low severity *1	High severity #2	Light lube oil	Low severity *3	High severity #4	Heavy lube oil	Low severity *5	High severity #6
Density 15/4	0.8678	0.8606	0.8526	0.8767	0.8699	0.8604	0.8868	0.8786	0.8676
Viscosity at 40 °C (cSt)	26.91	23.8	21.19	56.52	49.85	38.18	117.2	97.86	70.08
Viscosity at 100 °C (cSt)	4.76	4.5	4.2	7.78	7.32	6.37	12.24	11	9.1
Viscosity index	93	103	100	102	107	117	94	97	105
Colour	6.5	L 0.5	L 0.5	7.5	L 1	L 0.5	> 8	L 2	L 0.5
Asphaltenes (w/w-%)	0.0105	-	-	0.0092	-	-	< 0.01	-	-
Carbon Conradson (w/w-%)	0.63	< 0.1	< 0.1	0.12	< 0.1	< 0.1	0.33	< 0.1	< 0.1
Nitrogen (ppm)	280	49	< 1	312	57	< 1	307	137	< 1
Sulphur (ppm)	0.412	0.1025	0.0005	0.526	0.163	0.0008	0.7285	0.2735	0.0021
ndM method (w/w-%)									
Aromatic carbon	12.11	10.72	8.72	11.63	10.25	8.48	11.94	10.22	8.18
Paraffinic carbon	71.20	72.06	72.76	72.66	73.42	75.09	72.68	73.75	75.57
Naphthenic carbon	16.70	17.22	18.52	15.70	16.32	16.43	15.38	16.03	16.25
Gas Chromatography analysis in ppm									
Anthracene	< 1	< 1	< 0.5	< 1	< 1	< 0.5	< 1	< 1	< 0.5
Benzo(a)anthracene	37	< 1	< 0.5	4	< 1	< 0.5	3	< 1	< 0.5
Benzo(k)fluoranthe e	5	< 1	< 0.5	2	< 1	< 0.5	< 1	< 1	< 0.5
Benzo(b)fluoranthe e	25	< 1	< 0.5	11	< 1	< 0.5	4	< 1	< 0.5
Benzo(ghi)perilene	16	< 1	< 0.5	40	4.7	< 0.5	12	2.30	< 0.5
Benzo(a)pyrene	16	< 1	< 0.5	11	< 1	< 0.5	4	< 1	< 0.5
Chrisene	3	< 1	< 0.5	2	< 1	< 0.5	-	< 1	< 0.5
Dibenz-ah-anthracene	< 1	< 1	< 0.5	2	< 1	< 0.5	< 1	< 1	< 0.5
Fluoanthene	24	< 1	< 0.5	2	< 1	< 0.5	< 1	< 1	< 0.5
Indeno(123-cd)pyrene	10	< 1	< 0.5	27	< 1	< 0.5	6	< 1	< 0.5
Phenanthrene	2	8.7	< 0.5	< 1	1	< 0.5	< 1	1.30	< 0.5
Pyrene	34	5.8	< 0.5	< 1	< 1	< 0.5	2	< 1	< 0.5
PNA IP 346 (w/w-%)	2.8	1	0.2	1.3	0.6	-	1	0.6	0.2

* Low severity in the hydrotreatment of the light fraction: Temperature of first catalyst: 300 °C. Temperature 2nd catalyst: 280 °C. H_2 partial pressure: 105 bar.

\# High severity in the hydrotreatment of the light fraction: Temperature of first catalyst: 340 °C. Temperature 2nd catalyst: 340 °C. H_2 partial pressure: 105 bar.

Total LHSV (h^{-1}): ^{1}:0.507; ^{2}:0.5; ^{3}:0.507; ^{4}:0.292; ^{5}:0.481; ^{6}:0.295.

Source:[21, Viscolube 2002]

Base oil produced is more dependent on the technology used to treat the waste oil than on the differences of the waste oil collected. Some examples of this are shown in Table 5.31.

WORKING DRAFT IN PROGRESS

Table 5.31: Product issues related to different waste oil regeneration techniques

Process (deasphalting, demetallisation + finishing)	Main products (Values correspond to kg/tonne of WO unless otherwise stated)
Sulphuric acid + clay treatment	Low quality re-refined base oil: 621 PAH content of the base oils produced can be comparatively high (4–17 times higher than virgin base oils) Gas oil: 70
Caustic soda and bleaching earth treatment (ENTRA)	High quality re-refined base oil (Group II): 520 Light ends: 170 Diesel: 170
Vacuum distillation	In modern vacuum distillation equipment designed for processing used oils, the distillate produced has a metal content of less than 1 ppm (according to licensors)
Vacuum distillation + chemical treatment or clay treatment.	The base oils produced by clay treatment or by chemical treatment have a metal content of < 1 ppm. This process may not reduce the PAH content of the oil by as much as hydrotreatment
Thin film evaporator (TFE) + clay treatment	Medium quality re-refined base oil: 530–650 Gas oil: 150
TFE + hydrofinishing	High quality re-refined base oil: 630 Gas oil: 100
TFE + solvent extraction	High quality re-refined base oil: 600 Gas oil: 120–150
TFE + solvent extraction + hydrofinishing	High quality re-refined base oil • lubricant Group II: 370 • lubricant Group I: 300 Gas oil: 85
TDA (thermal deasphalting) + clay treatment	Medium quality re-refined base oil: 500–600 Gas oil: 60–80
TDA + hydrofinishing (high pressure)	High quality re-refined base oil: 670 Gas oil: 70
PDA (propane deasphalting) + hydrofinishing (medium pressure)	High re-refined base oil: 660–700 Gas oil: 43–55 This process yields more marketable products than regeneration by a chemical treatment
Distillation and alkali treatment (Vaxon – Cator)	
Vacuum distillation + chemical treatment or clay treatment	As much as by hydrotreatment or solvent extraction
DCH (Direct contact hydrogenation)	Base oil (group II): ~~770 – 820~~ 650–700 Light ends: ~~20 – 40~~ 30 ~~Heavy fuel or diesel: 70 – 80~~ Gas oil (desulphurised): 80 Heavy fuel oil: 150
~~Thermal clay treatment~~	
~~Hydrofinishing~~	
Vacuum distillation + chemical treatment	Base oil: 540 kg Fuel oil: 6105 MJ Bitumen fluxant: 48 kg Other fuels: 3720 MJ Fuel saving

Source: [3, Silver Springs Oil Recovery Inc. 2000] [4, Monier, V. and Labouze, E. 2001] [7, Jacobs, A. and Dijkmans, R. 2001] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [93, UBA Germany 2003] [98, WT TWG 2004] [164, UBA]

WORKING DRAFT IN PROGRESS

5.2.2 Current emission and consumption levels

5.2.2.1 Emissions from the re-refining of waste oils

From ex-**Section 3.4.3.1 Emissions from the re-refining of waste oils**

In order to evaluate emissions from the re-refining of waste oils, several issues need to be considered:

- waste lubricating oils contain shorter chain organics than new lubricating oils and therefore VOCs are likely to be relevant;
- sulphur and chlorine are known 'problem' compounds found in waste oils;
- aromatic compounds are more polar in general than aliphatic molecules and are therefore more likely to be present in the aqueous phase.

The oil processing sector has a narrow range of operations and is the most likely to respond to a generic method of calculating emissions if the oil constituents can be identified. The following tables detail the different pollutants and media where they can be found. Some tables have been constructed to focus on the pollutants (~~Table 5.32 and~~ Table 5.33) whereas others focus on the activities that may lead to pollution (Table 5.34).

Ancillary emissions typically occur from the on-site generation of heat for the distillation process (combustion products such as NO_X, SO_X and CO).

Table 5.32: Common emissions from waste oil treatment plants

~~**Species**~~	~~**Air**~~	~~**Water**~~	~~**Waste and soil**~~
~~*Organic compounds*~~			
~~Benzene~~	~~yes - some data, but difficult to apportion between air/water/land~~	~~yes - some data, but difficult to apportion between air/water/land. Polar compound~~	~~yes - some data, but difficult to apportion between air/water/land~~
~~Ethyl benzene (VOC)~~	~~No data available~~	~~yes (as BTEX)~~	~~yes (as BTEX)~~
~~Toluene~~		~~yes - some data, but difficult to apportion between air/water/land~~	~~yes - some data, but difficult to apportion between air/water/land~~
~~Xylenes~~	~~yes - some data, but difficult to apportion between air/water/land~~	~~yes - some data, but difficult to apportion between air/water/land~~	~~yes - some data, but difficult to apportion between air/water/land~~
~~VOCs~~	~~yes - some incomplete data, but difficult to apportion between air/water/land. Lower chain alkanes likely to go to air.~~ ~~Since used oil usually contains light ends such as gasoline, VOCs may be emitted from storage (from the tank and their associated pipework) for every process considered. The behaviour of oils undergoing heating and agitation generates VOCs emissions~~	~~BTEX in particular are polar molecules, but also volatile, and are present in the aqueous phase and/or evaporated to the air~~	
~~Naphthalene~~		~~Some data available~~	~~Some data available~~

WORKING DRAFT IN PROGRESS

~~Species~~	**~~Air~~**	**~~Water~~**	**~~Waste and soil~~**
~~Biphenyl~~		~~Limited data, may not be relevant~~	~~Limited data~~
~~Phenol~~	~~Not air emissions expected because too soluble in oil and water~~	~~Relevant but no data~~	~~Relevant but no data~~
~~Sulphur and nitrogen compounds~~	~~The gradual increase in sulphur and nitrogen additives in lubricating oils may require sites to monitor for these~~		~~Found in used oil sludge~~
~~PCBs and chlorinated solvents: Identified as present in some analyses~~		~~Solvents and lighter compounds are removed in the dewatering. Naphtha and light distillate cuts are typically distilled off upstream of the main processing facilities. If the hydrocarbon streams are fed to a hydrotreater, the chlorides may be removed~~	~~Used oil sludge~~
~~PAHs. These used to be a problem in re-refined base oils. However, recent tests indicate that it is possible to remove PAHs in the regeneration process of modern plants, thus avoiding the accumulation of PAHs.~~ ~~PAHs are destroyed by severe hydrogenation which also removes nitrogen, sulphur, metals and chlorides~~	~~PAHs are unlikely to be discharged to the air during the oil treatment processes. They are not volatile compounds, and their position as an air carcinogen is due to them being released as a combustion product from fossil fuels.~~ ~~Potential for PAH emission may be during the processing of oil filters. Most filters are crushed at some point, producing a fine oil mist. There may be a hood and an exhaust vent, but this is a potential mechanism to deliver PAHs to the air and the oil in oil filters have a larger concentration of particulate matter and hence PAHs. This may not be of significant importance, as it is the smaller particles that are more likely to form an air discharge.~~ ~~The behaviour of oils undergoing heating and agitation may generate PAHs emissions.~~	~~Relevant but no data~~	~~The heavy PAHs in the regeneration plants end up in either the residue stream and/or the asphalt blends. The lighter ones remain in the lube oil cuts.~~ ~~Also possibly found in a used oil sludge. Relevant but no data~~
~~Other air pollutants~~			
~~CO_2 from many combustion processes~~			

WORKING DRAFT IN PROGRESS

~~**Species**~~	~~**Air**~~	~~**Water**~~	~~**Waste and soil**~~
~~Odour~~	~~Odour has been identified as an important problem in re-refining installations~~		
~~*Typically water and waste parameters*~~			
~~Total nitrogen~~		~~Nitrogen and phosphorus additives~~	~~Nitrogen and phosphorus additives~~
~~Total phosphorus~~		~~Nitrogen and phosphorus additives~~	~~Nitrogen and phosphorus additives~~
~~TOC~~		~~Calculated from COD as 1/3 of COD~~	~~Not available except as calculated from oil content, but this will be too low (or COD)~~
~~Chloride~~		~~Additives in oil and salt on roads~~	~~Additives in oil and salt on roads~~
~~Oil~~		~~The oil itself is a visual pollutant when it floats on water, and drinking water is rapidly tainted by the taste of oil~~	~~Used oil sludge~~
~~*Metals*~~			
~~Metals~~			~~The metals from regeneration processes are mostly in the residue cut. The volatile metals are removed by the hydrotreatment guard reactor if they are hydrotreated. Also possibly found in used oil sludge~~
~~Arsenic~~	~~Not expected~~	~~Some data available~~	~~Some data available~~
~~Cadmium~~	~~Not expected~~	~~Some data available, but being questioned~~	~~Some data available, but being questioned~~
~~Chromium~~	~~Not expected~~	~~Some data available~~	~~Some data available~~
~~Copper~~	~~Not expected~~	~~Limited data~~	~~Limited data~~
~~Lead~~	~~Not expected~~	~~Some data available, but being questioned~~	~~Some data available, but being questioned. In the re-refining options, lead ends up in the heavy residues which results in it being 'locked up' in a bitumen product~~
~~Manganese~~	~~Not expected~~		
~~Nickel~~	~~Not expected~~	~~yes, but no data~~	~~yes, but no data~~
~~Zinc~~	~~Not expected~~	~~Some data available~~	~~Some data available~~

~~*Source:*[2, Concawe 1996] [6, ANPA and ONR 2001] [10, Ministry for the Environment 2000] [34, Babtie Group Ltd 2002] [60, WT TWG 2003]~~

Table 5.33 reflects how the components of the waste oil distribute emissions to air, sewers and products. As can be seen, most of the contaminants remain in the recovered oil. The main exception to this is VOCs, where there is a possibility of their transfer to air, with the amount depending on the type of oil and whether the oil is heated during treatment.

WORKING DRAFT IN PROGRESS

Table 5.33: Matrix for allocating input species to air, oil and water streams for hot and cold processes

	Hot processing			Cold processing		
	Air	**Products**	**Water**	**Air**	**Products**	**Water**
Benzene	0.6	0.3	0.1	0.2	0.7	0.1
Toluene	0.3	0.7	0	0.1	0.9	0
Xylenes	0.1	0.8	0.1		0.9	0.1
Naphthalene		1			1	
Biphenyl		1			1	
Benz(a)anthracene		1			1	
Benzo(a)pyrene		1			1	
Heptane	0.2	0.8			1	
Octane	0.1	0.9			1	
Nonane		1			1	
Decane		1			1	
Undecane		1			1	
Arsenic		1			1	
Cadmium		1			1	
Chromium		1			1	
Copper		1			1	
Lead		1			1	
Nickel		1			1	
Zinc		1			1	

NB: Figures correspond to the share distribution of substances in output streams. For example, for each kg of benzene entering the hot processing, 0.6 kg ends up as an emission to air, 0.3 kg goes into the oil and 0.1 kg into the waste water. 1 means that all the input goes to that output.
Source: [34, Babtie Group Ltd 2002]

WORKING DRAFT IN PROGRESS

Table 5.34: Principal emission sources at oil recycling premises

	Point source emissions		
Activity/Plant	**To air**	**To water**	**To disposal**
Filter shredding	Oil mist		
Magnetic separation	Oil mist		
Drum emptying/shredding	Oil mist		
Tanker unloading	Tank venting		
Coarse straining	Oil mist		
Bulk storage	Tank venting. Very few tank vents are linked ~~together~~. Tank vents will discharge the 'air' that the tank contains when it is displaced during tank filling. This emission is unlikely to carry significant pollution unless the tank contents have been heated or agitated	Settled water (via treatment)	Settled sludge
Cold oil settling	Tank venting	Settled water (via treatment)	Settled sludge
Hot oil settling	Tank venting	Settled water (via treatment)	Settled sludge
Vibrating sieve	Mist and vapour		Sludge
Enclosed filters			Used elements and sludge
Bauxite towers			Spent bauxite
Vacuum dehydration	Vapour (via scrubbers)		
Product blending	Tank venting		
Pumped sludge storage/decanting	Tank venting		
Cold effluent settling	Tank venting		
Hot effluent settling	Tank venting		
Biological effluent treatment	Aeration air		
Filter press			Filter cake
Plate separator		Effluent	Settled sludges
Mechanically handled sludge/solids storage and loading			Mixed solid wastes
Waste oil-fired boiler	Stack emissions		
Old interceptor waste	As it usually comes from paved surfaces where it has already been exposed to air, it will probably have already emitted all that it is capable of emitting to air at this stage unless it is heated during treatment		

NB: Many sites have an accidental spillage of oils to the site base during unloading, or during the storage or transfer of materials on site. The site base is usually designed to retain liquid spills and to return these to the plant, but there will be some evaporation into the air.
Source: [34, Babtie Group Ltd 2002] [98, WT TWG 2004]

The following Table 5.35 identifies emissions to air and water and the solid waste generated for each type of waste oil treatment. In some cases, the emissions are quantified with data in the table.

WORKING DRAFT IN PROGRESS

Table 5.35: Environmental issues generated by different waste oil re-refining techniques

Process	Emissions (values in kg/tonne of WO if not otherwise specified)		
	Air	Water	Soil and residues
Oil separation from water stream	Could produce a range of other emissions such as metals, naphthalene, additional nitrogen, toluene, xylenes and PAHs	Could produce a range of other emissions such as metals, naphthalene, toluene, xylenes and PAHs	Could produce a range of other emissions such as metals, naphthalene, toluene, xylenes and PAHs
Laundering. Closed loop recycling of industrial oil	From the oil recovery process the emission is 20–40 mg/m^3 VOCs whilst heating. 262 kg VOC were released against 100 mg/Nm^3 and l0 t/yr limits	Waste water	Laundering can be considered a closed loop system because it generates very little (if any) waste oil. The contaminated filter sludge contains 20–30 % oil. This waste stream is reprocessed with quicklime and made suitable for co-combustion in a cement kiln. The acceptability of one technique, which used a clay known as 'fuller's earth' to remove contaminants, is waning as conditions for disposal to landfill become more stringent. The technique is still used in New Zealand, but disposal of the contaminated clay is likely to become an issue. Releases to land are: filter cake which includes solids and metal fines (< 100 t/yr against a consent limit of 600 t/yr) and in some cases chlorinated solvent sludges. 80–85 % of drums are recycled while the others are scrapped
Reclaiming industrial lubricants		Waste water from dewatering processes	
Vacuum distillation	Vacuum distillation of waste oils produces sulphur compounds, mercaptans (odorous) and PAHs (some may be carcinogenic)		All the metals contained in the used oil end up in the vacuum residue. This residue may be blended with a crude vacuum residue in such a proportion so as to enable its use as a component in bitumen
Distillation/clay process			Produces large quantities of the oil-absorbed clay which need to be disposed of. High temperature-activated clay allows a lower clay/oil ratio, thus increasing the overall yield and reducing the quantity of oily clay needing to be disposed of
Thin film evaporator (TFE) + clay treatment		Water: 90	Clay: 50–60 Bitumen (metals and additives): 130 Sludge and light ends: 35 The process produces residues (requiring disposal)
Acid/clay process			This process produces large quantities of sludges and solids requiring disposal. These sludges (acid tars) are highly

WORKING DRAFT IN PROGRESS

Process	Emissions (values in kg/tonne of WO if not otherwise specified)		
	Air	Water	Soil and residues
			acidic and contain high concentrations of PAHs, sulphuric acid and sulphur compounds, as well as most of the metals from the used oils. These tars are unsuitable for landfill because of their physical and chemical properties. This latter constraint can sometimes be overcome by: • Dispatching the acid sludge jointly with the oily clay, in granulated form, to cement factories or to contractors • Incinerating, but the gases need to be treated with caustic soda and the resulting waste water needs to be dealt with. This neutralisation treatment generates ~~in quantity~~ as much inactive waste as the amount of acid tar treated • Treating to produce sulphuric acid or SO_2. The used clay (4 % by weight of feedstock + absorbed oil content) also needs to be incinerated by the same method as described above
Vacuum distillation + chemical treatment or clay treatment			Used clay and used chemicals need to be safely disposed of. The route currently in use is to burn them in cement kilns or in a chemical waste incinerator
Vacuum distillation and hydrotreatment	Emissions common to any process handling oil products		The disposal of spent hydrotreating catalysts needs to be handled by a specialised company familiar with this problem. The residue produced from the vacuum distillation stage is similar to asphalt and may be sold. Fuels that are taken out in the defuelling stage can also be used on site or sold. The catalyst used is nickel-molybdenum and is either recycled by a nickel smelter or landfilled
TFE + hydrofinishing		Water: 90	Sludge and light ends: 30 Sulphur: 35 Bitumen: 130
TFE + solvent extraction		Water: 90	Sludge and light ends: 30 Extract: 60 Bitumen: 130
TFE + solvent extraction + hydrofinishing		Water: 65	Sludge and light ends: 20 Sulphur: 4 Bitumen: 160
TDA (thermal deasphalting) + clay treatment		Waste water: 770	Light ends/solvents: 35 Clay: 130 Bitumen (metals and additives): 120
TDA + hydrofinishing (high pressure)		Waste water: 770	Light ends/solvents: 35 Spent catalyst: 0.5 Bitumens: 120
PDA (propane deasphalting) + hydrofinishing		Waste water: 770	Light ends/solvents: 30 Bitumens: 130

WORKING DRAFT IN PROGRESS

Process	Emissions (values in kg/tonne of WO if not otherwise specified)		
	Air	**Water**	**Soil and residues**
(medium pressure)			
Vacuum distillation + chemical treatment	1116 kg eq CO_2 2.8 kg eq SO_2 VOCs: 0.04 kg eq. C_2H_4 3.6 g particulates	0.0011 kg eq phosphates in water	Waste to eliminate: 24 Waste to recover: 33
Distillation and alkali treatment (Vaxon-Cator)		None. Recycled to a product	Small
Solvent extraction and distillation (Sener-Interline)		Discharges to water are from the residuum/water separator	None
DCH (Direct contact hydrogenation)		Waste water: 60	~~Bitumens: 50~~ Spent catalyst: ~~0.75~~ 0.5
Thin film evaporator (TFE)		Process water, water decanted from storage tanks and contaminated surface water are treated in the effluent plant. This presents a problem for the site in that the water has a very high COD which can vary between 40 000 mg/l and 100 000 mg/l against a discharge consent limit of 80 000 mg/l. It contains materials such as glycols, polyglycols, esters and glycerols	The residue from the TFE is extracted whilst still mobile and blended with other secondary fuel oils which are also produced on site. Most of the organometallic constituents of the additives end up in the residue, so their ultimate destination is in a secondary fuel oil released to air as combustion products. There is a high dilution of the residue into the secondary fuel oil formed and the blend meets fuel oil specifications. Other residues, which include storage tank and effluent plant sludges, are removed from the site and centrifuged for reclamation of the oil. The solid residue from that process is then landfilled
Caustic soda and bleaching earth treatment (ENTRA)		Waste water: 60	Bleaching earth, caustic soda and residue: 150
Waste oil transfer station		Waste water: 102	Sludge and solids: 2.13 Shredded steel: 85
Treatment of transformer oils			Spent bauxite catalyst Non-returned drums and pallets
Treatment of oil interceptor waste, soluble cutting oils, spray booth waste from water-based paint, gully waste, leachates		Waste water: 1613	Pumpable sludge: 47 Tank and tanker 'dig out' and screened waste: 43
Re-refining of lubricant oil (1)	CO_2: 123 SO_2: 1.04 NO_X: 0.35	Waste water: 84	Oil/chemical waste – sludge: 0.088
Used solvent oils and oily waters		Waste water: 444	Solids and sludge: 171
Treatment of oil water mixtures and leachates		Effluent: 1042	Filter cake and sludge: 55
Integration in a mineral oil refinery	Provided that adequate		Metals are encapsulated in asphalt, so the leaching of metals will be extremely low.

WORKING DRAFT IN PROGRESS

Process	Emissions (values in kg/tonne of WO if not otherwise specified)		
	Air	Water	Soil and residues
	pretreatment of used oils is performed to remove water and light ends and to reduce the organic chloride content, the emissions are related to those occurring in a refinery (see Refinery BREF)		However, some problems of corrosion damage to the plant and loss of cracking catalyst activity need to be solved before this can be considered a viable option
Integration into a lubricant part of a refinery	It could release particulates, sulphur, halides, heavy metals and their oxides to air		Most of the lube oil additives are bottomed out in this cut. The metals in the residue after the solvent extraction process are still leachable. There could be problems in its disposal to asphalt, especially in winter, when the market may slow. This cut would not be fit for blending in heavy fuels, not only for failing the filtration tests, but also for environmental reasons. The aromatic extracts which are contaminated with chlorine are believed to be disposed of outside the refinery
Regeneration	CO_2 equivalent (kg eq. CO_2/kg of oil) 3.19 Acidification potential (g eq. H+/kg of oil) 0.06 VOC emissions (g/kg of oil): 9.05 CO emissions (g CO/kg of oil) 9.74	COD (g COD/kg of oil): 35.02	Waste (g/kg of oil): 411
~~Chemical treatment + distillation + HF~~			

[1] Calculations were made based on the yearly treatment/usage of 26 000 tonnes of dehydrated waste oil and producing 8000 tonnes of base oil, 12 000 tonnes of fuel oil and 4000 tonnes of asphalt.

Source:[3, Silver Springs Oil Recovery Inc. 2000][4, Monier, V. and Labouze, E. 2001] [7, Jacobs, A. and Dijkmans, R. 2001] [8, Birr-Pedersen, K. 2001] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [10, Ministry for the Environment 2000] [26, UK, H. 1995] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [93, UBA Germany 2003] [98, WT TWG 2004] [100, WT TWG 2004]

Table 5.36 gives the environmental performance criteria of different treatment systems arising from an industry survey. ~~In the survey, a profound discussion for each figure in the table is given~~. Each figure represents the absolute value that is assigned to that treatment system, concerning a specific criterion and estimating the performance of the system relative to the other systems for said criterion.

WORKING DRAFT IN PROGRESS

Table 5.36: Evaluation of the environmental performance of several reuse and re-refining activities

Process	Environmental criteria				
	S compounds	**Metals**	**Products of incomplete combustion + VOCs**	**Reuse of materials**	**Reuse of energy**
Laundering. Closed loop recycling (reuse)	1	1	3	1	5
Chemical re-refining without distillation	2	2	3	1	5
Re-refining with distillation	1	1	1	1	5
Blending into vacuum residue of a refinery	5	3	4	5	1

NB: S compounds: the ~~ultimate~~ final destination of the sulphur content originating from the waste oil.
Metals: the ~~ultimate~~ final destination of the metals originating from the waste oil.
Products of incomplete combustion + VOCs: the emission of VOCs or products of incomplete combustion (CO, PAHs, soot, dioxins, furans, etc.) originating from the waste oil.
Values: 1 best performance, 5 worst – on a relative scale.

Source: [7, Jacobs, A. and Dijkmans, R. 2001]

Emissions to air

The emissions to air are partially controlled at some sites, but uncontrolled at others. VOC emissions are known to occur. Although the lubricating system is a semi-closed system, it is not gastight, therefore it would be expected that the volatile gases would have boiled off and left the system at ~~during~~ normal operating temperatures.

~~Abatement systems for reducing oil emissions to the air are in place in some plants. At other sites, the excess oil concentration in buildings is simply vented to the air through exhaust fans; with all the tanks having vents to the air.~~

Most plants will accept that there is an odour problem from the oil. The control of odour from such plants requires a high level of management control and attention. Odours are typically generated during storage, e.g. odour problems can arise by leaving hatches open at the top of each settlement tank and oil storage tank, or in open vibrating sieves.
~~No generally recognised reliable figures have been found for the concentration of contaminants in the air emitted from waste oil re-refining processes. However, some matrix distributions are shown inTable 5.37.~~

WORKING DRAFT IN PROGRESS

Table 5.37: Air emissions matrix for all common process in oil and solvent regeneration plants

~~Activity~~	~~Oil filters~~	~~25 litre oil drums~~	~~205 litre oil drums~~	~~Bulk used engine oil~~	~~Used industrial oils~~	~~Oily waters (interceptors)~~	~~Fuel oils~~	~~Electrical oils~~
~~Filter bin unloading~~	▨							
~~Filter bin storage~~	▨							
~~Filter crushing~~	▨							
~~Filter shredding~~	▨ ~~*~~							
~~Magnetic separation~~	▨ ~~*~~							
~~205 litre drum unloading~~		▨	▨					
~~205 litre drum storage~~		▨	▨					
~~205 litre drum emptying~~		▨	▨					
~~25 litre drum unloading~~		▨	▨					
~~25 litre drum storage~~		▨	▨					
~~25 litre drum emptying/shredding~~		▨ ~~*~~	▨					
~~Tanker unloading~~				▨	▨	▨	▨	▨
~~Coarse straining~~				▨	▨	▨	▨	▨
~~Bulk storage~~				▨	▨	▨	▨	▨
~~Cold oil settling~~				▨	▨	▨	▨	▨
~~Hot oil settling~~				▨ ~~*~~	▨ ~~*~~	▨	▨	▨
~~Distillation~~				▨ ~~*~~	▨ ~~*~~	▨	▨	▨
~~Vibrating sieve~~				▨	▨	▨	▨	▨
~~Centrifuge~~				▨	▨	▨	▨	▨
~~Bauxite towers~~								▨ ~~*~~
~~Vacuum dehydration~~								▨ ~~*~~
~~Product blending~~				▨	▨	▨	▨	▨
~~Pumped sludge storage/decanting~~				▨	▨	▨	▨	▨
~~Effluent incineration~~				▨ ~~*~~	▨ ~~*~~	▨ ~~*~~	▨ ~~*~~	▨
~~Cold effluent settling~~				▨	▨	▨	▨	▨
~~Hot effluent settling~~				▨ ~~*~~	▨ ~~*~~	▨ ~~*~~	▨ ~~*~~	▨
~~Biological effluent treatment~~				▨ ~~*~~	▨ ~~*~~	▨ ~~*~~	▨ ~~*~~	▨
~~Effluent clarification~~				▨	▨	▨	▨	▨
~~Effluent balance tank~~				▨	▨	▨	▨	▨
~~Plate separator~~				▨	▨	▨	▨	▨
~~Mechanically handled sludge/solids storage and handling~~				▨	▨	▨	▨	▨
~~Waste oil fired boiler~~				▨ ~~*~~	▨ ~~*~~	▨ ~~*~~	▨ ~~*~~	▨

~~Note: The grey blocks indicate emissions are likely and the asterisks indicate the locations that are thought to be the larger sources~~
~~*Source*: [34, Babtie Group Ltd 2002]~~

WORKING DRAFT IN PROGRESS

Table 5.38 Air emissions from several re-refining waste oil installations operating in the EU

~~**Capacity**~~	~~**t/yr**~~		~~**6824**~~	~~**15000**~~		~~**17171**~~	~~**46208**~~		~~**90500**~~	
~~Fumes generated~~		~~Million Nm^3/yr~~			~~14.89~~			~~175.4~~		~~210.5~~
~~Oxygen~~	~~%~~			4		~~7.4~~	~~3~~		~~10~~	
~~CO^2~~	~~t/yr~~						~~24000~~			
~~PM~~	~~mg/Nm^3~~	~~kg/yr~~	4	~~0~~		~~4.23~~	~~11.17~~	~~1960~~	~~28.4~~	
~~SO^*~~	~~mg/Nm^3~~	~~kg/yr~~	~~14~~	~~4000~~	~~60000~~		~~529.7~~	~~92910~~	~~4.2~~	~~884~~
~~NO^*~~	~~mg/Nm^3~~	~~kg/yr~~	~~63.7~~			~~90~~	~~225.8~~	~~39610~~	~~802.5~~	~~168891~~
~~TOC~~	~~mg/Nm^3~~			~~0~~					~~3~~	
~~CO~~	~~mg/Nm^3~~	~~kg/yr~~	~~501.6~~	~~0~~		~~193~~	~~7.4~~	~~1300~~	~~18.9~~	~~3978~~
~~HCl~~	~~mg/Nm^3~~	~~kg/yr~~		~~0~~		~~2.8~~	~~1.5~~	~~263~~	~~0.8~~	
~~HF~~	~~mg/Nm^3~~			~~0~~					~~0.08~~	
~~Total metals~~	~~mg/Nm^3~~			~~0~~					~~0.423~~	
~~Hg~~	~~mg/Nm^3~~			~~0~~					~~0.026~~	
~~Cd + Tl~~	~~mg/Nm^3~~	~~kg/yr~~		~~0~~			~~0.0008~~	~~0~~	~~0.0008~~	
~~PAH~~	~~mg/Nm^3~~	~~kg/yr~~	~~0.0008~~	~~0~~			~~8E-07~~	~~0.000175~~	~~0.0008~~	
~~PCB~~	~~mg/Nm^3~~	~~kg/yr~~		~~0~~			~~8E-07~~	~~0~~		
~~Chlorobenzenes~~	~~mg/Nm^3~~	~~kg/yr~~		~~0~~			~~0.08~~	~~0~~		
~~PCDD/PCDF~~	~~ngTEQ/Nm^3~~	~~g/yr~~		~~0~~			~~0.008~~	~~0.00175~~	~~8~~	
~~CFC~~	~~mg/Nm^3~~	~~kg/yr~~		~~0~~			~~0~~	~~0~~		
~~Odour~~	~~EU O.U./Nm^3~~			~~0~~						
~~Noise~~	~~dB(A)~~			~~75~~			~~55~~			

~~Note: For the installations having only one column, the figures correspond to the concentration column~~
~~*Source*: [44, TWG 2003]~~

Table 5.39 and Table 5.40 below show respectively – for the nine plants that participated in the data collection – the parameters monitored in air emissions and the origin of emissions together with the abatement techniques used.

WORKING DRAFT IN PROGRESS

Table 5.39: Parameters monitored in air emissions at plants performing re-refining of waste oil

Pollutant measured	Type of measurement	Plants concerned	Emissions range (mg/Nm^3)
NO_X	Continuous	610_1, 610_2, 619_1, 620_2, 620_3, 620_4, 620_5, 620_6, 620_7, 620_8, 620_9*	107–201
	Periodic	160C, 514, 605_2, 605_3, 619_2, 620_2, 620_3, 620_4, 620_5, 620_6, 620_7, 620_8, 620_9*	47–229
SO_X	Continuous	610_1, 610_2, 619_1	23–942
	Periodic	160C, 514, 605_2, 605_3	0–1265
CO	Continuous	610_1, 610_2, 619_1, 620_2, 620_3, 620_4, 620_5, 620_6, 620_7, 620_8, 620_9*	2–40
	Periodic	160C, 514, 605_2, 605_3, 620_2, 620_3, 620_4, 620_5, 620_6, 620_7, 620_8, 620_9*	0.8–567
Dust	Continuous	610_1, 610_2, 619_1	0.6–7.5
	Periodic	605_2, 605_3	0
HCl	Continuous	620_1	0
	Periodic	160C, 514, 624	0.6–16.1
PAHs	Periodic	160C, 514, 619_4, 619_5	0.0009–0.005
HF	Periodic	160C, 624	0.06–1.99
H_2S	Periodic	514	1
	Continuous	610_1, 610_2	0.9 – 1.4
CH_4	Periodic	160C, 619_1	1–1.5
NMVOC	Periodic	160C, 619_1	3.1–7.3
NMVOC carcinogenic	Periodic	160C	0.09
PCDD/F	Periodic	160C, 619_1	0.002–0.027
Mineral oil	Periodic	619_4, 619_5,	0.1
TVOC	Periodic	160C, 514	3.1–19
TOC	Continuous	620_1	0.75
VOC	Periodic	619_6	40
Odour	Periodic	160C	2.2 OU_E/m^3
Hg	Periodic	160C	0.0435
Sb+As+Pb+Cr+Co+Cu +Mn+Ni+V	Periodic	160C	1.051
Cd	Periodic	160C	0.0001
As	Periodic	160C	0.001
Pb	Periodic	160C	0.001
Tl	Periodic	160C	0.0001

*The monitoring regime of Plant 620 changed during the reference period.
NB: 619_3 is not mentioned because it is not a measurement but a stoichiometric calculation of the composition of the gas burnt in the flare.

WORKING DRAFT IN PROGRESS

Table 5.40: Origin of emissions to air and associated abatement techniques

Plant code	**Origin of emissions to air**	**Abatement techniques**	**Pollutant monitored**	**Average air flow (m^3/h)**
092	The emission point is the common stack for combustion air from the hot oil heater, the steam generator and outlet from the carbon filter. Only one release	Activated carbon adsorption installed in case of fallout of the hot oil heater, which serves as the incinerator for the uncondensed vapours. Only operating 10–30 hours per year.	Regulatory requirements for SO_2, NO_X, particles < 10 µm, mercaptans and H_2S but no measurements done in the reference years	NI
160C	VOC treatment (upstream and downstream storage, process, loading station)	Thermal oxidation	Air flow NO_X CO Air temperature Air O_2 content SO_X HCl PAHs HF H_2S CH_4 NMVOC NMVOC with risk phrase PCDD/PCDF TVOC TOC Odour Cd Tl Hg As Pb Sum of metals	7393
235	NI	Wet scrubbing with sorbent injection, Dry scrubbing with sorbent injection	Monitoring according to 17. BImSchV and 1. BImSchV (waste incineration and combustion plants) but no details given	NI
514	Product storage tanks and vacuum distillation plant	Thermal oxidation	SO_X NO_X CO (carbon monoxide) H_2S HCl TVOC PAHs	NI
570	Distillation	Alkaline oxidative scrubber system, Thermal oxidation	NI	NI
605_1	Re-refining and other preparations for reuse of waste oils - Flare	Condensation, Basic scrubber system, Wet scrubbing, Flaring	Not monitored	NI

WORKING DRAFT IN PROGRESS

605_2	Re-refining and other preparations for reuse of waste oils - Diathermic Oil Heater (Natural gas-fired heater)	NI	NO_X CO Air temperature Air O_2 content SO_X Dust	NI
605_3	Re-refining and other preparations for reuse of waste oils - Boilers (Natural gas-fired heater)	NI	NO_X CO Air O_2 content SO_X Dust	NI
610_1	Whole process -Heater stack	NI	Air flow NO_X CO Air temperature Air O_2 content SO_X Dust H_2S	14617
610_2	Whole process - Heater stack	Low-NO_X burners implemented	Air flow NO_X CO Air temperature Air O_2 content SO_X Dust H_2S	13460
610_3	Whole process - Flare	Low-NO_X burners implemented	Not monitored	NI
619_1	Hot oil furnace (burns natural gas and refinery off-gas)	NI	Air flow NO_X CO Air temperature Air O_2 content SO_X Dust CH_4 NMVOC NMVOC with risk phrase PCDD/PCDF	20032
619_2	Stream reformer furnace	NI	Air flow NO_X Air temperature Air O_2 content	950
619_3	Flare	NI	Every six months the flow and the composition of the inlet gas to the flare plants is analytically determined. Every six months the SO_2 output from the flare is also stoichiometrically calculated on the basis of the content of S in the inlet gas	25
619_4	Laboratory hoods E101	Activated carbon adsorption	Air flow Air temperature PAHs Other	2872

WORKING DRAFT IN PROGRESS

619_5	Laboratory hoods E102	Activated carbon adsorption	Air flow Air temperature PAHs Other	2854
619_6	Oil storage tanks	Activated carbon adsorption	Air flow Air temperature Other	1624
620_1	Off-gas burner	Thermal oxidation, Venturi scrubber system, Wet scrubbing, Dry electrostatic precipitation (ESP)	Air flow Air temperature Air O_2 content HCl TOC	16185
620_2	Boiler 'Babock 3000'	NI	Air flow NO_X CO	2736
620_3	Furnace of hydrofinishing	NI	Air flow NO_X CO	3212
620_4	Steam reforming furnace for hydrogen production	NI	Air flow NO_X CO	3212
620_5	Furnace of TDA distillation column	NI	Air flow NO_X CO	18080
620_6	Biological treatment plant air capture	Activated carbon adsorption	Air flow NO_X CO	3212
620_7	Breathing air from used oil tanks	Activated carbon adsorption	Air flow NO_X CO	3212
620_8	Natural gas-fired boilers for steam production	NI	Air flow NO_X CO	6370
620_9	Natural gas-fired boilers for steam production	NI	Air flow NO_X CO	2508
624	Vacuum distillation	Alkaline oxidative scrubber system, Thermal oxidation	Air flow Air temperature Air O_2 content HCl HF	5712
NI: No information.				

As can be seen, a significant part of the emissions to air is generated by combustion of fuel, which is used to produce heat or steam for the process.

As for the emissions from the distillation process itself, they are treated by thermal oxidation or incineration, which may be associated with scrubbing.

Emissions to water

The emissions to water are generally well documented. This is due to regulations and enforced limitations regarding discharges to foul sewers or disposal by alternative routes. The quantities of effluent discharged are thus usually well known.

Discharges are typically sampled regularly, providing monitoring data to allow the calculation of emissions ~~for the radicals on the analysis programme~~. Sites handling large volumes of water and that have a constant discharge to the sewerage system are usually sampled daily; those where the water volume is small tend to be tested on a batch basis prior to each discharge. ~~Table 5.41 and Table 5.42 show the concentrations of water parameters and the emission matrix of the emissions to water, generated by the re-refining of waste oil.~~

WORKING DRAFT IN PROGRESS

Table 5.41: Waste water parameters from different re-refining processes of waste oil

~~Water parameters~~	~~Oily water~~ [2] ~~(mg/l)~~	~~Process water~~[2] ~~(mg/l)~~	~~Effluent concentration (mg/l)~~
~~Temperature~~			~~25 ºC~~
~~pH~~			~~7.8~~
~~Colour~~			~~clear~~
~~COD~~ [1] ~~(TOC)~~	~~120~~	~~17000~~	~~20 – 20000~~
~~Oil/grease~~			~~<10~~
~~Hydrocarbons~~			~~5 – 15~~
~~Anionic tensioactives~~			~~0.2 – 0.5~~
~~Non-anionic tensioactives~~			~~1.0 – 2.0~~
~~Total tensioactives~~			~~1.2 – 2.5~~
~~Benzene~~			~~364~~
~~Toluene~~			~~1306~~
~~Phenols~~	~~1.5~~	~~180~~	~~0.2 – 0.4~~
~~Naphthalene~~			~~283~~
~~Chlorinated solvents (various)~~			~~309 – 666~~
~~1, 2 Dichloroethane~~			~~<1.0~~
~~Hexachlorobutadiene~~			~~<0.001~~
~~Hexachlorobenzene~~			~~<0.001~~
~~1, 2, 4 Trichlorobenzene~~			~~<0.001~~
~~Various PCBs~~			~~<0.001~~
~~Benz(a)anthracene and benzo(a)pyrene~~			~~each below 0.02~~
~~Ammonia~~			~~4.0 – 6.0~~
~~Suspended solids~~			~~<400~~
~~Chloride~~			
~~Total nitrogen~~			
~~Total phosphorus~~			~~0.05 – 0.2~~
~~Total metals:~~			~~<10~~
• ~~aluminium~~			~~<0.5~~
• ~~arsenic~~			~~3.4~~
• ~~barium~~			~~80~~
• ~~cadmium~~			~~<0.01 – 0.34~~
• ~~chromium~~			~~10~~
• ~~copper~~			
• ~~iron~~			~~<0.6~~
• ~~lead~~			~~271~~
• ~~zinc~~			~~250~~

[1] ~~Partially are demulsifers and detergents~~

[2] ~~Water parameters of the waste water sent to biological treatment after stripping treatment~~

~~*Source:*[26, UK, H. 1995] [34, Babtie Group Ltd 2002][44, TWG 2003]~~

WORKING DRAFT IN PROGRESS

Table 5.42: Water emissions matrix for all common process in oil and solvent recycling plants

~~Activity~~	~~Bulk used engine oil~~	~~Used industrial oils~~	~~Oil waters (interceptors)~~	~~Fuel oils~~	~~Electrical oils~~
~~Cold effluent settling~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Hot effluent settling~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Biological effluent treatment~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Effluent clarification~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Effluent sludge filter press~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Effluent balance tank~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Plate Separator~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Source: [34, Babtie Group Ltd 2002]~~					

Table 5.43: Water emissions from different re-refining installations operating in the EU

~~Capacity~~	~~t/yr~~		~~6824~~	~~15000~~		~~17171~~	~~19960~~		~~46208~~		~~90500~~	
~~Waste water generated~~		~~m^3/yr~~			~~1800~~			~~6180~~		~~298287~~		~~375000~~
~~Waste water generated/plant capacity~~		~~m^3/t~~			~~0.12~~			~~0.3096~~		~~6.4553~~		~~4.1436~~
~~Suspended solids~~	~~mg/l~~	~~kg/yr~~						~~931~~	~~6860~~	~~22.99~~	~~0~~	~~0~~
~~TOC~~	~~mg/l~~	~~kg/yr~~							~~1490~~	~~4.99~~		
~~BOD$_5$~~	~~mg/l~~	~~kg/yr~~		~~4000~~	~~7200~~						~~13300~~	~~38~~
~~COD~~	~~mg/l~~	~~kg/yr~~		~~8000~~	~~14400~~	~~300~~		~~27703~~	~~25650~~	~~85.99~~	~~39550~~	~~113~~
~~Hydrocarbons~~	~~mg/l~~	~~kg/yr~~	~~0.18~~						~~430~~	~~1.44~~		~~0.4~~
~~Phenols~~	~~mg/l~~	~~kg/yr~~	~~0.4~~	~~0~~		~~0.8~~		~~42.58~~	~~14~~	~~0.04~~	~~105~~	~~0.3~~
~~AOX~~	~~mg/l~~	~~kg/yr~~							~~0~~	~~0~~		
~~BTX~~	~~mg/l~~	~~kg/yr~~	~~0.4~~						~~0~~	~~0~~		
~~Total Nitrogen (as N)~~	~~mg/l~~	~~kg/yr~~							~~10000~~	~~0.033~~		~~0.008~~
~~Nitrit N (NO$_2$–N)~~	~~mg/l~~	~~kg/yr~~							~~180~~	~~0.6~~		~~0.32~~
~~CN, free~~	~~mg/l~~	~~kg/yr~~							~~0~~	~~0~~		~~0.008~~
~~Sulfid (free)~~	~~mg/l~~					~~1~~						~~0.4~~
~~F, total~~	~~mg/l~~											~~0.4~~
~~P, total~~	~~mg/l~~	~~kg/yr~~							~~2980~~	~~9.99~~	~~140~~	~~0.4~~
~~Total metals~~	~~mg/l~~			~~0.56~~								
~~Al~~	~~mg/l~~	~~kg/yr~~		~~0.08~~					~~476~~	~~1.6~~	~~140~~	~~0.4~~
~~Fe~~	~~mg/l~~	~~kg/yr~~		~~0.08~~					~~952~~	~~3.2~~	~~35~~	~~0.1~~
~~As~~	~~mg/l~~	~~kg/yr~~		~~0.08~~					~~116~~	~~0.4~~		~~0.0024~~
~~Cr, total~~	~~mg/l~~	~~kg/yr~~		~~0.08~~					~~952~~	~~3.2~~		~~0.08~~
~~Cr(VI)~~	~~mg/l~~	~~kg/yr~~		~~0.08~~					~~44~~	~~0.16~~		~~0.008~~
~~Cu~~	~~mg/l~~	~~kg/yr~~		~~0.08~~					~~92~~	~~0.32~~		~~0.024~~
~~Hg~~	~~mg/l~~	~~kg/yr~~		~~0.08~~					~~1.12~~	~~0.004~~		~~0.00032~~
~~Ni~~	~~mg/l~~	~~kg/yr~~		~~0.08~~					~~476~~	~~1.6~~		~~0.16~~
~~Pb~~	~~mg/l~~	~~kg/yr~~		~~0.08~~				~~0.291~~	~~68~~	~~0.24~~		~~0.04~~
~~Zn~~	~~mg/l~~	~~kg/yr~~		~~0.08~~				~~1.276~~	~~236~~	~~0.8~~		~~0.24~~
~~Note: when only one column exists for a certain capacity, it refers to concentration values~~ ~~*Source*:[44, TWG 2003]~~												

Table 5.44 and Table 5.45 below show respectively – for the nine plants that participated in the data collection – the pollutants monitored in water emissions and the origin of emissions together with the abatement techniques used. Only one plant discharges water directly to the environment.

WORKING DRAFT IN PROGRESS

Table 5.44: Pollutants monitored in emissions to water at plants re-refining waste oil

Parameter measured	Monitoring	Plants concerned	Range (mg/l except for pH, toxicity and flow)	Number of measurements during the 3-year reference period (2010-2012)
Flow (m^3/h)	Continuous	092, 160C, 235, 605_1, 610_1, 619_1, 620_1	0.8-66.6 m^3/h	NA
COD	Continuous	619_1	112	NA
	24-hours proportional composite sample	610_1	120	NA
	Composite sample	092	10 514	7
	Grab sample	160C, 235, 605_1, 620_1	33-17 075	6-36
TSS	Continuous	619_1	34	NA
	Composite sample	092	4.6	7
	Grab sample	160C, 605_1, 620_1	3.3-15.3	6-36
pH	Composite sample	092	8.6	7
	Grab sample	160C, 235, 605_1, 620_1	6.8-7.9	6-36
Total N	24-hours proportional composite sample	610_1	17	NA
	Composite sample	092	154	6
	Grab sample	160C, 235, 620_1	0.04-30	4-33
BOD_5	Composite sample	092	6764	7
	Grab sample	235, 605_1	9-469	36
Total P	24-hours proportional composite sample	610_1	0.43	NA
	Composite sample	092	0.17	7
	Grab sample	160C, 235, 605_1, 620_1	0.8-5.5	6-36
Zn	24-hours proportional composite sample	610_1	0.05	NA
	Composite sample	092	0.015	4
	Grab sample	235, 605_1, 620_1	0.03-0.2	1-36
THC	Continuous	619_1	1	NA
	Grab sample	160C, 605_1, 620_1	0.2-23.3	6-36
Sulphates	24-hours proportional composite sample	610_1	15 300	NA
	Composite sample	092	0.6	5
	Grab sample	235, 620_1	493-2317	6-36
Cd	Composite sample	092	0.00003	5
	Grab sample	235, 605_1, 620_1	0.0024-0.1	1-36
Pb	Composite sample	092	0.001	4
	Grab sample	235, 605_1, 620_1	0.01-0.08	1-36
Cr	Composite sample	092	0.002	4
	Grab sample	235, 605_1, 620_1	0.02-0.1	1-36
Cu	Composite sample	092	0.01	4
	Grab sample	235, 605_1, 620_1	0.01-0.1	1-36
Ni	Composite sample	092	0.003	4
	Grab sample	235, 605_1, 620_1	0.04-0.1	1-36
NH_3-N	Composite sample	092	109	4
	Grab sample	605_1, 620_1	5-17	6-36
Hg	Continuous	610_1	0.0017	NA

WORKING DRAFT IN PROGRESS

	Composite sample	092	NI	NI
	Grab sample	605_1	<0.01	1
Phenols	Grab sample	160C, 605_1, 620_1	0.04-38.17	6-36
F^-	Grab sample	160C, 235	1-8.3	12-36
As	Composite sample	092	0.001	4
	Grab sample	605_1	<0.01	1
Cr(VI)	Grab sample	605_1, 620_1	0.01-0.019	1-6
Fe	Grab sample	235, 620_1	0.12-0.19	6-36
Chlorine	Composite sample	092	NI	NI
	Grab sample	620_1	0.034	6
AOX	24-hours proportional composite sample	610_1	0.067	NA
	Grab sample	160C	4.42	12
TOC	Grab sample	235	57	36
HOI	Grab sample	235	0.54	36
V	Grab sample	235	0.021	36
Cl^-	Grab sample	620_1	158	2
NO_2^-/NO_3^-	Grab sample	620_1	7.9	6
Mn	Grab sample	620_1	0.1	6
Toxicity	Grab sample	620_1	0 mort%	6
BTEX	Grab sample	620_1	0.007	6
Sum metals	Grab sample	160C	3.7	12
Co	Composite sample	092	NI	NI
NA: Not applicable. NI: No information				

WORKING DRAFT IN PROGRESS

Table 5.45: Origin of emissions to water and associated abatement techniques

Emission point	Abatement techniques	Origin of emissions to water	Point of release	Receiving body	Flow (m^3/h)
092	Pre-treatment with an evaporation unit	Processes: distillation and solvent extraction. Steps: distilled water from waste oil and process water from vacuum generation by steam jet system as well as process water from stripping of base oil for final solvent removal.	Waste water stream pretreated before discharge by truck to municipal WWT	NI	0.75
160C	None	Re-refining and other preparations for reuse of waste oils	Discharge from the WT plant, as well as from on-site waste water pretreatment facilities, to an off-site common WWT facility	Transitional waters (i.e. surface water in the vicinity of river mouths)	0.9
235	Steam stripping, Skimming, Flotation, Active sludge systems – conventional, Nitrification/ denitrification, Press filtering	All processes	Discharge from the WT plant, as well as from on-site waste water pre-treatment facilities, to an off-site common WWT facility	Artificial water body (e.g. reservoir)	11.6
514	NI	NI	NI	NI	NI
570	NI	NI	NI	NI	NI
605_1	Equalisation, Sedimentation (ponds), API separator system, Membrane bioreaction, Ultrafiltration, Dewatering	Re-refining and other preparations for reuse of waste oils	Discharge from the WT plant and its auxiliary systems, as well as from on-site waste water pretreatment facilities, to a urban/municipal sewer system	NI	6.5
610_1	Chemical oxidation, Active sludge systems – conventional, Ozonation, Nitrification/ denitrification	Whole process	Discharge from the WT plant, as well as from on-site waste water pre-treatment facilities, to an off-site common WWT facility	Artificial water body (e.g. reservoir)	11.9

WORKING DRAFT IN PROGRESS

619_1	Pretreatment with evaporation unit and sour water stripping, Active sludge systems – conventional, API separator system, Chemical oxidation, Decantation, Equalisation, Flotation, Skimming, Powdered activated carbon treatment	Whole process	Discharge from the WT plant, as well as from on-site waste water pretreatment facilities, to an off-site common WWT facility	Artificial water body (e.g. reservoir)	43.66
620_1	Pretreatment with sour water stripping, Equalisation, Skimming, Active sludge systems – conventional, Filtration, Sand filtration	Whole process	Discharge from the on-site common WWT facilities to the environment (when the design/operation of the WWT facility is mainly influenced by waste water streams coming from WT plant)	River/Stream	66.64
624	NA	No water emissions	NA	NA	NA
NI: No information. NA: Not applicable					

The analysis of emissions to water from Plant 620 directly discharging to a water body after treatment is dealt with in Section 5.7.2.3.2.

Solid ~~waste~~ residues ~~and discharges to land~~

Sludges are typically tested for metal content, oil content and moisture content. This is carried out less frequently than the testing of the aqueous waste to sewerage systems.

~~and~~ Table 5.46 shows the ~~concentrations of water parameters and the emission matrix of the emissions to water,~~ types of residues generated by waste oil re-refining.

WORKING DRAFT IN PROGRESS

Table 5.46: Types of waste generated in re-refining processes of waste oil

Type of ~~waste~~ residues	~~Waste~~ Residue parameters				
	Metals	**Moisture**	**HC and TOC**	**S compounds**	**Other**
Sludges	Some toxic metals may be contained	X	X	X	
Tank bottom sludges			X		
Solid particulates from filters	X		X		PAHs and PCBs
Interceptor waste	X	Low	X		Phosphates, PAHs, non-lubricant related solids
Cleaned oil filters	X				

X means the pollutant is present in the residue considered
Source:[26, UK, H. 1995] [34, Babtie Group Ltd 2002] [44, TWG 2003]

Table 5.47: Emissions to land matrix for all common process in oil and solvent recycling plants

~~**Activity**~~	~~**25 litres Oil drums**~~	~~**205 litres Oil drums**~~	~~**Bulk used engine oils**~~	~~**Used industrial oils**~~	~~**Oily waters (interceptors)**~~	~~**Fuel oils**~~	~~**Electrical oils**~~
~~Bulk storage~~			~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Cold oil settling~~			~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Hot oil settling~~			~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Distillation~~			~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Vibrating sieve~~			~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Centrifuge~~			~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Enclosed filters~~			~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Effluent sludge filter press~~			~~*~~	~~*~~	~~*~~	~~*~~	~~*~~
~~Mechanically handled sludge/solids storage and handling~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~	~~*~~

~~*Source:* [34, Babtie Group Ltd 2002]~~

From ex-**Section 3.5.3 "Emissions from the preparation of waste fuel"**

WORKING DRAFT IN PROGRESS

Table 5.48: Example of emissions from an oil recycling plant that heats the oil during the process

~~Waste IN~~			
~~Type of waste oils~~	**~~Annual amount (tonnes)~~**	**~~Oil content (% oil)~~**	**~~Water content (% water)~~**
~~Waste motor oil~~	~~62000~~	~~97~~	~~3~~
~~Interceptor waste~~	~~25000~~	~~4~~	~~96~~
~~Soluble oils~~	~~16000~~	~~25~~	~~75~~
~~Fuel oils~~	~~7000~~	~~98~~	~~2~~
~~Oils from transfer stations or the processing of oil filters~~	~~4000~~	~~97~~	~~3~~
~~Other oil bearing waste streams~~	~~200~~	~~99~~	~~1~~
~~Waste OUT and residues~~			
~~Product~~			
~~Cleaned waste oil to be used as fuel~~	~~75150~~	~~99.5~~	~~0.5~~
~~Disposal to sewer~~		**~~Oil (mg/l)~~**	**~~COD (mg/l)~~**
~~Sewer discharge~~	~~40000~~	~~200~~	
~~Disposals to landfill~~		**~~% Oil (dry solids)~~**	**~~Water content (% water)~~**
~~Landfill: screenings~~	~~6000~~	~~11~~	~~25~~
~~Landfill: process sludge~~	~~12000~~	~~5~~	~~50~~
~~Landfill: other waste~~	~~4000~~	~~2~~	~~40~~
~~Other liquid disposal~~	~~4000~~	~~2~~	~~98~~
~~Other solid disposal~~	~~3000~~	~~5~~	~~95~~
~~*Source:* [34, Babtie Group Ltd 2002]~~			

5.2.2.2 Consumption in the re-refining of waste oils

From ex-**Section 3.4.2 "Consumptions of waste treatments to obtain a recycled material"**

~~Consumptions in the re-refining of waste oils~~
Other than transportation, the main operating overhead relates to the generation of steam for heating waste oil.

Table 5.49 shows the consumption of different waste oil re-refining techniques.

WORKING DRAFT IN PROGRESS

Table 5.49: Consumption of different waste oil re-refining techniques

Process	Compounds used within the process	Consumption (values in kg/tonne of waste oil if not otherwise specified)
Acid/clay process	Sulphuric acid as a precipitate agent of heavy metals. Clay as a filtration/neutralisation agent	36
Pretreatment of waste oil	Demulsifiers to help in the settling process	NI
Distillation/clay process	Clay	40
Propane deasphalting (PDA)	Consumption of energy is higher than in the regeneration by chemical treatment or by hydrogenation	NI
Thin film evaporator (TFE) + clay process	Clay	60
TFE + hydrofinishing	Hydrogen and catalysts	NI
TFE + solvent extraction	Solvent	NI
TFE + chemical treatment + solvent extraction	Energy Caustic Solvent	3.2 MJ/kg of used oil 10 0.3
TFE + solvent extraction + hydrofinishing	Hydrogen catalyst Mohawk chemical Hydrogen gas	0.25 12 2
TDA (thermal deasphalting) + clay treatment	Clay	100
TDA + hydrofinishing (high pressure)	Catalyst	0.5
PDA (propane deasphalting) + hydrofinishing (medium pressure)	Propane	8.25
With thermal clay treatment	Fossil energy resources	4.26 MJ/kg of used oil
Hydrofinishing	Energy	9.93 MJ/kg of used oil
Vacuum distillation + chemical treatment	Fossil fuel consumption Primary energy Water usage	47 kg eq crude oil 2681 MJ 3300
Regeneration process	Fossil energy resources	42.46 MJ/kg of oil
Caustic soda and bleaching earth treatment (ENTRA)	Caustic soda Bleaching earth	30 20
DCH (Direct contact hydrogenation)	Hydrogen Catalyst	~~70~~ 60 ~~N~~m^3/t of used oil 0.5 kg/t of used oil

NI: No information

Source: [3, Silver Springs Oil Recovery Inc. 2000] [4, Monier, V. and Labouze, E. 2001] [7, Jacobs, A. and Dijkmans, R. 2001] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999][34, Babtie Group Ltd 2002] [60, WT TWG 2003] [98, WT TWG 2004]

~~gives the consumptions for the re-refining of part of the waste oil to base oil which can then be re-used as lubricating oil, together with the regeneration of the remaining waste oil to fuel oil.~~

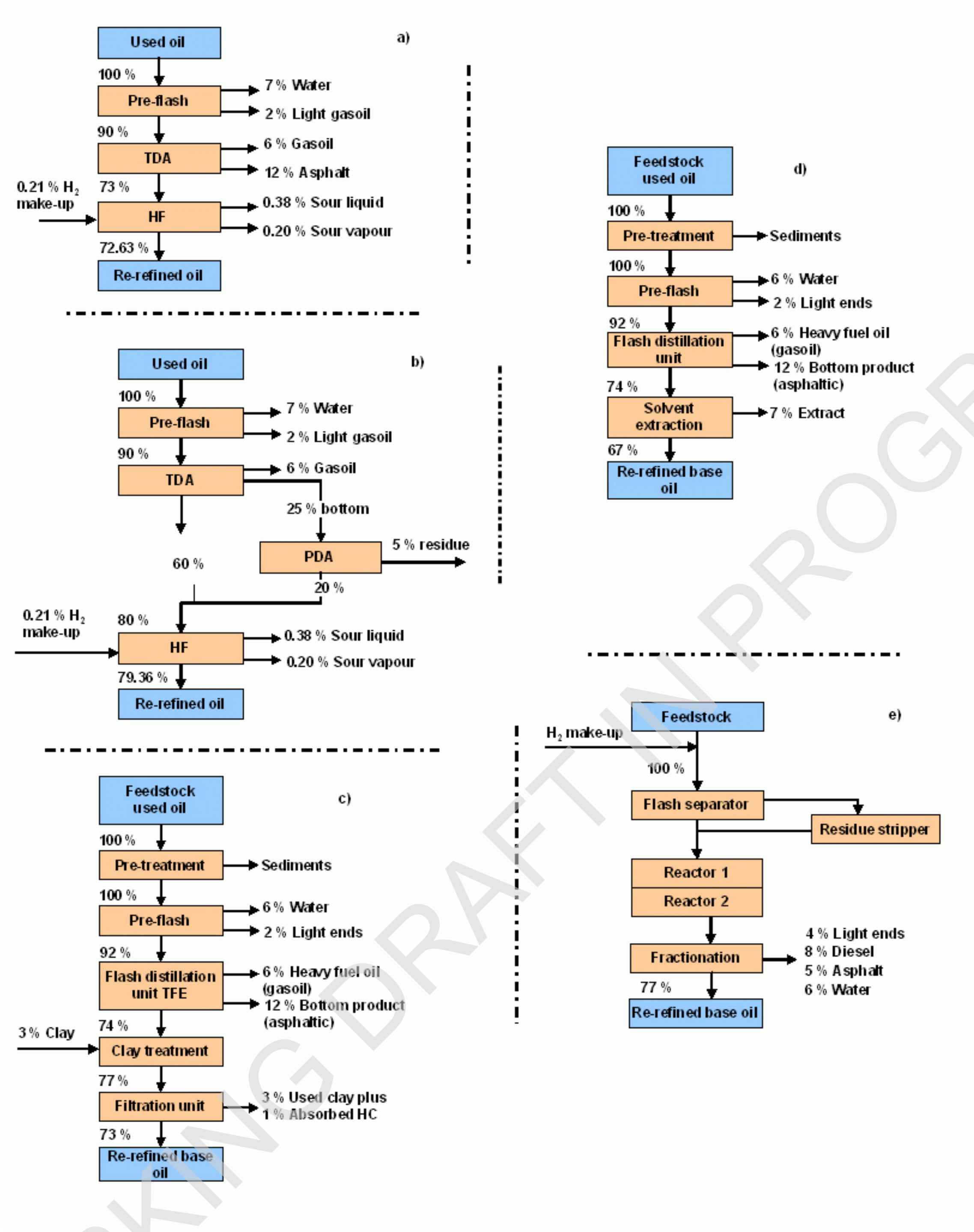
WORKING DRAFT IN PROGRESS

Table 5.50: Consumptions of waste oil re-refining activities

	~~**Consumptions**~~	~~**Units**~~
~~**Economics**~~		
~~Capital investment expenses for treatment plant~~	~~4.85 (36)~~	~~EUR (DKK) millions~~
~~Maintenance~~	~~0.094 (0.7)~~	~~EUR (DKK) millions per year~~
~~Operation period~~	~~20~~	~~years~~
~~Labour input~~	~~10~~	~~number of persons~~
~~**Resources used**~~		
~~Chemicals~~	~~291.5~~	~~tonnes~~
~~Water~~	~~8000~~	~~m^3~~
~~Electricity~~	~~1150~~	~~MWh~~
~~Fuel oil~~	~~1200~~	~~m^3~~
~~Base: 26000 tonnes yearly collected waste oil to base oil (8000 tonnes), fuel oil (12000 tonnes) and asphalt (4000 tonnes)~~ ~~*Source*: [8, Birr-Pedersen, K. 2001]~~		

Figure 5.9 depicts a block diagram showing a comparison of the inputs and outputs of different re-refining processes.

WORKING DRAFT IN PROGRESS



NB: a) TDA/HF, b) TDA/PDA/HF, c) TFE/clay treatment, d) TFE/solvent, e) DCH.
HF = Hydrofinishing. % represents the amount that ~~goes in~~ enters that stream based on 100 % used oil entering the system.
Source: [21, Viscolube 2002] [60, WT TWG 2003] [98, WT TWG 2004]

Figure 5.9: Inputs and outputs of re-refining processes

Table 5.51 shows the consumption of the TDA system and the TDA system combined with a PDA system.

WORKING DRAFT IN PROGRESS

Table 5.51: Consumption values of the TDA system and the TDA system combined with a PDA process

Traditional TDA/HF system						
Consumption and utilities	**PF**	**TDA**	**HF**		**Total**	**Unit**
Electrical consumption	1.5	12	20		33.5	kWh
MP steam	285	322	70		677	kg
Cooling water (make-up)(1)	1.1	5	0.3		6.4	tonne
Fuel (absorbed heat)	/	670	711		1380	MJ
Hydrogen	/		2.1		2.1	kg
Catalysts	/		0.2+0.05(2)		0.2+0.05(2)	tonne
Propane make-up						kg
High recovery system						
Consumption and utilities	**PF**	**TDA**	**HF**	**PDA**	**Total**	**Unit**
Electrical consumption	1.5	12	20	13	46.5	kWh
MP steam	285	322	70	135	812	kg
Cooling water (make-up)(1)	1.1	5	0.3	4	10.4	tonne
Fuel (absorbed heat)		670	711	920	2300	MJ
Hydrogen			2.1			kg
Catalysts			0.2 + 0.05(2)		0.2 + 0.05(2)	tonne
Propane make-up				0.8	0.8	kg

(1) Based on 10 % evaporation losses.
(2) Demetallisation catalyst + Refining catalyst.

NB: Consumption based upon 100 kt/yr waste oil capacity, considering 10 % water content. All the parameters are expressed in unit/tonne of waste oil.

HF: hydrofinishing, PDA: Propane deasphalting, TDA: Thermal deasphalting, PF: Pre-flash, MP: medium pressure.

Source:[44, TWG 2003] [98, WT TWG 2004]

Table 5.52: Consumptions from different waste oil re-refining plants in the EU

~~Capacity~~	~~t/yr~~	~~2001~~	~~4600~~	~~6824~~	~~15000~~	~~17171~~	~~19960~~	~~46208~~	~~90500~~
~~Fuel consumption~~	~~GJ/yr~~		~~19146~~	~~33486~~	~~40671~~	~~54751~~	~~16705~~	~~405883~~	
~~Electricity consumption~~	~~MWh/yr~~	~~345~~	~~225~~	~~1200~~	~~1380~~	~~2024~~	~~655~~	~~9215~~	
~~Heat consumption~~	~~MWh/yr~~	~~157~~			~~0~~	~~15208~~			
~~Water~~	~~m^3/yr~~	~~617~~		~~80000~~	~~9848~~	~~9929~~	~~1557~~	~~407000~~	~~2213000~~
~~Cooling~~	~~MJ/yr~~				~~44000~~				
~~Electricity/Plant capacity~~	~~kWh/t~~	~~172.4~~	~~48.9~~	~~175.8~~	~~92~~	~~117.9~~	~~32.8~~	~~199.4~~	
~~Heat/Plant capacity~~	~~kWh/t~~	~~78.5~~				~~885.7~~			

~~*Source:*[44, TWG 2003] [98, WT TWG 2004]~~

WORKING DRAFT IN PROGRESS

Table 5.53 shows the specific consumption of energy and water of re-refining plants that participated in the data collection.

Table 5.53: Specific consumption of water and energy

Plant capacity (t/day)	**120**	**140**	**144**	**240**	**375**	**420**	**485**	**500**
Specific water usage (l/tonne of waste oil treated)	2788	867	102	6658	1916	11693	34850	2723
Specific energy consumption (kWh/tonne of waste oil treated)	1989	1013	495	1743	1103	2052	1109	798
Specific electricity consumption (kWh/ tonne of waste oil treated)	141	102	235	210	77	194	200	47

The highest figures provided for water usage relate to cooling water. One plant indicated that the amount of cooling water was calculated as an estimated 60 % of total water usage.

A large amount of the energy demand in the re-refining of waste oil is heat, which is provided by fossil fuel (e.g. natural gas), or by vapour imported from other sources.

From ex-**Section 3.5.2 "Consumptions of preparation of waste fuel"**

Table 5.54: Consumptions in the thermal treatment of waste oils

~~**Material consumed**~~	~~**Application**~~
~~Chemicals antioxidants~~	~~Added to light fuel oils and light distillates fractions in order to stabilise the products~~
~~*Source:*[75, Wateo 2002]~~	

Table 5.55 shows the average raw material consumption of the plants that participated in the data collection.

Table 5.55: Raw material consumed at re-refining plants

Material concerned (average consumption over the 3-year reference period in t/year)	**Waste oil processing**	**Water treatment**	**Air treatment**
Alkalis	5–2723	35–451	20–1040
Acids	6-279	4	/
Activated carbon	/	2	0.8–22
Catalysts	0.5–122	/	/
Detergents	17	/	/
Oxidising agents	7	561	/

WORKING DRAFT IN PROGRESS

5.2.3 Techniques to consider in the determination of BAT

This section covers the techniques to be considered in the determination of BAT for the re-refining of waste oil.

5.2.3.1 Acceptance of waste oils to be re-refined

From ex-**Section 4.4.1.2 "Selection of waste oils to be re-refined"**

Description
Set up acceptance procedure for ensuring the knowledge and the selection of waste oils to be re-refined that includes the verification of the presence of chlorinated compounds (e.g. solvents or PCBs) in the waste oils.

Technical description
The acceptance procedure allows verification that the incoming waste oils are suitable for recycling, such as the following:

~~Waste oils suitable to be recycled are:~~
- (Black) engine oils, which have homogeneous characteristics and are sought by re-refining plants.
- Black industrial oils are potentially suitable for regeneration but, due to the content of additives and other substances, are not typically preferred by re-refining plants
- Light industrial oils, which are relatively clean. They can either be re-refined on site or can be reused for other purposes. Their market is very specific and independent from the classical supply routes of recycling.

Achieved environmental benefits
~~Improvement~~ Knowledge and selection of the feedstock quality can lead to ~~enhance~~:

- improving the environmental performance ~~of an installation~~; ~~as well as the quality of the product~~.
- ~~Improve the Segregated used lubricants can have a higher recovery value as fuel and as a new material for reuse re-refining when used lubricants are segregated.~~
- avoiding operational and environmental problems when chlorinated compounds (e.g. solvents or PCBs) are prevented from entering the re-refining process ~~then operational and environmental problems can be avoided~~.

Environmental performance and operational data
One report states that 60–65 % of waste oils are eligible for regeneration, although other experts suggest a figure of around 50 % ~~of waste oils~~. The waste oils most suitable for regeneration are those that are not too heavily polluted and that have a high viscosity index and an absence of esters and biolubricants. (Black) engine oils represent more than 70 % of the waste oil stream. Black industrial oils represent about 5 % of all waste oil, with light industrial oils representing about 25 %. Experts consider the following waste oils can be recycled more than once ~~to be re-recyclable~~:

- engine oils without chlorine ~~(EWL code: 130205)~~;
- hydraulic oils without chlorine ~~(EWL code: 130110)~~;
- non-chlorinated mineral diathermic oils ~~(EWL code: 130306)~~;
- engine oils with chlorine ~~(EWL code: 130204)~~ – although only under certain conditions (i.e. limitation of chlorine or PCB content);
- hydraulic oils with PCB ~~(EWL code: 130101)~~ – although only under certain conditions (i.e. limitation of chlorine or PCB content);
- hydraulic oils with chlorine ~~(EWL code: 130109)~~ – although only under certain conditions (i.e. limitation of chlorine or PCB content).

TWG, please confirm

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Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
No information available.

Driving force for implementation
~~Economic reasons to produce a good~~ Quality of end product.

Example plants
No information provided

Reference literature
[4, Monier, V. and Labouze, E. 2001] [60, WT TWG 2003] [98, WT TWG 2004] [101, WT TWG 2005]

Ex-Section **4.4.1.4 "Distillation and chemical treatment or solvent extraction"** moved to Section 5.2.1

Ex-Section **4.4.1.5 "Solvent extraction process and distillation"** moved to Section 5.2.1

~~**Description**~~

Ex-Section **4.4.1.6 "Thin film evaporator and different finishing processes"** moved to Section 5.2.1

Ex-Section **4.4.1.7 "Thermal de-asphalting process"** moved to Section 5.2.1
Ex-Section **4.4.1.8 "Recycling in a lubricating oil refinery"** moved to Section 5.2.1
Ex-Section **4.4.1.9 "Hydrotreatment"** moved to Section 5.2.1

Ex-Section **4.4.1.10 "Direct contact hydrogenation process"** moved to Section 5.2.1
Ex-Section **4.4.1.11 "Solvent extraction"** moved to Section 5.2.1
Ex-Section **4.4.1.12 "Caustic soda and bleaching earth treatment"** moved to Section 5.2.1
Ex-Section **4.4.1.13 "Treatment in a refinery"** deleted because not applied

Ex-**Section 4.4.1.1 "Generic techniques to increase the yield of re-refining"** deleted. It concerns the output waste and the process.

5.2.3.2 Reduction of water usage and emissions to water in waste oil re-refining plants

From ex-Section 4.4.1.14

Description
Water is reused and waste water is pre-treated before discharge to a Waste Water Treatment Plant.

Technical description
Some techniques include the following:

a. Ensuring that any effluent water (e.g. water distilled from the used oil, process water including the caustic scrubber blowdown) ~~are~~ is treated before direct discharge.

WORKING DRAFT IN PROGRESS

b. ~~using a waste water treatment unit (e.g. demulsifier and flocculant, flocculation and biological treatment, ultrafiltration and microfiltration). More information can be found in Section~~

c. Pretreating waste water prior to the waste water treatment plant to reduce the COD concentration in waste water to be treated in the WWTP. The pretreatment of waste water consists of a suitable combination of techniques such as:
   - evaporation (see Section 2.3.6.5.7);
   - steam stripping (see Section 2.3.6.5.5).

d. Reusing the cleaned waste water as cooling water ~~by~~ after applying a suitable waste waster treatment ~~WWTP and by generating water products that may be re-used outside the installation~~

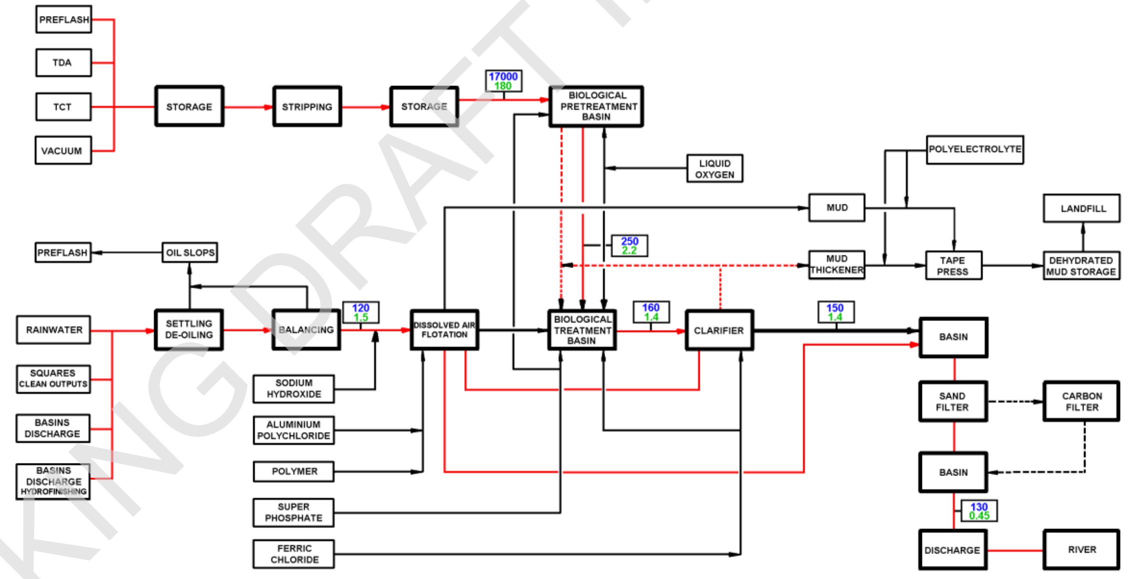
e. ~~Feeding the effluent water to the heater along with the oils in order to incinerate the harmful constituents~~.

Achieved environmental benefits

- Reduction of emissions to water.
- Reduction of water usage.

Environmental performance and operational data

~~Three examples on the achieved values treatments are shown in~~
~~Figure 5.10,~~
~~Figure 5.11,~~
~~Figure 5.12 and~~
~~Table 5.56 and~~
~~Table 5.57.~~



~~Note: Figures in boxes are all given in ppm. The upper figures correspond to COD and the lower figures correspond to phenol content~~
~~*Source:* [21, Viscolube 2002]~~

~~**Figure 5.10: Achievable levels in a waste water treatment used in a re-refining process**~~

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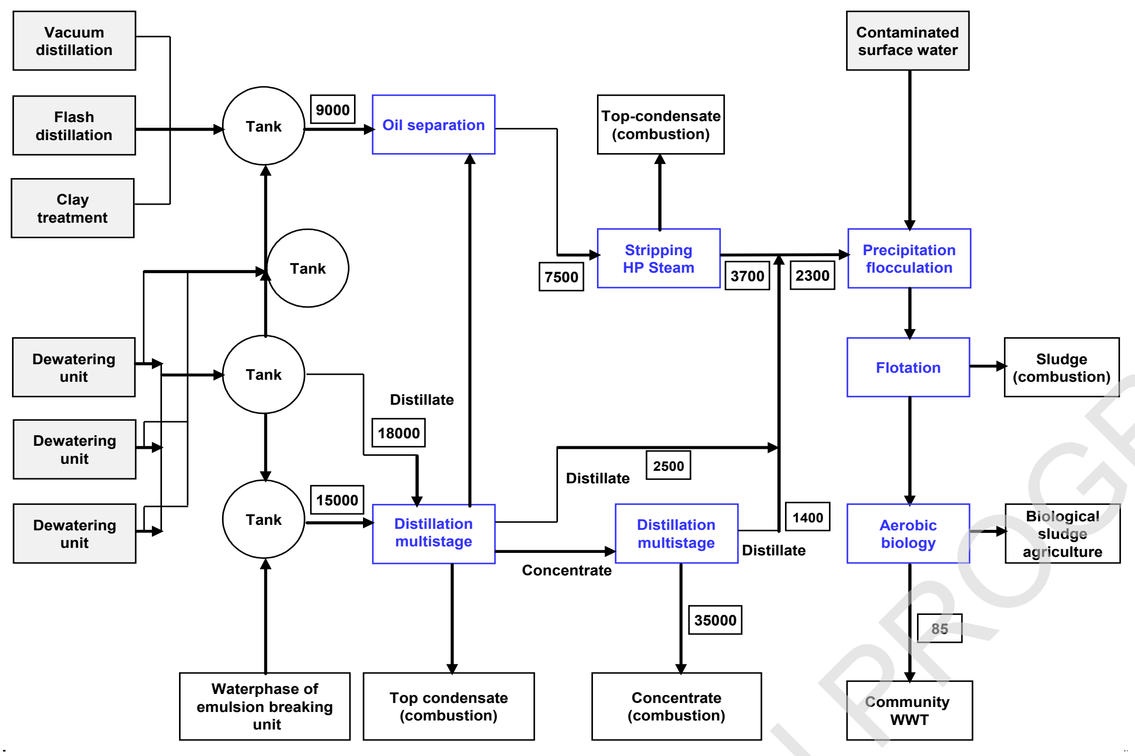
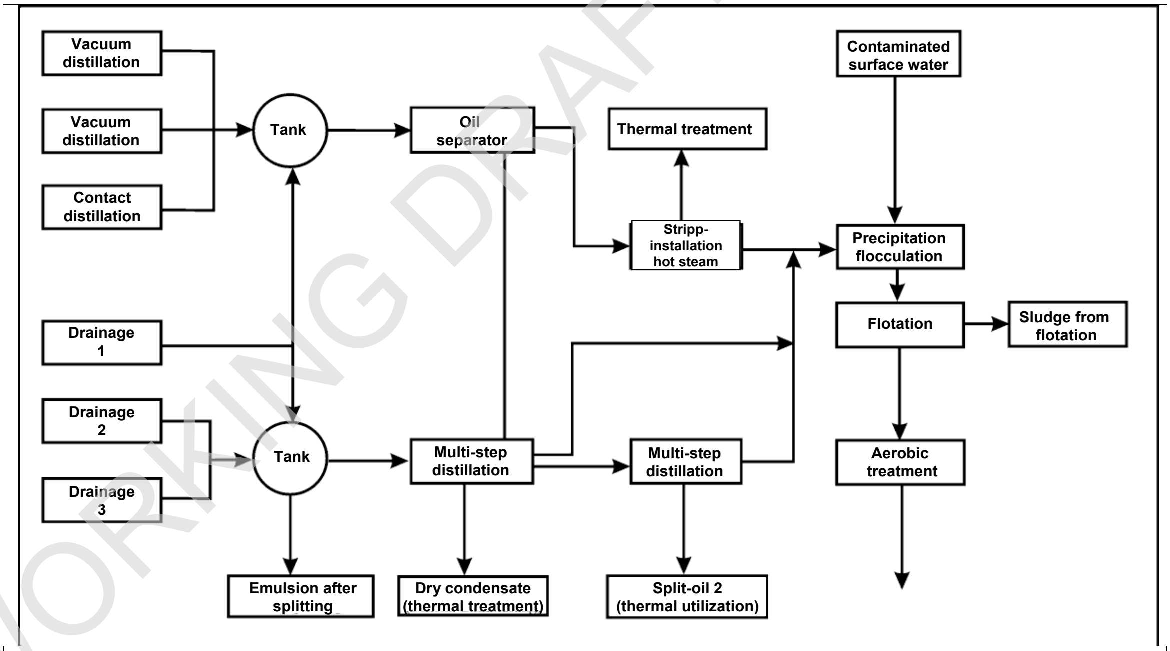


~~Note: Values in the figure correspond to TOC contents in ppm~~
~~*Source:* [93, UBA Germany 2003]~~

~~**Figure 5.11: Waste water treatment used in a re-refining process (TFE/clay treatment)**~~



~~*Source:* [98, WT TWG 2004]~~

~~**Figure 5.12: Waste water treatment used in a waste oil treatment plant**~~

~~The parameters in the~~
~~**Table 5.56** and~~
~~**Table 5.57** below can be achieved with a waste water treatment plant the same as above.~~

WORKING DRAFT IN PROGRESS

~~**Table 5.56: Composition of different inputs and outputs from different streams of the WWTP in a waste oil refinery**~~

~~**Parameter**~~	~~**branch precipitation/flocculation (mg/l)**~~	~~**branch biology (mg/l)**~~	~~**downpipe in-house biology (mg/l)**~~
~~COD~~			~~200 – 500~~
~~TOC~~	~~1800 – 3500~~	~~1300 – 2200~~	~~60 – 150~~
~~Nitrite- N~~		~~1 – 20~~	~~<0.1 – 1.0~~
~~Total nitrogen~~		~~80 – 280~~	~~10 – 60~~
~~Total phosphorous~~		~~1 – 15~~	~~2.0 – 5.0~~
~~AOX~~		~~0.1 – 0.4~~	~~<0.10 – 0.25~~
~~Hydrocarbons~~	~~50 – 300~~	~~<1.0 – 10~~	~~<0.1 – 2.0~~
~~Benzene and derivatives~~		~~0.01 - 0.03~~	~~<0.01~~
~~Phenol index~~		~~1 – 50~~	~~<0.2~~
~~Pb~~	~~<0.05 – 0.06~~	~~<0.05~~	~~<0.05~~
~~Cd~~	~~<0.02~~	~~<0.02~~	~~<0.02~~
~~Cr~~	~~<0.02 – 1.0~~	~~<0.02~~	~~<0.02~~
~~Fe~~	~~1 – 10~~	~~1 – 20~~	~~1 – 10~~
~~Cu~~	~~<0.02 – 0.2~~	~~<0.02 – 0.1~~	~~<0.02 – 0.1~~
~~Ni~~	~~<0.02 – 0.5~~	~~<0.02 – 0.3~~	~~<0.02 – 0.1~~
~~Zn~~	~~<0.1 – 1.0~~	~~<0.1 – 0.1~~	~~<0.1~~

~~*Source*:[98, WT TWG 2004]~~

~~**Table 5.57: Achievable levels in the effluent after biological WWTP in waste oil treatment units**~~

~~**Waste water parameter**~~	~~**Value (ppm)**~~
~~Hydrocarbons~~	~~<0.01 – 5~~
~~COD~~	~~20 – 400*~~
~~Phenols~~	~~0.15 – 0.45~~

~~* Values of 400 can be achieved without dilution of the treated waste water with other water streams~~
~~Source:[26, UK, H. 1995] [98, WT TWG 2004][100, WT TWG 2004] [101, WT TWG 2005]~~

~~Biological treatment is an option to consider, however it has not been found to be reliable. Daily monitoring of the sewer discharge includes the monitoring of ammonia levels, but not total nitrogen. There is no monitoring of phosphorus levels.~~

See section 5.7.2.3.2 for the environmental performance of the plant with direct discharge to the environment.

Plant 605 reports the use of a membrane bioreactor (MBR) since 2012. The main environmental and operational benefits of MBR application are as follows:

1) High removal efficiency of organic matter and nutrients (COD < 500 mg/l, NH_3-N < 10 mg/l, phenols < 1 mg/l, hydrocarbons < 6 mg/l, PO_4-P < 6 mg/l).
2) Zero solids discharge in the final effluent.
3) Low sludge production.
4) Flexibility in hydraulic and organic loading.
5) Reduced chemical consumption.
6) Small foot print. The biological process can operate at a much higher concentration of Mixed Liquor Suspended Soil (MLSS). This dramatically reduces the tankage requirements.
7) The membranes can be easily cleaned *in situ*.
8) The membranes can be easily removed for inspection/replacement.
9) Cross-flow membranes can be retrofitted. Existing MBR systems can be extended by adding further modules.
10) The MBR system does not require significant operational attention. Process control is reduced to monitoring effluent quality and MLSS concentration, adjustments of the caustic soda feed rate and scheduling membrane recovery cleaning.

WORKING DRAFT IN PROGRESS

Cross-media effects
WWTPs typically generate ammonia and VOC emissions to air.

See Section 2.3.6 for more details.

Technical considerations related to applicability
See Section 2.3.6 for more details.

Driving force for implementation
Local environmental quality standards for emissions to the municipal sewer system.

Economics
Table 5.58 gives an example of the costs related to the use of a membrane bioreactor (MBR) (Plant 605).

Table 5.58: Economics of a membrane bioreactor

Capital costs	EUR 500 000
Operational costs	
Pumping	EUR 49 000 per year
Aeration/mixing	EUR 67 000 per year
Membrane maintenance costs	
Chemical consumption for membrane cleaning	EUR 1 200 per year
Membrane module(1)	EUR 4 000

(1) Lifetime is estimated at 4–6 years.

See Section 2.3.6 for more details.

Example plants
~~The biological section of a UK oil recovery plant consisted of four aeration units which were used tanks to treat the aqueous layer from oil treatment as well as landfill leachates. There are some re-refining processes that do not generate waste water for external treatment. These systems make a total utilisation of the water contained in used oil (e.g. utilisation of treated water as Table 5.45refrigeration fluid or in the production of a fertilising compound).~~

See Table 5.45. Plants using pretreatment are plants 92, 235, 619 and 620.

Reference literature
[21, Viscolube 2002] [26, UK, H. 1995] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [93, UBA Germany 2003][98, WT TWG 2004] [100, WT TWG 2004] [160, WT TWG 2014]

5.2.3.3 Residue [~~waste~~] management in waste oil re-refining installations

From ex-**Section 4.4.1.15 "Waste management in waste oils re-refining installations"**

Description
Techniques to reduce residues generated by the re-refining of waste oils.

Technical description
Techniques include:

- ~~burning the~~ ~~non-lubricant recovered oils~~ using residues as heater fed in a heater equipped with a gas scrubber to ~~raise~~ generate energy for the plant;
- ~~treating and disposing of all used filters~~
- ~~applying a thermal treatment for all residues.~~
- ~~using the residues from the vacuum distillations and evaporators as asphalt products.~~

WORKING DRAFT IN PROGRESS

Achieved environmental benefits
Reduction of the amount of residues generated by the treatment.

Environmental performance and operational data
No information available.

Cross-media effects
Incineration of residues generates emissions to air.

Technical considerations related to applicability
No information available.

Driving force for implementation
~~To reduce waste generation.~~
Reduction of costs associated with waste disposal.

Example plants
Typically used in waste oil regeneration facilities.

Reference literature
[34, Babtie Group Ltd 2002] [98, WT TWG 2004]

5.2.3.4 Reduction of VOC emissions from waste oil re-refining plants

Description
Thernal oxidation of emissions to air.

Technical description
Collection of VOC emissions from the process, the storage and the loading/unloading activities and abatement by thermal oxidation (see Section 2.3.4.6).

Achieved environmental benefit
Reduction of emissions to air of organic compounds.

Environmental performance and operational data
Table 5.59 summarises the information related to the monitoring of organic compounds carried out by the plants from the reference list using thermal oxidation.

WORKING DRAFT IN PROGRESS

Table 5.59: Measurement of organic compounds in air emissions at plants re-refining waste oils using thermal oxidation

Emission point	**Average air flow (m^3/h)**	**Origin of emissions to air**	**Abatement technique**	**Type of VOC measured (as mentioned in the questionnaires) and average value (mg/Nm^3)**	**Standard used for monitoring**	**Number of measurements in the three-year reference period**
160C	7393	VOC treatment (upstream and downstream storage, process, loading station)	Thermal oxidation	TVOC: 3.1	NF EN 12619	3
				NMVOC: 3.1	XP X 43-554	3
				CH_4: 1.5	XP X 43-554	3
514	NI	Product storage tanks and vacuum distillation plant	Thermal oxidation	TVOC: 19	NI	2
620_1	16185	Off-gas burner	• Burner • Scrubbing with an aqueous urea solution to reduce NOx content. • Scrubbing with NaOH to reduce SO_2 • ESP to reduce dust	TOC: 0.75	NI	Continuous

NI: No information.

Cross-media effects
See the CWW BREF [138, COM 2014].

Technical considerations related to applicability
See the CWW BREF [138, COM 2014].

Driving force for implementation
Legislation on air pollution.
The steam produced allows energy savings.

Economics
See the CWW BREF [138, COM 2014].

In the case of Plant 620, the environmental treatment unit has a payback of seven years, which is shorter than other abatement techniques without energy recovery.

WORKING DRAFT IN PROGRESS

Example plants

In Plant 620, all the off-gases produced from the process are fed into a burner where a temperature of about 1000 °C is reached. An aqueous urea solution is fed into the end of the combustion chamber in order to greatly reduce the NO_X content. The gas obtained from the combustion with oxygen is then cooled using a boiler from which steam is recovered and sent into the plant steam network. In order to respect the emission level of SO_2, the gas stream is sent into a scrubbing column where NaOH is used to reduce the SO_2 to below the legal limit. This stream is finally sent into an ESP where the dust is reduced.

The plant achieves the following emission levels:

- dust < 30 mg/Nm^3;
- $SO_2 < 50$ mg/Nm^3;
- $NO_X < 350$ mg/Nm^3;
- CO < 100 mg/Nm^3;
- HCl < 10 mg/Nm^3;
- TOC < 20 mg/Nm^3;
- $NH_3 < 5$ mg/Nm^3.

Reference literature

[138, COM 2014] [160, WT TWG 2014]

WORKING DRAFT IN PROGRESS

5.3 Physico-chemical treatment of waste with calorific value [~~Treatments primarily aimed at producing material to be used as fuel or for improving its energy recovery~~]

5.3.1 Overview

From ex-**Section 3.5 Emissions and consumptions from waste treatments aimed to produce a material to be used as fuel**

~~[1, Langenkamp H. 1997] [3, Silver Springs Oil Recovery Inc. 2000] [4, Monier, V. and Labouze, E. 2001] [5, Krajenbrink et al. 1999] [7, Jacobs, A. and Dijkmans, R. 2001] [8, Birr-Pedersen, K. 2001] [10, Ministry for the Environment 2000] [12, ÖWAV Working Commitee 2002] [22, Woodward-Clyde 2000] [22, Woodward-Clyde 2000] [30, Ecodeco 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [35, EIPPCB 2001] [36, CEFIC 2002] [42, EIPPCB 2003] [58, VDI and Dechema 2002] [60, WT TWG 2003] [75, Watco 2002] [78, Eucopro 2003] [82, Pretz et al. 2003] [84, Ribi, J. 2003] [98, WT TWG 2004] [100, WT TWG 2004]~~

~~This section contains the emissions and consumptions of treatments mentioned in Section 2.5, i.e. those devoted to processing waste in order to produce a material that will be used as fuel. The following sections (Sections 3.5.X) detail information available to site operators from their current recording record systems and highlights the areas where emissions are likely to occur. Emissions associated with ancillary treatments, e.g. transfer station operation are covered in Section 3.1.~~

from ex-**Section 2.5 "Treatments primarily aimed at producing material to be used as fuel or for improving its energy recovery"**

[2, Concawe 1996] [4, Monier, V. and Labouze, E. 2001]
[5, Krajenbrink et al. 1999] [7, Jacobs, A. and Dijkmans, R. 2001] [9, Marshall, G.; Andrews, S.; Carter, M. and Dispain, G. 1999] [15, Langenkamp, H. and Nieman, H. 2001] [24, Militon et al. 1998], [28, Scori 2002] [30, Ecodeco 2002] [33, UK EA 2001] [34, Babtie Group Ltd 2002] [35, EIPPCB 2001] [36, CEFIC 2002] [37, Hogg, D.; Favoino, E.; Nielsen, N.; Thompson, J., et al. 2002] [42, EIPPCB 2003],[58, VDI and Dechema 2002] [60, WT TWG 2003][72, Hogg, D. 2001] [78, Eucopro 2003] [82, Pretz et al. 2003] [98, WT TWG 2004]

This section covers those treatments and processes which are mainly applied to obtain a material, prepared from waste, to be used as fuel or to change its physico-chemical properties to allow a better recovery of its calorific value.

Although the output waste of the processes described in this section is mainly used as fuel, it is not the aim of this document to define the specifications of the output.

Some treatments may produce some outputs that may be used for other purposes other than as fuel. These processes are very similar and only depend on the physical properties of the ~~starting~~ input waste and the physical properties that the output waste ~~OUT~~ needs to have to be able to be burnt in a combustion chamber. ~~Discussion of~~ The actual combustion of the waste is not discussed in this document as it is covered in the individual sectorial BREFs (e.g. waste incineration, cement, ~~and~~ lime and magnesium oxide, large combustion plants, iron and steel, etc.).

Waste which has some calorific value is currently used as a fuel in certain combustion processes, e.g. waste incineration, in cement or lime kilns, large combustion plants, heating plants, chemical works, industrial boilers, ceramic plants, brick production, iron and steel production, non-ferrous metal production. Some of the sectors using waste as a fuel are directly linked to the production of that waste. This implies that some wastes, produced in stable

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processes (therefore of a certain consistency), may not need any further preparation for their onward use in that sector and therefore they are often delivered directly to the plant where they will be used (e.g. used oils, used solvents). In these cases, no treatment is carried out on the waste, so consequently this activity is not included in the scope of this document (these ~~ones~~ waste streams are represented in **Figure 5.13** as brown arrows). The type of waste streams that are technically suitable for use in co-incineration plants is an issue that will be tackled in individual sectorial BREFs. This document considers and analyses the environmental issues involved in handling and transforming different types of waste into a material suitable to be used as fuel in different processes as represented by the blue arrows in **Figure 5.13**

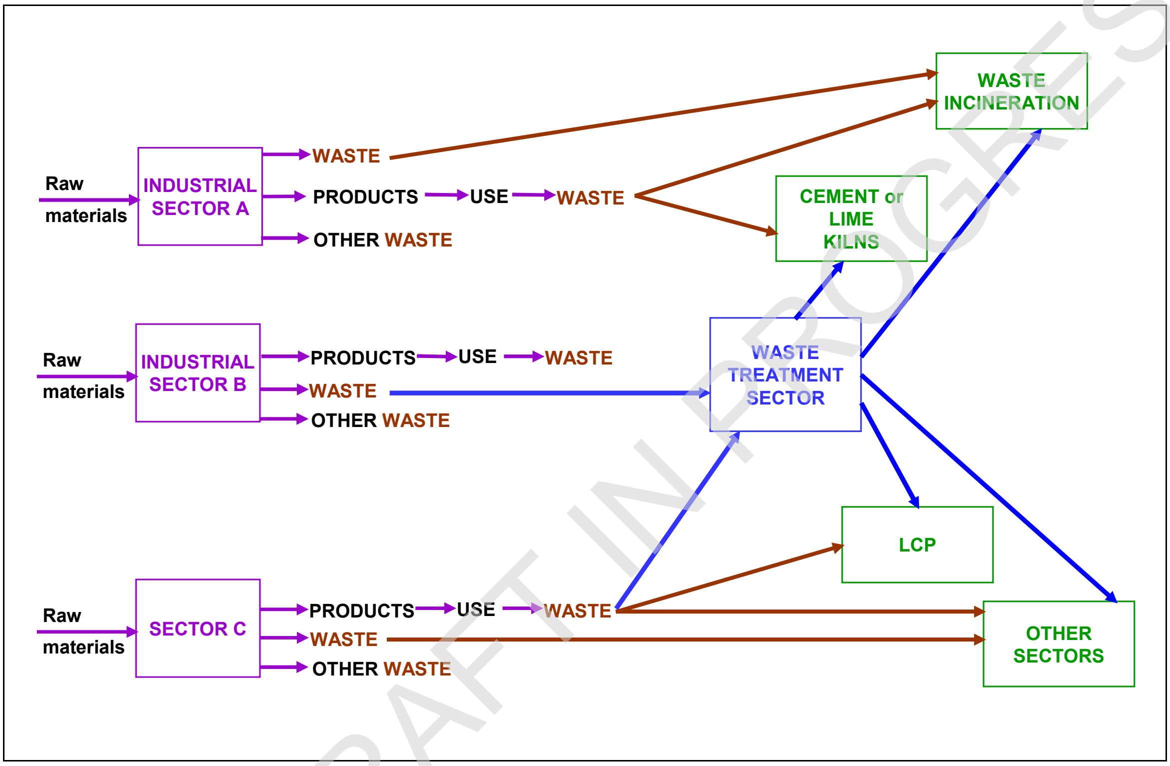

Figure 5.13: Some current possibilities for the use of waste as a fuel in different sectors

Note: This figure does not intend to show all the possibilities that may appear. Some options are not shown in the figure to ~~increase~~ improve its readability.

To cite a few instances, the use of waste oil as a substitution fuel without any treatment is one option that is used across Europe, varying in popularity depending on local economic and legislative circumstances. Most national regulations allow the burning of waste oil in cement kilns. Waste oils are accepted under special conditions as cement kiln fuel in France, Germany, Italy, Spain and the UK, but seem to be banned for that use in the Netherlands, for instance. In other countries they are simply not used.

TWG, please confirm or provide additional information

~~Common techniques used in the production of these materials for their use as a fuel are described in Section 2.1.~~

From ex-Section **4.5.2 "Prepare different types of waste fuel"**

~~Description~~

The preparation of different types of waste fuel needs to consider the technical characteristics of the combustion process using it (e.g. cement plant, lime plant, power plant (hard coal, lignite), specialised waste fuel combustion). These combustion processes have different technical characteristics.

The extent of the waste treatment operation depends on the waste fuel application. Some examples are:

WORKING DRAFT IN PROGRESS

a. type of waste used to prepare the waste fuel;
b. techniques used for waste fuel storage;
c. kind of furnace feeding (bulk material, blow feeding);
d. fuel mix used in the combustion process;
e. type of combustion process, grate firing with a diameter < 150 mm or pyrolysis with a diameter < 150 mm with a high tolerance of metals and heavy particles;
f. type of feeding of the waste fuel: blow feeding of a blast furnace with a diameter < 20 mm (cement kiln, lignite power plant) only for parts with a velocity of less than 2 or 3 m/s;
g. tolerance of some components: e.g. a chlorine content of < 0.3 % also depends on the fuel mix (cement) in contrast to e.g. < 5 % in some waste fuels.

The types of solid waste fuel that can be prepared typically fall into one of the following categories:

- from MSW (mainly household waste);
- from mixed commercial bulky household waste and other waste;
- from dry monostreams or homogeneous selected waste streams;
- from filter cakes, sludges and other wet wastes.

The treatment ~~has used an influence on~~ changes the physico-chemical characteristics of the waste fuel prepared. For example, comminution can be carried out up to the required grain size of the solid waste fuel. Another example is that the cleaning may separate the ~~trash~~ rubbish content and foreign impurities by mechanical processing and comminution. That means that it is possible to have a fuel yield from 100 to x % of fuel quality because of ~~increasing~~ the water and ash contents increasing.

~~**Achieved environmental benefits**~~
~~Provide the user with the required physico-chemical properties of the waste fuel.~~

~~**Operational data**~~
~~The technology used to prepare a certain waste fuel depends on the characteristics of the input material and the requirements of the users and this is not covered in this Section. For example, the extent of mechanical and biological processing depends on the origin of the waste. One type of waste from different origins may have different compositions/qualities. For example paper/cardboard 03 03 08, paper production 15 01 01, packaging material 19 12 01, mechanical processing 19 12 12, mechanical processing (including mixtures) 20 01 01, and municipal waste all have different compositions. Another example can be nappies, a) as a residue from production b) as a high calorific fraction from municipal solid waste (approx. 15 – 20 % of weight nappies).~~

~~The influence of waste collection (and in case of consumption waste, the national or regional habits) on the characteristics of the waste streams needs to be considered.~~
~~**Driving force for implementation**~~
~~Some guidances are also available (e.g. North Rhine Westphalia in Germany).~~

Reference literature
[98, WT TWG 2004] [100, WT TWG 2004]

Waste input

From ex-**Section 3.5.1 "Waste IN for the preparation of waste fuels"**

Table 5.60 shows some examples of the types of waste used for the production of solid and liquid waste fuel.

WORKING DRAFT IN PROGRESS

Table 5.60: Some examples of the types of waste used for the preparation of solid and liquid waste fuels

Type of waste fuel to be prepared	Type of waste	Examples
Solid waste fuel	Pasty wastes (mainly from hazardous waste)	High viscosity solvents, oil sludges, distillation residues, sludges from the treatment of industrial sludges (mechanical industry, chemical industry, pharmaceutical industry, etc.), paint and varnish sludges, ink sludges, polyol, glues, resins, grease and fats, other pasty wastes
	Powder wastes (mainly from hazardous waste)	Carbon black, toner powder, paints, spent catalysts, tensides, other powders
	Solid wastes (mainly from hazardous waste)	Polluted polymers, impregnated sawdust, sludges from waste water treatment, resins, paints, glues, spent activated carbon, polluted soils, hydrocarbon sludges, polluted absorbents, organic residues from the chemical and pharmaceutical industries, spent plastic packaging, waste woods, other solid wastes
	Liquid wastes which are not suitable for preparation of liquid waste fuel (mainly from hazardous waste)	Liquids with risk of polymerising
	Non-hazardous solid waste	Household and commercial solid wastes, packaging wastes, wood, paper, cardboard, cardboard boxes (02, 03, 15, 17, 19, 20), textiles, fibres (04, 15, 19, 20), plastics (02, 07, 08, 12, 15, 16, 17, 19, 20), other materials (08, 09, 15, 16, 19), high calorific fractions from mixed collected wastes (17, 19, 20), construction and demolition waste, source-separated fractions from MSW, monostreams of commercial and industrial waste
Liquid waste fuel by blending	Organic liquid waste fuel	Solvents, xylenes, toluenes, white spirit, acetone, cleaning and degreasing solvents, petroleum residues, distillation residues, off-specification organic liquid products
Liquid waste fuel by fluidification	Organic liquid waste fuel	Used solvents, pasty organic wastes (ink sludges, paint sludges, adhesives wastes, etc.), oil residues, pulverulent wastes such as paint powder, filter cakes, residues from organic chemical synthesis, oil and fat, spent ion exchange resins, distillation residues, wastes from cosmetic industries
Liquid waste fuel by emulsions	Organic liquid waste fuel	Oil emulsions from mechanical and metallurgical industries, wastes and sludges containing oil from petroleum refining, from the collection and storage of oil products, wastes from oil distillation and regeneration, production failures, pasty wastes such as grease, ink and adhesive wastes, pulverulent waste such as paint powder, washing powder wastes, used bases such as sodium, used oils

NB: Numbers within brackets correspond to EWL codes ~~chapters~~.
Source: [15, Langenkamp, H. and Nieman, H. 2001] [28, Scori 2002] [78, Eucopro 2003] [82, Pretz et al. 2003] [98, WT TWG 2004]

WORKING DRAFT IN PROGRESS

Table 5.61 shows the typical heating values of some types of waste.

Table 5.61: Typical heating values of different types of waste

Type of waste	Heating value (MJ/kg)
Hazardous waste	21.0–41.9
Non-hazardous industrial waste	12.6–16.8
Municipal waste	7.5–10.5
Plastic	21.0–41.9
Wood	16.8
Tyres	25.1–31.4
Source:[1, Langenkamp H. 1997] [98, WT TWG 2004]	

~~Fuel preparation plants and combustion installations that may use waste as (part of) fuel generally take in more than one type of waste. Some types of waste materials that are used for co-incineration are shown in Table 5.62~~

Table 5.62: ~~Some types of materials used in some co-incineration processes~~

~~Type of waste~~	~~Combustion plants (including district heating and marine engines)~~	~~Cement kilns~~	~~Iron and steel (blast furnaces)~~	~~Ceramics (brick kilns)~~	~~Lime kilns~~	~~Asphalt production~~	~~Pulp and paper~~
~~Animal products~~	~~Animal meal~~ ~~Meat and bone meal~~ ~~Tallow~~ ~~Manure~~ ~~Chicken litter~~ ~~Fat~~	~~Meat and bone meal~~					
~~Charcoal residues~~	~~Charcoal residues~~[+]						
~~Chemicals~~	~~Organic acids~~ ~~Liquid solvents~~ ~~Phosphorus oven gas~~	~~Spent solvents~~ ~~Paint sludges~~ ~~Hydrocarbons~~ ~~Distillation residue~~					
~~Municipal waste~~	~~RDF~~ ~~Waste paper~~ ~~Packing materials~~ ~~Plastics~~ ~~Textiles~~ ~~Wood~~	~~RDF~~ ~~Waste paper~~ ~~Plastics~~ ~~Textiles~~ ~~Wood~~	~~RDF~~ ~~Plastics~~ ~~Textiles~~ ~~Wood~~	~~RDF~~ ~~Textiles~~ ~~Wood~~	~~RDF~~ ~~Textiles~~ ~~Wood~~	~~RDF~~	~~Waste paper~~
~~Oily materials~~	~~Tar~~ ~~Waste oil~~	~~Waste oils~~ ~~Cutting oils~~	~~Waste oils~~		~~Waste oils~~	~~Waste oils~~	
~~Rubber~~	~~Shredded tyres~~	~~Used tyres~~ ~~Rubber~~ ~~Car shredding residues~~ ~~Carpets~~		~~Used tyres~~			
~~Sludge~~	~~Sewage sludge~~	~~Sewage sludge~~ ~~Paper sludge~~					
~~Vegetables~~	~~Energy crops such as willow~~ ~~Agricultural residues such as straw, cereal plants, pasture from landscape cultivation~~						
~~Wood~~	~~Wood residues~~ ~~Demolition wood~~ ~~Forest residues~~ ~~Wood chips~~ ~~Biomass pellets/briquettes~~	~~Waste woods~~					

[+] ~~Some trials have been made on the use of waste in cupola furnaces in foundries.~~

~~Note: Table should not be interpreted as exhaustive. Other combinations not mentioned in this table may actually be used.~~

~~*Source*: [1, Langenkamp H. 1997] [35, EIPPCB 2001] [42, EIPPCB 2003] [58, VDI and Dechema 2002] [98, WT TWG 2004] [99, EIPPCB 2003]~~

WORKING DRAFT IN PROGRESS

Deleted: already said in Table 5.61

~~The following sections which have titles in bold give more detailed information on each type of waste used as fuel. Typical compositions of the type of waste are in some cases made available.~~

~~Chemicals~~

~~Paint and solvent wastes have a heating value of more than 21 MJ/kg wet matter. The contents of chlorine, cadmium and zinc may be high.~~

~~Municipal solid waste~~

~~See section Mechanical treatment~~

~~Oily materials~~

~~See section PCT waste oil~~

~~Rubber~~

~~Table 5.63 shows some characteristics of tyres used as fuel.~~

Table 5.63: Fuel characteristics of tyres

~~Parameter~~	**~~Value~~**	**~~Units~~**
~~Calorific value~~	~~36 – 38~~	~~MJ/kg~~
~~Chloride~~	~~0.15 – 0.25~~	~~%~~
~~As~~	~~<2~~	~~ppm~~
~~Cd~~	~~<5 – 10~~	~~ppm~~
~~Co~~	~~<5 – 27~~	~~ppm~~
~~Cr~~	~~<5 – 97~~	~~ppm~~
~~Cu~~	~~10 – 30~~	~~ppm~~
~~Hg~~	~~0.17 - <1~~	~~ppm~~
~~Mn~~	~~6 – 11~~	~~ppm~~
~~Ni~~	~~<5 – 40~~	~~ppm~~
~~Pb~~	~~<5 – 410~~	~~ppm~~
~~Sb~~	~~55 – 410~~	~~ppm~~
~~Sn~~	~~14 – 21~~	~~ppm~~
~~Tl~~	~~0.25 – 75~~	~~ppm~~
~~V~~	~~<5 – 60~~	~~ppm~~
~~Zn~~	~~14.5 – 16.1~~	~~g/kg~~
~~Source: [1, Langenkamp H. 1997]~~		

~~Sludge~~

~~Sludge typically contains water. An increase in the content of water for a given dry composition of sludge decreases its heating value. For example, sludge with a content of 33 % dry matter has a heating value of less than 5 MJ/kg wet matter. The content of chlorine is typically low but the mercury content may be significant in certain sludges.~~

~~Wood~~

~~Sawdust, sawmill chips and PVC have a heating value of between 14 and 21 MJ/kg wet matter. Construction waste has a heating value of between 14 and 17 MJ/kg wet matter. Some physico-chemical parameters of scrap wood are shown in~~

WORKING DRAFT IN PROGRESS

Table 5.64: Metals' content of scrap wood

~~**Metals**~~	~~**Concentration (ppm)**~~
~~Lower heating value (MJ/kg)~~	~~17.3~~
~~Cl~~	~~0.1 %~~
~~Cd~~	~~0.7 – 3.4~~
~~Cr~~	~~50~~
~~Hg~~	~~0.2~~
~~Pb~~	~~53 – 1000~~
~~Tl~~	~~<0.1~~
~~Zn~~	~~1500~~
~~*Source*: [1, Langenkamp H. 1997] [58, VDI and Dechema 2002]~~	

Output waste

From ex-**Section 3.5.4 "Waste fuels (waste OUT)"**

~~The intention of this section is to give an overview of the type of specifications that waste fuel typically has to have in order to be used in different combustion processes. Waste fuel is the term used in this document to name the fuel prepared from waste. As stated in the Scope chapter, descriptions of the combustion processes themselves are not covered in this document. Combustion is covered in the other industrial sector BREFs covered by IPPC.~~

~~The co-incineration of waste materials impacts on plant efficiency, and/or emissions to air and water, and also effects the quality of combustion residues and by-products. The impact of using waste as a fuel instead of using conventional fuels is determined by the different properties of the waste from the main fuel. For example, the emissions caused by the burning of waste oils in a coal fired power plant, in a fuel oil fired power plant or in a cement kiln are different because the nature of the process and the applied abatement techniques, e.g. solid vs. liquid fuel, end-of-pipe techniques, alkalinity of the cement kilns, temperature of the combustion (from 800 °C for fluid bed furnaces up to 2000 °C for cement furnaces), and the type of combustion plant (power plant, district heating or CHP) can be very different in each case. Consequently, those issues are covered in each industrial sector BREF, together with the discussion on the applied combustion process; and hence these issues cannot be covered here.~~

Part of the heating value of the waste to be used as fuel and the other important fuel properties that determine whether a specific fuel can be applied in a combustion plant arise from its chemical composition and physical properties. Fouling, slagging and corrosion of the boiler, when used in combustion power/heat plants, are possible negative aspects that are also related to its chemical composition, in particular to the presence of certain components in the total fuel mix such as alkali metals, chlorine and sulphur. These components may therefore have a great influence on the availability of the combustion power/heat plant – as they can lead to plant downtime; they can also affect the ash characteristics, e.g. sintering and melting behaviour. Ash composition can be an important factor in the economics of the combustion plant. Polluting elements, such as heavy metals, can negatively influence the options for ash use, resulting in high costs for ash disposal. The physical form in which the fuel occurs is also of importance because the feeding systems must be capable of handling the fuel without problems and particles must be small enough for complete burn-out in the relevant combustion technology. Pellets, fluff, briquettes and bales are the most commonly applied physical forms for solid waste fuel.

Furthermore, for combustion processes the volatiles are an important fuel parameter with regard to flame stability and burn-out of the fuel. Generally, solid waste fuels consist of wood, paper and plastics which are high in volatiles, e.g. compared to coal.

From ex-**Section 3.5.4.2 "Specifications of waste fuel to be used in cement kilns" deleted Specification of output outside scope.**

~~The two tables below (Table 5.65 andTable 5.66) contain examples of specifications used by cement kilns in some countries. These tables do not contain the full picture of what is actually~~

WORKING DRAFT IN PROGRESS

~~happening in Europe, so it should be considered that the information given here is not exhaustive.~~

~~The sampling and measurements required for accepting substitute fuels in cement kilns in some countries is shown in Table 5.65.~~

~~Table 5.65: Examples of specifications of a waste to be accepted as fuel in some countries' cement kilns~~

~~Substances or criteria to be measured~~	**~~Units~~**	**~~United Kingdom~~**	**~~Flanders~~[1] ~~(Belgian region)~~**	**~~Italy~~[2]**	**~~New Zealand~~[3]**
~~Calorific value~~	~~MJ/kg~~	~~23 – 29~~	~~>15~~	~~>15~~	
~~Water/solvent separation~~		~~not detectable~~			
~~Water content~~	~~%~~			~~<25~~	
~~Total S~~	~~%~~	~~<0.3~~	~~<0.4~~	~~<0.6~~	~~0.1 – 2.8~~
~~Total Cl~~	~~%~~	~~<2~~	~~<0.5~~	~~<0.9~~	~~0.03 – 0.76~~
~~Total F, Br, I~~	~~%~~	~~<0.5~~			
~~F~~	~~%~~		~~<0.1~~		
~~Total Br, I~~	~~%~~		~~<0.01~~		
~~Total N~~	~~%~~		~~<1.0~~		
~~Al~~	~~ppm~~				~~10 – 1000~~
~~As~~	~~ppm~~	~~<50~~	~~<10~~	~~<9~~	~~<50 – 60~~
~~Be~~	~~ppm~~		~~<1~~		
~~Cd~~	~~ppm~~		~~<10~~		~~<10 – 20~~
~~Cd + Tl~~	~~ppm~~	~~<40~~			
~~Cd + Hg~~				~~<7~~	
~~Co~~	~~ppm~~	~~<100~~			
~~Cr~~	~~ppm~~	~~<200~~		~~<100~~	~~<10 – 80~~
~~Cu~~	~~ppm~~	~~<600~~		~~<300~~[6]	~~<10 – 165~~
~~Hg~~[4]	~~ppm~~	~~<20~~			~~<10~~
~~Hg, Tl~~	~~ppm~~		~~<2~~		
~~Mn~~	~~ppm~~	~~<250~~		~~<400~~	
~~Mo~~	~~ppm~~		~~<20~~		
~~Ni~~	~~ppm~~	~~<50~~		~~<40~~	
~~Pb~~	~~ppm~~	~~<500~~	~~<200~~	~~<200~~[5]	~~10 – 1080~~
~~Sb~~	~~ppm~~	~~<50~~			
~~Sn~~	~~ppm~~	~~<100~~			
~~V~~	~~ppm~~	~~<50~~	~~<200~~		
~~Zn~~	~~ppm~~		~~<500~~		~~108 – 3670~~
~~Sb, As, Cr, Co, Cu, Pb, Mn, Ni, Sn, V~~	~~ppm~~	~~<1800~~			
~~Solid and ash content~~	~~%~~	~~Depends on the type of waste fuel~~		~~<20~~	
~~PCB content~~					~~<10~~
~~Other species~~		~~Depends on the type of waste fuel~~			

[1] ~~It has been reported that no cement kiln is now operating in Flanders~~

[2] ~~An SRF producer reported production of a waste fuel with the following characteristics: calorific value of more than 18.8 MJ/kg, water content of less than 20 %, total chlorine content of less than 1 % and an ash content of less than 6 %~~

[3] ~~For waste oil used in a cement kiln~~

[4] ~~Lower values have been reported (2 – 5 ppm if the facility is equipped with a bag house filter with activated carbon and less than 1 ppm if such equipment is not implemented) but no reference to any country or installation was given~~

[5] ~~refers only to volatile Pb~~

[6] ~~refers only to soluble Cu compounds~~

~~More data can be found in the German legislation (Table 1 of Stellungnahme der LAGA zu RAL GZ 724) and in the work carried out by CEN/TC 343 WG 2.~~

~~*Source*: [1, Langenkamp H. 1997] [22, Woodward-Clyde 2000] [30, Ecodeco 2002] [98, WT TWG 2004] [100, WT TWG 2004]~~

WORKING DRAFT IN PROGRESS

~~Table 5.66 shows some examples of specifications applied to different types of waste to be accepted in French cement kilns.~~

~~Table 5.66: Examples of specifications of different types of waste to be accepted as waste fuel in the French cement kilns~~

~~**Substances or criteria to be measured**~~	~~**Units**~~	~~**Catalysts**~~	~~**Industrial sludges**~~	~~**Polluted water with high COD contents (>10000 ppm)**~~	~~**Animal meal**~~	~~**Animal fat**~~	~~**Waste oil**~~
~~PCB/PCT~~	~~ppm~~	~~<50~~	~~<50~~	~~<50~~			~~<50~~
~~Pentachlorophenol~~		~~none~~	~~none~~	~~none~~			~~none~~
~~Hg~~	~~ppm~~	~~<10~~	~~<10~~	~~<10~~			
~~Hg + Cd + Tl~~	~~ppm~~	~~<100~~	~~<100~~	~~<100~~			
~~Sb + As + Pb + Cr + Co + Ni + V + Sn + Te + Se~~	~~ppm~~	~~<10000~~	~~<2500~~	~~<2500~~			
~~Heavy metals~~	~~%~~						~~<1~~
~~pH~~			~~3 – 12~~	~~3 – 12~~			~~3 – 12~~
~~Calorific value~~	~~kJ/kg~~		~~8400~~	~~8400~~	~~18800~~	~~38500~~	~~38500~~
~~Total hydrocarbons~~	~~%~~	~~<0.5~~					
~~CaO + SiO^2 + Fe^{2}O^3 + Al^{2}O^3~~	~~%~~	~~>80 *~~					
~~Water~~	~~%~~	~~<10~~	~~40 – 70~~				~~<15~~
~~Alkalis (Na^{2}O + K^{2}O)~~	~~%~~	~~<5~~	~~<1.5~~	~~<5~~			~~<5~~
~~Total Cl~~	~~%~~	~~<0.6~~	~~<0.3~~	~~<0.6~~	~~<0.6~~	~~<0.1~~	~~<0.6~~
~~Total S~~	~~%~~	~~<5~~	~~<2~~	~~<2~~	~~<0.4~~	~~<0.1~~	~~<2~~
~~Total P (as P^{2}O^5)~~	~~%~~	~~<2~~	~~<5~~				
~~F~~	~~%~~	~~<2~~					
~~Br~~	~~%~~	~~<0.5~~					
~~I~~	~~%~~	~~<0.5~~					
~~F + Br + I~~	~~%~~		~~<1~~	~~<1~~			~~<1~~
~~Solid residue at 900 °C~~	~~%~~		~~<30~~	~~<5~~			~~<5~~
~~Viscosity at 20 °C~~	~~cp~~			~~250~~			~~250~~

~~Notes:~~
~~* on a dry basis~~
~~The types of wastes not accepted for processing in cement kilns in France are radioactive products, explosives, peroxides, perchlorates and strong oxidants, tear compounds, mineral cyanides, hospital waste, waste polluted with pathogenic microbes and highly flammable liquids.~~
~~Some of the wastes listed here correspond to wastes that are directly sent from the waste producer to the cement kiln, and then, these are not treated before being used in the cement kilns. Some wastes listed here do not correspond strictly to use of waste as fuel.~~
~~Some substances mentioned here have an impact on the cement kiln process or product (e.g. alkalis, phosphorous, viscosity). For more information see the Cement and Lime BREF.~~
~~Source: [27, Szabo 2002] [98, WT TWG 2004] [100, WT TWG 2004]~~

WORKING DRAFT IN PROGRESS

Table 5.67: Standard values for pollutant content of waste used in the cement kilns used in Switzerland

~~Substance~~	~~A~~		~~B~~	~~C~~
	~~mg/MJ~~	~~mg/kg (at 25 MJ/kg)~~	~~mg/kg~~	~~mg/kg~~
~~Ag~~	~~0.2~~	~~5~~	~~-~~	~~-~~
~~As~~	~~0.6~~	~~15~~	~~20~~	~~30~~
~~Ba~~	~~8~~	~~200~~	~~600~~	~~1000~~
~~Be~~	~~0.2~~	~~5~~	~~3~~	~~3~~
~~Cd~~	~~0.08~~	~~2~~	~~0.8~~	~~1~~
~~Co~~	~~0.8~~	~~20~~	~~30~~	~~100~~
~~Cr~~	~~4~~	~~100~~	~~100~~	~~200~~
~~Cu~~	~~4~~	~~100~~	~~100~~	~~200~~
~~Hg~~	~~0.02~~	~~0.5~~	~~0.5~~	~~0.5~~
~~Ni~~	~~4~~	~~100~~	~~100~~	~~200~~
~~Pb~~	~~8~~	~~200~~	~~50~~	~~75~~
~~Sb~~	~~0.2~~	~~5~~	~~1~~	~~5~~
~~Se~~	~~0.2~~	~~5~~	~~1~~	~~5~~
~~Sn~~	~~0.4~~	~~10~~	~~50~~	~~30~~
~~Tl~~	~~0.12~~	~~3~~	~~1~~	~~2~~
~~V~~	~~4~~	~~100~~	~~200~~	~~300~~
~~Zn~~	~~16~~	~~400~~	~~400~~	~~400~~
~~Toxic organic compounds~~	~~No standard value. However, some restrictions are mentioned if PCB, dioxins or similar toxic compounds are suspected or organic compounds are present~~			

~~Column A applies to wastes used as fuel introduced either in the main burner at the clinker outlet of the rotating kiln or the inlet of the rotating kiln. The standard values in colum A (mg/MJ) are based on the lower calorific value of the waste. For reasons of clarity, the standard values in (mg/kg waste) are based on a lower calorific value of 25 MJ/kg. The value of 25 MJ/kg corresponds to the calorific value of hard coal. If the calorific value of the waste is less than or greater than 25 MJ/kg, the permissible heavy metal content changes proportionally~~

~~Column B applies to wastes used as alternative raw materials in producing clinker. This waste substitutes part of the raw material normally used or serves to correct the raw meal composition, i.e. the calcium, iron, silicon or aluminium content~~

~~Column C applies to waste used at the grinding stage in the production of Portland cement. Portland cement consists of 90 – 95 % ground cement clinker and 5 – 10 % gypsum, as well as other materials added at the grinding stage.~~

~~*Source:*[98, WT TWG 2004]~~

Ex-**Section 3.5.4.4 "Quality assurance system" deleted:** Specification of output outside scope.

~~The information given in this section presents a survey about existing quality assurance systems and the recent developments.~~

~~European CEN/BT/TF 118~~

~~The CEN Task Force 118 'Solid Recovered Fuels' was established in April 2000. The Task was to prepare a technical report about the production and the application of solid waste fuel within the EU as well as the development of a work programme as the basis for an European standard in the future. The European classification model is based on solid waste fuel characteristics, source material and origin. The report concluded that it is necessary to develop a European standard. CEN was given the mandate to develop, as a first step, a set of technical specifications concerning solid waste fuel, and produced exclusively from non hazardous wastes, for energy recovery in waste incineration or co-incineration plants. As a second step, CEN was given a mandate to transform this set of technical specification into European Standards.~~

~~German RAL~~

~~Early in 1999, a german association started its endeavours to install the quality label for solid waste fuel from non-hazardous waste. The label is awarded to solid waste fuel producers which comply to the requirements by guaranteeing constant qualities. The standards firstly relate to cement industry and power stations. Accordingly, solid waste fuel has to fulfil the criteria given~~

WORKING DRAFT IN PROGRESS

~~in annexes 1 and 2 to the quality assurance system. Annex 1 contains a list with all allowed wastes which are applicable as a basic principle. In annex 2, values are given which have to be met. These values are shown in Table 5.68. The inspections in acknowledging as well as in the supervision procedure occur in two phases. These systems include sampling matters, how to calculate mean values, acknowledging procedure (first inspection), self-monitoring, independent supervision and re-inspection.~~

Table 5.68: Heavy metal contents which have to be complied with according to BGS/12/

	~~Content of heavy metals~~ 4)	
~~**Parameter**~~	~~**Median (mg/kgDM)**~~	~~80th percentile (mg/kgDM)~~
~~Calorific value~~		
~~Humidity~~		
~~Ash content~~		
~~Chlorine content~~		
~~Cadmium~~	4	~~9~~
~~Mercury~~	~~0.6~~	~~1.2~~
~~Thallium~~	~~1~~	~~2~~
~~Arsenic~~	~~5~~	~~13~~
~~Cobalt~~	~~6~~	~~12~~
~~Nickel~~	~~25 1) 80 2)~~	~~50 1) 160 2)~~
~~Selenium~~	~~3~~	~~5~~
~~Tellurium~~	~~3~~	~~5~~
~~Antimony~~ 5)	~~50~~	~~120~~
~~Lead~~	~~70 1) 190 2)~~	~~200 1) - 3)~~
~~Chromium~~	~~40 1) 125 2)~~	~~120 1) 250 2)~~
~~Copper~~	~~120 1) 350 2)~~	~~- 3) - 3)~~
~~Manganese~~	~~50 1) 250 2)~~	~~100 1) 500 2)~~
~~Vanadium~~	~~10~~	~~25~~
~~Tin~~	~~30~~	~~70~~
~~Beryllium~~	~~0.5~~	~~2~~

1) ~~For solid recovered fuel from production specific waste~~

2) ~~For solid recovered fuel from the high calorific fractions of municipal waste~~

3) ~~Restriction not until a secured database is given by the fuel processing~~

4) ~~The heavy metal contents are valid up to a calorific value NCV_{DM} of ≥ 16 MJ/kg for the high calorific fractions from municipal waste and up to a calorific value NCV_{DM} of ≥ 20 MJ/kg for production specific waste. For calorific values falling below, the values need to be lowered accordingly, an increase is not allowed.~~

5) ~~Values adapted in case of digestion with aqua regia in a closed microwave system~~

~~[82, Pretz et al. 2003] [98, WT TWG 2004]~~

~~Finnish SFS 5875~~

~~The Finnish waste disposal system is based on a separate collection of wastes for the recycling and for solid waste fuel production. Different solid wastes and Finnish boilers with a high technical standard are used for a highly efficient production of energy followed by low emission levels. The application of solid waste fuel in the Finnish multifuel boiler is estimated as 'well suited'. The regulations concern separate collected, dry solid, high calorific fractions or for dry, high calorific fractions derived from household wastes. The regulation defines operations and demands to control the solid waste fuel production and also refers to the complete waste management chain, from the waste recovered paper source up to the disposal. For each part of the disposal chain, the standard requires a person in charge to monitor the technical and quality requirements.~~

~~Analogical to the German standard, the annexes of the Finnish standard define concrete requirements concerning thresholds for heavy metals as well as for the framework of analysis, sampling, etc. The thresholds are predefined which have to be adhered to as well as regulations as regard to the matter of contracts. It includes supervision operation, quality requirements and quality classes.~~

WORKING DRAFT IN PROGRESS

~~In comparison to the German standard, the Finnish standard divides wastes into three quality classes. For categorisation of solid waste fuel in Finland, seven elements are analysed. Table **5.69** presents the criteria for the classification of quality classes.~~

~~**Table 5.69: Quality classes according to SFS 5875/13/**~~

~~**Parameter**~~	~~**Unit**~~	~~**Quality classes**~~		
		~~**I**~~	~~**II**~~	~~**III**~~
~~Chlorine~~	~~weight -%~~	~~<0.15~~	~~<0. 5~~	~~<1.5~~
~~Sulphur~~	~~weight -%~~	~~<0.2~~	~~<0.3~~	~~<0.5~~
~~Nitrogen~~	~~weight -%~~	~~<1.0~~	~~<1.5~~	~~<2.5~~
~~Potassium and Sodium~~	~~weight -%~~	~~<0.2~~	~~<0.4~~	~~<0.5~~
~~Aluminium (metallic)~~	~~weight -%~~	~~–1)~~	~~–2)~~	~~–3)~~
~~Mercury~~	~~mg/kg~~	~~<0.1~~	~~<0.2~~	~~<0.5~~
~~Cadmium~~	~~mg/kg~~	~~<1.0~~	~~<4.0~~	~~<5.0~~

~~1) Metallic aluminium is not allowed, but is accepted within the limits of reporting precision.~~
~~2) Metallic aluminium is minimised by source separation and by the fuel production process.~~
~~3) Metallic aluminium content is agreed separately.~~

~~[82, Pretz et al. 2003]~~

~~**Austrian ÖG SET**~~
~~Within a joint project of the Austrian association (Österreichische Gütegemeinschaft für Sekundärenergieträger), a quality assurance concept for solid recovered fuels (SRF) has been worked out.~~

~~*Objective*~~
~~In order to meet the requirements for the thermal utilisation of wastes/residues in industrial co-incineration, the waste/residue quality has to be accurately defined. During production of waste fuels, special attention has to be given to the quality assurance of these predefined fractions. For the technical feasibility on an industrial scale, practical experience showed that not only the chemical contents and the composition, defined by the origin of the waste, but also the physical parameters like particle size and agglomeration, defined by the mechanical pretreatment, in order to comply with these requirements of the ÖG-SET are decisive.~~

~~In order to reach those requirements, the ÖG-SET aims with the following as the basis for a quality mark:~~

- ~~preparing regulations for sampling and sample preparation~~
- ~~evaluating the implications of the prepared regulations on the application of solid recovered fuels in industrial co-incineration, power and heat production~~
- ~~preparation of a quality assurance concept.~~

~~*Organisation*~~
~~The main prerequisite to put the resulting regulations in action is a wide support from the companies concerned who deal with the production and the thermal utilisation of solid recovered fuels.~~

~~*Activities*~~
~~The following activities are carried out:~~

- ~~catalogue criteria for the utilisation of SRF in different industrial incineration/energy and heat production plants~~
- ~~preparation of regulations for the sampling of SRF~~
- ~~carrying out an inter-laboratory test for the determination of standard deviations in mean contents resulting by sampling, sample preparation and analysis~~
- ~~preparation of a quality assurance concept~~

WORKING DRAFT IN PROGRESS

- ~~definition of the basic requirements for a quality mark.~~

~~Taking into account five industrial branches and the applied technologies for thermal utilisation (e.g. coal dust burners, rotary ovens, fluidised beds), five working groups (cement industry, pulp/paper and board industry, electric power stations, steal industry and wood industry) were established. In each group producers and users of SRF were taking part to ensure a holistic approach. For the different utilisation technologies, essential criteria were gathered and defined for the thermal utilisation of waste and residues. Principally, three different types of quality attributes were distinguished:~~

- ~~exclusion criteria~~
- ~~physico-chemical quality attributes~~
- ~~other quality attributes.~~

~~These quality attributes contain a compendium of the criteria and quality attributes defined by the working groups. Every plant manager taking into account his plant's requirements, can choose attributes for his required SRF quality from the lists. For sourcing, the criteria can be included in the specification of the SRF.~~

~~*Preparation of the basis for specification*~~
~~The preparation of a specification sheet facilitates the communication between the SRF producer and user. For the sourcing of SRF, additional criteria like the following ones can be made:~~

- ~~transport and storage criteria (e.g. bulk density)~~
- ~~type of transport (e.g. by road, by rail).~~

~~The additional information can ease the handling of SRF considerably.~~

~~*Inter laboratory test*~~
~~Two SRF (one less and one more heterogeneous) test schemes have been worked out. One test was carried out for guide parameters defined with the statistic evaluation of existing data. The chemical parameters from the criteria list were investigated as well. The first step was the calculation of the sample mass and sample number, based on the framework provided by CEN TC 292 WG1 'Characterisation of waste – Sampling techniques for waste' (draft from 02/2001). The sample volume and sample number were calculated by using a targeted total deviation, the particle size, the bulk density and the heterogeneity of the waste expressed by the standard deviation reached in earlier examinations. Based on the results of the inter laboratory test, the guidelines for sampling and sample preparation were defined.~~

~~*Preparation of a quality assurance concept*~~
~~To ensure the required quality criteria, a quality concept is currently under preparation, which takes into account the special demands of the application and utilisation of SRF.~~

~~Company quality assurance~~
~~There are internal quality assurance systems existing in some companies. Table 5.70 gives an overview about the system.~~

WORKING DRAFT IN PROGRESS

~~Table 5.70: Quality assurance system of RWE Umwelt AG (Germany)~~

~~**Process step**~~	~~**Measures**~~	~~**Supplementary measures**~~
~~Origin (waste producer, sorting plant, mechanical biological processing)~~	~~Collection of wastes, avoidance of impurities, contractual arrangements about allowed qualities of wastes, declaration analysis, documentation of disposed amounts~~	~~Instruction courses for waste producers, periodic controls of the waste producing company by the disposer~~
~~Processing plant (delivery)~~	~~Regular sampling and analysis, reserve samples, documentation of input and processed amounts~~	~~Regular sampling and analysis of the outgoing materials by an external official expert~~
~~Processing plant (output)~~	~~Regular sampling and analysis, reserve samples, documentation of the delivered amounts~~	
~~Cement and lime kilns, power plants~~	~~Regular sampling and analysis, reserve samples, documentation of the input amounts~~	

~~[82, Pretz et al. 2003]~~

Table below deleted: gasification is excluded from the scope; see KOM conclusion 1.3b

Table 5.71: Outputs generated by the gasification of waste oils

~~**Output**~~	~~**Amount (per tonne of input waste oil)**~~	~~**Units**~~
~~Methanol~~	~~1080~~	~~kg~~
~~Savings in the primary input of fuels typically used in gasification~~		
~~**Consumptions**~~		
~~Fossil fuel~~	~~109~~	~~kg eq. crude oil~~
~~Primary energy~~	~~7110~~	~~MJ~~
~~Water consumption~~	~~1350~~	~~kg~~

~~[4, Monier, V. and Labouze, E. 2001]~~

5.3.2 Applied processes and techniques

5.3.2.1 Preparation of solid output [~~waste fuel~~] mainly from solid waste

Ex-Section **"2.5.1.1 Preparation of solid waste fuel by mechanical (and biological) treatment from non-hazardous wastes"** moved to Section 3.3.2.

5.3.2.1.1 Drying the solid waste [~~fuel~~]

From ex-**Section 4.5.3.2 "Drying the solid waste fuel"**

Purpose
Increases the heating value of the solid waste and, in some cases, achieves ~~satisfying~~ satisfactory sorting results.

Principle of operation
Dewatering and drying of the input waste.

Feed and output streams
See Section 5.3.1.

WORKING DRAFT IN PROGRESS

Process description

Depending on the water content and the physical characteristics of the wastes, a first step of dewatering can be applied. It may consist of one of the following operations: gravity thickening, centrifugal thickening, flotation thickening, gravity belt and rotary drum thickening. Some techniques include the following:

a. Using thermal drying for the material. In convection (direct or adiabatic) dryers, there is direct contact between the heating medium and the product to be dried. The moisture from the fuel is removed by the heating medium. In conduction dryers, there is no direct contact between the heating medium and the product. Heat transfer takes place through heating surfaces. Moisture is removed by the carrier gas, which is approximately 10 % of the quantity used in convective processes. Therefore, conduction dryers may be preferred for dusty or odorous wastes.
b. Using a biological degradation/drying system. According to the applied process, the degradation is more or less distinct; sometimes the focus is on the drying. Depending on the applied system, incidental process water arising during the biological degradation will have to be cleaned before being released to the watercourse. To maintain the biological activity, the system is fed with air. The exhaust air is collected and ~~also has to be~~ cleaned.

~~**Cross-media effects**~~

~~In the case of thermal drying, heat is necessary. A study shows that in the case of drying sewage sludge, the energy recovery is higher in the case of thermal drying. The reasons are that the required energy for biological drying (provided by the organic material in the sewage sludge) is higher and the calorific value of the waste fuel tends to be lower.~~

~~**Applicability**~~

~~Radiant dryers are not applied for drying waste solids. Applicable to the dewatering and drying of sludges.~~

Biological drying is more applicable to non-hazardous waste.

Users

No information available.

Reference literature

[42, EIPPCB 2003] [60, WT TWG 2003][78, Eucopro 2003] [82, Pretz et al. 2003][98, WT TWG 2004] [100, WT TWG 2004]

5.3.2.1.2 Pelletising and agglomeration

From ex-**section 4.5.3.12 "Pelletising and agglomeration"**

Purpose

Increases the density of the products.

Principle of operation

Agglomeration of input waste.

Feed and output streams

See Section 5.3.1.

Process description

Disc agglomerators consist of metal housing with one or more discs inside. The inner side of the reactor is filled with material discontinuously. The discs, which have superstructures to stir the material ~~much better~~, start to rotate converting the frictional energy into frictional heat. The material is homogenised by stirring and then begins to melt with the rising frictional heat. At the moment that the material begins to plasticise, the energy consumption rises and can provide the signal to empty the reactor. After the process, the material ~~has to be~~ is cooled down.

WORKING DRAFT IN PROGRESS

~~Cross-media effects~~
~~Because of the complete melting, the energy consumption for this process is much higher than for pelletising.~~

~~Operational data~~
~~Depending on the equipment for discharge, the material may be granulated.~~

~~Applicability~~
Due to the fact that such systems rely on the melting of some waste components, it can only be applied when those components are available (e.g. plastics).

Users
No information available.

Reference literature
[82, Pretz et al. 2003][98, WT TWG 2004]

Ex-**Section 2.5.1.3 "Preparation of solid waste fuel by the carbonisation of contaminated wood"** deleted (see conclusions of PCT Workshop)

5.3.2.2 Preparation of solid output [~~waste fuel~~] mainly from liquid and semi-liquid [~~hazardous~~] waste

From ex-**Section 2.5.1.2 "Preparation of solid waste fuel mainly from liquids and semi-liquid hazardous waste"**

Purpose
The goal of ~~the~~ this preparation ~~of such~~ ~~fuel~~ is to make a tailor-made, homogeneous, and free flowing output ~~waste fuel~~, which can be used in combustion processes and this may also make it easier for it to be traded/used.

Principle of operation
A mechanical preparation of solid output ~~waste fuel~~ includes ~~-ing~~, for instance, the impregnation of waste over a support (e.g. sawdust, crushed paper or cardboard, adsorbents).

Feed and output streams
The types of wastes used are pasty, powders and solid waste, mainly hazardous. In some specific cases, some liquid wastes may be used.

Process description
An example of the process layout for the production of solid waste fuel is presented in Figure 5.14. The design of the layout, as well as the selected installation, is chosen according to the type of waste, the availability of the waste, and the end specification of the waste fuel.

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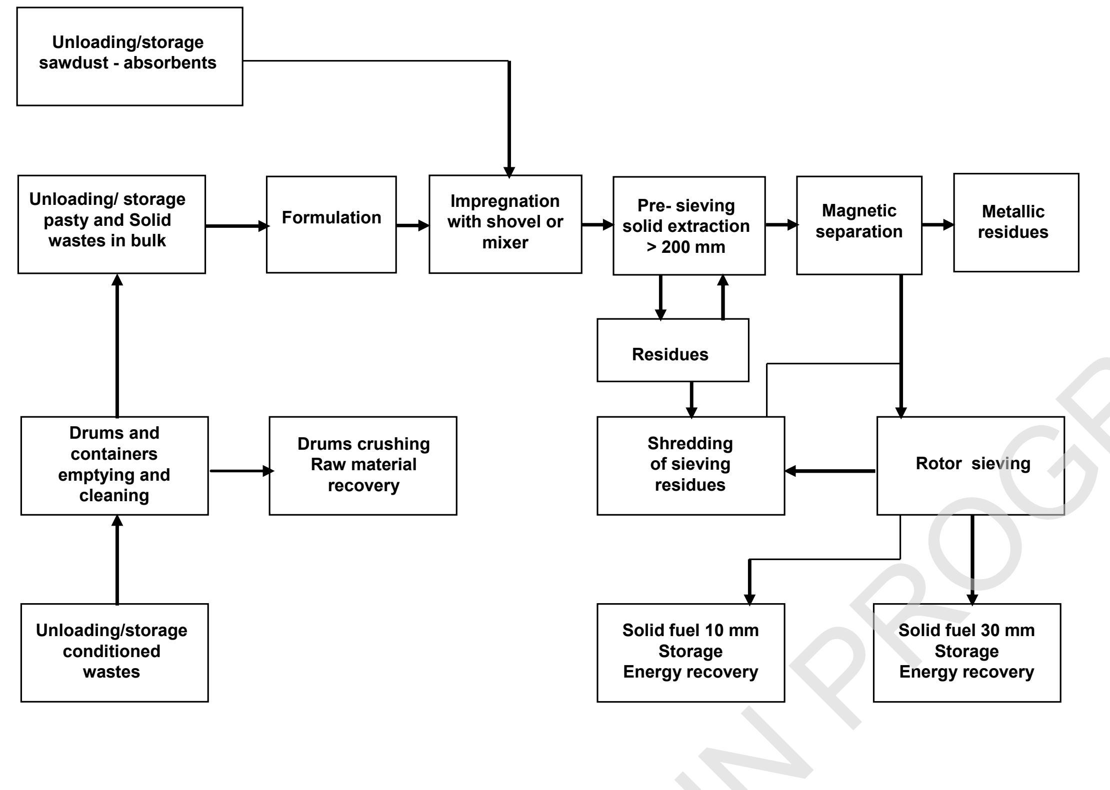


Source:[78, Eucopro 2003]

Figure 5.14: An example of the production of solid fuel from liquid or semi-liquid hazardous waste

The main processes and production steps are as follows:

- Feeding of the waste from the storage to the production units. Pre-homogenisation of the incoming wastes is based on physico-chemical characteristics. This step is critical for ensuring the compliance of the waste fuel with the final user's specifications.
- Shredding and/or sieving of coarse particles. Wastes that contain big particles are ~~need to be~~ shredded or sieved before introduction into the mixing unit.
- Feeding of the mixing unit.
- Mixing operations. Materials can be fed directly or through a hopper to stabilise, regulate and control the quantity of waste introduced into the mixing unit. A conveyor belt is used after the mixing operation to transport the material to the sieve.
- Scrap extraction by magnetic separators or Foucault (eddy) current systems to remove non-ferrous metals.
- Sieving operations by rotary or vibrating sieves. The dimensions, and the design of the sieve mesh depend on the granulometry specifications and the off-specification waste fuels (different fractions are possible in some installations, depending on the reuse possibilities of the big particles). Off-specification fractions can be reprocessed in the production process, treated in a dedicated shredder, and/or treated in incineration or dedicated co-processing units.
- Storage of waste fuel before loading.
- Dispatch of the waste fuel. Loading of the trucks (or potentially trains or ships) is carried out by cranes, conveyor belts or bulldozers.
- Cryogenic crushing and separation of used packaging of paint, ink, and similar substances.

Users

Co-incineration plants (e.g. cement kilns).

WORKING DRAFT IN PROGRESS

5.3.2.3 Preparation of liquid output [~~waste fuels~~]

From ex-**Section 2.5.2 preparation of liquid waste fuels**

In this section, treatments carried out to prepare liquid fuels from liquid or semi-liquid materials are covered. The liquid waste fuel produced has properties enabling it to become fluid and move when a difference of pressure or gravity is applied. Some of the materials produced may be very viscous and can be very difficult and expensive to pump, however they still maintain fluid properties. The ~~waste OUT~~ output of these treatments is referred to in this section as 'liquid waste fuel', regardless of whether the fuel is semi-liquid or liquid. Those processes that start from liquid or semi-liquid waste and end up as a solid waste fuel are included in Section 5.3.2.2.

Typically, the materials prepared by these types of treatments are hazardous wastes. Several liquid waste fuels can be prepared according to the different wastes and market requirements:

- organic liquid preparation by blending;
- fluidification;
- emulsions;
- sludges (the preparation of these types of waste is considered an emerging technique).

~~The main processes used in the preparation of wastes to be used as fuel are:~~

- ~~knowledge, controls, follow-up and traceability of wastes (a common technique as described in in Section 2.1)~~
- ~~transport of wastes (a common technique as described in in Section 2.1)~~
- ~~reception of wastes (a common technique as described in in Section 2.1)~~
- ~~unloading of wastes (a common technique as described in in Section 2.1)~~
- ~~storage units used before treatment~~
- ~~reconditioning~~
- ~~homogenisation and blending~~
- ~~crushing~~
- ~~sieving~~
- ~~fluidification~~
- ~~phase separation for liquid wastes: settling, centrifugation, extraction, …~~
- ~~drying~~
- ~~washing.~~

5.3.2.3.1 Preparation of organic liquid waste fuels by blending [~~mainly hazardous~~] wastes

From ex-**Section 2.5.2.1 "Preparation of organic liquid waste fuels by blending mainly hazardous wastes"**

Purpose

The aim of this operation is to blend and homogenise compatible wastes from several producers and/or sources. The purpose of this operation is to:

- provide a nearby service to producers with only small quantities of organic liquid wastes;
- rationalise the logistic organisation (transport, etc.);
- develop an adapted solution for packed wastes with several phases (liquid/pasty or solid);
- separate the different phases (water, organic liquid, sludges or solid) from a composite waste in order to optimise the recovery;
- prepare the homogeneous and stable wastes in accordance with specifications.

Principle of operation

These operations may involve the grouping of small quantities and/or pretreatment activities such as phase separation or settling. Blending and homogenisation are the main operations.

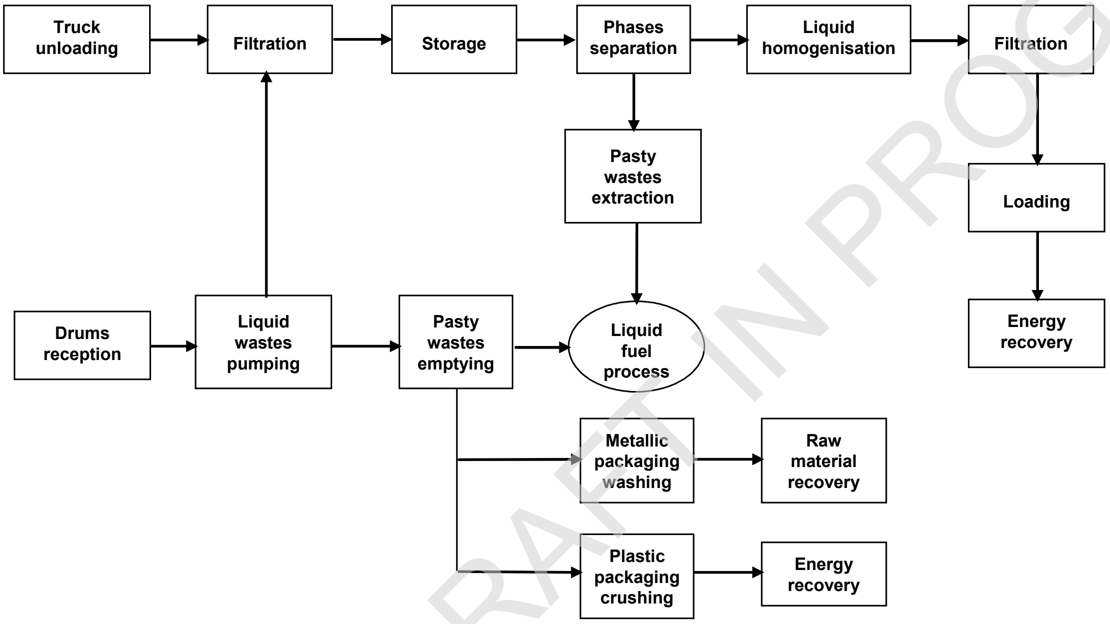
WORKING DRAFT IN PROGRESS

Feed and output streams

Liquid and semi-liquid waste with a high organic content. The wastes utilised include solvents, oils, oil sludges, emulsions, distillation residues, tank bottom sludges, oil emulsions from mechanical and metallurgical industries, wastes and sludges containing oil from petroleum refining and from the collection and storage of oil materials, waste from oil distillation and regeneration from production failure; pasty wastes such as grease, ink and adhesive wastes; pulverulent wastes such as paint powder, washing powder wastes, etc.

Process description

An example of the process layout for the preparation of liquid fuel from waste is presented in Figure 5.15.



Source:[78, Eucopro 2003], [98, WT TWG 2004]

Figure 5.15: An example of the process layout for the preparation of organic liquid waste fuel

Note: ‘Liquid fuel process’ uses pasty waste to produce other liquid fuels.

The main processes and production steps are as follows.

Unloading and grouping

- Liquid wastes in bulk. After filtration and/or settling, organic liquids are sent by a centrifuge or membrane pump to metallic cylindro-conical tanks equipped with a blending device in order to avoid settling or phase separation (consisting of a pendular mixer or pumping system which blends the top and the bottom of the tank by continuous circulation).
- Packed wastes (drums, etc.). Before grouping, the packaging is emptied with techniques adapted to its physico-chemical characteristics. Generally, two phases exist: a liquid one and a pasty (and sometimes solid) one in the bottom of the drum.

Preparation

This step consists of operations such as settling, grinding, filtration and blending. A stirring propeller or a recirculation system is used in order to keep the wastes homogeneous. Sometimes, a grinding system is used with a recirculation technique in order to decrease the granulometry of any solid particles which may be in the liquid waste.

WORKING DRAFT IN PROGRESS

Dispatch

Before loading, the liquid preparation is filtered through a 3 mm filter. The loading of the trucks is carried out with all the security systems necessary.

Users

Co-incineration plants (e.g. cement kilns).

5.3.2.3.2 Preparation of liquid output [~~waste fuels~~] by fluidification of [~~hazardous~~] wastes

From ex-**Section 2.5.2.2 "Preparation of liquid waste fuels by fluidification of hazardous wastes"**

Purpose

The aim of this operation is to blend and homogenise compatible wastes from several producers and/or sources.

Principle of operation

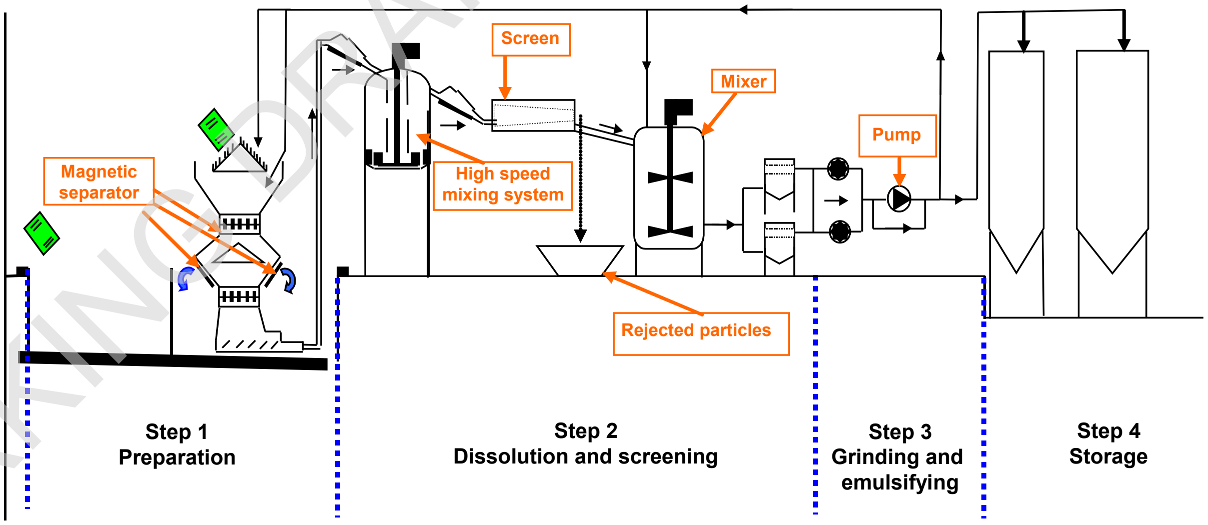
Fluidification means processes where liquid, pasty and solid wastes are homogenised and shredded together in order to produce a liquid fuel ~~which can be used as fuel~~.

Feed and output streams

Typically hazardous waste such as oil residues, used solvents, residues from organic chemical synthesis, oil and grease, etc.

Process description

Figure 5.16 gives an example of fluidification process.



Source: [78, Eucopro 2003]

Figure 5.16: An example of the process layout for the production of liquid waste fuel by fluidification

The main processes and production steps are:

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Pre-homogenisation
Pre-homogenisation of the incoming wastes is based on the physico-chemical characteristics. Pre-homogenisation consists of producing a premix with physical characteristics acceptable for the fluidification process. This step prevents different kinds of problems arising inside the process, such as blockages in the hoppers/pipes/machinery.

Feeding of the waste from the upstream storage facilities to the fluidification process
Solid wastes are handled with a mechanical shovel, hydraulic arm, crane bridge or hydraulic loader. They are transferred to the fluidification process with a screw conveyor or a reddler conveyor. Sludges are handled with hydraulic shovels, crane bridges and/or hydraulic piston pumps able to handle high viscosity materials. Liquid wastes are handled by pumps. Pumping technologies must be able to accept fluctuations in the quality and presence of particles in suspension.

Fluidification process
This is composed of four main steps:

'Calibration' of the pasty part
This step consists of shredding coarse particles, extracting any foreign metallic parts blended accidentally with chemical wastes and then transferring this pasty material into the mixing tank. The shredders used are slow-motion shredders, used for flammable and low flashpoint wastes (e.g. mono-rotor or bi-rotor rotary shears) and dedicated shredders for specific wastes (e.g. cryogenic shredders). Technologies for the extraction of undesired solid portions include ferrous and non-ferrous metal separators for metals and vibrating sieves and/or static grates for bigger particles. The transfer of the material is carried out by screws and pumps (e.g. concrete pumps).

A simplified design is also possible for lower investments: this consists of a smaller capacity unit, which is dedicated to less difficult waste (i.e. that free of coarse pieces). In this case, the material may be transferred into the mixing step by shredding. A rotary filter may be installed to remove large quantities of useless materials.

Dissolution and screening
This second step dissolves and emulsifies the pasty parts into a solvent phase, to obtain a homogeneous material.

The dissolution of solid organic compounds in a liquid phase composed of solvents and/or waste water is carried out by special mixers, rotary screens and buffer tanks. The mixers must respond to the constraints of the sticky material containing strong and voluminous solids in suspension. They pulverise the solids between rotor and stator and blend them into the liquid phase. Next, the liquid mixture is admitted inside a rotary screen, which extracts the pieces of plastic lining fragmented by the shredding in the previous step. A buffer tank collects the material in the course of preparation at the end of this step.

Grinding and emulsifying
This third step consists of finely grinding any solid particles remaining in suspension in the liquid phase. It also consists of making a fine emulsion between the aqueous phase and the hydrocarbon phase constituting the liquid waste fuel. The stability and the quality of combustion of the waste fuel depend directly on both its homogeneity and the size of ~~fragmentation of~~ the solids in suspension.

These criteria require high velocity technologies of grinding/emulsifying protected by magnetic separators and mechanical filters. The equipment must be flexible enough in order to accept fluctuations in viscosity, density and the nature of the solids in suspension.

The liquid waste fuel is controlled at this step, during the filling of the buffer tank. Some parameters such as pH and viscosity can be controlled continuously in the process. Other parameters such as LHV, composition and flashpoint are controlled from samples taken during

WORKING DRAFT IN PROGRESS

production. If the quality does not meet the specifications, the fuel must be reprocessed before being transferred to the storage unit.

A simpler design is possible for small capacity units: here steps 2 and 3 may be carried out at the same time. In this case, the mixing and buffer tank will be the same and the grinding line will run into the mixing tank.

Storage and dispatching
Once a high level is reached inside the buffer tank, the material can be transferred by pump into the final storage. During this transfer, a latter adjustment of the quality of the fuel can be carried out by means of grinders and filters operating on the transfer line. The storage ~~capacity~~ facility is generally composed of vertical cylindro-conical tanks with blending equipment. Two technologies for blending are appropriate to homogenise the liquid fuel:

- a long marine mixer installed on the roof of the tank;
- a pumping system which blends the top and the bottom of the tank by loop circulation.

Dispatching to the customer is carried out by a truck loading station. This loading station is fed by the storage unit mentioned above.

Users
Co-incineration plants (e.g. cement kilns).

5.3.2.3.3 Preparation of emulsions from liquid/semi-liquid [~~hazardous~~] waste

From ex-**Section 2.5.2.3 "Preparation of emulsions from liquid/semi-liquid hazardous"**

Purpose
The aim is to produce a homogeneous and stable waste fuel from liquid and semi-liquid waste.

Principle of operation
This process is based on the control of blending by means of the addition of selected chemicals or tensides.

Feed and output streams
Emulsions are typically produced from hazardous wastes such as oils and emulsions from the mechanical and metallurgy industries, wastes and sludges containing oil from petroleum refining, production failure, etc.

Process description
~~Installations~~ Processes are similar in design and layout to those used for the pasty raw meal preparation for clinker production in cement kilns. **Figure 5.17** gives an example of emulsion process.

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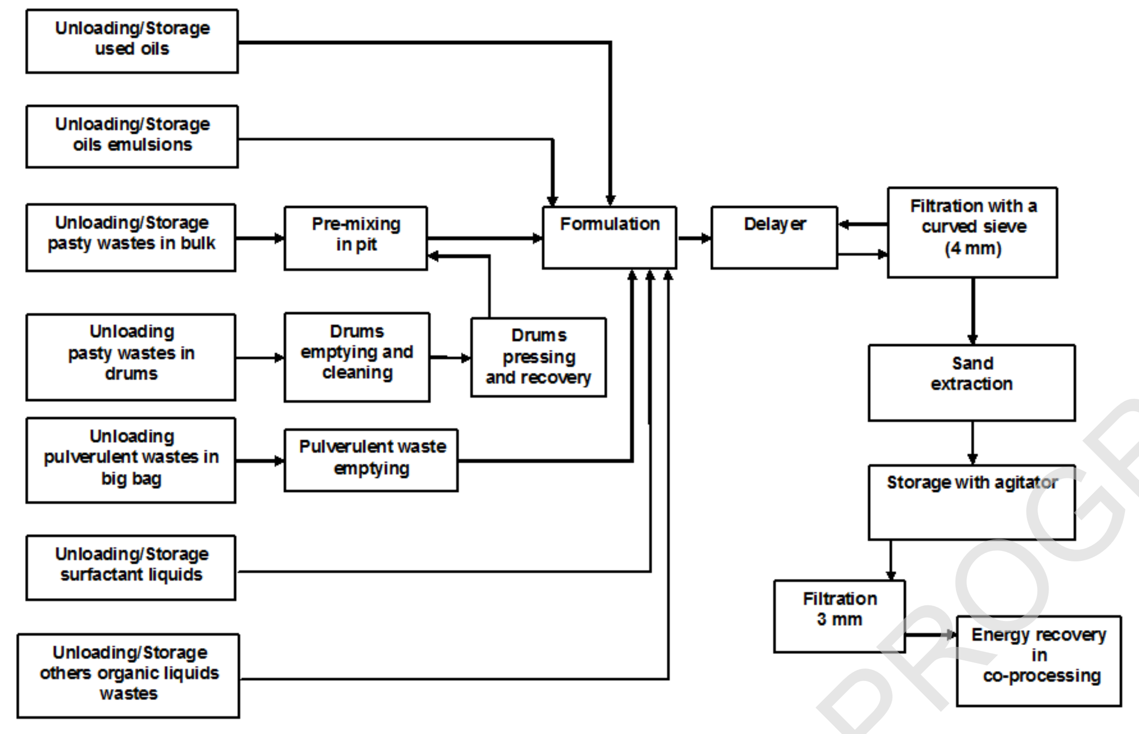

Source: [78, Eucopro 2003], [98, WT TWG 2004]

Figure 5.17: An example of the process layout out for the preparation of emulsions

The main processes and production steps are as follows:

Feeding of the waste from the storage to the production units
Before introduction into the production process, wastes are deconditioned with equipment adapted to their physical characteristics. Pasty wastes extracted from drums are put in special pits. They are first ~~handled~~ moved by means of a mechanical shovel to a homogenisation pit. Then, they are transferred to a hopper in order to be introduced into the production process by a screw conveyor or a concrete pump. Pulverulent wastes, such as paint and washing powder, are received in big bags. They are put directly into the production process with equipment adapted to capture dust emissions. Liquid wastes are handled by pump. Pumping technologies (centrifugal pump, volumetric pump with out-rotor, etc.) must be able to accept a viscosity fluctuation and the presence of particles in suspension.

Formulation
According to the physico-chemical characteristics of the waste stored, the laboratory defines the specifications, including the nature and quantities of wastes, which can be put into the production processes. Compatibility tests are also developed. Such tests are carried out at any operation, in order to comply with the waste fuel specifications.

Production process
The production process, which is a batch process, is carried out by special mixers (called ‘delayers’), closed in order to prevent VOC emissions. The different components are introduced into the mixer according to laboratory specifications. An agitator provides for stable emulsion production. During this step, several parameters are monitored, such as viscosity, pH, temperature and motor specification. One of the purposes of this monitoring is to detect any polymerisation reactions, as these could cause production problems.

Screening
Once the emulsion is achieved, it is circulated again with a centrifugal pump to the mixer and through a curved screen providing particle retention above 4 mm.
Sand extraction

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When the mixer is emptied and before being sent to the storage ~~capacity~~ facility, the material is pumped to a concrete pit with a sedimentation area. The aim is to separate through density any mineral solid particles (e.g. sand) which may be present in the material.

Storage and dispatching

The material is transferred by centrifugal pump to storage. The ~~capacity of the~~ storage facility is generally composed of concrete or steel vertical cylindrical tanks with blending equipment.

Three technologies for blending are appropriate to maintain the homogeneity:

- a submerged agitator;
- a low agitator with a scraper in order to avoid sedimentation;
- a pumping system which blends the top and the bottom of the tank with high flow (around 250 m^3/h) loop circulation.

The waste fuel quality is controlled in order to be sure that its characteristics comply with customer specifications. In some specific cases, ~~the addition of~~ waste with a high calorific value may be ~~made~~ added if the calorific value is considered too low.

Dispatching to the co-processing factories is carried out by a truck loading station. A final screening (through a filter of 3 mm ~~size~~) is undertaken whilst loading.

Users

Co-incineration plants (e.g. cement kilns).

5.3.2.4 Treatments of waste oils [~~for the preparation of fuel~~] other than re-refining

From ex-**Section 2.5.2.4 "Treatments of waste oil where waste OUT is basically used as a fuel"**

Deleted: repetition of Re-refining of waste oil

~~There are two main options for the treatment of waste oils (see Figure 5.7) One way is to treat the waste oil to reconvert it to a material that can be used as a base oil to produce lubricants. This is referred to as 're-refining' in this document and it is covered in Section The other way is the treatment of the waste oil to produce a material that will be mainly used as fuel or for other uses (e.g. absorbant, mould release oil, flotation oil). These treatments are covered in this section. As is the case in the whole document, this classification has been adopted for this document and it is not intended to provide any attempt to define any of the R codes from EC waste legislation.~~

The calorific value of waste oils can be utilised. When used as a substitute fuel, principally for coal, diesel and light fuel oil, used oil has an economic value. A number of different burning applications for used oil exist, distinguishable partly by the temperature at which they burn, and partly by the control technology they use to reduce environmental effects. Before its use as fuel, several cleaning or transformation treatments may need to be applied. These are summarised in Table 5.72.

WORKING DRAFT IN PROGRESS

Table 5.72: Treatments applied to waste oils before their use as fuel

Type of treatment	Changes that occur in the waste oils after treatment	Fuel use	Industrial sector use
No treatment. Used directly in a combustion process (not covered in this document)	No change	Directly used as fuel in kilns, furnaces, etc.	Waste incinerators, Cement kilns, Space heaters (garages, greenhouses, workshops, etc.) (1), On board ships (typically using marine oils), Quarry stone industries
Mild reprocessing	Removal of water and sediments	Waste fuel blend ~~to~~ with fuel oil (replacement of fuel oil)	Cement kilns, Road stone plants, Large marine engines, Pulverised power plants
Severe reprocessing (chemical or thermal processes) (process described in Section 5.2)	Demetallised heavy fuel oil (or heavy distillate)	Waste fuel blend ~~to~~ with fuel oil (replacement of fuel oil)	Marine diesel oil, Fuel for heating plants
Thermal cracking	Demetallised and cracked material	Distillate gas oil	Gas oil (also called heating oil, diesel oil, furnace oil, etc.), Demetallised heavy fuel oil, Marine gas oil, Re-refined light base oil not used as fuel
Hydrogenation (process described in Section 5.2)	Reduction of sulphur and PAH contents		
Gasification ~~2~~ (not covered in this document)	Converted to synthetic gas (H_2 + CO)	Fuel gas	Chemical production of methanol, Large combustion plants (e.g. gas turbines)

(1) Forbidden in some MS.
~~2 More information in Section~~
Source: [2, Concawe 1996] [4, Monier, V. and Labouze, E. 2001] [60, WT TWG 2003] [98, WT TWG 2004]

From ex-**Section 3.5.1 "Waste IN for the preparation of waste fuels"**

Feed and output streams
~~**Oily materials**~~

Waste oils
~~More information on the composition of waste oils can be found in Section .~~ Used oils may have a significant, but variable, chlorine content, including organochlorines. The fate of these chlorine compounds will vary, not only with the treatment route, but also with the form in which the chlorine is present. It is therefore difficult to make any general comments on the effects of chlorine other than that in the combustion routes there is a risk of dioxin formation and that in the reprocessing options there are risks of corrosion problems, acid gas emissions and contamination of the output streams.

Waste lubricating oils and oils recovered from interceptors are sold for use as fuel. Because these oils can create carbon deposits when burnt, they tend to be used in applications where this is of no concern. The main users are the road stone industry and coal-fired power stations, which use it for flame stabilisation and power boosts.

Waste fuel oils
Waste fuel oils arise from a variety of situations such as tank drainage from vehicle fuel tanks, when a boiler fuel store is drained, when the plant converts to natural gas, or when tanks are

WORKING DRAFT IN PROGRESS

removed during site clearances. These oils are generally not contaminated although they may have deteriorated with age and sometimes carry the 'tank bottom dirt' settled from many years of filling. In most plants, comparatively little of this type of material is accepted and it will be reasonable to consider it ~~its analysis~~ comparable to fuel oils 'as sold'.

Gasification is specially designed to process heavy fuels, as well as a wide range of hydrocarbon wastes. This process is not described in this document.

Fuel oils range in specification but, in general, they are used rather than sent for treatment and so the quantities will be small. They typically have a lower boiling point than lubricating oils, contain more of the lower chain hydrocarbons and have a higher risk of VOC emissions during treatment. However, the content of the metals is typically low (although vanadium and nickel have been found in fuel oils). PAHs are typically stable and non-volatile. Unused fuel oils have a lower boiling point range than lubricating oils. Comparisons between the compositions of fuel oils and lubricants are shown in

Table 5.73 below.

Table 5.73: Typical composition of fuel oils and lube oils

	Normal carbon chain length	**Boiling point range (ºC)**	**Important compounds**
Kerosene	Middle distillate, C_6 to C_{16}	150–300	N alkanes, cycloalkanes, low concentrations of mono aromatics, low concentrations of BTEX and PAHs
Fuel oil (N° 2)	Middle distillate, C_8 to C_{21}	200–325	Very low BTEX, toluene 0.06 %, ethyl benzene 0.034 %, xylenes 0.23 %, high concentrations of n-alkanes, C_8 0.1 %, C_{20} 0.35 %), lower concentrations of branched alkanes, cycloalkanes monoaromatics, naphthalenes (0.22 %) and PAHs, nickel 0.00005 %
Fuel oil (N° 6)	Residual oil, C_{12} to C_{34}	350–700	Very low BTEX, low naphthalenes and PAHs, high n-alkanes (C_9 0.0034 %, C_{20} 0.1 %) and cycloalkanes, nickel 0.0089 %
Lube oils	Heavy end distillate, C_{18} to C_{34}	326–600	Low concentrations of BTEX, high concentrations of branched alkanes and cycloalkanes

Source:[34, Babtie Group Ltd 2002]

From ex-**Section 3.5.4.3 "Waste oil used as fuel"**

Output

Used oils have some valuable properties for their use as a fuel oil blendstock, e.g. they have a lower sulphur content and viscosity in comparison to other heavy fuels. Blending into fuel oil at the refinery could be a viable option for oils when it can be shown that the contaminant levels are within acceptable limits for the fuel oil specifications.

Waste oil is used as a fuel in a number of power stations in the UK. Typical specifications are shown in Table 5.74 below. It is reported that waste oil suppliers consistently have difficulty in meeting the chlorine specification because of the contamination of used oils in the UK. This arises from other wastes such as transformer oils and chlorinated greases.

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Table 5.74: Typical specifications for recovered fuel oil supplied to UK power stations

Properties	Units	Min.	Max.
Physical			
Density at 15 °C	g/cm^3	0.88	0.95
Flashpoint	°C PMCC	65	
Net calorific value	GJ/tonne	40	
Viscosity at 40 °C	Centi Stokes	30	55
Chemical			
Water content	w/w-%	0	3
Sulphur	w/w-%	0	1
Chlorine	ppm	0	1100
PCB	ppm	0	10
Lead	ppm	0	200
Vanadium	ppm	0	50
Copper	ppm	0	50
Cadmium	ppm	0	10
Chromium	ppm	0	30
Nickel	ppm	0	50

Source:[34, Babtie Group Ltd 2002] [45, DETR 2001]

~~**Waste OUT from the mild reprocessing of waste oils**~~

~~The cleaned waste oils from these processes are typically blended with other fuel oils. The processed waste oil will still contain heavy metals, halogens and sulphur~~.

Deleted: gasification is excluded from the scope; see KOM conclusion 1.3b

~~**Waste OUT from the gasification of waste oil**~~

~~For co-gasification with coal, the metals contained within the used oil can be fixed in an inert, non-hazardous bottom ash. Sulphur compounds are converted to hydrogen sulphide and removed by conventional scrubbing and converted to elemental sulphur. There are no metals, fugitives or dioxin emissions from the process.~~

Table 5.75: Outputs generated by the gasification of waste oils

~~**Outputs**~~	~~**Units**~~	~~**Amount (per tonne of input waste oil)**~~
~~Methanol~~	~~kg~~	~~1080~~
~~Saving of primary input of fuels typically used in gasification~~		

~~[4, Monier, V. and Labouze, E. 2001]~~

From ex-**Section 2.5.2.4.1 Direct burning of waste oils. Outside scope.**

~~Burning waste oils without any treatment is one disposal/treatment option that is used across Europe, varying in popularity depending on local economic and legislative circumstances. There are four sectors identified where waste oils are directly burned: cement kilns (see Cement and Lime BREF); waste incinerators (see Waste Incineration BREF); as a reducing agent/fuel in blast furnaces (see Iron and Steel BREF), and in large combustion plants (see Large Combustion Plant BREF). As these are already covered in other BREFs, they will not be included under the scope of this document.~~

5.3.2.4.1 Mild reprocessing of waste oils

From ex-**Section 2.5.2.4.2 "Mild reprocessing of waste oils"**

Purpose

To clean the waste oils to improve the physical properties so that they can be used as a fuel by a wider variety of end users.

Principle of operation

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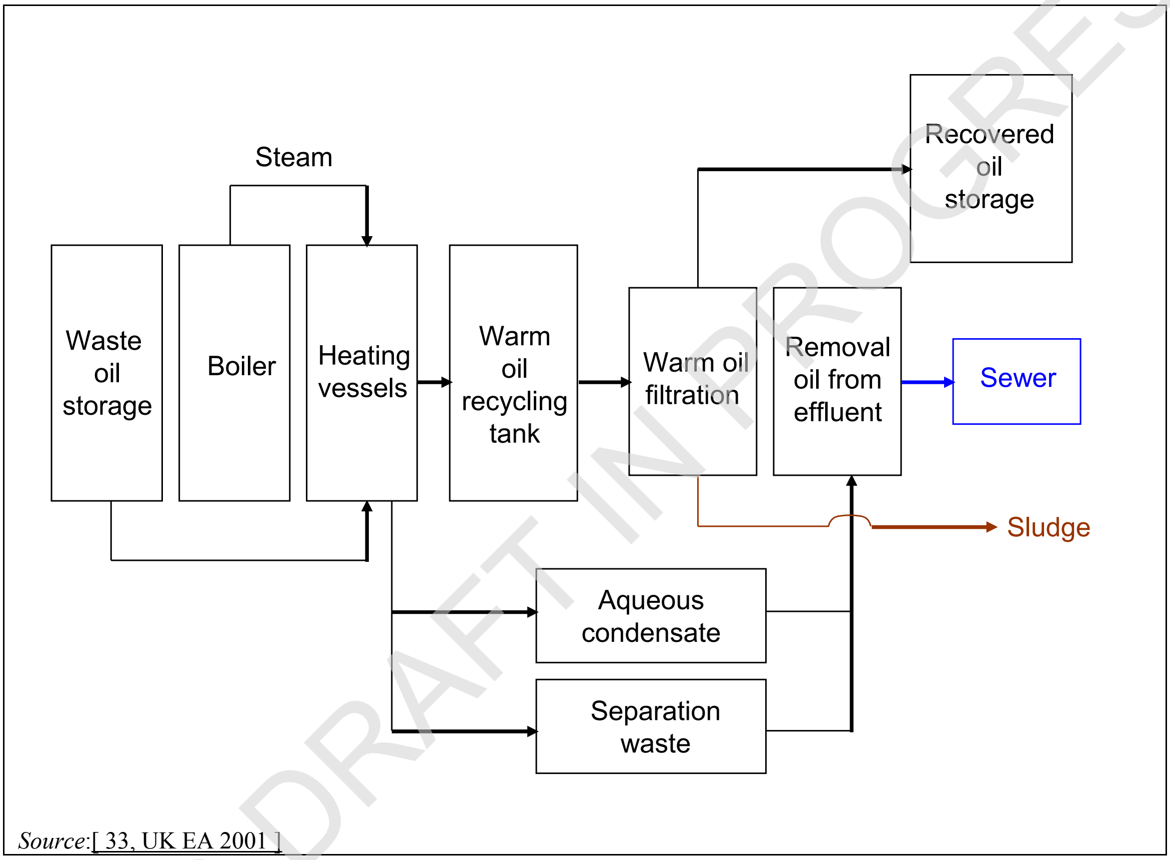
The treatments involve the settling of solids and water, chemical demineralisation, centrifugation and membrane filtration.

Feed and output streams

Waste oils in general. A simple cleaning process is applied to waste oil destined for asphalt drying or for fuel blending before further use.

Process description

Figure 5.18 below shows an example of mild reprocessing of waste oil.



Source:[33, UK EA 2001]

Figure 5.18: An example of mild reprocessing of waste oil

Settling

Water and sediments are settled in a tank after mixing the used oil with a demulsifier. Settling is facilitated by heating the tank up to 70/80 °C. If necessary, the clear oil is decanted and passed through a series of filters. The waste water and sediments are treated. A simple cleaning process to remove water and sediments (although typically, this does not deal with the heavy metals, halogens and sulphur) is ~~given~~ carried out before the further use of the waste oil as a replacement for fuel oil.

Chemical demineralisation

This process is used to clean metallic contaminants and additives. The chemical process relies on the precipitation of salts such as phosphates, oxalates and sulphates. The waste fuel is suitable for burning as 'black oil' and produces less air pollutants because of its pretreatment. Water is usually removed by demulsification and heating. The precipitate is removed by settling and filtration. Unfortunately, the chemicals and plant required are quite expensive when compared to the value added to the waste fuel produced. Also, a concentrated hazardous waste is generated.

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Centrifugation
Liquid phases are separated in a centrifugal separator, using the principle of difference of densities.

Membrane filtration
Produces high-grade recycled oil, a concentrated waste oil, and waste water.

Ex-**Section 4.5.4.3 "Membrane filtration as a mild reprocessing of waste oils"**

~~**Description**~~
~~Have a pretreatment to protect the membrane system.~~
~~**Achieved environmental benefits**~~
~~Better quality of the waste oils and protection of the membranes.~~

~~**Applicability**~~
~~Commonly used when treating waste oil by membrane filtration.~~

~~**Economics**~~
Membrane filtration leads to a significant added cost. Typically, the value of the plant required, including that for the protection of the membrane step, is expensive compared to the added value of the product.

~~**Example plants**~~
~~Reflects operational experience.~~

~~**Reference literature**~~
~~[98, WT TWG 2004]~~

Users
Used oil has been a substitute for light gas oil for several years. It provides a lowering of operational costs and a useful disposal route for used oil. Details of the extent of this route in Europe are unclear but it is likely that the combined fuel oil may be sold as bunker fuel, for use in asphalt plants and power stations. The material, after membrane filtration, is suitable for use as power station ignition fuel or as a diesel extender. Concentrated waste oil, after membrane filtration, can be used as coal spray, where contaminants are bound with silica compounds upon burning. Table 5.76 summarises some of the uses of waste oil after mild reprocessing.

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Table 5.76: Use of mild reprocessed waste oil (WO) as fuel

Sector where treated WO is used	**Comments**	**Countries where it is used**
Road stone plants or asphalt mixing plants	Reprocessed WOs are burnt to dry hard stone for the manufacture of road surfacing materials. The stones are dried, then sized, after which they are mixed with bitumen and filler	Common in Belgium and the UK. However, in Italy some environmental authorities do not permit this use
Dry limestone	Reprocessed WOs are burnt to dry limestone. Some acid contaminants are likely to be captured by the solid material	
Blending into fuel oil	The processed oil may be blended into fuel oil. In this case, the maximum amount of processed used oil which may be blended with other heavy streams is limited by specifications on the ash content (generally about 0.1 % maximum), and sulphur content and may be subject to meeting a viscosity range specification	
Power stations	Reprocessed WO is utilised in pulverised coal power stations, mainly as a furnace start-up fuel, but it is also used sometimes as an addition to the main fuel where heat input is restricted. See the LCP BREF [42, EIPPCB 2003]	
Burning used oil in space heaters	After a separate pretreatment step where water and sediments are removed, the cleaned waste oil (see Section 5.2.1) is burnt in small space heaters in garages, workshops and greenhouses. Special stand-alone heaters are manufactured for this purpose. In this type of burner the exhaust gases are not usually scrubbed and emissions of harmful and polluting substances to air are likely. This route is usually ~~carried out~~ followed on a small scale (typically < 10 MW_{th}). This use provides an economic heating source and the used oil is disposed of at the point of generation	Such burning is said to account for approximately 40 kt of used oil in the UK per year. In Belgium and Denmark it is illegal in most cases to use it in garages, workshops and greenhouses (it is necessary to have a permit to dispose of it as a hazardous waste)
On board ships	Typically this involves used marine oils. The waste oils originating from shipping and from land sources are mixed in order to obtain better treatment and separation parameters. The oil is used as a finished waste fuel or as cutterstock, which means that different streams are blended in order to meet a viscosity range specification. The combined fuel oil is sold as bunker fuel. For the removal of the water, the waste oil is decanted. If necessary, demixing can be improved by adding emulsion breakers and/or raising the temperature. The oil is then filtered and centrifuged. The resulting oil goes to a storage tank and is sampled. Some cleaned waste oils are currently used in marine motors for electricity production.	Some examples are in Spain
Source: [33, UK EA 2001] [60, WT TWG 2003]		

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Ex-Section **2.5.2.4.3 Severe reprocessing** deleted: already in Section 5.2.1 Re-refining of waste oil

~~**Purpose**~~

~~Burning after 'severe' reprocessing aims to separate the combustible WO portion from the less desirable bottoms fraction which contains the metals, the non-combustible ash, grit and dirt. The 'severe' reprocessing transforms the used oils into fuels which can be burned with similar conditions to those for burning other oil fuels.~~

~~Principle of operation~~

~~Uses of flash column and (vacuum) distillation columns to produce a cleaner waste fuel suitable to be used as fuel. Several commercial processes exists (see process description below).~~

~~Feed and output streams~~

~~The demetallised waste oil produced (also called heavy distillate or heavy fuel oil) is burnt as a marine diesel oil or as fuel for heating plants.~~

Covered by Distillation processes mentioned in Table 5.25

~~Waste OUT from the 'Trailblazer' process (see process description below)~~

- ~~light hydrocarbons consisting of gasoline, kerosene, etc.~~
- ~~vacuum distillates. These comprise ash-free hydrocarbons in the diesel range and meet the fuel oil specification for several applications, including for use as a marine diesel oil~~
- ~~asphalt extender. This material is the residual bottoms from the vacuum tower. The metal, additives and degradation compounds are contained in the asphalt extender. The metal encapsulated in the finished asphalt material shows low leachability under a variety of tests.~~

Moved into Table 5.25

~~Waste OUT from the propane de-asphalting process (see description below)~~

~~The base oil produced is only suitable as a diesel extender because they produce unfinished lube basestocks which are not marketable. The 'bottoms' produced are suitable as bitumen. This process yields more marketable materials than regeneration by chemical treatment or by hydrogenation. This is the reason why sometimes this process under certain operational conditions may be seen as a re-refining process because a high percentage of base oils are produced. More information can be found in Table 5.25.~~

~~Process description~~

~~Some chemical treatments exist (acid/clay, solvent extraction, propane extraction, etc., with no finishing step) as do thermal treatments ('Trailblazer' process, 'Vaxon' process, etc.). A short description of the processes currently available in the market follows:~~

Moved into Table 5.25

~~'Vaxon' process~~

~~This consists of a series of vacuum cyclone evaporators, followed by a chemical treatment of the distillates obtained. There are several stages:~~

- ~~the first stage removes water, naphtha and light ends~~
- ~~the second stage removes gasoil, spindle oil or light fuel oil from the bulk of waste oil~~
- ~~the third and fourth stages separate different distillate cuts from the residue (in which all the metals, additives, sediments, heavy hydrocarbons and degradation compounds are concentrated).~~

~~The resultant distillates are then available as good quality industrial fuel. This process has been modified to create re-refined base oils (see Table 5.25).~~

Covered by Distillation processes mentioned in Table 5.25

~~'Trailblazer' process~~

~~In this process the used oil is dehydrated in a flash tower, heat soaked and then processed by vacuum distillation to produce three output streams. The ash-free distillate oil yield with this process is 80 % on a dry basis.~~

Moved into Table 5.25

~~Propane de-asphalting process (PDA)~~

~~Two types of process exist. These are called 'single stage' and 'two stages'. More information can be found in Table 5.25. Oil is mixed with liquid propane at a high pressure and ambient temperature in the de-asphalting unit for the separation of the residual asphaltic fraction. The~~

WORKING DRAFT IN PROGRESS

~~components of waste oil that are not soluble in propane (i.e. the asphaltic fraction containing carbon, metallic additives, resins, additives, polymers, degradation compounds and asphalt), precipitate and can be removed via settling. The process consists of the steps shown in Table 5.77:~~

Table 5.77: **Information on the PDA process**

~~Dewatering and de-fuelling~~	~~Pre-flash.~~ ~~Water, light ends and fuel traces contained in the used oil are removed by atmospheric or mild vacuum stripping; one or two columns may be used for this operation~~
~~De-asphalting~~	~~PDA, fractionation and hydrotreating.~~ ~~Asphalt is separated by extracting the recoverable fractions of the used oil with liquid propane. Two versions exist:~~ ~~1) single stage: downstream of the PDA extraction unit, the clarified oil is separated from the propane and fed to the hydrotreating. Finally, fractionation in a vacuum column produces the desired lubricating oil cuts~~ ~~2) two stages: the clarified oil coming from the first PDA unit is distilled and fractionated in a vacuum column. The bottom fraction, still containing impurities, is fed to a second PDA unit; the resulting asphaltic fraction is recycled back to the first PDA unit. The oil fractions coming from the side cuts of the vacuum column, along with the heavy cut clarified in the second PDA stage, are hydrogenated separately in the hydrotreatment. The two stage process, compared to the single stage, provides an extended life for the hydrotreating catalyst, but has higher investment and operating costs~~
~~Fractionation~~	~~Vacuum distillation~~
~~Finishing~~	~~Clay or hydrotreatment:~~ ~~after the subsequent distillation steps, the chlorine content of the distillates is lowered by treatment with metallic sodium~~
~~Yield~~	~~74 % in dry basis for IFP process (97 % dewatering de-fueling, 80 % de-asphalting), 95 % hydrofinishing (medium pressure)~~ ~~80 % in dry basis for the Snamprogetti. 5 % fuel, 9 % gasoil and 6 % residue~~
~~Common plant size~~	
~~Advantages~~	~~High yield and good waste fuel quality (if hydrotreated)~~
~~Drawbacks~~	~~More or less expensive according to the number of stages for the PDA.~~ ~~Significant amount of residues to be disposed of~~
~~Comment~~	~~Single stage: IFP was the first company to apply this technology in 1968 at Pieve Fissiraga in Italy (Viscolube plant). One plant in Italy producing 57 kt/yr~~ ~~Two stages: Snamprogetti installed this technology in 1982 at the Ceccano plant (Viscolube) in Italy.~~

~~[4, Monier, V. and Labouze, E. 2001] [60, WT TWG 2003]~~

deleted: covered by Distillation processes mentioned in Table 5.25

~~Users~~

~~A 'trailblazer' process plant with a capacity of 150 kt/yr used oils is in operation in Louisiana, US. Some of those processes are similar to the ones used within refineries. The waste fuels of those processes are typically used as marine diesel oil or a fuel for heating plants.~~

5.3.2.4.2 Thermal cracking

From ex-**Section 2.5.2.4.4 "Thermal cracking"**

Purpose and principle of operation

Thermal cracking uses heat to break down long chain hydrocarbon molecules (e.g. the ones found in waste oils) into shorter ones thus generating lighter liquid fuels. In this way, larger molecules of more viscous and less valuable hydrocarbons are converted to less viscous and more valuable liquid fuels.

Feed and output streams

Thermal cracking can accept various types of hydrocarbon feedstock: waste oils, waste marine fuels, deep frying oils and, possibly with design considerations, waste plastics (e.g. waste oils returned in their original container). The strategy of thermal cracking is to crack large viscous molecules into more valuable shorter molecules ranging from demetallised heavy fuel oil to

WORKING DRAFT IN PROGRESS

re-refined light industrial lube oil, including gas oil products as well as other materials for other uses. According to this, the thermal cracking can be configured to give the following set of outputs (Table 5.78).

Table 5.78: An example of outputs under appropriate operating conditions

Plant configuration	Outputs	%
1	Off-gases Naphtha Demetallised heavy fuel oil or marine gas oil Heavy residues	5 8 77 10
2	Off-gases Naphtha Gas oil (also called diesel fuel, heating oil, furnace oil) Light lube oil Heavy residues	10 15 65 Small fraction 10
3	Off-gases Naphtha Gas oil Re-refined light lube oil (1) Heavy residues	5 10 30 45 10

(1) Sometimes this configuration is enclosed as a re-refining process because of the high percentage of re-refined lube oil. Some cracked materials are used as flotation oil, mould-release oil or as naphthalene absorbent in coke oven gas cleaning.

Source: [4, Monier, V. and Labouze, E. 2001] [60, WT TWG 2003] [98, WT TWG 2004]

If the configuration for gas oil production is desired, this is the most severe cracking mode and thus heat input is maximised and the throughput is at the design capacity. If demetallised heavy fuel oil or light lube oil is preferred as the primary output from the plant, the process operating conditions can be changed to achieve this. Due to these variability facts, thermal cracking offers a big opportunity to adapt to fluctuations in the market values of products.

From ex-**Section 3.5.4.3 "Waste oil used as fuel"**

Table 5.79 gives a summary of the components present in the products from the thermal cracking of waste oils.

Table 5.79: Components of the output from the thermal cracking of waste oils

Component	Comments
Chlorinated hydrocarbons	If the cracked fuel is hydrotreated, chlorinated compounds are removed. Heavy PCBs (boiling point higher than the waste oil) are destroyed during this process. Light PCBs are only partly destroyed during this process. Organic chloride compounds may still remain in the distillate.
Chlorine	A maximum specification for chlorine of 50 ppm was set by the Dutch government.
Metals	The efficiency of the vacuum column enables the production of distillates with metal contents of less than 1 ppm. All metals present in the used oil end up in the bottom of the cracking section.
PAHs	The heavy PAHs are cracked, and are burnt with light naphtha. The lighter PAHs are added to the pool of light fuels.
Sulphur	The gasoline will have a sulphur content that depends on the sulphur level in the used oil feed and the stabilisation method applied.

Source:[3, Silver Springs Oil Recovery Inc. 2000] [98, WT TWG 2004]

It is likely that, in order to meet EU requirements for the sulphur content in liquid fuels (automotive and/or heating oil), the resulting cracked products will require either treatment for sulphur reduction or will have to be blended away in lower sulphur products (thereby making indirect use of someone else's desulphurisation capability).

WORKING DRAFT IN PROGRESS

Table 5.80: Outputs generated by the thermal cracking of waste oils

~~**Outputs**~~	~~**Units (per tonne of input waste oil)**~~	~~**Mainly to produce fuel oil**~~ [1]	~~**Mainly to produce gasoil**~~ [2]
~~Fuel oil (32 of 700 MJ and <0.5 % S)~~	~~kg~~	~~849~~	
~~Secondary fuels~~ [3]	~~kg~~	~~63~~	
~~Gasoil~~	~~kg~~		~~706~~
~~Naphtha~~	~~kg~~		~~51~~
~~Bitumen~~	~~kg~~		~~38~~

~~1 Thermal cracking: Thermal + chemical treatment (with H_2SO_4)~~
~~2 Thermal cracking adjusted to produce primarily gasoil. Finishing with a purification and stabilisation stage~~
~~3 Many are waste fuel generated during the process~~
~~*Source*:[4, Monier, V. and Labouze, E. 2001] [100, WT TWG 2004]~~

Process description

The process operates at very high temperatures (thus evaporating all the water present). After removal of the water, much of the heavy metal content is removed as sludge or via an acid treatment prior to the cracking step. The pretreated waste oil is thermally cracked at 420 °C at low pressure (without a catalyst). The subsequent distillation and stabilising steps yield a marketable fuel (gas oil). Depending on the intensity of the cracking, the material may either be a fuel oil, a fuel suitable for blending with diesel (diesel extender) or materials used as light lube oil and for other uses. Several processes exist today, such as the following:

SOC processes

- SOC1: dewatering is followed by thermal cracking, performed in fired heater coils with soaking drums or heated kettles. This process is suitable for small plants, in the 6–15 kt/yr range but it has only a limited feed acceptance.
- SOC2: dewatering is followed by thermal cracking, performed in an indirectly fired rotary kiln. This process is suitable for large capacities and can also process more refractory oils than thermal cracking (such as synthetic oils) and higher carbon residues (bunker fuels, etc.).

GNP processes

This thermal cracking of waste oils, utilising ‘refinery calibre’ systems and equipment, is a relatively recent development. The process consists of a screening and dewatering stage; followed by a thermal cracking stage; a separation or distillation stage, depending on the output mix desired; and finally a purification and stabilisation stage. This technology is characterised by large operational and output flexibility and adaptability to the changing market values of materials. It can also be manipulated to maintain output quality even with wide feed variability. As a matter of fact, the process' ~~operational~~ operating conditions (temperature, pressure, residence time, etc.) can be varied to produce a primary output (be it heavy fuel oil, gas oil or base oil) that can be maximised, whilst minimising the secondary output streams (consumed in the process for calorific value or sold).

Thermally cracked gas oil is unstable if not further processed. It can discolour rapidly and precipitate gums and tars. A stabilisation and purification operation supplementing the thermal cracking can produce a gas oil which is not odorous, meets regulatory and consumer colour criteria, minimises the formation of gums and tars during storage and which is not highly acidic. For this, several methods are available:

- The Robys^{TM} process.
- Several chemical stabilisation methods (clay absorption, solvent extraction).
- Hydrotreatment. Except for a stand-alone WO thermal cracking plant, this treatment might not be feasible due to the very high capital costs and the requirement for hydrogen gas.

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The typical yield for processes using thermal cracking is 71 %, this resulting from the partial yields in the processes of 95 % dewatering, 90 % thermal cracking itself, 83 % distillation and 99.5 % purification/stabilisation.

Users

Thermal cracking is a common mineral oil refinery process that is well known and proven. At least two plants exist in Europe. One is a 40 kt/yr plant in Belgium and another a 20 kt/yr facility operating in Spain. The latter mixes all the light and heavy fractions obtained to feed a thermal engine producing electricity. More than seven plants are in operation in the US, with a total capacity of more than 160 kt/yr. The plant size for this technology ranges from 7–40 kt/yr.

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Ex-**Section 4.5.4.2 "Thermal cracking of waste oils"** deleted

~~**Description**~~

~~See Section **5.3.2.4.2**.~~

~~**Achieved environmental benefits**~~

~~The use of thermal cracking in a refinery reduces the CO_2 emissions, as it reduces the refinery crude intake.~~

~~**Economics**~~

~~Thermal cracking is capital consuming: capital costs and fixed operating costs represent about 80 % of the overall cost (WO purchase excluded). A thermal cracking plant costs in the order of a third to half the amount of a regeneration plant of similar size (although that comparison is not necessary relevant since the outputs produced are different). Experts agree that thermal cracking with its lower capital cost allows plants to be profitable at the 30 kt/yr plant size. No subsidies are necessary.~~

Table 5.81: Cost and waste oil gate fees for three different capacities of grass-root thermal cracking plant

~~**Parameter**~~	~~**Capacity A**~~	~~**Capacity B**~~	~~**Capacity C**~~	~~**Units**~~
~~Capacity~~	~~40~~	~~50~~	~~80~~	~~kt/yr~~
~~Capital costs~~	~~11~~	~~13~~	~~20~~	~~EUR million~~
~~Specific cost~~	~~135~~	~~123~~	~~112~~	~~EUR/tonne of WO~~
~~Cost on internal return on finance~~ ~~(1)~~	~~50~~	~~46~~	~~44~~	
~~Revenues~~	~~144~~	~~144~~	~~144~~	~~EUR/tonne of WO~~
~~WO gate fee~~	~~-10~~	~~-21~~	~~-32~~	
~~(1) on the basis of a 15 % risk adjusted rate of return on finance (included in the cost line).~~				
~~*Source*:[4, Monier, V. and Labouze, E. 2001] [98, WT TWG 2004]~~				

~~The investment cost for using waste oil as fuel in severe reprocessing is USD 12 million (1995) for a treatment of 54 kt/yr (assumptions: storage: 15 days, working capital: 15 days). The investment cost for the Texaco Trailblazer producing marine diesel oils is USD 11 million (1994) for a treatment of 54 kt/yr (same assumptions as above). Other information shows that the approximate value of used oil when used in severe reprocessing (the value at the plant gate (1994) assuming an IRR of 15 % after tax and working capital of 15 days) without collection is USD 47/t and 63 including the collection cost (average collection cost assessed at USD 110/t within Europe).~~

~~**Reference literature**~~

~~[2, Concawe 1996] [3, Silver Springs Oil Recovery Inc. 2000] [4, Monier, V. and Labouze, E. 2001]~~

Ex-**Section 2.5.2.4.5 Hydrotreatment** moved into Table 5.25

~~Hydrotreatment is a dedicated name for catalytic hydrogenation in the mineral oil industry. For waste oils, the main purpose is essentially to remove PAHs. It also reduces the sulphur content in the oil (this is a potentially useful characteristic if diesel and diesel extender is the intended output).~~

5.3.2.5 Production of biodiesel from vegetable waste oils

From ex-**Section 2.5.2.5 "Production of biodiesel from vegetable waste oils"** and ex-**Section 3.4.1 "Waste IN treated to obtain a recycled material"**

Purpose
To produce biodiesel from vegetable waste oil.

Principle of operation
Involves cleaning of the waste oils.

Process description
First the waste oils are filtrated and water is removed. The waste oil is then separated by distillation to obtain the outputs.

Feed and output streams
The types of waste oils treated are collected in waste transfer facilities and from the restaurant sector. The output is mainly biodiesel, which is used for transport and glycerine.

~~**Vegetable waste oils**~~
~~Cooking oils from restaurants and hotels.~~

Users
At least two plants exist in the EU (in Spain and Austria) and one is planned to be constructed in Portugal.

TWG members, please provide information on the existing plants

Ex-**Section 2.5.3 Preparation of gaseous fuel from waste** deleted: gasification is excluded from the scope; see KOM conclusion 1.3b

~~**Purpose**~~
~~To prepare a gaseous fuel from a liquid or solid waste.~~

~~**Principle of operation**~~
~~Two ways of producing fuels from waste exists and these are:~~

- ~~gasification of the waste at high temperatures by partial oxidation and then conversion of materials containing carbon into synthesis gas (mainly H_2 and CO)~~
- ~~production of biogas (mainly methane) by the anaerobic digestion of waste (covered under biological treatments in Section).~~

~~**Feed and output streams**~~
~~Used oil can be fed, alone or in combination with other feedstocks, to gasification plants for the conversion of materials containing carbon to synthesis gas (H_2 and CO). This process can also use mixed wastes that cannot be economically separated; for example, oil and plastic which may be found together when used oil is returned in its original container.~~

~~**Process description**~~
~~See the Refinery and the WI BREFs.~~

~~**Users**~~

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~~Gasification technology has been used worldwide for a long time in more than 100 plants and it provides a well used option for the re-use of waste oil as well as other types of wastes. This option is typically used when gas fuel has a use on site. In Greve (close to Florence in Italy), a gasifier operates using the RDF pellets from Florence. Here, they use the gas fuel for two purposes. The first purpose is to produce electricity in a gas boiler plant for the national grid. The second purpose is to deliver gas to a cement kiln located close to the gasifier. The synthetic gas can also be used for the production of methanol.~~

5.3.3 Current emission and consumption levels

Table 5.82 summarises the information related to plants from the reference list performing physico-chemical treatment of waste with calorific value. The treatment processes are described in the sections mentioned in the table.

Table 5.82: Plants from the reference list performing physico-chemical treatment of waste with calorific value

Plant	Waste input description	Waste input physical state	Output	Process involved	Relevant sections of the document
078	Paint, ink, glue, resin, oily sludge, tar, grease, reaction and distillation residues, soap, detergents, cosmetics, filtration earth and cakes, petrochemicals, packaging and contaminated materials, absorbents having the status of waste for the production of solid fuel (wood sawdust etc.)	Solid and multiphase	Substitute solid fuel, Mixed plastics, Ferrous metal	Shredding, Mixing, Formulation and pre-homogenisation of the incoming waste	5.3.2.2
148C	Energetic waste from numerous industrial origins, sludge from oil/water separators, from storage tank and barrel cleaning, cleaning water, washing liquids, aqueous liquid waste from chemical industry, pasty, organic unreactive wastes (used packaging, etc.)	Solid, liquid and pumpable	Aqueous output, Liquid fuel, Dehydrated sludge, Wood, Ferrous metal, All waste under temporary storage activities	Preparation of hazardous waste liquid fuel through physical processes including homogenisation, phase separation and mixing/blending processes	5.3.2.3

WORKING DRAFT IN PROGRESS

152C	High HC concentration, Low HC concentration	Liquid	Liquid fuel, Sludge with hydrocarbons, Residues from waste water treatment	Density separate, Distillation	5.3.2.4.1
172C	Used oils, hydrocarbon wastes, non-halogenated solvents, paint, ink, varnish sludge, distillation residues, grease, water-based liquid waste from chemical, cosmetic industries, WEEE, aerosols, used batteries, used packaging and contaminated materials	Liquid, pasty, solid, multiphase	Other solid fuel, Liquid fuel, Aqueous output, Used packages, Transit WEEE and waste out of specification for the processes	Preparation of hazardous waste liquid fuel through physical processes including homogenisation, phase separation and mixing/blending processes	5.3.2.3
174C	Used oils, mixed hydrocarbon waste, paint, ink, varnish sludge, distillation residues, grease, Halogenated and non-halogenated, used diluent (toluene, xylene, etc.), used alcohols, cleaning water, aqueous washing liquids, aqueous liquid waste water cosmetic industries, waste packaging, contaminated materials, mineral organic solid waste	Liquid, pasty, solid, multiphase	Aqueous output, Liquid fuel, Pasty waste not adapted for fluidification, Mixed plastics, Ferrous metal	Fluidification	5.3.2.3
332	Waste solvents from chemical and pharmaceutical manufacturing, waste plastic packaging and PPE.	Liquid	Liquid fuel	Mixing	5.3.2.3
425_426	All kinds of organic hazardous waste	Liquid, pasty, solid, multiphase	Liquid fuel, Other solid fuel, Ferrous metal	Shredding, mixing, granulating.	5.3.2.2, 5.3.2.3

WORKING DRAFT IN PROGRESS

440[1]	Used oils from industrial facilities, including process oils, and used oils from carshop repairs and maintenance, used oils from industrial facilities, including process oils, and used oils from carshop repairs and maintenance	Liquid	Waste oil	Density separation	5.3.2.4.1
450	Waste solvents with LCV > 3 000 kcal/kg, Pasty waste, Organic waste waters with LCV < 3 000 kcal/kg	Liquid and pasty	Liquid fuel, Ferrous metal, Mixed plastics, Residues from shredding	Shredding, mixing	5.3.2.3
469	Liquid waste, industrial origin, Pasty and solid waste, industrial origin	Liquid and multiphase	Liquid fuel, Sawdust impregnated with organic compounds (paints, hydrocarbons), solvents and an inert fraction	Shredding, mixing	5.3.2.3
507	Infectious clinical waste (no chemicals or pharmaceuticals) (EWC 18 01 03, 18 02 02 and 20 01 99), blood bags and blood preserves, offensive wastes such as outer dressings and protective clothing - masks, gowns and gloves that are not contaminated with body fluids, hygiene waste and sanitary protection - e.g. nappies and incontinence pads, sterilised ('autoclaved') laboratory waste	Solid, liquid and multiphase	RDF, Other waste for disposal	Thermal screw	5.3.2.1

WORKING DRAFT IN PROGRESS

508	Infectious clinical waste (no chemicals or pharmaceuticals) (EWC 18 01 03, 18 02 02 and 20 01 99), blood bags and blood preserves, offensive wastes such as outer dressings and protective clothing - masks, gowns and gloves that are not contaminated with body fluids, hygiene waste and sanitary protection - e.g. nappies and incontinence pads, sterilised ('autoclaved') laboratory waste	Solid, liquid and multiphase	RDF, Other waste for disposal	Thermal screw	5.3.2.1
549	Waste oil and water emulsions	Pumpable	Regenerated oil, Aqueous output, Residues from waste water treatment, Oily sludge from oil/water separation process	Emulsion breaking	5.3.2.3
553	Calorific waste liquids and sludge	Pumpable	Liquid fuel, Wood	Mixing	5.3.2.3
(1) This plant carried out only activities of temporary storage in the reference years.					

This section focuses on the emissions and consumption of the plants with similar processes for the treatment of waste with calorific value, i.e. plants carrying out mixing of liquid wastes or mixing of liquid wastes with solid wastes to obtain liquid and/or solid output (see Sections 5.3.2.2 and 5.3.2.3). This operation may be followed or preceded by a shredding step.

5.3.3.1 Emissions to air

Table 5.83 and Table 5.84 show, for the relevant plants on the reference list, the origin of emissions to air, the associated abatement techniques and the pollutants monitored in air emissions. The VOCs are generally collected from different steps of the process, such as storage, unloading and mixing, and channelled to a VOC destruction system (thermal oxidation) or a VOC recovery system (activated carbon adsorption or cryogenic condensation).

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Table 5.83: Origin of emissions to air and abatement techniques of plants performing PCT of waste with calorific value

Plant	Techniques for emissions to air	Origin of emissions to air	Average air flow (Nm^3/h)
078	Regenerative thermal oxidation	Whole plant	48 235
148C	Activated carbon adsorption	Fuel preparation and sludge dehydration	37 767
172C_1	Regenerative thermal oxidation, Activated carbon adsorption	Channelled release linked with hazardous solid fuel production and liquid fuel production (mainly composed of solvents)	45 488
172C_2	Activated carbon adsorption	Liquid fuel fabrication (emulsion technique)	22 459
174C	Activated carbon adsorption	All waste liquid fuel processes including mixing steps and loading	11 472
332	Wet scrubbing, Activated carbon adsorption	Blending and mixing	Not monitored
425_426	Four-step system for cleaning of process air to stack: 1: Bag filter. 2: Saturated coal filter. 3: Oxidising bed at approximately 1000 °C. 4: Wet scrubber for acid gases including neutralisation with NaOH.	Shredding, mixing, granulating	11 651
450	Cryogenic condensation	Storage, shredding and blending	61
469	Thermal oxidation and Neutralisation with lime	All	17 308
553	Synthetic Oil absorption scrubber, Activated carbon adsorption	All vent stacks	Not monitored

WORKING DRAFT IN PROGRESS

Table 5.84: Pollutants monitored in air emissions of plants performing PCT of waste with calorific value

Pollutant measured	Type of measurement	Plants concerned	Ranges (mg/Nm3)
Dust	Continuous	425_426	0.4
	Periodic	078, 148C, 172C_1, 172C_2, 469	0.2–3
TVOC	Continuous	148C, 172C_1, 172C_2	5–24
	Periodic	172C_2, 174C, 332, 553	3.3–117.1
TOC	Continuous	425_426, 469	7.3–11.5
	Periodic	450	36.7
NMVOC	Periodic	078, 148C, 172C_1, 172C_2	3.8–113.3
HCl	Continuous	425_426	0.2
	Periodic	148C, 172C_1	0.3–2.3
NO_X	Periodic	078, 148C, 172C_1	0.4–11.5
CO	Periodic	078, 172C_1	5.1–16.5
SO_X	Periodic	148C, 172C_1	0.2–2.5
Cd+Hg+Tl	Periodic	148C, 172C_1	0.005–0.0052
As+Te+Se	Periodic	172C_1	0.007
Sb+As+Pb+Cr+Co+Cu+Mn+Ni+V	Periodic	148C	0.149
PCDD/PCDF	Periodic	469	0.009

Figure 5.19, Figure 5.20 and Figure 5.21 show the values measured in air emissions for TVOC, NMVOC and dust respectively.

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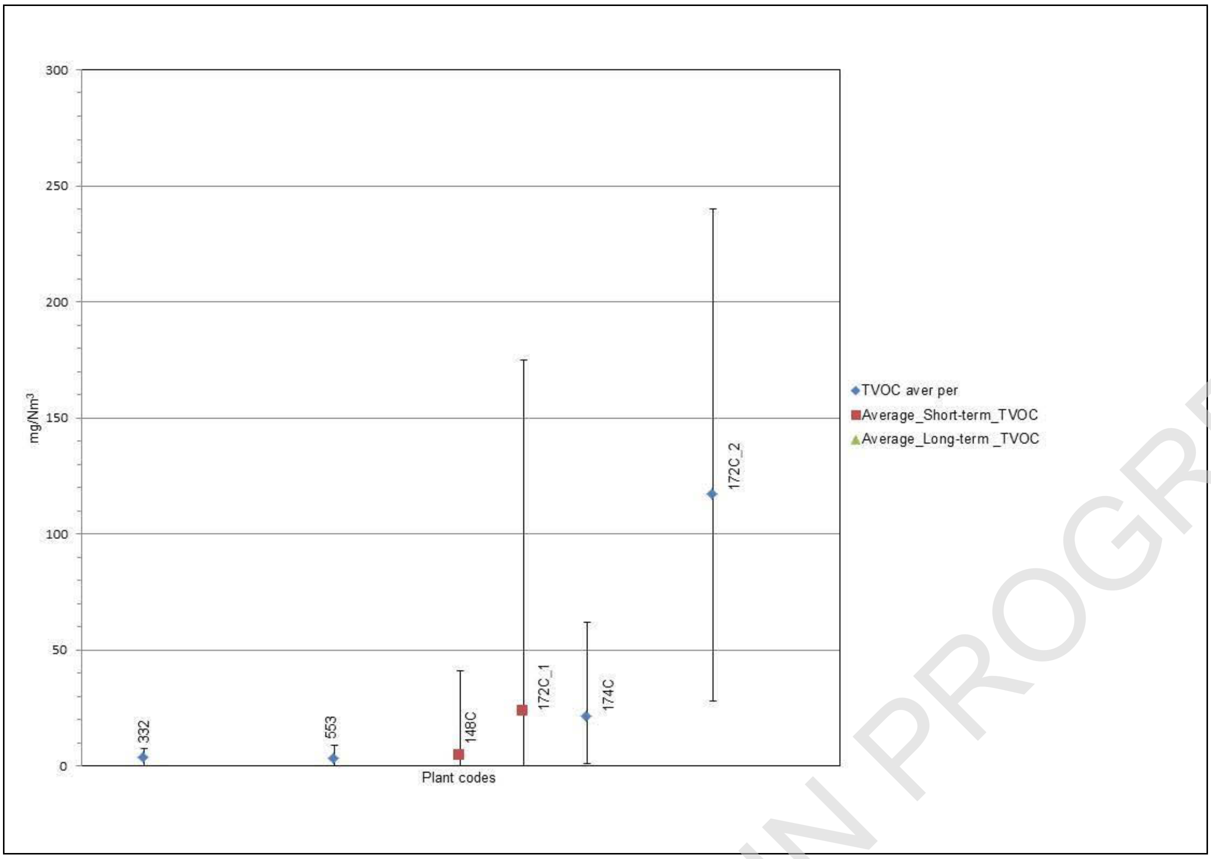

Figure 5.19: TVOC measured in air emissions of plants performing PCT of waste with calorific value

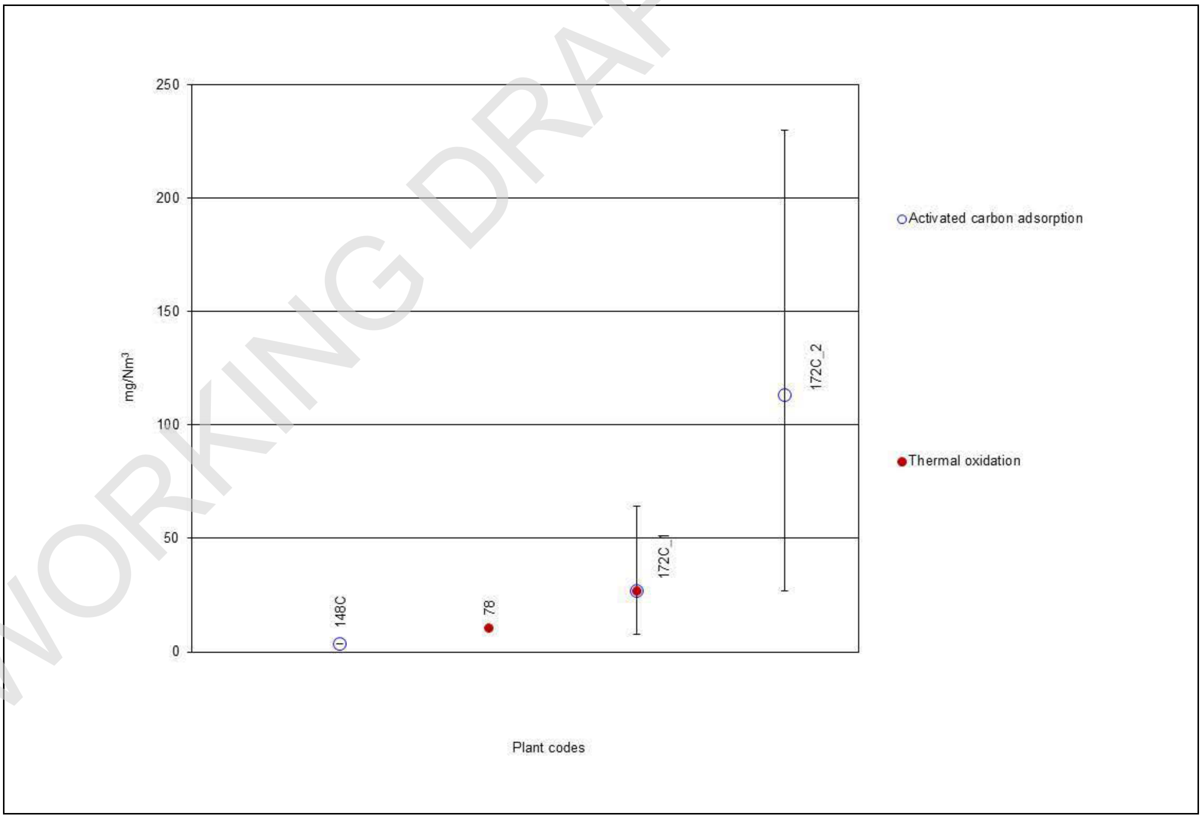

Figure 5.20: NMVOC measured in air emissions of plants performing PCT of waste with calorific value

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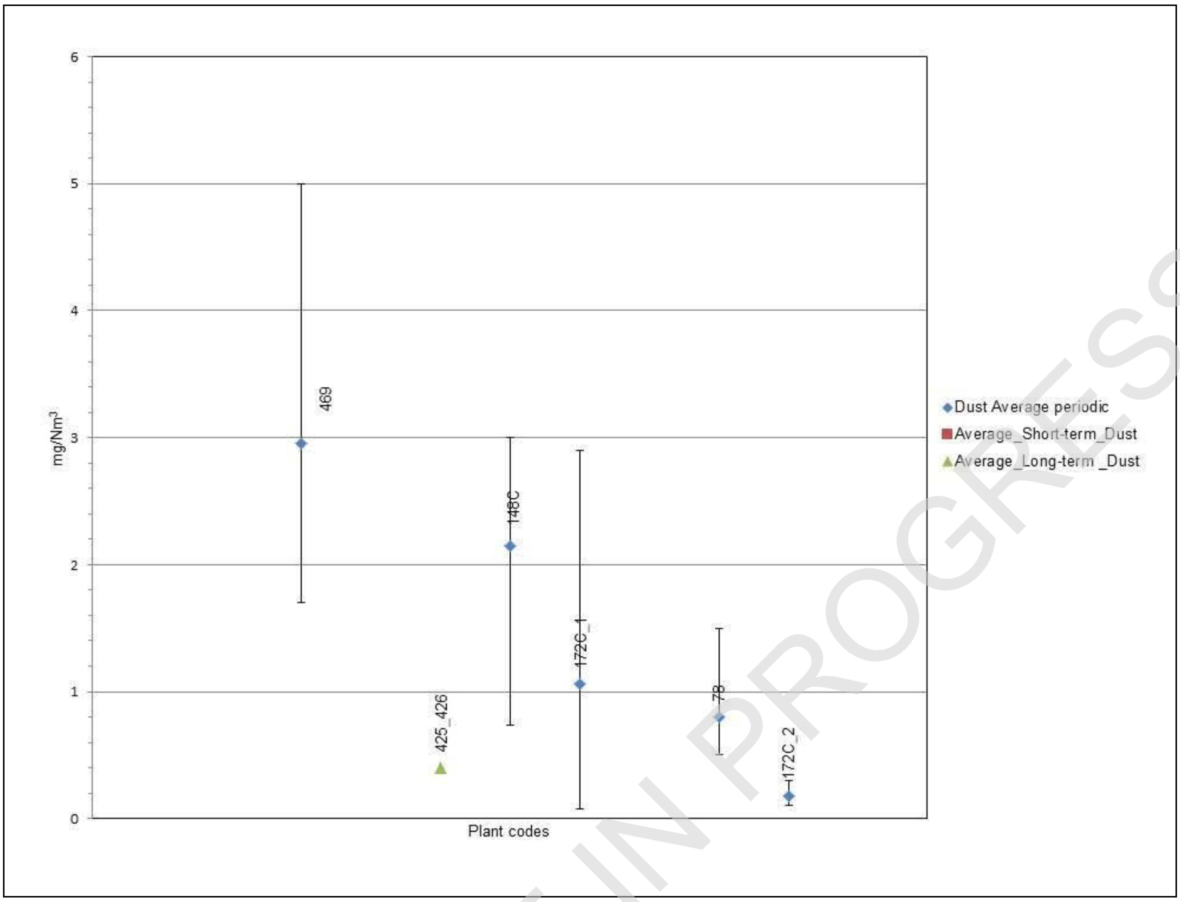

Figure 5.21: Dust measured in air emissions of plants performing PCT of waste with calorific value

5.3.3.2 Emissions to water and water usage

Table 5.85 shows, for the relevant plants on the reference list, the origin of emissions to water, the associated abatement techniques and the pollutants monitored in water emissions. As can be seen, there are no emissions to water at four of the plants. Of the other five plants, two have direct discharge of waste water to the environment but, in these cases, the released water is said to be only run-off water or sanitary water.

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Table 5.85: Origin of emissions to water and associated abatement techniques at plants performing PCT of waste with calorific value

Plant	**Techniques for emissions to water**	**Origin of emissions to water**	**Point of release**	**Receiving body**	**Average water flow (m^3/h)**
078	NA	No water is used in the process. The only water rejected is sanitary water and there is a sewage system to treat it. It is linked to a collecting system. The uncontaminated water is treated in a municipal collection system. The contaminated surface water (water from roads) is treated by a sludge and oil removal system	NA	NA	NA
148C	First decantation and oil separation, then the water is stored in a dedicated basin (minimum: 650 m^3) before release by batch to an external WWTP. Controls are done before each batch.	Rainwater collected from the whole plant (circulation area, etc.).	Discharge from the WT plant, as well as from on-site waste water pretreatment facilities, to an off-site common WWT facility	NI	NI

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172C	Filtration, Powdered activated carbon treatment, Decantation, Other (Intermediate storage before release)	Concerns only the storm water from roads and parking areas. The contaminated washing water and the rinsing water are included in the output waste sent to thermal treatment	Discharge from the on-site common WWT facilities to the environment (when the design/operation of the WWT facility is mainly influenced by waste water streams coming from the WT plant)	River/Stream	7
174C	Decantation Buffer tanks	Concerns only the non-polluted rainwater from the plant and sanitary water	Discharge from the on-site common WWT facilities to the environment (when the design/operation of the WWT facility is mainly influenced by waste water streams coming from WT plant)	NI	NI
332	NA	No emission	NA	NA	NA
425_426	NI	NI	NI	Coastal water (sea/ocean)	0.9–1.6
450	NA	Rain in process areas and spills. There is no point of release of WW. All WW is recirculated into the process. Only rainwater is released in a municipal sewer after being analysed.	NA	NA	NA
469	NI	NI	NI	NI	NI
553	NA	There is no emission to water from the process.	NA	NA	NA

NA: Not applicable.
NI: No information.

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Table 5.86 shows the parameters monitored in water emissions at plants where water is released.

Table 5.86: Pollutants monitored in water emissions at plants performing PCT of waste with calorific value

Pollutant measured	Type of measurement	Plants concerned	Ranges (mg/l except for pH)	Number of measurements during the 3-year reference period (2010-2012)
pH	Continuous	425_426	7.4	NA
	Composite sample	148C, 172C, 174C	7–8	2-35
TSS	Composite sample	148C, 172C, 174C	4.5–14.3	3-35
BOD_5	Composite sample	148C, 172C, 174C	1.6–5.9	2-12
COD	Composite sample	148C, 172C, 174C	20.9–60	3-35
THC	Composite sample	148C, 172C, 174C	0.1–0.5	2-35
CN^-	Composite sample	148C, 172C, 174C	0.0055–0.05	2-12
Pb	Composite sample	148C, 172C, 174C	0.004–0.135	3-35
Cr (VI)	Composite sample	148C, 172C, 174C	0.007–0.032	3-35
Phenol	Composite sample	148C, 172C, 174C	0.004–0.023	3-34
F^-	Composite sample	148C, 172C	0.3–0.5	3
Cd	Composite sample	172C, 174C	0.002–0.056	3-35
Hg	Composite sample	148C, 172C	0.001–0.167	3
As	Composite sample	148C, 172C	0.004–0.007	3
Cu	Composite sample	148C, 174C	0.02–0.088	3-35
Ni	Composite sample	148C, 174C	0.01–0.109	3-35
Zn	Composite sample	148C, 174C	0.05–0.328	3-35
AOX	Composite sample	148C, 172C	0.0267–0.0285	2-3
TKN	Composite sample	148C	3	3
Cr	Composite sample	148C	< 0.01	3
Mn	Composite sample	148C	0.036	3
Sn	Composite sample	148C	< 0.02	3
Total N	Composite sample	172C	5.2	2

WORKING DRAFT IN PROGRESS

Total P	Composite sample	172C	0.2	3
Metals Cr(VI), Pb, Hg	Composite sample	172C	0.18	3
Fe	Composite sample	174C	0.66	35
Zn+Cu+Ni+Al+Fe+Cr VI+Cd+Pb+Sn	Composite sample	174C	NI	NI
TOC	Continuous	425_426	15.9	NA

NI: No information.
NA: Not applicable

Figure 5.22 below shows the specific water usage of plants performing PCT of waste with calorific value. It should be underlined that, at all five plants that mention water usage, the water is not used for the process itself but for cleaning/rinsing or for sanitary purposes. At three other plants, no water usage is reported.

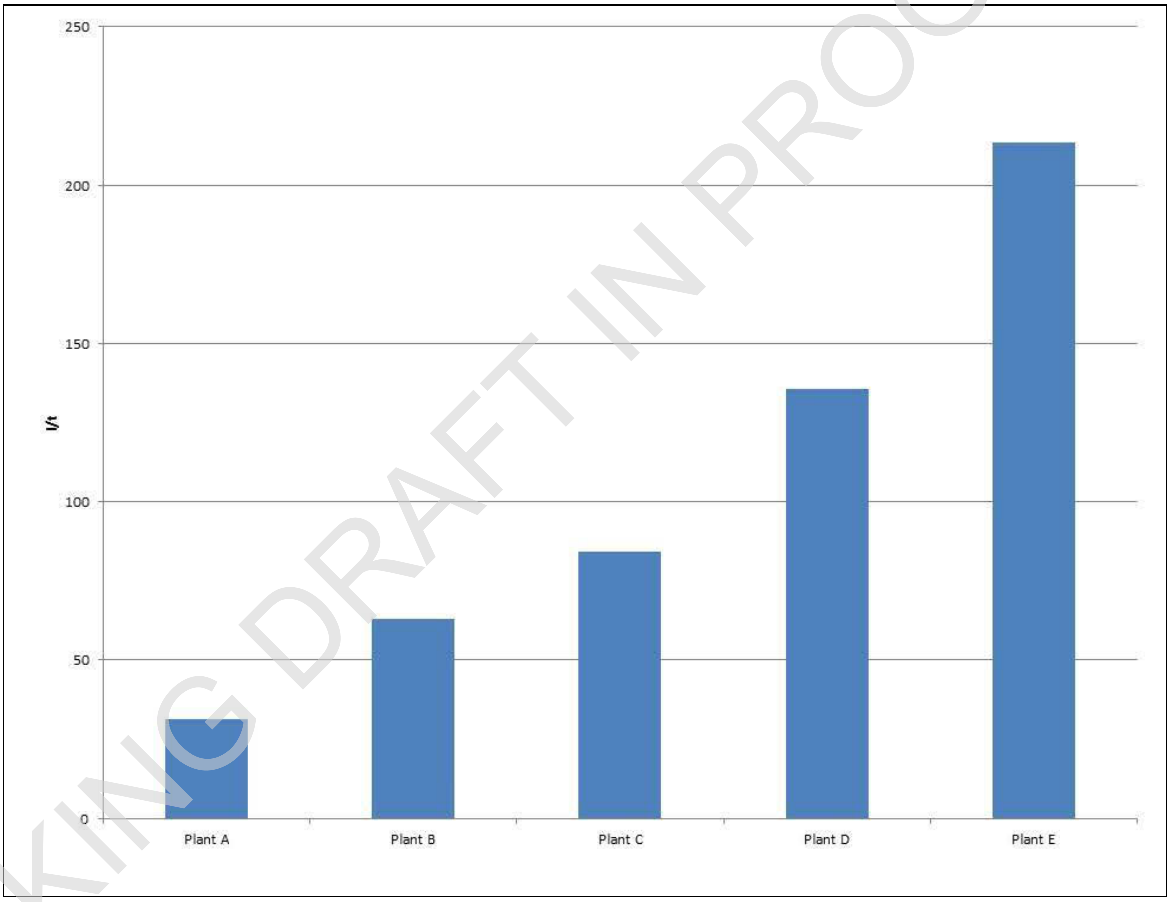

Figure 5.22: Specific water usage (litres per tonne of waste treated) of plants performing PCT of waste with calorific value

From ex-**Section 3.5.3 "Emissions from the preparation of waste fuel"**

~~**Preparation of solid waste fuel by the carbonisation of contaminated wood**~~

~~Contaminated wood may contain POPs, mercury, arsenic and other typical contaminants~~

~~Table 5.87 shows the emissions of the preparation of waste oils when producing a liquid fuel.~~

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Table 5.87: Emissions generated from the preparation of waste oils to be used as fuel

~~Emission Pathway~~	~~Medium~~	~~Through~~
~~Waste oil storage~~	~~Air~~	~~Displacement of vapour during loading~~ ~~'Breathing' via vents~~
~~Boiler~~	~~Air~~	~~Combustion gases via stack. Most oil re-processing facilities generate steam from in-house boilers~~
~~Heating vessels~~	~~Air~~	~~Heating vessels are typically insulated mild steel tanks. Heat is delivered to the oil by a heat exchange system typically based on internal or 'blind' steam coils. This arrangement can be difficult to clean and maintain. This may lead to inefficient energy use related to raising steam.~~ ~~VOCs are emitted during the heating of oil to drive off water vapour. Emissions may consist of displaced vapour comprising water vapour and VOCs. Carbon absorption could be used but may be affected by water vapour. Condensation needs to be considered to collect the organic fraction, which can be used as boiler feed or incinerated~~
~~Warm oil receiving tank~~	~~Air~~	~~VOCs from the transfer of warm oil to receiving tanks~~
~~Warm oil filtration~~	~~Air~~	~~VOCs emitted when warm oil is passed through filters to remove solids. Warm oil from the heating vessels is typically passed over open filters to remove solids. These are situated either in open yards or buildings. The filters used are typically vibrating metal mesh more commonly used in relation to mineral aggregates. It is crucial to the sale of the recovered fuel oil that the high solids content that the warm oil retains, is removed. The action of the removal of solids is aggressive and the filters need to be robust to deal with the solids and also the warm oil. This stage is a source of VOCs and odour~~
~~Removal of oil from effluent~~	~~Air~~	~~Oil is removed from liquid effluent prior to discharge to foul sewer or other waters, usually by oil/water interceptors, tilting plate separator and or by filtration techniques. VOCs are a significant emission when drawn off from a process tank into open channels and also when this is warm and passed over a tilting plant separator~~
~~Removal of oil from effluent~~	~~Water~~	~~Effluent to sewer. VOCs are released from warm water to sewer~~
~~Separation water~~	~~Air~~	~~VOCs released during watering off~~
~~Recovered oil storage~~	~~Air~~	~~VOCs displacement~~
	~~Land~~	~~Removal of sludge from storage and heating vessels and filtration units~~

~~*Source:* [33, UK EA 2001]~~

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~~Table 5.88 shows some mass balances of four different treatment plants (A - D).~~

Table 5.88: Inputs and outputs for waste oil treatment plants producing a material to be used as fuel

~~**Site**~~	~~**Waste IN (excluding non oil/solvent items such as batteries)**~~	~~**Products**~~	~~**Discharge to sewer**~~	~~**Waste for processing off-site**~~	~~**Waste to landfill**~~
~~A~~	~~Bulk waste oil: 14340~~	~~Fuel oil for the asphalt industry: 12800~~			
	~~Hydraulic fluid: 15~~				
	~~Mixed oily waste: 100~~				
	~~Used oil filters: 1355~~				
	~~Paints and solvents 100~~				
~~B~~	~~Mixed waste oils: 15000~~	~~Fuel oil: 13000~~	~~Waste water: 700~~	~~Compacted oil filters: 30~~	~~Sludge: 500~~
	~~Used oil filters: 90~~				
~~C~~	~~Contaminated water from factory interceptors: 14000~~	~~Fuel oil for further treatment or blending: 2000~~	~~High COD waste water: 13600~~		~~Pumpable sludge: 300~~
	~~Used oils from garages and factories: 2000~~				
	~~Surplus fuel oils: 100~~				
~~D~~	~~Used motor lubricating oil (In tankers): 80000~~	~~Used lube oil treated for use as fuel: 72000~~	~~Waste water with traces of hydrocarbons: 2500~~		~~Sludge from sieves: 6~~
	~~Used lube oils in drums: 100~~				~~Tank bottom sludge: 6~~
	~~Surplus fuel oils: 300~~	~~Kerogas (mixed lube and fuel oil): 1000~~			~~Cut pieces of 25 litres oil drums: 10~~
					~~Debris, rags, etc: 5~~

~~Note: Values within cells correspond to the annual amount in tonnes of the mentioned material~~
~~*Source*: [34, Babtie Group Ltd 2002]~~

Table 5.89: Example of emissions from an oil recycling plant that heats the oil during the process

~~**Waste IN**~~			
~~**Type of waste oils**~~	~~**Annual amount (tonnes)**~~	~~**Oil content (% oil)**~~	~~**Water content (% water)**~~
~~Waste motor oil~~	~~62000~~	~~97~~	~~3~~
~~Interceptor waste~~	~~25000~~	~~4~~	~~96~~
~~Soluble oils~~	~~16000~~	~~25~~	~~75~~
~~Fuel oils~~	~~7000~~	~~98~~	~~2~~
~~Oils from transfer stations or the processing of oil filters~~	~~4000~~	~~97~~	~~3~~
~~Other oil bearing waste streams~~	~~200~~	~~99~~	~~1~~
~~**Waste OUT and residues**~~			
~~**Product**~~			
~~Cleaned waste oil to be used as fuel~~	~~75150~~	~~99.5~~	~~0.5~~
~~**Disposal to sewer**~~		~~**Oil (mg/l)**~~	~~**COD (mg/l)**~~
~~Sewer discharge~~	~~40000~~	~~200~~	
~~**Disposals to landfill**~~		~~**% Oil (dry solids)**~~	~~**Water content (% water)**~~
~~Landfill: screenings~~	~~6000~~	~~11~~	~~25~~
~~Landfill: process sludge~~	~~12000~~	~~5~~	~~50~~
~~Landfill: other waste~~	~~4000~~	~~2~~	~~40~~
~~Other liquid disposal~~	~~4000~~	~~2~~	~~98~~
~~Other solid disposal~~	~~3000~~	~~5~~	~~95~~

~~**[56, Babtie Group Ltd, 2002]**~~

WORKING DRAFT IN PROGRESS

Table 5.90: Emissions generated by the thermal cracking of waste oils

~~**Outputs**~~	~~**Mainly to produce fuel oil**~~ [1]	~~**Mainly to produce gasoil**~~ [2]	~~**Units (per tonne of input waste oil)**~~
~~Fuel oil (32 of 700 MJ and <0.5 % S)~~	~~849~~		~~kg~~
~~Secondary fuels~~ [3]	~~63~~		~~kg~~
~~Gasoil~~		~~706~~	~~kg~~
~~Naphtha~~		~~51~~	~~kg~~
~~Bitumen~~		~~38~~	~~kg~~
~~**Emissions**~~			
~~CO^2~~	~~2845~~		~~eq. kg~~
~~SO^2~~	~~9.8~~		~~eq. kg~~
~~VOC~~	~~0.08~~		~~kg eq. C^{2}H^4~~
~~Particulates~~	~~0.4~~		~~g~~
~~Phosphates in water~~	~~0.0012~~		~~kg eq.~~
~~Waste to eliminate~~	~~18~~		~~kg~~
~~Waste to recover~~	~~24~~		~~kg~~
~~Waste water~~		~~50~~	~~kg~~
~~Solvents~~		~~29~~	~~kg~~
~~Heavy residues~~		~~61~~	~~kg~~
~~Naphtha~~		~~36~~	~~kg~~
~~Off-gases~~		~~29~~	~~kg~~

[1] ~~Thermal cracking: thermal + chemical treatment (with H_2SO_4)~~

[2] ~~Thermal cracking adjusted to produce primarily gasoil. Finishing with purification and stabilisation stages~~

[3] ~~Many are waste fuels generated during the process~~

~~*Source*: [4, Monier, V. and Labouze, E. 2001] [100, WT TWG 2004]~~

~~*Emissions to air*~~

~~Some emissions commonly caused by the processing of waste oils to produce a product that can be used as fuel are shown in the following table (Table 5.91).~~

Table 5.91: Environmental issues related to the processing of waste oils to be used as fuel

~~**Environmental issue in the processing of waste oil**~~	~~**Comments**~~
~~Chlorinated hydrocarbons~~	~~They increase the level of chlorine in the waste oil~~
~~Dioxins~~	~~They have been cited by environmental health officials in a recent used oil regeneration and basestocks fire~~
~~Lead~~	~~In the reprocessing option, lead will end up in the heavy residues, which will result in it being 'locked up' in a bitumen product. Due to the changing of gasoline specifications, lead contamination is of diminishing importance~~
~~Metals~~	~~In the thermal cracking process, at least 98 % of the metals are removed as a non-leachable solid powder, collected in sealed containers, and used as an additive to asphalt~~
~~Non-volatile metals~~	~~The other metals likely to be present may be retained in the bitumen residue, as with lead~~
~~PAHs~~	~~PAHs used to be a problem in processing base oils from a health and environmental point of view. These are formed during an incomplete combustion of organic matter. PAHs are relatively difficult to break down. However, recent tests indicate that it is possible to remove PAHs in the regeneration process of modern plants, thus avoiding the accumulation of PAHs~~
~~Sulphur compounds~~	~~Odour and SO^x emissions, if used as fuel within the processing plant~~

~~*Source*: [3, Silver Springs Oil Recovery Inc. 2000] [7, Jacobs, A. and Dijkmans, R. 2001] [34, Babtie Group Ltd 2002]~~

~~*Emissions to water*~~

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~~Waste oil preparation may give rise to miscible or dissolved organic substances, for example, demulsifers and detergents, within the effluent.~~

Deleted: gasification is excluded from the scope; see KOM conclusion 1.3b

~~For co-gasification with coal, the metals contained within the used oil can be fixed in an inert, non-hazardous bottom ash. Sulphur compounds are converted to hydrogen sulphide and removed by conventional scrubbing and converted to elemental sulphur. There are no metals, fugitives or dioxin emissions from the gasification process.~~

Table 5.92: Outputs generated by the gasification of waste oils

~~**Outputs**~~	~~**Amount (per tonne of input waste oil)**~~	~~**Units**~~
~~Methanol~~	~~1080~~	~~kg~~
~~Saving of primary input of fuels typically used in gasification~~		
~~**Emissions**~~		
~~CO^2~~	~~1431~~	~~kg eq.~~
~~SO^2~~	~~0.21~~	~~kg eq.~~
~~VOC~~	~~0.05~~	~~kg eq. C^2H^4~~
~~Phosphates~~	~~0.0079~~	~~kg eq phosphates in water~~
~~Waste to eliminate~~	~~1~~	~~kg~~
~~Waste to recover~~	~~36~~	~~kg~~

~~**[4, Monier, V. and Labouze, E. 2001]**~~

~~*Emissions to air*~~

Table 5.93: Air emissions from the preparation of waste fuel from hazardous waste

~~**Emissions**~~	~~**From**~~	~~**Solid waste fuel**~~	~~**Liquid waste fuel**~~
~~Dust, absorbents mainly from sawdust, powdery wastes (paints, resins, washing powder, catalysts, etc.)~~	~~Unloading and handling of absorbents and/or pulverulent wastes~~	~~m~~	~~n/a~~
	~~Processing~~	~~l/m~~	~~l (mainly for fluidification)~~
	~~Loading~~	~~m~~	~~n/a~~
	~~Achieved performance (mg/Nm^3)~~ [1]	~~1 – 10~~	~~1 – 5~~
~~VOC and odour~~	~~Sampling~~	~~l/m~~	~~m/h~~
	~~Unloading operation (truck, drums, and containers)~~	~~m~~	~~m/h~~
	~~Processing~~	~~m (sieving)~~	~~l~~
	~~Achievable performance NMVOC (mg/Nm^3)~~ [2]	~~10 – 50~~	~~10 – 110~~

~~Notes:~~

[1] ~~by use of bag filters~~

[2] ~~by regenerative thermal oxidiser for solid waste fuel and by regenerative thermal oxidiser or by activated carbon treatment for liquid waste fuel~~

~~l: low emissions – m: medium emissions – h: high emissions – n/a: not applicable~~

~~*Source*: [78, Eucopro 2003]~~

~~*VOCs and odour*~~

~~Most accepted wastes contain organic compounds. In certain circumstances, according to vapour pressure and temperature, they are more or less volatile. These volatile organic compounds (VOCs) can be potentially harmful for the environment and workers health and can also cause a bad smell. This is why these emissions need particular attention and follow up. The level of VOC emissions depends on the nature of the waste, its flashpoint, the vapour pressure of the components, and their concentration. VOC emissions are also influenced by the type of process applied and by the prevailing climatic conditions.~~

WORKING DRAFT IN PROGRESS

~~*Noise*~~

~~All the process lines and equipment need to be designed and built according to EU noise regulations for operators inside the plant and for neighbours. Incoming and outgoing transport vehicles are the main source of noise around and inside the plants.~~

~~Other noise sources include handling machines such as mechanical shovels, loaders, hydraulic shovels, screeners, shredders, grinders, pumps, agitators, motors used for the ventilation network, and VOC treatment units.~~

~~*Emissions to water*~~

~~The sources of waste water are cleaning water from drum cleaning, truck cleaning, the cleaning of facilities, road tankers and skips, and process water (from wastes settling during transport, from drying, etc.). In the absence of measured water parameters of the waste water from these installations, Table 5.94 shows a compilation of ranges from some permits applied to installations. With the exceptions of major accidents, these installations have no impact on groundwater. A piezometer network with analysis once or twice a year is generally used for the survey.~~

Table 5.94: Ranges of values given in permits for some installations

~~**Physico-chemical parameters**~~	~~**Permit limit values (mg/l)**~~
~~pH~~	~~5.5 – 9.5~~
~~Maximum temperature~~	~~30 – 45~~
~~TSS~~	~~30 – 60~~
~~COD~~	~~50 – 300~~
~~Hydrocarbons~~	~~2 – 10~~
~~BOD^5~~	~~30 – 40~~
~~N-kjeldahl~~	~~n.a. – 40~~
~~N global~~	~~10 – 50~~
~~Total phosphates~~	~~1 – 10~~
~~CN (free)~~	~~0.1~~
~~Cd~~	~~0.05 – 0.2~~
~~Cr(VI)~~	~~0.01 – 0.1~~
~~Cr total~~	~~0.02 – 0.5~~
~~Cu~~	~~0.03 – 0.5~~
~~Fe~~	~~10 – 15~~
~~Hg~~	~~0.05 – 0.15~~
~~Ni~~	~~0.05 – 0.5~~
~~Pb~~	~~0.05 – 0.5~~
~~Sn~~	~~0.01 – 2~~
~~Zn~~	~~0.3 – 2~~
~~Total Metals*~~	~~10 – 15~~
~~* Sb + Co + V + Tl + Pb + Cu + Cr + Ni + Zn + Mn + Sn + Cd + Hg + Se + Te~~ ~~*Source:* [78, Eucopro 2003]~~	

WORKING DRAFT IN PROGRESS

~~By-products and wastes generated~~

Table 5.95: Wastes generated in the preparation of hazardous waste to be used as fuel

~~Effluents treatment wastes and other wastes for disposal~~	**~~Composed of~~**	**~~Amount (kg/tonne of waste fuel produced)~~**
~~Residues coming from the packaging of the delivered wastes~~		~~1.5 – 20~~
~~'Consigned' IBCs, containers or drums~~		
~~Metallic containers and drums~~		
~~Plastic containers and drums~~		
~~Palettes~~		
~~Big bags~~		
~~Plastic sheet~~		
~~Scrap extraction during the production stage~~	~~These residues are composed of metallic parts which can be voluminous~~	
~~Rotating, vibrating and static sieve/screen rejects~~	~~These residues are composed of blocks of different solid wastes (such as resins, paintings, glues, tars, bitumen, polluted soils, etc.), pieces of wood, sand, polluted plastics, lining, pieces of textile sheets~~	~~0 – 3~~
~~Effluent treatment residues~~	~~For example, activated carbon from waste water and air effluent treatment~~	
~~Laboratory residues and rejected samples~~		~~0.015~~

~~Note: the amount of by-products is strongly linked with the type of packaging. For example, in the case of small packaged wastes, the iron scrap fraction can reach up to 150 kg/tonne of waste fuel~~
~~*Source*: [78, Eucopro 2003] [98, WT TWG 2004]~~

~~The control of soil quality can be assured by the follow up/monitoring of air emissions, effluents, and groundwater quality.~~

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5.3.3.3 Energy and raw material consumption

Figure 5.23 shows the specific energy consumption of plants performing PCT of waste with calorific value.

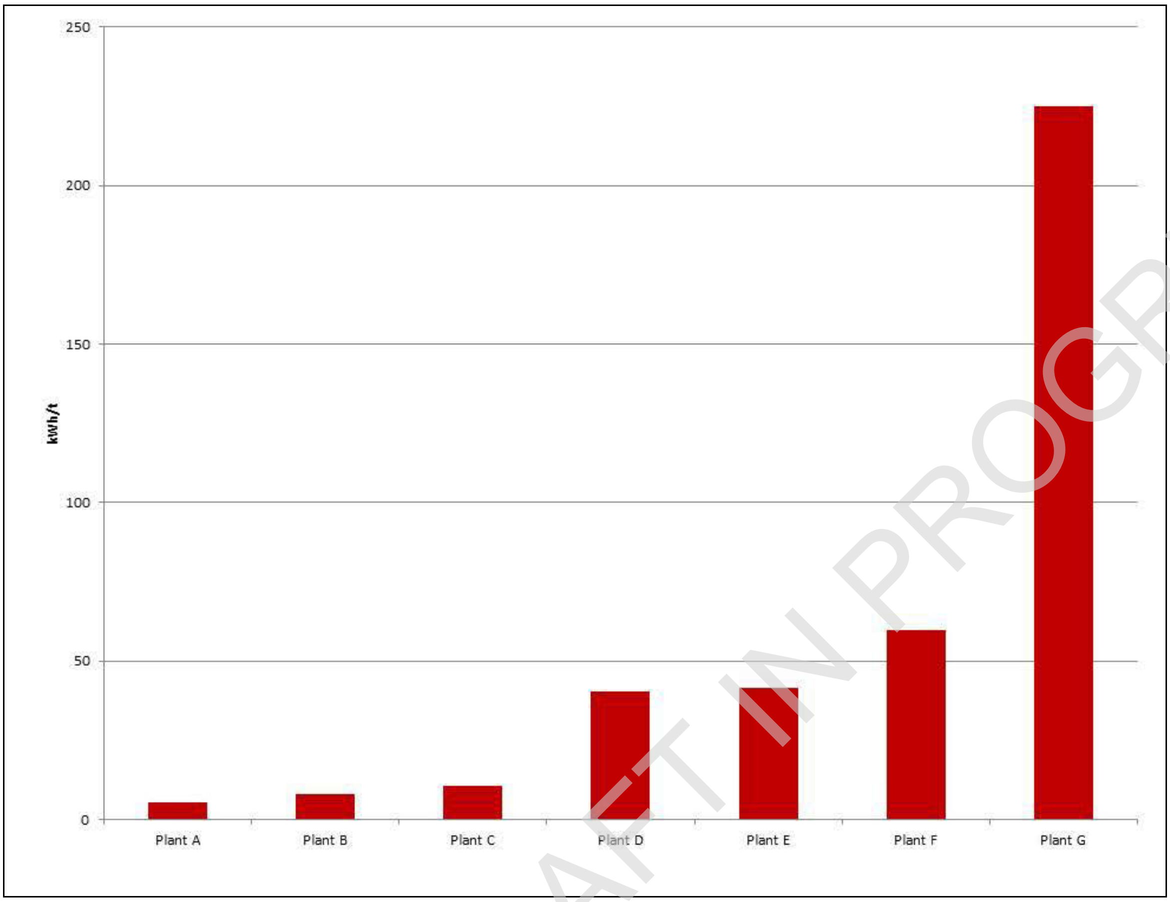

Figure 5.23: Specific energy consumption (kWh per tonne of waste treated) of plants performing PCT of waste with calorific value

Table 5.96 shows the consumption of raw material at plants performing PCT of waste with calorific value.

Table 5.96: Consumption of raw material at plants performing PCT of waste with calorific value

Auxiliary material	Amount used in waste treatment (t/year) Average over the three reference years
Sawdust	9597–10 095
Nitrogen (m^3/year)	483–274 644
Activated carbon	5–38.3
Flocculants	1
Adsorbents	1
Anti-foaming product	< 1

From ex-**Section 3.5.2 "Consumptions of preparation of waste fuel"**

~~**Consumptions in the preparation of waste oil to be used as fuel**~~

WORKING DRAFT IN PROGRESS

Table 5.97: Consumptions in the thermal treatment of waste oils

~~Material consumed~~	~~Application~~
~~Chemicals antioxidants~~	~~Added to light fuel oils and light distillates fractions in order to stabilise the products~~

~~**[119, Wateo, 2002]**~~

~~Consumptions in the preparation of hazardous waste to be used as fuel~~

Table 5.98: Consumptions in the preparation of hazardous waste to be used as fuel

~~Consumptions~~	~~Solid waste fuel~~	~~Liquid waste fuel~~
~~Electricity (kWh/tonne waste fuel produced)~~	~~5 – 25~~	~~5 – 20~~
~~Fuel (litre/tonne waste fuel produced)~~	~~0.15 – 3~~	~~0.05 – 2~~
~~Adsorbents~~	~~Between 20 and 40 % of absorbents per tonne of waste fuel produced are used, depending on required specifications.~~ ~~The types of absorbents are fresh sawdust, sawdust from wood recovery, polyurethane, paper by-product, textiles, etc.~~	
~~Water (litres/tonne of waste fuel - for cleaning installation, trucks and eventually drums; maintenance, spraying installations for dust abatement)~~[1]	~~5 – 20~~	~~5 – 20~~
~~Nitrogen m^3/tonne waste fuel produced (inertising mixers, shredders or liquid storage)~~	~~1 – 2.5~~	~~1 – 2.5~~
~~Others raw materials for effluent treatment~~		
~~Notes: Energy data do not include energy consumption for ventilation and air treatment.~~ ~~The electricity consumption varies widely according to the type of wastes, the packaging and on the level of automation. For example, in the case of packaged drums to be shredded, the electricity consumption can reach 25 kWh/t, while in the case of bulk wastes in a non automated process line it will be between 5 and 10 kWh/t. Moreover, when the electricity consumption is high, the fuel consumption is usually on the low side.~~ ~~The fuel consumption is mainly for utility vehicles and will decrease with the automation level.~~ ~~The total energy consumption represents less than 5 % of the total energy content of the waste fuel.~~ [1] ~~Water consumption is related with good housekeeping of the installation. It varies widely according to the type of wastes, the packaging and the eventual use of recovered rainwater. If drums or containers need to be cleaned or rinsed for further use, an additional consumption of 2 to 20 l/tonne is required.~~ ~~*Source:*[78, Eucopro 2003]~~		

~~The big difference in energy consumption in relation to the amount of input material relates to the kind of processing plant applied and the type of generated solid waste fuel used; for instance, whether drying facilities are installed or if the generated solid waste fuel is made in different grain sizes and shapes.~~

~~Except for thermal drying processes, fuel is not required for solid waste fuel production; fuel is only necessary to run vehicles at the process area, such as fork-lift trucks or wheel loaders. One producer for thermal drying reported a gas consumption is about 21250 GJ per year. This specific consumption amounts to 1390 MJ/t input material.~~

~~In general, no further ingredients besides waste are deployed and which end up in product. To ensure failure-free operation, the process and material handling equipment have to be lubricated. Several detergents are applied. Furthermore, there are auxiliary materials applied to support the~~

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~~exhaust gas cleaning process, such as sodium hydroxide (consumption: 18 kg/kt) and phosphate (consumption: 3 kg/kt).~~

~~Separation, digestion and biological degradation require energy. The consumption of electricity by separation and digestion is approximately 60 kWh/t input material, of which the separation accounts to about 8 to 15 kWh. Through the incineration of the biogas in a gas engine, with an efficiency of 35 %, approximately 120 kWh$_e$/t waste are produced. This results in a net production of approximately 60 kWh$_e$/t waste. Producing the digestate requires approximately 100 MJ$_e$/t input materials. Biological drying requires also approximately 100 MJ$_e$/t input materials.~~

Table 5.99: Consumptions generated by the thermal cracking of waste oils

~~**Waste OUT**~~	~~Mainly to produce fuel oil~~ [1]	~~**Units (per tonne of input waste oil)**~~
~~Fuel oil (700 MJ and <0.5 % S)~~	~~849~~	~~kg~~
~~Secondary fuels~~[2]	~~63~~	~~kg~~
~~**Consumptions**~~		
~~Fossil fuel consumption~~	~~4~~	~~eq. crude oil~~
~~Primary energy~~	~~343~~	~~MJ~~
~~Water consumption~~	~~431~~	~~kg~~

~~1 Thermal cracking: Thermal + chemical treatment (with H_2SO_4)~~
~~2 Many of them are waste fuels generated during the process~~
~~*Source:*[4, Monier, V. and Labouze, E. 2001] [100, WT TWG 2004]~~

5.3.4 Techniques to consider in the determination of BAT

Techniques to consider for the physico-chemical treatment of waste with calorific value depend on the processes used for the treatment (see Section 5.3.2).

5.3.4.1 Reduction of VOC emissions to air when preparing waste fuel from liquid and semi-liquid waste

Description
Recovery or destruction of captured VOC emissions.

Technical description
As mentioned in Section 2.3.5.3, measures are taken to ensure the prevention of diffuse VOC emissions and the capture of VOC emissions generated during loading/unloading, storage, blending/mixing and shredding of waste.

From ex-**Section 4.5.4.1 "Generic techniques for preparation of liquid waste fuel"**

~~Some~~ Techniques include:

~~a. using heat exchange units external to the vessel. There, water vapour is driven off and the oil feedstock may be heated to 90 °C, which serves to separate the majority of suspended (as opposed to dissolved) water. This occurs as a result of the reduction in the viscosity of the oil phase (brought about by the increased temperature), using gravity separation to achieve the desired result as the water sinks to the tank bottom~~
~~b. using carbon adsorption or condensation to avoid VOC emissions. When using condensation the collected organic fraction can be used as boiler feed~~
controlling VOC emissions when removing the high solids content from liquid waste ~~to be used as fuel. For this,~~ where warm oil from the heating vessels is typically passed over open filters to remove the solids. These are situated either in open yards or in buildings. VOCs are emitted when warm oil passes through the filters to remove the solids. The filters used are typically of the vibrating metal mesh type, more commonly used in relation to mineral

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aggregates. Extraction of the vapour from filtration ~~needs to be possible from~~ is made via hoods over open filters. Centrifuges can also be used for the purpose of separating any solids from oil with the advantage of minimal emissions.

~~c. removing oil from liquid effluent prior to discharge to foul sewers or other waters, usually by oil/water interceptors, tilting plate separators and/or filtration techniques and then using the oil as fuel~~

d. ~~ensuring that in a multi-chamber oil interceptor every single chamber oil interceptor is large enough to allow six minutes retention at maximum foreseeable flowrates~~

~~e. using a vertical agitator without any bearing inside the tank.~~

These captured VOC emissions are channelled to a VOC treatment system, including for example:

- adsorption (see Section 2.3.4.9);
- thermal oxidation (see Section 2.3.4.6);
- wet scrubbing (see Section 2.3.4.10).

~~**Achieved environmental benefits**~~

~~Cleans and reduces emissions from the treatment of liquid wastes. It is crucial to the sale of the liquid waste fuel that any high solids content, that the warm oil retains, is removed.~~

~~**Cross-media effects**~~

~~VOC emissions may be significant when the oil is drawn off from a process tank into open channels and also when warm oil is passed over the tilting plate separator.~~

~~**applicability**~~

~~applicable to oil reprocessing: The primary objective is to produce a fuel oil from the waste oil. Two technologies of blending are appropriate to homogenise the liquid fuel:~~

- ~~a long marine mixer installed on the roof of the tank~~
- ~~a pumping system which blends the top and the bottom of the tank by loop circulation.~~

~~Drying and heating operations need to take into account the emissions and the flammability hazards.~~

Achieved environmental benefit

Reduction of VOC emissions to air.

Environmental performance and operational data

Carbon adsorption may be affected by the presence of water vapour. ~~The action of removing the solids is aggressive and the filters need to be robust to deal with the solids and also the warm oil. Oil interceptors cannot separate water miscible substances.~~

~~Tilted plate separators (technique d noted in the Description section above) require much less retention time. Oil/water interceptors are sized based upon their design, the maximum foreseeable flowrates and the emission values required~~

Table 5.100 shows the VOC emissions of the plants from the reference list, together with the monitoring regime and the measurement standard used.

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Table 5.100: Measurement of VOC in air emissions at plants performing PCT of waste with calorific value

Plant	Average air flow (m^3/h)	Origin of emissions to air	Abatement technique	Type of VOCs measurement and associated concentration (in mg/Nm^3)	Standards used	Number of measurements in the three-year reference period
078	48 235	Whole plant	Regenerative thermal oxidation	NMVOC: 10.5	EN 13526	8
148C	37 767	Fuel preparation and sludge dehydration	Activated carbon adsorption	NMVOC: 3.75	NF EN 12619* and NF EN 13526	3
				TVOC: 5	NF EN 13526	Continuous
172C_1	45 488	Channelled release linked with hazardous solid fuel production and liquid fuel production (mainly composed of solvents)	Regenerative thermal oxidation, Activated carbon adsorption	NMVOC: 27	CH_4 measurement: X 43-554 - Subtraction CH_4 from the TVOC	5
				TVOC: 24	FID	Continuous
172C_2	22 459	Liquid fuel fabrication (emulsion technique)	Activated carbon adsorption	NMVOC: 113.3	CH_4 measurement: X 43-554 - Subtraction CH_4 from the TVOC	5
				TVOC:117.1	NF EN 13526 NF EN 12619*	5
				TVOC: 26	FID	Continuous
174C	11 472	All waste liquid fuels processes including mixing steps and loading.	Activated carbon adsorption	TVOC: 21.4	NF EN 12 619*	3
332	Not monitored	Blending and mixing	Wet scrubbing, Activated carbon adsorption	TVOC: 4	Since 2014 BS EN 12619:2013* has been used for monitoring of TVOC	12
425_426	10 409–11 651	Shredding, mixing, granulating	Bag/fabric filter system, Activated carbon adsorption, Thermal oxidation, Basic scrubber system	TOC: 11.5	NI	Continuous
450	61	Storage, shredding and blending	Cryogenic condensation	TOC: 36.7	AE/IT21/PC/10	3

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					(ITAEMASA). By determining the ionisation current resulting from the combustion of its organic compounds in a hydrogen flame	
469	17 308	All	Thermal oxidation, Neutralisation	TOC: 7.3	UNE-EN ISO IEC 17025:2005	Continuous
553	Not monitored	All vent stacks	Synthetic oil absorption scrubber, Activated carbon adsorption	TVOC: 3.3	PID meter	156 (weekly measurement)
*Supersedes EN13526.						

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Cross-media effects
See CWW BREF [138, COM 2014].

Technical considerations related to applicability
See CWW BREF [138, COM 2014].

Economics
See CWW BREF [138, COM 2014].

Driving force for implementation
- Legislation on air pollution.
- Recovery of VOCs.

Example plants
See Table 5.100.

Reference
[33, UK EA 2001] [78, Eucopro 2003] [100, WT TWG 2004] [138, COM 2014] [160, WT TWG 2014]

WORKING DRAFT IN PROGRESS

5.4 Regeneration of waste solvents

[31, LaGrega et al. 1994] [59, Indaver 2002] [85, Cruz-Gomez, M. J. 2002] [86, UBA Germany 2003] [98, WT TWG 2004] [100, WT TWG 2004] [103, VROM 2004] [104, UBA Germany 2004] [106 UBA Germany 2012] [146, PCT SG]

5.4.1 Applied process and techniques

From ex-**Section 2.4.2 "Regeneration of waste solvents"**

Once the waste solvent is passed to a waste manager, there are two main options for its treatment:

- Utilisation of the calorific value by using it directly as a fuel or blended with other fuels. The use of waste solvents as fuels is covered in Section 5.3.2.3.
- Treatment of the waste solvent to reconvert it to a material that can be reused as a solvent. This treatment is referred to in this document as 'regeneration'. This section details different treatments that are ~~actually~~ currently applied to clean waste solvents ~~for their clean-up~~ and to regenerate them to produce solvents.

The solvents and organic acids can be treated to a degree such that they can be returned to the production cycle as secondary raw materials.

Purpose

Waste solvent is regenerated for reuse.

Principle of operation

~~Clean-up is achieved by different types of distillations which are the main types of separation process used.~~ Solvent is separated from contaminants which made it a waste.

Feed and output streams

From ex-Section **3.4.1 Waste IN of waste treatment to obtain a recycled material**

~~**Waste solvents**~~

Waste solvents may be generated in the following industrial sectors:

- paints, coatings and paint removers;
- inks;
- chemical and pharmaceutical industries;
- film production;
- production of synthetic fibres;
- rubber, plastic and resin solutions;
- solvents for degreasing;
- solvents for dry cleaning;
- for agricultural products;
- aerosol cans and dispensers.

The wastes that are considered solvents correspond mainly to EWL codes 07, 08, 09 and 14. The final code corresponds to a category especially devoted to organic solvents. There are four main classes of solvent mixtures which make the solvent unusable in its present state and this promotes its recovery. These are the following:

- Mixture with air. This usually occurs when the solvent has been used to dissolve a resin or polymer which is laid down by evaporating the solvent. Recovery from air can pose problems because the solvent may react on a carbon bed adsorber or be ~~hard~~ difficult to recover from the steam used to desorb it.
- Mixture with water. Whether this arises in the solvent-based process or in some part of the recapture of the solvent, it is very common to find that the solvent may be

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contaminated with water. Removal of water is a simple matter in many cases but in others it is so difficult that restoration to a usable purity may prove to be uneconomic. It should always be borne in mind that the water removed in the course of solvent recovery is likely to have to be discharged as an effluent and its quality is therefore important.

- Mixture with a solute. A desired product is often removed by filtration from a reaction mixture. The function of the solvent in this case is to selectively dissolve the impurities (unreacted raw materials and the products of unwanted side reactions) in a low viscosity liquid phase, with a very low solvent power for the product. The choice of solvent is often limited in such cases, but significant improvements in the solvent's chemical stability can sometimes be found by moving up or down a homologous series without sacrificing the selectivity of the solvent system. A less sophisticated source of contamination by a solute occurs in plant cleaning, where the solvent power for any contaminant is of primary importance but where water miscibility, to allow cleaning and drying to take place in a single operation, is also an important property.
- Mixtures with other solvents. A multi-stage process such as that typically found in the fine chemical and pharmaceutical industries can involve the addition of reagent dissolved in solvents and solvents that are essential to the yields or even to the very existence of the desired reaction.

Solvent regeneration is common practice in many industries, with a wide range of solvents currently being regenerated: halogenated solvents, non-halogenated solvents, hydrocarbons, alcohols, glycols (anti-freeze), organic acids (acetic acid), cleaning agents, automotive brake fluid and refrigerants. ~~the more common of which are shown in~~

Table 5.102 shows the typical regenerated waste solvents.

Table 5.101: Commonly regenerated waste solvents

~~**Hydrocarbon family**~~	~~**Chemicals**~~
~~Alcohols~~	~~Ethyl, isopropyl~~
~~Aliphatics~~	~~Hexane, heptane~~
~~Aromatics~~	~~Benzene, aromatic naphtha, toluene, xylene, turpentine~~
~~Chlorinated~~	~~Trichloroethylene, perchloroethylene, methylene chloride~~
~~Esters~~	~~Ethyl acetate, butyl acetate~~
~~Ketones~~	~~Methyl ethyl ketone, methyl iso-buthyl ketone~~
~~Mixtures of solvents~~	~~Toluene/xylene, ketones, alcohols, phenols, toluene/heptane~~
~~*Source*: [31, LaGrega et al. 1994] [98, WT TWG 2004] [100, WT TWG 2004]~~	

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Table 5.102: Typical regenerated waste solvents

Class	Typical examples
Aldehydes	Furfural
Aliphatic hydrocarbons	Cyclo-Hexane, Hexane, Heptane White Spirit Hydrocarbons C_9-C_{12} (Flashpoint > 62 °C), Pentane, Kerosene, Iso-dodecane, Iso-hexane
Amides	Dimethylformamide
Amines	Aniline, Di-isopropyl amine, Triethylamine
Aromatic heterocyclic compounds	Pyridine
Aromatic hydrocarbons	Benzene, Toluene, Xylene
Chlorofluorocarbons (HCFCs)	R11, R12, R114, R134a, etc.
Esters/Inorganic salts	Methyl formate, Methyl acetate, Ethyl acetate, Butyl acetate, Propyl acetate, Iso-amyl acetate, Potassium acetate, Sodium acetate, Iso-propyl acetate, n-Butyl acetate, Mixed esters
Ethers	Tetrahydrofuran, Diethyl ether, Diisopropyl ether
Glycols	Monoethylene glycol (MEG), Monopropylene glycol (MPG), Diethylene glycol (DEG), Dipropylene glycol (DPG), Triethylene glycol (TEG)
Halogenated solvents	Chloroform, Dichloromethane (DCM), Monochlorobenzene, Perchloroethylene (PERC), Trichlorethylene (Tri), Chlorobenzene
Ketones	Acetone, Methyl ethyl ketone (MEK), Methyl iso-butyl-ketone (MIBK) Alcohols: Methanol, Ethanol, Butanol, Propanol, Iso-propanol, Iso-butanol, tertiary-Butanol
Nitriles	Acetonitrile
Organic acids	Acetic acid
Organosulphur compounds	Dimethyl Sulfoxide
Solvent mixtures	Miscellaneous and numerous varieties from trade wastes

Source: [146, PCT SG].

A waste solvent can be considered regenerative if it meets several criteria, for example relating to safety, the economic feasibility and activity of the producer, and the quality, quantity and technical capability of the recovery unit. Waste solvents are subject to an initial laboratory analysis and in some cases pilot/lab-scale distillation to determine their suitability for solvent regeneration, the key processing parameters and the expected product yield. An integral part of this assessment is the key process safety parameter of thermal stability, consideration of the make-up and treatment/recovery/disposal route of any residual waste or waste water arising.
This pre-assessment takes place before the waste stream is accepted on site and involves chemists and technical plant operators as well as commercial staff.

Output

From ex-Section **3.4.4 Waste OUT from re-recycling/regeneration treatments**

~~**Regenerated solvents**~~

Probably the most desirable product of solvent recovery is one that can be used instead of a purchased new solvent in the place where it was used initially. This does not necessarily mean that the recovered solvent meets the same specifications as the virgin material. The specifications of the new solvent will usually have been drawn up by a committee formed of representatives of both users and producers, who know what the potential impurities are in a product made by an established process route. ~~The specifications have to satisfy all potential uses but for any given user, some specifications may be immaterial.~~

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~~Table 5.103: Specification of products for treatment of chloro-organic compounds versus DIN-Standard~~

~~**Product property**~~	~~**Unit**~~	~~**DIN 53978**~~	~~**PERC**~~
~~Colour~~	~~HAZEN~~	~~<15~~	~~<5~~
~~Water~~	~~ppm~~	~~<50~~	~~<25~~
~~PERC~~	~~Area-%~~	~~≥99.9~~	~~>99.98~~
~~Sum of 1,1,1-trichloroethane and trichloroethylene~~	~~Area-%~~	~~0.025 ± 0.003~~	~~<0.02~~
~~Relative density~~	~~g/ml~~	~~1.620 - 1.625~~	~~1.624~~
~~Alkalinity~~	~~ppm NaOH~~	~~≤30~~	~~25~~
~~*Evaporation*~~			
~~Residue~~	~~ppm~~	~~≤50~~	~~25~~
~~Free chlorine~~		~~0~~	~~0~~
~~Information on a chlorinated hydrocarbon distillation installation~~ ~~*Source*:[97, Germany 2003]~~			

The solvent recycling industry encompasses waste volumes to recycle, from one litre for laboratory solvents to ship loads. Recycled product qualities vary from blended solvents for do-it-yourself stores to monostream solvents in pharmaceutical purity.

Solvents can be used and recycled again and again without a decline in quality. In a long-term view, virgin solvent top-up volumes to run a process are less than 25 %. Considering an overall recycling yield of 75 %, the spent solvent volume decreases over the successive recycling operations from 100 % to 25 %.

Process description

~~Figure 2.15 and Figure 2.16 give examples of flow diagrams of waste solvent regeneration plants~~.

The process includes distillation (batch, continuous or by use of steam, etc.) where high recovery rates are readily achieved. It is ultimately the incoming waste solvent and the desired recovered solvent output purity characteristics that dictate the technology to be deployed for reuse, but more simple techniques including filtration, centrifuging or stripping may suffice for certain reuses.

Distillation

Distillation is by far the most important industrial method of phase separation. Distillation involves the partial evaporation of a liquid phase followed by condensation of the vapour. This separates the starting mixture (the feed) into two fractions with different compositions; namely a condensed vapour (the condensate or distillate) that is enriched with more volatile components and a remaining liquid phase (the distilland) that is depleted of volatiles. Distillation processing can be divided into sub-categories according to:

- operating mode (continuous or batch);
- operating pressure (vacuum, atmospheric or pressurised);
- number of distillation stages (single or multi-stage);
- introduction of inert gases (for example steam, to aid separation);
- use of additional compounds to aid separation (azeotropic and extractive distillation).

Different types of distillation are described below:

- *Thin film evaporation*: a rotating wiper system distributes the crude product to a film on the inner surface of a heated cylinder. The wiping system speeds up the evaporation process by keeping the product film turbulent so that the heat transfer and mass transfer are optimised. The lower boiling fraction of the raw material evaporates within a short time out of the product film; the residence time of the

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product at the evaporator wall is very short. The concentrate is continuously discharged out of the bottom part of the evaporator.
- *Short path evaporation*: a subset of thin film distillation technology, at which lower working pressures and therefore lower boiling temperatures can be realised. Different to the traditional wiped film evaporator design, the condenser is located inside the short path evaporator body. There is no vapour line between evaporator and condenser.
- *Single stage flash distillation*: a distillation (batch) without separation is a flash distillation to remove solids and discolour the product.
- *Multi-stage distillation*: distillation (batch or continuous) which is able to separate the mixture into their individual components / pure solvents.
- *Pressure swing distillation*: a double distillation undertaken at different pressures that results in a different composition being obtained at each distillation stage. This is due to the fact that the composition of certain azeotropes is pressure-dependent which allows the elimination of a single component (e.g. water) from the resulting product and the purification of the main solvent.
- *Azeotropic distillation*: specific technique of adding another component or solvent to generate a new, lower-boiling azeotrope that is heterogeneous (e.g. producing two immiscible liquid phases) with the subsequent purification of the main component/solvent. This technique is required to separate materials of similar or even identical boiling points via distillation techniques.
- *Extractive distillation*: it uses a separation solvent, which is generally non-volatile, has a high boiling point and is miscible with the mixture, but does not form an azeotropic mixture. The solvent interacts differently with the components of the mixture thereby causing their relative volatilities to change. This enables the new three-part mixture to be separated by normal distillation.

More complex separations

Only a limited number of separation problems may be solved by simple distillation processes and this approach can be unsuitable for feeds containing components with similar boiling temperatures. Higher efficiency can be achieved by increasing the contact surface area or by contacting the liquid and vapour phases. Rectification columns provide intensive mass transfer by the repeated countercurrent contact of the vapour and liquid streams in multiple stages. Rectification columns are of the plate or packed design, and will vary in size depending on the nature of the waste streams and the desired purity of the product. The internal structure provides a large contact surface which is constantly regenerated. The mass transfer contact area is maximised by ensuring that the column packing is fully wetted.

Heat is required at the bottom of a distillation column for evaporating the feed, and condensation energy is needed at the top of the column.

Where simple distillation is insufficient to extract the desired solvent from the waste stream, solvent extraction techniques (usually using a solvent of the opposite polarity) are then the most important liquid-liquid separation processes used. Typical use of extraction techniques include:

- separation of components with similar boiling points (e.g. separating aromatics from other hydrocarbons);
- separation of high boiling point substances from aqueous solution;
- separation of mixtures with high boiling points;
- separation of temperature-sensitive compounds;
- separation of azeotropic mixtures.

In order to extract a substance, an extraction aid must be added to form a second liquid phase solution. Generally, the desired substance is then separated from the solvent aid by distillation and the spent solvent is recycled.

Pervaporation

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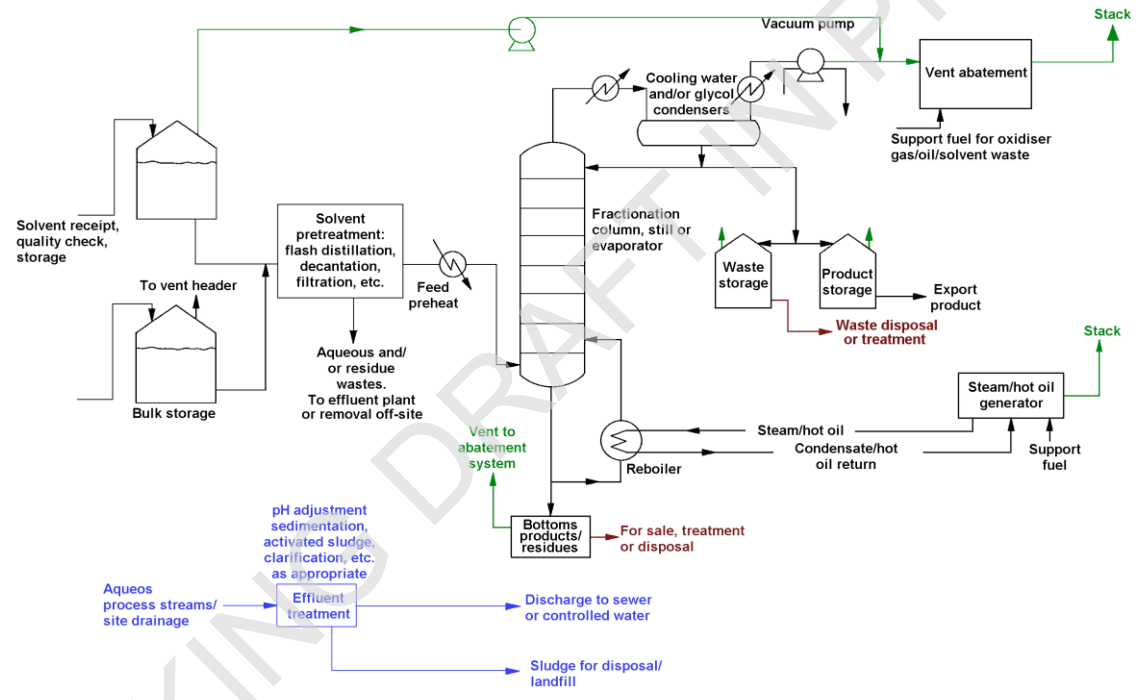
A further technique employed in the European solvent regeneration sector is pervaporation (or pervaporative separation). This is a processing method for the separation of mixtures of liquids by partial vaporisation through a non-porous or porous membrane whereby a membrane acts as a selective barrier between a liquid phase and a vapour phase. This technique entails a two-stage process, the liquid's permeation through the membrane and then its evaporation into the vapour phase. Typically, the upstream side of the membrane is at ambient pressure and the downstream side is under vacuum to allow the evaporation of the selective component after its permeation through the membrane.

Other separation methods

Where the waste stream requires solid separation, the main solid-liquid separation techniques are centrifuging, filtration, sedimentation/clarification and evaporation/drying. Certain techniques such as thin film evaporation are used for waste solvents containing higher levels of solid contamination.

Separation by adsorption can also be used to separate components, for example water adsorption on a molecular sieve.

A typical process flow through a specialist solvent regeneration plant can be seen in Figure 5.24.



Source:[85, Cruz-Gomez, M. J. 2002]

Figure 5.24: Example flow diagram of a waste solvent regeneration installation

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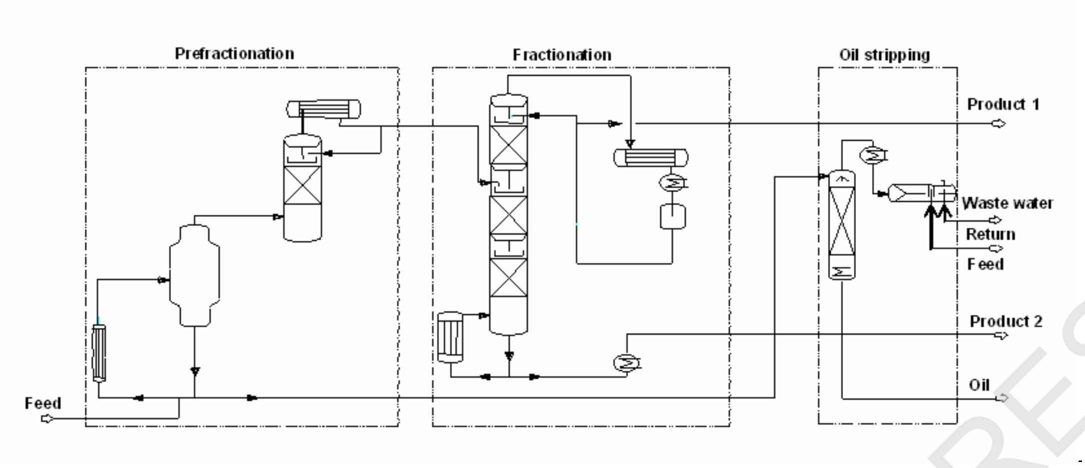

~~*Source:*[98, WT TWG 2004]~~

~~**Figure 5.25: Example Flow diagram of chlorinated solvent regeneration**~~

~~Table 5.104 shows the unit operations typically used for the regeneration of waste solvents.~~

~~**Table 5.104: Unit operations used for the regeneration of waste solvents**~~

~~**Technique**~~	~~**Purpose and principle of operation**~~	~~**Users**~~
~~Absorption~~	~~Transfer solvent from a gas to a liquid~~	
~~Adsorption~~	~~Recover solvent from solvent laden air~~	
~~Centrifugation~~	~~Removes suspended solid or separates two distinct (or insoluble) liquid phases, one phase is, for instance, the solvent being recovered~~	
~~Condensation~~	~~Eliminates solvent vapours from gas streams~~	
~~Decantation~~	~~Phase separation due to different densities. Separation of liquid solvent and water~~	
~~Distillation~~	~~Separation of liquid mixtures.~~ ~~Thin film evaporators.~~ ~~Rectification.~~ ~~Fractionation~~	~~The distillation of contaminated solvents for partial subsequent use as a fuel in boilers is one technique used (for reducing metal levels in the solvent), (some plants exist in Belgium, Italy, Spain)~~
~~Evaporation~~	~~Removal of solvent as a vapour form from a solution or slurry~~	
~~Filtration~~	~~Separation of solid particles from liquid solvent~~	
~~Liquid-liquid Extraction~~	~~Applied to liquid solvents~~	
~~Membrane separation~~	~~Recovery of solvents from liquid or gas streams~~	
~~Neutralisation~~	~~Applied to liquid solvents~~	
~~Salting out~~	~~Applied to liquid solvents~~	
~~Sedimentation~~	~~Applied to liquid solvents with a high level of solids~~	
~~Storage~~	~~See Section 2.1.2~~	
~~Stripping~~	~~Transfer of solvent from a liquid stream to a gas stream~~	

~~[85, Cruz-Gomez, M. J. 2002] [86, UBA Germany 2003] [98, WT TWG 2004]~~

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Users
~~This activity is carried out in the chemical, pharmaceutic and painting industries. Five plants are currently in the Netherlands.~~
It is estimated that 41 plants across Europe carry out regeneration of waste solvent. [146, PCT SG]

~~The evaporation capacity depends on the specific evaporation heat of the distilled solvents and amounts to up to 1.3 t/h. The use of a reflux separator can further improve the separation; however, the flowrate is then reduced. Multiphase distillates are cooled and then separated in heavier and lighter phases which are then collected in different containers. Distillation can be performed both under ambient pressure and under vacuum. Furthermore, the facility can carry out other processes such as azeotrope solvent drying or azeotropic esterification. Additionally, organic acids may be treated in a specific ceramics bubble.~~

~~The input material containing solvents is pumped into the distillation containers. These containers are heated indirectly by fresh vapour of maximum 6 bar at approximately 158 ºC. For heavily contaminated solvents, distillation bubbles of steel are available which are equipped with stirrers for homogenising the contents. Waste solvent mixtures containing only small quantities of residues, or highly corrosive substances such as organic acids, can be distilled using enamelled bubbles. The resulting plumes are transported through a packed column and condensed at the pipes of the overhead cooler~~

5.4.2 Current emission and consumption levels

From ex-Section **3.4.3.2 Emissions from the regeneration of waste solvents**

Emission levels
The most important concern in the solvent recovery sector is the volatile organic emissions, which result from waste solvent reclamation.

Ancillary emissions typically occur from the on-site generation of heat for the distillation process (combustion products) and are not covered in this document. Likewise, acidic gaseous and particulate emissions ~~can also result from solvent recovery operations. Acidic gaseous emissions mainly consist of gaseous chloride, hydrogen fluoride, and sulphur oxides. Since the unit operation presenting the major source of acidic gases and particulate~~ from the solvent ~~recovery industry is that of~~ incineration are not covered here and ~~this issue will be~~ are part of the Waste Incineration BREF. Incinerator stack emissions consist of solid contaminants that are oxidised and released as particulates, unburnt organics, and combustion stack gases.

Emission points include storage tank vents, condenser vents, incinerator stacks and fugitive losses. VOC emissions from equipment leaks, open solvent sources (e.g. sludge draw-off and the storage of ~~to~~ material from distillation and initial treatment operations), solvent loading, and solvent spills are ~~classified as~~ fugitive.

Solvents may be accidentally spilt during handling, distillation, or purification activities. Materials that are spilt onto the ground may spread over an area, vaporise, and then result in emissions to air, water, or land ~~emissions~~. Emissions resulting from significant accidental situations such as spills also need to be estimated.

~~Releases~~ Emissions to air may arise from a number of sources including non-condensable vapours from distillation/fractionation operations, and breathing losses from storage tanks and local exhaust ~~extraction vents~~ ventilations (LEV) located at material handling or drumming off points. Emission concentrations would be expected to be high except from sources such as LEVs. Concentrations and types of emitted compounds may vary significantly. The flow rates from continuous fractionation columns operating under vacuum at steady conditions are generally very low (1–10 m^3/hr). However, when ~~manifolded~~ added together, emission flows

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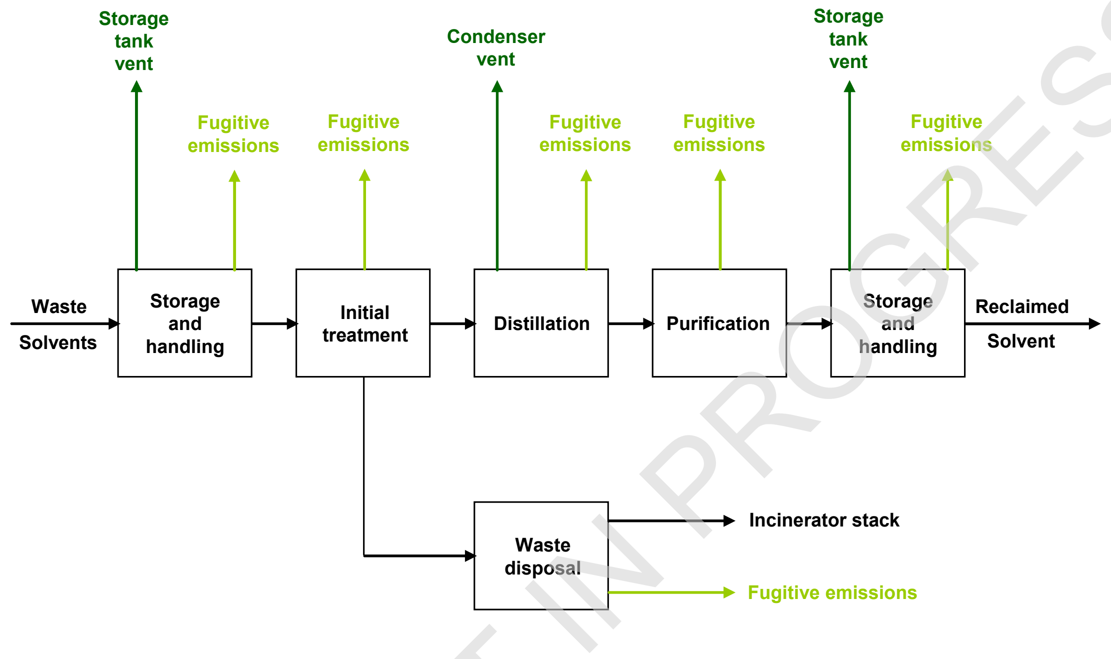
could be up to 500 m^3/hr. Where LEV systems are connected to ~~tied into~~ abatement equipment this can significantly increase flow rates and the dilution of vent gases. To minimise the size of abatement equipment, there is a benefit in keeping process and LEV vents separate.

Figure 5.26 shows an example of waste solvent regeneration plant.



Source: [85, Cruz-Gomez, M. J. 2002]

Figure 5.26: Example of a waste solvent regeneration scheme and emission points

Table 5.105 gives an overview of the processes used by plants from the reference list which carry out regeneration of waste solvents.

WORKING DRAFT IN PROGRESS

Table 5.105: Plants from the reference list performing regeneration of waste solvents

Plant code	Waste input description	Process	Waste output description	Capacity of waste treatment activity (t/day)
056	Used solvents from pharma, chemical and paint industries; virgin solvent to purify to higher quality	Atmospheric and other kinds of distillation	Solvent for reuse, residues from distillation, water from waste solvent/cleaning or rainwater from production plant	50
168C	Different types of organic solvents	Vacuum distillation and fractional distillation	Clear recovered solvent without any impurities, residues from the distillation column, contaminated packaging and unrecoverable spent solvents	160
169C	Waste from chemical and paints industry	Atmospheric distillation, density separation and vacuum distillation	Stabilised residues, regenerated hazardous solvents	80
170	The main origin is oil separation	Atmospheric distillation, azeotropic distillation, density separation, fractional distillation, simple distillation, adsorption, vacuum distillation, solvent extraction	Purified water, regenerated solvent, residues, dry matter, residues from waste water treatment, mixed plastics	270
214	Used solvents from different industries	Simple distillation, density separation, fractional distillation, vacuum distillation, azeotropic distillation, centrifugation	Regenerated solvents, solvent/water mixtures for incineration, distillation residue for incineration	240
394	Solvents	Fractional distillation, atmospheric distillation, vacuum distillation	Solvents (product, no waste code), residue after distillation, packaging	100
420	Organic solvents	Vacuum distillation	Solvents (product, no waste code), residue after distillation, packaging (drums 200 l)	10

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447C	Chemical wastes other than acids or bases	Vacuum distillation	Organic solvents principally	90
476	Organic waste from chemical processes; solvent mixture; waste formulation, manufacture, distribution and use of paint and varnish; waste formulation, manufacture, distribution and use of adhesives, sealants and resins; liquid solutions from chemical reactions; Ion exchange resins; waste formulation, manufacture, distribution and use of printing inks; mixed organic and inorganic chemical product; absorbents, filter materials, wiping cloths and protective clothing dirty; liquid cleaning solutions; dirty packaging; sludge and other waste from processes of filtration, distillation and purification	Simple distillation, vacuum distillation	Distillation waste, other.	20
554	Organic solvents	Fractional distillation	Pure solvents are either returned to originator or sold to third-party customers, waste process water containing dissolved organic materials, other output used as support fuel or incinerated	120

Table 5.106 shows the emissions to air from these plants. It should be noted that in some cases the air flow is very low or not even monitored.

WORKING DRAFT IN PROGRESS

Table 5.106: Emissions to air from plants performing regeneration of waste solvents

Plant code	Origin of emissions to air	Techniques for emissions to air	Range of air flow (Nm^3/h)
056_1	Recycling waste solvents: steam boiler	Activated carbon adsorption Condensation	1404
056_2	Recycling waste solvents: hot oil boiler	Activated carbon adsorption Condensation	643
056_3	Recycling waste solvents: release from storage tanks/vacuum system/distillation units	Activated carbon adsorption Condensation Cryogenic condensation	NI
168C	Applied to the whole plant, for the channelled circuit	Condensation Wet scrubbing	20
169C	Distillation	Condensation Wet scrubbing	829
170	Regeneration of spent solvents	Condensation Washing column Activated carbon adsorption	Not monitored
214	Regeneration of spent solvents	Air emissions are collected by vacuum, cleaned in a washer and then incinerated in the steam generator	NI
394	Air from distillation unit and unloading tanks	Activated carbon adsorption Thermal afterburning Wet scrubbing	Not monitored
420	Regeneration of spent solvents	Good Housekeeping, management system	797
447C	Waste treatment process	NI	35
476	Regeneration of spent solvents fuel: steam boiler	Activated carbon adsorption	Not monitored
554	NI	Acid scrubber system Activated carbon adsorption	Not monitored
NI: No information.			

WORKING DRAFT IN PROGRESS

The parameters measured in air emissions are given in Table 5.107 and Table 5.108. The latter table concerning VOC emissions to air has to be read carefully as the values of VOC concentrations in air emissions have to be associated to the flow rates of these emissions which in some cases are very low. In some cases (56, 170), only diffuse emissions are monitored or, in other words, the emissions from the distillation unit are considered fugitive emissions.

When measured, VOC emissions to air are mostly given in terms of non-methane VOCs (NMVOC) and expressed as a concentration or as a flux (Plants 168, 420).

Table 5.107: Parameters measured in emissions to air from plants performing regeneration of waste solvents

Parameter measured	Type of measurement	Plants concerned	Ranges (mg/Nm^3 except for flow and temperature)
Air flow	Continuous	168C	1–25 Nm^3/h
	Periodic	056_1, 056_2, 169C, 420, 447C	35–1404 Nm^3/h
Air temperature	Continuous	168C, 447C	25–70
	Periodic	169C, 420, 476	6.9–175.6
O_2	Periodic	056_1, 056_2, 169C, 420, 476	0–21
SOx	Periodic	056_1, 056_2, 420, 447C, 476	0–1549
CO	Periodic	056_1, 056_2, 420, 447C, 476	0–55
NMVOC	Continuous	168C	See Table 5.108
	Periodic	169C, 170, 420, 447C	
	Estimated	420	
TVOC	Periodic	169C, 554	
TOC	Continuous	394	
NMVOC with risk phrase	Continuous	168C	
Dust	Periodic	056_1, 056_2, 056_3, 168C	1-5
NO_X	Periodic	056_1, 056_2, 420, 476	0–805
NH_3	Periodic	554	0.3
CO_2	Periodic	56_1, 56_2	5.3–7.9 vol-%
R40, R45, R61	Periodic	170	NI

NI: No information.

WORKING DRAFT IN PROGRESS

Table 5.108: VOC emissions from plants performing regeneration of waste solvents

Plant	Abatement technique	Parameter measured	Average value	Type of measurement	Average air flow (Nm^3/h)	Number of measurements during the three reference years	Monitoring standard used
56_3	Activated carbon adsorption Condensation Cryogenic condensation	No direct monitoring	NA	NA	NA	Once a year	NA
168	Condensation Wet scrubbing	NMVOC, NMVOC Xn, R10, Xi	30 000 ppm (or 133 g/Nm^3) 3080 kg/year 0.5 kg/h as yearly average	Continuous, expressed in volume ppm	20	Continuous	NF EN 13526(1)
		NMVOC carcinogenic, mutagenic, reprotoxic	0	Periodic		2 tests of these substances per year These tests are carried out by an external company which is authorised/licensed by the authorities	
169	Condensation Wet scrubbing	TVOC	4437 mg C/Nm^3	Periodic	829	NI	NF EN 12619 and NF EN 13526(1)
		NMVOC	3695 mg C/Nm^3				XP X 43 554
170	Condensation Washing column Activated carbon adsorption	NMVOC	< 110 mg/m^3	Periodic	Not monitored	12 times in 2011	NI
214	Air emissions are collected by vacuum, cleaned in a washer and then incinerated in the steam generator	NI	NI	NI	NI	Every 3 years, measurement of boiler emissions	NI

WORKING DRAFT IN PROGRESS

394	Activated carbon adsorption Thermal afterburning Wet scrubbing	TOC	< 20 mg/Nm^3	Continuous	Not monitored	Continuous	FID measurement
420	Good housekeeping Management system	NMVOC and equivalent C	0.006 kg/h for NMVOC 5 mg C/m^3	Measured	797	1 time/year	NEN-EN 13526(1)
447	NI	NMVOC	24 973 mg/Nm^3	Periodic	35	18 times (6 times/year)	UNE EN 13526(1)
554	Acid scrubber system Activated carbon adsorption	TVOC	2.9 mg/Nm^3 (VOC class A) and 14 mg/Nm^3 (VOC class B)	Periodic	Not monitored	Annual check by external contractor. Measurement #1 = Class A VOCs. Measurement #2 = Class B VOCs	Measures done with a hand-held PID VOC detector on a daily basis and controlled once a year

(1) Superseded by EN 12619:2013.
NA: Not applicable.
NI: No information.

WORKING DRAFT IN PROGRESS

As for emissions to water, Table 5.109 and Table 5.110 give an overview of the origin of emissions to water, the abatement techniques and the pollutants measured in water emissions.

One plant mentions not having any water discharge. Of the other nine plants, five have direct discharge of waste water which comes essentially from the cooling circuit of the installations or from the blowdown of the steam circuit.

Table 5.109: Emissions to water from plants performing regeneration of waste solvents

Plant code	Origin of emissions to water	Techniques for emissions to water	Point of release	Receiving body	Range of water flow (m^3/h unless mentioned otherwise)
56	Water from steam circuit and water from cooling circuit. All other waste waters from cleaning tanks and installation, water fractions from distillation and rainwater from production zones are stored separately, analysed and treated in external industrial waste water plants	None	Discharge from the WT plant to the environment without treatment for unpolluted water. Contaminated waste water is treated in external WWTP	Transitional waters (i.e. surface water in the vicinity of river mouths)	0.2
168	Regeneration of spent solvents: draining of the cooling towers	None	Discharge from the WT plant to the environment without treatment (all waste decant waters are destroyed by incineration in a furnace at 800 °C)	River/Stream	4200 m^3/year
169	No release of process water	NA	NA	NA	NA
170	All plant	Active sludge systems – conventional, Coagulation, Decantation, Flocculation, Powdered activated carbon treatment, Aeration, Air stripping	Discharge from the on-site common WWT facilities to the environment (when the design/operation of the WWT facility is mainly influenced by waste water streams coming from WT plant)	Transitional waters (i.e. surface water in the vicinity of river mouths)	50
214	NI	NI	NI	NI	NI
394	Release of untreated cooling water and flush water steam boiler. Discharge waste water not related to this process	None	NI	NI	NI

WORKING DRAFT IN PROGRESS

420	Release of untreated groundwater	Good housekeeping, Management system	Discharge from the WT plant to the environment without treatment	Transitional waters (i.e. surface water in the vicinity of river mouths)	10
447	Waste treatment process	No pretreatment. Water samples are sent to an authorised laboratory for analysis.	Discharge from the WT plant and its auxiliary systems, as well as from on-site waste water pretreatment facilities, to an urban/municipal sewer system	Groundwater	2.7
476	NI	NI	Discharge from the WT plant and its auxiliary systems, as well as from on-site waste water pretreatment facilities, to an urban/municipal sewer system	River/Stream	Not monitored
554	Discharge to river of low-grade aqueous waste (from blowdown of boiler and bleed from cooling towers)	None	Discharge from the WT plant to the environment without treatment	River/Stream	0.5
NA: Not applicable. NI: No information.					

WORKING DRAFT IN PROGRESS

Table 5.110: Parameters measured in emissions to water from plants performing regeneration of waste solvents

Pollutant measured	Type of measurement	Plants concerned	Ranges (mg/l except for pH)	Number of measurements during the three reference years
TSS	Composite sample	56, 554	5–37.9	3
	Grab sample	168, 447, 476	3–14	4 to 9
COD	24-hour flow-proportional composite sample	170	100	NA
	Composite sample	56	152	1
	Grab sample	168, 447, 476	38.8–73	3 to 10
BOD_5	24-hour flow-proportional composite sample	170	35	NA
	Composite sample	56, 554	19–36	1 to 3
pH	Composite sample	554	7.9	3
	Grab sample	168, 447	7.4–7.5	3 to 10
TOC	Composite sample	554	0.1	3
	Grab sample	168, 447	3–19	3 to 4
Total P	24-hour flow-proportional composite sample	170	1	NA
	Grab sample	447, 476	0.6–1.1	4 to 10
AOX	24-hour flow-proportional composite sample	170	0.4	NA
	Grab sample	168, 447	0.3–1.3	3 to 8
TKN	24-hour flow-proportional composite sample	170	6	NA
	Grab sample	447	1.6	10
NH_3-N	Composite sample	554	1.7	3
	Grab sample	476	4.4	4
Cd	24-hour flow-proportional composite sample	170	0	NA
	Composite sample	56	< 0.001	1
Hg	24-hour flow-proportional composite sample	170	0	NA

WORKING DRAFT IN PROGRESS

	Composite sample	56	< 0.0002	1
As	24-hour flow-proportional composite sample	170	0	NA
	Composite sample	56	< 0.01	1
Pb	24-hour flow-proportional composite sample	170	0	NA
	Composite sample	56	< 001	1
Cr	24-hour flow-proportional composite sample	170	0	NA
	Composite sample	56	< 0.01	1
Cu	24-hour flow-proportional composite sample	170	0.1	NA
	Composite sample	56	< 0.02	1
Ni	24-hour flow-proportional composite sample	170	0	NA
	Composite sample	56	< 0.01	1
Zn	24-hour flow-proportional composite sample	170	0.04	NA
	Composite sample	56	0.05	1
BTEX	Grab sample	447	545.5	9
PCDD/F (Tetrahydrofuran)	Grab sample	447	23	4
TDS	Grab sample	168	2.9	3
BOD_7	Grab sample	168	NI	NI
THC	Grab sample	168	0.1	3
Cl^-	Grab sample	447	118.7	10
S^{2-}	Grab sample	447	0.2	4
Total N	Composite sample	56	1.8	1
Soluble salts (µS/cm)	Grab sample	476	1527	4
NI: No information.				

The analysis of emissions to water from Plant 170 (discharging directly to the environment) is dealt with in Section 5.7.2.3.2.

WORKING DRAFT IN PROGRESS

~~Table 5.111: Principal emission sources and emissions matrices of oil and solvent recycling plants~~

~~Activity/Plant~~	~~Emissions~~			~~Accidental Emissions~~
	~~To air~~	~~To water~~	~~To landfill~~	
~~Filter bin unloading~~				~~Drainage, spillage and bursts discharging contents to ground~~
~~Filter bin storage~~				~~Spillage to ground~~
~~Filter crushing~~				~~Spillage to ground~~
~~Filter shredding~~	~~Oil mist~~			~~Spillage to ground~~
~~Magnetic separation~~	~~Oil mist~~			~~Spillage to ground~~
~~205 litre drum unloading~~				~~Spillage to ground~~
~~205 litre drum storage~~				~~Spillage to ground~~
~~205 litre drum emptying~~				~~Spillage to ground~~
~~25 litre drum unloading~~				~~Spillage to ground~~
~~25 litre drum storage~~				~~Spillage to ground~~
~~25 litre drum emptying/shredding~~	~~Oil mist~~			~~Spillage to ground~~
~~Tanker unloading~~	~~Tank venting~~			~~Spillage to ground~~
~~Coarse straining~~	~~Oil mist~~			~~Spillage to ground~~
~~Bulk storage~~	~~Tank venting~~	~~Settled water (via treatment)~~	~~Settled sludge~~	~~Spillage to ground~~
~~Cold oil settling~~	~~Tank venting~~	~~Settled water (via treatment)~~	~~Settled sludge~~	~~Spillage to ground~~
~~Hot oil settling~~	~~Tank venting~~	~~Settled water (via treatment)~~	~~Settled sludge~~	~~Spillage to ground~~
~~Distillation~~	~~Venting and fugitive~~			~~Spillage to ground~~
~~Vibrating sieve~~	~~Mist and vapour~~		~~Sludge~~	~~Spillage to ground~~
~~Centrifuge~~				
~~Enclosed filters~~			~~Used elements and sludge~~	~~Spillage to ground~~
~~Bauxite towers~~			~~Spent bauxite~~	~~Spillage to ground~~
~~Vacuum dehydration~~	~~Vapour (via scrubbers)~~		~~Spillage to ground~~	
~~Product blending~~	~~Tank venting~~			~~Spillage to ground~~
~~Pumped sludge storage/decanting~~	~~Tank venting~~			~~Spillage to ground~~
~~Incineration~~	~~Stack emissions (NO^x, CO, VOC, HCl, SO^2, etc.)~~			
~~Cold effluent settling~~	~~Tank venting~~			~~Spillage to ground~~
~~Hot effluent settling~~	~~Tank venting~~			~~Spillage to ground~~
~~Biological effluent treatment~~	~~Aeration air~~			
~~Effluent clarification~~				
~~Filter press~~			~~Filter cake~~	
~~Effluent balance tank~~				~~Spillage to ground~~
~~Plate separator~~		~~Effluent~~		
~~Mechanically handled sludge/solids storage and loading~~			~~Mixed solid wastes~~	~~Spillage to ground~~
~~Waste oil fired boiler~~	~~Stack emissions~~			

~~In solvent recovery operations, bottom streams consist of organics such as oily wastes and sludges or an aqueous residue. If water is treated on-site, sludges or other wastes may be created. Other emissions may come from discarded containers or samples, vessel washing~~

WORKING DRAFT IN PROGRESS

~~residues, or from volatilisation to the air. Some residues and sludges are removed hot from stills into drums and allowed to cool and solidify. They may then be removed for further treatment or disposal. In industrial systems there can be traces of impurities, which can arise from inhibitors, denaturants or plant rinsing; these impurities can cause problems, particularly when using azeotropic distillation techniques.~~

The primary wastes from solvent regeneration activities are the distillation residues. The amount of these residues is entirely dependent on the composition of the waste stream and can vary from zero to significant percentages.

Depending on the nature of the waste streams and the chosen process, there are two main approaches. The first is to keep the residues mobile as sludge/liquids that are capable of being pumped and to ensure full containment of the residues within the process. This may be followed by pumping or transporting the residues to ancillary waste treatment processes such as Secondary Liquid Fuel manufacture for subsequent thermal recovery. The alternative approach is to maximise the solvent recovered through the process and to load the residues that are then dry or nearly dry into containers for subsequent disposal. (For some solvent regeneration processes the distillation residue itself is subject to a further separation to maximise the extraction of valuable components.)

Both approaches have environmental advantages and disadvantages and the choice of a suitable option is largely determined by the nature of each waste stream. Key process safety parameters have to be closely controlled for these two processes; in the first case primarily relating to chemical compatibility, and in the second case the stability of residues as they become increasingly concentrated and dry. Ancillary waste streams consist of emptied containers, Personal Protective Equipment (PPE) and other solid wastes arising from the process.

~~Table 5.112: Air and water emission from an EU solvent regeneration installation~~

~~**Parameter**~~	~~**Concentration value**~~	~~**Concentration units**~~	~~**Load value**~~	~~**Load units**~~
~~*Air emissions*~~				
~~Fumes generated~~			~~14400000~~	~~Nm^3/yr~~
~~Oxygen~~	~~6~~	~~%~~		
~~CO^2~~			~~1268018~~	~~kg/yr~~
~~CO~~	~~49~~	~~mg/Nm^3~~	~~700~~	~~kg/yr~~
~~SO^2~~	~~86.9~~	~~mg/Nm^3~~	~~850~~	~~kg/yr~~
~~NO^x~~	~~44.1~~	~~mg/Nm^3~~	~~635~~	~~kg/yr~~
~~TOC~~	~~540~~	~~mg/Nm^3~~	~~237~~	~~kg/yr~~
~~*Water emissions*~~				
~~Waste water~~			~~2969~~	~~m^3/yr~~
~~Suspended solids~~	~~16~~	~~mg/l~~	~~47.5~~	~~kg/yr~~
~~COD~~	~~534~~	~~mg/l~~	~~1585~~	~~kg/yr~~
~~Phenols~~	~~0.08~~	~~mg/l~~		~~kg/yr~~
~~AOX~~	~~0.25~~	~~mg/l~~	~~0.742~~	~~kg/yr~~
~~Total N (as N)~~	~~16~~	~~mg/l~~	~~47.5~~	~~kg/yr~~
~~Total P~~	~~0.43~~	~~mg/l~~	~~1.27~~	~~kg/yr~~
~~Sulphide (free)~~	~~0.08~~	~~mg/l~~		~~kg/yr~~
~~Note: Capacity of the installation 27.5 kt/yr~~				

~~[44, TWG 2003]~~

During storage and handling, and in the distillation process, hydrocarbons are emitted to air. The emission of hydrocarbons (C_xH_y) through the distillation process is estimated to be 0.5 kg/t of waste solvent.

WORKING DRAFT IN PROGRESS

Some contaminated solvents contain water. After dewatering, the water fraction contains traces of solvent. This water fraction ranges from a negligible amount to a maximum of 5 % to 10 %. It is purified in a waste water treatment plant and discharged.

The amount of distillation bottom depends on the composition of the waste solvent. On average, the amount is estimated to be 25 % of the processed amount.

From ex-**Section 4.4.2.3.** Deleted and replaced by data collection.

~~Description~~

~~See Section . Some techniques that have been used in waste solvent facilites are waste water stripping plants, bio reactors, waste water staple tanks, waste water intermediate storage tanks and ultrafiltration facilities.~~

~~Achieved environmental benefits~~

~~The characteristics of the effluent after treatment is shown in the~~

~~Table 5.113: Characteristics of the effluent of a WWTP in a waste solvent regeneration facility~~

~~Compounds~~	**~~Average value~~**	**~~Units~~**
~~Colour~~	-	
~~Odour~~	-	
~~pH~~	~~8.7~~	
~~Electric conductivity~~	~~989~~	~~µS/cm~~
~~P total~~	~~0.46~~	~~mg/l~~
~~N total~~	~~32.9~~	~~mg/l~~
~~COD~~	~~18~~	~~mg/l~~
~~BOD~~[7]	~~<3~~	~~mg/l~~
~~Sb~~	~~<0.01~~	~~mg/l~~
~~Pb~~	~~<0.010~~	~~mg/l~~
~~Cd~~	~~<0.002~~	~~mg/l~~
~~Cr total~~	~~<0.002~~	~~mg/l~~
~~Co~~	~~0.006~~	~~mg/l~~
~~Ni~~	~~<0.002~~	~~mg/l~~
~~Zn~~	~~0.02~~	~~mg/l~~
~~Lightly volatile halogenated hydrocarbons~~	4	~~µg/l~~
~~AOX~~	~~320~~	~~µg/l~~
~~Note: Data from 2002~~		

~~[86, UBA Germany 2003]~~

~~Cross-media effects~~

~~See Section~~

~~Operational data~~

~~See Section .~~

~~Applicability~~

~~See Section~~

~~Economics~~

~~See Section .~~

~~Driving force for implementation~~

~~See Section .~~

~~Example plants~~

~~Waste solvent treatment plants typically have waste water treatment facilities.~~

~~Reference literature~~

~~[86, UBA Germany 2003]~~

WORKING DRAFT IN PROGRESS

[34, Babtie Group Ltd 2002] [98, WT TWG 2004] [146, PCT SG]

From ex-Section **3.4.2 Consumptions of waste treatments to obtain a recycled material**

~~Consumptions of the regeneration of waste solvents~~

~~shows consumption data for two facilities operating in the EU. Other data reported energy consumptions lower than 1 GJ/tonne.~~

~~Table 5.114: Consumptions of two regeneration treatment of waste solvents~~

~~**Consumption parameter**~~	~~**Units**~~		
~~Capacity~~	~~kt~~	~~12~~	~~27.5~~
~~Gas fuel~~	~~GJ/yr~~	~~19651~~	
~~Fuel consumption~~	~~GJ/yr~~		~~31628~~
~~Electricity~~	~~MWh/yr~~	~~1571~~	~~2984~~
~~Water~~	~~m^3/yr~~	~~19000~~	~~40776~~

~~[44, TWG 2003] [86, UBA Germany 2003]~~

Energy consumption

The reported average energy consumption per tonne of waste treated is around 800 kWh/t, with a range of 60–2560 kWh/t. The main energy demand in distillation processes is for heat, which is provided mostly by fossil fuel and/or imported heat.

Water usage

The reported average water usage per tonne of waste treated is around 1 200 l/t, with a range of 220–3 700 l/t. Water is used as cooling water and in boilers.

Raw material consumption

Table 5.115 shows the range of raw material consumption by plants from the reference list performing regeneration of waste solvents.

Table 5.115: Examples of raw material consumption by plants performing regeneration of waste solvents

Raw material	**Range of consumption in the reference period (t/year)**
Alkali	1–660
Conditioners	100
Acids	64–450
Detergents	10
Biocides	1.6–15
Activated carbon	10–150
Adsorbents	2
Ion exchangers	10
$FeCl_3$	200–270
Liquid nitrogen (m^3/year)	111 000–154 600

5.4.3 Techniques to consider in the determination of BAT

Ex-**section 4.4.2.1 "Selection of waste solvents to be recycled"** deleted because covered by techniques "pre-acceptance" and "acceptance" of waste (Section 2.3.2)

From ex-**Section 4.4.2.2 "Improvement of regeneration treatment of waste solvents"**

Points a, b, c, g, h and i deleted: they relate to the process, not to prevention and limitation of emissions

WORKING DRAFT IN PROGRESS

~~a. applying azeotropic distillation~~
~~b. applying vacuum distillation~~
~~c. using thin-film evaporators~~

Point d deleted: covered by Section 2.3.1.1

~~d. heating the feed stream with the distillate by means of a heat-exchanger and insulation measures~~
~~g. using distillation for the separation of organic solvents from solids~~
~~h. using rectification for the removal of contaminating substances and achieving a certain quality of the wastes OUT~~
~~i.dewatering by means of a decanter if the solvents contain water.~~

Point e deleted: apply to the user of solvent, not to the regeneration plant

~~applying a cascade re-use of solvent (i.e. where the solvent is used once for high quality cleaning and then used again for other cleaning or for operations that do not require a pure solvent)~~

Covered by sections 2.3.5.3

~~using vapour balancing systems and directing the waste gas to abatement techniques (e.g. activated carbon filtration, enclosed systems and using vapour balance lines during loading). The removal efficiency of an activated carbon filter is at least 90 %.~~

~~Achieved environmental benefits~~

~~.Emission values of 50 mg C/Nm^3 in the waste gas after the treatment mentioned in technique f in the description section above are achievable.~~

~~Operational data~~

~~The use of vapour balancing systems during solvent charge is typically used to reduce fugitive VOC emissions (e.g. Germany). The waste gas is usually treated by adsorption on activated carbon~~

~~Applicability~~

~~The distillation technique is applicable to all regenerative solvents and refrigerants. The capacities of the example installations range from approximately 2 – 60 kt/yr.~~
~~Azeotropic distillation is commonly used to enhance solvent recovery. An azeotrope or azeotropic mixture is a mixture of liquids that behave as a single substance when boiled (i.e. both the vapour and the liquid have the same composition). Azeotropic distillation consists of adding a substance (typically steam) to form an azeotropic mixture with the solvent to be recycled. The azeotropic mixture will have a lower boiling point than the original mixture and recovery of the solvent will thus be facilitated.~~
~~Vacuum distillation is designed to handle solvents with higher boiling points (above 200 °C).~~

~~Cross-media effects~~

~~The application of cascade re-use of solvents could develop using solvents in open devices and for instance, to clean machines or coating devices. In such cases a defined composition of the solvent mixture needs to be known and the solvents should not contain volatile organic compounds which are asignated as risk materials for human health.~~

~~Distillation of waste solvents produce emissions of hydrocarbons to the air and waste water that need to be treated.~~

~~The distillation technique is applicable to all regenerative solvents and refrigerants. The capacities of the example installations range from approximately 2 – 60 kt/yr.~~

~~Driving force for implementation~~

WORKING DRAFT IN PROGRESS

~~Some organic solvents are especially dangerous compounds for human health. Some restrictions (e.g. closed installations) are mentioned in Directive 1999/13/EC.~~

~~Preference order for waste management in accordance with the Waste Framework Directive and the Sixth Environmental Action Programme of the European Community.~~

~~Example plants~~
~~Re-refining of N-methyl-2-pyrrolidone (NMP) used in electronic manufacturing.~~

~~Reference literature~~
~~[31, LaGrega et al. 1994] [86, UBA Germany 2003] [98, WT TWG 2004]~~

5.4.3.1 Evaporation of distillation residues

From ex-**Section 4.4.2.4 "Evaporation of distillation residues"**

Description
Recovery of the solvent from the distillation residue.

Technical description
Vacuum dryer and other drying techniques are ~~in use~~ used for distillation bottoms to evaporate the residue from the distillation columns and recuperate the solvents.

Achieved environmental benefits
Increase in the percentage of solvent recovered. ~~Valorisation~~ Good use is made of 99 % of the container solvents. This can reduce the total solvent concentration by approximately a factor of ten. Resins and pigments may also be ~~valorised~~ taken advantage of. At the same time they may reduce the odour and VOC emissions that may be generated by the bottoms.

Environmental performance and operational data
~~For example,~~ A distillation bottom sludge may have a significant concentration of solvent, which, if the material is in liquid form, may render it suitable for recovery.

Energy (heat and power) is necessary to run such systems. There are systems for the treatment of up to 4000 tonnes of distillation residues per year, from which it is possible to obtain between 1500 and 2000 tonnes of solvents per year. The specific kneading energy is up to 0.1 kWh/kg. The separation of heating and cooling zones facilitates efficient product temperature control.

Cross-media effects
Treatment of the solid residue that is generated ~~should be treated~~. VOCs are emitted to air and are treated before being emitted.

Technical considerations relevant to applicability
This technique ~~it~~ does not need ~~so~~ much floor space ~~surface~~ and ~~it~~ is easily applicable to existing plants. It is applicable to distillation residues of painting solvents, polymers, elastomers, pharmaceutical products and food products. ~~VOCs arise from a wide range of waste types. Obvious examples are waste oil and solvents.~~
However, the stability of residues may decrease as they become increasingly concentrated and dry.

Economics
The investment cost is EUR 1.2 million. Operating costs vary between EUR 100 to 150 per tonne of residue treated.

Driving force for implementation
To improve the recovery of solvents and minimise waste.

WORKING DRAFT IN PROGRESS

Example plants

At least six plants use this system around the world. At least four are in the EU. Drying techniques are in use in the UK for the distillation ~~of~~ bottom sludges.

TWG members, please confirm

Reference literature

[28, Scori 2002] [33, UK EA 2001] [44, TWG 2003] [98, WT TWG 2004]

5.4.3.2 Monitoring of diffuse and fugitive VOC emissions to air

Description

Diffuse and fugitive VOC emissions to air are monitored by measurement or calculation.

Technical description

Diffuse and fugitive VOC emissions may be monitored by one or a combination of these methods:

- Measurement by sniffing or optical gas imaging in application of LDAR (see Section 2.3.5.4).
- Solvent mass balance, considering the input solvent, the output solvent, the channelled emissions to air, and the distillation residues. Useful indications can be found in Annex VII to Directive 2010/75/EU.
- Engineering calculation: Emissions estimation equations are available for the following types of emissions found at a solvent recycling facility:
  - material loading;
  - surface evaporation;
  - material storage; and
  - spills.

  Inputs for theoretical equations generally fall into the following categories:
  (1) chemical/physical properties of the material involved, such as vapour pressure and vapour molecular weight;
  (2) operating data, such as the amount of material processed and operating hours; and
  (3) physical characteristics and properties of the source, such as tank colour and diameter.
- Emission factors: these are numbers that can be multiplied by known data such as plant/process activity data or throughput data. Emission factors are typically based on the results of source tests performed at an individual facility or at one or more facilities within the same or similar industries. Emission factors may be used to calculate total VOC emissions from solvent recycling facilities, as well as emissions from specific types of equipment typically found at such a facility. These types of equipment include the following:
  - process equipment;
  - distillation and purification systems;
  - parts washing equipment; and
  - process piping.

[139, ROM], [165, AUS]

Achieved environmental benefits

Control of diffuse and fugitive VOC emissions to air.

Environmental performance and operational data

Table 5.116 shows the monitoring of diffuse VOC emissions at plants performing regeneration of waste solvents.

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Table 5.116: Monitoring of diffuse VOC emissions at plants performing regeneration of waste solvents

Plant	Range	Monitoring of diffuse emissions
56_3	674 kg/year	Measurement once a year by external company following Flemish regulation VLAREM II 4.4.6.
168	583–5958 kg/year	Calculated (through the solvent management plan)
169	NI	Calculated (through the solvent management plan)
170	NI	Calculation
214	NI	NI
394	NA	Not monitored
420	NA	Not monitored
447	NA	Not monitored
476	NA	Not monitored
554	NA	Not monitored
NI: No information. NA: Not applicable.		

Cross-media effects
None identified.

Technical considerations relevant to applicability
Generally applicable.

Economics
No information available.

Driving force for implementation
- Legislation on air pollution.
- Identification of leaks and optimisation of the process.

Example plants
Plants 56, 168, 169, 170.

Reference literature
[166, Leefmilieu et al. 2015]., [122,IED], [139, ROM] [160, WT TWG 2014]

5.4.3.3 Reduction of VOC emissions to air

Description
Recirculation of waste gas from the solvent regeneration process in the steam boiler.

Technical description
Emissions from tanks, distilling operations and vacuum pumps' exhaust are collected in a waste gas treatment system. Collected emissions are cooled and chilled to condense and partially separate solvents. This waste gas with some remaining solvents is incinerated as a by-stream in the steam boiler supplying the plant. In the event that the steam boiler is out of operation or the

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waste air volume exceeds the steam boiler's air demand this pretreated waste gas is fed to activated carbon beds and then released.

Achieved environmental benefits

No VOCs are released; organic compunds are incinerated. The remaining solvents' calorific value is used to support the recycling process by reducing natural gas consumption. Other benefits include a reduced volume of purchased activated carbon and the recycling of activated carbon.

Environmental performance and operational data

The base energy used in the steam boiler (99 %) is natural gas. Solvents not condensed out of the waste gas are burnt and their energy becomes part of the heat for distilling. The steam boiler's burner is adjusted to handle two energy streams (natural gas and waste air). The list below shows the permitted values of steam boiler exhaust. As shown in Table 5.117, the actual measurements are below (<) or far below (<<) the permitted ones.

Table 5.117: Emissions to air from solvent recycling

Parameter	Comparison of emission levels with permitted concentration values	Unit
Steam boiler exhaust (stack gas)	About 4400	Nm^3/h
Dust	<< 5	mg/Nm^3
SO_2	<< 10	mg/Nm^3
NO_X	< 200	mg/Nm^3
TOC	< 20	mg/Nm^3
CO	< 60	mg/Nm^3
HCl	< 0.1	Kg/h

Source: [164,UBA]

It is important to consider that the stack gas from steam boilers contains all captured emissions from the solvent recycling plant. Solvents in waste air are incinerated.

Cross-media effects

No information available.

Technical considerations relevant to applicability

Halogenated solvent wastes are not accepted in order to avoid generating and emitting PCBs. All incoming wastes are analysed and any halogenated solvents are detected. The tolerable content of halogenated solvents is < 1 w/w-%.

Economics

No information available.

Driving force for implementation

Legislation on air pollution.

Example plants

Plants 214, 394.

Reference literature

[164,UBA] [160, WT TWG 2014]

WORKING DRAFT IN PROGRESS

5.4.3.4 Abatement of channelled VOC emissions to air

Description
Collection and abatement of VOC emissions with a combination of techniques.

Technical description
All captured air emissions from tanks, gas exchange operations, distilling operations and vacuum pumps' exhaust are collected in a single waste air treatment system. Collected was gas is treated by a combination of one or several of the following techniques:

- condensation (Section 2.3.4.8);
- cryogenic condensation (Section 2.3.4.8);
- activated carbon adsorption (Section 2.3.4.9);
- wet scrubbing (Section 2.3.4.10).

Condensation and/or cryogenic condensation are also part of the process itself to condense the distillation product and adequate control of condenser parameters is essential to minimise VOC emissions from the condenser vents. Condenser (cooling) failure results in an automatic process shutdown.

Achieved environmental benefits
Reduction and control of channelled VOC emissions.

Environmental performance and operational data
See Table 5.108 for the reported values of VOC emissions to air. Table 5.118 below shows the mass of VOC released per year and per tonne of solvent treated which has been calculated for three of the plants of the reference list.

Table 5.118: Mass of VOC released in channelled air emissions per year and per tonne of solvent treated

Plant[1]	Kg of VOC per year and per tonne of solvent treated (based on measures of NMVOC)
Plant A	0.02-0.10
Plant B	0.06
Plant C	0.16-0.36
[1]For reasons of confidentiality concerning the quantity of solvent treated, the plants have been anonymised	

Cross-media effects
See CWW BREF [138, COM 2014].

Technical considerations relevant to applicability
Activated carbon beds tend to self-ignite when loaded with ketones. [164, UBA]

Economics
See CWW BREF [138, COM 2014].

Driving force for implementation
Legislation on air pollution.

Example plants

WORKING DRAFT IN PROGRESS

Plants 56, 168, 169, 170, 554.

Reference literature
[164, UBA], [146, PCT] [160, WT TWG 2014] [138, COM 2014]

5.4.3.5 Reduction of waste water generation and of water usage

See also CWW BREF Section 3.3.1.7

Description
Liquid ring pumps with high boiling point liquids.

Technical description
Solvent recycling by distillation is most often carried out in vacuum conditions. A vacuum is commonly generated by means of injectors operated with water or high-pressure steam as the driving force or water-ring vacuum pumps. By operating these devices, water is polluted by virtue of its use. Water-miscible solvents (such as ketones) and alcohols combined with non-miscible components, such as hydrocarbons, make non-miscible ones partly miscible. Therefore, hydrocarbons cannot be skimmed away from the water surface. Waste water polluted with solvents and hydrocarbons is generated.

In this technique, a vacuum down to 20 mbar absolute is generated using liquid ring pumps with high boiling point liquids. Solvent vapours generated by the distillation process under vacuum are absorbed into that high boiling point liquid. This liquid is alternately cooled and heated in a continuous process. When becoming hot, the condensed and soluble solvents are desorbed and the liquid ring fluid is returned to the vacuum pump for the next reuse. Desorbed solvents are condensed and recovered.

After several hundred hours of operation, the liquid ring fluid itself needs regeneration by distillation.

Achieved environmental benefits
- Limitation of waste water generation.
- No waste water treatment needed.
- No water usage.

Environmental performance and operational data
The formerly polluted waste water (about 20 m^3/day, sometimes containing > 1000 mg/l hydrocarbons) has disappeared.

Cross-media effects
No information available.

Technical considerations relevant to applicability
Generally applicable.

Economics
No information available.

Driving force for implementation
- Avoidance of generation of waste water.
- Improvement in yield of recycling process.
- Cost savings.

WORKING DRAFT IN PROGRESS

Reference plants:
ORM Bergold Chemie GmbH, Bochum and Langlau, Germany.

Reference literature
[164, UBA],

Ex-**Section 4.4.2.5 "Full automatisation of residue incineration"** deleted. Waste incineration is outside the scope.

WORKING DRAFT IN PROGRESS

5.5 Regeneration / recovery of pollution abatement components / FGT waste

This section includes information on the recovery of components from waste generated by abatement techniques. ~~(see also Section)~~

5.5.1 Applied processes and techniques

5.5.1.1 Regeneration of spent activated carbon

From ex-**Section 2.4.4 "Regeneration of activated carbon"**

Purpose
To treat the spent activated carbon to produce a material with properties and qualities very similar to the original activated carbon.

Principle of operation
Thermal treatments are the main processes used for regeneration. During the process, drying, thermal desorption and heat treatment are carried out.

Feed and output streams
Activated carbon is commercially available in three forms: extruded, granular and powder. Since powdered carbon is extremely difficult to regenerate, this activity is not carried out on powdered carbon. Only the first two forms are therefore considered in this section.

From ex-**Section 3.4.1 "Waste IN treated to obtain a recycled material"**

~~**Waste activated carbon**~~
Most industrial plants tend to send their spent carbon off site for regeneration by a large centralised carbon manufacturer. Quantities of spent carbon from industrial sources (textiles, refinery products, carpet mills, plastic industry, phenolic resins, herbicides, explosives, detergents, solvents, dyes), whilst reasonably substantial, do not approach those obtained from potable water purification. From discussions with various carbon regenerators, it appears that water treatment provides the single largest source of spent carbon. Activated carbon adsorption systems can be used for a wide variety of applications, and can potentially contain a cocktail of adsorbed pollutants. The contaminants found in spent activated carbons are typically:

- chlorine;
- COD/BOD;
- pesticides;
- bulk organics imparting colour, taste and/or odour (i.e. humic acids);
- general organics such as phenol;
- metals such as iron, aluminium, cadmium and mercury;
- inorganic elements such as calcium and phosphorus;
- dyes (cause of colour);
- detergents;
- ~~phenols;~~
- explosives (only in material that comes from the manufacture of explosives).

~~Activated carbon products are basically available in three forms: extruded activated carbon, granular activated carbon, and powder activated carbon. The last form is not regenerated.~~

From ex-**Section 2.4.4 "Regeneration of activated carbon"**

Process description
Regeneration is normally carried out thermally and is typically composed of the following operations.

WORKING DRAFT IN PROGRESS

Receipt, handling and dewatering
Spent activated carbon is normally received on site as a drained solid in tankers. Water is added at the regeneration site in order to turn the carbon into slurry, which is fed to a tank where it is dewatered and charged into a kiln to be regenerated.

Thermal regeneration
After separation from the water, the moist carbon is fed into the furnace for regeneration. During thermal regeneration, drying, thermal desorption (i.e. removal of the organic chemicals) and high temperature (650 °C to 1000 °C) heat treatment in a slightly oxidising controlled atmosphere are carried out.

The types of equipment generally used are multiple hearth furnaces, directly fired rotary kiln furnaces and indirectly fired rotary kiln furnaces (where there is no contact between the kiln content with the flue-gases generated by the burner). Fluid bed furnaces and infrared furnaces may also be used.

From ex-**Section 4.4.4.1 "Choice of furnace used to regenerate the waste activated carbon"**

~~**Description**~~
~~The options are 'multiple hearth hurnaces', 'direct fired rotary kilns' and 'indirect heated kilns'. (where there is no contact between the kiln content with flue-gases generated from a burner)~~

~~**Achieved environmental benefits**~~
The multiple hearth furnace has significant advantages over other types of furnace from the standpoint of regeneration efficiency because the temperature of each hearth may be independently controlled. The direction of the exit gases may be either co-current or countercurrent to the flow of carbon. In some designs, the afterburner may be incorporated within the furnace at the 'zero' hearth level. The multiple hearth furnace shows better mass transfer and temperature control characteristics than the rotary kiln and has a carbon residence time of typically one to two hours. Carbon losses may be up to 10 % by weight.

Directly fired rotary kilns may be operated with the carbon flowing either co-currently or countercurrently to the flow of combustion air. In the countercurrent mode of operation, the exit gases leaving the kiln are at a higher temperature than in the co-current mode, which allows the potential for designing the afterburner to less stringent criteria while still destroying gaseous contaminants.

Indirectly heated kilns offer the advantage of eliminating ~~the need for~~ the mixing of burner flue-gases with process gases.

Indirectly heated furnaces are normally constructed with a metal tube and are not likely to be suitable for industrial applications due to corrosion problems which may appear during the treatment of some industrial carbons.

~~The applications of the~~ Indirectly fired kilns are generally used for the treatment of industrial carbons where more onerous temperature criteria apply to the afterburner.

Note to TWG: the two sentences above seem to be contradictory. Please provide information on the applicability of indirectly fired kilns.

~~**Operational data**~~
Owing to the absence of exposed metal surfaces, rotary kilns are normally able to operate at higher temperatures than multiple hearth furnaces. Carbon losses in rotary kilns may be in the range of 5–15 % by weight. Careful attention is ~~needs to be~~ paid to the seals between the rotating kiln and the end plates to prevent any leakage of gases and dust ~~particulate matter~~. Fugitive emissions from this area are normally controlled by operating the kiln at a slightly negative pressure.
.

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Infrared furnaces are relatively new in application and are predominantly found in the United States. Their mode of firing is by infrared elements and indirect heating of the carbon. As a result, they avoid the ~~production~~ generation of a combustible gas, ~~production~~ which can result in lower volumes of air requiring treatment in the abatement chain. They are, however, limited to maximum capacities of around 1000 t of waste treated/yr.

TWG members, please provide information on this process: is it used, still emerging, abandoned?

~~*Flue-gas treatment*~~

From ex-**Section 2.4.4 "Regeneration of activated carbon"**

Other treatments

Other treatments are available such as steam, chemical and biological regeneration. However, they are only used for *in situ* regeneration on site and not at ~~separate facilities~~ standalone waste treatment plants. Steam regeneration is a non-destructive technique and is primarily used where the spent carbon contains highly volatile compounds. The resulting steam/VOC vapours are condensed. Chemical regeneration is a non-destructive technique that uses a variety of gaseous or liquid desorbants. There are numerous regenerative materials available, many of them highly specific to the individual application.

Users

The most common use of these techniques is in the thermal regeneration of activated carbon, especially in facilities regenerating industrial or potable water/food-grade carbons. This is because of the potential for carbons from a variety of sources to be contaminated with a range of organics. The other methods, such as steam regeneration, tend to be applied in specific areas and are typically undertaken on site.

~~Multiple hearth furnaces are used extensively worldwide. In conjunction with multiple hearth furnaces, rotary kilns (directly and indirectly fired) are one of the most common types of furnaces employed. Fluid bed furnaces are mainly used in Europe on potable water applications and also in North America for waste water and decolourising.~~

~~**Example plants**~~

~~The indirect fired kiln concept is becoming more widespread.~~

~~The only known indirect fired rotary kiln example in Europe was in the UK and this is believed to be no longer functional.~~

~~An activated carbon regeneration plant located on a drinking water site using a multiple hearth furnace: the plant consists of silos for containing spent and reactivated carbon, separate spent and reactivate transfer water system to transport carbon from silos and to and from the furnace. The unit also has a direct transfer system to the water works for treating the carbon from that particular site. Spent and reactivated carbon is transported from other sites using bulk road tankers.~~

Reference literature

[16, UK Environment Agency 1996] [25, UK Department of the Environment 1991] [98, WT TWG 2004]

5.5.1.2 Regeneration of resins

From ex-**Section 2.4.5 "Regeneration of resins"**

[16, UK Environment Agency 1996], [25, UK Department of the Environment 1991], [98, WT TWG 2004]

Purpose

To regenerate ion exchange resins for their reuse.

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Principle of operation
Thermal regeneration which may be accomplished by using hot water or steam.

Feed and output streams
The feed corresponds to spent resin with the output of the process being regenerated resin.

From ex-**Section 3.4.1 "Waste IN treated to obtain a recycled material"**

~~Waste ionic resins~~
A large proportion of resins sold worldwide are used in water treatment (i.e. water softening). The remaining balance is divided between chemical processing, extractive metallurgy, and food and pharmaceutical processing.

Operating ion exchange resins may concentrate toxic ions such as chromate and cyanide, or heavy metals. Due to the predominance of water applications, they may also contain pesticides, chlorine, phenols and inorganic elements such as calcium, sodium, manganese and phosphorus.

Conventional ion exchange resins are bead-shaped, and behave like plastic ball bearings when handled. They contain ion-active sites throughout their structure, have a uniform distribution of activity, and can usually resist breakages resulting from handling or from osmotic shock (i.e. a rapid change in solution environment). Most beads are sold in the 40 µm to 1.2 mm size range.

From ex-**Section 3.4.3.5 "Emissions from the regeneration of ion exchange resins"**

The releases from a process of this nature are small and confined mainly to ~~those~~ emissions to water. Some emissions resulting from different regeneration plants are shown in Table 5.119.

Table 5.119: Range of emissions found in different ion exchange regenerators

Air pollutants	**From**	**Concentration (mg/Nm^3)**
HCl	~~from~~ Filling of bulk storage	< 5
Water pollutants		**Concentration (µg/l)**
Effluent flow rate $^{(2)}$	NI	5–10 m^3/h
Cd	NI	< 0.5–3$^{(1)}$
Hg	NI	0.86$^{(1)}$
Organic Sn	NI	< 0.3–2.0$^{(1)}$
Solid waste		
Waste resins	NI	NA
Fines	NI	NA
Backwash filter	When resin is combined with activated carbon as a guard or a backwash filter	NA

NI; No information
NA: Not applicable
Reference conditions of flue-gas: dry gas, 6 % O_2.
$^{(1)}$ Values that correspond to peak values.
$^{(2)}$ Steam regeneration can produce large quantities of contaminated aqueous effluent.

[25, UK Department of the Environment 1991] [26, UK, H. 1995]

From ex-**Section 2.4.5 "Regeneration of resins"** deleted: solvent washing is not addressed in the chapter

Process description
~~The attractive forces encountered in resin adsorption are usually weaker than those of granulated activated carbon adsorption. Due to this, regeneration of resins can be achieved by simple, nondestructive methods such as solvent washing, and the solute can be recovered. Thermal regeneration of resin adsorbents is generally not possible due to their temperature sensitivity, although in recent years some new products are becoming available that can be regenerated by hot water.~~

WORKING DRAFT IN PROGRESS

Steam regeneration

Steam regeneration is only possible if the temperature limits of the resins are within those of the available steam pressure. For example, styrene-based polymeric adsorbents are usually stable to 200 °C, whilst acrylic-based resins are only stable up to 150 °C. The adsorbed solvent and other organic constituents can cause the resin matrix to swell and weaken. It is important, therefore, that the removal of these constituents by steaming does not result in the disruption and break-up of the resin matrix.

Hot water regeneration

From ex-**Section 4.4.5.1 "Techniques for the regeneration of resins"**

~~Description~~

~~Applicability~~

Hot water regeneration is only possible for thermally stable resins.

~~Some techniques include:~~

~~a. applying a pH balancing system~~
~~b. applying hot water regeneration.~~

~~Achieved environmental benefits~~

Hot water regeneration increases the rate of resin regeneration. The ~~alternative~~ use of ~~heat (i.e.~~ hot water~~)~~ to regenerate resins potentially provides reductions in effluent volume and requires lower energy requirements, particularly where heat recovery is employed on the regenerated fluid.

~~Economics~~

The principal technique employed to control releases to water is a pH balancing system. ~~Such a system can cost in the region of GBP 30000 to 40000. This compares with a total plant cost in the order of GBP 250000, excluding civil works. Hot water regeneration lowers the operating costs.~~

Users

Resin regeneration~~ This technique~~ is not widely used but it may be applied to resins used for the desalination of brackish water for a cleaner process water usage. It ~~would~~ is not ~~be~~ used for deionised water applications.

Reference literature

[25, UK Department of the Environment 1991] [26, UK, H. 1995]

Ex-**Section 4.4.5.2 "Pollution control techniques applicable to activated carbon and for resin regeneration"** deleted. It is only a cross-reference to former section 4.4.4.4

5.5.1.3 Regeneration of waste catalysts [~~and recovery of components from abatement techniques~~]

From ex-**Section 2.4.3 "Regeneration of waste catalysts and recovery of components from abatement techniques"**

~~As mentioned in the Scope, This section covers the regeneration of waste catalysts. and the recovery of components from abatement techniques. Alternative ways to regenerate spent catalysts exist, such as the~~ The recovery of the metals from catalysts (some precious metal recovery treatments are already covered in the Non-Ferrous Metals Industries BREF)~~,~~ ~~regeneration of catalysts (covered in this document)~~ and the treatment of spent catalysts as raw materials for other processes~~, which are not covered in this document~~ (e.g. the treatment of spent alumina-supported catalysts in the cement industry which is covered in the Production of Cement, Lime and Magnesium Oxide BREF) are not covered in this document. This document

WORKING DRAFT IN PROGRESS

only includes *ex situ* regeneration of waste catalysts ~~installations~~. *In situ* regeneration is typically part of a production process where a catalyst is used and thus is not covered by the scope of this document.

~~This section is intended as well to include information on the recovery of components from waste generated from abatement techniques (see also Section)~~

Note for TWG: all three plants on the reference list treating spent catalysts do not perform catalyst regeneration but catalyst incineration, already covered by NFM BREF.

Purpose
Waste catalysts and waste from abatement techniques are typically disposed of. However, most catalysts used in abatement techniques (e.g. NO_X abatement) are regenerated.

Principle of operation
Regeneration of precious, platinum and noble metal catalysts to remove coke deposits can successfully restore the activity, selectivity, and stability ~~performance~~ of the original fresh catalyst. Coke deposits are removed by controlled combustion.

Feed and output streams
Catalysts from the refinery industry such as those used in hydrotreating, hydrocracking, reforming and isomerisation are typically regenerated. Noble metal catalysts are also regenerated. The metals that are ~~typically economically interesting to be~~ worth recovering for economic reasons are rhodium, cadmium, platinum, iridium, Raney nickel and some petroleum catalysts with nickel-cobalt, cobalt-molybdenum, and cobalt.

From ex-**Section 3.4.1 "Waste IN treated to obtain a recycled material"**

~~**Waste catalysts**~~
Spent catalysts
The spent catalysts that may be regenerated *ex situ* are as follows.

Metal catalysts
~~For example,~~ These include platinum-alumina reforming catalysts which can be regenerated by the removal of carbonaceous deposits from the catalyst surface using a carefully controlled combustion procedure, followed by platinum redispersion and rechloriding of the catalyst support.

Noble metal catalysts
These can be regenerated by removing the coke deposits to successfully restore the activity, selectivity, and stability ~~performance~~ of the original fresh catalyst. Coke deposits are removed by controlled combustion.

Base metal catalysts
Hydroprocessing catalysts can be regenerated using different methods such as regenerative oxidation treatment to remove coke (*ex situ* regeneration) or redispersion of the metals in the case of poisoning by the sintering of metals.

Zeolites
These can be regenerated relatively easily by using methods such as heating to remove adsorbed materials, ion exchanging with sodium to remove cations, or a pressure swing to remove adsorbed gases. However, they are not regenerated *ex situ* because the structure is , ~~in most cases~~,usually damaged and, depending on the application, the pores can be contaminated with heavy metals or other catalyst poisons.

WORKING DRAFT IN PROGRESS

From ex-**Section 3.4.4 "Waste OUT from re-recycling/regeneration treatments"**

Regenerated catalysts

Table 5.120 shows the carbon and sulphur levels, the surface area, and the average length of the spent catalyst feed and the regenerated product from the belt-only and fine regeneration techniques in one plant. The spent catalyst was analysed for its surface area after laboratory regeneration.

Table 5.120: Commercial regeneration of cobalt-molybdenum catalyst

Product quality	Spent catalyst from top bed of second reactor	Belt-only regeneration	Fine regeneration
Carbon (w/w-%)	22	0.7	0.9
Sulphur (w/w-%)	7.5	0.9	0.8
Surface area (m^2/g)	185	190	197
Average length (mm)	2.56	2.72	2.68

NB: The values above correspond to the regeneration of more than 580 tonnes of spent CoMo hydrotreating catalyst from a customer's distillate hydrotreater in 1997. The unit had two reactors with two catalyst beds per reactor. The pre-~~job~~operation analyses showed that the catalyst could be recovered from all four beds, but, as expected, the highest quality catalyst was towards the back end of the unit.
Source:[81, Ruiz, C. 2002]

Overall, the spent catalyst was heavily loaded with hydrocarbons (15 w/w-%) and coke (total loss on ignition 30 %). The company started regenerating the highest quality catalyst from the bottom bed of the second reactor and worked back towards the catalyst at the front of the unit. The ~~job~~ operation began prior to the fine regeneration plant, so initially the catalyst was being stripped with inert gas in the belt-stripping unit.

The properties of both regenerated products compare favourably with that of the spent catalyst. The surface areas of the regenerated samples are slightly higher than those from the laboratory regeneration.

Process description

Ex situ thermal regeneration is performed in specially designed equipment as well as in standard equipment, e.g. moving-bed belt calciners or rotary calciners.

~~The regeneration of precious, platinum and noble metal catalysts to remove coke deposits can successfully restore the activity, selectivity, and stability performance of the original fresh catalyst. Coke deposits are removed by controlled combustion.~~

As an example, after the coke is burnt off, a catalyst containing platinum can be regenerated by chlorine treatment at an elevated temperature. The chlorine treatment causes redispersion of the platinum by converting it to a volatile platinum chloride, which is then transported through the gas phase and deposited on the pore walls, where it is treated ~~in~~ with H_2 and reduced. The result is an increased dispersion of the platinum and a reactivated catalyst.

The common unit operations used in this sector are drying, use of furnaces, leaching ~~equipment~~ and solvent extraction. Some end-of-pipe processes used to control air emissions are dust removal techniques (e.g. electrostatic precipitators, cyclones, fabric filters, ceramic filters, scrubbers, flares), gas scrubbing systems (e.g. scrubbers, dioxin capture systems, VOC abatement systems), and waste water treatments.

Users

There is a very precise process in France (Eurocat) which is applied to the recycling of one specific catalyst family (hydrotreatment) coming mainly from refineries. There is only one

WORKING DRAFT IN PROGRESS

moving-belt calciner process plant in the EU, which has been located in Luxembourg since 1979.

Reference literature
[60, WT TWG 2003] [81, Ruiz, C. 2002] [98, WT TWG 2004]

5.5.1.4 Treatment of FGT waste

5.5.1.4.1 Recycling of Residual Sodium Chemicals from FGT wastes

From ex-**Section 4.3.2.16 "Purification and recycling of FGT wastes"**

Purpose
The technology described here realises the separation ~~between~~ of soluble and insoluble parts of the FGT waste, solidifying the insoluble part and purifying and reusing the soluble part (constituted of inorganic salts) in some industries.

Principle of operation
The process aims to recycle the water-soluble fraction of sodium-based FGT waste to produce purified brine by dissolution of the salts and purification of the resulting brine, by separation of insoluble matter, and by adding specific additives and chemical treatments. The purified brine resulting from the recycling process is a REACH registered product.

Feed and output streams
~~The sodium-based FGT wastes are mainly constituted of sodium chloride (as a result of HCl neutralisation), sodium sulphate (as a result of~~ ~~SO_2~~ ~~neutralisation), sodium carbonate (result of sodium bicarbonate excess), fly ash and adsorbent (activated carbon or lignite coke).~~

Feed

Gaseous acid compounds contained in the flue-gas are transformed into sodium salts by the injection of ground sodium bicarbonate into the flue-gas stream. Typical overall chemical reactions involving the neutralisation of the acid components are the following:

$$HCl + NaHCO_3 \rightarrow NaCl + H_2O + CO_2$$
$$SO_2 + 2\ NaHCO_3 + \tfrac{1}{2}\ O_2 \rightarrow Na_2SO_4 + H_2O + 2\ CO_2$$
$$HF + NaHCO_3 \rightarrow NaF + H_2O + CO_2$$

The neutralisation involves a stage of thermal activation which converts sodium bicarbonate into a sodium carbonate with a high specific surface and porosity:

$$2\ NaHCO_3\ (T > 140°C) \rightarrow Na_2CO_3 + CO_2 + H_2O$$

In a typical flue-gas treatment process, activated carbon is usually injected together with sodium bicarbonate. The solid waste arising from the sodium bicarbonate-based treatment is completely removed from the gaseous stream by a filtration step, usually a bag filter, installed downstream of the sodium bicarbonate injection. Such solid waste is usually called 'RSC' – Residual Sodium Chemicals.

There are two filtration possibilities for dry flue-gas treatment processes:

- One single filtration step: only a bag filter is installed downstream of the sodium-based reagent injection. In such a layout, fly ashes are collected together with RSC. ~~In flue-gas single filtration systems, fly ash is mixed with neutralisation salts and~~ In this case, the soluble part represents about ~~50~~ 40 % of the waste input. ~~IN~~
- Two filtration steps: a pre-dedusting filter is installed upstream of the sodium-based reagent injection. This step may consist of an electrostatic precipitator, a cyclone or a bag filter. In this first step the fly ashes are collected separately from the RSC, which are collected on a second filter. ~~in flue-gas double filtration systems, the first filter~~

WORKING DRAFT IN PROGRESS

~~catches most of the fly ash and sodium-based FGT wastes collected at the second filter~~ They contain about ~~90~~ 85 % soluble salts.

The main physico-chemical characteristics of typical RSC are listed in Table 5.121.

Table 5.121: Typical physico-chemical characteristics of RSC

Visual aspect	Fine grey powder
Free-flowing density	0.3–0.4 t/m^3
Average particle size distribution	D50 approx. 50 µm
$NaCl + Na_2SO_4 + Na_2CO_3$	> 95 % *
Metals (Al, Pb, Zn, Cu, Fe, Sn, etc.)	0.1–500 mg/kg each
Insoluble matter, with pre-dedusting	< 15 %
Insoluble matter, without pre-dedusting	< 60 %

(*):referred to the ratio of soluble matters contained in the RSC
Source: [114, CEFIC 2014]

Output
The outputs consist of the following:

- The soluble part of FGT waste which is reused in the chemical industry, replacing the use of fresh materials (salt is one of the main raw materials for soda ash plants). This soluble part is recycled at a rate higher than 95 %.
- The landfilled solid part of FGT waste which has a very low soluble fraction and ~~so its solidification is~~ solidifies better; ~~so there is~~ resulting in a lower consumption of hydraulic binders and a lower quantity of final waste. The dry filter cake mass is less than 20 % of the original RSC.

Process description
The process for recycling the water-soluble fraction of the RSC can be described by ~~includes~~ the following steps (see Figure 5.27 below):

a. reception of trucks;
b. sampling and analysis;
c. pneumatic transfer of RSC into storage silos;
d. addition of water and additives;
e. filtration;
f. temporary storage of solids resulting from the filtration, for later disposal or recovery;
g. purification of clear raw brine in three sequential steps:
    i. filtration on sand filter;
    ii. organic matter removal on active carbon column;
    iii. in-depth heavy metal removal on two ion exchange resin columns;
h. purified brine storage in a buffer tank for analysis;
i. brine transfer by pipeline to the soda ash plant for recycling.

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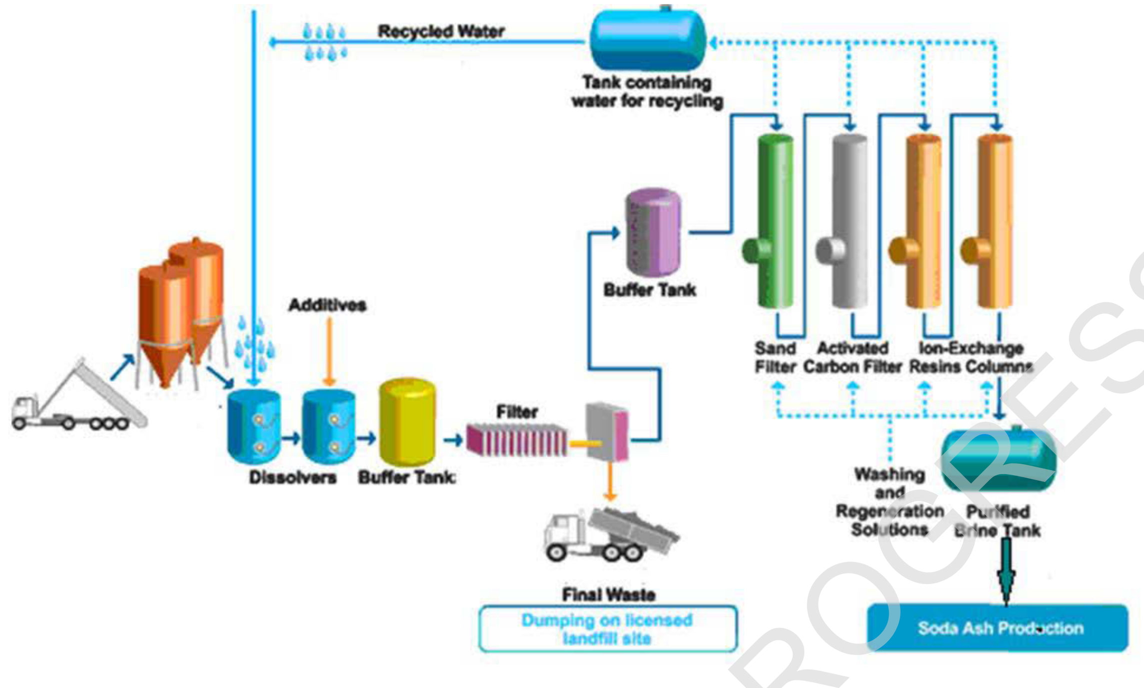

Source: [114, CEFIC 2014]

Figure 5.27: RSC recycling process schematic

The process works at ambient temperature and therefore does not require a high energy input.

The treatments do not generate liquid effluents (all liquids are reused as process water to form the recycled brine) and no significant air emissions are reported (ambient temperature process). Storage silos are equipped with filters to prevent dust emission during RSC transfer from the silo trucks. CO_2 is the sole gaseous emission due to combustion of natural gas when it is necessary to heat the brine because of low ambient temperatures.

~~a. mixing the FGT waste with hydraulic binders: prepares the solidification of the unsoluble part~~
~~b. dissolving in water and adding additives: the soluble part is dissolved and most heavy metals are precipitated~~
~~c. filtering this suspension: resulting products are a self-solidifying filter cake with a very low soluble fraction (after washing), and a raw brine containing soluble salts~~
~~d. purifying the brine (with various steps including ion exchange resins) in such a way that it may be re-used in the manufacture of sodium carbonate (soda ash).~~

~~This process has no outputs other than the solidified filter cake (to be landfilled) and the purified brine, which replaces part of the fresh raw material used by the soda ash plant: there is no liquid effluent at all.~~

~~Economics~~

This process is to be compared with the solidification and landfilling of FGT waste. From this point of view, (1) the solidification is much eased by the separation of the soluble part, and (2) the quantity of ~~ultimate~~ final residues is reduced. This process has been reported to be competitive in some countries. Operational costs are low and the investment cost of the treatment plant is the key factor. ~~Therefore this process must be implemented in centralised units serving numerous incineration plants~~. The capital expenditure is EUR 10–20 million for a capacity of 25–60 kt RSC/year.

~~Driving force for implementation~~

~~This process is favoured by the following observed evolutions:~~

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- ~~severe ruling on landfilling: when safe solidification required~~
- ~~resistance to new landfilling site projects as there is a trend to landfill as little as possible~~
- ~~trend to promote recycling.~~

Users ~~Example plants~~

This process is implemented in dedicated and centralised plants located close to the soda ash plant using the produced purified brine, and which receive FGT waste coming mainly from ~~various~~ MSW incineration plants, but also from combustion plants, chemical plants, ceramic and glass manufacturing, etc.

~~It is applied to the FGT waste coming from the dry sodium bicarbonate flue-gas cleaning process used in municipal solid waste incineration.~~

Two plants work on an industrial~~ly~~ scale using this process or a slight variation of it: one in Italy (Tuscany), with a capacity of 10 kt FGT waste/yr, and one in France (Lorraine), with a capacity of 50 kt FGT waste/yr. Both supply purified brine as raw material to a soda ash plant.

TWG, please confirm

Reference literature

[98, WT TWG 2004] [100, WT TWG 2004] [114, CEFIC 2014]

5.5.1.4.2 Recovery of salts from FGT by solution/evaporation

From ex-**Section 4.3.2.8 "Recovery of salts from FGT by solution/evaporation"**

Purpose

The main objective of the operation is to avoid the discharge of saline waste water to the sewerage system. This is achieved by evaporation of the scrubber liquid from the wet flue-gas treatment system.

Principle of operation ~~Description~~

When solid wastes are produced, the recovery potential can be considered. The recovery, for example, of, ~~e.g.~~ salts (NaCl, $CaCl_2$, HCl and gypsum) may be a possibility. These products could be obtained by evaporation or recrystallisation of the salt from the flue-gas cleaning system ~~of~~ waste water, either locally or at a centralised evaporation plant.

Feed and output streams

When the scrubber fluid is treated separately and subjected to evaporation, recoverable products like salts or hydrochloric acid can be obtained. The potential reutilisation ~~potential~~ of such products strongly depends on the product quality.

~~Achieved environmental benefits~~

Process description

In salt recovery, the scrubber liquid is treated with sodium hydroxide and calcium carbonate to produce solid gypsum, which after separation leaves a liquid containing mainly sodium and calcium chloride. The recovered products are subjected to quality control or even treated further for quality improvement and then ~~traded off~~ sold.

If solid sodium chloride needs to be separated individually from the above solution this is achieved by evaporation of the solution to a salt content of more than 30 %, at which level pure salt is crystallised. The above recovered salt products are most commonly reutilised in areas with a de-icing demand in wintertime.

The reuse of the recovered salts and gypsum may save natural resources.

~~Cross-media effects~~

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The major drawbacks of external waste water evaporation for salts not only relate to operational and material problems but also to the high energy consumption necessary for evaporation.

~~Operational data~~

The evaporation of waste water containing salt is dependent on the salt concentration, which can vary greatly. Apart from problems of corrosion, the relatively high investment and operational costs need to be taken into account.

For the production of gypsum only a few operational problems exist. However, the gypsum quality is determined not only by its purity with respect to the presence of other undesirable components but also due to its colour. Normally, a production of about 2–5 kg of recyclable products ~~of about 2–5 kg/~~per tonne of waste can be expected.

~~By~~ When producing calcium chloride, focus ~~should be~~ is put on the extreme corrosion potential that may arise and risk an unintended phase shift from a solid to a liquid state and vice versa.

Users ~~Applicability~~

This technique can be applied in municipal waste incinerators with wet flue-gas treatment systems. For MSW incinerators with wet scrubbing of the incineration flue-gas, no discharge of the waste water is permitted due to legislation and local demands. The cleaned waste water from the wet scrubbers will still contain salts which are normally not desirable in the sewage pipe system because they can cause corrosion or increase the salt content of fresh water bodies. For this reason the waste water is normally treated thermally and, where the waste water is used for cooling, by injection into and evaporation in the raw incinerator flue-gas. Here, no recoverable products are obtained.

Evaporation of treated saline waste water can be done at both centralised and decentralised plants. In the latter case, the MSW incinerator itself could supply the energy needed for evaporation.

For gypsum production, this could be achieved primarily by operational changes only, i.e. implementation and operation of suitable dewatering devices, including cyclones, pumps, etc.

Evaporative processes have been implemented with success in several countries, especially in Germany where ~~several~~ a number of incineration plants have applied this technology.

~~Economics~~

The costs for the evaporation and storage of the recovered products are several times the costs for production of the same salts from natural resources. Thus, this technique is primarily applied for environmental reasons rather than economic ones.

Due to the production of already large amounts of high quality gypsum from energy production processes at power plants, gypsum produced in the above manner from MSW incinerators is only used for applications with a ~~lower~~ demand ~~of~~ for lower quality gypsum ~~quality~~. If reuse is not possible, then the gypsum is ~~has to be~~ disposed of, thus incurring a corresponding disposal cost.

~~Driving force for implementation~~

~~Due to legislation, the discharge of scrubber liquid from wet flue-gas systems should be minimised. Even though the waste water is intensively treated for removal of, e.g. heavy metals and other harmful impurities, this hardly affects the total amount of salts. A substantial reduction of salt emission from the individual MSW incinerator to the local surrounding area is only accomplished by evaporation of the scrubber liquid. By separation of the solid gypsum, the amount of FGT waste for disposal is reduced.~~

~~Example plants~~

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Reference literature
[80, Iswa 2003] [98, WT TWG 2004] [100, WT TWG 2004]

5.5.1.4.3 Washing of Air Pollution Control residues

Purpose
To treat waste powders such as Air Pollution Control residues (APCr) in order to produce a secondary aggregate.

Principle of operation
The washing process treats waste powders such as Air Pollution Control residues (APCr) in order to make them suitable for use in the manufacture of construction products. The waste input powders consist of useful mineral phases but also contain undesirable soluble fractions. High concentrations of soluble material are not desirable in the production of construction products and have previously restricted the recycling of APCr.

Feed and output streams
The main feed is APCr.

During the process, the chloride levels are significantly reduced; concentrations as low as 0.2 % can be achieved where required. The chloride is transferred to the effluent which is discharged to a foul sewer under the terms of a trade effluent consent. The heavy metals within the APCr are not solubilised, but are instead converted to less soluble species during the process.

The consumption of water can be significantly reduced by recycling process water to the point of saturation. The waste generated by the washing process is classified as hazardous due to the residual calcium hydroxide it contains. The properties of the waste can be adjusted to convert calcium hydroxide to gypsum by the addition of sulphuric acid. Both calcium hydroxide and gypsum have useful properties for the production of construction products. Where required, the relative concentrations of these materials can be tailored to the final use of the residue.

Process description
The APCr are delivered to the site by bulk road tanker and discharged to a powder storage silo equipped with high level alarms, load cells, level indicators and reverse jet filters. The APCr are then slurried using water. After a period of time the slurry is pumped through a membrane filter press. The slurry fills the chambers within the filter press plates, capturing the solid particles and allowing the liquid to pass through. The solids are held within the filter press and undergo additional washing and drying steps before the process is complete.

The liquid filtrate from the process is held within a storage tank and can be recycled into the process as slurry water until such a point that it becomes saturated. The solid residues are held within the filter press until such a point that the press is opened. The solids then fall into an articulated tipper trailer and are ready to be shipped to a receiving site.

Users
Two plants in the United Kingdom have reported using this process.

Reference literature
Plant 498

5.5.1.5 Acid extraction

From ex-**Section 2.3.3.1 "Extraction and separation"**
TWG, please confirm it is still relevant

Purpose
To extract heavy metals and salts from solid wastes, using acid.

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Principle of operation

The technique solubilises compounds and removes them with water.

Feed and output streams

Treatment options using extraction and separation processes can, in principle, cover all types of processes extracting specific components from the wastes.

The process can remove a significant part of the total amount of heavy metals from the waste input ~~IN~~ (Cd: ≥ 85 %; Zn: ≥ 85 %; Pb and Cu: ≥ 33 %; Hg: ≥ 95 %); the leachability of the material is reduced by a factor 10^2–10^3. Zinc, cadmium and mercury are recycled.

The dioxin content of the bottom ash increases when the treated ash is disposed of 'as combined' with bottom ash; however, the leaching potential of the mixture is higher because of the higher density.

Process description

From ex-**Section 4.3.2.9 "Acid extraction"** **TWG, please confirm it is still relevant**

A number of processes use acid extraction; some examples are given in Table 5.122.

Table 5.122: Acid extraction technologies

Process	Characteristics
Acid extraction process	This process combines the acid extraction of soluble heavy metals and salts by using the (acidic) scrubber blowdown. Before using the scrubber liquid, mercury is removed by ~~either a~~ filtration (when activated carbon is introduced into the scrubber) and/or a specific ion exchanger. Both boiler ash and fly ash are treated this way. The Liquid/Solid (L/S) ratio in the extraction step is about 4; the pH is controlled at 3.5 by the addition of hydrated lime. Within the residence time of about 45 minutes, sulphate (from the SO_2 scrubber) is precipitated to gypsum. The solid residue is dewatered, then countercurrently washed on a belt filter and finally landfilled, normally as a mixture with bottom ash. The filtrate is ~~has to be~~ treated in order to remove heavy metals by neutralisation, precipitation and ion exchange. The dewatered and rinsed filter cake contains about 25 % zinc and is therefore recycled in metallurgical processes.
Combination of acid extraction with thermal treatment	This process combines acid extraction with thermal treatment. First, boiler and fly ashes are washed with the first stage wet scrubber solution, and dewatered. Then the solid residues are treated in a rotary kiln for one hour at around 600 °C, destroying majority of the organic compounds and volatilising mercury. The off-gas is treated in an activated coal filter. The waste water is treated to remove heavy metals. The scrubber solution from the second scrubber is used to wash the bottom ash and to neutralise acidic effluent streams.
Acid extraction sulphide process	This process combines fly ash and NaOH scrubber solution with water with an L/S ratio of 5. After mixing, the pH is adjusted to about 6–8 with HCl to extract heavy metals, and NaHS is added to bind heavy metals as sulphides. Then a coagulation agent is added and the slurry is dewatered. The filter cake is landfilled and the waste water is treated in a subsequent treatment unit to remove heavy metals.
Source:[80, Iswa 2003] [98, WT TWG 2004]	

Users

Several techniques have been proposed both in Europe and in Japan for air pollution control residues.

Most of the plants that operate for 24 hours can adapt the weekly operation period (4–7 days) according to the arising FGT waste.

The system can be used only ~~on~~ in incinerators with a wet FGT system ~~having~~ with a permit allowing the discharge of treated waste water.

The start-up of the first plant was in 1996. Six plants currently operate in Switzerland and one in the Czech Republic.

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Economics

The process costs of treating the FGT waste are about EUR 150–250/t (including charges for recycling the zinc filter cake).

~~**Driving force for implementation**~~

This technique provides a method to treat solid waste according to Swiss legislation at competitive costs (compared to the export for German underground disposal).

Reference literature

[80, Iswa 2003] [100, WT TWG 2004]

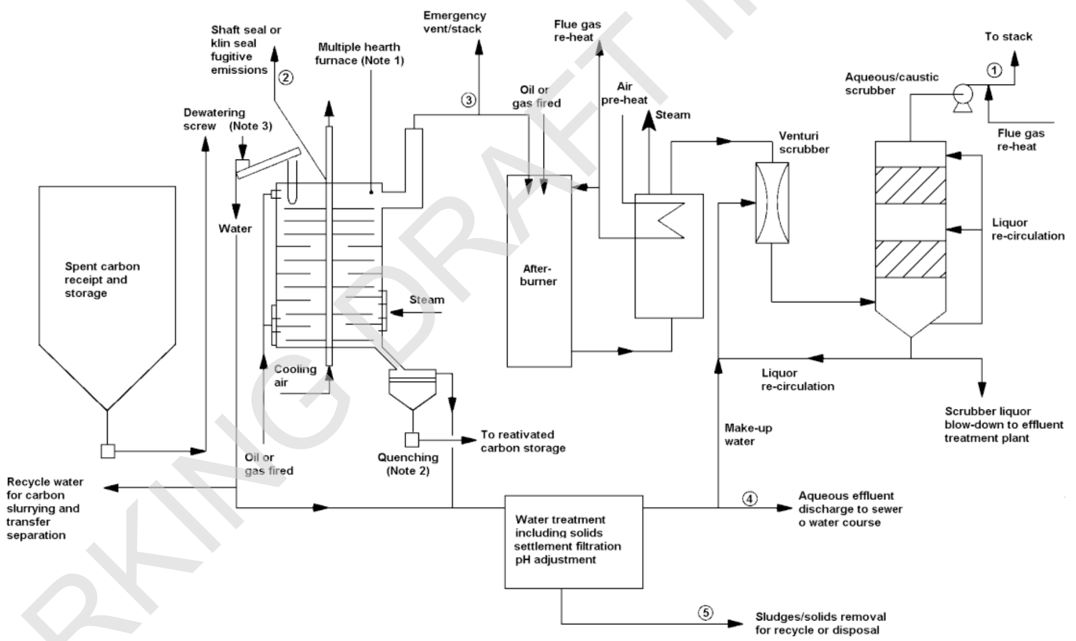
5.5.2 Current emission and consumption levels

5.5.2.1 Regeneration of activated carbon

From ex-**Section 3.4.3.4 "Emissions from the cleaning and regeneration of carbon"**

The main environmental issues related to the thermal regeneration of activated carbon are primarily gaseous effluents such as carbon dioxide. Acidic gases and pesticides may prove a problem if there are no control measures such as afterburners and/or scrubbers.

Figure 5.28 shows a schematic of a generic activated carbon regeneration process, including the release routes that are listed in Table 5.123.



Source:[16, UK Environment Agency 1996]

NB: Numbers in the diagram refer to the numbers of the first column of **Table 5.123**.

Note 1 Multiple hearth furnace illustrated but thermal reactivation may also be carried out in a rotary kiln.

Note 2 Carbon exiting the kiln may also be cooled by other means.

Note 3 Other techniques for dewatering may be used.

Figure 5.28: Schematic flow diagram of a generic carbon regeneration plant

Releases to the environment commonly associated with the regeneration of activated carbon processes are listed in Table 5.123.

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Table 5.123: Potential release routes for ~~prescribed substances and other substances which may cause harm~~ pollutants

	Source releases to:	Dust/ solids	CO + CO_2	NO_X	SO_X	Halogens	Organic compounds or partial oxidation products	Metals, metalloids or compounds
1	Flue-gases from flue-gas treatment	A	A	A	A	A	A	A
2	Fugitive emissions from seal leakages	A	A	A	A	A	A	A
3	Emergency vent stack (if applicable)	A	A	A	A	A	A	A
4	Aqueous effluent discharge	W					W	W
5	Effluent treatment plant sludge						L	L

NB: The releases to each medium will be determined to a significant degree by the application for which the carbon has been used, and hence release of some substances to water and land is possible.
Legend: A: Air, W: water, and L: residues (land).
Source:**[16, UK Environment Agency 1996]**

Emission results from different regeneration plants are shown in Table 5.124.

Table 5.124: Range of emissions found in different carbon regenerators

Air pollutants	**Concentration (mg/Nm^3)**
Particulates	1–34
CO	< 3–160
NO_X (as NO_2)	126–354
SO_2	< 2–60
HCl	< 1–22
HF	< 1
VOCs (TOC)	5–15
Dioxins and furans (PCDD and PCDF) (TEQ)	< 0.01–0.18 ng/Nm^3
Cd	< 0.05
Hg	< 0.05
Other heavy metals	0.1–0.5
Water pollutants	**Concentration (mg/l)**
Suspended solids	50–300
COD	400
Simazine	0.001
Atrazine	0.001
TEQ (TCDD and TCDF)	0.28–0.4 ng/l
Al	30
Cd	0.0005
Hg	0.0001
Mn	30
Solid waste	**Composition**
Refractory linings	NI
General industrial waste	NI
Sludge from settlement ponds	Mainly carbonaceous fines

NI: No information
NB: Reference conditions of flue-gas: dry gas 6 % O_2.
Source:[26, UK, H. 1995]

Liquid effluent from regeneration plant

Water is used for the transport of activated carbon as slurry to and from the regenerator. This gives rise to a black water effluent which ~~should be~~ is clarified and recycled. Water separated from the slurry will contain suspended solids and possibly ~~prescribed substances~~ pollutants (e.g. pesticides) and is routed to the effluent treatment plant.

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The clean hot activated carbon is either dry cooled or quenched in cold water. For the wet cooling system, the water becomes alkaline and is therefore dosed with acid. This water ~~should be~~ is purged from the system to prevent the accumulation of mineral salts, with fresh/recycled water make-up as necessary.

Water is also used intermittently in large amounts to backwash activated carbon storage hoppers, both to remove fines and to level the top surface of the activated carbon. Sufficient water storage is ~~needs to be~~ provided so that this water can be clarified and recycled.

Techniques for controlling releases to land

In the regeneration of activated carbon most deliveries of carbon are made in bulk tankers. In certain circumstances drums may be used. Where this is the case, drums are reconditioned and reused so that disposal is minimised. Other process waste includes sludge or filter cake from filter presses or settlement tanks in an effluent treatment plant. ~~In the case where~~ When disposal is to land the method of disposal ensures that, if the cake or sludge was to dry out, windblown dust of fine carbon particulates cannot occur. Other wastes will include refractory bricks and linings where repairs to kilns and furnaces have taken place periodically.

5.5.2.2 Regeneration of waste catalysts

From ex-**Section 3.4.3.3 "Emissions from the regeneration of waste catalysts"**

Knowing the source of the spent catalyst can often provide information on potential emissions due to the presence of acids, oils, organic contaminants (they may ~~produce~~ generate PCDD during melting processes), etc. This directly influences the potential emissions to air, water and land.

The physical state of the waste catalyst can also influence the emissions (e.g. the particulate emissions depend on the particulate size of the waste catalyst, oil content, etc.). Some potential emissions from different catalyst regeneration plants are shown in Table 5.125

Table 5.125: Potential emissions found in different catalyst regenerators

Air pollutants	~~**From**~~
~~Particulates —~~ Dust (from fugitive emissions)	~~Fugitive emissions~~
SO_2	
NO_X	
VOCs	
Dioxins	
Metals	
Water pollutants	
Suspended solids	
Oil	
TOC	
Metals	
Solid waste	
Oil	
Metals	
Dust (e.g. from abatement systems)	~~e.g. from abatement systems~~

~~NB: Reference conditions of flue-gas: dry gas, 6 % O_2.~~

Source: [81, Ruiz, C. 2002]

WORKING DRAFT IN PROGRESS

From ex-**Section 3.4.2 "Consumptions of waste treatments to obtain a recycled material"**

Consumption for regeneration of spent catalysts
Table 5.126 shows an overall material balance for an example regeneration. Almost 375 tonnes of catalyst was recovered for reuse.

Table 5.126: Mass balance in a commercial regeneration of cobalt-molybdenum catalyst

Overall material balance	**Values in kg**
As received material	620 982
Inert support	- 27 099
Unregenerated dust and fines	- 9569
Total unregenerated feed to regenerator	= 584 314
Shorts from length grading and regenerated dust and fines	- 37 191
Loss on ignition	- 172 143
Net regenerated catalyst	= 374 980
Source:[81, Ruiz, C. 2002]	

5.5.2.3 Treatment of FGT wastes

Table 5.127 gives an overview of the plants from the reference list treating FGT wastes. Table Table 5.128 and Table 5.129 show respectively the emissions to air and the emissions to water of these plants.

The emissions are generally very limited: emissions from vents of silos and storage tanks are collected and treated by bag filters or activated carbon filters and most of the process water is recycled into the process. In one case the excess waste water is tankered to an off-site WWTP and in the other case the filtrate undergoes further treatment by anaerobic digestion.

Table 5.127: Plants from the reference list treating FGT wastes

Plant code	**Waste input description**	**Process**	**Waste output description**	**Section in this document**
189C	Sodium-based residues coming from flue-gas treatment, refused salt	Solubilisation, Precipitation, Press filtration (to remove heavy metals, activated carbon and insoluble matter), Ion exchange (to remove heavy metals), Filter cake stabilisation (to remove soluble salts)	Sodium chloride-concentrated brine, Filter cake, Filter cake as secondary material	5.5.1.4.1
333C	Sodium-based residues coming from flue-gas treatment	Solubilisation, Precipitation, Press filtration (to remove heavy metals, activated carbon and insoluble matter), Ion exchange (to remove heavy metals), Water washing of the filter cake (to remove soluble salts)	Sodium chloride-concentrated brine, Filter cake	5.5.1.4.1
498	APCr, waste inorganic acid	Washing	Sludges from physico-chemical treatment, Aqueous effluent	5.5.1.4.3

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Table 5.128: Emissions to air from plants treating FGT wastes

Plant code	Origin of emissions to air	Techniques for emissions to air	Parameter monitored in air emissions
189C	Storage silos are equipped with filters to prevent dust emission during RSC transfer from the silo trucks	Bag filters	NI
333C	No emissions to air	NI	NI
498	NI	NI	NI
NI: No information.			

Table 5.129: Emissions to water from plants treating FGT wastes

Plant code	Origin of emissions to water	Point of release	Receiving body	Techniques for emissions to water	Parameters monitored in water emissions
189C	The RSC recycling process does not release any liquid effluent: any kind of waste water, like rainwater from the site, accidental spillages, and acid/basic liquors arising from the ion exchange resin regeneration and washing steps, is totally recycled internally into the process	NA	NA	NA	NA
333C	No emissions to water	NA	NA	NA	NA
498	Physico-chemical	Discharge from the WT plant and its auxiliary systems, as well as from on-site waste water pretreatment facilities, to an urban/municipal sewer system	River/Stream	No technique for waste water treatment. Aqueous filtrate is collected into storage for screening prior to being recycled or discharged as a trade effluent	Analysis conducted by the WWTP operator in the framework of the effluent trading
NA: Not applicable.					

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Water usage

The reported average water usage per tonne of waste treated is 2 200 l/t, with a range of 270–3 000 l/t. Two plants indicated that all water is recycled in the process. One plant reported that water recycling is in progress.

Energy consumption

The reported average energy consumption per tonne of waste treated is around 110 kW/t, with a range of 81–207 kWh/t. Electricity is the main energy source.

Raw material consumption

Table 5.130 shows the range of raw material consumption by plants from the reference list treating FGT wastes.

Table 5.130: Examples of raw material consumption by plants from the reference list treating FGT wastes

Raw material	Range of consumption in the reference period (t/year)
Alkalis	223–1754
Reducing agents	170–380
Acids	115–450
Other chemicals	45–270

5.5.3 Techniques to consider in the determination of BAT for the regeneration of activated carbon

5.5.3.1 Flue-gas treatment

From ex-**Section 4.4.4.2 "Flue-gas treatment"**

Description

Treatment of flue-gas generated by activated carbon regeneration includes heat recovery as well as primary and secondary techniques for control of air emissions.

Technical description

~~Some techniques include:~~

~~a. using an afterburner for the gases exiting the furnace or kiln. The afterburner needs to be in operation at all times when carbon is present in the kiln~~
~~b. designing the regenerator and associated ducting and equipment to operate under a reduced pressure, in order to prevent the escape of regenerator gases into the air~~

Applying heat recovery

Typically this involves gas/gas heat exchangers to allow the preheating of combustion air and flue-gas reheating. There may also be a waste heat boiler used for the generation of steam, which is also used in the reactivation of the carbon.

~~c. cooling the flue-gases with a quench section or venturi scrubber~~
~~d. using an aqueous or caustic scrubber. Spray absorption techniques may also be used. It will be necessary to provide a pH control on the scrubber liquor~~
~~e. routing the flue-gases to the stack via an induced draft fan with partial reheating of the flue-gases~~
~~f. using either wet or dry electrostatic precipitators, venturi scrubbers or fabric filters. Inertial separators, e.g. cyclones when used alone, are unlikely to meet low emission values.~~

Reduction of flue-gas to be treated

By using an indirectly fired kiln, there is a ~~The~~ lower volume of gas requiring heating and abatement, which saves on energy and the size of abatement equipment. Burner flue-gases that have indirectly heated the kiln are then directed to the base of the stack where they may be combined with the kiln off-gases to reduce the visibility of the emitted plume. This method may

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offer the advantage of affording higher partial pressures of steam in the kiln, which is likely to reduce the formation of oxides of nitrogen. Also, the formation of halides rather than elemental halogens is likely to be promoted, with the halides being more easily removed in downstream scrubber systems.

Techniques to control emissions to air

Table 5.131 gives and overview of primary and secondary techniques used for the abatement of emissions to air.

From ex-**Section 4.4.4.4 "Pollution control techniques applicable to activated carbon regeneration"**

Table 5.131: Applicability of techniques for the treatment of flue-gases generated by activated carbon regeneration

Pollution control techniques for the abatement of particles and acid gases	~~**Applicability to activated carbon regeneration**~~ **Description**
Primary measures for particulate control	Furnace temperature Turning rate of the rotary furnace Fuel type Designing the regenerator and associated ducting and equipment to operate under a reduced pressure, in order to prevent the escape of regenerator gases into the air
Secondary measures for particulate and acid gases control	Afterburner for the gases exiting the furnace or kiln. The afterburner needs to be in operation at all times when carbon is present in the kiln Mechanical collectors Wet scrubbers. Spray absorption techniques may also be used. It will be necessary to test the pH of the scrubber liquor ~~Dry scrubber~~ Electrostatic precipitators (ESPs) Fabric filters Inertial separators, e.g. cyclones when used alone, are unlikely to achieve low emission values Cooling the flue-gases with a quench section or venturi scrubber
Primary measures for NO_X control	Reduce furnace and combustion temperatures Reduce excess air and thus lower the concentration of atomic oxygen in higher temperature zones Reduce the residence time in all higher temperature areas Control the furnace heat release rate, and eliminate high temperature peaks Flue-gas recirculation (FGR) Air staging Fuel staging Furnace insulation Low entrance of secondary (cold) air Reduced air/fuel ratio
Secondary measures for NO_X control	Selective catalytic reduction (SCR) Selective non-catalytic reduction (SNCR) The DESONO_X process The SNO_X process The EDTA-Chelate process The SO_X NO_X RO_X BOX
Source: [25, UK Department of the Environment 1991] [98, WT TWG 2004]	

Achieved environmental benefits

- Optimises energy efficiency.
- Reduces the emissions of ~~the flue-gas generated.~~ particulates, acid gases and NO_X to air.

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Environmental performance and operational data

The regenerator includes an afterburner chamber, which is equipped and operated in such a way that the flue-gas resulting from the regeneration of the carbon is raised, after the last injection of air, in a controlled and homogeneous fashion and taking account of the most unfavourable conditions, to a temperature of at least 850 ºC as measured at the inner wall of the combustion chamber. This needs to be held for at least two seconds in the presence of at least 6 vol-% oxygen dry gas, as measured at the exit of the afterburner. For carbon which has been used in industrial applications where halogenated or other thermally resistant substances are likely to be present (e.g. containing more than a certain small percentage), the temperature is typically raised to at least 1100 ºC. The residence time, minimum temperature and the oxygen content of the exhaust gases need to be verified. However, in some circumstances not specified by the TWG, it may be possible to achieve an equivalent effect with less stringent conditions (some generic information on this issue can be found in the WI BREF).

A spray dryer followed by fabric or ceramic filters has the additional advantage of allowing further neutralisation reactions to occur between the trapped solid residues and the exhaust gas stream. This can lead to a reduction in alkali requirements for a spray dryer of 10–15 % ~~against~~ compared to a wet scrubber.

Table 5.132 shows the achievable levels for key substances in the context of the processes concerned.

Table 5.132: Air emission benchmarks for release to air

Substance	Achievable levels (mg/Nm^3)
Total particulate matter	20
Hydrogen chloride	30
Sulphur dioxide (as SO_2)	50
Oxides of nitrogen (as NO_2)	350
Carbon monoxide (measured after last injection of air)	50
VOCs (as C) (excluding particulate matter)	20
Dioxins and furans (International Toxicity Equivalent – ITEQ)	1 ng/m^3

NB: The above concentrations are for non-continuous monitoring.
Source: [16, UK Environment Agency 1996]

Cross-media effects

~~Technique f in the Description section, requires reheating of the flue-gas~~.
Some air abatement techniques generate liquid waste which needs to be treated.

Technical considerations related to applicability

~~**Applicability**~~

Indirectly heated furnaces are normally constructed with a metal tube and are not likely to be suitable for industrial applications due to corrosion problems that may appear during the treatment of some industrial carbons.

Flue-gases from either multiple hearth furnaces or rotary kilns generally follow a similar path of treatment. In the case of co-currently fired rotary kilns, it may be possible to achieve these same conditions without an afterburner.

The flue-gas treatment depends on the application for which the carbon has been ~~put~~ used and the nature of the fuel used to fire the kiln and afterburner. The equipment described above may typically be used for carbon that has been used for potable water treatment or for food-grade applications.

For carbon used in industrial applications, more extensive abatement measures may be required. ~~Waste gas treatment facilities may vary depending on the application for which the carbon has been used. More stringent requirements may be needed for carbon that has been used for~~

WORKING DRAFT IN PROGRESS

~~industrial applications~~. In these cases, further chemical scrubbing may be needed to attain the desired achievable release levels. It may also be necessary for the post-regeneration stage to be maintained at temperatures of at least 1100 ºC for a two-second residence time in the presence of at least 6 vol-% oxygen and dry gas, to ensure complete oxidation of certain refractory compounds.

Driving force for implementation

~~In certain local circumstances and because of visual issues (e.g. visible plume suppression), sometimes techniques c and f in the description section above are required by certain authorities.~~
Legilsation on air pollution.

Economics

No information available.

Example plants

No information available.

Reference literature

[16, UK Environment Agency 1996] [25, UK Department of the Environment 1991] [26, UK, H. 1995][98, WT TWG 2004] [100, WT TWG 2004] [101, WT TWG 2005]

Ex-**Section 4.4.4.3 "Waste water treatment plants"** deleted because it is replaced by descriptions of individual techniques in Section 2.3.6

Description

~~These processes need a system for the treatment of the liquid effluent generated in the flue-gas treatment plant.~~

Technical description

~~Some techniques include the following:~~

~~a. Applying two-stage hydroxide precipitation at different pH values.~~
~~b. Utilising sulphide precipitation to remove metals.~~
~~c. Utilising flocculation, settlement, filtration or centrifuges to separate the suspended materials. A preliminary chemical or physical pretreatment stage may also be necessary to condition the suspended solids and improve the separation.~~
~~d. Adjusting the pH to promote the precipitation of specific chemicals and to achieve an acceptable effluent.~~
~~e. Using natural zeolites, ion exchange resins, activated carbon and reverse osmosis techniques to remove noxious impurities (e.g. pesticides). Concentration by evaporation is also a possibility.~~
~~f. Applying a biological treatment to remove BOD, phenols, cyanides and ammonia.~~

~~**Achieved environmental benefits**~~

Table 5.133 ~~indicates the achievable release levels for key substances in the context of the processes concerned.~~

WORKING DRAFT IN PROGRESS

~~**Table 5.133: Achievable water emission values**~~

~~**Substance**~~	~~**Achievable**~~ (1)	~~**Units**~~
~~COD~~		~~NI~~
~~Suspended solids~~	~~50~~ (2)	~~mg/l~~
~~Cadmium~~	~~5~~ (3)	~~μg/l~~
~~Mercury~~	~~1–10~~	~~μg/l~~
~~Other heavy metals~~	~~<0.5~~	~~mg/l~~
~~Dioxins and furans, PAHs and other organics~~		
~~Simazine~~	~~1~~ (4)	~~μg/l~~
~~Atrazine~~	~~1~~ (4)	~~μg/l~~

~~(1) The levels quoted represent a flow-weighted monthly average concentration.~~

~~(2) By sedimentation or settlement. Lower releases may be achieved by filtration, if necessary, depending on the receiving water and the level of contamination with other pollutants.~~

~~(3) By precipitation and filtration which can be expected to achieve 70 % reduction. Subsequent treatment in the biological treatment plant of a sewage treatment works will reduce this to below the limit of detection.~~

~~(4) For waste water carbons, trace quantities of pesticides may be leached from granulated activated carbon (GAC) into waste water prior to discharge to a sewer. Many GAC regeneration plants install small GAC filters on the outlet to the sewer as a precaution.~~

~~*Source*: [16, UK Environment Agency 1996][98, WT TWG 2004]~~

~~**Technical considerations related to applicability**~~

~~Applied to the effluent from quenching or scrubbing flue-gas treatment.~~

~~**Example plants**~~

~~Many examples exist in the sector.~~

~~**Reference literature**~~

~~[16, UK Environment Agency 1996][98, WT TWG 2004]~~

5.5.4 Techniques to consider in the determination of BAT for the recovery of components from catalysts

5.5.4.1 Flue-gas treatment [Generic techniques used in the treatment of waste catalyst]

From ex-**Section 4.4.3.1 "Generic techniques used in the treatment of waste catalyst"**

Description

Treatment of flue-gas generated by spent catalyst regeneration includes heat recovery as well as primary and secondary techniques for control of air emissions.

Technical description

Heat recovery

a. Applying heat recovery in the form of energy production or recuperation. For this aim, recuperative burners, heat exchangers and boilers can be used to recover heat. Steam or electricity can be generated for use on or off site, e.g. to preheat process or fuel gases.
b. Using oxygen or oxygen-enriched air ~~or oxygen~~ in the burners.
c. Preheating the combustion air used in burners.
d. Preheating the material charged to the furnace.
e. Automatically controlling the point of extraction using dampers and fan controls so that the systems are deployed when and where they are needed, for example during charging or during the ‘roll-out’ of a converter.

Primary techniques to control air emissions

From ex-**Section 4.4.3.2 "To improve control of the process"**

a. Using sealed furnaces, which can allow a very high capture efficiency of the fumes.

WORKING DRAFT IN PROGRESS

b. Using ducts and fans to convey the collected gases to abatement or treatment processes. Variable speed fans are used to provide extraction rates that are suitable for changing conditions such as the gas volume, with a minimum energy consumption.

Secondary techniques to control air emissions
See Table 5.134.

From ex-Section **4.4.3.3 'Abatement techniques used in the waste catalyst regeneration sector'**

Table 5.134: Abatement techniques applied in regeneration of spent catalysts

Abatement technique	Location where it is applied	Section in this document where the abatement technique is analysed
~~Applying~~ Cooling waste gas prior to a fabric filter system ~~installation~~	Exit of the furnace	NA
Fabric filter	Exit of the furnace	2.3.4.4
Wet scrubber	Exit of the furnace	2.3.4.10

NA: Not applicable.
Source: [81, Ruiz, C. 2002]

Achieved environmental benefits

- Heat and energy recovery, which is an important factor in this industry due to the high proportion of costs that energy represents.
- Reduction of emissions to air.

Environmental performance and operational data

The use of oxygen-enriched air or oxygen in the burners reduces the overall energy consumption by allowing the complete combustion of carbonaceous material. At the same time, waste gas volumes are significantly reduced allowing smaller fans, etc. to be used.

The advantage of preheating the combustion air used in burners is well documented. If an air preheat of 400 °C is used, there is an increase in flame temperature of 200 °C, while if the preheat is 500 °C the flame temperature increases by 300 °C. This increase in flame temperature results in a higher efficiency and a reduction in the overall energy consumption. The alternative to preheating combustion air is to preheat the material charged to the furnace. Theory shows that 8 % energy savings can be obtained for every 100 °C preheat and in practice it is claimed that preheating to 400 °C leads to a 25 % energy saving, while a preheat of 500 °C leads to a 30 % energy saving.

The technique used to recover heat varies from site to site depending on a number of factors, such as the potential uses for heat and energy on or near the site, the scale of operation and the potential for gases or their constituents to foul or coat heat exchangers

Many techniques aimed at energy recovery are relatively easy to retrofit but occasionally there may be some problems with deposition of metal compounds in heat exchangers. A good design is based on a sound knowledge of the compounds released and their behaviour at various temperatures. Heat exchanger cleaning mechanisms are also used to maintain their thermal efficiency.

From ex-**Section 4.4.3.2 "To improve control of the process"**

Applying cooling prior to a bag filter system ~~installation~~ is an important technique as it provides temperature protection for the filter and allows a wider choice of fabric. It is sometimes possible to recover heat at this stage. The temperature of the gases after this heat exchanger can be

WORKING DRAFT IN PROGRESS

between 200 ºC and 450 ºC. The second heat exchanger reduces the gas temperature to 130 ºC before the bag filter. The heat exchangers are normally followed by a cyclone, which removes larger particles and acts as a spark arrester.

Cross-media effects
Liquor from wet scrubbing needs to be treated.

Technical considerations related to applicability
Generally applicable.

Driving force for implementation
Energy savings and legislation on air pollution.

Economics
No information available.

Example plants
No information available.

Reference literature
[81, Ruiz, C. 2002]

From ex-**Section 4.4.3.2 "To improve control of the process"**

~~**Description**~~
~~Some techniques include:~~

c. ~~adjusting the temperature levels and residence time of the catalyst in the unit, in order to achieve desired levels of carbon and sulphur~~
d. ~~having a good temperature control during the regeneration process~~
e. ~~designing the residence time in the pretreater to be very short (in the order of a few minutes), to minimise attrition normally associated with fluidised bed processes~~
f. ~~applying sizing (i.e. length graded) technology after regeneration. The length grading technology removes short catalyst particles (typically those with lengths 1 – 2 times the diameter) that cannot be removed with conventional screening. In an example, length grading was set up to accept only a relatively small cut, to increase the average length by 0.1 – 0.2 mm without discarding too much material.~~

~~**Achieved environmental benefits**~~
~~Improves the control of the process and the efficiencies of abatement techniques. The effectiveness of collection depends on the efficiency of the hoods, the integrity of the ducts and on the use of a good pressure/flow control system.~~

~~**Driving force for implementation**~~
~~Product requirements.~~

~~**Reference literature**~~
~~[81, Ruiz, C. 2002]~~

WORKING DRAFT IN PROGRESS

5.6 Treatment of excavated contaminated soil

This section deals with biological treatment as well as physico-chemical treatment of excavated contaminated soil.

From ex-**Section 3.3.4 "Waste OUT from physico-chemical treatments"**

~~*Waste OUT from excavation*~~

~~Excavation has been found to decrease the soil moisture content and the dry bulk density of the soil. Data show that the water content fraction decreases by 35 % to 56 % and the dry bulk density of the soil decrease by 13 %.~~

From ex-**Section 3.3.1 "Waste IN in physico-chemical treatments"**

According to a meeting devoted to assessing indicators for soil contamination [68, Fons-Esteve et al. 2002], there are three main indicators used to establish whether soil is contaminated or not. These are typically acidification, eutrophication (the typical indicator is nitrogen content) and the content of heavy metals (e.g. mercury). Contaminated soil can contain rocks, bricks and reinforcing rods that could damage the equipment used for material handling if not removed.

5.6.1 Applied process and techniques

5.6.1.1 Thermal desorption

From ex-**Section 2.3.3.9 "Thermal desorption"** and ex-**Section 4.3.2.11 "Thermal desorption of soil"**

Purpose

To separate relatively volatile compounds from solid waste.

Principle of operation

In the thermal desorption process, volatile and semi-volatile contaminants are removed from soils, sediments, slurries, and filter cakes. Typical operating temperatures are between 175 °C and 370 °C, but temperatures from 90 °C to 650 °C may be employed. Thermal desorption promotes physical separation of the components rather than combustion.

Feed and output streams

Soil contaminated with non-biodegradable organic compounds, soil contaminated with petroleum fuels, soil contaminated with hazardous wastes and tar containing asphalt or similar waste are the types of waste processed by this treatment. The contaminants are transferred to a further treatment.

Thermal desorbers effectively treat soils, sludges, and filter cakes and remove volatile and semi-volatile organic compounds. Some higher boiling point substances such as PCBs and dioxins may also be removed (if present). Inorganic compounds are not easily removed with this type of process, although some relatively volatile metals such as mercury may be volatilised. The temperatures reached in thermal desorbers generally do not oxidise metals.

~~**Applicability**~~

~~Applicable to soils contaminated with volatile compounds at the operating temperature.~~ High molecular weight organic compounds may foul or plug baghouses or condenser systems. Therefore, the types of petroleum products that can be treated by specific technologies may be limited. Rotary dryers can typically treat soils that have an organic content of less than 2 %. Thermal screw units may treat soils that contain up to 50 % organics.

Process description

After contaminated soil is excavated, the waste material is screened to remove objects greater than 4–8 cm in diameter. Direct or indirect heat exchange vaporises the organic compounds,

WORKING DRAFT IN PROGRESS

producing an off-gas which is typically treated before being vented to the air. In general, any one of four desorber designs are used: rotary dryer, asphalt plant aggregate dryer, thermal screw, and the conveyor furnace. The treatment systems include both mobile and stationary process units designed specifically for treating soil, and asphalt aggregate dryers that can be adapted to treat soils. Mobile systems are most often used, due to reduced soil transportation costs and to allow for backfilling of the treated soil. However, stationary systems are also available. ~~and it may be feasible to provide regional services. The desorbed gases may be incinerated.~~

In order to destroy contaminants, the desorption process needs a subsequent afterburning and waste gas treatment. The reason is that desorption merely strips them from the solid or liquid phase and transfers them to the gas phase. Therefore, devices to control air emissions are necessary. The efficiency of the thermal desorption process will vary with the chemical and physical properties of the specific contaminants. Metals (e.g. lead) tend to remain in the soil after treatment, so additional soil processing or treatment may be required (e.g. stabilisation). Thermal desorbers may operate near or above 500 °C, so some pyrolysis and oxidation may occur, in addition to the vaporisation of water and organic compounds.

Thermal desorbers operating~~e~~ at low~~er~~ temperatures~~,~~ ~~so~~ lead to significant fuel savings ~~may result when compared to incineration~~. They also produce smal~~ler~~ volumes of off-gases to be treated. Typical specifications for thermal desorption systems are shown in Table 5.135.

WORKING DRAFT IN PROGRESS

Table 5.135: Comparison of features of thermal desorption and off-gas treatment systems

	Rotary dryer	**Asphalt plant**	**Thermal screw**	**Conveyor furnace**
Mobility	Fixed and mobile	Fixed	Mobile	Mobile
Typical site size (tonnes)	450–23 000	0–9000	450–4500	450–5000
Soil throughput (tonnes/hour)	9–45	23–90	3–14	5–9
Maximum soil feed size (cm)	5–8	5–8	3–5	3–5
Heat transfer method	Direct	Direct	Indirect	Direct
Soil mixing method	Shell rotation and lifters	Shell rotation and lifters	Auger	Soil agitators
Discharge soil temperature (°C)	150–300 (1) 300–650 (2)	300–600	150–250 (3) 300–250 (4) 500–850 (5)	300–800
Soil residence time (minutes)	3–7	3–7	30–70	3–10
Thermal desorber exhaust gas temperature (°C)	250–450 (1) 400–500 (2)	250–450	150	500–650
Gas/solids flow	Co-current or countercurrent	Co-current or countercurrent	Not applicable	Countercurrent
Atmosphere	Oxidative	Oxidative	Inert	Oxidative
Afterburner temperature (°C)	750–1000	750–1000 (6)	Generally not used	750–1000
Maximum thermal duty (MJ/hr) (7)	10 500–105 000	5300–105 000	7400–10 500	10 500
Heat-up time from cold condition (hours)	0.5–1.0	0.5–1.0	Not reported	0.5–1.0
Cool-down time from hot condition (hours)	1.0–2.0	1.0–2.0	Not reported	Not reported
Total petroleum hydrocarbons				
Initial concentration (mg/kg)	800–35 000	500–25 000 (8)	60–50 000	5000
Final concentration (mg/kg)	< 10–300	< 20 (8)	ND–5500	< 10.0
Removal efficiency (%)	95.0–99.9	Not reported	64–99	> 99.9
BTEX				
Initial concentration (mg/kg)	Not reported	Not reported	155	Not reported
Final concentration (mg/kg)	< 1.0	Not reported	< 1.0	< 0.01
Removal efficiency (%)	Not reported	Not reported	> 99	Not reported

ND: not detectable.
(1) Carbon steel materials of construction.
(2) Alloy materials of construction.
(3) Hot oil heat transfer system.
(4) Molten salt heat transfer system.
(5) Electrically heated system.
(6) Not used on all systems.
(7) Total duty of thermal desorber plus afterburner.
(8) Vendor information.

Some techniques to optimise the desorption of contaminants are as follows:

From ex-**Section 4.3.2.11 "Thermal desorption of soil"**

a. Using of a bench-scale test to determine the suitability of thermal desorption and the best residence time and temperature to use.
The effectiveness of thermal desorption is related to the final soil temperature that is achieved, which in turn is a function of residence time and heat transfer. The temperatures and residence times effective in bench-scale systems have also proven to be effective in pilot-scale systems.
b. Applying the appropriate temperature.
The typical treatment temperature range for petroleum fuels from leaking underground storage tank sites is 200–480 °C. For the treatment of soils containing pesticides, dioxins, and PCBs, temperatures need to exceed 450 °C.

WORKING DRAFT IN PROGRESS

c. Reducing the moisture content of the soil to be treated within a specified range (this being applied due to the cost of treating waste with a high water content). The typical acceptable moisture range for rotary dryers and asphalt kilns is 10–30 %, while thermal screw systems can accommodate higher water loadings of 30–80 %. To remove VOCs, the ideal soil moisture content is 10–15 % for limiting the VOCs that the water vapour can carry away.

Users
Treatment of contaminated soils and tar containing asphalt and similar waste.

Reference literature
[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997] [29, Inertec; dechets, F. and Sita 2002] [98, WT TWG 2004]

5.6.1.2 Soil washing

From ex-**Section 2.3.3.13 "Soil washing"**

Purpose
Soil washing is carried out to separate the decontaminated fractions and pollutants.

Principle of operation
Soil washing is an *ex situ* process in which contaminated soil is excavated and fed through a water-based washing process. It operates on the principle that contaminants are associated with certain size fractions of soil particles and that these contaminants can be dissolved or suspended in an aqueous solution or removed by separating out clay and silt particles from the bulk soil. Additives such as surfactants or chelating agents are sometimes used to improve the separation efficiency (the treatment using additives may be referred to as chemical extraction). The aqueous solution containing the contaminants is treated by conventional waste water treatment methods.

The process is a water-based process and removes contaminants from soils in one of two ways:

a. by dissolving or suspending them in the wash solution (which is treated later by conventional waste water treatment methods);
b. by concentrating them into a smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing (similar to the techniques used in the mineral processing industry).

The concept of reducing soil contamination through the use of particle size separation is based on the finding that most organic and inorganic contaminants tend to bind, either chemically or physically, to clay, silt, and organic soil particles. The silt and clay are attached to sand and gravel particles by physical processes, primarily compaction and adhesion. Washing processes that separate the fine (i.e. clay and silt) particles from the coarser (i.e. sand and gravel) soil particles effectively separate and concentrate the contaminants into a smaller volume of soil that can be further treated or disposed of more easily.

Feed and output streams
Soil washing is effective for a wide range of organic and inorganic contaminants, including petroleum and fuel residues. Removal efficiencies range from 90 % to 99 % for volatile organic compounds and from 40 % to 90 % for semi-volatile compounds. Compounds with low water solubility such as metals, pesticides or PCBs sometimes require acids or chelating agents to assist in the removal. Some pilot-scale projects on radionuclides' pollution treatment have been reported. The washing process is also applicable for contaminated sand and gravel from construction and demolition waste.

WORKING DRAFT IN PROGRESS

While these separation processes may be more effective in treating soils contaminated with petroleum fuels, generally they are employed to treat soils containing metals or heavy organic compounds.

Soil washing may can be effective for the remediation of soils with a small amount of clay and silt particles, but large amounts of clay and silt particles mitigate the effectiveness of soil washing.

From ex-**Section 3.3.4 "Waste OUT from physico-chemical treatments"**

~~Waste OUT from a classical soil washing unit~~

Generally, soil washing units produce recycled materials suitable for the construction industry (concrete producers, asphalt plants) or as refilling materials after internal quality control and external control have been carried out on the specific properties of the materials (to ensure compliance with local regulations).

Different fractions can be distinguished:

- Coarse fraction: gravel which can be calibrated in several ways. These are basically formed by fine gravel measuring 2–20 mm and coarse gravel measuring 20–80 mm.
- Sand fraction: this consists of sand generally sized from 60 µm to 2 mm.
- Residual organic fraction (> 60 µm): these fractions are incinerated or sent to an appropriate landfill.
- Fine residual fraction (filter cake < 60 µm): usually this is sent to a special landfill with or without additional treatment (e.g. inertisation, stabilisation) or may be sent for a further treatment if required (e.g. thermal desorption, classical incineration).

Table 5.136 gives an illustration of the feed and output streams of soil washing.

Table 5.136: Output balance of a plant treating contaminated soil by washing

	Capacity (t/yr)
Waste input ~~IN~~	68 000
Output ~~waste OUT~~	50 500
◦ sand	36 000
◦ gravel	13 000
◦ fines	1 500

Source: [44, TWG 2003]

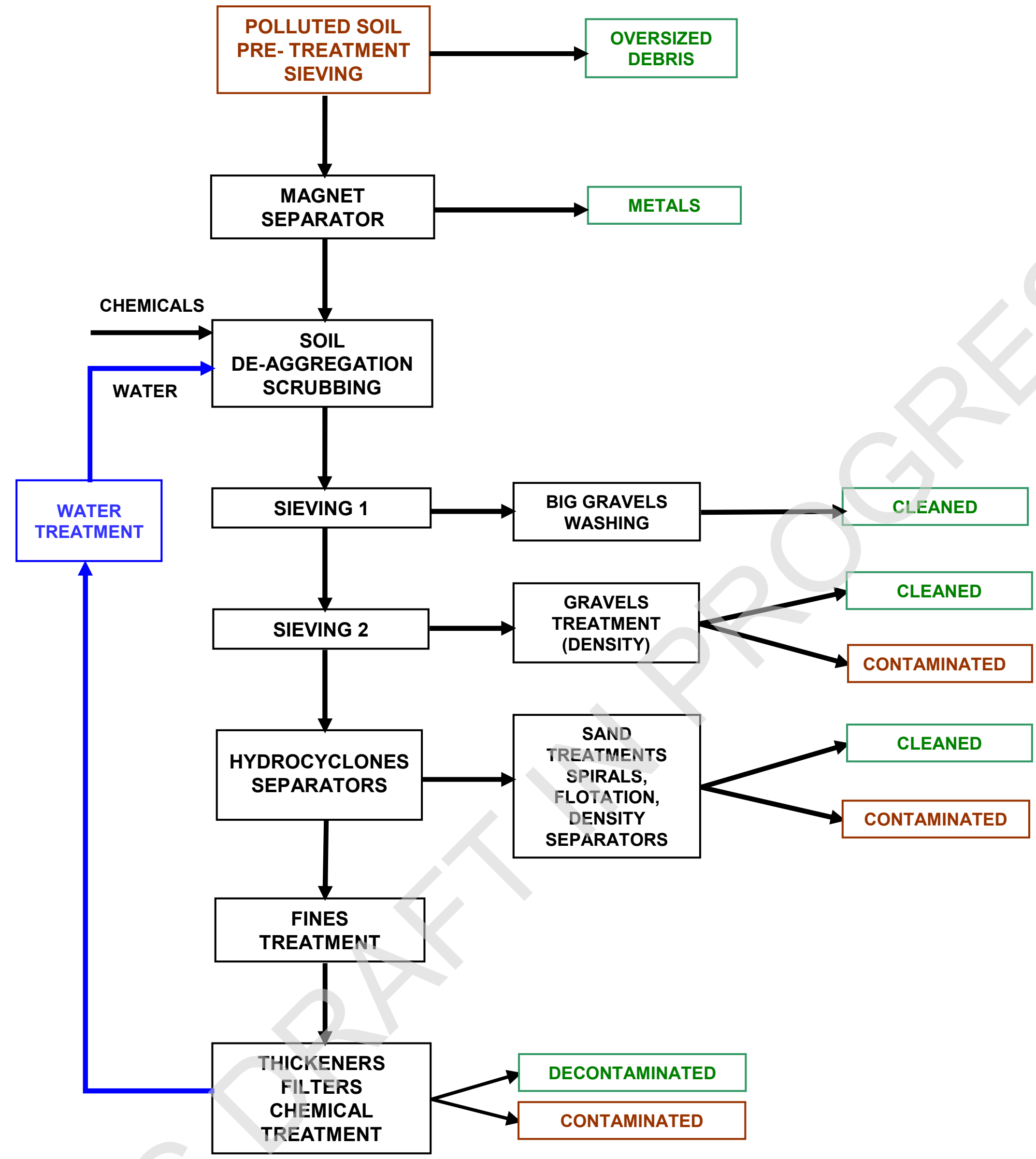
Process description

The excavation and removal of debris and large objects precedes the soil washing process. Sometimes water is added to the soil to form a slurry that can be pumped. After the soil is prepared for soil washing, it is mixed with washing water, and extraction agents are sometimes added.

After separation from the washing water, the soil is rinsed with clean water and may be returned to the site. The suspended soil particles are removed by gravity from the washing water as sludge. Sometimes flocculation is used to aid in sludge removal. This sludge is more contaminated than the original soil and undergoes further treatment or secure disposal. The spent washing water from which the sludge is removed is treated and recycled. Residual solids from the recycling process may require further treatment.

Figure 5.29 presents a general flow scheme of a soil washing plant.

WORKING DRAFT IN PROGRESS



Source: [79, Perseo, P. 2003]

Figure 5.29: General flow scheme of a soil washing plant

WORKING DRAFT IN PROGRESS

Typically, soil washing segregates a soil into a small volume of highly contaminated silt and clay and a larger volume of cleaned coarser soil.

Physical separation methods are mechanical methods for separating mixtures of solids to obtain a concentrated form of some constituents. Physical separation methods include screening, attrition scrubbing, or using hydrogravimetric separators as such hydrocyclones, jigs and spiral classifiers. In addition, in the majority of cases, the processes use water-based chemical agents, which provide both dispersion and extraction. Chemicals (dispersants, collectors, frothers, etc.) may be added in some cases to enhance the quality of the separation.

From ex-**Section 4.3.2.13 "Soil washing"**

~~ensuring that the sludge and solids from waste water treatment are subjected to appropriate treatment and disposal.~~

Table 5.137 and Table 5.138 give an overview of the performance of soil washing.

Table 5.137: Summary of the performance data for soil washing

Plant example	Contaminants	Concentration in the untreated soil (ppm)	Range of removal efficiencies (%)	Residual concentrations (ppm)
Example 1	Oil and grease	NI	50–83	250–600
Example 2	Pentachlorophenol	NI	90–95	< 115
	Other organics	NI	85–95	< 1
Example 3	Oil and grease	NI	90–99	< 5–2400
Example 4	Volatile organics	NI	98– > 99	< 50
	Semi-volatile organics	NI	98– > 99	< 250
	Most fuel products	NI	98– > 99	< 2200
Example 5	Aromatics	NI	> 81	> 45
	Crude oil	NI	97	2300
Example 6	Total organics	NI	96	159–201
	PAHs	NI	86–90	91.4–97.5
Example 7	Oil	NI	> 99	20
Example 8	Hydrocarbons	NI	96.3	82.05
	Chlorinated hydrocarbons	NI	> 75	< 0.01
	Aromatics	NI	99.8	< 0.02
	PAHs	NI	95.4	15.48
Example 9	Fuel oil	7666	65	2650
Example 10	Fuel oil	7567	73	2033
Example 11	Fuel oil	9933	72	2833

NI: no information
Source:[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]

~~below presents some indicative general efficiencies for soil washing treatment.~~

Table 5.138: Efficiencies of different components for soil washing

Pollutants	General efficiency [(1)]
TPH (C_{10}-C_{40})	90–98
PAHs	90–97
BTEX	90–97
PCBs	90–97
Metals	
As	60–80
Cd	60–80
Cr	80–90
Cu	75–85
Hg	85–95
Ni	85–90
Pb	90–95
Zn	85–95

[(1)] General efficiency = (1 – conc. in decontaminated sand/conc. in polluted soil) * 100.
Source: [79, Perseo, P. 2003]

Users

The soil washing technique is very well established in the Netherlands, Germany and Belgium, due to the sandy nature of the local soils. In 2003, eight plants in the Netherlands, six in Germany and six in Belgium were in operation. The technology is starting to become more developed in Switzerland and in northern Italy. Most plants have a capacity of 30–60 tonnes an hour. Furthermore, numerous on-site remediation projects have been performed with mobile plants, presenting usually smaller capacities (from 10 to 30 tonnes per hour).

TWG members, please confirm or provide updated information

Reference literature

[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997][79, Perseo, P. 2003]

WORKING DRAFT IN PROGRESS

Ex-Section **2.3.3.14 "Treatment of asbestos"** deleted: only one sentence which does not have added value

Ex-Section **2.3.3.15 "Bottom ash treatment"** deleted: excluded from scope, see KOM conclusion 1.5b

5.6.1.3 Vapour extraction

From ex-**Section 2.3.3.10 "Vapour extraction"** and ex-**Section 4.3.2.12 "Vapour extraction"**

Purpose

Vapour extraction can be used as a method for treating solid waste, e.g. excavated contaminated soil, with volatile hydrocarbons.

Principle of operation

In general terms, vapour extraction removes volatile organic constituents from contaminated waste by creating a sufficient subsurface airflow to strip contaminants from the vadose (unsaturated) zone by volatilisation. As the contaminant vapours are removed, they may be vented directly to the air or controlled in a number of ways.

Feed and output streams

Vapour extraction has been widely used to treat excavated soil contaminated with gasoline or chlorinated solvents (e.g. TCE). It is also sometimes used to minimise the migration of vapours into structures or residential areas during some other types of *in situ* remediation not covered in this document.

Spills or leaks of fuels typically involve liquids containing dozens of different constituents. For removal by this treatment to be effective, the contaminants must generally have vapour pressures greater than 1.0 mm Hg at -7 °C. Complete removal of contaminants may not be possible with this technique alone. Moreover, ~~The treatment is applicable to excavated soil. However,~~this technique it is not applicable for saturated soils or for soils with low air permeability~~, but~~. It is however applicable to the treatment of soil contaminated with PCBs.

Air emissions are released from a point source and, thus, can be readily controlled. The success of the method varies with the volatility (vapour pressure) of the contaminants present.

Significant residual contamination may remain in the solid waste after treatment

Process description

The success of the treatment for a given application depends on numerous factors with the two key criteria being the nature of the contamination and the nature of the waste (e.g. soil). The tendency of the organic contaminants to partition into water or to be adsorbed onto soil particles also affects its effectiveness, and hence the compound's water solubility, the Henry's Law constant, and the sorption coefficient to the solid waste are of interest. The temperature affects each of these variables and hence the rate of vapour diffusion and transport. Increasing the temperature is one option commonly considered for enhancing the treatment performance. Solid waste can be heated in one of three ways: 1) introduction of heated air or steam, 2) input of electromagnetic energy through the waste, or 3) heat release through a chemical reaction. The use of heated air or steam appears to be the most widely used approach.

From ex-Section 4.3.2.12

As the vapours are removed from the solid waste, they are treated to reduce air emissions. Direct combustion is theoretically possible if the hydrocarbon content of the exhaust gas is high enough, but the concentration typically drops significantly during removal. Therefore, natural gas or some other fuel is needed to maintain combustion. Also, for safety reasons, dilution air is typically added to maintain the VOC concentration below the lower explosive limit. For lower levels of hydrocarbons, catalytic oxidation or carbon adsorption may be effective.

WORKING DRAFT IN PROGRESS

Typical systems, measures, and equipement include extraction, monitoring, air inlet, vacuum pumps, vapour treatment devices, vapour/liquid separators, and liquid phase treatment devices.

Users

Vapour extraction has been used successfully for several years as a combined two-phase treatment of both groundwater and contaminated soil, and is increasingly being employed. Although this treatment may be used for a variety of soil types, its effectiveness depends on the ability of air to flow through the soil.

From ex-Section 4.3.2.12

~~**Economics**~~

Large volumes of excavated soil can be treated in a cost-effective manner.

Reference literature

[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997] [69, UNEP 2000] [98, WT TWG 2004] [100, WT TWG 2004]

5.6.1.4 Solvent extraction

From ex-**Section 2.3.3.11 "Solvent extraction"** and ex-**Section 4.3.2.14 "Solvent extraction"**

Purpose

Solvent extraction is much more effective for treating organic compounds than inorganic compounds and metals. It can be used in conjunction with other processes to reduce remediation costs.

Principle of operation

Solvent extraction differs from soil washing in that it employs organic solvents (e.g. propane, butane, carbon dioxide, aliphatic amines (e.g. triethylamine)) rather than aqueous solutions to extract contaminants from the soil. Like soil washing, it is a separation process that does not destroy the contaminants. It works as the contaminants will have a greater solubility in the solvent than in the soil.

Feed and output streams

Sediments, sludge, and soils contaminated with volatile organic compounds (VOCs), petroleum wastes, PCBs, and halogenated solvents can be effectively treated with solvent extraction. The removal of inorganic compounds such as acids, bases, salts, and heavy metals is limited, but these types of compounds usually do not hinder the remediation process. Metals may undergo a chemical change to a less toxic or leachable form, however their presence in the waste streams may still restrict disposal and recycling options.

Whilst these separation processes may be more effective in treating soils contaminated with petroleum fuels, they are generally employed to treat soils containing metals or heavy organic compounds.

The concentrated contaminants can be analysed and subsequently designated for further treatment, recycling, or reuse before disposal. While solvent extraction may improve the condition of the solids, often they may still need dewatering, treatment for residual organic compounds, additional separation, stabilisation, or some other treatment. The water from the dewatering process, the solids, and the water from the extractor are ~~will need to be~~ analysed to aid in the choice of the most appropriate treatment and disposal.

From ex-**Section 4.3.2.14"Solvent extraction"**

~~Applicable for the removal of PCB from soil.~~ The contaminated solvent must then be treated to destroy the PCBs.

Table 5.139 gives an illustration of the performance of solvent extraction.

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Table 5.139: Results of the remediation of API separator sludge by solvent extraction

Compound	Initial concentration (mg/kg)	Final concentration (mg/kg)	Removal (%)
Anthracene	28.3	0.12	99
Benzene	30.2	0.18	99
Benzo(a)pyrene	1.9	0.33	83
Bis-(2-ethylhexyl)phthalate	4.1	1.04	75
Chrysene	6.3	0.69	89
Ethylbenzene	30.4	0.23	99
Naphthalene	42.2	0.66	98
Phenanthrene	28.6	1.01	96
Pyrene	7.7	1.08	86
Toluene	16.6	0.18	99
Total xylenes	13.2	0.98	93
Source: [79, Perseo, P. 2003]			

Process description
The remediation process begins with excavating the contaminated soil and feeding it through a screen to remove large objects. In some cases, solvent or water is added to the waste in order to aid pumping it to the extraction unit. In the extractor, solvent is added and mixed with the waste to promote the dissolving of the contaminants into the solvent. Laboratory testing can determine which solvent adequately separates the contaminants from the soil. Generally, the solvent will have a higher vapour pressure than the contaminants (i.e. a lower boiling point) so that, with an appropriate pressure or temperature change, the solvent may be separated from the contaminants, compressed, and recycled to the extractor.

Users
Treatment of contaminated soil.

Reference literature
[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997] [69, UNEP 2000]

Ex-Section **2.3.3.12 "Excavation and removal of contaminated soil"** deleted: excluded from scope; see KOM conclusion 1.2d

5.6.1.5 Biodegradation [Biological treatments applied to contaminated soil]

From ex-**Section 2.2.3 "Biological treatments applied to contaminated soil"**

Purpose
To reduce the contamination of soil.

Principle of operation
Aerobic (see Section 4.2) and anaerobic degradation (see Section 4.3) of pollutants in the excavated soil.

Feed and output streams
The types of contaminants to be treated are biodegradable pollutants, fuels (gasoline, kerosene, gas oil, heating oils, heavy fuels), mineral oil, waste oils and heavy organic oils. The main products of this type of treatment are decontaminated excavated soils.

From ex-**Section 3.2.1 "Waste IN in biological treatments"**

~~**Biological treatments applied to contaminated soil**~~
Table 5.140 shows the desired characteristics of soil to be treated by biodegradation.

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Table 5.140: Desired inlet feed characteristics for slurry biodegradation processes for soil decontamination

Characteristic	Desired range
Organic content	0.025–25 w/w-%
Solids content	10–40 w/w-%
Water content	60–90 w/w-%
Solids particle size	< 0.635 cm diameter
Feed temperature	15–35 °C
Feed pH	4.5–8.8

Source: [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]

The effectiveness of slurry biodegradation for certain general contaminant groups is shown in Table 5.141.

Table 5.141: Applicability of slurry biodegradation for treatment of contaminants in soil, sediments and sludges

Contaminant	Applicability
Organic contaminants:	
Halogenated semi-volatiles	2
Non-halogenated semi-volatiles	2
Pesticides	2
Halogenated volatiles	1
Non-halogenated volatiles	1
Organic cyanides	1
PCBs	1
Dioxins/furans	0
Organic corrosives	0
Inorganic contaminants:	
Inorganic cyanides	1
Asbestos	0
Inorganic corrosives	0
Non-volatile metals	0
Radioactive materials	0
Volatile metals	0
Reactive contaminants:	
Oxidisers	0
Reducers	0

NB:
0 = No expected effectiveness - expert opinion is that the technology will not work.
1 = Potential effectiveness - expert opinion is that the technology will work.
2 = Demonstrated effectiveness - successful treatability test on some scale has been completed.
Source:[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]

Table 5.142 gives an illustration of the performance of slurry degradation.

From ex-**Section 3.2.4 "Waste OUT from biological treatments"**

~~**Biological treatments applied to contaminated soil**~~

WORKING DRAFT IN PROGRESS

Table 5.142: Performance of a slurry biodegradation process treating wood-preserving wastes

Compound	Initial concentration		Final concentration		Removal (1)	
	Solids (mg/kg)	Slurry (mg/kg)	Solids (mg/kg)	Slurry (mg/kg)	Solids (%)	Slurry (%)
Phenol	14.6	1.4	0.7	< 0.1	95.2	92.8
Pentachlorophenol	687	64	12.3	0.8	98.2	92.8
Naphthalene	3670	343	23	1.6	99.3	99.5
Phenanthrene and anthracene	30 700	2870	200	13.7	99.3	99.5
Fluoranthene	5470	511	67	4.6	98.8	99.1
Carbazole	1490	139	4.9	0.3	99.7	99.8

NB: Treatment carried out using a 190 m^3 reactor.
(1) Includes the combined effect of volatilisation and biodegradation.
Source: [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]

From ex-**Section 2.2.3 "Biological treatments applied to contaminated soil"**

Process description

The lack of oxygen is the most limiting factor of pollutant biodegradation in soil and lots of different processes have been developed to optimise soil oxygenation. The various biological treatments differ with the aeration techniques used. Two types of processes exist: *in situ* and *ex situ*.

In situ biodegradation

In situ biodegradation is the term for biological treatment processes that are performed in the original place where the contaminated soil is found. Such processes are not covered in this document.

Ex situ biodegradation

Ex situ biodegradation is the general term for treatment processes in which the contaminated soil or sludge is excavated and remediated through biological processes. *Ex situ* bioremediation technology most often involves slurry phase bioremediation where aqueous slurry is created by combining contaminated soil or sludge with water and then the contaminants are biodegraded in a self-contained reactor or in a lined lagoon. *Ex situ* biodegradation also encompasses solid phase bioremediation, such as landfarming, composting, and biopiles. In these processes, the contaminated soil is excavated, and oxygen, nutrients, water, or microorganisms are added to enhance the natural biodegradation of the contaminants.

Slurry phase bioremediation

There are two main objectives behind using slurry phase bioremediation: (1) to destroy the organic contaminants in the soil or sludge, and, equally important, (2) to reduce the volume of contaminated material. Slurry biodegradation has been shown to be effective in treating highly contaminated soils that have fuel or other organic contaminant concentrations ranging from 2500 mg/kg to 250 000 mg/kg. The slurry process has also shown some potential for treating a wide range of contaminants, including pesticides, creosote, pentachlorophenol, PCBs, and other halogenated organics.

Waste preparation is required before applying slurry biodegradation. The preparation may include excavation and handling of the waste material, as well as screening to remove debris and large objects. Particle size reduction, water addition, and pH and temperature adjustment may also be required to meet feed specifications.

Once biodegradation of the contaminants is completed, the treated slurry is sent to a separation/dewatering system. A clarifier for gravity separation can be used to remove the water from the soil.

Solid phase bioremediation

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Solid phase bioremediation involves the excavation and preparation of contaminated soil to enhance the bioremediation of contaminants in the soil. The techniques typically used for preparation of the soil to be bioremediated are sifting/riddling, homogenisation, nutrient improvement and compost addition. The bioremediation is carried out in biopiles (soil turning or air injection).

Aerobic digestion involves the storage of biodegradable waste with a bulking agent to increase the porosity of the soil material. Bioremediation is similar to composting in that the contaminated soil is piled in large mounds. However, for these processes, air is usually provided by pulling a vacuum through the pile.

Users
Contaminated soils.

Ex-**Section 4.2.9 "Aerobic digestion of slurries"** deleted because of repetition of 5.6.1.5

5.6.2 Current emission and consumption levels

From ex-Section 3.3.3.2

Deleted: outside scope according to KOM conclusion 1.2d

~~**Emissions from soil excavation and removal activities**~~

~~VOC emissions from handling operations in soil excavation and removal result from the exchange of contaminant-laden soil pore gas with the atmosphere when soil is disturbed, and from some diffusion of the contaminants through the soil. There are several potential emission points involved in excavation; all are considered to be fugitive area sources. For excavation, the main emission points of concern are emissions from:~~

- ~~exposed waste in the excavation pit~~
- ~~material as it is dumped from the excavation bucket, and~~
- ~~waste/soil in short-term storage piles.~~

~~In addition, the earth-moving equipment will involve additional sources of emissions of VOC, particulate matter, nitrogen oxides, etc. It is known that large amounts of VOCs may be released from soil during handling, so VOCs are typically the emissions of most concern. Emissions of particulate matter and associated metals and semi-volatile compounds may be of concern at particular sites.~~

~~Given the frequency with which the excavation of contaminated soils is carried out, surprisingly little air emission or emission rate data for excavation have been published.~~

~~However, some measured emission rates for two sites for combined excavation and dumping operations are available and quote figures as high as 4 g/min for specific compounds. Here, most of the VOCs present in the soil was stripped from the soil during excavation, based on a comparison of measured total emissions versus the mass of these same contaminants in the soil (calculated from soil concentration data). This was true for both sites, despite differences in soil concentrations and soil type.~~

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Table 5.143: Results of emission measurements

~~**Activity**~~	~~**Sludge volume**~~ ~~(m^3)~~	~~**Exposed surface area**~~ ~~(m^2)~~	~~C_{8+} hydrocarbon emission rate~~ ~~**(g/s)**~~	~~C_{8+} emission flux ($g/m^2/s$)~~
~~Sludge disturbance~~	~~25 – 27~~	~~45 – 125~~	~~1.33~~	~~0.01 – 0.03~~
~~Sludge excavation~~	~~26 – 48~~	~~125 – 261~~	~~7.76~~	~~0.03 – 0.06~~
~~Sludge dewatering~~	~~1.7~~	~~3.3~~	~~1.24~~	~~0.38~~
~~Post-disturbance~~	~~26~~	~~91~~	~~1.11~~	~~0.01~~

~~*Source*: Based on [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]~~

~~The magnitude of volatile organic compound (VOC) emissions depends on a number of factors, including the type of compounds present in the waste, the concentration and distribution of the compounds, and the porosity and moisture content of the soil. The key operational parameters are the duration and liveliness of the handling, and the size of equipment used. The longer or more energetic the moving and handling, the greater likelihood that organic compounds will be volatilised. The larger the volumes of material being handled per unit operation, the lower the percentage of VOCs that are stripped from the soil, because the surface area to volume ratio is minimised.~~

~~Soil containing benzene or other volatile carcinogens would likely pose a large risk to on-site workers and the surrounding populace if it were to be excavated.~~

~~The magnitude of emissions from soil handling operations will vary with the operating conditions. The rate of excavation and dumping, the drop height, the amount of exposed surface area, the length of time that the soil is exposed, the shape of the storage piles, and the dryness of the surface soil layers will all influence the levels of VOC emissions. Add-on control technologies are available for minimising emissions, but these are relatively ineffective and costly to implement compared with the controls for point sources.~~

Table 5.144 gives an overview of the plants from the reference list treating contaminated soil, together with the process used and the associated emissions to air and water.
There are three types of plants on the reference list:

- plants performing biodegradation of contaminated soil, where, except in one case, there are no channelled emissions to air and emissions to water mostly originate from run-off water or from landfills which are operated on the same site;
- plants performing thermal desorption of contaminated soil, where emissions are mainly to air;
- plants performing water washing of contaminated soil, where emissions are mainly to water.

This section focuses on the last two categories.

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Table 5.144: Plants from the reference list treating contaminated soil

Plant code	Waste input	Waste input description	Process	Origin of emissions to air	Origin of emissions to water
014	Contaminated soil Water-based liquid waste Other industrial solid waste	Soil from site remediation, landfill leakage, industrial waste water, industrial waste	Soil water washing	Soil washing plant	Process water treatment unit
040	Contaminated soil	Hazardous and non hazardous waste: mainly contaminated soil (70–80 %), concrete, used construction materials and waste	Dry and wet sieving Crushing Soil water washing with addition of flocculants and pH control (process and waste water treatment are identical). Specific weight separator for wood and other materials with lower specific weight.. Physico-chemical waste water treatment plant with champer filter press (process and waste water treatment are identical).	Storage of hazardous waste and soil washing	Soil washing
105	Contaminated soil	Contaminated soil typically from former industrial sites being renovated or other types of clean-up operations	Aerobic biodegradation	No channelled emissions to air	All water at the open-air process is collected in a concrete tank. The water is used on a continuous basis for the biological soil-cleaning process (humidification, for dust control, and for evaporation. No water is emitted to outside recipients

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186C	Contaminated soil	NI	Biological degradation (residence time 3–6 months) and air stripping	NI	NI
188C	Contaminated soil	NI	Desorption in directly fired rotary kiln	Desorption	No emissions to water
353_359	Contaminated soil	Organic contaminated soil (mainly hydrocarbons)	Aerobic biodegradation	Aerobic biodegradation	The water stream is mainly due to the storm water collected from the roof building and the internal square/transit route
481	Green waste Sludge Contaminated soil Other	Wood and other green waste from gardens and parks, sludge from the municipal waste water treatment plant, fibre waste from production of pulp and paper, contaminated soil, horse manure, bottom ash from combustion plant at pulp and paper installation, fire-damaged paper and water-damaged paper, bark	Ferromagnetic separation, aerobic biodegradation (The composting process is carried out until sufficient biodegradation is achieved to use the compost to cover the closed parts of the landfill with soil).	No channelled emissions to air	All processes including leachate from the landfill. Water is discharged to an on-site common WWT facility (when the design/operation of the WWT facility is mainly influenced by waste water streams coming from activities other than the WT plant)

WORKING DRAFT IN PROGRESS

482_483	Contaminated soil Sludge Waste with calorific value WEEE Other	Oil contaminated soil, sewage sludge from municipal waste water treatment and from small-scale residential waste water treatment, wood waste and other calorific waste, Unspecified HW, treated-wood waste WEEE+ other waste (fluorescent lamps, cooling equipment, electronic waste)	Aerobic biodegradation (residence time > 1 year). Contaminated soil and sewage sludge is composted in open air strips. The waste is mixed with 'green waste' to get the correct N/C ratio, and a structure that allows oxygen. Contaminated soil is composted and stored on sealed concrete surfaces with collection of water directed to the external WWTP.	No channelled emissions to air	The main part of the waste water originates from the landfill. Waste water is treated in a municipal waste water treatment plant
494	Waste with calorific value	Drilling cuttings from oil-based muds	Indirectly fired rotary kiln	Indirectly fired rotary kiln Thermal oxidiser	Indirectly fired rotary kiln
625	Contaminated soil	Soil contaminated with hazardous substances from various locations	Aerobic biodegradation (residence time: 1 year on average. Can typically range from 3 to 48 months)	No channelled emissions to air. No air emission control requirements, but odorous/volatile heaps are covered if necessary. If a significant smell is detected, the waste treatment in question is stopped	Batch transport of excess of collected leachate from sedimentation basin. The excess leachate is transported to municipal waste treatment plant by truck

NI: No information.

WORKING DRAFT IN PROGRESS

5.6.2.1 Emissions from thermal desorption

From ex-**Section 3.3.3.2 "Emissions from the physico-chemical treatment of waste solids and sludges"**

Air emissions from thermal desorption systems are influenced by the waste characteristics, the desorption process applied, and the emissions control equipment used. The air emissions associated with thermal desorption come from several sources. The point sources of air emissions vary widely with each process. The stack of an afterburner vents combustion products, as does a fuel-fired heating system if the combustion gases are not fed into the desorber. A fuel-fired heating system typically operates with propane, natural gas, or fuel oil. If the VOC emission controls consist of a ~~baghouse~~ bag filter, scrubber, and vapour phase carbon adsorber, the off-gas will contain small concentrations of the original contaminants, as well as the products of any chemical reactions that might occur. The volume of off-gas from a thermal desorption unit depends on the type of processor. ~~Table 5.147 below gives some values for emissions from thermal desorption~~. Table 5.145 and Table 5.146 below give an overview of the air emissions at the two plants from the reference list performing thermal desorption.

Table 5.145: Control of air emissions at plants performing thermal desorption of contaminated soil

Plant	**Heating mode**	**Average flow rate of air emissions (Nm^3/h)**	**Abatement techniques**	**Pollutants measured**
188C	Direct heating	30771	Alkaline scrubbing (for SO_2), Thermal oxidation (temperature 850 °C and residence time of 2 seconds for VOCs, PAHs, VOC) Activated carbon adsorption (for mercury and PCDD/PCDF), Bag/fabric filter system (for dust)	Dust, SO_X, NO_X, CO, HCl, HF, TVOC, Cd+Tl, Hg, Sum metals, PCDD/PCDF
494$^{(1)}$	Indirect heating	3993	Cyclone, Condensation of oil and aqueous fractions to further recover and separate oil product and clean water which can be recycled through the system, Thermal oxidation	SO_X, NO_X, CO, TVOC

(1) Monitoring of stack is not required, therefore data are only available for 2010.

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Table 5.146: Emissions to air measured at plants performing thermal desorption of contaminated soil

Parameter measured	Type of measurement	Plants concerned	Range of average values (mg/Nm^3 except for flow)	Number of measurements during the three reference years	Standards or methods used
Flow (m^3/h)	Continuous	188C	30 771	Short-term average: 1/2h / Long-term average: Daily	NI
	Periodic	494	3993	1	NI
Dust	Continuous	188C	Short-term average: 10.1 Long-term average: 4.4	Short-term average: 1/2h / Long-term average: Daily	Beta
SO_X	Continuous	188C	Short-term average: 42 Long-term average: 12.1	Short-term average: 1/2h / Long-term average: Daily	IR
	Periodic	494	1087	1	TGN M21
NO_X	Continuous	188C	Short-term average: 148.3 Long-term average: 116.4	Short-term average: 1/2h / Long-term average: Daily	IR
	Periodic	494	478	1	BS EN 14792
CO	Continuous	188C	Short-term average: 23.3 Long-term average: 9.9	Short-term average: 1/2h / Long-term average: Daily	IR
	Periodic	494	9.8	1	BS EN 15058
HCl	Continuous	188C	Short-term average: 4.1 Long-term average: 1.4	Short-term average: 1/2h / Long-term average: Daily	IR
HF	Continuous	188C	Short-term average: 0.9 Long-term average: 0.3	Short-term average: 1/2h / Long-term average: Daily	IR
TVOC	Continuous	188C	Short-term average: 8.9 Long-term average: 3.4	Short-term average: 1/2h / Long-term average: Daily	IR
	Periodic	494	3.7	1	BS EN 12619
Cd+Tl	Periodic	188C	0.016	6	NF EN 14385
Hg	Periodic	188C	0.113	6	NF EN 13211
Sum metals	Periodic	188C	0.158	6	NF EN 14385
PCDD/PCDF	Periodic	188C	0.035	6	NF EN 1948-1-2-3

NI: No information.
IR: infrared

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Table 5.147: Emissions from direct and indirect heating thermal desorption

	~~Flow of gases (Nm^3/h)~~	~~Pollutants that may be contained~~
~~Direct heating~~	~~17000 – 85000~~	~~VOC~~
~~Indirect heating~~	~~1700 – 8500~~	~~VOC~~
~~*Source*: [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]~~		

Various types of thermal desorption systems can produce up to nine residual process streams: treated soil, oversized media rejects, condensed contaminants, water, ~~particulate control~~ dust, clean off-gas, phase separator sludge, aqueous phase spent carbon, and vapour phase spent carbon. Off-gases from indirectly heated units, ~~i.e.~~ e.g. thermal screws, can be treated with smaller chemical/physical systems, such as a ~~baghouse~~ bag filter or a condenser, followed by an afterburner.

Table 5.148: Generic emissions from thermal desorption

~~Pollutant~~	~~From~~
~~Fugitive emissions~~	• ~~excavation of contaminated soil~~ • ~~classifier, feed conveyor, and the feed hopper~~ • ~~components of the thermal desorption system and controls~~ • ~~exhaust gases from the heating system, treated soil, particulate control dust, untreated oil from the oil/water separator, spent carbon from liquid or vapour phase carbon adsorber, treated water, and scrubber sludge~~
~~Particulate matter, nitrogen oxides (NO^x), carbon monoxide (CO) and acid gases~~	~~Combustion and pyrolysis~~
~~Dioxins, furans and phenol~~	
~~*Source*: [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]~~	

As for emissions to water, in one case there is no water release mentioned (Plant 188C) and in the other (494) waste water is tankered to off-site WWT after oil is skimmed out but no measurement is performed.

Table 5.149: Characteristics of inputs and outputs of asphalt aggregate dryers

~~Parameter~~	~~Initial concentration~~ [1] ~~(ppm)~~	~~Final concentration~~ [1] ~~(ppm)~~	~~Removal efficiency (%)~~	~~Typical off-gas characteristics~~[2] ~~stack concentration~~
~~PM~~		~~700 – 1000 mg/Nm^3~~		
~~Benzene~~	~~0.11 - 39.5~~	~~<0.01 – 0.06~~	~~84.5 – 99.9~~	~~4.3 – 8.6 ppm~~
~~Toluene~~	~~0.27 – 2~~	~~<0.01 – 0.1~~	~~n/a~~	~~0.6 – 0.8 ppm~~
~~m,p-Xylenes~~	~~<0.8 – 3~~	~~0.2 – 1.2~~	~~<75~~	~~0.42 – 3.5 ppm~~
~~o-Xylenes~~	~~3.1 – 15.6~~	~~<0.01~~	~~99.7 – 99.9~~	
~~Total Xylenes~~	~~13.1~~	~~0.1~~	~~99.2~~	
~~Ethylbenzene~~	~~0.11~~	~~<0.01~~	~~>90~~	
~~THC~~	~~39 – 393~~	~~5.7 – 9.5~~	~~85 – 97.5~~	~~129 – 2800 ppm~~
~~VOC~~		~~0.045 – 2.27 kg/h~~		
~~Diesel~~	~~1875~~	~~<1~~	~~>99.9~~	
~~Naphthalene~~				~~5136 – 6757 µg/Nm^3~~
~~Acenaphtylene~~				~~634 – 901 µg/Nm^3~~
~~Acenaphthene~~				~~317 – 638 µg/Nm^3~~
~~Fluoranthene~~				~~405 – 763 µg/Nm^3~~
~~Phenanthrene~~				~~385 – 645 µg/Nm^3~~
~~Anthracene~~				~~<1.4 – 427 µg/Nm^3~~
~~Fluoranthene~~				~~24 – 135 µg/Nm^3~~
~~Pyrene~~				~~32 – 111 µg/Nm^3~~

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~~[1] Based on two or three installations depending on the parameter.~~

~~[2] Based on two installations. Emission control equipment consists of a wet scrubber and cyclonic demister. ppm values refered to dry conditions~~

~~The VOC emissions from asphalt aggregate dryers will vary by several orders of magnitude depending on whether afterburners are used as a control device. These treatment systems typically do not employ VOC controls, unless they have been modified for soil remediation.~~

~~A company has estimated the typical emissions for soil treatment in a modified asphalt aggregate dryer. This system consists of a direct-fired rotary drum operating at 290 – 540 °C. A primary cyclonic tube collector and pulse-jet baghouse are used to control particulate emissions. A thermal oxidiser (i.e. an afterburner) destroys organic compounds in the off-gas stream (99 – 99.99 % efficiency). Based on a processing rate of 32 – 54 t/h.~~

~~*Source*:[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]~~

Table 5.150: Estimated emissions of selected compounds for the clean-up of PCB contaminated soil using a thermal desorption process

~~Contaminant~~	~~Units~~	~~Residence time (minutes)~~	~~Temperature (°C)~~	~~Initial concentration~~	~~Final concentration~~	~~Rate of uncontrolled emissions (g/h)~~	~~Estimated emissions rate (g/h)~~
~~PCBs~~	~~ppm~~	~~19~~	~~550~~	~~37.5~~	~~2~~	~~1.14~~	~~5.68e-02~~
~~2,3,7,8-TCDD~~	~~ppb~~	~~40~~	~~560~~	~~260~~	~~0.018~~	~~0.00832~~	~~4.16e-04~~
	~~ppb~~	~~19~~	~~560~~	~~236~~	~~0.018~~	~~0.00755~~	~~3.78e-04~~
	~~ppb~~	~~10.5~~	~~560~~	~~266~~	~~0.018~~	~~0.00851~~	~~4.26e-04~~
	~~ppb~~	~~24~~	~~460~~	~~233~~	~~0.5~~	~~0.00744~~	~~3.72e-04~~
	~~ppb~~	~~5.6~~	~~550~~	~~48~~	~~0.084~~	~~0.00153~~	~~7.67e-05~~
	~~ppb~~	~~20~~	~~555~~	~~56~~	~~0.23~~	~~0.00178~~	~~8.92e-05~~

~~Overall estimated efficiency is 95 %~~

~~*Source*: [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]~~

Energy consumption

The reported average energy consumption per tonne of waste treated is around 300 kWh/t. The main energy source is fossil fuel (liquid or gaseous).

Water usage

The reported average water usage is around 135 l/tonne of waste treated, with a range of around 90–180 l/t. In one case, water is used mainly for dust suppression (dried solids are wetted). In the other case, water is used in a wet scrubber and for soil cooling.

Raw material consumption

Table 5.151 below gives an overview of the raw material consumption at plants performing thermal desorption of contaminated soil.

Table 5.151: Consumption of raw material at plants performing thermal desorption of contaminated soil

Raw material	Range of consumption in the reference period (t/year)
Alkalis	29.9–39.9
Activated carbon	0–25
Bag filters	0–336 units
Flocculants	1

5.6.2.2 Emissions from vapour extraction of solid waste

The air emissions associated with vapour extraction systems come primarily from the stack. Additional releases of volatile organics may occur from the treatment of any contaminated water that is extracted. Fugitive emissions are considered negligible due to the negative pressure throughout most of the system.

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Emissions include untreated volatile organics from the extraction process. ~~A removal and subsequent emission of~~ Semi-volatile organic compounds will be removed ~~also occur~~, though less ~~efficiently~~ completely than for VOCs, leading to subsequent emissions to air. There may also be smaller amounts of air emissions associated with the control system. Due to the variety of technologies used for vapour treatment, stack emissions may also include some products of incomplete combustion, NO_X, particulate matter, CO, and acid gases. Of primary concern, however, are the volatile organics emitted from the point sources. Air emissions data for several vapour extraction systems are summarised in Table 5.152.

Table 5.152: Emissions from vapour extraction systems

No of systems surveyed	Parameter	Units	Range or value	Approximate average
13	Flow rate per well	m^3/min	0.2–8	2
	Removal	kg/day	0.9–113	27
	Exhaust gas concentration	ppmv	20–350	100
17	Total flow rate	m^3/min	0.1–161	23
	Treatment:	n^o systems		
	• none		9	
	• carbon		6	
	• catalytic incineration		1	
	• combustion		1	
	Removal rate	kg/day	2–195	45
17	Total flow rate	m^3/min	0.7–318	62
	Pollutant concentration	ppmv	150–3000	400
	Control efficiency	%	90–99	95
Source: [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]				

The emission rate of VOCs over time from continuously operated vapour extraction systems tends to show an exponential-type decay curve.

Outside the scope according to KOM conclusion 1.2d

Table 5.153: Estimated emissions for an *in situ* vacuum extraction system

~~**Pollutant**~~	~~Peak uncontrolled stack emissions[1] (g/h)~~	~~Peak controlled stack emissions[2] (g/h)~~
~~Trichloroethylene (TCE)~~	~~1712~~	~~17.1~~
~~trans-1,2-Dichloroethylene (DCE)~~	~~99.4~~	~~0.99~~
~~1,1,1-Trichloroethane (TCA)~~	~~13.6~~	~~0.14~~
~~Tetrachloroethylene (PCE)~~	~~3.18~~	~~0.03~~
~~TOTALS~~	~~1830~~	~~18.3~~
~~[1] Uncontrolled emissions based on the removal rate of each contaminant~~ ~~[2] Based on estimated 99 % overall control efficiency for two carbon adsorption canisters in series~~ ~~*Source*: [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]~~		

5.6.2.3 Emissions and consumption of soil washing

In the soil washing process, the greatest potential for emissions of volatile contaminants occurs in the excavation, material handling, feed preparation, and extraction processes. The waste streams also have the potential to be sources of VOC emissions. The solvent recovery process involves vaporisation of the solvent, so fugitive emissions are possible from this as well as from other stages of the solvent process. Waste streams also have the potential to be sources of VOC emissions if any VOCs are already present in the waste stream. For solvent extraction processes, emissions of the solvent itself may also be a cause for concern.

WORKING DRAFT IN PROGRESS

Storage areas need to be kept under specific control to avoid pollution dispersion, especially of dust. For liquid effluents, the plants are always equipped with a water-slurry treatment unit, where the water is sent before being discharged.

Soil washing generates four waste streams: contaminated solids separated from the washing water; waste water; waste water treatment sludge and residual solids; and air emissions.

Table 5.154 and Table 5.155 give an overview of air emissions at the two plants from the reference list carrying out water washing of contaminated soil.

Table 5.154: Control of air emissions at plants performing water washing of contaminated soil

Plant	Average flow rate of air emissions (Nm^3/h)	Abatement techniques	Pollutant measured in air emissions
014	17	Wet scrubbing (one horizontal and one vertical wet scrubber)	Dust
040(1)	NI	Bag/fabric filter system Activated carbon adsorption Water spraying (dust)	TOC, Hg, Pb, Cr, Ni
(1) Abatement system installed in summer 2014. No measurements provided in the questionnaire. NI: No information.			

Table 5.155: Pollutants measured in air emissions from plants performing water washing of contaminated soil

Pollutant measured	Type of measurement	Plants concerned	Average (mg/Nm^3)	Number of measurements during the three reference years	Standard or method used
Dust	Periodic	14	1.9	3	Gravimetric
TOC	Periodic	40	NI	3	NI
Hg	Periodic	40	NI	3	NI
Sb	Periodic	40	NI	3	NI
Cr	Periodic	40	NI	3	NI
Ni	Periodic	40	NI	3	NI
NI: No information.					

As for water, there are no plants with direct discharge to the environment. Table 5.156 and Table 5.157 give an overview of the emissions to water at the two plants from the reference list carrying out water washing of contaminated soil.

WORKING DRAFT IN PROGRESS

Table 5.156: Control of emissions to water at plants performing water washing of contaminated soil

Plant code	Origin of emissions to water	Point of release	Receiving body	Techniques for emissions to water	Average Water flow (m3/h)	Pollutants measured in water emissions
014	Process water treatment unit	Discharge from the WT plant and its auxiliary systems, as well as from on-site waste water pretreatment facilities, to an urban/municipal sewer system	NI	Decantation, flocculation, neutralisation, sedimentation (ponds), precipitation, buffer tanks, flotation, sand filter, activated carbon filter	5.5	pH, THC, PAHs, CN^-, Sulphates, Cd, Hg, Pb, Cr, Cu, Zn, AOX, BTEX, PCB
040	Soil washing	Discharge from the WT plant and its auxiliary systems, as well as from on-site waste water pretreatment facilities, to an urban/municipal sewer system	River/Stream	Decantation with flocculants, press filtering, filtration, active carbon filtration/adsorption, pH control and regulation with CO_2 injection, buffer tanks, biological nutrient removal. The pretreated waste water is discharged in a common biological WT plant (not part of the treatment plant). Internal water circuit. Reduction of water usage and minimisation of waste water. The used water in the plant is reused internally after cleaning as often as possible (circuit) before discharge to the waste treatment plant.	15	pH, TSS, THC, PAHs, F^-, S^{2-}, SO_3^{2-}, CN^-, NO_2^-/NO_3^-, Cd, Hg, As, Pb, Cr, Cr(VI), Co, Cu, Ni, Zn, Chlorine, Phenols, AOX, BTEX, Sn

NI: No information.

WORKING DRAFT IN PROGRESS

Table 5.157: Parameters measured in emissions to water at plants performing water washing of contaminated soil

Pollutant measured	Type of measurement	Plants concerned	Average measurement (mg/l except for pH)	Number of measurements during the three reference years
pH	Composite sample	14	8.4	NI
	24-hour flow-proportional composite sample	40	8.4-11.4	Daily average
TSS	24-hour flow-proportional composite sample	40	61	Daily average
THC	24-hour flow-proportional composite sample	40	0.087	Daily average
	Composite sample	14	2.52	NI
PAHs	24-hour flow-proportional composite sample	40	0.057	Daily average
	Composite sample	14	0.0006	NI
F^-	24-hour flow-proportional composite sample	40	1.7	Daily average
S^{2-}	24-hour flow-proportional composite sample	40	0.1	Daily average
SO_3^{2-}	24-hour flow-proportional composite sample	40	0.5	Daily average
CN^-	24-hour flow-proportional composite sample	40	0.04	Daily average
	Composite sample	14	0.005	NI
Sulphates	Composite sample	14	644	NI
NO_2^-/NO_3^-	24-hour flow-proportional composite sample	40	5.8	Daily average
Cd	24-hour flow-proportional composite sample	40	0.005	Daily average
	Composite sample	14	0.008	NI
Hg	24-hour flow-proportional composite sample	40	0.0011	Daily average
	Composite sample	14	0	NI
As	24-hour flow-proportional composite sample	40	0.017	Daily average
Pb	24-hour flow-proportional composite sample	40	0.01	Daily average
	Composite sample	14	0.0349	NI
Cr	24-hour flow-proportional composite sample	40	0.089	Daily average
	Composite sample	14	0.0273	NI
Cr(VI)	24-hour flow-proportional composite sample	40	0.036	Daily average

WORKING DRAFT IN PROGRESS

Co	24-hour flow-proportional composite sample	40	0.008	Daily average
Cu	24-hour flow-proportional composite sample	40	0.023	Daily average
	Composite sample	14	0.184	NI
Ni	24-hour flow-proportional composite sample	40	0.0074	Daily average
Zn	24-hour flow-proportional composite sample	40	0.019	Daily average
	Composite sample	14	0.325	NI
Chlorine	24-hour flow-proportional composite sample	40	0.1	Daily average
Phenols	24-hour flow-proportional composite sample	40	0.113	Daily average
AOX	24-hour flow-proportional composite sample	40	0.059	Daily average
	Composite sample	14	0.9	NI
BTEX	24-hour flow-proportional composite sample	40	0.0025	Daily average
	Composite sample	14	0.0017	NI
PCB	Composite sample	14	0	NI
Sn	24-hour flow-proportional composite sample	40	0.014	Daily average

Table 5.158: Emissions from an installation treating contaminated soil by washing

~~**Water parameter**~~	~~**Concentration (mg/l)**~~
~~Suspended solids~~	~~60~~
~~BOD^5~~	~~25~~
~~COD~~	~~350~~
~~Nitrit N (NO^2-N)~~	~~10~~
~~P, total~~	~~2~~
~~Cr, total~~	~~0.3~~
~~Cu~~	~~0.5~~
~~Hg~~	~~0.005~~
~~Ni~~	~~0.3~~
~~Pb~~	~~0.3~~
~~Zn~~	~~2~~
~~Residues generated by the process[1]~~	
~~Sludges~~	~~Mineral sludges~~
~~Other residual fractions~~	~~Particle PAHs and metal oxides~~
~~**Note: Capacity of the installation is 68 kt/yr**~~ ~~[1] The subsequent fate of these residues are reported to be landfill~~ ~~*Source*: [33, UK EA 2001]~~	

From ex-**Section 3.3.2 "Consumptions of physico-chemical treatments"**

Waste solids and sludges

~~Table 5.160 show consumption values from soil washing treatment plants.~~

WORKING DRAFT IN PROGRESS

Table 5.159: Consumptions of soil washing processes plants

~~Consumption~~	~~Used for~~	~~Value~~
~~Electrical~~	~~Pumps and attrition units~~	~~15 – 25 kWh per processed tonne of soil~~
~~Chemical~~	~~Function of the treated pollution. Some chemicals (such as the floculating agents) are usually used in all plants~~	~~3 to 5 kg per tonne of dry sludge~~
~~Water~~	~~Mainly due to loss of water with the residual filter cake~~	~~0.1 to 0.3 tonnes per tonne of processed soil~~
~~*Source*: [79, Perseo, P. 2003]~~		

Table 5.160: Consumptions of a installation treating contaminated soil by washing

~~Capacity~~	~~t/yr~~	~~68000~~
~~Fuel consumption~~	~~MJ/yr~~	~~0~~
~~Electricity consumption~~	~~MWh/yr~~	~~900~~
~~Electricity/plant capacity~~	~~kWh/t~~	~~13.235~~
~~Heat consumption~~	~~MWh/yr~~	~~0~~
~~Cooling~~	~~MJ/yr~~	~~0~~
~~Chemicals~~	~~sodium hydroxide~~ ~~anti-foaming products~~ ~~polyelectrolyte~~	
~~*Source*: [44, TWG 2003]~~		

The reported average energy consumption per tonne of waste treated is around 13 kWh/t, with a range of 8–18 kWh/t. Electricity is the main source of energy, although fossil fuel is also used for on-site manipulation and transportation of the waste input.

The reported average water usage per tonne of waste treated is around 86 l/t, with a range of 63–110 l/t. One plant indicated using water mainly for dust emissions abatement (water spraying), and that it recycles a large amount of the used water.

Table 5.161 summarises the consumption of raw material at plants performing water washing of contaminated soil.

Table 5.161: Consumption of raw material at plants performing water washing of contaminated soil

Raw material	**Range of consumption in the reference period (t/year)**
Flocculants	1–6
CO_2 injection for pH control/adjustment	0–3.1
Acids	NI
Bases	NI
Detergent	NI
Activated carbon	0–10.1
NI: No information.	

5.6.2.4 Emissions and consumption of biodegradation

From ex-**Section 3.2.2 "Consumptions of biological treatments"**

~~**Biological treatment of contaminated soils**~~

Most often, organic pollutants are used as a source of carbon and energy by microorganisms. Also, the concentration of nutrients like nitrogen and phosphorus must be adjusted to support

WORKING DRAFT IN PROGRESS

microbial growth. Usually, an ammonium salt like NH_4Cl is used for nitrogen addition and phosphorus as phosphate salt. However, microorganism growth needs lots of elements like vitamins and some metals (Fe, Mg, Cu, etc.). These elements can be naturally present in soil but improvement can sometimes be necessary. C/N/P ratios are sometimes used to determine the total quantity of nutrients necessary. In fact, the nutrient concentration in the soil must be regularly tested. Polluted soil is sometimes mixed with compost (generally in the proportion of 10 % to 30 % of compost, and never above 40 %) to optimise biological treatment. ~~Compost addition is most often included between 10 % and 30 % and never exceeds 40 %~~. Water is sometimes also used in order to increase the moisture content in the soil.

Oxygen and nutrients (nitrogen and phosphorus) are added to the contaminated soil to biostimulate biodegradation. Increasing the microorganisms' flora with specific organisms (e.g. bacteria, fungus) increases the biodegradability of the contaminants.

From ex-**Section 3.2.3 "Emissions from biological treatments"**

~~**Biological treatments applied to contaminated soil**~~

Air emissions due to ex situ biodegradation

Little information exists on volatile losses from *ex situ* bioremediation processes. Table 5.162 summarises the data available for both slurry phase and biopile systems. Although these data are limited, volatilisation appears to be a small component of the overall removal of hydrocarbons in these processes.

Table 5.162: Summary of emission data for *ex situ* bioremediation systems

Contaminants	Emission rate	Total emissions	Biodegradation/ Volatilisation	Notes
Slurry phase bioremediation				
Creosote	0.07–6.3 g HC/h	NI	NI	Off-gas concentrations peaked during day 1 and decreased to near baseline by day 5
Petroleum sludge	NI	910 kg HC	NI	425 000 kg of soils were treated. Emissions reduced to background by day 6
Petroleum sludge	NI	10–20 kg/yr; 1.5 kg dredging; 30 kg storage tank; 4 kg pond	NI	A full-scale system is estimated to have 500–2000 kg of VOC emissions
Biopile				
Gasoline	NI	NI	99 %/1 %	Air emissions measured for the stockpiling/handling, mixing, and curing operations. Mixing components accounted for 96 % of contaminants lost. 73 % of VOCs lost were trapped in carbon units
Petroleum	0.01 kg/hr HC once through; 0.03 kg/hr HC after treatment (carbon)	NI	NI	Off-gas was also recycled back to the biopiles to further reduce emissions
Petroleum	16 ppb BTEX start-up; 5 ppb BTEX (day 8); <1 ppb BTEX (day 35)	NI	>99 %/<1 %	

HC: Total hydrocarbons.
NI: no information.
Source:[17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997]

In open lagoons and in aerobic digestion and land treatment processes, the primary environmental factors which influence air emissions, in addition to the biodegradability and

WORKING DRAFT IN PROGRESS

volatility of the waste, are process temperature and wind speed. Emissions tend to increase with an increase in surface turbulence due to wind or mechanical agitation. The temperature affects emissions through its influence on microbial growth. At temperatures outside the band for optimal microbial activity, volatilisation will increase. Emissions from self-contained reactors are also determined by reactor design parameters such as the amount of air or oxygen used to aerate the slurry. Higher gas flows will strip more volatiles out of the solution and increase air emissions.

Energy consumption
The reported energy consumption per tonne of waste treated is 23 kWh/t. Both electricity and fossil fuel are used, almost equally.

Water usage
The reported water usage per tonne of waste treated is around 50 l/t. Water is reported to be used at the same consumption level in the process, as cleaning water and for air emissions abatement. Around one third of the used water is recycled.

Table 5.163 summarises the consumption of raw material at plants performing biodegradation of contaminated soil.

Table 5.163: Consumption of raw material at plants performing biodegradation of contaminated soil

Raw material	Range of consumption in the reference period (t/year)
Biological activator	0–0.5
Activated carbon	0–0.3
Fertilisers	NI
NI: No information.	

5.6.3 Techniques to consider in the determination of BAT

5.6.3.1 Thermal desorption

Ex-Section **4.3.2.11 'Thermal desorption of soil'** partially moved to Section 5.6.1 accordingly with KOM conclusion 2.2f

Question for TWG: please provide information about advantages and disadvantages of direct and indirect heating of contaminated soil. More precisely, what are the respective environmental performance and applicability?

5.6.3.1.1 Reduction of dust and VOC emissions to air from thermal desorption of contaminated soil

Description
Collection of waste gas and an appropriate combination of abatement techniques such as:

- thermal oxidation;
- bag filter;
- adsorption on activated carbon;
- condensation;
- cyclone.

WORKING DRAFT IN PROGRESS

~~d. having in place collection and control equipment such as afterburners, thermal oxidisers, fabric filters, activated carbon, or condensers for the treatment of gases.~~

Technical description
See Sections 2.3.4.2, 2.3.4.4, 2.3.4.6, 2.3.4.8 and 2.3.4.9 for a description of cyclones, fabric filters, thermal oxidation, condensation and adsorption respectively.

Achieved environmental benefit
Reduction of emissions to air of dust and VOCs.

Environmental performance and operational data
See **Table 5.146**.

Cross-media effects
See the CWW BREF [138, COM 2014]..

Technical considerations related to applicability
See the CWW BREF [138, COM 2014]..

Driving force for implementation
Legislation on air pollution.

Economics
See the CWW BREF [138, COM 2014]..

Example plants
Plants 188 and 494.

Reference literature
[160, WT TWG 2014].

~~**Economics**~~
~~Typically cheaper than incineration.~~

~~**Driving force for implementation**~~
~~Thermal desorption differs from incineration with regard to the regulatory and permitting requirements. Perhaps most importantly, thermal desorption enjoys more public acceptance than other thermal treatment methods.~~

5.6.3.2 Soil washing

Ex-Section **4.3.2.13 'Soil washing'** partially moved to Section 5.6.1.2

5.6.3.2.1 Treatment and reuse of generated waste water for water washing of contaminated soil

Description
Process water is reused as much as possible in the process. The excess process waste water is discharged after treatment, which consists of a suitable combination of the following techniques:

- neutralisation;
- flocculation;
- decantation/sedimentation;
- filtration;
- adsorption;
- precipitation;
- flotation.

WORKING DRAFT IN PROGRESS

Technical description
See Sections 2.3.6.3, 2.3.6.4.2, 2.3.6.4.4, 2.3.6.4.5, 2.3.6.4.6, 2.3.6.5.1 and 2.3.6.5.8 for a description of neutralisation, flocculation, sedimentation, flotation, precipitation, filtration and adsorption respectively.

~~**Technical description**~~

~~a. recycling the blowdown water as much as possible~~
~~b. using carbon filters for the treatment of collected air emissions from the waste site or soil washing unit~~
~~c. ensuring that the sludge and solids from waste water treatment are subjected to appropriate treatment and disposal.~~

Achieved environmental benefits

- Minimisation of water usage.
- Reduction of waste water release.

Environmental performance and operational data
See Table 5.157 for details of the emissions to water.

Cross-media effects
Higher energy (electricity) consumption by pumps, filters and treatment equipment.

Technical considerations relevant to applicability
Generally applicable. Recycled water may need to undergo some or all steps of the waste water treatment before reuse to avoid the accumulation of pollutants in the process.

Economics
See the CWW BREF [138, COM 2014]..

Driving force for implementation

- Reduction of water usage.
- Legislation on water pollution.

Example plants
Plant 14 recycles about 90 % of the process water, depending on the contamination of the soil treated.

Plant 40 uses water in the process with a continuous circulation of 700 m^3/h. This process water is fully cleaned/purified/recycled once every operating hour and, after this cleaning by means of a decanter, sand filter, active carbon filter and pH adjustment, it is reused continuously in the process.

Reference literature
[160, WT TWG 2014].

5.6.3.2.2 Control of emissions to air from soil washing

Description
Collection of waste gas and an appropriate combination of abatement techniques such as:

- wet gas and dust scrubber;
- bag filter;
- adsorption on activated carbon.

WORKING DRAFT IN PROGRESS

~~e. having in place collection and control equipment such as afterburners, thermal oxidisers, fabric filters, activated carbon, or condensers for the treatment of gases.~~

Technical description

See Sections 2.3.4.4, 2.3.4.9 and 2.3.4.10 for a description of fabric filters, adsorption and scrubbing respectively.

Achieved environmental benefit

Reduction of emissions to air of dust and VOCs.

Environmental performance and operational data

See **Table 5.155**.

Cross-media effects

See the CWW BREF [138, COM 2014]..

Technical considerations related to applicability

See the CWW BREF [138, COM 2014]..

Driving force for implementation

Legislation on air pollution.

Economics

See the CWW BREF [138, COM 2014]..

Example plants

Plants 14 and 40.

Reference literature

[160, WT TWG 2014].

Ex-Section **4.3.2.14 'Solvent extraction'** moved to Section 5.6.1.4

Ex-Section **4.3.2.15 'Evaporation'** deleted because covered by Section 2.3.6.5.7

Ex-Section **4.3.2.6 Purification and recycling of FGT wastes** moved to Section 5.6.1.4: refer to process; see KOM conclusion 2.2f

Ex-Section **4.3.3 Physico-chemical treatments of specific wastes** deleted: subsections moved to Chapter 2 (see below)

Ex-Section **4.3.3.1 Treatment of oils contaminated with PCB** moved to Section 5.8

WORKING DRAFT IN PROGRESS

5.7 Physico-chemical and/or biological treatment of water-based liquid/pumpable waste ~~[waste waters]~~

5.7.1 Applied process and techniques

From ex-**Section 2.3.1 "Physico-chemical treatments of waste waters"**

The processes used for the treatment of water-based liquid/pumpable waste are similar to the techniques used for the treatment of waste water. The corresponding detailed information is therefore described only once in Section 2.3.6.

Purpose
~~Ph-c plants~~ Physico-chemical and/or biological treatments of water-based liquid/pumpable waste are planned in such a manner that the maximum amount of recyclable materials can be separated so that a minimum amount of auxiliary materials is used. The purposes of these ~~physico-chemical~~ treatments ~~plants~~ are as follows:

- To enable delivery of environmental protection goals, in particular, water quality management. ~~In Ph-c plants,~~ Materials which may be hazardous to water are either treated, withheld and/or converted to a non-hazardous form.
- To enable the correct disposal of large quantities of, in general, aqueous liquid waste and waste requiring special controls.
- To separate the oil or the organic fraction to be used as fuel.

The procedures serve the specific application of physico-chemical reactions for material conversion (e.g. neutralisation, oxidation, reduction) and for material separation (e.g. filtration, sedimentation, distillation, ion exchange).

Principle of operation
During the physico-chemical and/or biological treatment of water-based liquid/pumbable waste ~~contaminated waste water~~, water is separated and processed for discharge to sewerage systems or water bodies. This processed water becomes subject to various pieces of water legislation as soon as it is discharged.

Feed and output streams
The waste input to be treated ~~in Ph-c plants is~~ consists of aqueous liquids~~. Ph-c plants generally treat waste liquids~~ or sludge with a relatively high water content (> 80 w/w-%). ~~Regardless of their origin and their relationship to their material characteristics,~~ The water-based liquid/pumpable wastes commonly treated ~~by these plants~~ are of two main categories, although sometimes mixed:

- water and minerals (e.g. acidic, alkaline, metals, toxics), or
- water and organics (e.g. oils, fuels, solvents, organic dissolved salts, COD, POPs).

[108, Physico-Chem. Subgroup 2014]

The waste input type can be:

- emulsions/cooling lubricants;
- acids (e.g. pickling acids from surface treatments; some further information ~~on~~ can be found in the STM BREF);
- alkaline solutions;
- concentrates/saline solutions containing metals ;
- Washing water;
- waste water containing hydrocarbons; ~~a gasoline/oil separator~~

WORKING DRAFT IN PROGRESS

- solvent mixtures;
- cyanide wastes;
- Sludge;
- aqueous liquid wastes with high concentrations of biodegradable materials;
- aqueous marine waste.

~~An indication of the type of wastes accepted at sites in the UK is given in Table 5.164.~~

Table 5.164: Waste types accepted at physico-chemical treatment plants in the UK

~~**Waste stream**~~	~~**Percentage of sites accepting each type of waste (%)**~~
~~Neutral aqueous inorganics~~	~~69~~
~~Acids~~	~~62~~
~~Oils~~	~~62~~
~~Alkalis~~	~~54~~
~~Neutral aqueous organics~~	~~54~~
~~Contaminated containers~~	~~23~~
~~Cyanides~~	~~23~~
~~Organic sludges~~	~~8~~
~~Water reactive chemicals~~	~~8~~

~~[34, Babtie Group Ltd 2002]~~

From ex-**Section 3.3.1 "waste IN in physico-chemical treatments"**

WORKING DRAFT IN PROGRESS

~~**Waste waters**~~

~~The waste waters treated by physico-chemical treatments are:~~

- ~~the core waste streams – these are inorganic acids and alkalis and their rinse-waters, together with cleaning, washing and interceptor wastes from a range of processes~~
- ~~chemical industry wastes – these may include aqueous alcohol/glycol streams and process wash-waters~~
- ~~(possibly) cleaning wastes with low levels of chlorinated compounds such as dichloromethane or phenolic compounds. Cleaning waters from the food industry may contain these substances as well~~
- ~~aqueous wastes containing solvents~~
- ~~high nitrogen wastes (potential for ammonia emissions)~~
- ~~wastes containing phosphorus~~
- ~~occasional inorganic wastes: for example wastes containing arsenic~~
- ~~cyanide wastes – typically this waste will consist of solid or liquid cyanide salts, for example, sodium cyanide from surface metal treatments. They may also be present in printing wastes, usually as silver cyanide. Examples of cyanide based plating solutions include copper, zinc and cadmium cyanides~~
- ~~developer waste (photographic wastes) typically includes a solution with a high percentage of ammonia salts, predominantly thiosulphate~~
- ~~waste waters from shaping; oil wastes; organic chemical processes; and water and steam degreasing processes~~.

Without going into detail and/or individual and special cases, the essential sources of ~~Ph-c plant treatable~~ water-based liquid/pumpable wastes are indicated in Table 5.165.

Table 5.165: Types of water-based liquid/pumpable waste

EWL chapter	Title	EWL list
06	Wastes from inorganic chemical processes	0601 waste acidic solutions 0602 waste alkaline solutions 0603 waste salts and their solutions 0604 waste containing metals 0605 sludges from on-site effluent treatment
07	Wastes from organic chemical processes	0701 wastes from the manufacture, formulation, supply and use (MFSU) of basic organic chemicals 0702 wastes from the MFSU of plastics, synthetic rubber and man-made fibres 0706 wastes from the MFSU of fats, grease, soaps, detergents, disinfectants and cosmetics
11	Inorganic wastes containing metal from metal treatment and the coating of metal; non-ferrous hydrometallurgy	1101 liquid wastes and sludges from metal treatment and coating of metals (e.g. galvanic processes, zinc coating processes, pickling processes, etching, phosphating, alkaline degreasing)
12	Wastes from shaping and surface treatment of metals and plastics	1201 wastes from shaping (including forging, welding, pressing, drawing, turning, cutting and filing) 1202 wastes from mechanical surface treatment processes (blasting, grinding, honing, lapping, polishing) 1203 wastes from water and steam degreasing processes
13	Oil wastes	1304 bilge oils 1305 oil/water separator contents
19	Wastes from waste treatment facilities, off-site waste water treatment plants and the water industry	1908 wastes from waste water treatment plants not otherwise specified
Source: [77, Schmidt et al. 2002]		

The essential mass flow from ~~Ph-c plants~~ physico-chemical treatment of water-based liquid/pumpable waste is the waste water, corresponding to about 85–95 % mass of the waste accepted for treatment.

Depending on the waste input type and the combination of processes used, the output can be:

- sludge,
- filter cake,
- waste oil,
- waste fuel,
- spent solvent,
- solid residue,
- water,
- concentrate,
- etc.

[108, Physico-Chem. Subgroup 2014]

From ex-Section **3.3.3.1 Emissions from the physico-chemical treatments of waste waters**

The sludge generated from ~~physico-chemical~~ treatment ~~plants~~ of water-based liquid/pumpable waste can be pressed and sent to further treatment, pressed and mixed with other sludges (generally organic) on site or mixed with residues from flue-gas cleaning to give a solid product (with an exothermic reaction). Almost all of the sites produce a sludge/cake, which is then commonly incinerated or co-incinerated, or in a few cases directly landfilled.

Metal levels in the waste are well characterised, but organic contamination is not. Nitrogen and phosphorus are not typically quantified in waste and will be present in the aqueous solution.

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Table 5.166 summarises the waste which may be generated from waster-based/liquid waste treatment.

Table 5.166: Process-generated waste from treatment of water-based liquid/pumpable waste

Process-generated waste	Specific amount (kg/tonne of total waste processed ~~in the Ph-c treatment plant~~)
Oil	30–90
Concentrates (1)	14–40
Hydroxide sludge (2)	60–90
Mud from purification and emptying processes	10–50
NB: Data based on the data from Ph-c plant operators with a total capacity of 850 kt/yr. The data correspond to the year 2001. The average age of the plants is about 17 years (ranging from 4 to 39 years). Approximately 84 % (from 73 % to 91 %) of all the Ph-c plants for the treatment of accepted waste observed here can be attributed to EWL groups 11,12,13,16 and 19. The oil is generally recycled and the remaining substances recycled or disposed of, depending on their characteristics and the market conditions. (1) Concentrates from evaporation/stripping and membrane filtration as well as from ultrafiltration and ion exchangers. (2) The weight relates to damp mud, drained TS: ~35–45 %.	

[77, Schmidt et al. 2002]

Waste from the ~~Ph-c~~ treatment of water-based liquid/pumpable waste arises principally from precipitation/flocculation, concentrates from membrane filtration, evaporation or ion exchange; waste is also produced in cleaning and draining processes, constructions and containers. The extent to which waste can be used depends on the individual case. For example, separated oil is generally recyclable, concentrates from membrane filtration, evaporation or ion exchange can be recycled in some cases, sludge from precipitation/flocculation is generally disposed of, and waste from cleaning and draining is generally disposed of and disposal is usually by immobilisation or incineration.

Table 5.167 below shows the composition of sludge generated in the physico-chemical treatment ~~of waste waters~~ of water-based liquid/pumpable waste.

Table 5.167: Sludge generated in the treatment of water-based liquid/pumpable waste

Compound	Value	Unit
pH	7–9	
TOC	54.7	w/w-%
Loss of ignition	54.7	w/w-%
Hydrocarbons	30 000	mg/kg
PCDD/F	< 0.1	ng-TE/kg
PCB ($\sum$ 6)	< 0.12	mg/kg
EOX	10	mg/kg
CN total	< 0.1	mg/kg
As	0.2	mg/kg
Cd	2.7	mg/kg
Cr total	887	mg/kg
Cu	349	mg/kg
Hg	0.2	mg/kg
Ni	210	mg/kg
Pb	211	mg/kg
Tl	14	mg/kg
Zn	1970	mg/kg
Source: [104, UBA Germany 2004]		

The amount of sludge containing metal (filter cake) that is produced depends on the specific contaminants in the waste water, their concentrations and on the reagents and other chemicals that are used. The sludge quantity varies from 2.5 % to 10 % of the waste water input. By

WORKING DRAFT IN PROGRESS

replacing lime with sodium hydroxide, the amount of filter cake is reduced. However, lime is necessary for the precipitation of fluorides.

Filter cakes with a high concentration of metals, e.g. nickel and copper, can be used as a raw material in the metallurgical industry. In other cases, the filter cake is disposed of as solid waste.

Process description
~~Ph-c~~ Plants treating water-based liquid/pumbable waste are configured on a case-by-case basis depending on requirements and/or application. Each ~~Ph-c~~ plant has a specific individual technological and operational concept; this is geared towards the waste to be treated. For this reason, there is no standard ~~physico-chemical~~ water-based liquid/pumbable waste treatment plant. Although all plants have inspection and process laboratories and tend to have a neutralisation function, the range of pretreatment processes, sludge handling methods and the combination of input waste streams make each a unique operation. The modes of operation of the plants are:

- continuous operation: particularly suitable for large throughputs, waste of relatively constant composition and for automated operation;
- batch operation: particularly well suited to waste with very variable characteristics/reaction behaviour.

Physico-chemical and/or biological treatments of water-based liquid/pumpable waste generally include a combination of the following steps (see technical descriptions in Section 2.3.6):

- sieving;
- storage/accumulation;
- neutralisation;
- sedimentation;
- precipitation/flocculation;
- ion exchange;
- oxidation/reduction;
- sorption (adsorption/absorption);
- evaporation/distillation;
- membrane filtration;
- stripping;
- extraction;
- filtration/draining;
- acid splitting of emulsions - emulsion breaking;
- organic splitting of emulsions - emulsion breaking;
- centrifugation;
- biological treatment;
- all finishing techniques after biological treatment (including final treatment for the hard COD).

[146, PCT Subgroup 2015]

Table 5.168 below shows some differences between different ~~Ph-c~~ water-based liquid/pumbable waste treatments ~~plants~~.

WORKING DRAFT IN PROGRESS

Table 5.168: Analysis of some representative types of physico-chemical water-based liquid/pumbable waste treatments

	Treatment of				
	Emulsions	**Emulsions and oil/water mixtures**	**Emulsions and waste with contents to be detoxicated**	**Liquid and aqueous waste with some organic solvents**	**Liquid and aqueous waste containing organic solvents and tensides**
Sieving	■	■	■	■	■
Sedimentation					■
Ultrafiltration					▒
Evaporation					▒
Heating up				■	▒
Stripping				■	
Acid splitting	■	■	■		
Organic splitting			▒		▒
Oxidation/reduction			▒		
Membrane filtration				▒	
Flocculation/precipitation	■	▒	▒	▒	▒
Sedimentation	■	▒	▒	▒	▒
Draining	■	▒	▒	▒	▒
Sulphuric precipitation	■				
Filtration	■	▒	▒		
Ion exchanger	■				
Neutralisation				▒	▒

Note: Dark grey: required process; light grey: optional process.
Source:[77, Schmidt et al. 2002]

The unit operations typically used are sieving, storage/accumulation, neutralisation, sedimentation, precipitation/flocculation, ion exchange, oxidation/reduction, sorption (adsorption/absorption), evaporation/distillation, membrane filtration, stripping, extraction, filtration/draining, acid splitting of emulsions and the organic splitting of emulsions.

Frequently several unit operations are ~~will have to be~~ used to correctly treat a specific waste. The unit operations procedure combination (type of procedure, sequence of their application, controls) is specified by the plant laboratory, on the basis of the composition of the waste and its reaction behaviour.

In particular, the following parameters are considered before mixing water-based liquid wastes:

From Ex-**Section 4.7.2 "Parameters to consider before mixing waste waters"**

~~**Description**~~

~~Some techniques before mixing waste waters that are to be further treated include:~~

[77, Schmidt et al. 2002] [89, UBA Germany 2003] [98, WT TWG 2004]

a. Not mixing waste waters that contain adsorbable organically bound halogens (AOX), cyanides, sulphides, aromatic compounds, benzene or hydrocarbons (dissolved, emulsified or undissolved).
b. For the metals, using ~~as~~ mercury, cadmium, lead, copper, nickel and chromium as the classification parameters for the waste water, since, like arsenic and zinc, they all occur in waste water partly in dissolved form and partly as suspended sulphides and have to be reduced in waste water treatment plants. These parameters also serve to control the effectiveness of the waste water treatment.
c. Ensuring that measures are in place to isolate effluents if the test samples indicate a potential breach of specifications. Incidents of this nature ~~need to be~~ are recorded in the effluent log.
~~d. segregrating the collecting systems for potentially more contaminated waters (e.g. from storage and loading unloading areas) and less contaminated water (e.g. rainwater)~~

WORKING DRAFT IN PROGRESS

~~The procedures conducted by Ph-c plants~~ Water collected in physico-chemical and/or biological treatment of water-based liquid waste is hydraulically separated into contaminated waste water and uncontaminated rainwater, and ~~Ph-c plants have two separate technical~~ dewatering systems are separated.

~~**Achieved environmental benefits**~~
~~Avoids problems in the later treatment and dilution.~~

~~**Operational data**~~
~~Wastes and waste waters often contain a mixture of hard and soft COD compounds which may or may not affect BOD content.~~

~~**Applicability**~~
~~Technique d is typically carried out in two separated systems. One dedicated to rainwater typically not treated and another one collecting all the rest of aqueous efluents that are typically treated together. In same cases, rainwater coming from storage or loading/unloading areas may become more contaminated.~~

~~**Example plants**~~
~~Related to point e) of the description section, there have been a number of incidents in the UK where fire has been spread from one area of a site to another via the drainage system.~~

~~**Reference literature**~~

When treating nitrites containing water-based liquid waste, the following is considered:

From ex-Section **4.3.1.9 Techniques when treating waste water contaminated with nitrites**

~~**Description**~~
~~Some techniques include:~~
[77, Schmidt et al. 2002] [98, WT TWG 2004]

a. avoiding mixing nitrite wastes with other wastes;
b. checking and avoiding nitrous fumes during the oxidation and acidification of nitrites;
c. checking and avoiding nitrous fumes during the reduction of nitrites.

~~**Achieved environmental benefits**~~
~~Concentrations of less than 2.0 mg/l of nitrite can be achieved by good optimisation of the nitrites treatment process.~~

~~**Cross-media effects**~~
~~Use of an oxidiser agent is required in oxidation processes. Reducing agents used are urea or amidosulphuric acid.~~

~~**Example plants**~~
~~There are three plants operating such systems in Austria.~~

~~**Reference literature**~~

The following equipment is typically available for reactors in order to control reactions:

- storage vessels for separate storage, depending on the type of treatment;
- reaction containers with adjustable agitators and temperature indicators;
- sedimentation containers;
- metering equipment;
- receiver and storage tanks for chemicals;
- storage tanks and reservoirs for the waste to be treated;
- dosing equipment;
- material resistant to acids and alkalis;

WORKING DRAFT IN PROGRESS

- control of pH value for the chemicals;
- containers for settling and mixing ancillary agents;
- measurement and automatic controls;
- ventilation and filtering of the reaction tanks with facilities for cleaning the exhaust air.

Despite their different configurations and equipment, the following items apply to all processes:

- requirements for environmental protection, such as emission restrictions (in particular, waste water, exhaust air, groundwater protection);
- control of the plant by a works laboratory which also determines the treatment programme including the required controls and documentation;
- specialised and expert personnel (management level: qualification from university/university of applied sciences; operative level: skilled worker, laboratory assistant);
- the correct discharge of the waste water is guaranteed by its storage after treatment, and subsequent final inspection.

Simplified flow charts and descriptions of processes for the physico-chemical treatment of water-based liquid/pumpable waste are provided below. These examples show that the processes are designed according to the waste materials to be processed.
[146, PCT Subgroup 2015]

Treatment of emulsions
The emulsions are split by acid splitting. For this, spent acids and alkalis are mainly used as ancillary agents. The separated oil is sent to a further process.

The dissolved metals are separated by a three-stage separation step: precipitation/flocculation, sulphuric precipitation and ion exchange.

The concentrations of solute metals are reduced by flocculation/precipitation steps; the resultant mud is separated by sedimentation and mechanically drained. Both the waste water and the filtrate coming from the dewatering step are sent to a subsequent treatment. The aim of this subsequent treatment is to further reduce the concentrations of the solute metals by means of sulphuric precipitation and ion exchange which improves the metal removal efficiency.

The aqueous output is subjected to a final inspection (laboratory check) before release. Figure 5.30 below presents a simplified flow chart of the process.

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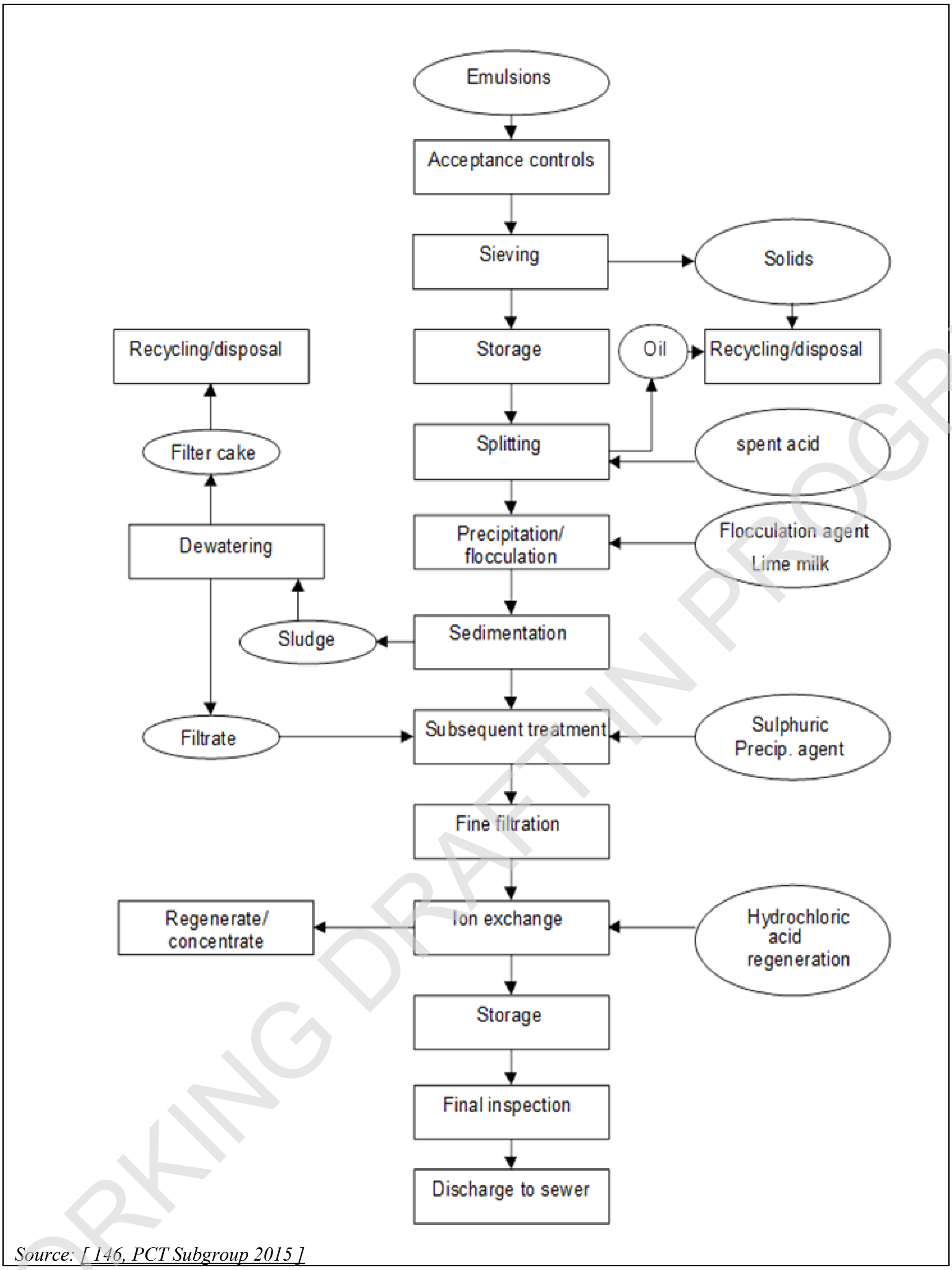


Source: [146, PCT Subgroup 2015]

Figure 5.30: Simplified flow chart of a physico-chemical treatment of water-oil emulsion

Treatment of organic solvents containing water-based liquid waste

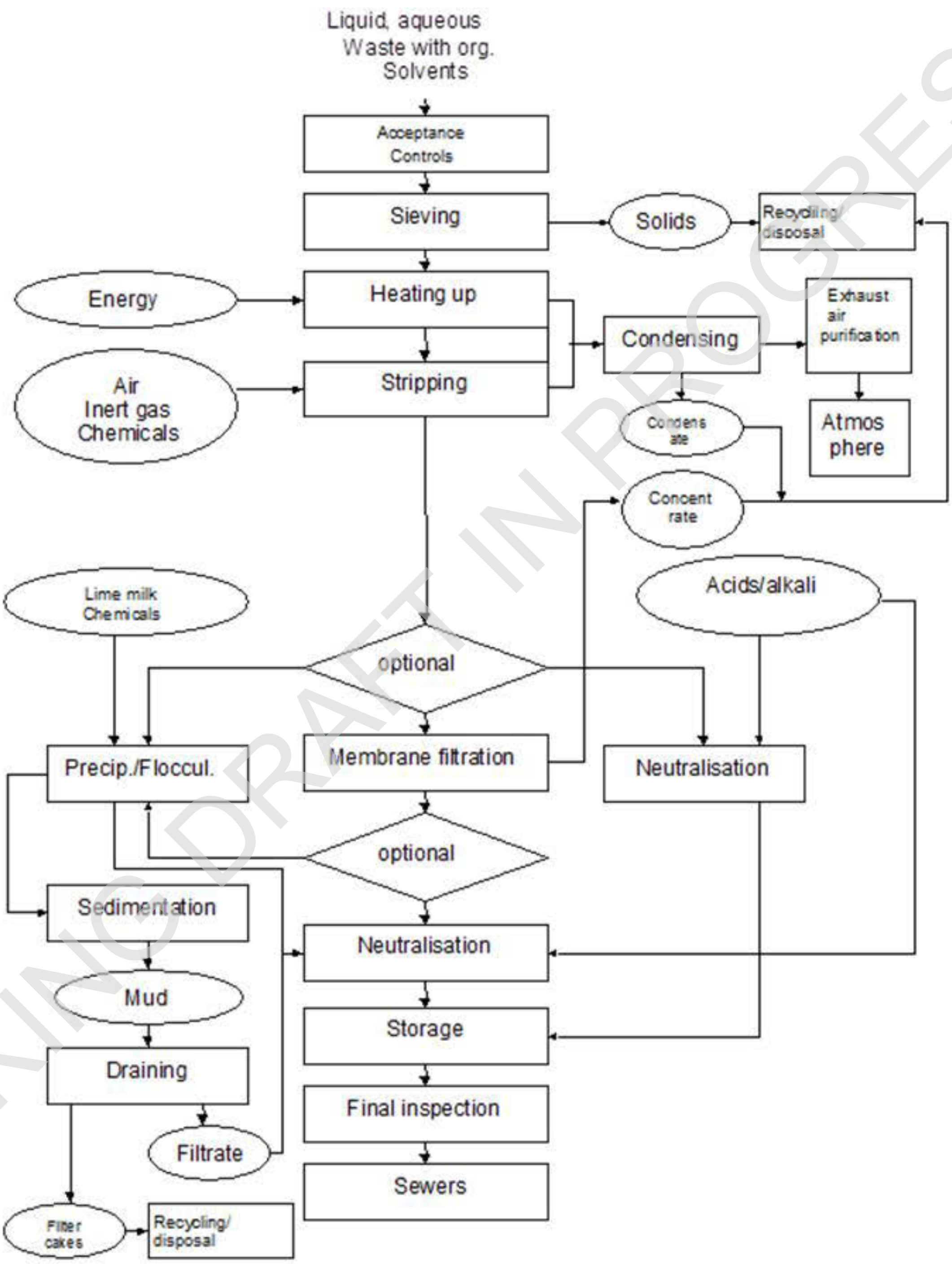
In the first process step, the organic solvents are separated by heating up and stripping. This produces a pretreated waste, which no longer contains vaporisable and inflammable materials, and therefore requires no special safety measures for further treatment.

To safely avoid the formation of explosive compounds, the stripping is performed using air or inert gas (e.g. nitrogen). It can be beneficial to change the pH value, for example in order to accelerate the stripping.

WORKING DRAFT IN PROGRESS

Considering the contaminants content of the output of the first step, membrane filtration, flocculation/precipitation and neutralisation are used for the second process step. The treatment programme drawn up by the laboratory specifies how the individual treatment methods are to be combined.

Figure 5.31 below presents a simplified flow chart of the process.



Source: [146, PCT Subgroup 2015]

Figure 5.31: Simplified flow chart of a physico-chemical treatment of solvents containing water-based liquid waste

The condensate from the heating and stripping steps is either recycled or disposed of, depending on its quality. The exhaust air is treated (e.g. activated carbon filter) before release.

WORKING DRAFT IN PROGRESS

The concentrate from membrane filtration, the drained mud as well as solids from sieving are recycled or disposed of.

The aqueous output is submitted to a final inspection (laboratory check) before release.

From ex-**Section 3.3.1 "waste IN in physico-chemical treatments"**

Treatment of aqueous marine waste

Most of the waste water from aqueous marine waste is contaminated with oil, organic substances and solid material (e.g. sediment). ~~The contents of heavy metals, salts and other inorganic substances in the water and oil fractions are relatively low shows the acceptance and processing criteria for flocculation/flotation and biological treatment.~~

Table 5.169: Acceptance and processing criteria for flocculation/flotation and biological treatment for aqueous marine waste

~~**Component**~~	~~**Limit value acceptance (mg/l)**~~	~~**Limit value processing (mg/l)**~~	~~**List mixing policy***~~
~~PCBs~~	~~Detection limit~~	~~Detection limit~~	~~X~~
~~Dioxins~~	~~Detection limit~~	~~Detection limit~~	~~X~~
~~Pesticides~~	~~Detection limit~~	~~Detection limit~~	~~X~~
~~Organotin compounds~~	~~Detection limit~~	~~Detection limit~~	~~X~~
~~Brominated diphenyl ethers~~	~~Detection limit~~	~~Detection limit~~	~~X~~
~~Inhibition respiration~~	~~10 %~~	~~10 %~~	
~~N-total (Kjeldahl)~~	~~to discuss~~	~~500~~	
~~CN~~	~~to discuss~~	~~5~~	
~~Phenol~~	~~to discuss~~	~~1500~~	
~~VOX~~	~~100~~	~~20~~	
~~EOX~~	~~10~~	~~5~~	~~X~~
~~Cd~~	~~0.1~~	~~0.1~~	~~X~~
~~Hg~~	~~0.01~~	~~0.01~~	~~X~~
~~Total heavy metals~~	~~25~~	~~25~~	~~X~~

~~*the limit value of acceptance is in accordance with the policy on mixing.~~
~~*Source:* [103, VROM 2004]~~

Figure 5.32 shows an example of the treatment of aqueous marine waste.

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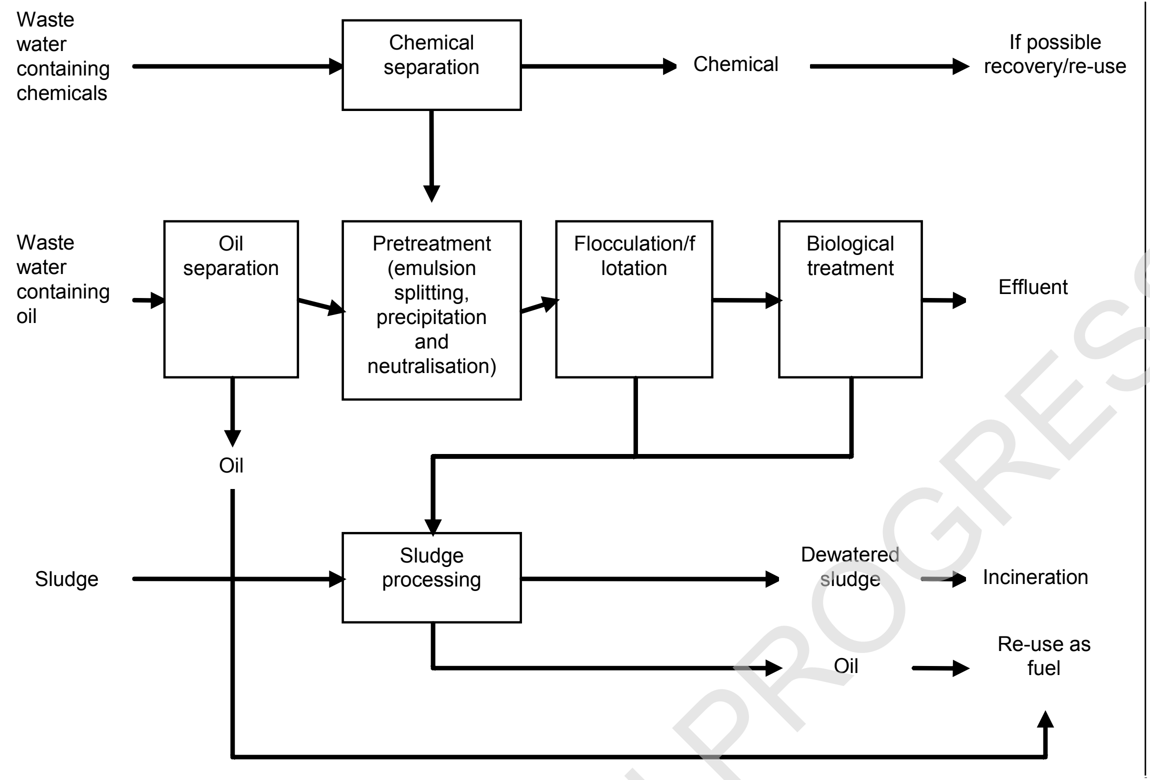

Source:[103, VROM 2004]

Figure 5.32: Simplified flow chart of a physico-chemical and biological process for the treatment of aqueous marine waste

The generated solid residues from aqueous marine waste are:

- solid residues from the decanter/centrifuge and filters (50 kg/t waste water);
- separated oil and chemical fractions (possibly suitable for reuse as fuel).

~~For several steps in the treatment, chemicals are used, e.g. alkalis, acids, flocculating and coagulating agents, activated carbon and oxygen. The use of waste acids and alkalis reduces the consumption of primary chemicals. In some data on the consumption of chemicals are presented.~~

~~Table 5.170: Data on consumption of chemicals in the treatment of aqueous marine waste and similar waste~~

~~**Chemical**~~	~~**Consumption**~~ ~~(kg/m^3 waste water)~~	~~**Comments**~~
~~Alkalis~~	~~2 – 3~~	
~~Acids~~	~~0 – 1~~	~~Depends on the use of waste acids~~
~~Flocculating/coagulating agents~~	~~1 – 7~~	
~~Oxygen~~	~~5~~	~~Depends on the use of air or oxygen~~
~~Activated carbon~~	~~0.04~~	

~~[104, UBA Germany 2004]~~

~~Water is required in centrifuges and for the preparation of chemicals. The use of the effluent from the biological treatment reduces the consumption of water.~~

Treatment of liquid photographic waste

From ex-**Section 2.4.8 "Treatment of liquid photographic waste"**

~~Purpose~~

~~Separate the waste input stream into valuable components (e.g. Ag).~~

WORKING DRAFT IN PROGRESS

~~Principle of operation~~

Desilvered liquids and photo processing waste with a low silver content, such as developers, are treated by means of sulphide precipitation and membrane filtration. By adding a sodium sulphide solution, silver ions and other metals are precipitated. The solid particles are filtered out by pressing the solution through membranes. The permeate from membrane filtration undergoes further treatment. The silver contained in the sludge is recovered by means of pyrometallurgical treatment and refinement. These treatments are described in the Non-Ferrous Metals Industries BREF.

Photo processing liquid wastes with a low silver content are treated by chemical removal. By adding sodium borohydride, metallic silver is precipitated. The silver is recovered from the sediment. The desilvered liquid undergoes further treatment.

~~Feed and output streams~~

~~Silver.~~

From ex-**Section 3.4.1 "Waste IN treated to obtain a recycled material"**

~~Treatment of liquid photographic waste~~

~~Table 5.171: Acceptance criteria for desilvered photographic liquid waste and similar waste waters (with the same processing path)~~

~~**Parameter**~~	~~**Concentration (mg/l)**~~	
~~Hydrocarbons~~	~~6000~~	~~emission in evaporation step (colour photo processing waste)~~
~~EOX~~	~~10~~	
~~Respiration inhibition~~	~~5 %~~	
~~Metals (Zn, Ni, Pb, Cr, Mo)~~	~~50~~	
~~Ag~~	~~50/100~~	~~black and white/colour photo processing waste~~
~~Cd~~	~~1.0~~	
~~Cu~~	~~25~~	
~~Hg~~	~~1.0~~	

~~[103, VROM 2004]~~

~~Process description~~

~~The treatment of the desilvered liquid photo processing waste with a high silver content consists of the following steps:~~

- ~~silver is removed from photo processing waste with a high silver content (>100 mg/l) by means of electrolysis. After refining, the silver is re-used~~
- ~~for a concentration of concentration of silver of 5 to 100 mg/l, desilvering by electroflocculation or sulphide precipitation and membrane filtration is applied. The created sludge is sent for incineration~~
- ~~colour processing waste water is, prior to further treatment, evaporated in a vacuum evaporator because of the presence of toxic and not easily degradable organic compounds~~
- ~~treatment in an activated carbon filter, where large organic and metal containing complex agents are absorbed by the carbon. When the carbon is saturated, it is regenerated and re-used~~
- ~~purification by means of flocculation and flotation~~
- ~~biological treatment (see Section XX)~~
- ~~evaporation in a vacuum evaporator. The condensate can be used as processing water or discharged~~
- ~~the sludge from the flocculation/flotation and biological treatment and the residue from the evaporator are incinerated or landfilled.~~

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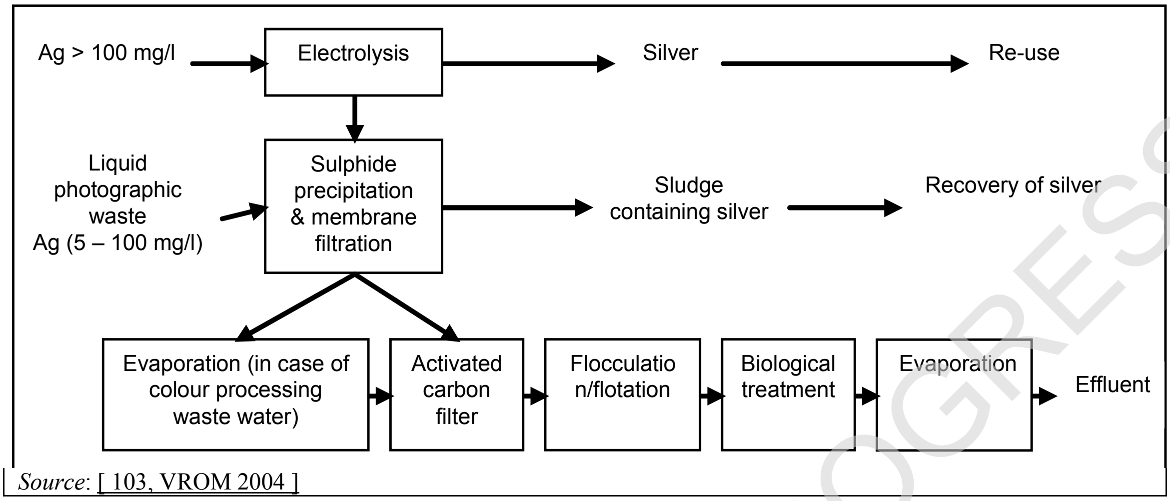
Figure 5.33 below gives an example of the process steps for the treatment of liquid photographic waste.



Source: [103, VROM 2004]

Figure 5.33: Simplified flow chart of a physico-chemical and biological treatment of liquid photographic waste

~~**Users**~~
~~Photographic industries.~~

Users
~~From 25 to 30 % of all hazardous waste in Germany is disposed of by Ph-c water-based liquid/pumbable waste treatment plants. Some examples of the operations carried out via a Ph-c plant are:~~

- ~~treatment of emulsions~~
- ~~treatment of emulsions and waste with contents to be detoxified~~
- ~~treatment of liquids, aqueous wastes with some organic solvents~~
- ~~treatment of emulsions and oil/water mixtures~~
- ~~treatment of liquids, aqueous wastes containing organic solvents and tensides~~
- ~~detoxification (oxidation/reduction) of waste containing nitrites, Cr(VI), cyanide (as pretreatment).~~

Physico-chemical and/or biological treatment of water-based liquid waste is widely used. The wastes processed are usually from various industrial and commercial production processes, and from maintenance, repair and cleaning activities. Some specific industrial sectors served are the printing and photographic industries. These are an example of those sites, which provide a service to a particular industrial sector, taking away a wide range of wastes and transferring those that cannot be treated or recycled in-house.

From ex-**Section 3.3.4 "Waste OUT from physico-chemical treatments"**

~~Much of the waste OUT from these processes goes to landfilling.~~

~~**Waste waters**~~
~~The essential mass flow from Ph-c plants is the waste water, corresponding to about 85 to 95 % of the mass of the waste accepted for treatment. The waste water quality of Ph-c plants is regularly monitored by the supervisory authorities and within a framework of self-monitoring. Due to this monitoring activity, extensive data are available on the composition of waste water from Ph-c plants.~~

WORKING DRAFT IN PROGRESS

~~**Table 5.172: Waste OUT from the physico-chemical treatment of contaminated waters**~~

~~**Water emission parameters**~~	~~**Ranges values of the annual average values (ppm)**~~	~~**Ranges of annual charge (kg/yr)**~~
~~pH~~	~~6.9 – 10.4~~	
~~Electric conductivity~~	~~1150 – 13500 µS/cm~~	
~~Transparency (view depth)~~	~~10 – 47 cm~~	
~~Suspended solids~~	~~<0.5 – 32~~ ~~<0.1 – 2.1 ml/l~~	~~<0.6~~
~~TOC~~	~~2200 – 3800~~	~~38061~~
~~BOD~~	~~5 – 2490~~	
~~COD[1]~~	~~200 – 17870~~	
~~Hydrocarbons~~	~~<0.1 – 19.8~~	~~89~~
~~Detergents (anionics)~~	~~0.6 – 14.8~~	
~~Mineral oil~~	~~5 – 10~~	
~~Phenol index~~	~~0.8 – 25~~	~~317~~
~~AOX~~	~~<0.01 – 0.7~~	~~9~~
~~EOX~~	~~<0.1 – 0.5~~	
~~BTX~~	~~<0.1 – 1.2~~	~~10~~
~~Cl~~	~~3975 – 35420~~	
~~Cl free~~	~~<0.1 – 0.3~~	
~~CN~~	~~<0.1 – 0.6~~	~~<1~~
~~CN free~~	~~<0.01 – 0.1~~	
~~F~~	~~0.5 – 8.6~~	
~~N - organic~~	~~109 – 440~~	
~~N - total~~	~~8.4 – 590~~	
~~NH3-N~~	~~22 – 1330~~	
~~Nitrate-N~~	~~0.9 – 472~~	
~~Nitrite-N~~	~~0.90 – 10.2~~	~~38~~
~~P - total~~	~~<0.1 – 14.75~~	
~~Sulphate~~	~~65 – 3630~~	
~~Sulphide~~	~~1012~~	
~~Sulphide free~~	~~<0.1 – 0.77~~	~~<1~~
~~Al~~	~~<0.1 – 5~~	~~63~~
~~As~~	~~<0.01 – 0.1~~	~~<0.1~~
~~Cd~~	~~0.0004 – 0.1~~	
~~Co~~	~~≤ 0.1~~	
~~Cr total~~	~~0.05 – 0.3~~	~~3.8~~
~~Cr (VI)~~	~~<0.01 – 0.1~~	~~<1~~
~~Cu~~	~~<0.1 – 0.4~~	~~2.5~~
~~Fe~~	~~0.2 – 20~~	~~253~~
~~Hg~~	~~0.0001 – 0.02~~	~~<0.02~~
~~Mn~~	~~<0.1 – 2.7~~	
~~Ni~~	~~0.05 – 1.4~~	~~3.8~~
~~Pb~~	~~<0.02 – 0.7~~	~~<1~~
~~Se~~	~~<0.1 – 0.5~~	
~~Sn~~	~~<0.1 – 0.4~~	
~~Zn~~	~~<0.1 – 3.9~~	~~12~~

~~Notes: Ranges have been constructed from several sets of emission data provided. A data set is based on the data from Ph-c plant operators with a total capacity of 850 kt/yr. The data correspond to year 2001. The average age of the plants is about 17 years (ranging from 4 to 39 years). Approximately 84 % (from 73 to 91 %) of all the Ph-c plants for the treatment of accepted waste covered here, can be attributed to EWL groups 11,12,13,16 and 19. Another set corresponds to 20/80 percentile of the annual average values for some Ph-c plants, and another to measured minimum/maximum values found in demulsification plant treatment (data from 1994 – 1999)~~

[1] ~~Some data relate to THE dissolved COD fraction and other correspond to the total COD~~

WORKING DRAFT IN PROGRESS

~~[77, Schmidt et al. 2002] [89, UBA Germany 2003] [98, WT TWG 2004] [103, VROM 2004] [104, UBA Germany 2004]~~

~~Outputs of lacquer treatment facility are shown in below:~~

~~Table 5.173: Waste OUT of physico-chemical treatment of contaminated water treating mainly lacquer coagulum and solvents~~

~~Material~~	~~Amount (t/yr)~~	~~Composition (mg/kg)~~
~~Dried material~~	~~10000~~	~~PCB <0.05~~ ~~BTEX 104.8~~ ~~As <1~~ ~~Cd 6.7~~ ~~Cr total 77~~ ~~Cu 905~~ ~~Hg 0.25~~ ~~Ni 43~~ ~~Pb 339~~ ~~Tl <0.5~~ ~~Cyanide total 6200~~
~~Organic process water~~	~~2000~~	~~Cd <0.5~~ ~~Hg <0.5~~ ~~Zn 1.7~~
~~Solvent reclaim~~	~~13000~~	

~~[90, UBA Germany 2003]~~

~~shows the emission levels achieved after a polishing step of the effluent, e.g. by sand filtration or ion exchange filters.~~

~~Table 5.174: Emission levels achieved after a polishing step of the effluent, e.g. by sand filtration or ion exchange filters~~

~~Compound~~	~~Concentration (mg/l waste water) (24 hour samples)~~
~~Free cyanide~~	~~1.0/0.2~~
~~Halogenated VOCs~~	~~0.1~~
~~Mineral oil~~	~~200 (random sample)~~
~~Ag~~	~~1.0/0.1~~
~~Cd~~	~~0.2~~
~~Cr (total)~~	~~1.0/0.5~~$^{+}$
~~Cr(VI)~~	~~0.1~~
~~Cu~~	~~2.0/0.5~~
~~Ni~~	~~2.0/0.5~~
~~Pb~~	~~2.0/0.5~~
~~Sn~~	~~3.0/2.0~~
~~Zn~~	~~2.0/0.5~~
$^{+}$~~standards for discharged load of metals (Cr, Cu, Ni, Pb and Zn) <200 g/day and >200 g/day~~	

~~[103, VROM 2004]~~

From ex-**Section 2.3.2 "Unit operations used in Ph-c treatments of waste waters"** deleted because covered by Section 2.3.6

~~Waste can be treated using any of a large number of commercially proven unit operations. The treatment methods fall into four categories:~~

- ~~phase separation (e.g. sedimentation, steam stripping)~~
- ~~component separation (e.g. ion exchange, electrodialysis)~~
- ~~chemical transformation (e.g. chemical oxidation, incineration)~~

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- ~~biological transformation (e.g. fixed film aerobic treatment).~~

~~summarises units operations used in physico-chemical treatments. Some more information on this issue can be found in the Common waste water and waste gas treatment BREF (CWW).~~

~~Table 5.175: Unit operations used in physico-chemical treatments of water-based liquid/pumpable waste~~

~~Unit operation~~	~~Purpose~~	~~Principle of operation~~
~~Separation operations~~		
~~Acid break-up of emulsions~~	~~The term 'acid break-up' is understood to be the treatment of emulsions. The aim of the treatment is the separation of the emulsion into waste water, oil/grease and undissolved metals as hydroxide sludge~~	
~~Centrifugation~~	~~Dewatering metal salt sludges from precipitation techniques~~	~~Separates solids and liquids by rapidly rotating the mixture in a vessel. Solids either settle at the bottom (sedimentation - type) or adhere to the inside wall of the vessel (filtration - type) through which the liquid passes~~
~~Evaporation and distillation~~	~~Evaporation and distillation are similar processes with different objectives. During evaporation the useful material in a mixture is evaporated through thermal effects and captured as vapour and generally condensed. Distillation is a separation process, which is used for the separation of mixtures, which obtains better separation ratios than evaporation~~	~~The aim of evaporation/distillation is to separate the oil into a good usable form. In the Ph-c plants, evaporation is used as a partition stage in order to separate vaporisable materials from the waste water. Depending on the ingredients of the waste water, evaporation can also be used as conditioning for a further preparation stage, such as membrane filtration. Evaporator technology is of great importance whenever organic solvents are to be separated from the waste to be treated~~
~~Extraction~~		~~Extraction is used for the specific separation of components from a mixture of substances. The mixture of substances is thoroughly mixed with a selective solvent. During mixing, the component from the mixture of substances migrate into the extracting agent. With the subsequent separation of the extracting agent from the substance mixture, finally the components of the mixture are also separated~~
~~Filtration/ dewatering~~	~~This is the most common operation applied, e.g. in drinking water treatment, industrial waste water treatment~~	~~Involves passing a mixture of liquid and solids (or gas and solids) through a filter medium to trap the solids. Different kinds of filters exist, such as gravel filters, sand filters and mechanical filters (e.g. waste water screen presses, chamber filter presses, membrane filter presses)~~

WORKING DRAFT IN PROGRESS

~~**Unit operation**~~	~~**Purpose**~~	~~**Principle of operation**~~
~~Filtration/ sieving~~	~~The sieving of the waste to be treated is essential for the protection and safety of functional units, such as pumps, sluice gates, valves~~	~~Sieving is a classifying/separating procedure with which the filtered material – liquid/solid mixture (slurry) – is separated into two mixtures, one with an average particle size smaller than the input, and another larger than the input~~
~~Filtration (by membranes)~~	~~Separation of substances/solids from liquid mixtures. Ultrafiltration can be used for break-up of emulsions~~	~~In membrane procedures the liquids to be treated are fed under controlled pressure and current conditions past a semi-permeable membrane. The separative power of the membrane is essentially based on the filtering effect and thus outputs are neither altered biologically nor chemically.~~
~~Flotation~~	~~Used by refining, meat packing, paint, paper milling and baking industries~~	~~Introduction of tiny air bubbles into a solution containing suspended particles. Particles attach to air bubbles and float~~
~~Ion exchange processes~~	~~Ion exchange is a process for the cleaning of liquid waste of dissolved electrically charged particles (ions) by means of ion exchanger materials. Can also be used in water softening, as Ca and Mg ions are removed from the liquid stream. Some of substances suitable for ion exchangers are liquid waste from the electroplating industry, chromium electrolytes/chromating baths, phosphoric acid pickling, hydrochloric acid pickling and sulphuric acid anodising baths. Groups of material unsuitable for ion exchangers are: organic compounds as these can irreversibly block the resins in the exchanger or whose removal may be incomplete; strong oxidising agents, as these may damage the anion exchanger resins; metal cyanide complexes, as strong base anion exchangers damage the resins; aromatic and halogenised hydrocarbons, as they cause the exchanger resins to swell at times and thus can lead to interruptions in the exchanger availability.~~	~~Ion exchange resins have the ability to exchange their settled groups of ions (cations or anion) with ions contained in the water~~
~~Oil separation processes~~	~~Gravity settlement without heat to produce an oil rich layer, that is skimmed off and sent to oil recyclers for further processing, and an aqueous phase plus sludge that is processed through the main plant. At some plants, this is a major part of the day-to-day activities. At others it is an occasional batch process and only operated when needed to provide a full service to major customers but where the company does not actively seek oil/water streams for treatment. Some sites add acid to the oil to assist in the separation process (emulsion breaking)~~	~~Gravity separation of soluble oils and oil/water mixtures~~

WORKING DRAFT IN PROGRESS

~~**Unit operation**~~	~~**Purpose**~~	~~**Principle of operation**~~
~~Organic splitting of emulsions~~		~~For the destabilisation of the emulsifying agent, polyelectrolytes and/or similar products are used. These allow good splitting of the emulsion comparable to acid splitting~~
~~Reverse osmosis~~	~~Used to produce drinking water from brackish groundwater and seawater. Also for recovery of electroplating chemicals from plating rinse water and sulphate from paper industry waste water. Used in leachate treatment~~	~~Uses a mechanical force, e.g. high pressure (17 100 atm) to drive solvent (usually water) through a membrane. This generate two fractions one that concentrate the dissolved components and another where the solvent is purified~~
~~Screening~~	~~Waste water containing solids, etc.~~	~~Removes large particles from waste water. There are three types of screens, rotating drums, vibrating and stationary~~
~~Sedimentation~~	~~Sedimentation is used in Ph-c plants specifically for the thickening of sludges, and the separation of heavy particles and suspended matter from the waste water and concentrate sludge~~	~~The forces of gravity cause the thicker phase of a suspension to separate. To this extent, the nature of the force determines the type of sedimentation: gravity sedimentation or centrifugal sedimentation~~
~~Sorption (absorption and adsorption)~~	~~If the waste water shows increased and/or inadmissibly high values of TOC, AOX or PCB, the organic materials generally separated using adsorption~~	~~Sorption is the uptake of a substance (gas, vapour, liquid) by another material, as a result of the contact of both materials.~~ ~~Absorption is designated as the penetration of a gas into a solid or liquid phase (absorbents) by diffusion. Adsorption is described as the accumulation of gases or solute materials at the surface of a solid or liquid material (adsorbents) by molecular forces. Adsorption is a physical process, and to this extent the chemical characteristics of the adsorbed material are unaltered~~
~~Stripping (by air or steam)~~	~~Stripping is used in order to be able to use the following procedures better and more effectively; or as a final stage to reduce the concentration of certain hydrocarbons (AOX). By stripping, volatile materials, for example hydrogen sulphide (H^2S), ammonia (NH^3), low boiling hydrocarbons and chlorine hydrocarbons (AOX) can be separated from aqueous solutions~~	~~Stripping is the driving out of easily vaporisable materials from liquid mixtures. Air or water vapour is used for stripping, with a simultaneous increase of the phase-boundary surfaces. Stripping is thus a separation process in which the separated material is in the exhaust air (stripping with air) or in the distillate (stripping with water vapour)~~
~~*Chemical processes*~~ *		
~~Electrolysis~~	~~The recovery of metals from solutions (e.g. silver from photographic waste)~~	~~Use of electrical power to reduce metals from solution~~
~~Neutralisation~~	~~To neutralise the waste water or to recuperate some components from it by precipitation at a specific pH(s). Depending on equipment configuration, neutralisation and sedimentation can be carried out in the same container~~	~~Neutralisation is the adjustment of the pH values to a neutral level, for instance, pH ~ 7. Neutralisation is achieved by adding acids or alkalis to the material to be neutralised and/or by the mixing of acids and alkalis~~

WORKING DRAFT IN PROGRESS

~~**Unit operation**~~	~~**Purpose**~~	~~**Principle of operation**~~
~~Oxidation/ reduction~~	~~Redox reactions in connection with the Ph-c treatment of waste activity involve the detoxicating of nitrite and cyanide (oxidation) and chromium (VI) compounds (reduction). Other possible treatments are the destruction of sulphides or peroxides. Wastes are made less toxic, simpler and less volatile by subtracting or adding electrons between reactants~~	~~Oxidation and reduction are processes which are generally coupled. Oxidation is the release of electrons, and reduction is the uptake of electrons.~~
~~Precipitation/ flocculation~~	~~The separation of dissolved or suspended materials (e.g. metals) by the addition of chemicals~~	~~Precipitation is the conversion of a solute substance to an undissolved substance, in general by the addition of chemicals. Flocculation is the agglomeration of more or less fine particles (as well as solute substances) into larger flocs; these are separated by sedimentation or filtration~~
~~Wet air oxidation~~	~~Sewage sludge~~	~~Solids solubilised and oxidised under high pressure~~
~~* Some of these treatments induce separations (e.g precipitation)~~		

~~**[57, Petts, J. and Eduljee, G. 1994], [77, Schmidt et al. 2002], [98, WT TWG 2004]**~~.

From ex-**Section 3.4.3.7 "Emissions from the treatment of photographic waste"**

~~*Emissions to air*~~

~~Treatment of photographic waste, especially fixers, can generate emissions to the air of ammonia, acetic acid and VOCs.~~

~~The emissions from physico-chemical treatments are reduced by treating the exhausted air in a wet oxidising scrubber. The concentrations in the exit gases of C_xH_y are approximately 600 mg/Nm^3 and of NH_3 <2 mg/Nm^3. The emissions from the biological treatment are reduced by means of a continuous automatic monitoring and regulation of the air or oxygen supply. The total C_xH_y emission is estimated to have a maximum of 20 g/t waste water.~~

~~In evaporation, some compounds will evaporate together with the water. Most of them will condense. Not condensed compounds are passed through the biological treatment that functions as a scrubber. The emissions from the evaporation step are negligible.~~

~~*Emissions to water*~~

~~In Table 5.176, emissions to water from physico-chemical and biological treatments are presented. Desilvered photographic liquid waste is just one of the processed waste waters. Therefore, the presented emissions give a rough indication of possible emissions from the treatment of this waste stream.~~

~~**Table 5.176: Emissions to water from the treatment of photographic liquid waste and other waste waters**~~

~~**Component**~~	~~**Emission (g/t waste water)**~~
~~Suspended solids~~	~~9~~
~~Chloride~~	~~29~~
~~Sulphur~~	~~0.3~~
~~COD~~	~~172~~
~~BOD~~	4
~~N-total (Kjeldahl)~~	~~351~~
~~Phosphorus~~	~~2~~
~~*Source*: [33, UK EA 2001]~~	

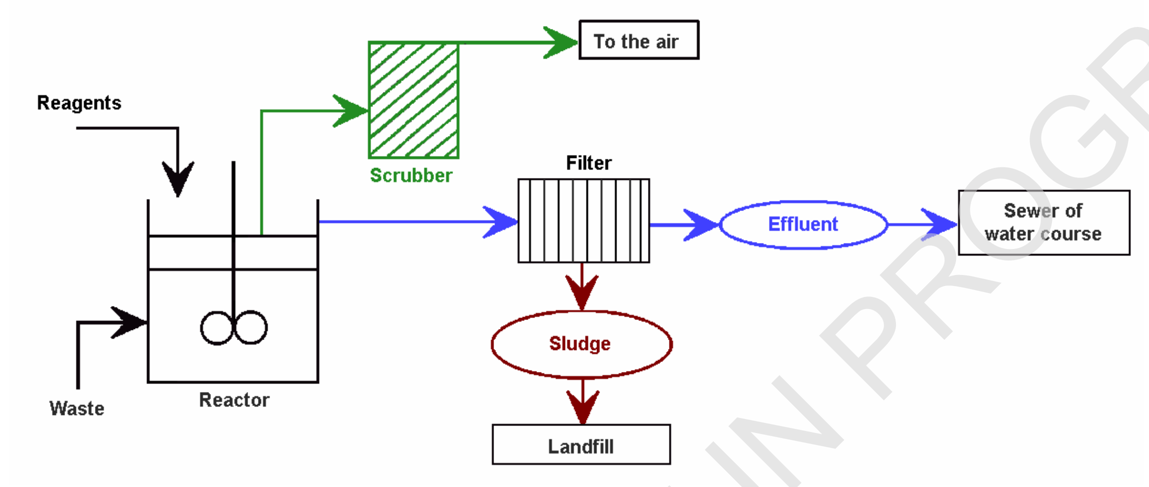
WORKING DRAFT IN PROGRESS

5.7.2 Current emission and consumption levels

5.7.2.1 Overview

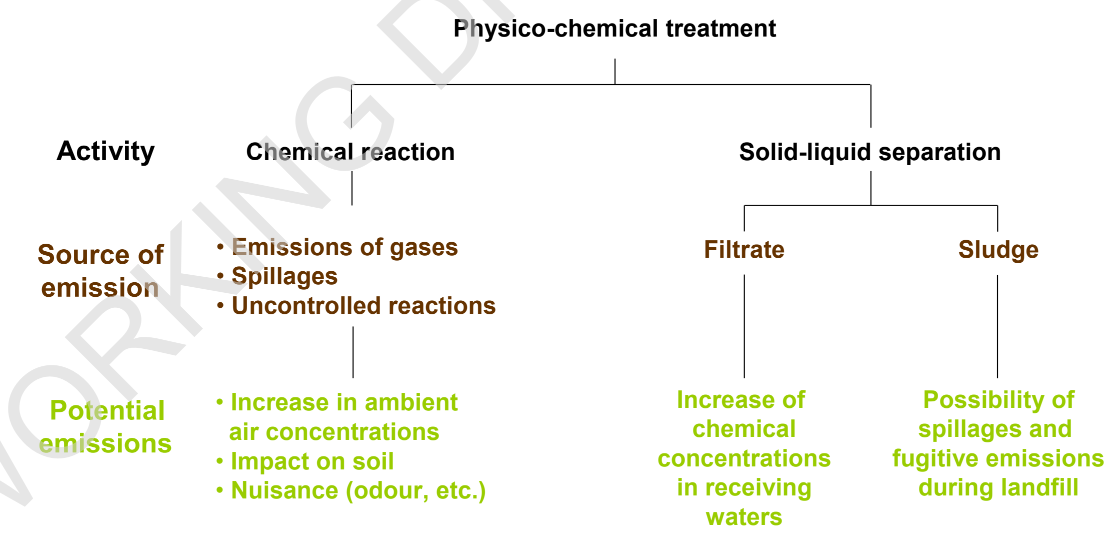
From ex-Section 3.3.3.1 Emission from the physico-chemical treatments of waste waters

The physico-chemical and/or biological treatment of water-based liquid waste ~~waters~~ generates a flow of decontaminated water ~~which corresponds to the so-called waste OUT stream of the treatment~~. An analysis of this stream is given in Section 5.7.2.3. The following two figures (**Figure 5.34** and **Figure 5.35**) ~~extrapolate flow diagrams leading to~~ summarise potential emissions from the physico-chemical and/or biological treatment of water-based liquid waste.



Source: [57, Petts, J. and Eduljee, G. 1994]

Figure 5.34: Main emission flows from the physico-chemical and/or biological treatment of water-based liquid waste



Note: Some of these emissions only appear in badly operated physico-chemical treatments
Source: [57, Petts, J. and Eduljee, G. 1994] [98, WT TWG 2004]

Figure 5.35: Potential emission streams from physico-chemical and/or biological treatment of water-based liquid waste

WORKING DRAFT IN PROGRESS

5.7.2.2 Emissions to air

From ex-Section 3.3.3.1 Emission from the physico-chemical treatments of waste waters

Some organic compounds can travel through the plant without being removed and then end up in the final sludge or effluent, whereas others may be evaporated during the exothermic reactions of neutralisation or during sludge pressing. Certain organic wastes contain ‘hidden’ species. For example, lubricating oils contain naphthalene, BTEX, phenols, copper and nitrogen and can lead to ammonia and xylene emissions to air during the oil separation from water, or to increased levels in the final site effluent. Aqueous wastes containing solvents may be emitted due to the heat of the process. High-nitrogen wastes have the potential for ammonia emissions to air.

Some materials passing through the plant (typically not captured by physico-chemical processes) are the TOC/COD, dichloromethane, phenol, BTEX and naphthalene associated with the waste water from oil pretreatment and the TOC, dichloromethane, phenol, BTEX and naphthalene associated with the waste from oil pretreatment.

The emissions to air from individual plants depend on the abatement system used. ~~Very few plants have monitoring programmes in place that can quantify their emissions to air.~~ Emissions to air from these treatments are typically VOCs, acid gases and ammonia. ~~Although difficult to quantify given the lack of monitoring programmes,~~ It can be seen that if closed treatment vessels and air collection/treatment systems are in use these emissions are reduced. Issues such as the presence of low concentrations of organic solvents in the waste might not always be picked up by WT operators, but these may be important environmentally as they could lead to relevant emissions to air during the process.

Emissions to air may be associated with rapid pH changes, rapid temperature rises and with vigorous agitation. Gaseous reaction products also still occur. Most plants will liberate VOCs from the waste through a mixture of heating, agitation or sludge pressing or drying. There is also always a possibility that reaction intermediates may be released as well. Emissions of metals to air can be assessed using analytical results. Evaporation also occurs in an uncontrolled manner, such as the evaporation of solvents when mixing solids and liquids or from the stirring of sludges in open tanks.

Emissions of organic compounds may appear when treating mixed waste streams (for example, from the neutralisation of acid, solvents are displaced into the vapour phase which cannot be abated by a wet scrubber used to abate acidic emissions) or are present because their recovery is neither technically nor economically viable (that is, as contaminants associated with wastes that are difficult to handle are treated by other methods).

~~Table 5.177: Air emissions from physico-chemical treatment of waste water~~

~~Air emission parameters~~	~~Measured annual average emission values (mg/Nm^3)~~	~~Mass flow (g/h)~~
~~Flow of exhaust air~~	~~325 Nm^3/t~~	
~~TOC^1~~	~~2.84 – 36~~	~~500 (534 kg/yr)~~
~~Dust~~	~~0.21~~	~~40.3 kg/yr~~
~~BTX~~	~~4.9~~	
~~Benzene~~		~~2.5~~
~~HCN~~	~~<0.05 – 0.12~~	~~0.043 – 15~~
~~H^{2}S~~	~~0.31~~	~~15~~
~~Cl^2~~	~~<0.03~~	~~15~~
~~SO^2~~	~~1.17~~	~~0.5~~
~~HCl~~	~~0.3~~	~~0.2~~
~~Hg~~	~~0.01~~	~~0.0034~~
~~Notes: Data based on the data from Ph-c plant operators with a total capacity of 850 kt/yr. The data correspond to year 2001. The average age of the plants is about 17 years (ranging from 4 to 39 years). Approximately 84 % (from 73 to 91 %) of all the Ph-c plants for the treatment of accepted waste covered here can be~~		

WORKING DRAFT IN PROGRESS

~~attributed to EWL groups 11,12,13,16 and 19.~~

~~Exhaust air emissions are in general measured intermittently. The measurements are essentially made to monitor the processes, where contamination of the exhaust air can be expected in the intended operation, such as evaporation or cyanide oxidation.~~

~~[1] Values correspond to mg of carbon~~

~~[77, Schmidt et al. 2002] [90, UBA Germany 2003] [104, UBA Germany 2004]~~

~~The emissions of VOC from aqueous marine waste treatments range from 0.4 to 0.6 kg/m^3 waste water if no exhaust gas treatment is applied. Biological treatment generates emissions of odour. One of the example plants reports an average emission level of 540 million ouE/h.~~

Table 5.178 below presents the reported emissions to air from physico-chemical and/or biological treatment of water-based liquid waste. It should be read together with Table 5.179 which presents the reported techniques used for air emissions abatement, the origin of air emissions, and the exhaust air flow.

Table 5.178: Emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

Pollutant measured	Monitoring	Plants concerned	Range (mg/Nm^3 except for and odour)	Number of measurements during the three reference years
Dust	Continuous	401_1, 449	Average: 1–5.6	NA
	Periodic	148, 149, 368_1, 423, 463_1, 463_2, 473	0.5–7.5	2 to 6
SO_X	Continuous	401_1, 449	Average: 12–35	NA
	Periodic	148, 317, 368_1, 423, 463_2, 468_1, 468_2, 473, 550	0.002–79	1 to 36
NO_X	Continuous	401_1	Average: 107–138	NA
	Periodic	148, 215_3, 217, 322, 368_1, 423, 463_2, 473, 550	0.0003–211	1 to 36
CO	Continuous	449	Average: 60	NA
	Periodic	368_1, 423, 473	1.6–425	3 to 6
HCl	Continuous	449	Average: 0.5	NA
	Periodic	140_3, 148, 149, 192, 215_5, 217, 317, 322, 401_404_1, 423, 449, 463_2, 468_1, 468_2, 468_3, 471 -1, 471 -2, 471 -3, 550	0.0005–11.3	3 to 36
HF	Periodic	140_3, 217, 401_404_1, 423	0.3	1 to 18
HCN	Periodic	322, 463_2	0.1–0.5	1 to 3
H_2S	Periodic	03, 07, 192, 217, 317, 550	0.0002–1.8	1 to 36
NH_3	Periodic	03, 07, 215_3, 215_4, 215_5, 317, 322, 401_404_1, 401_404_2 ,461_1, 461_2, 461_3, 463_2, 471_1, 550	0.00005–20	1 to 36
TVOC	Periodic	148, 149, 368_1, 368_2	1.9–30.5	2 to 6
NMVOC	Periodic	140_2, 148, 151, 468_4	0.08–52	1 to 25
TOC	Continuous	401_404_1, 449	27.9–44.2	
	Periodic	03, 192, 215_1, 215_2, 217, 423, 463_1, 463_2, 461_1, 461_2, 461_3, 471_2	3–84	1 to 6
Odour (OU_E/m^3)	Periodic	08, 368_2	190–450	1
Cd+Tl	Periodic	401_404_1, 423	0.0001	2
Hg	Periodic	401_404_1, 423	0.005	2
Sum metals	Periodic	423	0.07	2
PCDD/PCDF	Periodic	401_404_1	0.02	18
Benzol	Periodic	216, 217	0.1–4.5	1 to 8
Cd+Hg+Tl (gaseous)	Periodic	148C	0.005	3
NA: not applicable				

WORKING DRAFT IN PROGRESS

Table 5.179: Physico-chemical and/or biological treatment of water-based liquid waste – Abatement techniques used and origin of emissions to air

Plant code	Techniques used	Origin of emissions to air	Waste input description	Air exhaust flow (Nm^3/h)
3	Activated carbon adsorption Wet scrubbing with sorbent injection Biofiltering	Storage tanks Physico-chemical and biological treatment of water-based liquid waste	Lye and lye mixture Acids and acid mixtures Water-solvent mixtures Chemical construction waste Cooling and lubricating liquids Oil-water mixtures Emulsions Paint sludge-water mixtures Landfill leachate	9 800
4	Basic scrubber system Acid scrubber	Metal recovery, breaking emulsion	Organic and inorganic acids (e.g. HCl, HNO_3) Bases (e.g. NaOH, KOH) Solid (e.g. soluble salts) and liquid hazardous waste Oil-water mixtures Emulsions Landfill leachate	NI
7	Biofiltering Wet scrubbing	Physico-chemical and biological treatment of water-based liquid waste	Oil-water mixtures Oil separator content Emulsions Sand catcher Landfill leachate Sewage residues Paint sludge residues Glue residues Washing water containing cyanide	4 000

WORKING DRAFT IN PROGRESS

8	Acid scrubber system Activated carbon adsorption Alkaline oxidative scrubber system Biofiltering Wet scrubbing	Physico-chemical and biological treatment of water-based liquid waste	Emulsion Oil-water mixture Mixed acid Lye mixture Water from tank cleaning Waste oil Solvents Bitumen emulsion Drilling mud Oil separators, sand trap contents Paint sludge Pharmaceutical waste Laboratory waste Detergents	5 000
90	NA	No channelled emissions to air	Biodegradable waste water, e.g. from chemical, pharmaceutical and oil industries	NA
91	NI	Physico-chemical treatment of water-based liquid waste	Acids (chromic, hydrochloric, nitric and similar) containing heavy metals, cyanides	NI
140	Activated carbon adsorption Wet scrubbing	Emulsion breaking Centrifugation Evaporation-condensation Transfer station Treatment of waste waters containing inorganic substances including metal compounds recovery	All types of hazardous waste entering a transfer station with sorting/treatment prior to final treatment: Waste waters with a low organic content and high sediment content (soluble oily waters). Waste waters with a high organic content, low sediment content and salts (soaps, inks, cooling liquid, soluble oils containing waste). Hydrocarbon-containing waste waters and sludge Waste water with biodegradable organic content	13 800

WORKING DRAFT IN PROGRESS

144	Basic scrubber system	Neutralisation reactors	Used resins Acid (hydrochloric, nitric, sulphuric) Soda Leachates Inorganic solutions containing Cr(VI) Liquid waste containing CN Liquid waste containing phenols Liquid waste containing oil Water-based liquid waste with organics and biodegradable content	NI
148	Activated carbon adsorption	Fuel preparation and sludge drying	Energetic waste from numerous industrial origins, Sludge from oil-water separators, from storage tank and barrel cleaning Cleaning water, washing liquids Aqueous waste from chemical industry Pasty, organic unreactive wastes WEEE	38 000
149	Activated carbon adsorption	Physico-chemical treatment of water-based liquid waste	Used acids from research laboratories (industrial, university) Used bases from research laboratories (industrial, university) Cleaning water, washing liquids Liquid wastes from chemical industry Pasty, organic unreactive wastes WEEE	51 000

WORKING DRAFT IN PROGRESS

151	Activated carbon adsorption	Tank vents, centrifugation	Organics and biodegradable liquid waste Hydrocarbon liquid waste containing more than 10 % sediment	NI
153	NA	No channelled emissions to air	Waste fluids from various sectors: complex machining emulsions (water-oil-solids), oily waters from oil-water separators, aqueous washing liquids, etc. Water and sediments Any type of bulk/packaged waste, except: radioactive wastes, explosive compounds or wastes that might ignite spontaneously, hydrolysable wastes emitting noxious compounds when in contact with water, chemically or physically instable wastes, asbestos wastes	NA
154	Basic scrubber system	Tank vents	Liquid waste containing hydrocarbons Liquid waste containing organics and biodegradable organics Solvents Acids Bases Pesticides Oxidisers Laboratory effluents Sludge Other solid waste	NI

WORKING DRAFT IN PROGRESS

156	Biofiltering Adsorption on activated carbon and photocatalytic regeneration Basic scrubber system	Offloading, storage, emulsion breaking (organic physico-chemical) treatment, three-phase centrifugation Offloading, storage, mineral physico-chemical treatment	Mix of water-based/sediment/hydrocarbons liquid waste Liquid waste containing Cr(VI) Liquid waste containing CN Liquid waste containing phenols Acids Bases Flue-gas cleaning residues Metal hydroxide sludge or sludge from metal insolubilisation treatment (PC plant)	NI
159	Biofiltering	Centrifugation Tank vents	Waste with a high hydrocarbon content Waste with a low hydrocarbon content Water with oily emulsions Water with biodegradable organics content Solid organic waste which cannot be treated by any of the waste treatment activities of the plant	NI
192	Basic scrubber system	Treatment process	Spent chromic acid baths from the chromium plating industry Various hazardous liquid wastes mainly containing inorganic pollutants: typically, waste acids and bases, wastes containing anionic (cyanides, fluorides, etc.) and/or cationic (heavy metals, metalloids, etc.) contaminants	6 600

WORKING DRAFT IN PROGRESS

194	Wet scrubbing	NI	Water containing organics and/or metal compounds Waste waters with organic content and sediment and salts content (soaps, inks, cooling liquid, soluble oils containing waste, etc.) Waste water with biodegradable organic content	NI
215	Basic scrubber system Acid scrubber system	Physico-chemical treatment of water-based liquid waste	Acids Bases Hydrocarbons (oil and fuel liquid) Waste from surface treatment and mechanical forming Sludge	620–7 500
216	Activated carbon adsorption	Physico-chemical treatment of water-based liquid waste	Organic liquid waste	NI
217	Basic scrubber system Acid scrubber system Activated carbon adsorption	Physico-chemical treatment of water-based liquid waste	Inorganic liquid waste Organic liquid waste	2 500
317	Basic scrubber system Acid scrubber system Activated carbon adsorption	Physico-chemical treatment of water-based liquid waste	Inorganic liquid waste Inorganic acid Organic liquid waste	2 500
322	Alkaline oxidative scrubber system Wet scrubbing	Physico-chemical treatment of water-based liquid waste	Waste from surface treatment Water from rinsing Emulsion	1 000
347	Bag/fabric filter system Zeolite filter	Physico-chemical treatment of water-based liquid waste	Landfill leachates Washing water, process and meteoric Oil emulsions	NI
351	NA	No channelled emissions to air	Street cleaning residues Waste from sewage cleaning	NI
368	Acid scrubber system Thermal afterburning Biofiltering	Physico-chemical treatment of water-based liquid waste Biological treatment of water-based liquid waste	Liquid wastes with solvents Liquid wastes with organic contamination Sludge from the biological WWTP and wastes with organic contamination Biodegradable wastes	3 400–6 200
392	NA	No channelled emissions to air	Landfill leachate	NA
393	NA	No channelled emissions to air	Landfill leachate	NA
395	NI	Physico-chemical treatment of water-based liquid waste	Spent acids Spent bases	NI

WORKING DRAFT IN PROGRESS

401	Acid scrubber system Dry electrostatic precipitator (ESP) Basic scrubber system Thermal afterburning Water spraying (dust)	Emission from stack of all integrated process, after incinerator and flue-gas treatment	Separate oil and oil from oil-water separation Waste from paint, kit, wax, ink, pharmaceutical waste Oily or other organic waste Soil, TAR and other minerals	205 000
421	NA	No channelled emissions to air	Drilling waste (cuttings, mud and sludge)	NA
423	NI	Thermo-mechanical mixer	Drilling waste (cuttings, mud and sludge).	2 200
449	NI	Biological treatment process	Acids Bases Contaminated soil Sludge Waste oil Other waste: metal waste, WEEE, material containing asbestos	4 300
463	Activated carbon adsorption	Water-based liquid/pumpable waste treatment Disposal or recovery of hazardous waste Regeneration of acids or bases	Acids Bases Contaminated soil Sludge Waste oil	NI
468	Basic scrubber system	Physico-chemical process of water-based liquid waste Immobilisation of solid and/or pasty waste Centrifugation of waste oil	Acids Bases Liquid waste with high biodegradable content Waste oil Mixed hazardous waste	2 900–5 000
473	Electrochemical cells	Water-based liquid/pumpable waste treatment	Water/waste with hydrocarbons Basic waste Liquid cleaning solutions Waste ink Waste from the photographic industry Emulsions Oily sludge Antifreeze Leachate Liquid cleaning solutions	2 200

WORKING DRAFT IN PROGRESS

486	Enclosed process	Physico-chemical treatment of water-based liquid waste	Oily water from drained sludge, car washing, floor washing; flush pit-water, degreasers; cable pits, decontamination sites Water from flocculation of dye/colour waste IBC washing water Solvents and paint Solvents Used motor oil Oil emulsion Acids Bases Other waste: all types of electronic equipment (computers, fridges, telephones), demolition waste, different kinds of bases, pesticides, explosives, reactive flammable waste (organic peroxides and hydrogen peroxide)	NI
550	Basic scrubber system	Physico-chemical treatment of water-based liquid waste	Acids Various mixed wastes Neutral sludge	NI
607	Biofiltering	Sludge storage, sludge thickening and sludge dewatering	Indigenous liquid sludge and imported sludge	NI
NI: No information. NA: Not applicable.				

WORKING DRAFT IN PROGRESS

Figure 5.36, Figure 5.37, and Figure 5.38 below present the reported emissions to air of HCl, NH3 and TOC respectively from physico-chemical and/or biological treatment of water-based liquid waste.

Hydrogen chloride (HCl)
Of the 38 plants performing physico-chemical and/or biological treatment of water-based liquid waste, 13 (or 34 %) reported HCl concentration values in emissions to air, some of them having more than one point of release. The average reported HCl concentration is around 2 mg/Nm^3, with a range of 0.0005–11.3 mg/Nm^3.

The reported waste input is mainly acids, bases, oily water, etc.

Figure 5.36 below presents the reported periodic measurements of HCl emissions to air from physico-chemical and/or biological treatment of water-based liquid waste.

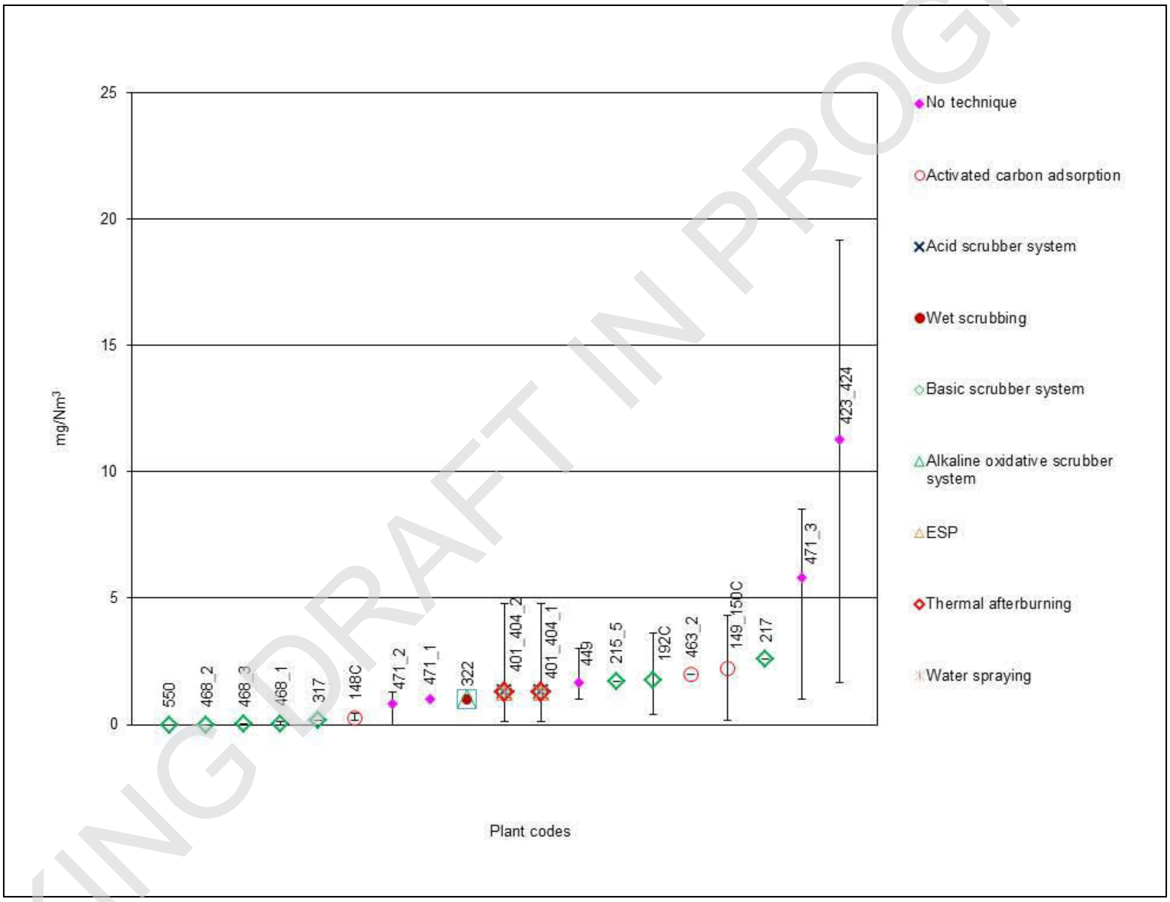


Figure 5.36: HCl emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

For the highest reported values, the implemented abatement techniques were not indicated.

Ammonia (NH_3)
Of the 38 plants performing physico-chemical and/or biological treatment of water-based liquid waste, 10 (or 26 %) reported NH_3 concentration values in emissions to air, some of them having more than one point of release. The average reported NH_3 concentration is around 3 mg/Nm^3, with a range of 0.00005–20 mg/Nm^3.

As for HCl, the waste input is mainly acids, bases, oily water, and also sludge, and landfill seepage.

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Figure 5.37 below presents the reported periodic measurements of NH_3 emissions to air from physico-chemical and/or biological treatment of water-based liquid waste.

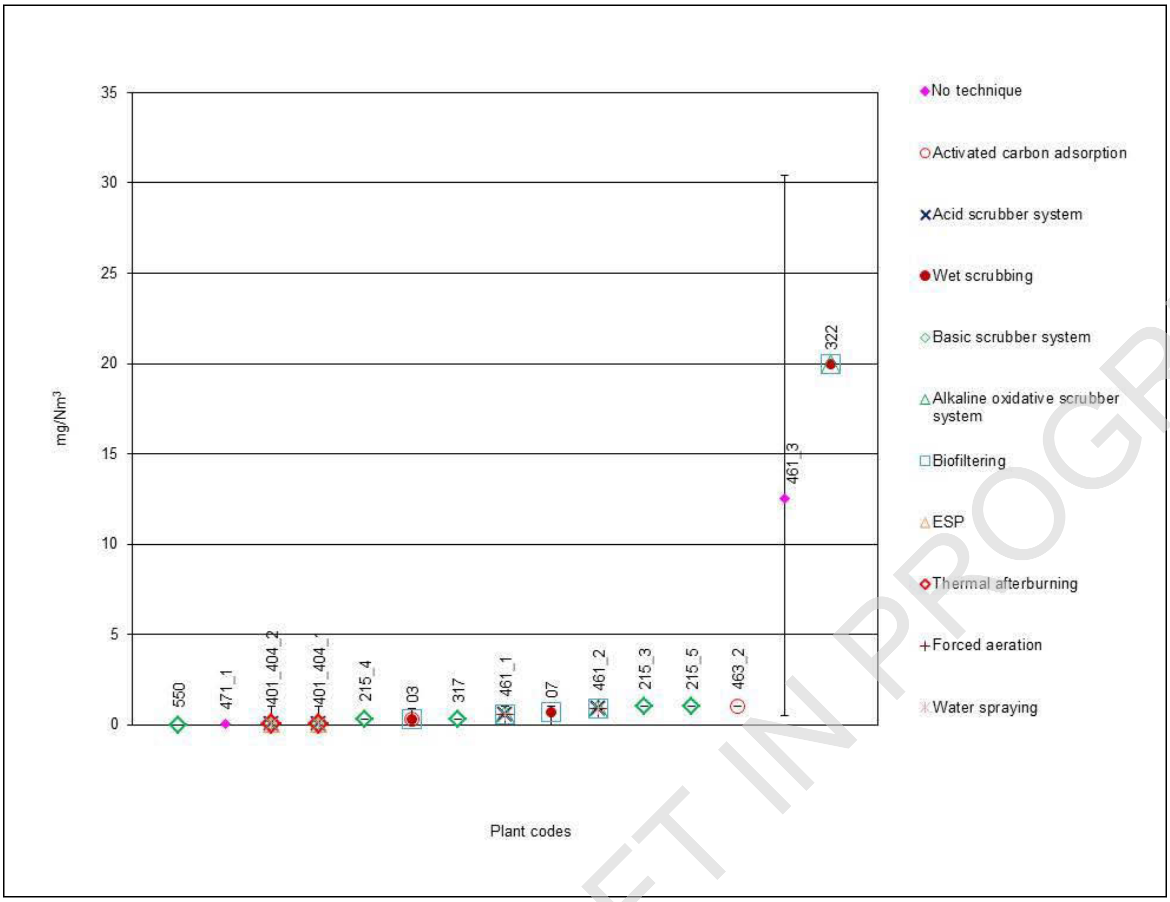

Figure 5.37: NH_3 emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

The waste input in Plant 461 is sludge and digestate from an urban WWTP. The implemented abatement technique is not reported.

The waste input in Plant 322 is acid, base, and rinsing water. The implemented abatement techniques are an alkaline oxidative scrubber and a wet scrubber. The NH_3 concentration value provided is estimated by means of a test device.

Volatile organic compounds (VOCs)

Of the 38 plants performing physico-chemical and/or biological treatment of water-based liquid waste, 14 (37 %) reported VOC concentration values in emissions to air, some of them having more than one point of release. VOC concentration values were expressed as TVOC (3 plants; 5 points of release), NMVOC (4 plants) and TOC (10 plants; 14 points of release). The average reported TOC concentration value is around 16 mg/Nm^3, with a range of 0.7–84 mg/Nm^3. The average reported TVOC concentration value is around 13 mg/Nm^3. The average reported NMVOC concentration value is around 25 mg/Nm^3.

Figure 5.38 below presents the reported periodic measurements of TOC emissions to air from physico-chemical and/or biological treatment of water-based liquid waste.

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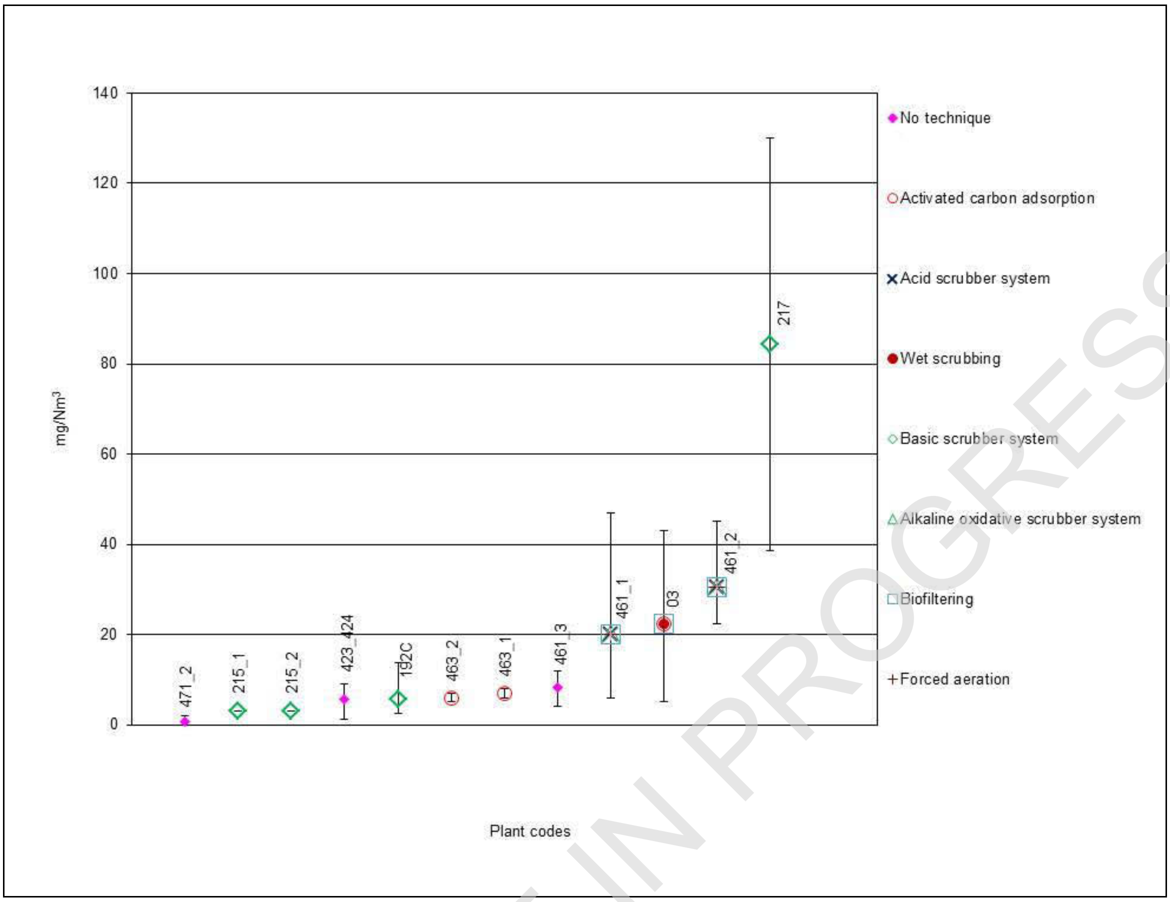

Figure 5.38: TOC emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

The waste input in Plant 217 is inorganic and organic liquid waste. The waste treatment process comprises several steps, such as air stripping, centrifugation, chemical oxidation, chemical reduction, and emulsion breaking. The implemented abatement techniques are a basic scrubber, acid scrubber, and activated carbon filter. The average value reported in Figure 5.38 is based on two measurements (one in 2010 and one in 2011), of 130 mg/Nm^3 and 39 mg/Nm^3 respectively.

5.7.2.3 Emissions to water

~~(For more information see Section 2.3.6~~).

5.7.2.3.1 Overview

From ex-Section 3.3.3.1 Emission from the physico-chemical treatments of waste waters

Aqueous output ~~residues (if any)~~ is ~~generally~~ sent either to a sewer (most of the cases according to the collected data), or to a receiving water body. Wastes from the chemical industry, high-nitrogen wastes (maybe landfill leachates) and oil recovery/reprocessing may introduce additional species and thus are ~~need to be~~ considered more carefully. High-nitrogen wastes increase the likelihood of a discharge of nitrous oxide. Metals, ammonia and organic chemicals are typically present in water streams.

In all cases, the effluent consents will require the protection of the sewerage treatment works from the plant discharge, ~~this protection is focused~~ focusing for example on COD, pH, oil content, ammoniacal nitrogen, metal content, sulphates and sulphides, as well as dichloromethane (the most common halogenated cleaning compound and liable to be a contaminant of washing water~~s~~ and interceptors). The total discharge volume will usually be known.

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~~Although precipitation techniques for metals are reasonably effective, a typical physico-chemical process (under a trade effluent consent) may discharge between 1 – 3 tonnes of metals to sewer annually (the actual value depends on the size of the plant and the amount and type of waste. For example, considering the emission values that appear in , and without considering Fe as a metal, a volume of waste water of 500000 m^3 is necessary to reach some of the upper levels of the range). This is associated with particulates carried over in the effluent from the process and arising from inefficiencies in either the precipitation stage or during settling out of the precipitated metals.~~

~~Most sites do not have data for the chloride, total nitrogen and total phosphorus in the sewer discharge. Rough calculations show that for sites where data are available, the emissions are low, unless the site specialises in phosphoric acid treatment or handles high nitrogen flows. Most sites are required to analyse for ammoniacal nitrogen so they can provide a minimum emission value.~~

~~The process of waste waters mixed with organic material (e.g. mix of mineral oil, synthetic oil, kerosene, interceptor waste, aliphatic hydrocarbon, aromatic hydrocarbon, alcohol, chlorinated solvents, esters, ethers, aldehydes, ketones, fats, waxes, greases) generates around 836 kg of waste water per tonne of waste IN and 5.5 kg of sludge per tonne of waste IN.~~

~~Emissions to water of salts, e.g. sulphates and chlorides, occur. These salts are added as reagents and are not removed in the process of precipitation, neutralisation and filtration. This causes the effluent to have high concentrations of these compounds.~~

5.7.2.3.2 Direct discharge

Table 5.180 below gives an overview of the most commonly measured emissions to water from physico-chemical and/or biological treatment of water-based liquid waste, for direct discharge. It should be read together with **Table 5.181** which gives a brief description of the treatment process, the techniques used, the waste input and output description, and the flow of emissions to water.

In this section, analysis of emissions to water from plants that have indicated also performing physico-chemical treatment of waste other than only water-based liquid waste, but directly discharging to a water body, are taken into account. This concerns Plants 170, 427, 569, and 620. They are marked with an asterisk in the tables below.

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Table 5.180: Emissions to water from physico-chemical and/or biological treatment of water-based liquid waste – Direct discharge

Pollutant measured	Monitoring	Plants concerned	Range (mg/l except for pH and NO^{2-}/NO^{3-})	Number of measurements during the three reference years
pH	Continuous	90, 144, 421, 423, 427*	Min./Max.: 6.5–8.4 Average: 7.3–8.2	NA
	24-hour flow-proportional composite sample	140, 156, 192, 368, 569*	Min./Max.: 5.5–17 Average: 7.8–9	NA
	Composite sample	154	7.4	36
	Grab sample	392, 449, 620*	7.8–7.9	3 to 35
TSS	24-hour flow-proportional composite sample	140, 144, 156, 192, 368, 427*, 569*	Min./Max.: 1–316 Average: 18–61	NA
	Composite sample	154, 421	33	36
	Grab sample	392, 393, 449, 620*	3.3–27	3 to 36
BOD_5	24-hour flow-proportional composite sample	90, 140, 170*, 368, 427*, 468, 569*	Min./Max.: 3–88 Average: 19–20	NA
	Grab sample	392, 393, 449	4–49	3 to 36
COD	24-hour flow-proportional composite sample	90, 170*, 368, 569*	Min./Max.: 67–570 Average: 88–270	NA
	Grab sample	392, 393, 449, 620*	33–328	3 to 36
TOC	Continuous	144, 368, 421	Min./Max.: 10–316 Average: 0.5–157	NA
	24-hour flow-proportional composite sample	140, 156, 192, 423, 427*	Min./Max.: 30–790 Average: 180–770	NA
	Composite sample	154, 620*	0.2–52	36
THC	24-hour flow-proportional composite sample	140, 156, 192, 368	Min./Max.: 0.05–62 Average: 0.1–8	NA
	Composite sample	154, 421, 423	0.05	36
PAHs	24-hour flow-proportional composite sample	421, 427*	0.0006–0.006	NA
	Grab sample	392	0.001	35
Cl^-	24-hour flow-proportional composite sample	144, 368, 427*	Min./Max.: 5770–234 000 Average: 40 000–77 000	NA
		368, 569*	Min./Max.: 161–1160 Average: 759–830	NA
	Grab sample	393, 449, 620*	158–1278	3 to 36
F^-	24-hour flow-proportional composite sample	192, 140	Min./Max.: 0.1–29 Average: 3.7–11	NA
	Composite sample	154	10.2	36
	Grab sample	449, 368	0.8–3.1	2 to 9

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SO_3^{2-}	24-hour flow-proportional composite sample	368	< 0.5	NA
CN^-	24-hour flow-proportional composite sample	140, 144, 156, 192, 427*, 569*	Min./Max.: 0.005–0.7 Average: 0–0.1	NA
	Composite sample	154	0.025	36
Sulphate	24-hour flow-proportional composite sample	368, 427*, 569*	Min./Max.: 0.1–2013 Average: 145–291	NA
	Grab sample	393, 449	262–328	2
Total N	24-hour flow-proportional composite sample	90, 427*, 569*	Min./Max.: 1–76.6 Average: 12–14	NA
	Grab sample	392, 393, 620*	0.04–39	1 to 33
TKN	24-hour flow-proportional composite sample	140, 170*	Min./Max.: 6–194 Average: 73–81	NA
	Grab sample	392, 393, 620*	0.3–13	36
NO^{2-}/NO^{3-}	24-hour flow-proportional composite sample	90, 140, 368, 423, 427*, 569*	Min./Max.: 0.02–35 Average: 0.05–25	NA
	Grab sample	392, 620*	0.015–7.9	9
NH_3-N	24-hour flow-proportional composite sample	90, 140, 156, 368, 423, 569*	Min./Max.: 00.1–1000 Average: 0.6–5.5	NA
	Grab sample	393, 449, 620*	0.8–10.1	2 to 35
Total P	24-hour flow-proportional composite sample	90, 140, 170*, 192, 368, 423, 427*, 569*	Min./Max.: 0.02–50.8 Average: 0.7–36	NA
	Grab sample	392, 393, 449, 620*	0.3–1.4	2 to 35
Cd	24-hour flow-proportional composite sample	140, 144, 156, 170*, 192, 421, 427*, 569*	Min./Max.: 0.0002–1 Average: < 0.1	NA
	Composite sample	154, 423	0.02	36
	Grab sample	368, 392, 393, 449, 620*	0.001–0.01	9 to 19
Tl	Composite sample	154, 423	0.01	36
Hg	24-hour flow-proportional composite sample	140, 144, 421, 427*, 569*	Min./Max.: 0.00005–0.01 Average: 0–0.04	NA
	Composite sample	154, 423	0.01	36
	Grab sample	368, 392, 393	0.00005–0.02	9 to 19
Sb	24-hour flow-proportional composite sample	368, 427*	Min./Max.: 0.08–0.1 Average: 0.1	NA
As	24-hour flow-proportional composite sample	140, 170*, 144, 368, 421, 427*, 569*	Min./Max.: 0–0.1 Average: 0.01–0.1	NA
	Composite sample	154, 423	0.03	36
	Grab sample	392, 393, 449	0.02	17 to 19
Pb	24-hour flow-proportional composite sample	140, 144, 170*, 156, 192, 368, 421, 427*, 569*	Min./Max.: 0.0008–2.9 Average: 0.003–0.5	NA

WORKING DRAFT IN PROGRESS

	Composite sample	154, 423	0.06	36
	Grab sample	392, 393, 449, 620*	0.005–0.025	17 to 19
Cr	24-hour flow-proportional composite sample	90, 140, 144, 156, 170*, 192, 368, 421, 427*, 569*	Min./Max.: 0–4.4 Average: 0.03–0.3	NA
	Composite sample	154, 423	0.03	36
	Grab sample	392, 393, 620*	0.01–0.04	17 to 19
Cr(VI)	24-hour flow-proportional composite sample	140, 144, 156, 192, 421, 569*	Min./Max.: 0.01–0.07 Average: < 0.05	NA
	Grab sample	368, 620*	0.02–0.04	9
Co (cobalt)	24-hour flow-proportional composite sample	368, 421, 427*	Average: 0.001–0.05	NA
Cu	24-hour flow-proportional composite sample	140, 144, 156,170*, 192, 368, 421, 427*, 569*	Min./Max.: 0.001–2 Average: 0.03–0.4	NA
	Composite sample	154, 423	0.06	36
	Grab sample	392, 393, 449, 620*	0.005–0.01	17 to 19
Mn	24-hour flow-proportional composite sample	144, 368, 421, 427*	Min./Max.: 0.02–10 Average: 0.3–0.5	NA
	Composite sample	154	0.3	36
	Grab sample	449, 620*	01	NI
Ni	24-hour flow-proportional composite sample	90, 140, 144, 156, 170*, 192, 368, 421, 569*	Min./Max.: 0.01–5 Average: 0.02–1.1	NA
	Composite sample	154, 423	0.2	36
	Grab sample	392, 393, 449, 620*	0.02–0.04	17 to 19
V	24-hour flow-proportional composite sample	144, 368, 421, 427*	Min./Max.: 0.002–0.1 Average: 0.1	NA
	Composite sample	423	NI	NI
Sum metals	24-hour flow-proportional composite sample	140, 144	Min./Max.: 0–9 Average: 0.3–2.1	NA
	Composite sample	154	3.4	36
Zn	24-hour flow-proportional composite sample	140, 144, 156, 170*, 192, 368, 421, 427*, 569*	Min./Max.: 0.01–8.8 Average: 0.04–2.6	NA
	Composite sample	154, 423	0.1	36
	Grab sample	392, 393, 449, 620*	0.02–0.5	3 to 19
Fe	24-hour flow-proportional composite sample	144, 156, 192, 368, 427*	Min./Max.: 0.01–10.9 Average: 0.3–10	NA
	Composite sample	154	1.1	36
	Grab sample	449, 620*	0.1–0.3	2
Chlorine	24-hour flow-proportional composite sample	368	< 0.1	NA
	Grab sample	620*	0.03	6

WORKING DRAFT IN PROGRESS

Phenols	24-hour flow-proportional composite sample	140, 144, 156, 368, 421, 427*, 569*	Min./Max.: 0.025–0.5 Average: 0.03–0.3	NA
	Grab sample	90, 449, 620*	0.01–0.035	12
AOX	24-hour flow-proportional composite sample	140, 170*	Min./Max.: 0.3–3.3 Average: 1.9	NA
	Composite sample	154	0.1	6
EOX	24-hour flow-proportional composite sample	192, 427*	Min./Max.: 0.002–7.8 Average: 0.2–0.7	NA
	Grab sample	392, 393	0.1	12 to 17
BTEX	24-hour flow-proportional composite sample	421, 427	Min./Max.: 0–0.002	NA
	Grab sample	620*	0.03	6

Note 1: For 24-hour flow-proportional composite samples, Min. is the lowest of the short-term or long-term reported values, Max. is the highest of the short-term or long-term reported values, and average is the maximum lowest–highest of the average short-term or long-term reported values.
Note 2: When reported, the indicated long-term average is: yearly (Plants 90 and 140) and monthly (Plants 140 and 368). The short-term average is daily (Plant 192) and weekly (Plant 368). Plant 156 indicated that the values are the arithmetic average of days of release.
Note 3: When reported, it is indicated that the samples are not filtered before measurements.
Note 4: Some plants reported also data on: surfactant (Plants 368 and 569*), toxicity (Plants 368, 392 and 427*), PCB (Plants 368 and 427*), PCDD/F (Plants 154 and 427*), and mineral oil (Plants 392, 393 and 569*).
*: Plants treating mainly wastes other than water-based liquid waste.
NI: no information
NA: not applicable

WORKING DRAFT IN PROGRESS

Table 5.181: Physico-chemical and/or biological treatment of water-based liquid waste – Direct discharge – Techniques used, removed substances, waste input description, output and type of release

Plant code	Treatment process	Removed substances	Techniques used	Waste input description	Output	Type of release (batch/ continuous) and water flow
90	First biodegradation (bioreactor) Pretreatment	Heavy metal (not running at the moment)	Active sludge systems Chemical precipitation Filtration Centrifugation	Biodegradable waste water, e.g. from chemical, pharmaceutical and oil industries	Aqueous output Residues from waste water treatment	Continuous 75 m^3/h
140	Neutralisation/precipitation Detoxication Metal compound recovery Emulsion breaking Biological treatment with activated sludge system Finalisation treatment (Ultrafiltration membrane) for 2 bioreactors + Decanter and sand filter for 1 bioreactor	Metals Cr(VI) and CN Metals TOC	Active sludge systems Ultrafiltration	All types of hazardous waste entering a transfer station with sorting/treatment prior to final treatment: Waste waters with a low organic content and high sediment content (soluble oily waters). Waste waters with a high organic content, low sediment content and salts (soaps, inks, cooling liquid, soluble oils containing waste). Hydrocarbon-containing waste waters and sludge Waste water with biodegradable organic content	Residues from waste water treatment Liquid fuel Residues from shredding Other solid fuel Residues from sorting Wood	Continuous 20 m^3/h

WORKING DRAFT IN PROGRESS

Plant code	Treatment process	Removed substances	Techniques used	Waste input description	Output	Type of release (batch/ continuous) and water flow
144	Removal of pollutants at source Hydrocarbon concentration and distillation/condensation of the aqueous phase Biological treatment of the biodegradable aqueous waste water Finalisation treatment (UF)	Anions or cations Cr(VI), CN, phenols Sludge Oil TOC, TSS, MES TSS	Coagulation Flocculation Precipitation Decantation	Used resins Acid (hydrochloric, nitric, sulphuric) Soda Leachates Inorganic solutions containing Cr(VI) Liquid waste containing CN Liquid waste containing phenols Liquid waste containing oil Water-based liquid waste with organics and biodegradable content	Recovered resin Aqueous output Other	Batch 10 m^3/h
154	Secondary treatment Finalisation treatment	TOC, sludge Biodegradable organics	Active sludge systems Neutralisation Decantation Press filtering Chemical precipitation Membrane extraction Flocculation Aeration Buffer tanks Centrifugation	Liquid waste containing hydrocarbons Liquid waste containing organics and biodegradable organics Solvents Acids Bases Pesticides Oxidisers Laboratory effluents Sludge Other solid waste	Liquid fuel Other residues from waste water treatment	Batch (4 hours 350 times a year) 20–30 m^3/h

WORKING DRAFT IN PROGRESS

Plant code	Treatment process	Removed substances	Techniques used	Waste input description	Output	Type of release (batch/ continuous) and water flow
156_1W	Two-phase centrifugation Three-phase centrifugation Emulsion breaking UF membrane Nanofiltration Deconditioning Detoxication Neutralisation. Metals precipitation. Sludge filtration Biological treatment (activated sludge) Adsorption on activated carbon	Sediment Oil (hydrocarbons) and sediment Oil (hydrocarbons) BOD$_5$ TOC, metals Cr(VI), CN, phenols Alkalinity-acidity, metals	Centrifugation + Breaking emulsion (Organic physico-chemical treatment) Biological treatment Nanofiltration Mineral physico-chemical treatment Saline biological treatment Activated carbon filtration	Mix of water-based/sediment/hydrocarbon liquid waste Liquid waste containing Cr(VI) Liquid waste containing CN Liquid waste containing phenols Acid liquid waste containing Basic liquid waste Flue-gas cleaning residues Metal hydroxide sludge or sludge from metal insolubilisation treatment (PC plant)	Residues from waste water treatment Other Mixed plastics Recovered activated carbon	NI 15 m^3/h
170*	Regeneration of spent solvents Physico-chemical and/or biological treatment of water-based liquid/pumpable waste	NA	Active sludge systems - conventional Coagulation Decantation Flocculation Powdered activated carbon treatment Aeration Air stripping	Spent solvent Oily water	Aqueous output Regenerated solvent Solvent residues, dry matter Residues from waste water treatment Mixed plastics	Continuous 40 m^3/h

WORKING DRAFT IN PROGRESS

Plant code	Treatment process	Removed substances	Techniques used	Waste input description	Output	Type of release (batch/ continuous) and water flow
192	Chemical oxido-reduction step Neutralisation Precipitation/flocculation/sedimentation of complex mineral species Sulphurisation Press filtration	If necessary for CN and Cr(VI) Metallic hydroxides Sludge dewatering	Neutralisation Precipitation step, followed by a flocculation step Sedimentation (ponds) Press filtering	Spent chromic acid baths from the chromium plating industry Various hazardous liquid wastes mainly containing inorganic pollutants: typically, waste acids and bases, wastes containing anionic (cyanides, fluorides, etc.) and/or cationic (heavy metals, metalloids, etc.) contaminants	Regenerated acid Recovered resin Aqueous output Residues from waste water treatment	Batch 200 m^3/h
368	Primary treatment Pretreatment	Organic complex compounds Solvents to be separated	Active sludge system Biological nutrient removal Wet oxidation	Liquid wastes with solvents Liquid wastes with organic contamination Sludge from the biological WWTP and wastes with organic contamination Biodegradable wastes	Stabilised residues Residues from waste water treatment Other	Continuous 560 m^3/h
392	Pre-denitrification Nitrification Post-denitrification Cascade aeration and polymer mixing Sludge sedimentation	Nitrogen Nitrogen Nitrogen Suspended solids	Buffer tanks Active sludge systems Nitrification/denitrification Sedimentation (ponds)	Landfill leachate	Aqueous output	Continuous 35 m^3/h
393	Pre-denitrification Nitrification Post-denitrification Cascade aeration and polymer mixing Sludge sedimentation	Nitrogen Nitrogen Nitrogen Suspended solids	Buffer tanks Active sludge systems Nitrification/denitrification Sedimentation (ponds)	Landfill leachate	Aqueous output	Continuous 10 m^3/h
421	Primary treatment Finalisation treatment Final wet maturation (Bioreactor)	NI	NI	Drilling waste (cuttings, mud and sludge)	Aqueous output Liquid fuel Decontaminated soil	NI

WORKING DRAFT IN PROGRESS

Plant code	Treatment process	Removed substances	Techniques used	Waste input description	Output	Type of release (batch/ continuous) and water flow
423	Primary treatment Finalisation treatment Final wet maturation (bioreactor)	NI	Chemical precipitation Flotation Active sludge systems Moving-bed trickling filter system	Drilling waste (cuttings, mud and sludge)	Decontaminated soil Aqueous output Liquid fuel	NI 7 m^3/h
427*	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste Immobilisation of solid and/or pasty waste	NI	Chemical precipitation Sedimentation (ponds) Filtration Adsorption	Spent acid from production of titanium oxide Flue-gas cleaning product from combustion of household waste Liquid waste from galvanic industry containing metals Metal hydroxide waste	Stabilised residues Aqueous output	Continuous 100 m^3/h
449	First biodegradation (bioreactor) Pretreatment	Metals	NI	NI	Aqueous output Residues from shredding Stabilised residues Mixed plastics	Continuous 3 m^3/h

WORKING DRAFT IN PROGRESS

Plant code	Treatment process	Removed substances	Techniques used	Waste input description	Output	Type of release (batch/ continuous) and water flow
569*	Physico-chemical and/or biological treatment of water-based liquid/pumpable waste Mechanical treatment of waste with calorific value Re-refining and other preparations for reuse of waste oils Immobilisation of solid and/or pasty waste	Inorganics and organics pollutants Water and sediments	Active sludge systems - conventional Chemical precipitation Coagulation Emulsion breaking Flocculation Flotation Press filtering Precipitation Reverse osmosis system Sand filtration Sedimentation (ponds)	Acids, chromic acids Bases Sludge with inorganic or organic contamination Cyanides Oily water, emulsions, lubricating waste oil Refrigeration liquids Inks Organic containing water, leachate; biodegradable liquid waste Biodegradable contaminated soils Fly ash Construction and demolition waste Non-biodegradable solid waste	Liquid fuel Mixed plastics Ferrous metal Paper, wood Oil	NI 20 m^3/h
620*	Re-refining and other preparation for reuse of waste oil: • Vacuum distillation • Centrifugation • Hydrogenation (e.g. of POPs)	Water, light ends Polymers and solids Asphalts Sulphur, nitrogen, metals, olefinic and aromatic compounds	Steam stripping (pretreatment before WWT) Equalisation Skimming Active sludge systems - conventional Filtration Sand filtration	Waste oil (lubricating, hydraulic, insulator, etc.) with or without chlorine Waste mineral oil from oil/water separation	Lubricant base oil Gas oil Asphalt Sludges from biological waste water treatment Solid waste from cleaning (tanks, pipes, process units), Aqueous output	NI 60 m^3/h

WORKING DRAFT IN PROGRESS

Plant code	Treatment process	Removed substances	Techniques used	Waste input description	Output	Type of release (batch/ continuous) and water flow
*: Plants treating mainly wastes other than water-based liquid waste. NI: No information.						

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Flow

Apart from Plants 192 (200 m^3/h) and 368 (560 m^3/h), the reported flows are below 100 m^3/hour. Three out of the 16 plants directly discharging to a water body reported using batch releases, of which one (Plant 154) is releasing several times per day. Five plants did not report any information on whether the release is continuous or batch.

Analysis of parameters

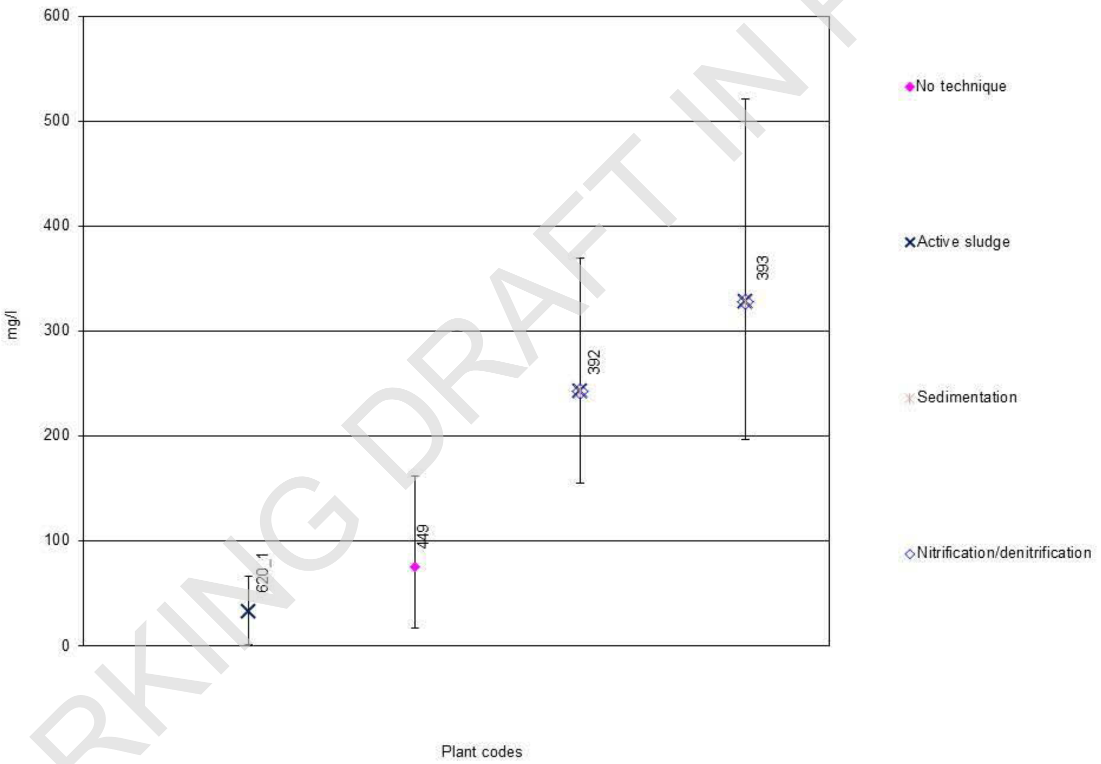
In all graphs and text below presenting the short-term and long-term averages, the spots and values refer to the maximum reported values for the average of 24-hour flow-proportional measurements. The spots and values for periodic measurements refer to the average of all measurements performed during the three reference years.

Chemical Oxygen Demand (COD)

Of the 16 plants directly discharging the effluent to a water body, 8 (or 50 %) reported COD concentration values in the effluent.

As shown in **Table 5.180**, average COD levels are between 33 mg/l and 328 mg/l.

Figure 5.39 below presents the reported COD emissions for periodic measurements.



Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.39: COD in water emissions from physico-chemical treatment of waste – Periodic measurements

Plants 392 reported an average COD concentration of 243 mg/l (periodic measurements – one measurement per month) in the effluent. The influent is landfill leachate with a nitrogen content (total N) of 237 mg N/l, a COD concentration of 374 mg/l, a low C/N ratio and with non-degradable carbon. In the effluent, the total N concentration is 39 mgN/l (efficiency 83 %), the TSS concentration is 27 mg/l, and the BOD$_5$ concentration is 4 mg/l. The COD abatement efficiency is 35 %.

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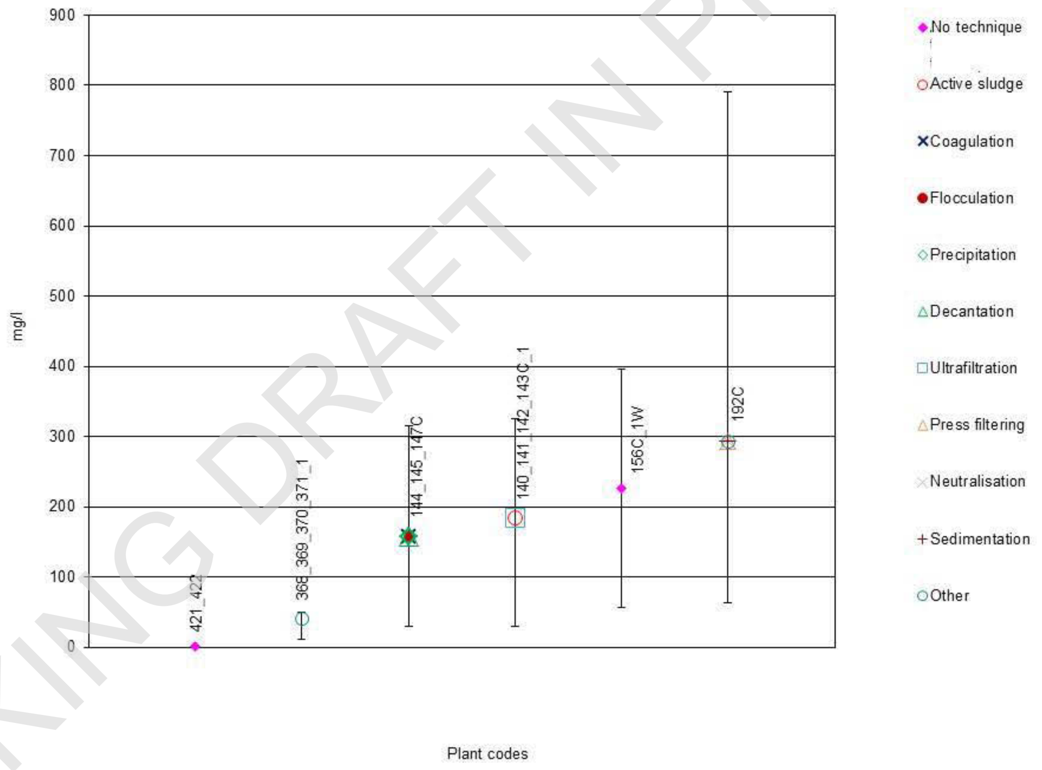
Plant 393 reported an average COD concentration of 328 mg/l. The influent is landfill leachate with a nitrogen content (total N) of 426 mgN/l, a COD concentration of 625 mg/l, a low C/N ratio and with non-degradable carbon. In the effluent, the total N concentration is 35 mgN/l (efficiency 92 %), the TSS concentration is 15 mg/l, and the BOD_5 concentration is 4.5 mg/l. The COD abatement efficiency is 47 %.

Additional information on parameters affecting the performance for reducing COD concentrations can be found in the CWW BREF. [138, COM 2014]

Total Organic Carbon (TOC)
Of the 16 plants discharging directly to a water body, 10 (63 %) reported TOC concentration values in the effluent.

As shown in Table 5.180, average TOC levels are between 0.5 mg/l and 470 mg/l.
Figure 5.40 and Figure 5.41 below present the reported short-term and long-term average values.



Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.40: TOC in water emissions from physico-chemical treatment of waste – Short-term average

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Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.41: TOC in water emissions from physico-chemical treatment of waste – Long-term average

Plant 140 reported an average TOC concentration of 184 mg/l (24-hour flow-proportional composite sample as a short-term average). The influent is water-based liquid waste with a high organic content, and with a TOC concentration of up to 70 g/l. The TOC abatement efficiency is calculated as a maximum at 99 % after final treatment. In the effluent, the reported average TSS concentration is 60 mg/l (24-hour flow-proportional composite sample as a short-term (daily) average). The reported average BOD_5 concentration is 20 mg/l (24-hour flow-proportional composite sample as a monthly average).

Plant 144 reported an average TOC concentration of around 160 mg/l (24-hour flow-proportional composite sample as a short-term average), with the indication that the implementation of activated carbon adsorption now allows a level of 100 mg/l to be achieved. The influent may contain up to 10 g/l TOC (acids, bases, inorganic solutions containing Cr(VI), CN, phenols). The TOC abatement efficiency is calculated as a maximum at 98 % after final treatment. In the effluent, the reported average TSS concentration is around 40 mg/l (24-hour flow-proportional composite sample as a short-term average). The BOD_5 concentration in the effluent was not reported.

Plant 156 reported an average TOC concentration of around 201 mg/l (24-hour flow-proportional composite sample as a short-term average). The influent is water-based liquid waste containing Cr(VI), CN, phenols, acids, bases, which can contain up to 2.5 % TOC (weight), or 15 g/l. The TOC abatement efficiency is calculated as a maximum at 98.5 %. In the effluent, the reported average TSS concentration is around 15 mg/l (24-hour composite sample as a short-term average). The BOD_5 concentration in the effluent was not reported.

Plant 192 reported an average TOC concentration of around 250 mg/l (24-hour flow-proportional composite sample as a short-term (daily) average). The influent is various liquid

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wastes containing inorganics. The TOC concentration in the effluent was not reported. In the effluent, the reported average TSS concentration is around 19 mg/l (24-hour flow-proportional composite sample as a short-term (daily) average). The BOD_5 concentration in the effluent was not reported.

Plant 423 reported an average TOC concentration of 770 mg/l (24-hour flow-proportional composite sample as a long-term average). The plant is treating drilling waste (cuttings, mud and sludge) which contains 12–15 % (weight) organics (POPs). The TOC concentration in the influent was not reported. The TSS and BOD_5 concentrations in the effluent were not reported.

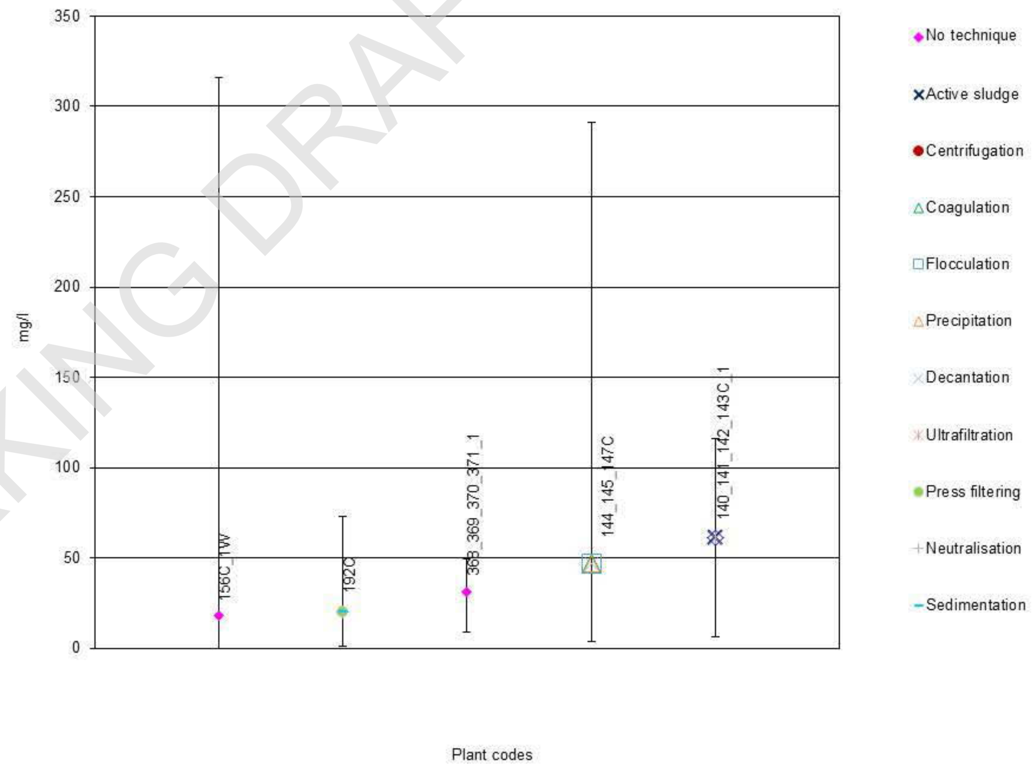
More information on parameters affecting the performance for reducing TOC concentrations can be found in the CWW BREF. [138, COM 2014]

Biologic oxygen demand in five days (BOD_5)
Of the 16 plants discharging directly to a water body, 7 (44 %) reported BOD_5 concentration values in the effluent.

In the effluents, the BOD/COD ratio is mostly < 0.2, indicating relatively non-biodegradable aqueous outputs.

Total suspended solids (TSS)
Of the 16 plants directly discharging to a water body, 13 (80 %) reported TSS concentration values in the effluent.

As shown in Table 5.180, average TSS levels are between 15 mg/l and 61 mg/l.
Figure 5.42 below presents the reported short-term average values.



Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.42: TSS in water emissions from physico-chemical treatment of waste – Short-term average

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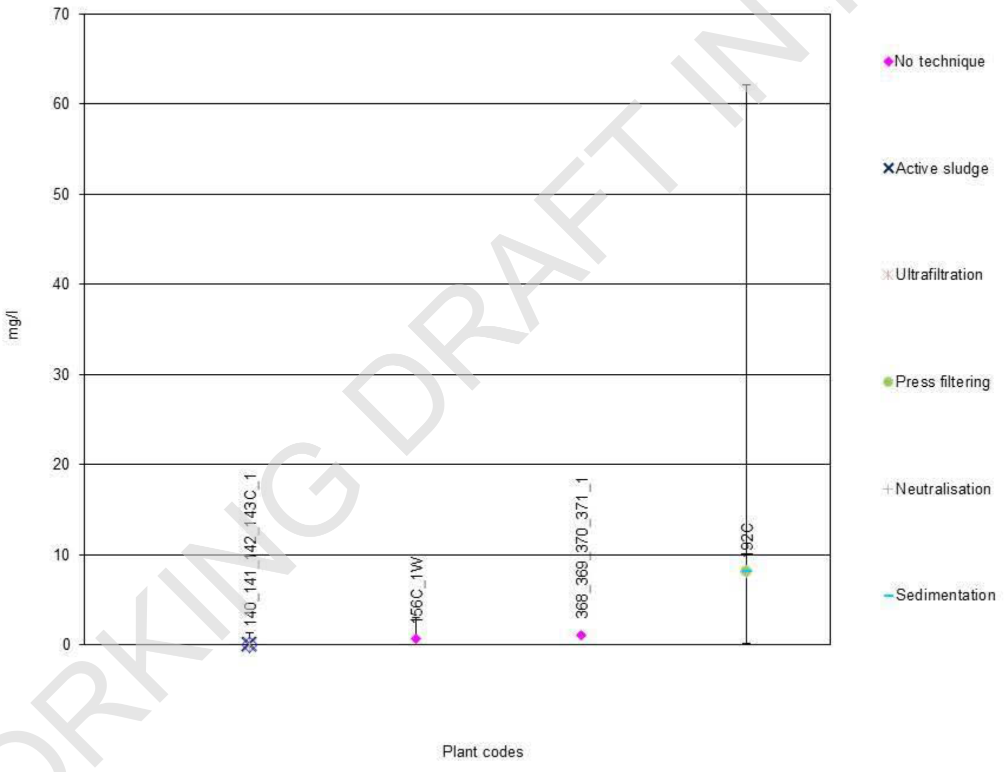
Plant 140 reported an average TSS concentration of around 60 mg/l (24-hour flow-proportional composite sample as a short-term (daily) average). The influent is water-based liquid waste with a high organic content. In the effluent, the reported average TOC concentration is 184 mg/l (24-hour flow-proportional composite sample as a short-term average), and the reported average BOD_5 concentration is 20 mg/l (24-hour flow-proportional composite sample as a monthly average).

Plant 144 reported an average TSS concentration of around 40 mg/l (24-hour flow-proportional composite sample as a short-term average). The influent is acids, bases, inorganic solutions containing Cr(VI), CN and phenols. In the effluent, the reported average TOC concentration is around 160 mg/l (24-hour flow-proportional composite sample as a short-term average), with the indication that the implementation of activated carbon adsorption now allows a level of 100 mg/l to be achieved. The BOD_5 concentration in the effluent was not reported.

Total hydrocarbons (THC)
Of the 16 plants directly discharging to a water body, 7 (58 %) reported THC concentration values in the effluent.

As shown in Table 5.180, average THC levels are between 0.05 mg/l and 8 mg/l. Figure 5.43 presents the reported short-term average values.



Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.43: THC in water emissions from physico-chemical treatment of waste – Short-term average

Plant 192 reported an average THC concentration of 8 mg/l (24-hour flow-proportional composite sample reported as a daily average). The influent comes from the regeneration of spent chromic baths, and various hazardous liquid wastes mainly containing inorganic pollutants (e.g. acids, bases, waste containing cyanides, fluorides, heavy metals, and

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metalloids). The plant reported batch releases of around 190 m^3/h, with an authorised maximum of 320 m^3/day.

Arsenic (As)

Of the 16 plants directly discharging to a water body, 12 (75 %) reported arsenic concentration values in the effluent.

As shown in Table 5.183, average arsenic levels are between 0.01 mg/l and 0.1 mg/l.

Plant 368 reported an average arsenic concentration of 0.1 mg/l (24-hour flow-proportional composite sample reported as a weekly average). The influent is liquid waste with solvents, liquid waste with organic contamination, sludge from the biological waste water treatment facility, and other biodegradable liquid waste. The plant is equipped with a wet oxidation system for oxidising organic and inorganic pollutants at high temperature and pressure. The plant reported a continuous release of around 525 m^3/h.

Plant 569 reported an average arsenic concentration of 0.1 mg/l (24-hour flow-proportional composite sample reported as a long-term average). The reported influents of the received water-based liquid wastes are acids, bases, oily water, sludge with organic contamination, leachate, and biodegradable liquid waste. The plant also receives contaminated soil, fly ash, waste oil, and inks, which are directed to specific treatments. The waste water treatment facility receives influent from all these processes, and also run-off waters. The plant reported releases of around 20 m^3/h. No indication of the type of release (continuous or batch) was provided.

Cadmium (Cd)

Of the 16 plants directly discharging to a water body, 15 (94 %) reported cadmium concentration values in the effluent.

As shown in Table 5.180, average cadmium levels are between 0.001 mg/l and 0.1 mg/l.

Figure 5.44 presents the reported cadmium in water emissions from physico-chemical treatment of waste.

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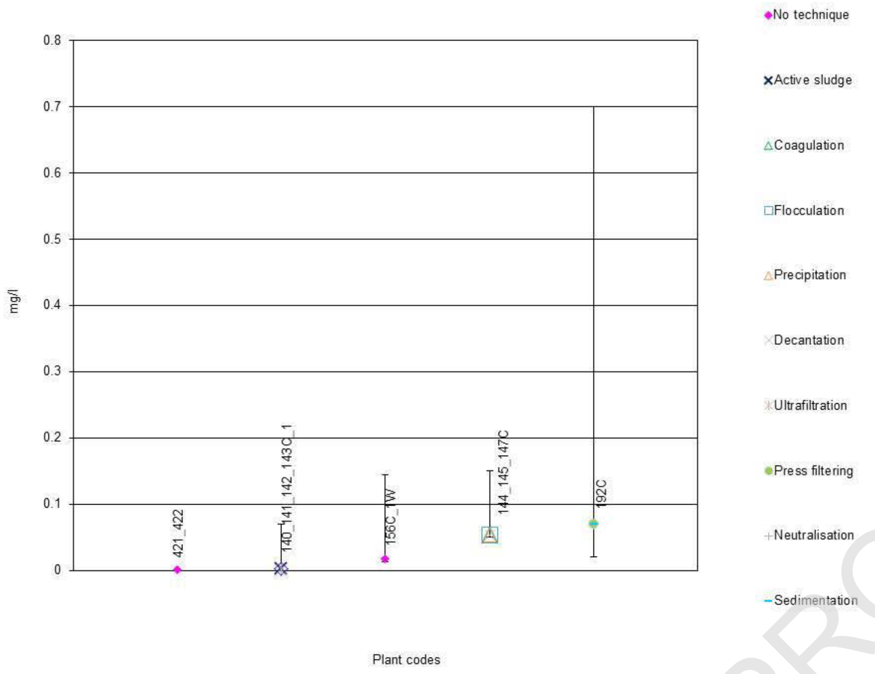

Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.44: Cadmium in water emissions from physico-chemical treatment of waste – Short-term average

Plant 144 reported an average cadmium concentration of 0.05 mg/l (continuous measurements – short-term average). The influents are water-based liquid waste containing acids (e.g. hydrochloric, nitric, sulphuric), bases (e.g. leachates), and organics and waste water containing organics and biodegradable organics. The aqueous effluent is partly directed to further treatment, partly used as industrial water, and partly sent to a biological treatment. The plant reported batch releases of around 10 m^3/h, which represents a load of 0.5 g/h, with an authorised maximum of 600 m^3/day.

Plant 192 reported an average cadmium concentration of 0.07 mg/l (24-hour flow-proportional composite sample reported as a daily average). The influent comes from the regeneration of spent chromic baths, and various hazardous liquid wastes mainly containing inorganic pollutants (e.g. acids, bases, waste containing cyanides, fluorides, heavy metals, and metalloids). The plant reported batch releases of around 200 m^3/h, which represents a load of 14 g/h, with an authorised maximum of 320 m^3/day.

Plant 569 reported an average cadmium concentration of 0.1 mg/l (24-hour flow-proportional composite sample reported as a long-term average. The reported influents of the received water-based liquid wastes are acids, bases, oily water, sludge with organic contamination, leachate, and biodegradable liquid waste. The plant also receives contaminated soil, fly ash, waste oil, and inks, which are directed to specific treatments. The waste water treatment facility receives influent from all these processes, and also run-off waters. The plant reported releases of around 20 m^3/h. No indication of the type of release (continuous or batch) was provided.

Chromium (Cr)

Of the 16 plants directly discharging to a water body, 15 (94 %) reported chromium concentration values in the effluent.

As shown in Table 5.180, average chromium levels are between 0.01 mg/l and 0.3 mg/l. Figure 5.45 presents the reported short-term average values.

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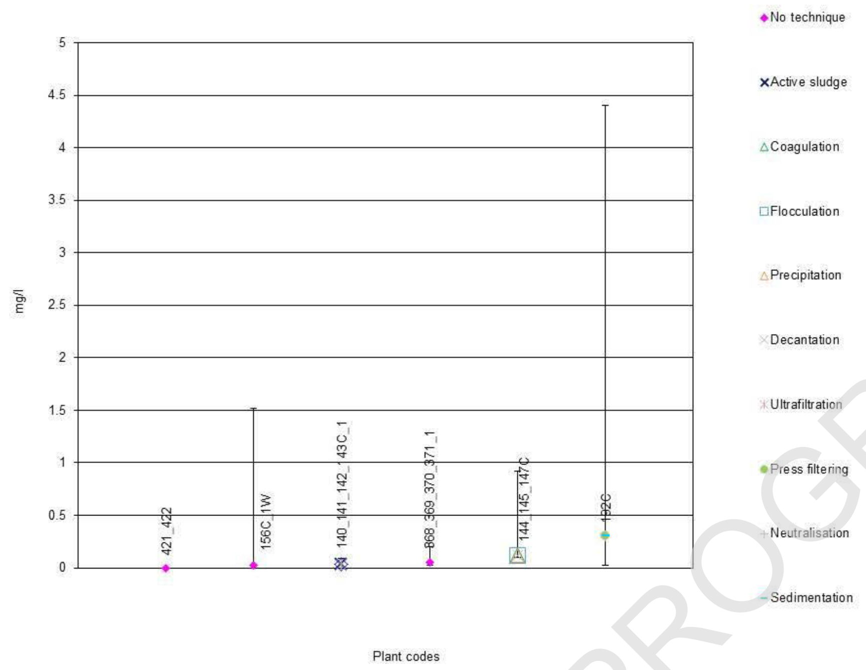


Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.45: Chromium in water emissions from physico-chemical treatment of waste – Short-term average

Plant 144 reported an average chromium concentration of 0.1 mg/l (continuous measurements – short-term average). The influents are water-based liquid waste containing acids (e.g. hydrochloric, nitric, sulphuric), bases (e.g. leachates), and organics and waste water containing organics and biodegradable organics. The aqueous effluent is partly directed to further treatment, partly used as industrial water, and partly sent to a biological treatment. The plant reported batch releases of around 10 m^3/h, which represents a load of 1 g/h, with an authorised maximum of 600 m^3/day.

Plant 192 reported an average chromium concentration of 0.3 mg/l (24-hour flow-proportional composite sample reported as a daily average). The influent comes from the regeneration of spent chromic baths, and various hazardous liquid wastes mainly containing inorganic pollutants (e.g. acids, bases, waste containing cyanides, fluorides, heavy metals, and metalloids). The plant reported batch releases of around 190 m^3/h, which represents a load of 45 g/h, with an authorised maximum of 320 m^3/day.

Plant 569 reported an average chromium concentration of 0.1 mg/l (24-hour flow-proportional composite sample reported as a long-term average). Water-based liquid wastes are acids, bases, oily water, sludge with organic contamination, leachate, and biodegradable liquid waste. The plant also receives contaminated soil, fly ash, waste oil, and inks, which are directed to specific treatments. The waste water treatment facility receives influent from all these processes, and also run-off waters. The plant reported releases of around 20 m^3/h. No indication of the type of release (continuous or batch) was provided.

Chromium VI (Cr(VI))

Of the 16 plants directly discharging to a water body, 8 (50 %) reported Cr(VI) concentration values in the effluent.

As shown in Table 5.180, average Cr(VI) levels are up to 0.05 mg/l. Three plants (Plants 140, 156 and 421) reported having no Cr(VI) in the effluent.

WORKING DRAFT IN PROGRESS

Plant 144, reported an average Cr(VI) concentration of 0.01 mg/l (continuous measurements – short-term average). The influents are water-based liquid waste containing acids (e.g. hydrochloric, nitric, sulphuric), bases (e.g. leachates), and organics and waste water containing organics and biodegradable organics. The aqueous effluent is partly directed to further treatment, partly used as industrial water, and partly sent to a biological treatment. The plant reported batch releases of around 10 m^3/h, with an authorised maximum of 600 m^3/day.

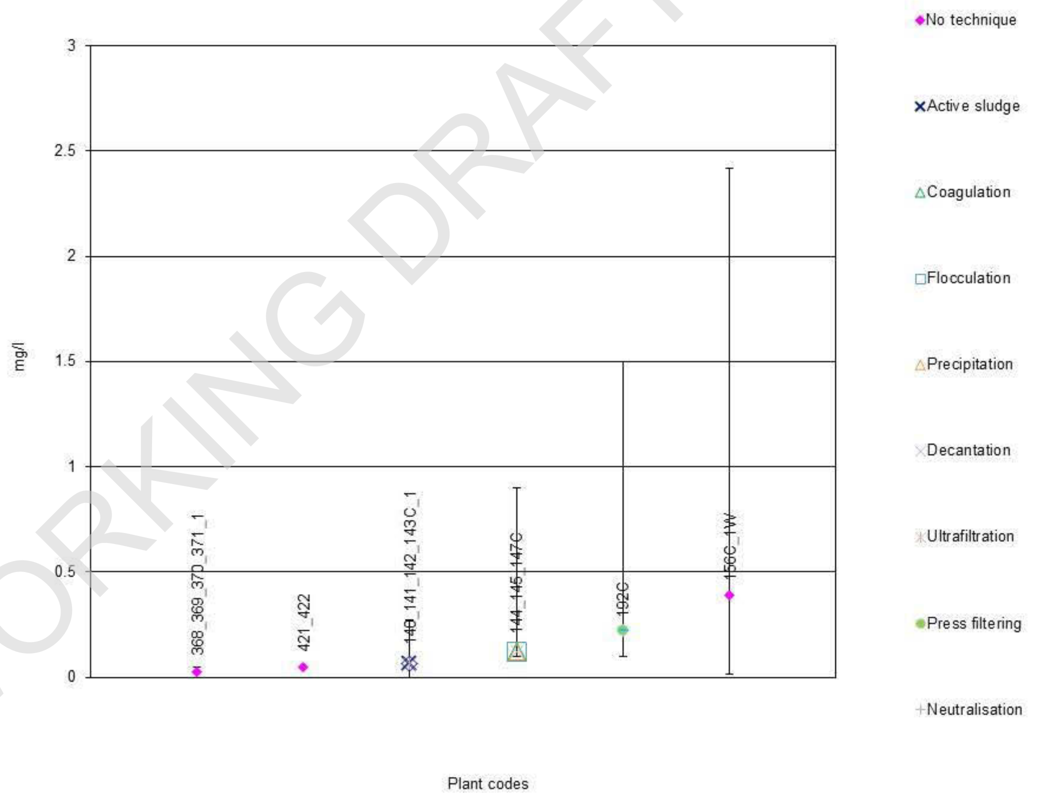
Plant 368 reported an average Cr(VI) concentration of 0.04 mg/l (periodic measurements reported as an average of six measurements over the three reference years). The influent is liquid waste with solvents, liquid waste with organic contamination, sludge from the biological waste water treatment facility, and other biodegradable liquid waste. The plant is equipped with a wet oxidation system for oxidising organic and inorganic pollutants at high temperature and pressure. The plant reported continuous release of around 525 m^3/h.

Plant 192 reported an average Cr(VI) concentration of 0.05 mg/l (24-hour flow-proportional composite sample reported as a daily average). The influent comes from the regeneration of spent chromic baths, and various hazardous liquid wastes mainly containing inorganic pollutants (e.g. acids, bases, waste containing cyanides, fluorides, heavy metals, and metalloids). The plant reported batch releases of around 190 m^3/h, with an authorised maximum of 320 m^3/day.

Copper (Cu)

Of 16 plants directly discharging to a water body, 15 (94 %) reported copper concentration values in the effluent.

As shown in Table 5.180, average copper levels are between 0.005 mg/l and 0.4 mg/l. Figure 5.46 below presents the reported short-term average values.



Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.46: Copper in water emissions from physico-chemical treatment of waste – Short-term average

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Plant 144 reported an average copper concentrations of 0.1 mg/l (reported as a short-term average of continuous measurements). The influents are water-based liquid waste containing acids (e.g. hydrochloric, nitric, sulphuric), bases (e.g. leachates), and organics and waste water containing organics and biodegradable organics. The copper concentration in the influent is reported as a maximum at 2 mg/l. The calculated copper abatement efficiency is 94 % as a maximum. The aqueous effluent is partly directed to further treatment, partly used as industrial water, and partly sent to a biological treatment. The plant reported batch releases of around 10 m^3/h, with an authorised maximum of 600 m^3/day.

Plant 569 reported an average copper concentration of 0.1 mg/l (24-hour flow-proportional composite sample reported as a long-term average. Water-based liquid wastes are acids, bases, oily water, sludge with organic contamination, leachate, and biodegradable liquid waste. The plant also receives contaminated soil, fly ash, waste oil, and inks, which are directed to specific treatments. The waste water treatment facility receives influent from all these processes, and also run-off waters. The plant reported releases of around 20 m^3/h. No indication of the type of release (continuous or batch) was provided.

Plant 192 reported an average copper concentration of 0.2 mg/l (24-hour flow-proportional composite sample reported as a short-term (daily) average). The influent comes from the regeneration of spent chromic baths, and various hazardous liquid wastes mainly containing inorganic pollutants (e.g. acids, bases, waste containing cyanides, fluorides, heavy metals, and metalloids). The plant reported batch releases of around 190 m^3/h, with an authorised maximum of 320 m^3/day.

Plant 156 reported an average copper concentration of 0.4 mg/l (24-hour flow-proportional composite sample reported as an arithmetic average of the number of release days - short-term average). The influent consists of mixed water/sediment/hydrocarbons, and liquid waste containing Cr(VI), CN, phenols, acids, bases, etc. The plant reported a water flow rate of around 12 m^3/h.

Mercury (Hg)
Of the 16 plants directly discharging to a water body, 10 (63 %) reported mercury concentration values in the effluent.

As shown in Table 5.180, average mercury levels are between 0.05 µg/l and 40 µg/l.

Plant 569 reported average mercury concentration of 40 µg/l (24-hour flow-proportional composite sample reported as a long-term average. Water-based liquid wastes are acids, bases, oily water, sludge with organic contamination, leachate, and biodegradable liquid waste. The plant also receives contaminated soil, fly ash, waste oil, and inks, which are directed to specific treatments. The waste water treatment facility receives influent from all these processes, and also run-off waters. The plant reported releases of around 20 m^3/h. No indication of the type of release (continuous or batch) was provided.

Nickel (Ni)
Of the 16 plants directly discharging to a water body, 15 (94 %) reported nickel concentration values in the effluent.

As shown in Table 5.180, average nickel levels are between 0.02 mg/l and 1.1 mg/l. Figure 5.47 below presents the reported short-term average values.

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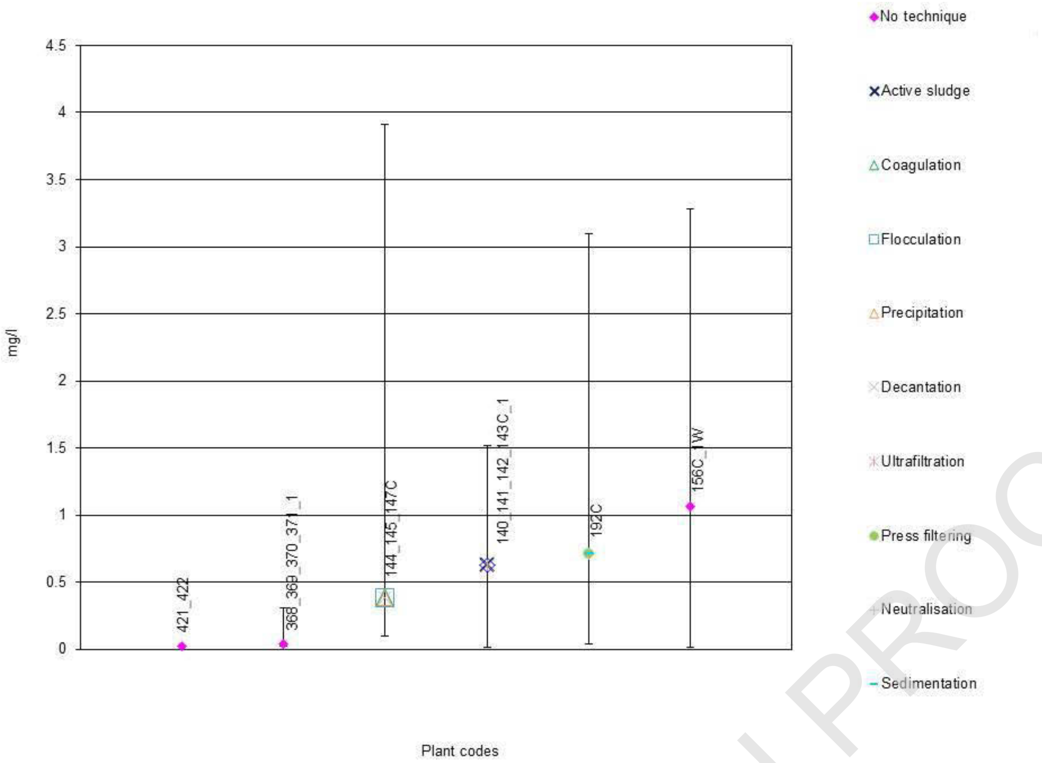


Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.47: Nickel in water emissions from physico-chemical treatment of waste – Short-term average

Plant 569 reported an average nickel concentration of 0.3 mg/l (24-hour flow-proportional composite sample reported as a long-term average. Water-based liquid wastes are acids, bases, oily water, sludge with organic contamination, leachate, and biodegradable liquid waste. The plant also receives contaminated soil, fly ash, waste oil, and inks, which are directed to specific treatments. The waste water treatment facility receives influent from all these processes, and also run-off waters. The plant reported releases of around 20 m^3/h. No indication of the type of release (continuous or batch) was provided.

Plant 140 reported an average nickel concentration of 0.6 mg/l (24-hour flow-proportional composite sample reported as a short-term average). The influent consists of a large variety of waste (with low or high organic content, hydrocarbons, oils, soaps, inks, cooling liquids, etc.). The maximum nickel concentration in the influent is reported as 2 mg/l. The calculated abatement efficiency is 69 %. The plant reported to have continuous release of around 19m^3/h.

Plant 192 reported an average nickel concentration of 0.7 mg/l (24-hour flow-proportional composite sample reported as a short-tem (daily) average). The influent comes from the regeneration of spent chromic baths, and various hazardous liquid wastes mainly containing inorganic pollutants (e.g. acids, bases, waste containing cyanides, fluorides, heavy metals, and metalloids). The plant reported batch releases of around 190 m^3/h, with an authorised maximum of 320 m^3/day.

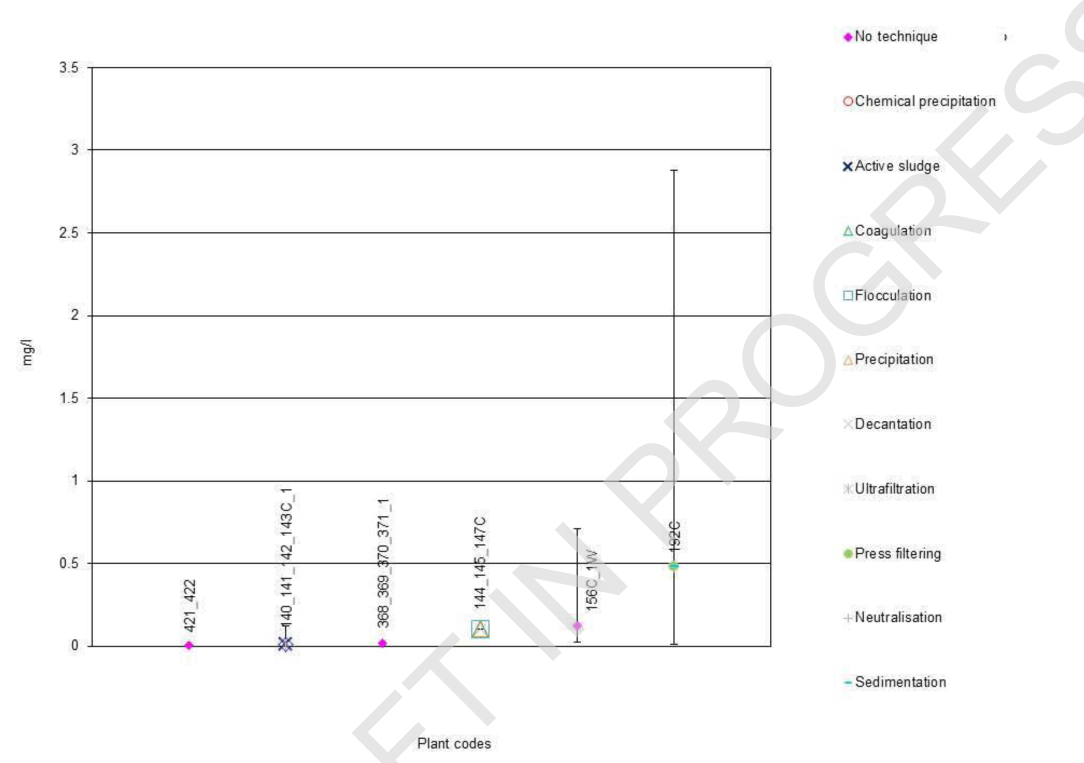
Plant 156 reported an average nickel concentration of 1.1 mg/l (24-hour flow-proportional composite sample reported as an arithmetic average of the number of release days - short-term average). The influent consists of mixed water/sediment/hydrocarbons, and liquid waste containing Cr(VI), CN, phenols, acids, bases, etc. The plant reported a water flow rate of around 12 m^3/h.

WORKING DRAFT IN PROGRESS

Lead (Pb)

Of the 16 plants directly discharging to a water body, 15 (94 %) reported lead concentration values in the effluent.

As shown in Table 5.180, average lead levels are between 0.03 mg/l and 0.5 mg/l. Figure 5.48 below presents the reported short-term average values.



Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.48: Lead in water emissions from physico-chemical treatment of waste – Short-term average

Plant 192 reported a maximum average lead concentration of 0.5 mg/l (24-hour flow-proportional composite sample reported as a short-tem (daily) average). The influent comes from the regeneration of spent chromic baths, and various hazardous liquid wastes mainly containing inorganic pollutants (e.g. acids, bases, waste containing cyanides, fluorides, heavy metals, and metalloids). The plant reported batch releases of around 190 m^3/h, with an authorised maximum of 320 m^3/day.

Zinc (Zn)

Of the 16 plants directly discharging to a water body, 15 (94 %) reported zinc concentration values in the effluent.

As shown in Table 5.180, average zinc levels are between 0.02 mg/l and 2.6 mg/l. Figure 5.49 below presents the reported short-term average values.

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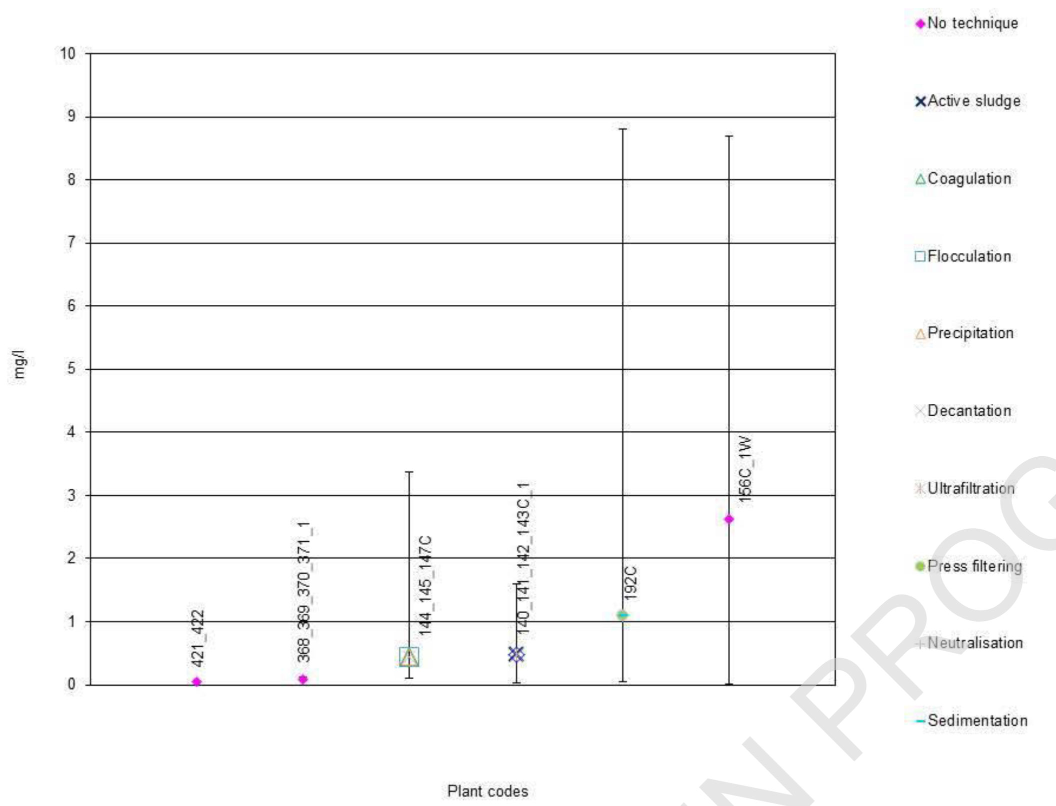

Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.49: Zinc in water emissions from physico-chemical treatment of waste – Short-term average

Plant 156 reported a maximum average zinc concentration of 2.6 mg/l. The influent consists of mixed water/sediment/hydrocarbons, and liquid waste containing Cr(VI), CN, phenols, acids, bases, etc. The plant reported a water flow rate of around 12 m^3/h.

Plant 192 reported a maximum average zinc concentration of 1.1 mg/l (24-hour flow-proportional composite sample reported as a short-term (daily) average). The influent comes from the regeneration of spent chromic baths, and various hazardous liquid wastes mainly containing inorganic pollutants (e.g. acids, bases, waste containing cyanides, fluorides, heavy metals, and metalloids). The plant reported batch releases of around 190 m^3/h, with an authorised maximum of 320 m^3/day.

Nitrogen compounds

As shown in Table 5.180, either Total N and/or Total Kjeldahl Nitrogen (TKN) and/or ammonia (NH_3-N) and/or nitrite/nitrate (NO^{2-}/NO^{3-}) are used for determining nitrogen-related parameters' concentration (see Table 5.183).

WORKING DRAFT IN PROGRESS

Table 5.182: Nitrogen compounds monitored in water emissions from physico-chemical treatments of waste – Direct discharge

Plant code	Monitored nitrogen-related parameter
90	Total N, NO^{2-}/NO^{3-}, NH_3-N
140	TKN, NO^{2-}/NO^{3-}, NH_3-N
156	NH_3-N
170	TKN
368	NO^{2-}/NO^{3-}, NH_3-N
392	Total N, TKN, NO^{2-}/NO^{3-}
393	Total N, TKN, NH_3-N
423	NO^{2-}/NO^{3-}, NH_3-N
427	Total N, NO^{2-}/NO^{3}
449	NH_3-N
569	NH_3-N, NO^{2-}/NO^{3}
620	TKN, NH_3-N, NO^{2-}/NO^{3}

Those parameters are not equivalent; therefore analytical results are not comparable (for example Total N > TKN). Additional information on this topic can be found in the CWW BREF [138, COM 2014].

Of the 12 plants measuring nitrogen-related compounds in water emissions, 6 reported Total N concentration values in the effluent. The reported average Total N values range between 12 mg/l and 39 mg/l.

Plant 392 reported an average Total N concentration of 39 mg/l (periodic measurements – one measurement per month) in the effluent. The influent is landfill leachate with a nitrogen content (Total N) of 237 mg N/l, a COD concentration of 374 mg/l, a low C/N ratio and with non-degradable carbon. In the effluent, the TSS concentration is 27 mg/l, the BOD_5 concentration is 4 mg/l, and the COD concentration is 243 mg/l (abatement efficiency of 35 %). The Total N abatement efficiency is 83 %.

Plant 393 reported an average Total N concentration of 35 mg/l. The influent is landfill leachate with a nitrogen content (Total N) of 426 mgN/l, a COD concentration of 625 mg/l, a low C/N ratio and with non-degradable carbon. In the effluent, the TSS concentration is 15 mg/l, the BOD_5 concentration is 4.5 mg/l, and the COD concentration is 328 mg/l (abatement efficiency of 47 %). The Total N abatement efficiency is 90 %.

Total phosphorus (Total P)

Of the 16 plants directly discharging to a water body, 12 (75 %) reported Total P concentration values in the effluent.

As shown in Table 5.180, average Total P levels are between 0.3 mg/l and 36 mg/l. Figure 5.50 below presents the reported short-term average values.

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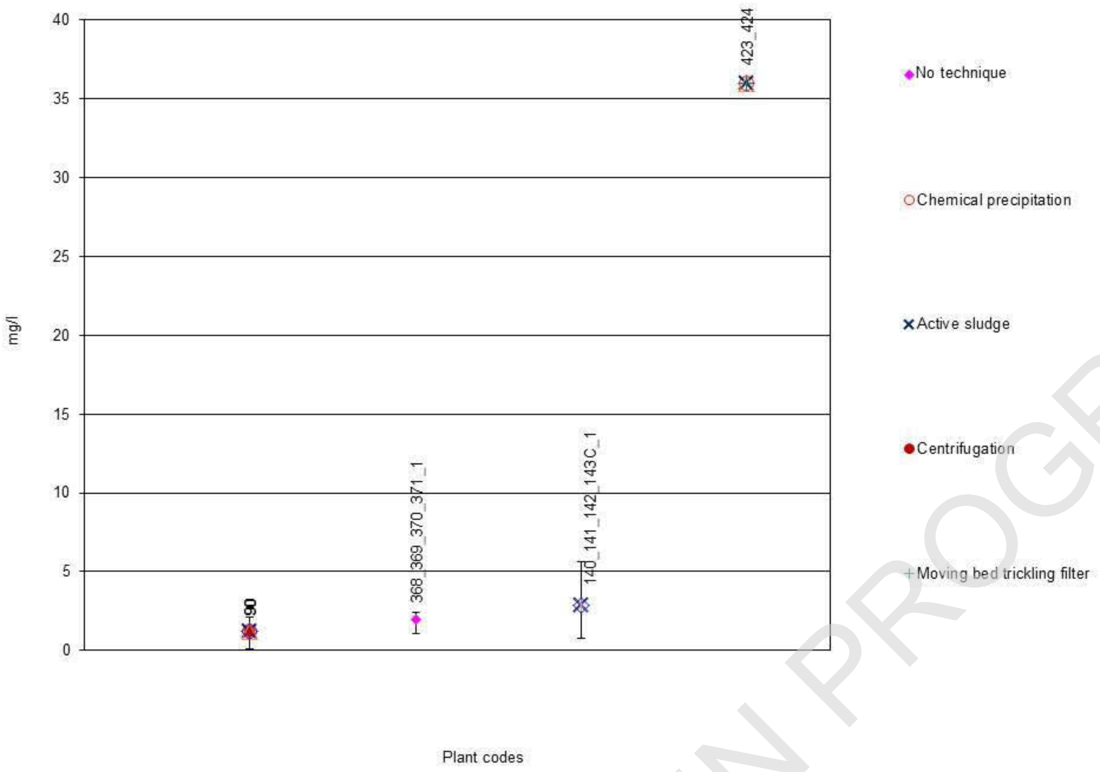

Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.50: Total P in water emissions from physico-chemical treatment of waste – Long-term average

Plant 423 reported an average Total P concentration of 36 mg/l (24-hour flow-proportional composite sample as a long-term average). The plant is treating drilling waste (cuttings, mud and sludge) which contains 12–15 % (weight) organics (POPs). The TSS and BOD_5 concentrations in the effluent were not reported. In the effluent, the plant reported an average TOC concentration of 770 mg/l (24-hour flow-proportional composite sample as a long-term average). The reported average flow rate is around 35 m^3/h.

Phenols

Of the 16 plants directly discharging to a water body, 10 (63 %) reported phenol concentration values in the effluent.

As shown in Table 5.180, average phenol levels are between 0.01 mg/l and 0.3 mg/l.

Figure 5.51 presents the reported phenols in water emissions from physico-chemical treatment of waste.

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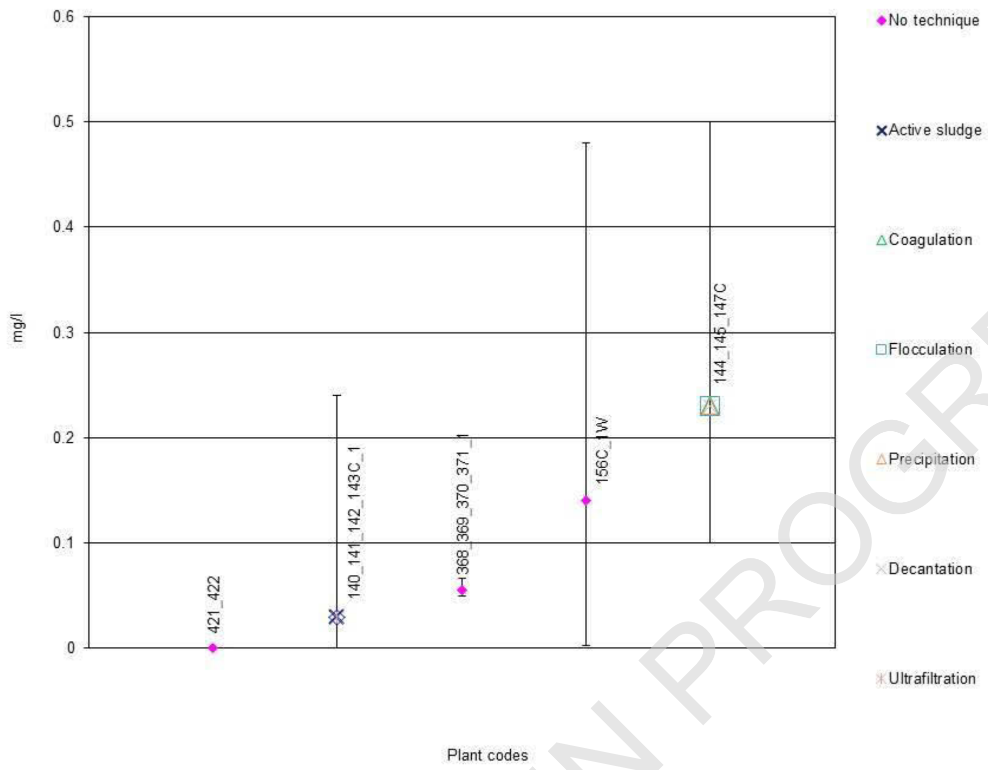

Note: No technique means that no information on abatment techniques for controlling emissions to water was provided in the questionnaire. However, information on the process steps aiming to treat water-based liquid waste is reported in table 5.181

Figure 5.51: Phenols in water emissions from physico-chemical treatment of waste – Short-term average

Plant 569 reported an average phenol concentration of 0.3 mg/l (24-hour flow-proportional composite sample reported as a long-term average). Water-based liquid wastes are acids, bases, oily water, sludge with organic contamination, leachate, and biodegradable liquid waste. The plant also receives contaminated soil, fly ash, waste oil, and inks, which are directed to specific treatments. The waste water treatment facility receives influent from all these processes, and also run-off waters. The plant reported releases of around 20 m^3/h. No indication of the type of release (continuous or batch) was provided.

Plant 144 reported a maximum average phenol concentration of 0.2 mg/l (reported as a short-term average of continuous measurements). The influents are water-based liquid waste containing acids (e.g. hydrochloric, nitric, sulphuric), bases (e.g. leachates), and organics and waste water containing organics and biodegradable organics. The phenol concentration in the influent is reported as a maximum at 200 mg/l. The calculated phenols abatement efficiency is 99 % as a maximum. The aqueous effluent is partly directed to further treatment, partly used as industrial water, and partly sent to a biological treatment. The plant reported batch releases of around 10 m^3/h, with an authorised maximum of 600 m^3/day.

Plant 156 reported a maximum average phenol concentration of 0.14 mg/l. The influent consists of mixed water/sediment/hydrocarbons, and liquid waste containing Cr(VI), CN, phenols, acids, bases, etc. The phenol concentration in the influent is reported as a maximum at 500 mg/l. The calculated phenol abatement efficiency is 99.9 % as a maximum. The plant reported a water flow rate of around 12 m^3/h.

WORKING DRAFT IN PROGRESS

5.7.2.3.3 Indirect discharge

Table 5.183 below presents an overview of the reported metal emissions to water from physico-chemical and/or biological treatment of water-based liquid waste releasing to a sewer or to an off-site waste water treatment plant (indirect discharge), which may not be fitted to treat such pollutants. It should be read together with Table 5.184 which shows that the techniques used are similar to those used in plants directly discharging to a receiving water body.

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Table 5.183: Emissions to water from physico-chemical and/or biological treatment of water-based liquid waste – Indirect discharge

Pollutant measured	Monitoring	Plants concerned	Range (mg/l)	Number of measurements during the three reference years
Cd	24-hour flow-proportional composite sample	3, 4, 8, 91, 151, 153, 156, 194, 473, 550	Min./Max.: 0.0004–0.8 Average: 0.0004–0.1	NA
	Composite sample	7, 149, 215, 216, 217, 317, 322, 463	0.002–0.05	3 to 36
	Grab sample	347, 351, 395, 486	0.0007–0.002	12 to 36
Hg	24-hour flow-proportional composite sample	3, 4, 8, 91, 151, 473	Min./Max.: 0.0005–0.01 Average: 0.0005–0.01	NA
	Composite sample	7, 148, 149, 153, 215, 217, 317, 322	0.0005–0.02	3 to 6
	Grab sample	347, 351, 395, 486	0.0001–0.0005	12 to 36
As	24-hour flow-proportional composite sample	3, 4, 8, 151, 473	Min./Max.: 0.01–0.1 Average: 0.01–0.1	NA
	Composite sample	7, 153, 217, 317, 322, 463	0.004–0.1	3 to 6
	Grab sample	347, 351, 395	0.001–0.01	12 to 36
Pb	24-hour flow-proportional composite sample	3, 4, 8, 91, 151, 153, 156, 159, 194, 473, 550	Min./Max.: 0.003–1.7 Average: 0.01–0.3	NA
	Composite sample	7, 149, 215, 217, 317, 322, 463	0.004–0.25	3 to 36
	Grab sample	347, 351, 395, 486	0.001–0.3	12 to 36
Cr	24-hour flow-proportional composite sample	3, 4, 8, 91, 151, 153, 156, 194, 473	Min./Max.: 0.01–0.6 Average: 0.01–0.15	NA
	Composite sample	7, 149, 215, 216, 217, 317, 322, 463	0.01–0.3	3 to 36
	Grab sample	347, 351, 395, 486	0.004–0.25	12 to 36
Cr(VI)	24-hour flow-proportional composite sample	4, 8, 151, 153, 156, 194	Min./Max.: 0–0.01 Average: < 0.01	NA
	Composite sample	7, 217, 317, 322	0.003–0.1	3 to 36
	Grab sample	347	0.04	36
Cu	24-hour flow-proportional composite sample	3, 4, 8, 91, 151, 153, 156, 194, 473, 550	Min./Max.: 0.01–4.9 Average: 0.01–0.6	NA
	Composite sample	7, 149, 215, 217, 317, 322, 463	0.02–0.3	3 to 36
	Grab sample	347, 351, 395, 486	0.002–0.08	12 to 36
Ni	24-hour flow-proportional composite sample	3, 4, 8, 91, 151, 153, 156, 194, 473, 550	Min./Max.: 0.009–5 Average: 0.009–1.7	NA
	Composite sample	7, 149, 215, 217, 317, 322, 463	0.01–0.5	3 to 36
	Grab sample	347, 351, 395, 486	0.01–0.3	12 to 36
Zn	24-hour flow-proportional composite sample	3, 4, 8, 91, 151, 153, 156, 194, 473, 550	Min./Max.: 0.01–12.6 Average: 0.2–3.6	NA
	Composite sample	7, 149, 215, 217, 317, 322, 463	0.05–0.5	3 to 36
	Grab sample	347, 351, 395, 486	0.03–0.3	12 to 36

WORKING DRAFT IN PROGRESS

Note 1: For 24-hour flow-proportional composite samples, Min. is the lowest of the short-term or long-term reported values, Max. is the highest of the short-term or long-term reported values, and average is the minimum–maximum of the reported values.
Note 2: When reported, the indicated long-term average is: yearly (Plants 90 and 140) and monthly (Plants 140 and 368).The short-term average is daily (Plant 192) and weekly (Plant 368). Plant 156 indicated that the values are the arithmetic average of days of release.
Note 3: When reported, it is indicated that the samples are not filtered before measurements.
NA: not applicable

WORKING DRAFT IN PROGRESS

Table 5.184: Physico-chemical and/or biological treatment of water-based liquid waste – Indirect discharge - Techniques used, removed substances, waste input description, output and type of release

Plant code	Water-based liquid waste treatment process	Removed substances	Techniques used	Waste input description	Output	Type of release (batch/ continuous) and water flow	Point of release
03	Primary treatment Finalisation treatment Post treatment (bioreactor)	Oil Heavy metals CSB NO_2 NO_3 Ammonia	NI	Bases and base mixtures Acids and acid mixtures Water-solvent mixtures Chemical construction waste Cooling and lubricating liquids Oil-water mixtures Emulsions Paint sludge-water mixtures Landfill leachate	Aqueous output Residues from waste water treatment Regenerated oil Concentrates	Continuous 3 m^3/h	Off-site common WWT facilities
04	Primary treatment Secondary treatment	NI	Air stripping Neutralisation Chemical reduction Chemical oxidation	Organic and inorganic acids (e.g. HCl, HNO_3) Bases (e.g. NaOH, KOH) Solid (e.g. soluble salts) and liquid hazardous waste Oil-water mixtures Emulsions Landfill leachate	Aqueous output Press cake	Batch 200–250 times a year 25 m^3/h	Urban/municipal sewer system
07	Primary treatment Finalisation treatment	Oil Heavy metals CSB NO_2 NO_3 Ammonia	Active sludge systems - SBR Flocculation Emulsion breaking Press filtering	Oil-water mixtures Oil separator content Emulsions Sand catcher Landfill leachate Sewage residues Paint sludge residues Glue residues Washing water containing cyanide	Aqueous output Regenerated oil Residues from waste water treatment	Batch 48 m^3/day	Urban/municipal sewer system

WORKING DRAFT IN PROGRESS

08	Hydroxide precipitation: removal of pollutants at source Primary treatment: All water-based waste streams first go through a basin system, where sinking and swimming solids are discharged Emulsion breaking Toxic compounds elimination (e.g. oxidising of cyanide) / Final wet maturation (bioreactor)	Heavy metals Solids Oils Toxic substances	Filtration Active sludge system – SBR Adsorption	Emulsion Oil-water mixture Mixed acid Lye mixture Water from tank cleaning Waste oil Solvents Bitumen emulsion Drilling mud Oil separators, sand trap contents Paint sludge Pharmaceutical waste Laboratory waste Detergents	Aqueous output Liquid fuel Residues from waste water Treatment Mix of output materials	Batch 170 times a year during one day 7 m^3/h	Urban/municipal sewer system
91	Primary treatment	NI	Chemical oxidation Chemical precipitation Dewatering Flocculation Adsorption	Acids (chromic, hydrochloric, nitric and similar) containing heavy metals, cyanides	Aqueous output Filter cake of metal hydroxide sludge	Continuous 2.5 m^3/h	Urban/municipal sewer system
149	Neutralisation Blending	NI	Decantation	Used acids from research laboratories (industrial, university) Used bases from research laboratories (industrial, university) Cleaning water, washing liquids Liquid wastes from chemical industry Pasty, organic unreactive wastes WEEE	Aqueous output Residues from shredding Ferrous metal Glass Wood Output from the temporary storage of hazardous waste	Batch Around 50 times a year during 4 hours	Off-site common WWT facilities
151	Centrifugation Emulsion breaking Biological treatment/activated sludge system UF membrane	Sludge TOC and sludge Biodegradable organics TSS	Active sludge systems - conventional Ultrafiltration	Organics and biodegradable liquid waste Hydrocarbon liquid waste containing more than 10 % sediment	Liquid fuel Sludge	Continuous 195 m^3/h	Urban/municipal sewer system

WORKING DRAFT IN PROGRESS

153	Breaking of emulsions and precipitation of complex hydroxide species Vacuum evaporation Triple-phase high-speed hot centrifugation Filtration on a recessed-plate filter press Gravity settling of sludges originating from cleaning operations Acid/base neutralisation of clarified waste waters Aerobic bioreactor	NI	Neutralisation Biological nutrient removal	Waste fluids from various sectors: complex machining emulsions (water-oil-solids), oily waters from oil-water separators, aqueous washing liquids, etc. Water and sediments Any type of bulk/packaged waste, except: radioactive wastes, explosive compounds or wastes that might ignite spontaneously, hydrolysable wastes emitting noxious compounds when in contact with water, chemically or physically instable wastes, asbestos wastes	Liquid fuel Aqueous output Complex dewatered hydroxide precipitate from filtration Sludge Output from repackaging and from temporary storage of hazardous waste	4 m^3/h	Urban/municipal sewer system
156C_2W	Two-phase centrifugation Three-phase centrifugation Emulsion breaking UF membrane Nanofiltration Deconditioning Detoxication Neutralisation Metal precipitation Sludge filtration Biological treatment (activated sludge) Adsorption on activated carbon	Sediment Oil (hydrocarbons) and sediment Oil (hydrocarbons) BOD_5 TOC, metals Cr(VI), CN, phenols Alkalinity-acidity, metals	Centrifugation + Emulsion breaking (Organic physico-chemical treatment) Biological treatment Nanofiltration Mineral physico-chemical treatment Saline biological treatment Activated carbon filtration	Mix of water-based/sediment/hydrocarbons liquid waste Liquid waste containing Cr(VI) Liquid waste containing CN Liquid waste containing phenols Acid liquid waste containing Basic liquid waste Flue-gas cleaning residues Metal hydroxide sludge or sludge from metal insolubilisation treatment (PC plant)	Residues from waste water treatment Mixed plastics Recovered activated carbon Oily phase from centrifugation	4 m^3/h	Urban/municipal sewer system

WORKING DRAFT IN PROGRESS

159	Bioreactor UF membrane	NI	Active sludge systems - conventional Ultrafiltration	Waste with a high hydrocarbon content Waste with a low hydrocarbon content Water with oily emulsions Water with biodegradable organics content Organic waste which cannot be treated by any of the waste treatment activities of the plant	Liquid fuel Aqueous output Other	Continuous 6 m^3/h	Urban/municipal sewer system
194	Decantation: removal of pollutants at source Evaporation/concentration Emulsion breaking Bioreactor UF membrane	Sediment Oily concentrates TOC/sludge biodegradable organics TSS	Active sludge systems - conventional Ultrafiltration	Water containing organics and/or metal compounds Waste waters with organic content and sediment and salts content (soaps, inks, cooling liquid, soluble oils containing waste, etc.) Waste water with biodegradable organic content	Aqueous output Residues from waste water treatment Concentrates Highly concentrated oily waste	5 m^3/h	Urban/municipal sewer system
215	Pretreatment Emulsion breaking Oil separation Evaporation	NI	Emulsion breaking Buffer tanks Dewatering Filtration Flocculation	Acids Bases Hydrocarbons (oil and fuel liquid) Waste from surface treatment and mechanical forming Sludge	Aqueous output Immobilised solid waste Regenerated oil Stabilised residues Other	5 m^3/h	Urban/municipal sewer system
216	Pretreatment Vacuum distillation Finalisation treatment	NI	Absorption Buffer tanks Decantation Emulsion breaking Evaporation Filtration Ultrafiltration Vacuum distillation	Organic liquid waste	Aqueous output Residues from waste water treatment	Batch Around 15 times a year during 8 hours	Urban/municipal sewer system

WORKING DRAFT IN PROGRESS

217	Pretreatment Primary treatment Finalisation treatment	NI	Absorption Aeration Air stripping Buffer tanks Centrifugation Chemical oxidation Chemical precipitation Chemical Reduction Dewatering	Inorganic liquid waste Organic liquid waste	Aqueous output Residues from waste water treatment	Batch Around 2000 times year during 5 hours 7 m^3/h	Urban/municipal sewer system
317	Pretreatment Primary treatment Finalisation treatment	NI	Absorption Aeration Buffer tanks Centrifugation Chemical oxidation Chemical precipitation Chemical reduction Dewatering Emulsion breaking	Inorganic liquid waste Inorganic acid Organic liquid waste	Aqueous output Residues from waste water treatment	Batch Around 1260 times a year during 5 hours	Urban/municipal sewer system
322	Pretreatment Primary treatment Finalisation treatment	NI	Emulsion breaking Chemical oxidation Chemical reduction Neutralisation Chemical precipitation Press filtering	Waste from surface treatment Rinsing water Emulsion	Aqueous output Residues from waste water treatment Recovered catalyst Liquid fuel	Batch Around 110 times a year during 4 hours	Urban/municipal sewer system
347	Primary treatment	Metals Solids Hydrocarbons	NI	Landfill leachates Washing water, process and meteoric Oil emulsions	Aqueous output Residues from waste water treatment Regenerated oil	20 m^3/h	Off-site common WWT facilities

WORKING DRAFT IN PROGRESS

351	Clarification/flocculation (with $FeCl_3$ and NaOH) If necessary, sand filter	Heavy metals Suspended solids	Coagulation Flocculation Chemical precipitation Sedimentation (ponds) Neutralisation	Street cleaning residues Waste from sewage cleaning	Residues from waste water treatment	30 m^3/h	Urban/municipal sewer system
395	Finalisation treatment	NI	Chemical precipitation Press filtering Neutralisation	Spent acids Spent bases	Aqueous output Filter cake Packaging	NI	Off-site common WWT facilities
401	NI	NI	Aeration Buffer tanks Coagulation Centrifugation Detoxification Dewatering Filtration Flocculation Flotation Skimming	Separate oil and oil from oil-water separation Waste from paint, kit, wax, ink, pharmaceutical waste Oily or other organic waste Soil, TAR and other minerals	Aqueous output Decontaminated soil Ferrous metal Regenerated solvent residues from waste water treatment Other	Batch when raining	Urban/municipal sewer system
463	Primary treatment	NI	NI	Acids Bases Sludge Waste oil Water-based liquid waste	Aqueous output Immobilised solid waste Liquid fuel Regenerated oil	NI	Urban/municipal sewer system
473	Primary treatment Finalisation treatment Post-treatment (bioreactor)	NI	Active sludge systems - SBR Evaporation	Water/waste with hydrocarbons Basic waste Liquid cleaning solutions Waste ink Waste from the photographic industry Emulsions Oily sludge Antifreeze Leachate Liquid cleaning solutions	Residues from waste water treatment Empty containers Used oil	NI	Urban/municipal sewer system

WORKING DRAFT IN PROGRESS

486	Precipitation/flocculation Decantation/sedimentation Secondary treatment: ultrafiltration Reverse osmosis with polysulfonate membrane Evaporator, for treating RO concentrate, to minimise water content	Sediment Emulsion, colloids and 'slurry' (oil and larger organic molecules) Substances dissolved in water, salt, metals and organic molecules Water	Decantation Buffer tanks Filtration Ultrafiltration Reverse osmosis system Evaporation Neutralisation	Oily water from drained sludge, car washing, floor washing; flush pit-water, degreasers; cable pits, decontamination sites Water from flocculation of dye/colour waste IBC washing water Solvents and paint Solvents Used motor oil Oil emulsion Acids Bases Other waste: all types of electronic equipment (computers, fridges, telephones), demolition waste, different kinds of bases, pesticides, explosives, reactive flammable waste (organic peroxides and hydrogen peroxide)	Residues from waste water treatment Liquid fuel Waste oil	Continuous 1.3 m^3/h	On-site common WWT facilities (when the design/operation of the WWT facility is mainly influenced by waste water streams coming from activities other than the WT plant)
550	Primary treatment Filter press	Metals Solids	Dewatering Filtration Neutralisation Precipitation	Acids Various mixed wastes Neutral sludge	Aqueous output Immobilised solid waste	Batch 270 times a year 16 m^3/h	Urban/municipal sewer system
607	Flocculation and physical separation of liquid and settled solids.	Solids	Active sludge systems - conventional Precipitation	Indigenous liquid sludge and imported sludge	Residues from waste water treatment	Continuous 820 m^3/h	Urban/municipal sewer system
NI: No information.							

WORKING DRAFT IN PROGRESS

The analysis of reported average metal concentrations in indirect discharge to water from physico-chemical and/or biological treatment of water-based liquid waste shows that, in most cases (70–75 %), the levels are comparable to those from plants directly discharging to a receiving water body.

From ex-Section **3.3.3.1 Emissions from the physico-chemical treatments of waste waters**

~~Emissions from particular physico-chemical activities~~

~~The emissions listed in below can be expected to occur from most treatment plants. The scale of the emission depends on the plant throughput and on the abatement systems applied.~~

~~Table 5.185: Emissions from physico-chemical treatment processes applied to waste water~~

~~**Physico-chemical activity**~~	~~**Air**~~	~~**Water**~~	~~**Residues/Soil**~~
~~Addition of solid sodium carbonate or addition of sulphuric acid to form nickel or chromium sulphate~~	~~Emissions of CO^2, plus other acid gases (e.g. SO^*) depending upon the initial solutions~~	~~Liquid fraction is returned into the treatment and blending part of the plant. This is a tiny fraction of the main waste IN~~	~~The product precipitates out and is left to cool and crystallise before being bagged and sent off for recycling~~
~~Cyanide oxidation~~		~~HOCl~~	
~~Fluorescent tubes/lamp processing~~	~~Hg and SO^*~~	~~The discharge is a weak sodium hydroxide solution~~	
~~Precipitation of metals~~		~~Zn, Cu, Cd~~	
~~Silver recovery systems~~	~~There is an unquantified issue of ammonia, and possibly SO^*, from photographic chemicals due to the high nitrogen and sulphur levels in the solutions.~~ ~~Additionally there may be There are additional VOC emissions due to bulking and transfer processes~~		~~Possibly high nitrogen levels in the waste~~
~~Treatment of printing and photographic waste~~	~~Ammonia, VOC and potentially SO^*~~	~~Suspended solids, nitrogen (mainly nitrate) and COD~~	~~Waste typically has a high nitrogen content~~
~~Use of raw caustic~~		~~Hg~~	
~~*Unit operations*~~			
~~Air stripping~~	~~Ammonia and VOCs, including organic solvents (e.g. DCM)~~		
~~Dissolved air flotation (DAF)~~			~~Sludges that are taken from the bottom of settlement tanks will generally be up to 4 % dry solids~~
~~Evaporation~~	~~Normally takes place in fully enclosed systems but various vent valves can result in fugitive emissions~~		
~~Filtration/pressing~~ ~~This is a common area for emissions from chemical plants~~	~~Ammonia and, if there is a high organic content in the wastestreams, VOCs~~		

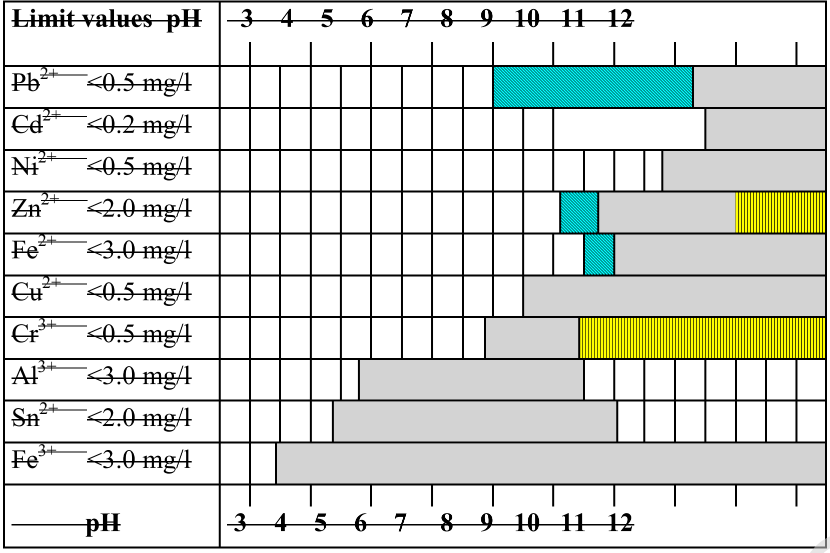
WORKING DRAFT IN PROGRESS

~~Physico-chemical activity~~	~~Air~~	~~Water~~	~~Residues/Soil~~
~~Ion exchanger~~		~~The eluate of an ion exchanger must be further treated in the plant according to its composition/concentration~~	
~~Mixing tanks~~	~~May produce a range of emissions, partly as the result of chemical reactions, and partly from heat effects reducing the solubility of gases in water.~~ ~~Ammonia is the most common gas mentioned as a problem at this stage of the process.~~		
~~Neutralisation~~	~~This can be a violent exothermic reaction with a rapid change in pH. Acidic acids such as CO^2, HCl, Cl^2, NO^*, and SO^*, as well as ammonia are emitted from the reactor tank, together with any contaminant volatile materials, such as cleaning solvents in wash waters. The gases can carry liquors and particulate matter with them~~	~~Typical components are chloride, phosphorus, nitrogen and metals~~	~~Typical components are chloride, phosphorus, nitrogen and metals~~
~~Organic splitting of emulsions~~			~~Generally smaller quantities of mud (filter cakes) develop in organic splitting than with acid splitting~~
~~Oxidation/reduction~~		~~The salination of the waste water is process-dependent~~	
~~Settlement~~	~~Emissions to the air are possible but unlikely~~		~~Sludges that are taken from the bottom of settlement tanks will generally be around 0.5 – 1.0 % dry solids content~~
~~Sludge management (e.g. pressing or sludge storage)~~	~~VOCs as fugitive emissions.~~ ~~Gases from solution~~		
~~Solvent extraction~~	~~Solvents as fugitive emissions.~~ ~~Significant potential for emissions on transfer and emergency releases~~	~~Solvents~~	
~~Stripping~~	~~Emissions are trapped in the areas provided in the Ph-c plant~~		

~~[33, UK EA 2001] [34, Babtie Group Ltd 2002] [77, Schmidt et al. 2002]~~

WORKING DRAFT IN PROGRESS

~~**Table 5.186: Range of precipitation values for various metals**~~



▒	~~pH ranges, with which the solubility of the metal hydroxide precipitation with caustic soda solution lies below the values mentioned in the first column~~
▥	~~Expansion of these ranges through the use of lime milk~~
▨	~~Expansion of these ranges through the use of soda~~

~~[77, Schmidt et al. 2002]~~

~~Precipitation sludge must be disposed of if recycling is not possible. Dewatering is generally necessary. Precipitation/flocculation materials must be selected to suit the dewatering procedure used. Sludge formed from materials containing aluminium generally display poor dewatering characteristics.~~

~~Precipitation/flocculation is a reaction and/or a reaction combination which is essentially dependent on the pH value. To this extent, the most significant reference parameter is the pH value. Since the waste water produced through precipitation/flocculation is discharged into sewerage systems, certain criteria must be met. In order to maintain these values, additional treatment steps and procedures for the treatment of waste water follow flocculation and precipitation.~~

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Table removed (see Section 2.3.6.5.2)

~~*Oxidation/reduction*~~

~~**Table 5.187: Consumption of chemicals for redox reactions**~~

~~**Redox reaction**~~	~~**Oxidant or reductor**~~	~~**pH**~~	~~**Observations**~~
~~Oxidation of cyanide and nitrite~~	~~Sodium hypochlorite (NaOCl) or chlor gas (Cl^2)~~	~~for CN: ~ 10~~ ~~for NO^2: ~ 3~~	- ~~reaction relatively quick~~ - ~~relatively high degree of salting up of the resultant waste water~~ - ~~formation of organic materials, which are shown as AOX (Note: the limit value is AOX = 1 mg/l in the waste water to be introduced into the sewerage system)~~
~~Oxidation of cyanide and nitrite~~	~~Hydrogen peroxide (H^2O^2)~~	~~for CN: ~ 10, catalyst: Fe (II) salts~~ ~~for NO^2: ~ 4~~	- ~~reaction relatively slow~~ - ~~negligible salting up of the waste water,~~ - ~~no new formation of materials as AOX~~ - ~~formation of mud, due to catalyst (Fe II salts)~~ - ~~formation of foam (in particular in the presence of organic materials)~~
~~Oxidation of nitrite~~	~~Aminosulphonic acid (NH^2SO^3H)~~	~~~ 4~~	- ~~reaction slowed~~ - ~~formation of sulphates~~ - ~~formation of elementary nitrogen~~
~~Reduction of chromate~~	~~Sodium hydrogen sulphite ($NaHSO^3$)~~	~~~ 2~~	- ~~fast reaction~~ - ~~causes salting up of the waste water~~ - ~~formation of mud~~
~~Reduction of chromate~~	~~sulphur dioxide (SO^2)~~	~~~ 2~~	- ~~fast reaction~~ - ~~slight salting of the waste water~~ - ~~slight mud formation~~
~~Reduction of chromate~~	~~Sodium dithionite ($Na^2S^2O^4$)~~	~~pH independent~~	- ~~fast reaction~~ - ~~leads to salting of the waste water~~ - ~~formation of mud~~
~~Reduction of chromate~~	~~Iron (II) sulphate or chloride ($FeSO^4/FeCl^2$)~~	~~~ 3~~	- ~~slow reaction~~ - ~~leads to the salting up of the waste water~~ - ~~formation of mud~~

~~[77, Schmidt et al. 2002]~~

Removed: information already in Section 2.3.6.5.8

~~*Sorption (adsorption/absorption)*~~

~~Table 5.188 contains information on various adsorbencies. The large area of activated carbon, which according to this is particularly well suited for the adsorption of materials is notable. However it must then be ensured that the material to be adsorbed (i.e. to be separated) also reaches the inner surface of the activated carbon. It is therefore the essential task of the reactor and plant technology to achieve an intensive contact between the material and the adsorbent to be separated. In the treatment of material mixtures, the effect and/or efficiency of adsorbents is determined in general by experiment.~~

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~~**Table 5.188: Physical data of adsorbents**~~

~~**TYPE**~~	~~**Characteristics**~~			
	~~**Specific surface** (m^2/g)~~	~~**Micropore volumes (ml/g)**~~	~~**Macropore volume (ml/g)**~~	~~**Apparent weight (g/l)**~~
~~Grain carbon for water purification~~	~~500 – 800~~	~~0.3 – 0.6~~	~~0.3 – 0.4~~	~~300 – 500~~
~~Powder carbon for decolourisation~~	~~700 – 1400~~	~~0.45 – 1.2~~	~~0.5 – 1.9~~	~~250 – 500~~
~~Fine-pore silica gel~~	~~600 – 850~~	~~0.35 – 0.45~~	~~<0.1~~	~~700 – 800~~
~~Large-pore silica gel~~	~~250 – 350~~	~~0.3 – 0.45~~	~~0.05 – 0.1~~	~~400 – 800~~
~~Activated alumina~~	~~300 – 350~~	~~0.4~~	~~approx. 0.1~~	~~700 – 800~~
~~Adsorbent resin~~	~~400 – 500~~			~~650 – 700~~

~~[77, Schmidt et al. 2002]~~

~~*Ion exchangers*~~

~~**Table 5.189: Overview of types of exchangers and their properties**~~

~~**Ion exchangers**~~	~~**Stability**~~		~~**Regeneration substance**~~
	~~**pH**~~	~~**°C**~~	~~**g/l resin**~~
~~Weak-acid, cation exchanger ionic form:~~ ~~H^+, PF^+~~	~~1 – 14~~	~~75 – 120~~	~~HCl: 70 – 140 or~~ ~~$H^2 SO^4$~~
~~Strong acid, cation exchanger ionic form:~~ ~~H^+~~	~~1 – 14~~	~~~120~~	~~HCl: ~80~~
~~Weak base, anion exchangers ionic form:~~ ~~OH^-, Cl^-~~	~~1 – 14~~	~~70 – 100~~	~~NaOH: ~60~~
~~Strong base, anion exchangers ionic form:~~ ~~OH^-, Cl^-~~	~~1 – 12~~	~~35 – 70~~	~~NaOH: ~80~~

~~[77, Schmidt et al. 2002]~~

From ex-**Section 3.6 "Emissions and consumptions from end-of-pipe treatments (abatement)"** deleted: already covered in Sections 5.7.2.2 and 5.7.2.3

~~[33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003] [73, Irish EPA 2003]~~

~~This section covers the emissions arising from those processes/activities, commonly called end-of-pipe or abatement techniques, used in the waste sector for the treatment of waste gas, waste water and process produced solid waste before those streams are disposed of. The main objective of these processes is to reduce the concentration of pollutants in the output streams. The loads and concentrations of pollutants in these streams will be reduced by end-of-pipe and abatement processes, but some pollutants may remain in the streams and others may be generated. The actual techniques are not decribed in this section, since they are techniques to consider in the determination of BAT and, thus they are analysed in Chapter 4. Some of the descriptions given are only in shortened forms in this document since they are available in other BREF documents (e.g. waste gas and waste water BREF).~~

~~**Emissions and consumptions of waste water treatments**~~

~~Effluents from waste treatment installations typically contain organic chemicals (e.g. measured as TOC or COD), nitrogen, phosphorus, and chloride, since most wastes originally contain some organic materials, even if only in association with fuel/oil spills from vehicles at the site or from surface de-icing. Large quantities of COD, nitrogen, phosphorus and chlorine could affect the performance of the sewage treatment works.~~

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~~The main emissions from waste water treatment systems will be carbon dioxide, methane and nitrous oxide to air, and TOC, nitrogen, phosphorus and chloride to water or sewer. The aqueous discharges are usually monitored, but emissions to the air are rarely monitored. There is generally some information on waste input that would allow large inputs of nitrogen rich wastes to be identified, and a minimum emission of nitrogen to the air to be calculated on a mass balance basis using the discharge data. If there is TOC/COD information at the waste IN, then a rough calculation of carbon dioxide emissions could be made.~~

~~In addition, there could be any number of additional emissions depending upon the waste IN, as indicated in Table **5.190** or depending on the waste water treatment plant step~~.

~~Table 5.190: Emissions from the different steps of a waste water treatment plant~~

~~WWTP part~~	**~~Emissions~~**
~~Reception~~	~~It is important in liquid waste biotreatment systems that the flow of substrate is relatively constant, so reception pits or equalisation tanks are an important feature of the process. These are usually filled from road tankers or from a pipe to the source. There is potential for spillage and emissions to the air (potentially air stripping) when the waste is transferred or mixed by aeration units within these tanks. Volatile chemical constituents are the most likely to result in fugitive air emissions if any~~
~~Primary processes~~	~~The initial stages of treatment usually provide for the removal of gross or fine solids. These may include coarse and/or fine screening, primary sedimentation or dissolved air flotation. The main potential sources of emissions are from transfer activities to and from these processes. Some components may preferentially concentrate in the solids, which are collected and stored after primary treatment. Flocculants or other additives may be used in clarification and can add additional species to the flow~~
~~Secondary processes~~	~~Predominantly these include an aerobic stage where the effluent is aerated with oxygen or air (HRT 0.5 – 3 days) to convert soluble organics to micro-organisms (sludge) and final effluent. Emissions can occur from the vigorous activity in the aeration tank and may result in an air stripping of volatiles. It is usually assumed that if the waste is treatable in this way, the emissions are not hazardous since the process is biological. Although this is the usual case, it is not necessarily the case and in one (past) instance, a known carcinogen was released through air stripping in the aeration tank, while the performance of the plant remained unimpaired.~~ ~~It is not easy to determine all the potential intermediate compounds that can occur as complex organics are broken down during the process, or their volatility under these circumstances.~~ ~~After the aeration tank, the final effluent is invariably separated in another clarifier or sedimentation tank. Again, some organic constituents and metals can bioaccumulate in the sludge~~

	*~~Gaseous emissions to air *~~*	*~~Aqueous emissions to sewer or controlled waters~~*	*~~Sludge/compost for re-use or for onward disposal to landfill~~*
~~Aerobic waste water systems~~	~~Carbon dioxide, odours (mainly due to organic compounds), microbes~~	~~TOC/N/P/Cl~~	~~TOC/N/P~~
~~Anaerobic waste water systems~~	~~Methane, carbon dioxide, microbes~~	~~TOC/N/P/Cl~~	~~TOC/N/P~~

~~* The actual range of gases produced is much larger and is likely to include ammonia and carbon monoxide in all processes, but these are small compared with the main degradation products.~~

~~[34, Babtie Group Ltd 2002]~~

~~Table 5.191 gives some qualitative values of the emissions from waste water treatments and advises how these can be calculated.~~

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~~Table 5.191: Relevant emissions for waste water treatment~~

	~~Emission to air~~	**~~Emission to surface waters/sewer~~**	**~~Emissions to land and solid waste~~**
~~Ammonia~~	~~Low.~~ ~~Where high ammonia wastes are accepted it may be possible to do a mass balance at some sites. Ammonia may be also generated in the removal of colloidal solids when using vacuum filtration~~		
~~Carbon dioxide (kg)~~	~~It may be possible to estimate the emission from TOC_{output} – TOC_{input}~~		
~~Methane~~	~~Low~~		
~~Nitrous oxide~~	~~Low~~		
~~Other species: metals and organics~~		~~It may be possible to estimate the intake from waste analysis and then to either undertake calculations based on analytical data from the outlet at the site, or the review the likelihood of discharges to air, water and sludge~~	
~~TOC~~			
~~COD~~			
~~BOD~~		~~10 – 20 mg/l (flow weighted monthly average), for any incoming load~~	
~~Total N~~			~~Nitrogen and phosphorus in the effluent will arise from the treatment of nitric acid, ammonia compounds, amines, etc. and phosphoric acid~~
~~Total P~~			
~~Chloride~~			
~~Fluoride~~		~~Fluoride is not a common part of the effluent, unless the site actively accepts wastes with this content~~	
~~Heavy metals~~			~~Where sources of mercury or cadmium cannot be eliminated or reduced by control at source, abatement will be required to control releases to water. In biological treatment 75 - 95 % of these metals will transfer to the sludge. Levels are unlikely to cause problems for the disposal of sludge but care will need to be taken to ensure that levels in the receiving water are acceptable~~

~~[33, UK EA 2001] [34, Babtie Group Ltd 2002] [60, WT TWG 2003]~~

~~VOC emissions~~

~~Emissions from aerobic treatment can occur from the aeration tank as the aeration is vigorous and may result in the air stripping of volatiles. It is often assumed that if the waste is treatable in~~

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~~this way, the emissions are not hazardous since the process is biological. This is not necessarily true and in one (past) instance, a known carcinogen was released (through air stripping in the aeration tank) while the performance of the plant remained unaffected. It is not easy to determine all the potential intermediate compounds that can occur as complex organics are broken down in the process, or their volatility under different circumstances. It can be expected that feedstocks containing a known volatile organic contaminant would release air emissions at this point in the process. A similar scenario would occur for feedstocks with excess nitrogen.~~

~~*Emissions of ammonia to the air*~~

~~Ammonia is often generated by air stripping systems in waste water treatment plants treating high nitrogen wastes such as landfill leachate.~~

~~*Sludge*~~

~~After the aeration tank, the final effluent is invariably separated in another clarifier or sedimentation tank. Once again, some organic constituents can bioaccumulate in the sludge.~~

5.7.2.4 Energy consumption

Figure 5.52 below presents the levels of consumption of energy (electricity and other energy sources, such as fuel and gas) reported by plants which indicated that their activity is only the physico-chemical and/or biological treatment of water-based liquid waste (some plants reported carrying out other waste treatment activities which renders comparison of the data on energy consumption impossible). As some operators raised confidentiality issues on waste input and output quantities, the information has been anonymised.

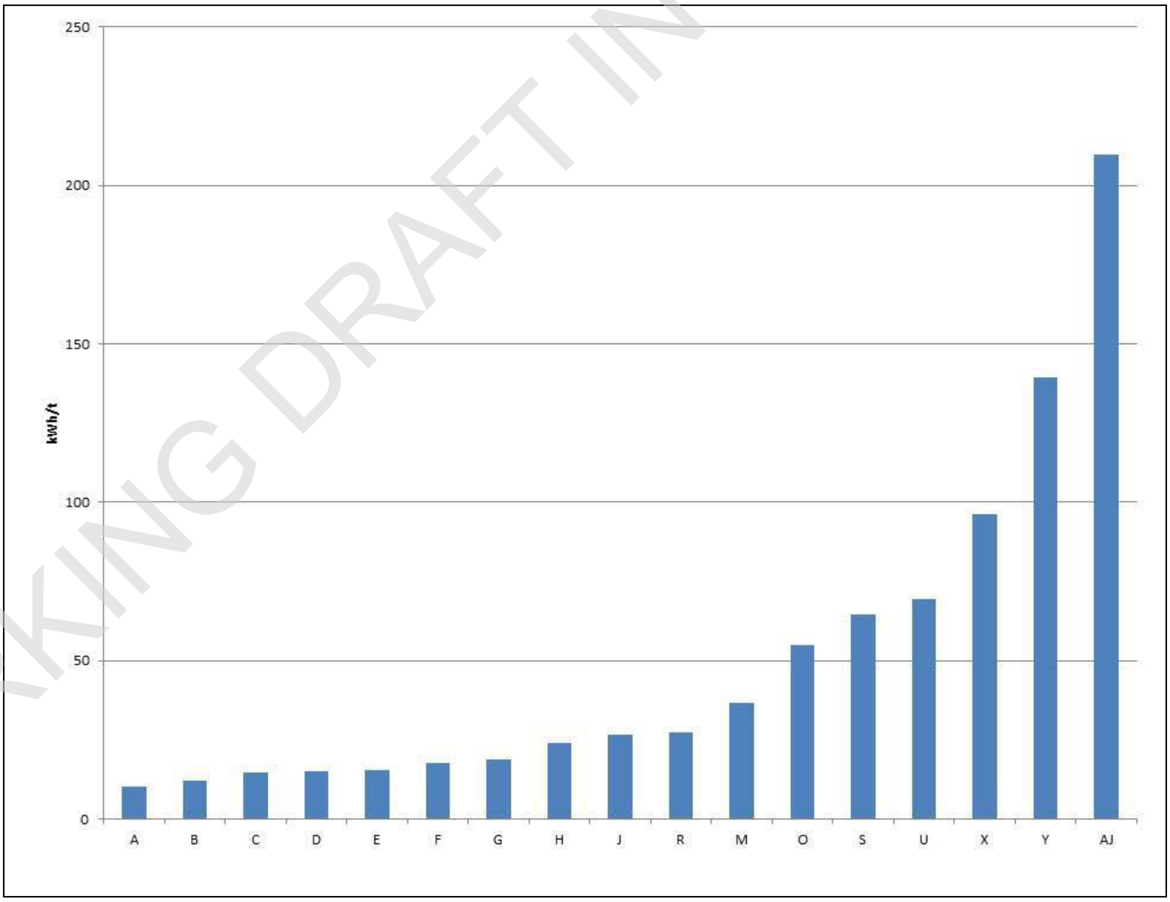

Figure 5.52: Physico-chemical and/or biological treatment of water-based liquid waste – Energy consumption per tonne of waste treated

The reported energy consumption per tonne of waste treated ranges from 10 kWh/t to 210 kWh/t, with an average of 50 kWh/t.

WORKING DRAFT IN PROGRESS

Depending on the waste input type and on the process, heat ~~is~~ may be required for the heating of tanks and pipelines in order to keep them frost-free, for the preparation of chemicals, for the improvement of separation processes and for other processes. The amount of energy consumed also depends on climatic conditions. Electricity is required for pumps, compressors and other facilities.

Further differences in energy consumption may be caused by a difference in storage capacity or the application of evaporation. The highest values were reported by plants performing evaporation, wet oxidation, etc., where a high amount of energy is needed.

~~The overall consumption of energy for heat production varies from 140 to 490 MJ/m3 waste water. The overall consumption of electricity varies from 65 to 170 MJ/m3 waste water. The energy data include other activities such as the cleaning of vessels, which means that they are an overestimate of the energy consumption needed for physico-chemical and biological treatment.~~

Consumption of energy of liquid photographic waste

From ex-**Section 3.4.2 "Consumptions of waste treatments to obtain a recycled material"**

The electricity required for electrolysis ranges from 12 kWh/t to 46 kWh/t of photographic liquid waste. The electricity consumption is dependent on the iron content. For bleach-fix, the consumption is higher due to the higher iron content. The ultrafiltration requires approximately 27 kWh_e and 13 MJ/t of liquid waste for the heating of the rinse water. The electricity consumption for the chemical removal of silver is estimated as 3.5 kWh/t of liquid photographic waste.

The energy consumption for evaporation is approximately 220 MJ/t of waste water. If evaporation is also applied as a pretreatment, in the case of colour photo processing waste water, the energy consumption is approximately 350 MJ/t of waste water. The required electricity for electroflocculation, in the case of extra desilvering, is approximately 80 kWh/t of waste water. Further physico-chemical and biological treatment requires approximately 5 kWh_e/t of waste water.

TWG, please confirm this is still valid

5.7.2.5 Raw material consumption

From ex-**Section 3.3.2 "Consumptions of physico-chemical treatments"**

Waste waters

In some physico-chemical treatments, bases are necessary. In some cases, waste bases are reused in waste applications for neutralisation purposes. The neutralising agent used could be a solid or liquid waste stream or a bought-in alkali, as most plants need to buy in some supplementary alkalis. Aqueous acid containing metals, alkali and neutral wastes are common additions and the ~~Ph-c~~ physico-chemical treatment plants for water-based liquid waste are typically designed to produce a sludge containing slightly alkaline metal. Table 5.192 shows the consumption levels of some physico-chemical treatments of contaminated water.

WORKING DRAFT IN PROGRESS

Table 5.192: Consumption levels of some physico-chemical treatments of water-based liquid waste

Parameter	Yearly consumption (t/yr) *	Specific consumption (kg/tonne of waste treated) *	Yearly consumption of inorganic pathway (t/yr)	Yearly consumption of organic pathway (t/yr)	Yearly consumption of WWT (t/yr)	Yearly consumption of lacquer treatment facility (t/yr)	Yearly consumption of laboratory chemical treatment (t/yr)
Average throughput	45 000	NI	20 000	66 000	30 000	Lacquer: 15 000 Solvent: 15 000 Lacquer powder: 1000	1000
Average consumption of acids	230 (1)	5.1	HCl: 69 Sulphuric: 48	HCl: 8 Phosphoric: 8	HCl: 39.4	NI	0.5
Lime	590 (1)	13.1	1023	NI	50	NI	10
Flocculation agents	290	6.4	NI	8	16	NI	NI
Other chemicals (2)	NI	0.4–3.0	NI	NI	NI	NI	NI
Sodium sulphite	NI	NI	10.2	NI	2	NI	NI
Water usage	NI	NI	759	9900	1788	2700	NI
Energy consumption	NI	NI	NI	275 kW	369 MWh	Fuel oil: 1139 m^3 Electricity: 189 MWh	NI
Waste water	NI	NI	11 573	48 348	12687	NI	250
Hydrogen peroxide	NI	NI	6.2	NI	NI	NI	0.1
Sodium hypochlorite	NI	NI	4.9	NI	NI	NI	NI
Iron chloride solution	NI	NI	NI	118	NI	NI	NI
Iron oxide	NI	NI	NI	NI	65.8	NI	NI
Sodium hydroxide	NI	NI	NI	110	NI	NI	1
Activated carbon	NI	NI	NI	6	NI	NI	NI
Potassium permanganate	NI	NI	NI	NI	0.4	NI	NI
Splitting additives	NI	NI	NI	NI	25	NI	NI
Amidosulphone acid	NI	NI	NI	NI	NI	NI	NI

* NB: Data based on the data from Ph-c plant operators with a combined capacity of 850 kt/yr. The data correspond to the year 2001. The average age of the plants is about 17 years (ranging from 4 to 39 years). Approximately 84 % (from 73 % to 91 %) of all the Ph-c plants for treatment of accepted waste observed here can be attributed to EWL groups 11,12,13,16 and 19.

(1) Values do not include accepted and used waste acids or waste alkalis.

(2) Detoxification chemicals, organic breaking up of emulsions, sorption, sulphuric precipitation.

NI: No information.

Source: [77, Schmidt et al. 2002] [90, UBA Germany 2003]

WORKING DRAFT IN PROGRESS

A total amount of approximately 0.4 m^3 of prepared chemicals is used per m^3 waste water. Table 5.193 shows the chemicals consumed and some of their consumption levels for detoxification, neutralisation and dewatering for the removal of metals.

Table 5.193: Chemicals consumed and some of their consumption levels for detoxification, neutralisation and dewatering for the removal of metals from waste waters

Chemical	Consumption
Lime or sodium hydroxide for neutralisation/precipitation	(NaOH 50 %) 120 l/m^3 of waste water
Sulphuric or hydrochloric acid for acidification	(HCl 30 %) 10 l/m^3 of waste water
Hypochlorite (oxidation cyanide)	NI
Iron (II) sulphate or sodium bisulphite (reduction Cr^{6+} to Cr^{3+})	NI
Aluminium sulphate or chloride (flocculation)	NI
Iron (III) chloride (flocculation)	NI
Sodium sulphide (precipitation)	0.3 kg/m^3 of waste water
Materials for the improvement of precipitation, flocculation, coagulation and complex destruction	NI
NI: No information. *Source*: [103, VROM 2004]	

Precipitation/flocculation

The following inorganic materials are predominantly used in precipitation/flocculation:

- caustic soda;
- soda ash (sodium carbonate);
- lime;
- iron (III) chloride;
- iron (II) chloride;
- aluminium sulphate;
- sulphides.

Synthetic flocculation materials are also used for the improvement of floc formation and sedimentation characteristics. They consist principally of non-ionic polymers, anionic polymers, cationic polymers and co-polymers of ionic and non-ionic compounds.

Table 5.194 shows the chemicals used for the precipitation of solute heavy metals; this information refers to chemically pure chemicals. In practice, it may be that the quantities actually required are 10–20 % greater. Precipitation values for different metals are shown in Table 5.186.

Table 5.194: Theoretical consumption of alkalis in precipitation per 100g metal

Used alkali (g)	Metal to be precipitated					
	Fe (II)	**Fe (III)**	**Cu**	**Ni**	**Cr**	**Zn**
CaO	100	150	88	96	162	86
$Ca(OH)^2$	134	201	116	126	213	114
NaOH	144	216	126	136	231	122
Na^2CO^3	190	285	168	181	307	162
MgO	73	110	63	69	117	62
$Mg(OH)^2$	105	158	92	100	169	90
Source: [77, Schmidt et al. 2002]						

From ex-**Section 3.4.2 "Consumptions of waste treatments to obtain a recycled material"**

Consumption of chemicals

Table 5.195 shows the consumption of chemicals for sulphide precipitation/ultrafiltration of photographic liquid waste.

WORKING DRAFT IN PROGRESS

Table 5.195: Consumption of chemicals for sulphide precipitation/ultrafiltration

Chemical	Consumption (kg/t of photo processing waste)	Function
Sodium sulphide (40 %)	0.1	Precipitation of silver (and other metals)
Citric acid	0.7	Cleaning of the membranes
Sodium hydroxide	0.01	Cleaning of the membranes
Detergents	0.01	Cleaning of the membranes
Water	75	Cleaning of the membranes
Source: [103, VROM 2004]		

For the chemical removal of silver, the consumption of chemicals is estimated at 1.5 litres of sodium borohydride and 2.5 litres of sulphuric acid per tonne of photographic liquid waste.

In the physico-chemical treatment of desilvered photographic liquid waste, several chemicals are used. The consumption levels are shown in Table 5.196. If evaporation is applied as a pretreatment, practically no chemicals are consumed in the following treatment steps. Most contaminants have already been removed in the evaporation step.

Table 5.196: Consumption of chemicals in the treatment of desilvered photographic liquid waste

Chemical	Consumption (kg/t of waste water)
Sodium hydroxide (33 %)	0.007
$FeCl^3$	0.003
Powder carbon	0.5
Flocculant (1)	5
Na^2S (40 %) (1)	15
(1) In the case of desilvering *Source*: [103, VROM 2004]	

5.7.3 Techniques to consider in the determination of BAT

Ex-Sections 4.3.1.1 to 4.1.3.5 and 4.1.3.7 to 4.3.1.20 moved to Section 2.3.6: techniques described relate to waste water treatment. Consistent with questionnaire

The techniques used in the treatment of water-based liquid waste are similar to those end-of-pipe techniques used for the treatment of waste water described in Section 2.3.6. Therefore this section contains only specific information on techniques to consider in the physico-chemical and/or biological treatment of water-based liquid/pumpable waste.

From ex-Section **4.3.1 Techniques used in physico-chemical treatment plants of waste water**

~~This section contains techniques considered to have a good environmental operating performance (e.g use of a good energy system) or that can help lead to a good environmental performance (e.g. environmental management systems). Techniques in this section relate to physico-chemical treatments described in Section .~~

~~**Technical description**~~

From ex-Section 4.3.1.3 items a and d

~~a. preventing the mixing of acidic/basic waste with other streams to be neutralised when the mix contains metals and complexing agents at the same time. This prevents the formation of metal complexes that are difficult (from an economic point of view) to separate afterwards. Complexing ions to watch out for include, for example, EDTA, NTA and cyanides~~

~~b. separately storing the neutralised waste water in order to avoid negatively affecting the quality of the treated waste water due to secondary reactions occurring if they were stored~~

WORKING DRAFT IN PROGRESS

~~together. Final inspection of the treated waste water needs to be performed after a sufficient storage time has elapsed.~~

5.7.3.1 Techniques for the prevention or reduction of emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

Description
Collection of waste gas and an appropriate combination of abatement techniques such as:

- adsorption (see Section 2.3.4.9);
- wet gas scrubber (see Section 2.3.4.10.1);
- biofilter (see Section 2.3.4.7)

Technical description
See Section 2.3.4.9, Section 2.3.4.10.1 and Section 2.3.4.7 for descriptions of adsorption, wet gas scrubbers and biofilters respectively.

Achieved environmental benefit
Reduction of emissions to air of HCl, NH_3, and organic compounds.

Environmental performance and operational data
Table 5.197, Table 5.198, and Table 5.199 below present the emissions to air of, HCl, NH_3, and TOC respectively from plants performing physico-chemical and/or biological treatment of water-based liquid waste which are equipped with an adsorption system, and/or wet gas scrubber system (acidic or basic), and/or biofilter system. Indications of the reported origin of emissions to air, the standard used for the monitoring, and the number of measurements during the three reference years are also given in these tables.

Additional information on the environmental performance of each technique can be found in the CWW BREF [138, COM 2014].

WORKING DRAFT IN PROGRESS

Table 5.197: HCl emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

Plant code	Average air flow (m^3/h)	Origin of emissions to air	Waste input	Abatement technique	HCl concentration (mg/Nm^3) Periodic measurements(1)	Standard used for the monitoring	Number of measurements in the three-year reference period
149	51 000	Physico-chemical treatment of water-based liquid waste	Acids Bases Organics	Activated carbon adsorption	2.2	NF EN 1911	2
192	6 600	Physico-chemical treatment of water-based liquid waste	Acids Bases Inorganics	Basic scrubber system	1.7	NI	6
215	620	Physico-chemical treatment of water-based liquid waste	Acids Bases Oily water Waste from surface treatment	Basic scrubber system Acid scrubber system	1.7	VDI 3496	1
217	2 500	Physico-chemical treatment of water-based liquid waste	Inorganics Organics	Basic scrubber system Acid scrubber system Activated carbon adsorption	2.6	NI	1
317	2 500	Physico-chemical treatment of water-based liquid waste	Acids Inorganics Organics	Basic scrubber system Acid scrubber system Activated carbon adsorption	0.2	DIN EN 1911	1
322	1 000	Physico-chemical treatment of water-based liquid waste	Waste from surface treatment	Alkaline oxidative scrubber system Wet scrubbing	1.0	Estimated with 'Dräger Röhrchen' test device	7
463	NI	Water-based liquid/pumpable waste treatment Disposal or recovery of hazardous waste Regeneration of acids or bases	Acids Bases Waste oil	Activated carbon adsorption	2	NI	3

WORKING DRAFT IN PROGRESS

468_1	4 100	Physico-chemical process of water-based liquid waste	Acids Bases Liquid waste with high biodegradable content Waste oil	Basic scrubber system	0.04	NI	3
550	NI	Physico-chemical process of water-based liquid waste	Acids Various mixed wastes	Basic scrubber system	0.0005	NI	36

(1) Average of measurements over the three reference years.
NI: No information.

WORKING DRAFT IN PROGRESS

Table 5.198: NH_3 emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

Plant code	**Average air flow (m^3/h)**	**Origin of emissions to air**	**Waste input**	**Abatement technique**	**NH_3 concentration (mg/Nm^3) Periodic measurements[(1)]**	**Standard used for the monitoring**	**Number of measurements in the three-year reference period**
3	9 800	Storage tanks Physico-chemical and biological treatment of water-based liquid waste	Acid Base Solvent mixtures Oily water Paint	Biofiltering Activated carbon adsorption Wet scrubbing with sorbent injection	0.3	NI	3
7	4 000	Physico-chemical and biological treatment of water-based liquid waste	Oily water Landfill leachate Paint Water containing cyanide	Biofiltering Wet scrubbing	0.7	ÖNORM M9415	3
215_3	620 - 4 300	Physico-chemical treatment of water-based liquid waste	Acid Base Oily water Waste from surface treatment	Basic scrubber system Acid scrubber system	0.3–1	VDI 3496	1
317	2 500	Physico-chemical treatment of water-based liquid waste	Acid Inorganics Organics	Basic scrubber system Acid scrubber system Activated carbon adsorption	0.3	VDI 3496	1
463	NI	Water-based liquid/pumpable waste treatment Disposal or recovery of hazardous waste Regeneration of acids or bases	Acid Base Waste oil	Activated carbon adsorption	1	NI	3
550	NI	Physico-chemical treatment of water-based liquid waste	Acid Various mixed wastes	Basic scrubber system	0.00005	NI	36

(1) Average of measurements over the three reference years.
NI: No information.

WORKING DRAFT IN PROGRESS

Table 5.199: VOC emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

Plant code	Average air flow (m^3/h)	Origin of emissions to air	Waste input	Abatement technique	VOC concentration (mg/Nm^3) Periodic measurements[1]	Standard used for the monitoring	Number of measurements in the three-year reference period
3	9 800	Storage tanks Physico-chemical and biological treatment of water-based liquid waste	Acid Base Solvent mixtures Oily water Paint	Biofiltering Activated carbon adsorption Wet scrubbing with sorbent injection	22	NI	3
192	6 600	Physico-chemical and biological treatment of water-based liquid waste	Acid Base Inorganics	Basic scrubber system	5.6	NF EN 12619	6
215	7 550	Physico-chemical and biological treatment of water-based liquid waste	Acid Base Oily water Waste from surface treatment	Basic scrubber system Acid scrubber system	3	VDI 3496	2
423	2 200	Thermo-mechanical mixer	Drilling waste (cuttings, mud and sludge)	NI	4.3	NI	3
463	NI	Physico-chemical and biological treatment of water-based liquid waste Regeneration of acids or bases	Acid Base Waste oil	Activated carbon adsorption	6	NI	3

(1) Average of measurements over the three reference years.
NI: No information.

WORKING DRAFT IN PROGRESS

Cross-media effects
See the CWW BREF [138, COM 2014] for the potential cross-media effects of each individual technique.

No cross-media effects are identified for the determination of an appropriate combination of abatement techniques for emissions to air.

Technical considerations relevant to applicability
See the CWW BREF [138, COM 2014] for technical considerations relevant to applicability of each individual technique.

Determining the appropriate combination of abatement techniques based on the characteristics of the waste input treated and on the treatment process is generally applicable.

Economics
See the CWW BREF [138, COM 2014].

Driving force for implementation
Environmental legislation.

Example plants
See Table 5.197, Table 5.198, and Table 5.199 above.

Reference literature
[160, WT TWG 2014]. [138, COM 2014]

WORKING DRAFT IN PROGRESS

From ex-**Section 4.3.1.21 Abatement techniques applied in Ph-c treatment plants**. Deleted because described in section 2 an detailed in the relevant subsections.

~~Table 5.200 shows the air abatement techniques applied in Ph-c treatment plants~~

Table 5.200: Off-gas treatment in large Ph-c installations in Austria

~~**Installation**~~	~~Offgas treatment for the treatment area/ reactors~~ [a]	~~**Air abatement/off-gas treatment in storage areas**~~
~~Solidification~~	~~Bag filter~~	~~Bag filter~~
~~Multifunctional Ph-c installation~~	~~Scrubber for acids~~ ~~Scrubber for NH^3 in operation, if necessary~~	~~n.a.~~
~~Multifunctional Ph-c installation~~	~~Scrubber for acids~~ ~~Oxidising scrubber~~	~~Carbon filter for some tanks containing oily waste~~
~~Multifunctional Ph-c installation~~	~~Off-gas is used during the incineration of hazardous waste~~	~~n.a.~~
~~Multifunctional Ph-c installation~~	~~4- to 5-step treatment system:~~ ~~Water scrubber (eliminating aerosols containing oil and dust)~~ ~~Scrubber for acids~~ ~~Scrubber for NH^3~~ ~~Biofilter, closed system~~ ~~Carbon filter in operation, if necessary~~	~~Ventilation for the whole plant, treatment of the off-gas~~
~~Multifunctional Ph-c installation~~	~~Scrubber for NH^3~~ ~~Biofilter~~	~~Biofilter~~
~~Multifunctional Ph-c installation~~	~~Scrubber for acids~~ ~~Scrubber for NH^3~~	~~Ventilation~~
~~Multifunctional Ph-c installation~~	~~Scrubber in operation during cyanide or nitrite oxidation~~	~~Ventilation~~
~~Multifunctional Ph-c installation~~	~~Scrubber for acids~~ ~~Oxidising scrubber~~ ~~Biofilter for the organic part~~	~~Biofilter together with off-gas of biological treatment of MSW~~
~~Multifunctional Ph-c installation~~	~~Scrubber for acids~~ ~~Scrubber for NH^3~~ ~~Biofilter (closed system)~~ ~~Off-gas funnel~~	~~Biofilter~~
~~Soil washing / attrition plant~~	~~1-step scrubber~~	~~n.a.~~

[a] ~~Many plants use the scrubbers only during Ph-c treatment in the reaction vessel. Other plants operate the air abatement system continuously.~~

~~n.a no information available~~

~~[98, WT TWG 2004]~~

~~Next Figure 5.53 and Table 5.201 shows the air abatement systems of a Austrian plant and the waste water parameters achieved after biological treatment of the waste waters.~~

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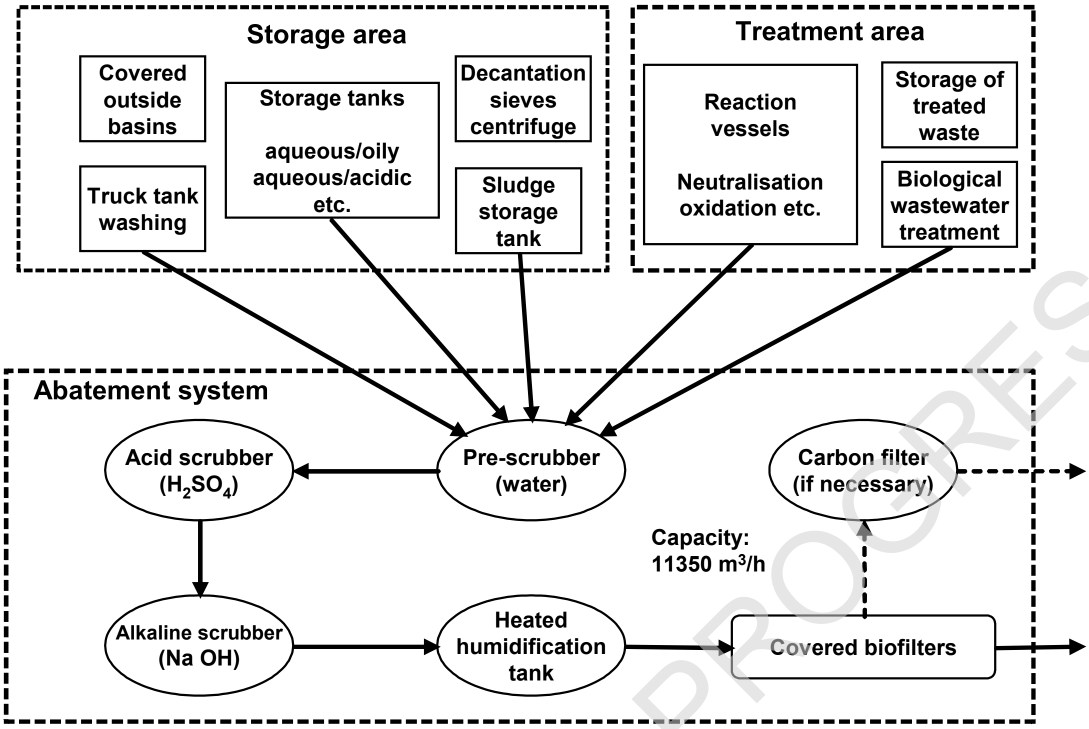

Source:[98, WT TWG 2004]

Figure 5.53: Air control and abatement system of a Ph-c plant

Table 5.201: Effluent concentration of an Austrian plant before and after tertiary waste water treatment (on-site sequential batch biological treatment)

~~Parameter~~	~~Feed (primary effluent) (mg/l)~~		~~Effluent after biological treatment (sequential batch reactor) (mg/l)~~	
	~~Minimum~~	~~Maximum~~	~~Minimum~~	~~Maximum~~
~~COD~~	~~2500~~	~~12000~~	~~600~~	~~1500~~
~~NH^4-N a)~~	~~25~~	~~16000~~	~~<1~~	~~150~~
~~Nitrite~~	~~10~~	~~300~~	~~<1~~	~~<1~~
~~Nitrate~~	~~10~~	~~1000~~	~~<1~~	~~<1~~
~~Phenols~~	~~10~~	~~500~~	~~<2~~	~~<2~~
~~Oil content~~	~~–~~	~~–~~	~~<0.5~~	~~–~~

~~a) Effluent after biological treatment: Often around 20 mg/l~~
~~*Source*:[98, WT TWG 2004]~~

From ex-**Section 4.3.1.2 "Techniques for Ph-c reactors"**. Items are moved to Section 2.3.2 and Section 2.3.13.1

~~a. clearly defining, the objectives and the expected reaction chemistry for each treatment process. There needs to be a defined end-point to the process so that the reaction can be monitored and controlled. The suitable inputs to the process need to be defined and the design needs to take into account the likely variables expected within the waste stream~~
~~b. assessing each new set of reactions and proposed mixes of wastes and reagents prior to treatment in a laboratory scale test mix of the wastes and reagents to be used. This needs to lead to all reactions that will occur in the full scale treatment and so the mixing of wastes needs to be done to a pre-determined batch 'recipe'. This needs to take into account the potential scale-up effects, for example, the increased heat of reaction with the increased reaction mass relative to the reactor volume, increased residence time within the reactor and modified reaction properties, etc.~~
~~c. specifically designing and operating the reactor vessel so that it is fit for its intended purpose. Such designs need to include considerations of the chemical process hazards, a~~

WORKING DRAFT IN PROGRESS

~~hazard assessment of the chemical reactions, considerations of appropriate prevention and protection measures, together with consideration of the planned process management, that is, working instructions, staff training, plant maintenance, checks, audits and emergency procedures~~

~~d. where appropriate, ensuring that the reactor vessels (or the mixing vessels where the treatment is carried out) are charged with premixed wastes and reagents. For example some reactor vessels may need to be 'pre-limed' or charged first with the reacting alkali to control the reaction, using for example calcium hydroxide solution made up prior to charging the reactor vessel~~

~~e. avoiding decanting the sacks or drums directly to the vessel. This practice can lead to:~~

- ~~concentration 'hotspots' at the surface of the reaction liquor~~
- ~~a loss of reaction control~~
- ~~the emission of fumes from the instantaneous reaction at the interface~~
- ~~the open hatch venting fumes and thus bypassing the appropriate abatement~~

~~f. monitoring the reaction to ensure that it is under control and proceeding towards the anticipated result. For this purpose, the vessels used for treatment need to be equipped with high level pH and temperature monitors. These need to be automatic and continuous and linked to a clear display in the control room or laboratory, together with an audible alarm. A risk assessment may require process monitors to be linked to cut-off devices. Monitoring of the reaction is necessary because the reaction characteristics in the reactor may vary from those found in the laboratory tests. Monitoring needs to provide an early indication of any deviation from the laboratory tests, and also needs to enable measures to be taken to halt or modify the reaction. There should, consequently, be a provision for the cooling and/or quenching of reactor vessels~~

~~g. ensuring that there is adequate mixing within a treatment vessel as this may determine the success of the reactor. The standard method for agitating the contents of a vessel is a rotating impeller. There is a geometric ratio between the size of the impeller and the clearance from the vessel (determined by type and size of vessel). This also depends on the agitation speed and characteristics of the waste. A seal is required where the impeller enters the vessel to prevent fugitive releases. A method of mixing should be provided~~

~~h. in order to track and control the process of change, keeping a written procedure for the proposal, consideration and approval of any changes or technical developments including all procedural or quality changes~~

From ex-**Section 4.3.1.2 "Techniques for Ph-c reactors"**. Removed: already in Section 2.3.5

~~a. enclosing all treatment/reaction vessels and ensuring that they are vented to the air via an appropriate scrubbing and abatement system~~

~~b. ensuring that any VOCs that are emitted due to the high temperature rise in the reaction vessels are returned to the treatment system after condensation in the scrubbers~~

~~c. monitoring the reaction throughout the course of the reaction. It may be necessary to extract the exhaust air of the reactor~~

~~d. having a system, as is the case at most sites, to exchange the air above the reaction vessels and to pass it through some type of treatment system to remove gases such as ammonia, hydrogen chloride, sulphur dioxide. Typically aqueous liquors from scrubbers are returned to the treatment plant, and activated carbon systems are regenerated (e.g. by steam stripping) or in case this is not possible, the activated carbon is incinerated.~~

Achieved environmental benefits

~~Control of the reaction/treatment process is crucial to environmental protection and to preventing possible accidents. A yield of 96 % removal of metals can be attained.~~

~~Environmental performance and operational data~~

~~Cross-media effects~~

WORKING DRAFT IN PROGRESS

~~Technical considerations relevant to applicability~~

~~Physico-chemical plants undertake input waste screening to enable them to store wastes in the correct tanks and to balance the reactions.~~

~~Economics~~

~~Driving force for implementation~~

~~Some national effluent standards are available, e.g. the Surface Waters Pollution Act in the Netherlands.~~

~~Example plants~~

~~In general, neutralisation reaction tanks are fitted with alkaline scrubber units and most of the acid gases are returned to the process along with some of the VOCs and almost all of particulate matter/liquors. The capacities of the example plants vary from 200 to 40000 m^3/yr.~~

~~Reference literature~~

~~[33, UK EA 2001] [34, Babtie Group Ltd 2002][60, WT TWG 2003] [77, Schmidt et al. 2002] [98, WT TWG 2004] [100, WT TWG 2004] [103, VROM 2004]~~

From ex-**Section 4.3.1.6 Oxidation/reduction.** Deleted. Covered by sections 2.3.6.5.2 and 2.3.6.5.3

~~Description~~

~~Some techniques include:~~

a. ~~abating the air emissions generated during oxidation/reduction~~
b. ~~having in place safety measures and gas detectors (e.g. suitable for detecting HCN, H_2S, NO_x).~~

~~Achieved environmental benefits~~

~~Reduces the emissions that may occur from the redox reactions.~~

~~Example plants~~

~~The collection of the exhaust air is ensured by suction with a fan and exhaust air filter. Here no measurements are made since the transported exhaust air rate is overdimensioned. The filter, which may involve acid or base scrubbers, is regularly controlled and if necessary regenerated.~~

~~Reference literature~~

~~[77, Schmidt et al. 2002]~~

WORKING DRAFT IN PROGRESS

5.8 ~~Physico-chemical~~ Treatment of waste containing POPs or mercury ~~[other wastes]~~

5.8.1 POP-containing waste

5.8.1.1 Applied processes and techniques

5.8.1.1.1 Decontamination of waste or equipment polluted with persistent organic pollutants (POPs)

Purpose
Decontamination of equipment or substances polluted with POPs before reuse, recycling or disposal.

Principle of operation
Decontamination is intended to remove POPs (chemical or infectious) from equipment or substances. These pollutants are undesirable because they present an important risk to health and/or the environment in the reuse, recycling or disposal of the equipment or substances in an environmentally sound way.

Process description
Separation can be performed by various techniques depending on the type of waste or equipment and the type of contaminants:

- washing with solvent, biocide, neutralising agent;
- crushing;
- sorting, sieving;
- vacuum cleaning;
- distillation;
- thermal processes, etc.

Operating precautions or conditions also are adapted to each case.

Feed and output streams
Feed
The feed is input waste which contains POPs and is intended to be reused or recovered at a level complying with requirements for its further use or disposal in an environmental sound way.

Some examples of process feed are: electrical transformers containing PCBs, used medical analysis devices contaminated by infectious agents, thin layer deposition equipment contaminated by arsenic, waste containing mercury (e.g. end-of-life fluorescent tubes containing mercury, batteries and button cells, spent activated carbon, mercury guards, thermometers, contactors).

Output
Generally, the output from WT plant is a treated waste. However, the output can be differentiated into two types. One type is the treated waste (typically representing the main part of the output) which in some cases can be reused or recovered elsewhere. The other type is represented by the waste generated by the treatment process itself. The appearance of the latter not only depends on the type of waste treated, but also on the type of treatment applied to the waste. Indeed, this second type of waste is more dependent on the treatment than on the actual type of waste treated.

The output waste is analysed according to the relevant parameters for the receiving facility or the further use, if so intended, in order to improve the knowledge of the output. For instance,

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porous parts of a contaminated transformer (wood and paper) are incinerated in a high-temperature kiln.

Reference literature
[146, PCT]

5.8.1.1.2 Decontamination of PCB-containing waste

High-temperature incineration is the most widely available and used technology for effective PCB destruction. The complete destruction of PCB molecules by incineration only takes place under well-defined conditions (a high temperature (1100 °C minimum) and a residence time of 2 seconds and 30 minutes for gaseous and solid fractions respectively). Incineration of PCBs is outside the scope of this document.

For slightly contaminated liquids, alternative technologies are sometimes used as a local solution in the absence of an adequate high-temperature incinerator.

Some oil types require special care and attention: lubrication oil in open applications can contain PCBs. Dissemination is to be avoided at all costs whenever the concentration exceeds 1 ppm of PCBs.

Mobile treatment systems can be applied to transformers in operation.

Two types of techniques should be considered:

- techniques for the cleaning of equipment;
- techniques for the destruction of PCBs.

Reference literature
[146, PCT]

5.8.1.1.2.1 Equipment cleaning

From ex-**Section 2.1.10 "Examples of waste treatment installations where only the common techniques are applied"**

Purpose
The decontamination of PCB-containing equipment.

Principle of operation
Technologies, for cleaning PCB-containing transformers can be divided into ~~two~~ three main categories: draining, retrofilling and solvent washing.

Process description
1) Draining: ~~of~~ The PCB-contaminated oil is drained from the transformer, which is followed by chemical decontamination of the oil (substitution of chlorine atoms of the PCB molecules contained in the oil by hydrogen atoms), checking the porous material of the transformer (wood, paper, etc.) and the space between metal pieces (copper winding, magnetic steel plate, etc.) and reinjection of the cleaned oil into the transformer for reuse.

2) Retrofilling: Reclassification of an oil transformer to non-PCB status involves the permanent reduction of the PCB concentration from more than 50 ppm to less than 50 ppm for the rest of its working life.

In order to reduce the PCB concentration in the core and coil of a PCB-contaminated transformer, the contaminated oil is drained out and it is replace with new, non-PCB containing oil.

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According to statistics, after a maximum period of nine months (depending on the type of transformer) in service under load, the PCB concentration in the tank will stabilise as the PCBs leach from the core. The core components that retain PCBs include the paper, wood, tape and particleboard as shown below. As long as a transformer is close to full load, about 90 % of the PCBs will leach from the core to the tank, leaving 10 % still in the core and coils.

For transformers that are contaminated with PCBs to levels exceeding 500 ppm, the units will have to be drained and refilled every nine months until the final PCB level is below 50 ppm. This process is referred to as 'serial retrofilling'. The number of 'steps' depends on the initial contamination and can only be assessed by sampling the transformer oil after the period mentioned.

3) Solvent washing: Extraction of the PCB oil, by solvent washing of the transformer, followed by dismantling and further decontamination of the components to allow recycling of the metal components.

After suitable pretreatment, low concentration PCB-containing oil may be hydrogenated at high temperatures so that it can be reused. Here, the transformers are not recovered as such.

An example of the ~~second case~~ third method is the following:
Carcasses of used transformers are ~~cleaned~~ washed ~~by means of trichloroethylene (TCE) wash~~ with perchloroethylene (PER). Here, the carcass is filled with the solvent and allowed to stand for an extended period before the solvent is replaced with fresh ~~TCE~~ PER. This operation is repeated (typically three times) until the carcass passes the required ‘swab test’. During the cleaning operation, the transformer carcass is ~~left open to the atmosphere~~ under a suction hood or ~~loosely~~ covered with a steel plate in order to minimise ~~. As a consequence, the activity results in evaporative~~ losses of ~~TCE~~ PER to air. After use, the PER is distilled on site for reuse, and the residual sludge is sent for incineration.

~~Typically this activity~~ Transformer decontamination is carried out at specialist and PCB-licensed sites, which clean the PCB-contaminated transformers and ~~bulk~~ store the PCB-contaminated oil. The wastes such as oils, drums, cleaning waters and cleaning solvent sludge are all sent ~~for~~ to off-site high-temperature incineration.

~~Cleaned~~ Transformer carcasses and windings are ~~sent for reclamation~~ recovered after thorough cleaning with ~~TCE~~ PER.

Cleaning of capacitors containing PCBs
Capacitors are similar to transformers in that they are made up of an active core, held in a metallic casing. However, the active core is not copper windings, but instead consists of interwoven rolls of fine aluminium foil, separated by thin films of paper and/or plastic. The techniques used for cleaning these capacitors are as follows:

- The casing of the capacitor is removed and decontaminated by solvent washing; this is a straightforward decontamination process since the casing is non-porous. The core is incinerated.
- It may be possible to go ~~the possibility of going~~ one step further by treatment of the core after its removal from the casing. This decontamination step usually involves shredding of the core followed by ~~and~~ treatment with a solvent. This allows the level of residual PCBs to be reduced.
- The technology ~~which allows~~ allowing the largest amount of recycling is similar to the above: ~~but this~~ it also treats the mixed aluminium/plastic/paper residues ~~to separate out~~ by separating these components and solvent washing. ~~The~~ Aluminium ~~metal~~ can then be reused; the only components to be disposed of by high-temperature incineration are ~~is~~ the mixed paper/plastic shreds.

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Feed and output streams
The feed is comprised of PCB-contaminated equipment.

The output includes PCB-contaminated oil; transformer carcasses, and windings; aluminium; and mixed plastic/papers.

Reference literature
[146, PCT]

5.8.1.1.2.2 Destruction of PCBs

From ex-**Section 2.3.5 "Physico-chemical treatments of other wastes"**

Purpose
Destruction and irreversible transformation of the POP content in wastes.

Principle of operation

From ex-**Section 4.3.3.1 "Treatment of oil contaminated with PCB"**

~~**Description**~~
The process is the dehalogenation of PCB-contaminated oil from electrical transformers. The process also allows the elimination of low-boiling compounds and oxidation products, which are responsible for the low dielectric properties of contaminated oil. At the end of the process, a filtration process is carried out in order to eliminate the by-products of the reaction.

Process description
~~**Physico-chemical treatment of wastes containing POPs**~~
Three ways have been identified for the destruction and irreversible transformation of the POP content in wastes [102, UNEP 2004]:

- ~~One is the~~ incineration on land (not covered in this document but in the Waste Incineration BREF which also covers plasma techniques);
- ~~another is the~~ use of waste containing POPs as fuel (e.g. co-incineration in cement kilns, which is not covered in this document); and
- ~~last one is the~~ physico-chemical treatment of waste containing POPs.

This section concentrates on the physico-chemical treatments ~~and they are~~ summarised below in Table 5.202, related to these very specific types of waste (e.g. waste containing PCBs, dioxins and furans).

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Table 5.202: Some specific treatments for waste containing PCBs and/or POPs

Process technique	Principle of operation	Feed and output streams	Process description
Dechlorination with metallic alkali	Reaction of metallic alkali with chlorine atoms contained in the chlorinated compounds	~~Waste IN~~ Waste Input: PCB-contaminated oils Output ~~waste OUT~~: organic compounds (oil which may be reused) and salt	The dispersion is carried out at a temperature above that of the melting point of the sodium, i.e. 98 °C. Being liquid, the metal surface can be renewed continuously. In this way a reasonable reaction rate can be achieved, thus decreasing the cost of the decontamination process. The process must avoid the formation of a polymer ~~(which occurs in one or two of the technologies identified)~~ or must take the formation of ~~such~~ this solid into account and introduce a separation step to yield the pure reusable oil
Dechlorination with KPEG	Reaction of potassium hydroxide (KOH) and polyethylene glycol (PEG) with chlorine atoms contained in the chlorinated compounds	Waste Input: Oils contaminated with PCB (less than 5000 ppm) Output: mineral oil, which may be reused after a regeneration treatment, and sludge (KCl)	Chlorines from PCBs are removed by polyethylene glycol (PEG) acting as a nucleophile in reaction with PCBs under the basic condition. This process has proven to be practical and highly cost-effective for PCBs treatment directly in transformer oil and the recovery of the treated oil. Furthermore, the process avoids the use of potentially dangerous alkali metals and alkali metal oxides being generally employed as catalysts. As the process is carried out at low temperatures (140–160 °C) the formation of furans and dioxins by thermal decomposition of PCB is not possible. The gases released are carbon dioxide and water vapour, which are retained by a filter of activated carbon. The waste generated by the treatment forms a 'sludge' product of the combination of chlorine molecules of PCBs extracted with the alkaline compounds. This 'mud' (alkali chloride) precipitates due to the insolubility and weight, by separating the cleared oil. Dechlorination treatment can reach less than 2 ppm (ASTM D4059 method)
Hydrogenation of POPs	Hydrogen reacts with chlorinated organic compounds or non-chlorinated organic contaminants, such as PAHs, at high temperatures	Waste input ~~IN~~: transformer fluids~~; bulk PCB solids, including electrical capacitors;~~ and high strength DDT waste pesticide mixtures Output ~~waste OUT~~: primarily methane and hydrogen chloride for PCBs and methane and minor amounts of light hydrocarbons for PAHs	Typical process used in mineral oil refineries and carried out at temperatures of 850 °C and higher. This technique converts approximately 40 % of the methane produced to hydrogen, via the water shift reaction, and the remaining part to hydrogen in the catalytic steam reformer. In this way, the process can operate without an external supply of hydrogen. For highly concentrated wastes, the process produces an excess of methane. It uses draw

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			combustion air from off site or ambient air on site, after first filtering it through activated carbon, for the combustion process
Solvated electron process	Free electrons in a solvated electron solution convert contaminants to relatively harmless substances and salts	Waste input ~~IN~~: halogenated organic compounds, including PCBs, dioxins, pesticides, chlorofluorocarbons (CFCs) and chemical warfare agents Output ~~waste OUT~~: decontaminated soils are said to be suitable for returning to the site, and, as an additional benefit , are enriched in nitrogen from the trace amounts of residual ammonia	This technique uses an alkali or alkaline earth metal dissolved in a solvent such as ammonia, or certain amines or ethers, to produce a solution containing free electrons and metal cations. The destruction efficiencies vary from 86 % to 100 %. Chlorine and other halogens are selectively stripped from organic halides by free electrons and captured by the metal cations to form salts (e.g. $CaCl_2$). For example, a PCB molecule can be converted to biphenyl in a rapid reaction at ambient temperatures
~~Supercritical water oxidation~~	~~A high temperature and pressure technique that uses the properties of supercritical water in the destruction of POPs~~	~~Waste IN: wastes containing organic compounds and toxic wastes~~ ~~Waste OUT: carbon dioxide; hydrogen to water; the chlorine atoms derived from chlorinated organic compounds to chloride ions; nitro-compounds to nitrates; sulphur to sulphates; and phosphorus to phosphate~~	~~Supercritical conditions~~
NB: Some other treatments outside the scope of this document are available for the treatment of wastes contaminated with POPs. These include co-incineration in cement kilns, hazardous waste incineration and plasma treatments. *Source*: **[69, UNEP 2000] [102, UNEP 2004] [146, PCT]**			

Note to TWG: Supercritical water oxidation has been deleted because this American technology is used in Europe in only one plant to treat chlorinated non-PCB waste (source: PCT Subgroup)

From ex-**Section 4.3.3.1 "Treatment of oil contaminated with PCB"**

~~Applicability~~

This technique is applied to oil transformers with PCB contents of between 25 ppm and 2000 ppm. The process can be applied to the following:

- Dehalogenation and recovery of bulking ex-transformer mineral oils contaminated with PCBs.
- Cleaning and recovery of operating transformers containing mineral oils contaminated with PCBs. This step is performed by means of recirculation of the dehalogenated mineral oil and it permits the extraction of the residual PCBs absorbed in the different components of the transformers (e.g. paper and wood).

~~Economics~~

The concentration range mentioned ~~in the~~ above ~~Applicability section,~~ is the typical range in which this technique is found to be economically viable. Technically there is not a problem when applied at higher concentrations but it has been found that there are other types of more economically viable PCB treatment processes.

TWG, please confirm the PCB concentration range

~~Driving force for implementation~~

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~~It exists mobile systems that can be applied to transformers in operation without the need to move them.~~

From ex-**Section 3.3.1 "Waste IN in physico-chemical treatments"**

Feed and output stream

~~Waste IN in the treatment of specific wastes~~

Hydrogenation of POPs

According to the US DOE, this system can handle most types of waste, including landfill leachates, lagoon bottoms, soils, sludges, liquids, and gases. However, the US DOE has cautioned that reaction by-products and intermediate reduction products need to be monitored in the off-gas from both the reduction process and the boiler. It also noted the need to determine the fate of mercury and other volatile inorganics.

The process is non-discriminatory; that is to say, organic molecules such as PCBs, PAHs, chlorophenols, dioxins, chlorobenzenes, pesticides, herbicides and insecticides are quantitatively converted to methane.

~~*Supercritical water oxidation*~~

~~Environment Australia reports that technology is limited to the treatment of waste that is either liquid or that has a particle size of less than 200 µm, and it is most applicable to wastes with an organic content of less than 20 %.~~

~~Supercritical water oxidation has been applied to a broad range of materials, e.g. aqueous waste streams, sludges, contaminated soils, industrial organic chemicals, plastics, synthetics, paints and allied products, industrial organics, agricultural chemicals, explosives, petroleum and coal products, and rubber and plastic products. It is applicable to the treatment of a range of contaminants including acrylonitrile waste water, cyanide waste water, pesticide waste water, PCBs, halogenated aliphatics and aromatics, aromatic hydrocarbons, MEK and organic nitrogen compounds.~~

Solvated electron technique

Table 5.203 below shows the input ~~waste IN~~ and output ~~waste OUT~~ for the treatment of chlorinated waste by the solvated electron technique.

Table 5.203: Products and disposal options for the use of the solvated electron technique

Material treated	Products	Disposal options
Concentrated PCBs	Biphenyl, $Ca(OH)_2$, $CaCl_2$	Landfill as salts
PCBs in soils	Biphenyl, $Ca(OH)_2$, $CaCl_2$, clean soil	Return soil to ground
PCBs on surfaces	Biphenyl, $Ca(OH)_2$, $CaCl_2$	Collect salts and landfill
PCB/oil mixtures	Biphenyl, $Ca(OH)_2$, $CaCl_2$, oil	Reuse oil and landfill salts
Concentrated HCB	Benzene, NaCl, NaOH	Separate benzene and landfill salts
HCB in soils	Benzene, NaCl, NaOH, clean soil	Separate benzene and return soil with salt to ground

Source: [69, UNEP 2000]

From ex-**Section 4.3.3.1 "Treatment of oil contaminated with PCB"**

~~Achieved environmental benefits~~

The output of dehalogenation is ~~an~~ oil with dielectric characteristics that make it possible for it to be reused for the same purpose, with a PCB content of less than 1 ppm.

~~Example plants~~

~~One example is operational in Italy.~~

Users

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No information available.

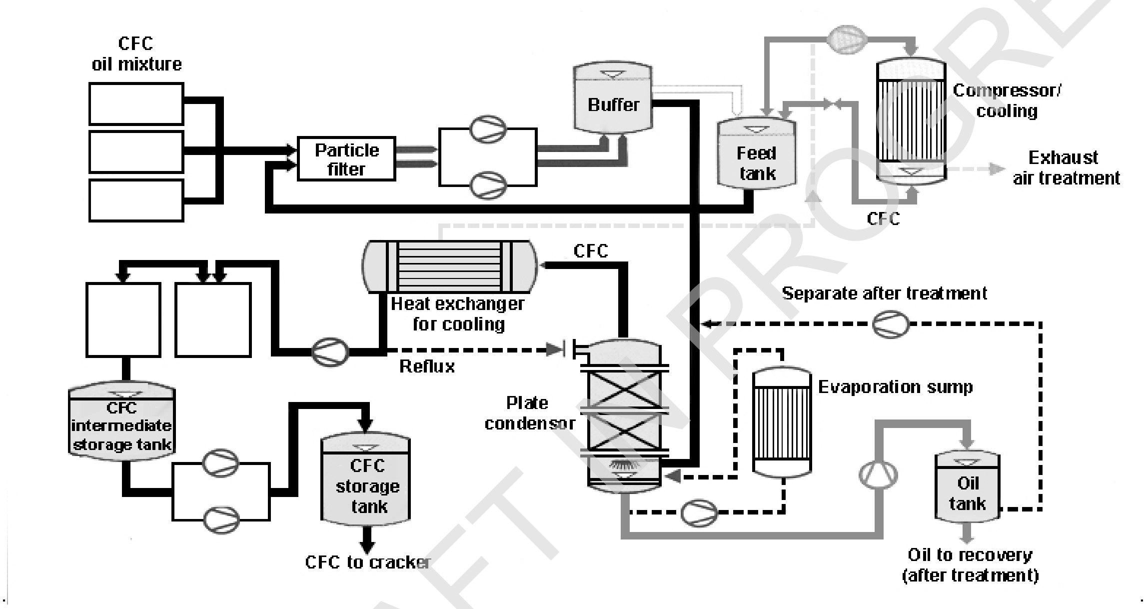
Reference literature

[30, Ecodeco 2002] [98, WT TWG 2004] [146, PCT]

From ex-**Section 2.3.5 "Physico-chemical treatments of other wastes"**

~~**Physico-chemical treatments of CFCs**~~

~~The aim is to treat the waste to transform the CFC in hydrochloric acid and hydrofluoric acid. An example of such plant is shown in Figure 5.54.~~



~~*Source*:[98, WT TWG 2004]~~

~~**Figure 5.54: Treatment of CFCs to generate hydrochloric acid and hydrofluoric acid**~~

From ex-**Section 3.3.4 "Waste OUT from physico-chemical treatments"**

~~*Waste OUT from a CFC treatment plant*~~

~~Table 5.204 below shows the specification of the products achieved by the cracking of the CFC solvents.~~

~~**Table 5.204: Specification of CFC cracked products**~~

~~**Parameters**~~	~~**Unit**~~	~~**Target**~~	~~**Actual value**~~
~~Water content~~	~~ppm~~	~~<50~~	~~34~~
~~Oil content~~	~~ppm~~	~~<100~~	~~60~~
~~Amine content~~	~~ppm~~	~~<100~~	~~10~~
~~Acid~~	~~ppm~~	~~<1~~	~~0.03~~
~~Halogens~~	~~vol-%~~	~~<0.1~~	~~0.004~~
~~PCB and PCT~~	~~vol-%~~	~~0~~	~~0~~
~~Information from a CFC distillation plant of Figure 5.54 shown in Section 5.8 This interconnection treatment facility converts CFCs into hydrochloric acid and hydrofluoric acid.~~ ~~*Source:* [97, Germany 2003] [98, WT TWG 2004]~~			

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5.8.1.2 Current emission and consumption levels

From ex-**Section 3.3.3.3 "Emissions from the treatment of specific wastes"**

Hydrogenation of POPs

At a Canadian facility, product gas was found to contain no detectable PCBs, while concentrations of total chlorobenzenes and dioxins were similar to those of the blank solutions. This suggests that the product gas did not contain quantifiable levels of these substances. When the product gas was burnt in the steam reformer, dioxins were emitted from the reformer stack at a concentration of 15 pg TEQ/Nm^3. This dioxin formation was attributed to the use of PCB-contaminated air from the site of the reformer's combustion air.

All outputs from the destruction of PCB-contaminated waste using this process can be contained and tested. There are no uncontrolled emissions from the process which could result in releases of PCB-contaminated air, solids or liquids to the surrounding environment. Releases of PCBs to the environment could only occur during waste handling prior to treatment, where the possibility of spillage exists.

Because the reaction takes place in a reducing atmosphere in the absence of oxygen, the possibility of dioxin and furan formation is said to be eliminated. If the hydrogen content is maintained at percentages greater than 50 % (dry basis), the formation of PAHs is prevented.

Table 5.205 shows the reported destruction efficiency of hydrogenation processes.

Table 5.205: Reported destruction efficiency of hydrogenation processes

Type of waste	**Destruction efficiency (%)**	**Destruction and removal efficiency (DRE) (%)**
PCB oils	99.999808–99.9999996	99.9999985–99.9999997
Chlorobenzenes	99.9999836–99.9999972	99.9999842–99.9999985
Dioxins present in PCB oils	99.999–99.9999	NI
NI: no information *Source*: [69, UNEP 2000]		

If either the product gas or the ambient air used as combustion air for the boiler or similar units contains hydrogen chloride or other chlorinated species, dioxins may be generated during their combustion. In order to meet the fundamental technical criteria for POP destruction, both the product gas and combustion air must be treated to remove such chlorine donors and so prevent dioxin formation.

Care is required to avoid high rates of gas generation, which could over-pressurise systems. The process has a limited surge capacity: over-pressurisation could therefore result in the release of waste material.

During typical operations, 30–50 % of the product gas is burnt as fuel for the boiler or other auxiliary units.

Residues generated by the process include product gas from the reactor, scrubber water and sludge from the product gas treatment, and small quantities of grit from the reactor. The product gas is either catalytically reformed to recover hydrogen or burnt as fuel in one or more of the auxiliary systems – the boiler, the catalytic reformer and/or the sequencing batch vaporiser.

Hydrogenation of PCBs and POPs

All emissions and residues are captured for assay and reprocessing, if needed. Destruction rates ranging from 99.9 % to 99.99999 % have been reported at sites operating on a commercial scale in Australia.

~~**Supercritical water oxidation**~~

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~~Process residues are usually contained and consist of water, gas (less than 10 ppm of CO and very low amounts of oxides of nitrogen, acid gases such as hydrogen chloride or sulphur oxides and particulates) and solids if the waste contains inorganic salts or organics with halogens, sulphur or phosphorus. Residues generated during the process such as ash and brine require disposal.~~

Table 5.206 gives an overview of the emissions to air of Plant 191 which carries out decontamination and dismantling of PCB-containing equipment. VOC emissions are generated by the use of solvent for equipment washing. There is no water release reported for this process.

Table 5.206: Emissions to air from Plant 191

Parameter/ pollutant measured	**Type of measurement**	**Average**	**Number of measurements during the three reference years**
Flow (m^3/h)	Periodic	55 825	9
NMVOC (mg/Nm^3)	Continuous	74	NA
PCB ($\mu g/Nm^3$)	Periodic	0.5	8
dl-PCB (ng I-TEQ/Nm^3)	Periodic	0.06	9
NA: not applicable			

No water usage was reported. Energy consumption was reported as the overall consumption for the integrated hazardous waste incineration.

5.8.1.3 Techniques to consider in the determination of BAT

5.8.1.3.1 Optimising the environmental performance of PCB decontamination

Description
Design and operational measures to prevent and reduce emissions generated by PCB-containing waste decontamination.

Technical description

a) Design measures to prevent dispersion of PCBs from the storage and treatment area:
- dedicated storm and run-off water collection system;
- resin coating applied to the whole concrete floor of the storage and treatment area (since most standard concrete floors absorb PCBs).

b) Implementation of staff access rules to prevent dispersion of contamination:
- accesses to storage and treatment areas are locked;
- special qualification needed to access the area where the waste or equipment polluted by POPs is handled;
- prior to accessing the restricted area, staff put on individual protective outfit depending on the POP in a 'clean' cloakroom;
- after leaving the restricted area, staff go to a 'dirty' cloakroom where the contaminated individual protective outfit is managed with special care.

c) Monitoring of PCB emissions to air.

d) Prevention of liquid PCB dispersion during the decontamination process:
- procedures for filling, emptying and (dis)connecting the vacuum vessel;
- external surfaces of the electrical transformers to be decontaminated are cleaned with anionic liquid;

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- pumping the PCB oil out of the transformer with a pump or under vacuum instead of gravity emptying;
- long period of dripping (12 hours at least) to avoid any PCB drop during further treatment operations, after the separation of the core from the casing.

e) Control of emissions to air:

- the ambient air of the decontamination workshop is treated on activated carbon filters;
- the vacuum pump exhaust is connected to a high-temperature kiln (PCB) or activated carbon filters.

f) Management of waste treatment residues:

- porous parts of the contaminated transformer (wood and paper) are incinerated in a high-temperature kiln (1100 °C);
- destruction of the PCBs in the oils (dechlorination, hydrogenation, solvated electron processes).

Achieved environmental benefits
All techniques aim at increasing the environmental performance of PCB decontamination.

Environmental performance and operational data
No information available.

Cross-media effects

- Possible consumption of reagents for the decontamination and/or the abatement system.
- Possible cross-media effects during the incineration of residues.

Technical considerations relevant for applicability
Generally applicable.

Economics
No information available.

Driving force for implementation

- POPs regulation (EC 850/2004).
- Occupational safety.

Example plants
In Plant 191, materials containing PCBs are introduced into closed heating vessels under depression (autoclaves) equipped with i) a vacuum pump to suck out air/steam mixtures and ii) a condenser to recover the solvent (prior to further distillation). The opening of the autoclaves is strictly controlled, and performed only after complete cooling. The complete PCB working zone (including dismantling workshop, autoclaves, distillation column, etc.) is located in specific bunded areas, within buildings equipped with devices for airstream collection. The various collected airstreams (process vents/fugitive emissions) are thoroughly treated, by high-temperature incineration and activated carbon adsorption respectively.

The solvent is regenerated through distillation on site, allowing the consumption of such reactants to be minimised, as well as the reduction of the final wastes requiring destruction through high-temperature incineration. VOC emissions from the whole process including solvent loading/regenerating operations are carefully prevented or treated, and monitored.

Reference literature
PCB, santé et environnement, Thierry Meunier, Jean-Claude Amiard, Marc Babut, Expected to be published end 2015 by Lavoisier TEC & DOC

TWG Please provide this article when published.

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[146, PCT] [160, WT TWG 2014]

5.8.1.3.2 Capture and control of VOC emissions from solvent washing

Description

Solvent emissions from solvent loading/handling operations, autoclaving and the final regeneration step (distillation column) are collected and distilled to recover solvent and reuse it in the process. The various collected airstreams over the whole working zone (process vents/fugitive emissions) are treated by high-temperature incineration or adsorption on activated carbon.

Technical description

The complete working zone is located on specific diked areas, within buildings equipped with devices for airstream collection. The continuously extracted airstream, which potentially contains VOCs and particularly Cl-NMVOC (like tetrachloroethylene), is passed through an adsorption device composed of multiple rechargeable boxes, wherein the key molecules are adsorbed onto highly activated granular carbon with a large surface area, and then removed from the carrier airstream.

The multiple-bed adsorber is sized (beds depths and surface loading rates), installed and operated in order to ensure optimal gas contact and sufficient time to reach adsorption equilibrium. The process removes the pollutants for which it is designed (chiefly Cl-NMVOC, i.e. molecules with high molecular weights (> 50 g/mol) and high boiling points (> 50 °C)), such as, typically, tetrachloroethylene (molecular weight: 165 g/mol, boiling point: 121 °C) to almost undetectable levels.

The system is of interest for (air)streams with low proportions of pollutants when applied for ambient air purification. For gas streams with high pollutant contents (typically solvent vents, etc.), high-temperature incineration may be performed.

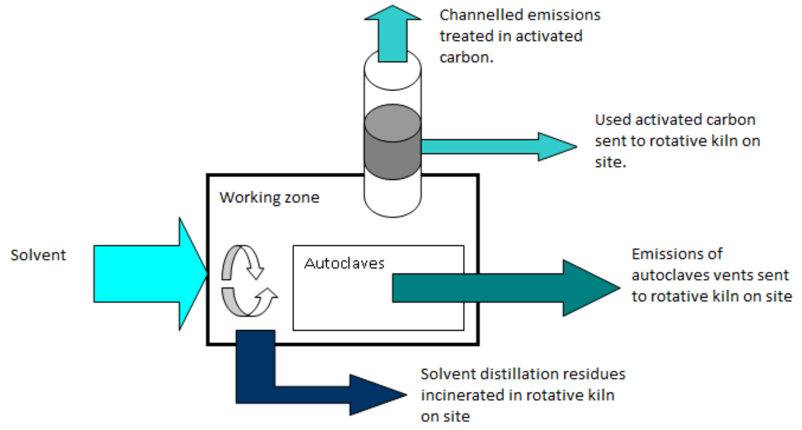
The diffuse VOCs emissions are monitored.

Achieved environmental benefit

- Reduction of VOC emissions.
- Recovery of solvent.

Environmental performance and operation data

Table 5.206 shows data on emissions to air and Figure 5.55 gives an example of air emissions treatment.



Source: Plant # 191

Figure 5.55: Flow chart of air emissions at a plant using solvent washing for PCB decontamination

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Cross-media effect
Incineration and distillation generate emissions to air.

Driving force for implementation

- Legislation on air pollution.
- Cost of solvent.

Technical considerations relevant for applicability
Generally applicable.

Economics
Once installed, the technology is simple to operate (almost unattended until the adsorbent becomes spent and then requires replacement), as well as to maintain. The operating costs rely chiefly on the amount of activated carbon consumed, keeping in mind that the value of the adsorbent is strictly related to its adsorption capacity (associated to its internal pore structure and tortuosity), rather than to only weight or volume.

Example plant
Plant 191.

Reference literature
[160, WT TWG 2014].

5.8.2 Treatment of mercury-containing waste

For reasons of simplicity and to avoid repetition in this document, this section addresses all types of treatment of mercury-containing waste, i.e physico-chemical treatment and mechanical treatment.

5.8.2.1 Applied processes and techniques

From ex-**Section 2.3.5 "Physico-chemical treatments of other wastes"**

~~Physico-chemical treatment of waste containing mercury~~
Purpose
The aim is to treat the waste to separate the mercury.

Principle of operation
Decontamination processes differ depending on the type of waste. All processes aim at separating the mercury from one/several other fractions. This can be done mechanically, chemically or thermally. The safe management of these processes involves the avoidance of mercury emission in order to protect health and the environment. In some cases, mercury can also be recovered for allowed uses.

Process description

From ex-**Section 4.3.3.3 "Treatment of waste containing mercury"**

~~Description~~
~~Some techniques are:~~
~~pretreat the waste containing mercury as follows~~: Some examples of treatment of mercury-containing waste are as follows:

~~shredding/crushing of batteries and button cells~~

- Sorting/breaking~~/separating~~ of thermometers and contactors and separation of the liquid mercury from the other fractions.

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- Centrifuging sludge containing mercury in order to remove most of the metallic mercury. The residual sludge has a low mercury content and is treated in the vacuum distillation process.
- Shredding/sieving the gas discharge lamps, removing the iron and separating it in fractions. The fluorescent powder containing mercury is treated in the vacuum distillation process.
- End-cut/air-push treatment of the gas discharge lamps through heating and cooling the end breaks. Afterwards, the fluorescent powder containing mercury is blown out (air-push). A selection unit can be added to this pretreatment technique. This detects the powders in order to selectively blow them out. Reuse of the powders is possible
- Dismantling of flat screen displays containing mercury lamps.
- Treatment of batteries and button cells by pyrometallurgy where the mercury in the flue-gas treatment is specifically trapped.
- Treatment of spent activated carbon and mercury guards from natural gas decontamination by thermal treatment where the mercury in the flue-gas treatment is specifically trapped.

Once the mercury has been removed from the waste, it can undergo ~~is carry out~~ the following sequence of treatments:

- separation and concentration of the mercury by evaporation and condensation;
- treatment of the off-gases with dust filters and activated carbon filters;
- return of the dust and the contaminated carbon from the gas treatment into the process.

When mercury containing waste is distilled, ~~treat~~ the distillate (water and organic fractions) is treated by the following techniques:

- Incineration in a waste incinerator.
- Conducting the gases from the distillation through an afterburner (at approximately 850 ºC) and a condenser. The off-gases are cleaned by flue-gas treatment (e.g. scrubber, dust filter and activated carbon filter). The separated dust and the contaminated carbon are returned to the distillation vessel. This alternative raises the recovery rate.
- Purifying the water fraction (after separation) and returning the deposit to the distillation vessel. This alternative raises the recovery rate.

In the process of vacuum distillation, waste containing mercury is evaporated under vacuum conditions at approximately 300–650 ºC. The liquid components (e.g. mercury, water and oil) are distilled from the waste and condensed. In the condensation, the mercury and the distillate are separated. The metallic mercury is drained and possibly refined. The mercury is recycled as a secondary raw material. ~~The destination of the residue from the vacuum vessel depends on the waste treated. It can be used as a secondary raw material (e.g. for batteries) or landfilled (e.g. in the case of sludge containing mercury).~~

From ex-**Section 2.3.5 "Physico-chemical treatments of other wastes"**

~~The process is shown in~~

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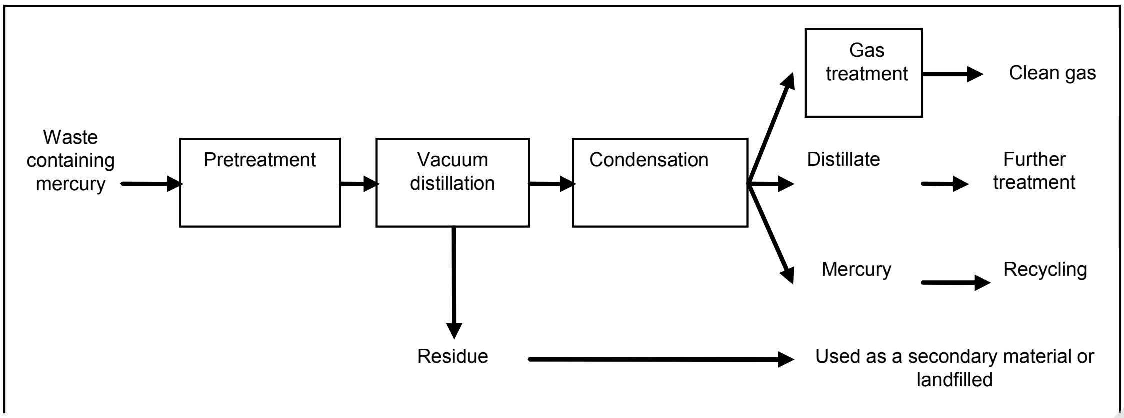

~~*Source*:[103, VROM 2004]~~

~~**Figure 5.56: Vacuum distillation of waste containing mercury**~~

From ex-**Section 4.3.3.3 "Treatment of waste containing mercury"**

Because of the hazardous nature of the vapours containing mercury, safety measures are required. These include exhaust systems; test measuring; locks; safety procedures for filling, emptying and (dis)connecting the vacuum vessels; and decontamination facilities. To minimise the risk of explosion, other safety measures, such as an airtight operation of the system; automatic pressure control; and smoke- and spark-free areas, are applied.

After decontamination, whatever the technique or the combination of techniques used, the rate of mercury removal is above 95 %.

Feed and output streams

From ex-**Section 2.3.5 "Physico-chemical treatments of other wastes"**

The feed is sludge containing mercury from the oil and gas production industry, batteries, catalysts, activated carbon filters, thermometers, waste from the dental sector, fluorescent tubes, blasting grit and soil. Different waste streams are treated separately in the vacuum distillation. The capacities of the example plants range from 300 t/yr to 600 t/yr of waste containing mercury.

From ex-**Section 4.3.3.3 "Treatment of waste containing mercury"**

In a thermal soil remediation plant, with a throughput of 2 t/h of soil containing mercury and with mercury raw gas concentrations of up to 20 mg/Nm^3, a maximum removal rate of 99.9 % has been reported. It has also been reported that the mercury content of the soil (1–300 mg/kg) decreased to less than 5 mg/kg following thermal treatment. Another treatment reported a resulting percentage of the mercury emitted to the air as being 0.0015 %. The emissions range from 0.04 mg/Nm^3 to 0.2 mg/Nm^3.

In the vacuum distillation of the sludge containing mercury (1–4 % mercury), 99.6 % of the mercury is recovered. About 0.1 % of the mercury is left in the residue and about 0.15 % is left in the distillate, which is to be incinerated. The latter percentage ends up in the off-gases. By means of the activated carbon filter, 99.9 % of this mercury is separated. The maximum concentration of mercury in the residue is 50 mg/kg (dry matter).

~~The destination of the residue from the vacuum vessel depends on the waste treated. It can be used as a secondary raw material (e.g. for batteries) or landfilled (e.g. in the case of sludge containing mercury).~~

~~**Cross-media effects**~~

~~consumption of energy for the distillation process and possible pretreatment~~
~~consumption of activated carbon and water in the gas treatment~~
~~emissions to air.~~

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~~Operational data~~
The consumption of electricity for the heating of the vacuum vessel and for the vacuum pump amounts to 3.5 GJ/tonne of waste. The consumption of cooling water is approximately 13 tonnes per tonne of waste containing mercury. For the treatment of the sludge containing 2 % mercury, the activated carbon needed amounts to 24 kg/tonne of sludge.

Output
Separated mercury or mercury containing residues may be managed as follows:

- When mercury is recycled for authorised uses, the purity of the mercury is at least above 99.95 % and should comply with the specifications of the end user. Distillation may be necessary to reach this level.
- Disposal of the remaining fractions containing mercury.
- Treatment of the liquid mercury in order to transform it into HgS with a Hg°/HgS transformation rate above 99.999 % before disposal in permanent dedicated storage.

~~Applicability~~

~~Driving force for implementation~~
~~landfilling is banned for several wastes containing mercury. In comparison with direct landfilling or incineration of the waste containing mercury, the amount of waste is less and contains no mercury and diffusion into the environment is prevented~~
~~the preference order for waste management in accordance with the Waste Framework Directive and the Sixth Environmental Action Programme of the European Union.~~

~~Example plants~~

From ex-**Section 2.1.10 "Examples of waste treatment installations where only the common techniques are applied"**

~~Fluorescent tubes/lamp processing~~
~~Separate mercury from lamp tubes. Currently, this is a tiny activity in some countries, but existing operations are now experiencing an increasing demand for their services. At this time, most use a crushing process. However, another process recently developed is a process without crushing with a 99 % recovery of the mercury~~

Users
~~Used in Sweden, Netherlands and Belgium~~
~~A thermal soil remediation plant in Sweden, two example plants in the Netherlands for the vacuum distillation treatment. Example plants where pretreatment is applied: one in the Netherlands (shredding of gas discharge lamps) and one in Belgium (end-cut/air-push treatment).~~
Two plants in Belgium and in the United Kingdom treat fluorescent tubes and discharge lamps with the shredding technique. The British plant also extracts residual mercury inside phosphor powder in a retort oven and treats mercury-containing flat panel displays which are shredded after external power has been removed. One plant in France treats florescent tubes with the end-cut/air-push technology.

Reference literature
[58, VDI and Dechema 2002] [98, WT TWG 2004] [100, WT TWG 2004] [103, VROM 2004] [146, PCT]

5.8.2.2 Current emission and consumption levels

Table 5.207 gives an overview of the plants from the reference list treating mercury-containing waste. These are plants treating WEEE such as fluorescent tubes, gas discharge lamps and flat panel displays. These devices are treated in shredders or by an end-cut/air-push machine.

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Table 5.207: Plants from the reference list treating mercury-containing waste

Plant code	Waste input description	Output description	Process
059	Fluorescent tubes and other mercury-containing waste	Non-ferrous metal, Ferrous metal, Glass, Fluorescent powder, Plastic	Shredder
146C	Fluorescent tubes	Refuse after sorting, lamps (bubble), breakings in machine, glass, metallic caps, powder, floor cleaning water	End-cut/air-push machine
588(1)	Small domestic appliances. Primary sources: Waste arising from public amenity sites and business users	Ferrous metal shred fragment Mixed polymer shred fragment Aluminium shred fragment Copper-rich shred fragment Mix of non-Fe and plastics Dust/Light fraction Polychlorinated biphenyls (PCB)-containing capacitors Batteries Printed circuit boards greater than 10 cm^2 Toner cartridges, liquid and paste, as well as colour toner Asbestos waste and components which contain asbestos Liquid crystal displays of a surface greater than 100 cm^2 and all those backlit with gas discharge lamps External electric cables Components containing refractory ceramic fibres Components containing radioactive substances Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm or proportionately similar volume	Dismantling small appliances
589(1)	WEEE gas discharge lamps containing mercury	Aluminium shred fragment Polymer shred fragment Glass fragment Phosphor powder Mercury	Shredder and retort plant
590(1)	Flat panel display (FPD), WEEE containing mercury. Primary sources: Waste arising from public amenity sites and business users	Ferrous metal shred fragment Aluminium shred fragment Copper-rich shred fragment Mixed polymer shred fragment Mixed light film plastics Mixed plastics and non-Fe fines Mixed glass and shredder fines Dust/Light fraction	Shredder

(1) Plants 588, 589 and 590 are three production lines of the same plant.

Table 5.208 and Table 5.209 give an overview of the emissions to air from the plants treating mercury-containing waste. Air is generally captured at the source (machine or work station) by a Local Exhaust Ventilation (LEV) system and treated with a dedusting device and activated carbon adsorption. Mercury is monitored in emissions to air at all the plants except Plant 588 which is in fact a work station for the manual dismantling of small appliances.

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Table 5.208: Emissions to air from plants treating mercury-containing waste

Plant code	Origin of emissions to air	Techniques for emissions to air
059	Air from the enclosed process is extracted and led over a sulphur-impregnated activated carbon filter	Deduster filter and activated carbon adsorption
146C_1	Treatment of mercury-containing waste (from the machine)	Cyclones and activated carbon adsorption
146C_2	Hall atmosphere	Dust filter and activated carbon adsorption
588[(1,2)]	Mechanical	Bag/fabric filter system, High Efficiency Particulate (HEPA) filter system, activated carbon adsorption
589[(2)]	Mechanical	Bag/fabric filter system, High Efficiency Particulate (HEPA) filter system, activated carbon adsorption
590[(1,2)]	Mechanical	Bag/fabric filter system, High Efficiency Particulate (HEPA) filter system, activated carbon adsorption
[(1)] Plants 588 and 590 are connected to the same air extraction system. [(2)]There are no air emissions to the environment for these three plants. The exhaust air is recirculated		

Table 5.209: Parameters measured in emissions to air from plants treating mercury-containing waste

Parameter measured	Type of measurement	Plants concerned	Ranges (mg/Nm^3 except for flow)
Flow (Nm^3/h)	Continuous	146_1, 146_2	2250–11 700
	Periodic	059, 588, 589, 590	11 325–22 040
Hg	Continuous	146_1, 146_2	0.0012–0.0016
	Periodic	059, 589, 590	0.0031–0.0338
Dust	Continuous	146_1	0.3
	Periodic	059, 588, 589	0.5–0.7
Cd	Periodic	588, 589	0.0028
Pb	Periodic	588, 589	0.0052
TOC	Periodic	059	< 1

There are no emissions to water reported from these plants.

Water usage
Water usage was reported by one plant as around 20 m^3/year for floor cleaning.

Energy consumption
The reported average energy consumption per tonne of waste treated is around 180 kW/t, with a range of 147–360 kW/t. Electricity is the main source of energy. One plant reported using propane for the process.

Table 5.210 shows the range of raw material consumption by plants from the reference list treating mercury-containing wastes.

WORKING DRAFT IN PROGRESS

Table 5.210: Examples of raw material consumption by plants treating mercury-containing wastes

Raw material	Consumption in the reference period
Activated carbon	50 m^3/year
Oxygen	6 m^3/year

5.8.2.3 Techniques to consider in the determination of BAT

5.8.2.3.1 Reduction of mercury emissions to air

Description

Collection at source, followed by abatement and surveillance of mercury emissions.

Technical description

- Processes treating mercury-containing wastes are enclosed, under negative pressure and connected to a local exhaust ventilation (LEV) system.
- Extracted air is treated by dedusting techniques such as cyclones (see Section 2.3.4.2), bag filters (see Section 2.3.4.4) or HEPA filters (see Section 2.3.4.5) as well as activated carbon filters (see Section 2.3.4.9).
- Treated air is released outside the buildings or recycled.
- The air flow from the LEV system and the mercury concentration in LEV-extracted air are monitored to enable assessment of the effectiveness of the LEV system's performance.
- Mercury levels are measured regularly around the processes to detect potential mercury leaks.

This technique may be applied to all shredder/hammer mill/crusher-type processes as well as to end-cut/push-air machines and separation equipment.

Achieved environmental benefit

- Limitation of mercury emissions to air.
- Reduction of diffuse mercury emissions in the process.

Environmental performance and operational data

Plant 588 is enclosed and generally operates under negative pressure (air extraction) for most of the process. This effectively eliminates fugitive emissions from the process, driving dust and other emissions through the dedicated LEV system. Dust emissions from the dedicated LEV outlet duct averaged 0.48mg/m^3, over the three-year period, with one result being spurious and negatively affecting the average. The average over 2012, for example, is 0.23 mg/m^3, with lead at 0.0051 mg/m^3 and cadmium at 0.0059 mg/m^3 for the same period. The air exhausted from the dedicated LEV is not released to (external) air but circulates within the internal processing environment. The air within the general processing environment is also addressed by a secondary 'ambient' LEV system for potential fugitive emissions and continuously improving the quality of air in the ambient environment. The dust fraction from the dedicated LEV dust collection point is also assessed on a regular basis and demonstrates the effective extraction, capture and retention of various metal elements from the air extracted from the process, including but not limited to lead and cadmium. For example the 2012 second quarter result from the dust fraction analysis contained 780 mg/kg lead, 19 mg/kg cadmium, 406 mg/kg antimony, 3900 mg/kg zinc, etc. The combined systems maintain a high quality of air within the processing environment but the significant environmental benefit is that there is no need to vent exhaust air to the external environment and thus risk pollution.

Table 5.211 and Table 5.212 show respectively the levels of mercury and dust measured in emissions to air from the plants treating mercury-containing waste.

WORKING DRAFT IN PROGRESS

Table 5.211: Mercury measured in emissions to air from plants treating mercury-containing waste

Plant	Average value (mg/Nm^3)	Type of measurement	Average air flow rate (Nm^3/h)	Number of measurements during the three reference years	Monitoring standard used
059	0.0063	Periodic	11325	4 in 2013	EN 13211:2001, AAS and ICP-AES; EN15259 (LUC/III/010)
146_1	0.0012	Continuous	2250	Continuously measured during machine operation	UV light (continuous measurements) and EN 13211 for periodic measurements)
146_2	0.0016	Continuous	11700	Continuously measured during operation	UV light (continuous measurements) and EN 13211 for periodic measurements)
589$^{(1)}$	0.0338	Periodic	22040	4 per year	BS EN 13211
590$^{(1)}$	0.0031	Periodic	22742	3 measures taken during plant trial	BS EN 13211
$^{(1)}$There are no air emissions to the environment for these plants					

Table 5.212: Dust measured in emissions to air from plants treating mercury-containing waste

Plant	Average value (mg/Nm^3)	Type of measurement	Average air flow rate (Nm^3/h)	Number of measurements during the three reference years	Monitoring standard used
059	<0.5	Periodic	11325	4 in 2013	EN13284-1; EN15259 (LUC/I/001)
146_1	0.3	Continuous	2250	Continuously measured during machine operation	NI
588$^{(1)}$	0.5	Periodic	21563	12	BS EN 13284-1
589$^{(1)}$	0.7	Periodic	22040	12	BS EN 13284-1
$^{(1)}$There are no air emissions to the environment for these plants					

Cross-media effects

- Noise emitted from the LEV system fans.
- Increased energy usage.
- Contaminants are concentrated in abatement devices.

Technical considerations related to applicability

Limiting factors may include the physical space available to deploy sophisticated LEV systems.

Economics

No information available.

Driving force for implementation

- Legislation on air pollution.
- Occupational safety.

Example plants

Plants 59, 146, 588, 589, 590

Reference literature

[146, PCT], [167, Goodship et al. 2012]) [160, WT TWG 2014]

WORKING DRAFT IN PROGRESS

5.9 Regeneration of [~~waste~~] spent acids [~~and bases~~]

From ex-**Section 2.4.6 "Regeneration of waste acids and bases"** **TWG, please confirm this is still relevant.** No information was provided via the data collection

[24, Militon et al. 1998] [60, WT TWG 2003] [95, WT TWG 2002] [98, WT TWG 2004]
~~As described in Section 1.3.10.1,~~ only waste sulphuric and hydrochloric acids are regenerated.

5.9.1 Regeneration of spent sulphuric acid

From ex-**Section 2.4.6.1 "Regeneration of spent sulphuric acid"**

~~As mentioned in Section 1.3.10.1~~, two ~~alternative~~ methods for regenerating spent sulphuric acid exist. One is the thermal decomposition of spent sulphuric acid to give SO_2, achieved in a furnace at temperatures of around 1000 °C. The SO_2 produced is then used as a feedstock in the production of H_2SO_4. Both processes (thermal decomposition and SO_2 conversion to H_2SO_4) are covered in the LVIC-AAF BREF [40, EIPPCB 2003]. There are some industrial processes where sulphuric acid is used (e.g. production of titanium dioxide). In such cases, the recycling of the spent sulphuric acid is an integral part of the process and will be covered in the BREF that covers that industrial process. The second ~~alternative~~ process to regenerate spent sulphuric acid is based on the reconcentration of weak/spent/waste sulphuric acid, with or without the separation of the potential impurities (e.g. salts). ~~This is also included in this BREF document.~~

Purpose
To reuse the spent sulphuric acid for the same purpose as it was originally used or for a new use.

Principle of operation
Reconcentration of the weak sulphuric acid by evaporation.

Feed and output streams
Spent/weak sulphuric acid is concentrated to a stronger acid solution.

Process description
Concentrations close to 70 % H_2SO_4 have been achieved by evaporation ~~and the process consists of water evaporation, without too much H_2SO_4 in the vapour phase~~. The range of temperatures varies with the processes. There are many processes but the most common are based on forced circulation evaporators, which allow a very stable operation; due to the large circulation, any solid in the acid will remain in the suspension and can be separated out in the concentrated acid, if necessary.

Because the cost of the process is very dependent on energy, (medium pressure steam), a multiple-effect evaporator can considerably reduce the operating costs ~~very much~~; vacuum operation allows lower operating temperatures and the use of more standard materials for equipment construction.

Another process for weak acid concentration uses hot gases (from sulphuric acid or any other process): by contacting hot gases and weak acid, the water will be evaporated towards the water saturation. The process takes place at atmospheric pressure but, due to the relatively high gas volume, some acid carry-over must be prevented, by demisters or other similar devices.

Submerged combustion processes consist of the production of flue-gases at very high temperatures, (in excess of 1500 °C), directly over the spent acid ~~level~~; the flue-gases pass through the spent acid allowing water to evaporate from it, ~~suffering~~ undergoing an adiabatic cooling down to 150–250 °C. Before being to discharged into the air, the gases are ~~need to be~~ cooled and scrubbed ~~out~~; in general, no especially high SO_2 emissions will be expected but NO_X levels might be important.

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Other processes, such as Chemico, have been used for 70 years for sulphuric acid concentration increase; the principle is quite the same, except that the combustion does not take place within the vessel and the temperature is considerably lower (in the range of 600 °C).

Users
The metal industry.

5.9.2 Regeneration of spent hydrochloric acid

From ex-**Section 2.4.6.2 "Regeneration of spent hydrochloric acid"**

Most often, hydrochloric acid (HCl) is produced as a by-product from chlorination processes. HCl is generally produced in the gaseous phase and directly reused in a chemical process. It can also be dissolved in water and used as a raw material for the production of other chemicals, such as a water treatment product (e.g. $FeCl_3$) in electrolysis or as a neutralisation agent. HCl can be used in applications such as metal pickling or ion exchange regeneration.

Afterwards, spent hydrochloric acid is neutralised rather than regenerated (see section 2.3.6.3). ~~Then, reference to Sections 5 and 0 needs to be made~~. Some other regeneration treatments exists, for example, reuse as a pickling acid. However, for this use, no treatment is carried out on these streams, so they are not covered in this document.

Additional information on regeneration of spent hydrochloric acid can be found in the chemical BREFs.

From ex-**Section 3.4.3.6 "Emissions from waste acids and bases treatments"**

Table 5.213 shows the type of emissions from the treatment of waste acids and bases.

Table 5.213: Emissions from the treatment of waste acids and bases

Activity	Air	Water	Soil and wastes
Treatment of waste acids	Halogens: HCl and HF NO_X	Halogens: HCl and HF	NA
Treatment of sulphuric acid	Sulphur oxides	NA	NA

NA: Not applicable
Source: [33, UK EA 2001]

Introduction of ex-**Chapter 3 Current consumption and emission levels** deleted, as the information is now included in each specific waste treatment/waste stream section

Ex-Section **4.5.3.2 Drying the solid waste fuel** moved to Section 0 Relates to the output quality

Ex-Section **4.5.5 Preparation of gas fuel from waste** deleted: excluded from scope; see KOM conclusion 1.3b

Ex-**Section 4.5.6 "Prevention and abatement techniques applied for the preparation of waste fuel from hazardous waste"** deleted and replaced by data from questionnaires.

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6 BEST AVAILABLE TECHNIQUES (BAT) CONCLUSIONS

This section has been completely rewritten compared to the original WT BREF

Scope

These BAT conclusions concern the following activities specified in Annex I to Directive 2010/75/EU, namely:

- *5.1. Disposal or recovery of hazardous waste with a capacity exceeding 10 tonnes per day involving one or more of the following activities:*
  - *(a) biological treatment;*
  - *(b) physico-chemical treatment;*
  - *(c) blending or mixing prior to submission to any of the other activities listed in points 5.1 and 5.2* [of Annex I to Directive 2010/75/EU]*;*
  - *(d) repackaging prior to submission to any of the other activities listed in points 5.1 and 5.2* [of Annex I to Directive 2010/75/EU]*;*
  - *(e) solvent reclamation/regeneration;*
  - *(f) recycling/reclamation of inorganic materials other than metals or metal compounds;*
  - *(g) regeneration of acids or bases;*
  - *(h) recovery of components used for pollution abatement;*
  - *(i) recovery of components from catalysts;*
  - *(j) oil re-refining or other reuses of oil;*

- *5.3*
  - *(a) Disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day involving one or more of the following activities, and excluding activities covered by Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment:*
    - *(i) biological treatment;*
    - *(ii) physico-chemical treatment;*
    - *(iii) pre-treatment of waste for incineration or co-incineration;*
    - *(iv) treatment of* […] *ashes;*
    - *(v) treatment in shredders of metal waste, including waste electrical and electronic equipment and end-of-life vehicles and their components.*
  - *(b) Recovery, or a mix of recovery and disposal, of non-hazardous waste with a capacity exceeding 75 tonnes per day involving one or more of the following activities, and excluding activities covered by Directive 91/271/EEC:*
    - *(i) biological treatment;*
    - *(ii) pre-treatment of waste for incineration or co-incineration;*
    - *(iii) treatment of* […] *ashes;*
    - *(iv) treatment in shredders of metal waste, including waste electrical and electronic equipment and end-of-life vehicles and their components.*

    When the only waste treatment activity carried out is anaerobic digestion, the capacity threshold for this activity shall be 100 tonnes per day.

- *5.5. Temporary storage of hazardous waste not covered under point 5.4* [of Annex I to Directive 2010/75/EU] *pending any of the activities listed in points 5.1, 5.2, 5.4 and 5.6* [of Annex I to Directive 2010/75/EU] *with a total capacity exceeding 50 tonnes, excluding temporary storage, pending collection, on the site where the waste is generated.*
- 6.11 *Independently operated treatment of waste water not covered by Directive 91/271/EEC and discharged by an installation* [undertaking activities covered under points 5.1, 5.3 and 5.5 above].

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These BAT conclusions do not address the following:

- surface impoundment of waste;
- disposal or recycling of animal carcases or animal waste;
- direct recovery (i.e. without pretreatment) of waste as a substitute for raw materials in installations performing activities covered in other BAT conclusions, i.e. direct recovery of lead batteries, zinc or aluminium salts or recovery of the metals from catalysts covered in the BAT conclusions for the non-ferrous metals industries; paper waste recycling covered in the BAT conclusions for the production of pulp, paper and board; use of waste as raw material in cement kiln covered in the BAT conclusions for the production of cement, lime and magnesium oxide;
- waste incineration, co-incineration, pyrolysis and gasification;
- landfill of waste;
- in situ remediation of contaminated soil (i.e. unexcavated);
- treatment of slags and bottom ash.

Other BAT conclusions and reference documents which could be relevant for the activities covered by these BAT conclusions are the following:

Reference document	Subject
Economics and Cross-Media Effects (ECM)	Economics and cross-media effects of techniques
Emissions from Storage (EFS)	Storage, transfer and handling of solids and liquids
Energy Efficiency (ENE)	General aspects of energy efficiency
Monitoring of emissions to air and water from IED installations (ROM)	Monitoring of emissions to air and water
Production of Cement, Lime and Magnesium Oxide (CLM)	Waste quality control and safety management for the use of hazardous waste materials
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	Waste water treatment techniques and treatment of water-based liquid waste

These BAT conclusions apply without prejudice to other relevant legislation, e.g. on health and safety.

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Definitions

For the purposes of these BAT conclusions, the following **definitions** apply:

Term used	**Definition**
Continuous measurement	Measurement using an 'automated measuring system' permanently installed on site
Diffuse emissions	Non-channelled emissions (e.g. of dust, VOC) which can result from 'area' sources (e.g. tanks) or 'point' sources (e.g. pipe flanges)
Emission Factors	Numbers that can be multiplied by known data such as plant/process activity data or throughput data to estimate emissions
Existing plant	A plant that is not a new plant
Flaring	High-temperature oxidation to burn combustible compounds of waste gases from industrial operations with an open flame. Flaring is primarily used for burning off flammable gas for safety reasons or during non-routine operating conditions.
Fugitive emissions	Diffuse emissions from 'point' sources
Laboratory smalls	Laboratory chemicals in containers of a small capacity
Mechanical Biological Treatment' (MBT)	Treatment of solid waste combining mechanical treatment (e.g. shredding) with biological treatment such as aerobic or anaerobic treatment
New plant	A plant first permitted at the site of the installation following the publication of these BAT conclusions or a complete replacement of a plant following the publication of these BAT conclusions
Pasty waste	Non-pumpable waste (e.g. sludge)
Periodic measurement	Determination of a measure (particular quantity subject to measurement) at specified time intervals using manual or automated methods
Recovery	Recovery as defined in Article 3(15) of Directive 2008/98/EC
Re-refining	Treatments carried out to waste oil to be transformed to base oil
Regeneration	Treatments and processes mainly designed to make the treated equipment (e.g. activated carbon) or material (e.g. spent solvent) usable again
Residues	Materials generated by the activities covered by the scope of this document, as waste or by-products.
Sensitive receptor	Area which needs special protection, such as: - residential areas; - areas where human activities are carried out (e.g. schools, daycare centres, recreational areas, hospitals or nursing homes).
Treatment of waste with calorific value	Treatment of waste wood, waste oil, waste plastics, waste solvents, etc. to obtain a fuel or to allow a better recovery of its calorific value
Waste holder	Waste holder as defined in Article 3(6) of Directive 2008/98/EC
Waste input	The incoming waste to be treated in the waste treatment plant

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For the purposes of these BAT conclusions, the following **definitions** of parameters apply:

Parameters	**Definition**
Arsenic	Arsenic, expressed as As, includes all inorganic and organic arsenic compounds, dissolved or bound to particles
Cadmium	Cadmium, expressed as Cd, includes all inorganic and organic cadmium compounds, dissolved or bound to particles
Chromium	Chromium, expressed as Cr, includes all inorganic and organic chromium compounds, dissolved or bound to particles
COD	Chemical oxygen demand. Amount of oxygen needed for the total oxidation of the organic matter to carbon dioxide. COD is an indicator for the mass concentration of organic compounds
Copper	Copper, expressed as Cu, includes all inorganic and organic copper compounds, dissolved or bound to particles
Hydrocarbon oil index (HOI)	The sum of compounds extractable with a hydrocarbon solvent (including long-chain or branched aliphatic, alicyclic, aromatic or alkyl-substituted aromatic hydrocarbons)
Lead	Lead, expressed as Pb, includes all inorganic and organic lead compounds, dissolved or bound to particles
Mercury	Mercury, expressed as Hg, includes all inorganic and organic mercury compounds, dissolved or bound to particles
Nickel	Nickel, expressed as Ni, includes all inorganic and organic nickel compounds, dissolved or bound to particles
PCBs	Polychlorinated biphenyls
Phenol index	The sum of phenolic compounds, expressed as phenol
TOC	Total organic carbon, expressed as C (in water), includes all organic compounds
Total N	Total nitrogen, expressed as N, includes free ammonia and ammonium nitrogen (NH_4–N), nitrite nitrogen (NO_2–N), nitrate nitrogen (NO_3–N) and organically bound nitrogen
Total P	Total phosphorus, expressed as P, includes all inorganic and organic phosphorus compounds, dissolved or bound to particles
Total suspended solids (TSS)	Mass concentration of all suspended solids (in water), measured via filtration through glass fibre filters and gravimetry
TVOC	Total volatile organic compounds as measured by a flame ionisation detector (FID) and expressed as total C (in air)
VOC	Volatile Organic Compound as defined in Article 3(45) of Directive 2010/75/EU
Zinc	Zinc, expressed as Zn, includes all inorganic and organic zinc compounds, dissolved or bound to particles

WORKING DRAFT IN PROGRESS

For the purposes of these BAT conclusions, the following **acronyms** apply:

Acronym	Definition
APC	Air pollution control
EMS	Environmental management system
EoLV	End-of-life vehicles (as defined in Article 2(2) of Directive 2000/53/EC)
FGT	Flue-gas treatment
HEPA	High-efficiency particle air filter
IBC	Intermediate bulk container
LDAR	Leak detection and repair
LEV	Local exhaust ventilation system
MBT	Mechanical biological treatment
MSW	Municipal solid waste
POP	Persistent organic pollutant
VHC	Volatile hydrocarbon
VFC	Volatile fluorocarbon
WT	Waste treatment
WWTP	Waste water treatment plant

WORKING DRAFT IN PROGRESS

General considerations

Best Available Techniques

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection.

Unless otherwise stated, the BAT conclusions are generally applicable.

[NOTE: Whilst cross-references are provided to other parts of this document in order to aid the work of the TWG, they will not be included in the final BAT conclusions themselves. Such cross-references are consequently displayed in *italic green* between square brackets.]

[TWG: please note that in order to avoid repetition, this section contains general considerations that are essential to the understanding of the BAT conclusions taken as a stand-alone document, such as:

- reference conditions for air emissions (e.g. dry gas, standard temperature/pressure, oxygen concentration)
- averaging periods
- sampling times
- conversions to reference conditions
- adopted units of measures]

Emission levels associated with the best available techniques (BAT-AELs) for emissions to air

Unless stated otherwise, emission levels associated with the best available techniques (BAT-AELs) for emissions to air given in these BAT conclusions refer to concentrations (mass of emitted substance per volume of waste gas) under the following standard conditions: dry gas at a temperature of 273.15 K and a pressure of 101.3 kPa, without correction for O_2, and expressed in µg/Nm^3 or mg/Nm^3.

For averaging periods of BAT-AELs for emissions to air, the following **definition** applies:

Averaging period	**Definition**
Average of values obtained during one year	Average of all valid measurement values obtained during one year

Emission levels associated with the best available techniques (BAT-AELs) for emissions to water

Unless stated otherwise, emission levels associated with the best available techniques (BAT-AELs) for emissions to water given in these BAT conclusions refer to concentrations (mass of emitted substances per volume of water), expressed in mg/l.

Unless stated otherwise, the BAT-AELs refer to the flow-weighted monthly average values of all the following samples taken during that period under normal operating conditions.

2. for a continuous discharge or batch discharge with a duration of 24 hours or more: 24-hour flow-proportional composite samples,
3. for a batch discharge with a duration of less than 24 hours: flow-proportional composite samples taken over the discharge period,

Time-proportional composite sampling can be used provided that sufficient flow stability is demonstrated.

WORKING DRAFT IN PROGRESS

The flow-weighted monthly average concentration (c_w) is calculated using the following equation:

$$\boxed{c_w = \sum_{i=1}^{n} c_i q_i \Big/ \sum_{i=1}^{n} q_i}$$

Where

n = number of measurements;
c_i = average concentration during ith measurement;
q_i = average flow rate during ith measurement.

WORKING DRAFT IN PROGRESS

6.1 General BAT conclusions

6.1.1 Overall environmental performance

6.1.1.1 Environmental management systems (EMS)

BAT 1. In order to improve the overall environmental performance, BAT is to implement and adhere to an environmental management system (EMS) that incorporates all of the following features:

I. commitment of the management, including senior management;
II. definition of an environmental policy that includes the continuous improvement of the installation by the management;
III. planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;
IV. implementation of procedures paying particular attention to:

   (a) structure and responsibility,
   (b) recruitment, training, awareness and competence,
   (c) communication,
   (d) employee involvement,
   (e) documentation,
   (f) effective process control,
   (g) maintenance programmes,
   (h) emergency preparedness and response,
   (i) safeguarding compliance with environmental legislation;

V. checking performance and taking corrective action, paying particular attention to:

   (a) monitoring and measurement (see also the Reference Report on Monitoring),
   (b) corrective and preventive action,
   (c) maintenance of records,
   (d) independent (where practicable) internal or external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;

VI. review of the EMS and its continuing suitability, adequacy and effectiveness by senior management;
VII. following the development of cleaner technologies;
VIII. consideration for the environmental impacts from the eventual decommissioning of the plant at the stage of designing a new plant, and throughout its operating life;
IX. application of sectoral benchmarking on a regular basis.

X. waste treatment strategy that includes inventories of waste input streams (see BAT 2 and BAT 14);
XI. procedures to ensure the compatibility of wastes before mixing/blending (see BAT 2);
XII. odour management plan (see BAT 8);
XIII. noise and vibration management plan (see BAT 18);
XIV. residues management plan (see description in Section 6.6.4);
XV. accident management plan (see description in Section 6.6.4).

Applicability
The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of

WORKING DRAFT IN PROGRESS

environmental impacts it may have (determined also by the type and amount of wastes processed).

[This BAT conclusion is based on information given in Sections 2.3.1.1 and 2.3.1.2]

6.1.1.2 Waste stream management

BAT 2. In order to improve the overall environmental performance, BAT is to use all of the techniques given below.

Technique		Description
a	To implement waste characterisation and pre-acceptance procedures	These procedures aim to ensure the technical (and legal) suitability of waste treatment operation for a particular waste prior to the arrival of the waste at the plant. It includes procedures to collect information about the waste to be treated and may include waste sampling and characterisation to achieve sufficient knowledge of the waste composition.
b	To implement waste acceptance procedures	Acceptance procedures aim to confirm the characteristics of the waste, as identified in the pre-acceptance stage. The procedures define the elements to be verified upon waste arrival at the plant as well as the waste rejection criteria. They may include waste sampling, inspection and analysis.
c	To implement a waste tracking system and inventory	A waste tracking system aims to keep control on the location and quantity of waste in the plant. It holds all the information generated (e.g. date of arrival on site, unique reference number, producer details, pre-acceptance and acceptance analysis results, intended treatment route, nature and quantity of waste held on site including all identified hazards) during waste pre-acceptance, acceptance, storage, treatment and/or transfer off-site.
d	To ensure waste segregation	Waste is separated prior to treatment depending on its properties in order to enable easier and environmentally safer treatment. Waste segregation relies on the physical separation of waste and on procedures that define when the mixing of waste is allowed and how it is carried out.
e	To assess waste compatibility	Compatibility assessment consists of a set of verification measures and tests in order to detect any unwanted and potentially dangerous chemical reactions between wastes (polymerisation, gas evolution, exothermal reaction, decomposition, crystallisation, precipitation, etc.) when mixing, blending or carrying out other treatment operations.

WORKING DRAFT IN PROGRESS

f	To sort incoming waste	Waste sorting(1) aims to prevent unwanted material to enter the waste treatment process. may include: • Manual separation by means of visual examinations to sort out the recyclables and contaminants; • Ferrous metals, non-ferrous metals or all-metals separators; • Optical separation by e.g. Near Infrared spectroscopy or X-ray systems; • Density separation by e.g. air classification, sink-float tanks, vibration tables; • Size separation by screening/sieving.
(1)Sorting techniques are described in Section 6.6.3		

[This BAT conclusion is based on information given in Sections 2.3.2.1, 2.3.2.2, 2.3.2.3, 2.3.2.4, 2.3.2.5, 2.3.2.6, 2.3.2.7, and 2.3.2.8]

6.1.1.3 Monitoring

BAT 3. BAT is to monitor emissions to water with at least the frequency indicated in , Table 6.1 and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Table 6.1: Monitoring of emissions to water

Substance / parameter	Standard(s)	Waste treatment process	Minimum monitoring frequency (1) (2) (3)
Total organic carbon (TOC) (4)	EN 1484	All treatments of waste except physico-chemical and/or biological treatment of water-based liquid waste	Once every week
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Chemical oxygen demand (COD) (4)	No EN standard available	All treatments of waste except physico-chemical and/or biological treatment of water-based liquid waste	Once every week
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Total suspended solids (TSS)	EN 872	All treatments of waste except physico-chemical and/or biological treatment of water-based liquid waste	Once every week

WORKING DRAFT IN PROGRESS

		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Hydrocarbon oil index (HOI)	EN ISO 9377-2	Mechanical treatment in shredder of metal waste	Once every week
		Re-refining of waste oil	
		Physico-chemical treatment of waste with calorific value	
Total nitrogen (TN)	EN 12260	Biological treatment of waste	Once every week
		Re-refining of waste oil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Total phosphorus (TP)	Various EN standards available (e.g. EN ISO 15681-1 and -2, EN ISO 6878, EN ISO 11885)	Biological treatment of waste	Once every week
		Re-refining of waste oil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Phenol index	EN ISO 14402	Re-refining of waste oil	Once every week
		Physico-chemical treatment of waste with calorific value	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Arsenic (As) (5)	Various EN standards available (e.g. EN ISO 11885, EN ISO 17294-2, EN ISO 15585)	Mechanical treatment in shredder of metal waste	Once every week
		Mechanical biological treatment of waste	
		Re-refining of waste oil	
		Water washing of excavated contaminated soil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Cadmium (Cd) (5)		Mechanical treatment in shredder of metal waste	Once every week
		Mechanical biological treatment of waste	
		Re-refining of waste oil	
		Water washing of excavated contaminated soil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Chromium (Cr) (5)		Mechanical treatment in shredder of metal waste	Once every week
		Mechanical biological treatment of waste	
		Re-refining of waste oil	

WORKING DRAFT IN PROGRESS

		Water washing of excavated contaminated soil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Copper (Cu) (5)		Mechanical treatment in shredder of metal waste	Once every week
		Mechanical biological treatment of waste	
		Re-refining of waste oil	
		Water washing of excavated contaminated soil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Nickel (Ni) (5)		Mechanical treatment in shredder of metal waste	Once every week
		Mechanical biological treatment of waste	
		Re-refining of waste oil	
		Water washing of excavated contaminated soil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Lead (Pb) (5)		Mechanical treatment in shredder of metal waste	Once every week
		Mechanical biological treatment of waste	
		Re-refining of waste oil	
		Water washing of excavated contaminated soil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Zinc (Zn) (5)		Mechanical treatment in shredder of metal waste	Once every week
		Mechanical biological treatment of waste	
		Re-refining of waste oil	
		Water washing of excavated contaminated soil	
		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day
Mercury (Hg) (5)	Various EN standards available (e.g. EN ISO 17852, EN ISO 12846)	Mechanical treatment in shredder of metal waste	Once every week
		Mechanical biological treatment of waste	
		Re-refining of waste oil	
		Water washing of excavated contaminated soil	

WORKING DRAFT IN PROGRESS

		Physico-chemical and/or biological treatment of water-based liquid waste	Once every day

(1) Monitoring frequencies may be adapted if the data series clearly demonstrate a sufficient stability of emissions over time.
(2) The sampling point is located where the emission leaves the installation.
(3) In the case of batch discharge with a duration < 24 hours, once per batch discharge.
(4) Either TOC or COD is monitored. TOC is the preferred option, because its monitoring does not rely on the use of very toxic compounds.
(5) The monitoring may not apply when the substance concerned is not present in the waste to be treated.

[This BAT conclusion is based on information given in Section 2.3.3.2]

BAT 4. BAT is to monitor emissions to air with at least the frequency indicated in Table 6.2, and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Table 6.2: Monitoring of channelled emissions to air

Parameter	Standard(s)	Waste treatment process	Monitoring associated with	Minimum monitoring frequency (1)
Dust	EN 13284-1	Mechanical treatment of waste	BAT 25	Once every six months
		Mechanical biological treatment of waste	BAT 37	Once every three months
		Physico-chemical treatment of solid and/or pasty waste	BAT 39	Once every six months
		Thermal treatment of spent activated carbon, waste catalysts and excavated contaminated soil	NA	
		Treatment of excavated contaminated soil	NA	
TVOC	EN 12619	Mechanical treatment in shredder of equipment containing VFCs and/or VHCs	BAT 29	Once every six months
		Mechanical biological treatment of waste	BAT 37	Once every three months
		Physico-chemical treatment of solid and/or pasty waste	BAT 39	Once every six months
		Re-refining of waste oil	BAT 41	
		Physico-chemical treatment of waste with calorific value	BAT 43	
		Regeneration of spent solvents	BAT 45	
		Thermal treatment of spent activated carbon, waste catalysts and excavated contaminated soil	NA	
		Treatment of excavated contaminated soil	NA	
		Physico-chemical and/or biological treatment of water-based liquid waste	BAT 52	
		Decontamination of equipment containing POPs (3)	NA	
NH_3	No EN standard	All biological treatments of waste	BAT 32	Once every three months

WORKING DRAFT IN PROGRESS

	available	Physico-chemical treatment of solid and/or pasty waste	BAT 39	Once every six months
		Physico-chemical and/or biological treatment of water-based liquid waste	BAT 52	
H_2S	No EN standard available	All biological treatments of waste	BAT 32	Once every three months
HCl	EN 1911	Thermal treatment of spent activated carbon, waste catalysts and excavated contaminated soil	NA	Once every six months
		Physico-chemical and/or biological treatment of water-based liquid waste	BAT 52	
HF	ISO 15713	Thermal treatment of spent activated carbon, waste catalysts and excavated contaminated soil	NA	Once every six months
Hg (total)	EN 13211	Treatment of mercury-containing waste	BAT 30	Once every six months
PCBs	EN 1948-1, -2, and -4 (2)	Decontamination of equipment containing POPs	NA	Once every six months
Relevant metals and metalloids except mercury (e.g. As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Se, Tl, V)	EN 14385	Mechanical treatment in shredder of metal waste	NA	Once every six months

NA: Not applicable
(1) Monitoring frequencies may be adapted if the data series clearly demonstrate a sufficient stability.
(2) Instead of EN 1948-1, sampling may also be carried out with CEN/TS 1948-5.
(3) When solvent is used for cleaning the contaminated devices.

[This BAT conclusion is based on information given in Section 2.3.3.3]

BAT 5. BAT is to monitor diffuse VOCs emissions to air from the regeneration of spent solvents and the solvent-using decontamination of equipment containing POPs at least once per year using one or a combination of the techniques given below.

	Technique	Description
a	Measurement	Sniffing, optical gas imaging, solar occultation flux or differential adsorption. See descriptions in Section 6.6.1
b	Emissions factors	Calculation of emissions based on emissions factors, periodically validated (e.g. once every two years) by measurements.
c	Solvent mass balance	Calculation of diffusion emissions using a mass balance considering the solvent input, channelled emissions to air, emissions to water, solvent in output, and process (e.g. distillation) residues.

[This BAT conclusion is based on information given in Sections 5.4.3.2 and 5.8.1.3.2]

BAT 6. BAT is to periodically monitor odour emissions from relevant sources in accordance with EN standards.

Description

Emissions can be monitored by dynamic olfactometry according to EN 13725.

WORKING DRAFT IN PROGRESS

Applicability
The applicability is restricted to cases where odour nuisance can be expected or has been substantiated.

[This BAT conclusion is based on information given in Section 2.3.3.4]

BAT 7. BAT is to monitor water consumption, energy consumption, raw material consumption, sludge generation, residue generation, and the amount of waste water generated, all broken down by process, with a frequency of at least once per year, and considering any significant changes in plant operation.

[This BAT conclusion is based on information given in Sections 2.3.7, 2.3.8, and 2.3.9)

6.1.2 Odorous and diffuse emissions to air

BAT 8. In order to prevent or, where that is not practicable, to reduce odorous emissions from the plant, BAT is to set up, implement and regularly review an odour management plan, as part of the environmental management system (see BAT 1), that includes all of the following elements:

- a protocol containing actions (see BAT 9) and timelines;
- a protocol for conducting odour monitoring as set out in BAT 6. It may be complemented by measurement/estimation of odour exposure or estimation of odour impact;
- a protocol for response to identified odour incidents;
- an odour prevention and reduction programme designed to identify the source(s); to measure/estimate odour exposure, to characterise the contributions of the sources; and to implement prevention and/or reduction measures.

Applicability
The applicability is restricted to cases where odour nuisance can be expected and/or has been substantiated.

[This BAT conclusion is based on information given in Sections 2.3.3.4, 2.3.5.1 and 4.5.1.3].

BAT 9. In order to prevent or, where that is not practicable, to reduce odorous emissions, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a	Minimise residence times	Minimise the residence time of odorous waste and potentially odorous waste in collection and storage systems, in particular under anaerobic conditions. When relevant, adequate provisions are made for the acceptance of seasonal peak volumes of waste.	Generally applicable.
b	Chemical treatment	Use chemicals to destroy or to reduce the formation of odorous compounds (e.g. oxidation or precipitation of hydrogen sulphide).	Generally applicable.

WORKING DRAFT IN PROGRESS

Technique		Description	Applicability
c	Optimise aerobic treatment	This can include: • controlling the oxygen content; • frequent maintenance of the aeration system; • use of pure oxygen; • removal of scum in tanks.	Generally applicable in case of aerobic treatment of waste.

[This BAT conclusion is based on information given in Sections 2.3.5.2, 4.5.1.2, and 4.5.2.1]

WORKING DRAFT IN PROGRESS

BAT 10. In order to prevent or, where that is not practicable, to reduce diffuse emissions to air, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a.	Limit the number of potential diffuse emissions sources	This includes: • appropriate design of piping layout (e.g. minimising pipe run length, reducing the number of flanges and valves, using welded fittings and pipes); • favouring the use of pressure transfer (e.g. gravity) rather than pumps; • limiting the drop height of material.	The design of piping layout is only applicable to new plants.
b.	Select and use high integrity equipment	This includes: • valves with double packing seals or equally efficient equipment; • high-integrity gaskets (such as spiral wound ring joints) for critical applications; • pumps/compressors/agitators fitted with mechanical seals instead of packing; • magnetically driven pumps/compressors/agitators.	Generally applicable.
c.	Select appropriate materials for equipment	This includes: • appropriate selection of construction material to avoid corrosion; • lining or coating of equipment and painting of pipes with corrosion inhibitors to prevent corrosion.	
d.	Ensure containment, collection and treatment of diffuse emissions	This includes: • storing and handling waste and material that may generate diffuse emissions in enclosed equipment or buildings; • collecting and directing the emissions to an appropriate abatement system (see Section 6.6.1); • dampening waste that can generate diffuse dust emissions with water.	
e.	Use semipermeable membrane covers	Active composting heaps are located in positively aerated plants covered with semipermeable membranes and sealed closed.	Only applicable to aerobic treatment of waste.

WORKING DRAFT IN PROGRESS

	Technique	Description	Applicability
f.	Limit potential generation of odour, dust and bioaerosols by considering meteorological conditions in the operation of the plant	This includes: • Monitoring weather conditions and wind direction and taking those conditions into account when undertaking major outdoor process activities. • Avoiding formation or turning of windrows or piles on windy days. • Undertaking screening and shredding when the wind speed is low or the wind direction is away from sensitive receptors. • Orientating windrows considering the direction of the prevailing wind. The smallest possible area of composting mass is exposed to the prevailing winds, to avoid 'stripping' of the windrow surface, and preferably at the lowest elevation within the overall site layout.	Only applicable to aerobic treatment of waste, when techniques (d) and (e) are not used.
g.	Maintenance and cleaning	This includes: • ensuring access to potentially leaky equipment; • regularly controlling protective equipment such as lamellar curtains, fast-action doors; • regularly cleaning halls, conveyor bands, etc.	Generally applicable.
h.	Set up and implement a leak detection and repair (LDAR) programme	See the description of the technique in Section 6.6.1	Only applicable to plants that contain a large number of piping components (e.g. valves) and that process a significant amount of lighter hydrocarbons.

[This BAT conclusion is based on information given in Sections 2.3.5.3, 2.3.5.4, 4.5.1.2, 4.5.2.2, and 4.5.2.3]

BAT 11. In order to prevent emissions to air from flares, BAT is to use flaring only for safety reasons or for non-routine operating conditions (e.g. start-ups, shutdowns) by using both of the techniques given below.

	Technique	Description	Applicability
a.	Correct plant design	This includes the provision of a gas recovery system with sufficient capacity and the use of high-integrity relief valves.	Generally applicable to new plants. Gas recovery system may be retrofitted in existing plants.
b.	Plant management	This includes balancing the gas system and using advanced process control.	Generally applicable.

[This BAT conclusion is based on information given in Section 2.3.5.5]

WORKING DRAFT IN PROGRESS

BAT 12. In order to reduce emissions to air from flares when flaring is unavoidable, BAT is to use both of the techniques given below.

	Technique	Description	Applicability
a.	Correct design of flaring devices	Optimisation of height, pressure, assistance by steam, air or gas, type of flare tips (either enclosed or shielded), etc., aimed to enable smokeless and reliable operation and to ensure the efficient combustion of excess gases.	Applicable to new flares. In existing plants, applicability may be restricted due to e.g. maintenance time availability during the turnaround of the plant.
b.	Monitoring and recording as part of flare management	Continuous monitoring of gas sent to flaring, measurements of gas flow and estimations of other parameters (e.g. composition of gas flow, heat content, ratio of assistance, velocity, purge gas flow rate, pollutant emissions (e.g. NO_X, CO, hydrocarbons, noise)). The recording of flaring events usually includes the estimated/measured flare gas composition, the estimated/measured flare gas quantity and the duration of operation. The recording allows for the quantification of emissions and the potential prevention of future flaring events.	Generally applicable.

[This BAT conclusions are based on information given in Section 2.3.5.5]

WORKING DRAFT IN PROGRESS

6.1.3 Emissions to water

BAT 13. In order to reduce water usage and to prevent or, where that is not practicable, to reduce the discharge of pollutants to water from waste treatment, BAT is to use all of the techniques given below.

Technique		Description	Applicability
a	Water-saving action plan and water audits	A water-saving plan includes: • flow diagrams and water mass balance, • establishment of water efficiency objectives, • implementation of water optimisation techniques (e.g. water pinch techniques, minimising use of washing and cleaning water). Water audits are carried out with the aim of increasing the reliability of the control and abatement performance of pollutants, reducing water usage, and preventing water contamination.	Generally applicable.
b	Segregation of different water streams in the water and drainage systems	Each water stream (e.g. road water, run-off water, process water) is collected and treated separately, depending on the pollution content. Uncontaminated water is reused as much as possible in the substitution of fresh water. Drainages from incompatible wastes are not mixed.	Generally applicable to new plants. Applicable to existing plants within the constraints given by the configuration of the water circuits.
c	Maximise internal water recycling	Increase the number and/or capacity of water recycling systems.	Water recycling may be limited by the content of impurities in the water.

[This BAT conclusion is based on information given in Section 2.3.7]

BAT 14. In order to prevent or, where that is not practicable, to reduce emissions to water, BAT is to use the technique given below.

Technique		Description
a	Integrated waste water management and treatment strategy	The integrated strategy is based on the inventory of waste water streams (see BAT 2), and considers the following principles: • segregation of waste water streams depending on the pollution load and the combination of techniques of the treatment process (see Section 6.6.2); • reduction of the remaining pollutants (e.g. organics) after the physico-chemical treatment, by means of e.g. activated sludge system; • reduction of remaining contamination with finishing techniques (post-treatment techniques such as: coagulation and flocculation, sedimentation, filtration, flotation); • in the case of indirect discharge, the level of emission of the remaining pollutants does not have a negative impact on the downstream WWTP and this plant can adequately deal with those remaining pollutants.

[This BAT conclusion is based on information given in Section 2.3.6.7]

WORKING DRAFT IN PROGRESS

BAT 15. In order to reduce emissions to water, BAT is to treat waste water before discharge to the environment with an appropriate combination of techniques given below.

Technique (1)		Typical pollutants targeted	Applicability
Preliminary and primary treatment, e.g.			
a	Equalisation	All pollutants	Generally applicable.
b	Neutralisation	Acids, alkalis	
c	Physical separation, e.g. screens, sieves, grit separators, grease separators or primary settlement tanks	Suspended solids, oil/grease	
Physico-chemical treatment, e.g.			
d	Adsorption	Organics, inorganics	Generally applicable.
e	Distillation/rectification	Organics	
f	Chemical precipitation	Metals, phosphorus	
g	Chemical oxidation	Nitrite, cyanide	
h	Chemical reduction	Chromium (VI)	
i	Ion exchange process	Metals	
j	Stripping	Hydrogen sulphide (H_2S), ammonia (NH_3), adsordable organically bound halogens (AOX), hydrocarbons	
Biological treatment, e.g.			
k	Activated sludge process	Biodegradable organic compounds	Generally applicable.
l	Membrane bioreactor		
Nitrogen removal			
m	Nitrification/denitrification	Total nitrogen, ammonia	Not applicable when the final treatment does not include a biological treatment.
Solids removal, e.g.			
n	Coagulation and flocculation	Suspended solids	Generally applicable.
o	Sedimentation		
p	Filtration (e.g. sand filtration, microfiltration, ultrafiltration)		
q	Flotation		

(1) The descriptions of the techniques are given in Section 6.6.2.

[This BAT conclusion is based on information given in Sections 2.3.6.1 to 2.3.6.7]

WORKING DRAFT IN PROGRESS

Table 6.3: BAT-associated emission levels (BAT-AELs) for direct discharge to a receiving water body

Parameter		BAT-AEL (Monthly average) (1)	Waste treatment process
Total organic carbon (TOC) (2)		10–40 mg/l	• Mechanical treatment of waste • Biological treatment of waste • Physico-chemical treatment waste
Chemical oxygen demand (COD) (2)		30–120 mg/l	
Total suspended solids (TSS)		5–35 mg/l	
Hydrocarbon oil index (HOI)		0.5–5 mg/l	• Mechanical treatment in shredder of metal waste • Re-refining of waste oil • Physico-chemical treatment of waste with calorific value
Total nitrogen (Total N)		5–30 mg/l (3)	• Biological treatment of waste • Re-refining of waste oil • Physico-chemical and/or biological treatment of water-based liquid waste
Total phosphorus (Total P)		0.3–3 mg/l	
Phenol index		0.05–0.2 mg/l	• Re-refining of waste oil • Physico-chemical treatment of waste with calorific value • Physico-chemical and/or biological treatment of water-based liquid waste
Metals and metalloids (4)	Arsenic (expressed as As)	0.01–0.05 mg/l	• Mechanical treatment in shredder of metal waste • Mechanical biological treatment of waste • Re-refining of waste oil • Physico-chemical and/or biological treatment of water-based liquid waste • Water washing of excavated contaminated soil
	Cadmium (expressed as Cd)	0.01–0.05 mg/l	
	Chromium (expressed as Cr)	0.01–0.05 mg/l	
	Nickel (expressed as Ni)	0.05–0.5 mg/l	
	Lead (expressed as Pb)	0.05–0.1 mg/l	
	Copper (expressed as Cu)	0.05–0.2 mg/l	
	Mercury (expressed as Hg)	0.001–0.01 mg/l	
	Zinc (expressed as Zn)	0.1–0.5 mg/l	

(1) The averaging period may be adapted when the monitoring frequency is reduced (see footnote (1) of Table **6.1**

(2) Either the BAT-AELs for COD or the BAT-AELs for TOC apply. TOC monitoring is the preferred option because it does not rely on the use of very toxic compounds.

(3) The upper end of the range may be up to 40 mg/l for Total N if the abatement efficiency is ≥ 70 % as a monthly average (considering all of the waste water treatment steps carried out).

(4) The BAT-AELs may not apply when the substance concerned is not present in the waste to be treated.

The associated monitoring is given in BAT 3

WORKING DRAFT IN PROGRESS

Table 6.4: BAT-associated emission levels (BAT-AELs) for indirect discharge to a receiving water body

Parameter		BAT-AEL (Monthly average) (1)	Waste treatment process
Hydrocarbon oil index (HOI)		0.5–5 mg/l	• Mechanical treatment in shredder of metal waste • Re-refining of waste oil • Physico-chemical treatment of waste with calorific value
Metals and metalloids (2)	Arsenic (expressed as As)	0.01–0.05 mg/l	• Mechanical treatment in shredder of metal waste • Mechanical biological treatment of waste • Re-refining of waste oil • Physico-chemical and/or biological treatment of water-based liquid waste • Water washing of excavated contaminated soil
	Cadmium (expressed as Cd)	0.01–0.05 mg/l	
	Chromium (expressed as Cr)	0.01–0.05 mg/l	
	Nickel (expressed as Ni)	0.05–0.5 mg/l	
	Lead (expressed as Pb)	0.05–0.1 mg/l	
	Copper (expressed as Cu)	0.05–0.2 mg/l	
	Mercury (expressed as Hg)	0.001–0.01 mg/l	
	Zinc (expressed as Zn)	0.1–0.5 mg/l	

(1) The averaging period may be adapted when the monitoring frequency is reduced (see footnote (1) of Table **6.1**).
(2) The BAT-AELs may not apply when the substance concerned is not present in the waste to be treated.

The associated monitoring is given in BAT 3

6.1.4 Consumption of raw materials and chemicals

BAT 16. In order to reduce the raw material and chemical consumption of waste treatment, BAT is to use the technique given below.

Technique		Description	Applicability
a	Use of waste instead of raw materials for waste treatment operations	Waste is used instead of raw materials for the treatment of other wastes by substituting chemicals or raw materials (e.g. APC residues as a replacement for hydrated lime in the neutralisation of waste acid).	Some applicability limitations derive from the presence of impurities in the waste that substitutes the raw material. Another limitation is the compatibility of the waste to be used as raw material with the wastes to be treated (see BAT 2).

[This BAT conclusion is based on information given in Section 2.3.8]

WORKING DRAFT IN PROGRESS

6.1.5 Energy efficiency

BAT 17. In order to use energy efficiently in waste treatment, BAT is to use all of the techniques given below.

Technique		Description
a	Set up and implement an energy efficiency plan	An energy efficiency plan entails defining and calculating the specific energy consumption of the activity (or activities), setting key performance indicators on an annual basis (e.g. MWh/tonne of waste processed) and planning the periodic improvement targets and related actions.
b	Establish a detailed energy balance	A detailed energy balance provides a breakdown of the energy consumption and generation (including exportation) by the type of source (i.e. electricity, gas, conventional liquid fuels, conventional solid fuels, and waste). This involves: (i) reporting the energy consumption information in terms of delivered energy; (ii) reporting the energy exported from the installation; (iii) providing energy flow information (for example, Sankey diagrams or energy balances) showing how the energy is used throughout the process.

[This BAT conclusion is based on information given in Sections 2.3.9.1 and 2.3.9.2]

6.1.6 Noise and vibrations

BAT 18. In order to prevent or, where that is not practicable, to reduce noise and vibration emissions, BAT is to set up, implement and regularly review a noise and vibration management plan, as part of the environmental management system (see BAT 1), that includes all of the following elements:

I. a protocol containing appropriate actions and timelines;
II. a protocol for conducting noise and vibration monitoring;
III. a protocol for response to identified noise and vibration events;
IV. a noise and vibration reduction programme designed to identify the source(s), to measure/estimate noise and vibration exposure, to characterise the contributions of the sources and to implement prevention and/or reduction measures.

Applicability
The applicability is restricted to cases where noise or vibration nuisance can be expected or has been substantiated.
[This BAT conclusion is based on information given in Sections 2.3.10.1 and 3.1.3.2.1]

WORKING DRAFT IN PROGRESS

BAT 19. In order to prevent or, where that is not practicable, to reduce noise and vibration emissions, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a	Appropriate location of equipment and buildings	Increasing the distance between the emitter and the receiver and using buildings as noise screens.	For existing plants, the relocation of equipment may be restricted by a lack of space or excessive costs.
b	Operational measures	This includes: i. improved inspection and maintenance of equipment; ii. closing of doors and windows of enclosed areas, if possible; iii. equipment operation by experienced staff; iv. avoidance of noisy activities at night, if possible; v. provisions for noise control during maintenance activities.	Generally applicable.
c	Low-noise equipment	This includes compressors, pumps and flares.	
d	Noise and vibration control equipment	This includes: i. noise-reducers; ii. equipment insulation; iii. enclosure of noisy equipment; iv. soundproofing of buildings.	Applicability may be restricted due to space requirements (for existing plants).
e	Noise abatement	Inserting obstacles between emitters and receivers (e.g. protection walls, embankments and buildings).	For existing plants, the insertion of obstacles may be restricted by a lack of space. For mechanical treatment in shredders of metal wastes, it is applicable within the constraints imposed by the possible deflagration in shredders.

[This BAT conclusion is based on information given in Sections 2.3.10.2 and 3.1.3.2.2]

WORKING DRAFT IN PROGRESS

6.1.7 Emissions to soil and groundwater

BAT 20. In order to prevent emissions to soil and groundwater from waste treatment, BAT is to use all of the techniques given below.

Technique		Description
a	Sealed surface and retention volume	The surface of the whole waste treatment area (e.g. waste reception, handling, storage, treatment and dispatch areas) is sealed (e.g. concrete base). Each storage tank for liquids is located in a liquid-proof retention area.
b	Adequate drainage infrastructure	The waste treatment area is connected to a drainage infrastructure. Run-off water falling on the treatment area is collected in the drainage infrastructure along with tanker washings, occasional spillages, drum washings, etc. and returned to the waste treatment plant or collected in an interceptor. Interceptors with an overflow to sewer have automatic monitoring systems, such as pH checks, which can trigger the shutting down of the overflow.
c	Design and maintenance provisions to allow detection and repair of leaks	Vessels and pipework are located above ground or a secondary containment of underground components is put in place. Regular monitoring for potential leakages is carried out. When underground pipework is used, it is equipped with suitable inspection channels.
d	Security basin	A basin used to collect surges that may be contaminated, e.g. firefighting water. The discharge of waste water from this basin to a receiving water body or to the sewer is only possible after further appropriate measures are taken (e.g. control, treat, reuse).

[This BAT conclusion is based on information given in Sections 2.3.11 and 2.3.14]

6.1.8 Management of residues

BAT 21. In order to reduce the amount of residues generated during waste treatment, BAT is to use the technique given below.

Technique		Description
a	Maximise the reuse of packaging	Packaging (drums, containers, IBCs, palettes, etc.) is reused for containing waste, when it is in good working order and sufficiently clean, on the basis of a compatibility check between the two substances contained (first and second use). If necessary, packaging is sent for appropriate treatment (e.g. reconditioning, cleaning, and washing).

[This BAT conclusion is based on information given in Section 2.3.12]

WORKING DRAFT IN PROGRESS

6.1.9 Emissions from accidents and incidents

BAT 22. In order to prevent or limit the environmental consequences of accidents and incidents, BAT is to use all of the techniques given below.

Technique		Description
a	Management of accidental emissions	Procedures are established and technical provisions are in place to manage accidental emissions such as spillages, firefighting water, or emissions from safety valves.
b	Event registration and assessment system	This includes: • A log/diary to record all incidents, near-misses, changes to procedures, abnormal events, and the findings of maintenance inspections. Leaks, spills and accidents can be recorded in the site diary. • Procedures to identify, respond to and learn from such incidents.
c	Protection measures	These include: • security measures to protect the plant against malevolent acts which could have environmental impacts; • fire and explosion protection system, containing prevention and detection equipment, and extinction equipment; • instrumentation and control equipment is accessible and maintained in emergency situations.

[This BAT conclusion is based on information given in Section 2.3.13.1]

WORKING DRAFT IN PROGRESS

6.1.10 Waste storage and handling

BAT 23. In order to prevent or, where that is not practicable, to reduce the environmental risk of the storage of waste, BAT is to use all of the techniques given below.

Technique		Description	Applicability
a	Storage location	Storage is located away from watercourses	Generally applicable to new plants.
b	Storage design	This includes: • Measures are taken to prevent, detect and mitigate overflows from tanks and vessels. Vessel overflow pipes are directed to a contained drainage system (i.e. the relevant bund area or another vessel). • Tanks and vessels are isolable.	Generally applicable.
c	Storage capacity	Measures are taken to avoid storage/accumulation of waste, such as: • a waste acceptance (see BAT 2) plan is used; • the maximum waste storage capacity is clearly established and communicated; • the quantity of waste stored is regularly verified against the maximum allowed storage capacity.	
d	Safe storage operation	This includes: • equipment used for loading, unloading and storing waste is clearly documented and labelled; • waste segregation measures are taken (see BAT 2); • substances known to be sensitive to heat, light, air, water, etc. are protected from such ambient conditions; • containers and drums are fit for purpose and stored securely.	
e	Storage of laboratory smalls	Dedicated area is used for sorting and repacking laboratory smalls	Only applicable for plants storing laboratory smalls.

[This BAT conclusion is based on information given in Section 2.3.13.2]

WORKING DRAFT IN PROGRESS

BAT 24. In order to reduce the environmental risk associated with the handling of waste, BAT is to use the following technique.

Technique		Description
a	Handling systems and procedures	This includes: • handling of waste is carried out by qualified and trained staff; • transfers and discharges of waste are duly documented and validated prior to execution; • measures are taken to ensure couplings are correctly fitted when connecting hoses or pipes; • measures are taken to prevent, detect and mitigate spills; • technical and, if relevant, construction precautions are taken to protect human health and the environment when mixing or blending wastes, depending on the composition and consistency of the wastes to be mixed or blended (e.g. vacuuming dust-like wastes).

[This BAT conclusion is based on information given in Section 2.3.13.3]

WORKING DRAFT IN PROGRESS

6.2 BAT conclusions for mechanical treatment of waste

Unless otherwise stated, the BAT conclusions presented in this section apply to the mechanical treatment of waste, in addition to the general BAT conclusions of Section 6.1.

6.2.1 General BAT conclusions for mechanical treatment of waste

6.2.1.1 Emissions to air

BAT 25. In order to reduce dust emissions to air, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a	Cyclone	See Section 6.6.1.	Generally applicable.
b	Wet scrubber		Not applicable to mechanical treatment of mercury-containing equipment.
c	Fabric filter		Not applicable to exhaust air ducts directly connected to the mill for mechanical treatment in shredders of metal waste.
d	Water injection into the shredder mill	The shredded material is made damp by injecting water into the mill. The amount of water is regulated in relation to the amount of energy consumed by the main motor. The airflow that contains residual dust is directed to cyclone(s) and/or wet (venturi) scrubber	Only applicable to mechanical treatment in shredders of metal waste in combination with techniques (a) and/or (b), within the constraints imposed by local meteorological conditions (low temperature).

Table 6.5: BAT-associated emission levels (BAT-AELs) for dust emissions to air from mechanical treatment of waste

Parameter	Unit	BAT-AEL (Average of samples obtained during one year)
Dust	mg/Nm^3	<2–5 (1)
(1) When a fabric filter cannot be applied in shredders of metal waste for safety reasons, the higher end of the range is 10 mg/Nm^3.		

The associated monitoring is given in BAT 4.

[This BAT conclusion is based on information given in Sections 3.1.3.1.1, 3.2.3.1.2 and 3.3.4.1.1]

WORKING DRAFT IN PROGRESS

6.2.2 BAT conclusions for the mechanical treatment in shredders of metal waste

6.2.2.1 General environmental performance

BAT 26. In order to improve the general environmental performance, and to reduce the risk of accidents and incidents, BAT is to use the technique given below.

	Technique	Description
a	Acceptance of waste input	This includes: a. set up and implement a detailed baled material inspection procedure before shredding; b. remove and return to the owner dangerous items (e.g. gas cylinders, dirty drums, EoLVs with dangerous parts) left in the waste stream by mistake; c. reception and acceptance of drums and containers only when accompanied by a certificate of cleanliness.

[This BAT conclusion is based on information given in Sections 2.3.2 and 3.1.3.1.2.3]

6.2.2.2 Diffuse emissions to air and deflagrations

BAT 27. In order to prevent or reduce deflagrations and related diffuse emissions, BAT is to use both of the techniques given below.

	Technique	Description
a	To use pressure relief equipment	In order to control deflagrations, pressure relief dampers are installed. They are equipped with rubber flaps preventing diffuse emissions in normal operation.
b	To set and implement procedures to reduce the number of deflagrations	This includes: • a protocol containing appropriate actions and timelines; • a protocol for conducting deflagration monitoring; • a protocol for response to deflagration incidents; • a deflagration reduction programme designed to identify the source(s), and to implement elimination and/or reduction measures (e.g. inspection of waste input and management of prohibited materials); • a review of historical deflagration incidents and remedies and the dissemination of deflagration knowledge.

[This BAT conclusion is based on information given in Sections 3.1.3.1.2.2 and 3.1.3.1.2.3]

6.2.2.3 Energy efficiency

BAT 28. In order to use energy efficiently, BAT is to use the technique given below.

	Technique	Description
a	Mill feeding regulation	Reduction of peak energy consumption and power losses and avoidance of unwanted shutdowns of the mill, by regulating the feed to ensure that the shredder load and rotor speed are as constant as possible.

[This BAT conclusion is based on information given in Section 3.1.3.3.1]

WORKING DRAFT IN PROGRESS

6.2.3 BAT conclusions for mechanical treatment in shredders of equipment containing VFCs or VHCs

6.2.3.1 Emissions to air

BAT 29. In order to prevent or, where that is not practicable, to reduce VOC emissions to air, BAT is to use one of the techniques given below.

Technique		Description
a	Removal of VOC from the shredding area and treatment by cryogenic condensation	Waste gas containing VFCs/VHCs is extracted from the shredding area, and inert gas (e.g. N_2) is blown in to reduce the O_2 concentration below 4 vol-%. This waste gas is then sent to a cryogenic condensation unit where it is liquefied (see description in Section 6.6.1). The liquid gas is stored in tanks for further treatment. The inert gas is recovered and reused to reduce the O_2 concentration.
b	Removal of VOC from the shredding area and treatment by adsorption	Waste gas containing VFCs/VHCs is extracted from the shredding area and led into adsorption filters (see description in Section 6.6.1). The spent activated carbon is regenerated by means of heated air pumped into the filter to evaporate trapped VFCs/ VHCs. After the filter, the gas is compressed and cooled in order to liquefy the VFCs/VHCs. The liquefied gas is then stored in tanks. The emitted gas is usually led back into the adsorbing filter in order to recover any residual VFCs/VHCs.

Table 6.6: BAT-associated emission levels (BAT-AELs) for TVOC emissions to air from mechanical treatment in shredders of equipment containing VFCs or VHCs

Parameter	Unit	BAT-AEL (Average of samples obtained during one year)
TVOC	mg/Nm^3	2–15

The associated monitoring is given in BAT 4.

[This BAT conclusion is based on information given in Section 3.2.3.1.1]

WORKING DRAFT IN PROGRESS

6.2.4 BAT conclusions for the mechanical treatment of mercury-containing equipment

6.2.4.1 Emissions to air

BAT 30. In order to prevent or, where that is not practicable, to reduce mercury emissions to air, BAT is to use the technique given below.

Technique		Description
a	Collection at source followed by abatement and surveillance of mercury emissions	This includes all of the following: • Processes used to treat mercury-containing equipment are enclosed, under negative pressure and connected to a Local Exhaust Ventilation system (LEV). • Extracted air from the processes is treated by dedusting techniques such as cyclones, fabric filters, HEPA filters as well as activated carbon filters (see Section 6.6.1). • Treated air is either released outside the buildings or recycled. • The air flow from the Local Exhaust Ventilation system (LEV) and mercury concentration in the LEV extracted air are monitored to enable the assessment of the effectiveness of the LEV performance. • Mercury levels in ambient air are measured regularly around the processes to detect potential mercury leaks.

[This BAT conclusion is based on information given in Section 5.8.2.3.1]

Table 6.7: BAT-associated emission levels (BAT-AELs) for mercury emissions to air from mechanical treatment of mercury-containing waste

Parameter	Unit	BAT-AEL (Average of samples obtained during one year)
Mercury (Hg)	µg/Nm^3	2–7

The associated monitoring is given in BAT 4.

WORKING DRAFT IN PROGRESS

6.3 BAT conclusions for biological treatment of waste

Unless otherwise stated, the BAT conclusions presented in this section apply to biological treatment of waste, in addition to the general BAT mentioned in Section 6.1.

6.3.1 General BAT conclusions for biological treatment of waste

6.3.1.1 General environmental performance

BAT 31. In order to minimise the generation of odorous emissions and to improve the general environmental performance, BAT is to use the technique given below.

	Technique	Description
a	Selection of waste input	Pre-acceptance, acceptance, and sorting of the waste input to enable an appropriate nutrient balance, and to prevent toxic compounds (i.e. toxic in terms of reducing biological activity) entering the biological systems.

[This BAT conclusion is based on information given in Section 4.5.1.1]

6.3.1.2 Emissions to air

BAT 32. In order to reduce channelled emissions of odorous substances, H_2S and NH_3, BAT is to use a biofilter (See Section 6.6.1).

Table 6.8: BAT-AELs (BAT-AELs) for channelled NH_3 and H_2S emissions to air from the biological treatment of waste

Parameter	Unit	BAT-AEL (Average of samples obtained during one year)
NH_3	mg/Nm^3	0.1–10
H_2S	mg/Nm^3	0.1–1 (1)
(1) The lower end of the range is associated with the use of a wet scrubber before the biofilter		

The associated monitoring is given in BAT 4.

[This BAT conclusion is based on information given in Section 4.5.1.4]

6.3.1.3 Emissions to water and water usage

BAT 33. In order to minimise generation of leachate and the volume of waste water, as well as to avoid contamination of ground or surface waters and to reduce water usage, BAT is to use the technique given below.

Technique	Description	Applicability
Water and leachate management	Segregation of leachate seeping from compost piles and windrows, surface water arising from roads, and uncontaminated run-off water from buildings.	Generally applicable to new plants. Applicable to existing plants within the constraints imposed by the configuration of the water circuit.
	When relevant in aerobic processes, the ceiling of the biological degradation hall is thermally insulated in order to minimise the generation of condensate.	Generally applicable.

WORKING DRAFT IN PROGRESS

	Recycling process waters (e.g. from dewatering of liquid digestate in anaerobic processes) or muddy residues, or using as much as possible alternative sources of water, e.g. condensed water, rinsing water, run-off water, within the process.	The recycling of water into the process is limited by potential contents of impurities (heavy metals, salts, pathogens, etc.).
	Adjusting the moisture content of the waste to its water-holding capacity and therefore minimising the generation of leachate.	Generally applicable.

[This BAT conclusion is based on information given in Section 4.5.1.5]

6.3.2 BAT conclusions for aerobic treatment of waste

6.3.2.1 General environmental performance

BAT 34. In order to reduce emissions to air and to improve the general environmental performance, BAT is to monitor the process and to control the key process parameters as mentioned below.

	Technique	Description	Applicability
a	Aerobic process monitoring	Proper monitoring and control of key process parameters, including: • waste input characteristics (e.g. C:N ratio, particle size); • water content; • air diffusion through the waste; • temperature.	Monitoring of the water content is not applicable to enclosed processes when health and/or safety issues have been identified.

[This BAT conclusion is based on information given in Section 4.5.2.1]

6.3.3 BAT conclusions for anaerobic treatment of waste

6.3.3.1 General environmental performance

BAT 35. In order to reduce emissions to air and to improve the general environmental performance, BAT is to monitor the process and to control the key process parameters as mentioned below.

	Technique	Description
a	Anaerobic process monitoring	Implement a monitoring system, manual and/or automatic, to: • ensure a stable reactor operation; • minimise operational difficulties, such as foaming, which may lead to odour problems; • provide sufficient early warning of system failures which may lead to loss of containment and, potentially, explosions. This includes monitoring of key process parameters, such as: • pH and alkalinity; • temperature and temperature distribution; • hydraulic loading rate; • organic loading rate including total solids and volatile solids fractions;

WORKING DRAFT IN PROGRESS

		• concentration of volatile fatty acids (VFA); • ammonia; • C:N ratio; • gas generation and composition; • gas pressure; • H2S concentration in the gas; • liquid and foam levels.

[This BAT conclusion is based on information given in Section 4.5.3.1]

6.3.4 BAT conclusions for mechanical biological treatment (MBT) of waste

The BAT conclusions for aerobic and anaerobic treatment of waste apply, when relevant, to mechanical biological treatment of waste.

6.3.4.1 Emissions to air

BAT 36. In order to prevent or, where that is not practicable, to reduce emissions to air, BAT is to use all of the techniques given below.

Technique		Description	Applicability
a	Separate collection of air flows	Splitting of the total volume flow that is to be treated into heavily polluted exhaust air and lightly polluted exhaust air.	Generally applicable to new plants. Applicable to existing plants within the constraints imposed by the configuration of the air circuits.
b	Partial reuse of exhaust air in the biological process	Use the exhausted air from the delivery waste input area (such as low bunkers and underground bunkers with or without mechanical treatment), or reuse the treated air as air supply (process air) for biological degradation. It may be necessary to condense the water vapour contained in the exhausted air before reuse. In this case, cooling is necessary, and the condensed water is treated before discharge.	

[This BAT conclusion is based on information given in Section 4.5.4.1]

BAT 37. In order to reduce dust and VOC emissions to air, BAT is to use one or a combination of the techniques given below, in addition to BAT 32.

Technique		Description
a	Fabric filter	See Section 6.6.1.
b	Wet scrubber	
c	Thermal oxidation	

[This BAT conclusion is based on information given in Section 4.5.4.1]

WORKING DRAFT IN PROGRESS

Table 6.9: BAT-associated emission levels (BAT-AELs) for dust and VOC emissions to air from mechanical biological treatment of waste

Parameter	Unit	BAT-AEL (Average of samples obtained during one year)
Dust	mg/Nm^3	2–5
TVOC	mg/Nm^3	5–15

The associated monitoring is given in BAT 4

WORKING DRAFT IN PROGRESS

6.4 BAT conclusions for physico-chemical treatment of waste

Unless stated otherwise, the BAT conclusions presented in this section apply to physico-chemical treatment of waste, in addition to the general BAT mentioned in Section 6.1

6.4.1 BAT conclusions for the physico-chemical treatment of solid and/or pasty waste

6.4.1.1 General environmental performance

BAT 38. In order to improve the general environmental performance, BAT is to use the technique given below.

	Technique	Description	Applicability
a	Acceptance procedures of solid and/or pasty waste to be treated	Acceptance procedures include controlling: • the waste input content of e.g.: o organics, o solid cyanides, o oxidising agents, o mercury; • H_2 emissions when fly ashes or air pollution control (APC) residues are mixed with water.	Controlling H_2 emissions is only applicable when the fly ashes or APC residues contain carbonate.

[This BAT conclusion is based on information given in Section 5.1.4.1.1]

6.4.1.2 Emissions to air

BAT 39. In order to reduce dust, VOC and NH_3 emissions to air, BAT is to use one or a combination of the techniques given below.

	Technique	Description
	Fabric filter	See Section 6.6.1.
	Wet scrubber	
	Biofilter	
	Adsorption	

[This BAT conclusion is based on information given in Section 5.1.4.2]

Table 6.10: BAT-associated emission levels (BAT-AELs) for dust, VOC, and NH_3 emissions to air from physico-chemical treatment of solid and/or pasty waste

Parameter	Unit	BAT-AEL (Average of samples obtained during one year)
Dust	mg/Nm^3	2–5
TVOC		2–15
NH_3		0.1–5

The associated monitoring is given in BAT 4

WORKING DRAFT IN PROGRESS

6.4.2 BAT conclusions for the re-refining of waste oil

6.4.2.1 General environmental performance

BAT 40. In order to improve the general environmental performance of waste oil re-refining, BAT is to use both of the techniques given below.

Technique		Description
a	Set up and implement acceptance procedures	Acceptance procedures include controlling the waste input content in chlorinated compounds (e.g. solvents or PCBs).
b	Residue management	Using the residues as heater feed in a heater equipped with wet scrubber to generate energy for the plant.

[This BAT conclusion is based on information given in Sections 5.2.3.1 and 5.2.3.3]

6.4.2.2 Emissions to air

BAT 41. In order to reduce VOC emissions to air, BAT is to use the technique given below.

Technique		Description
a	Thermal oxidation	See Section 6.6.1 . The waste gas may also be fed into a process furnace or a boiler.

[This BAT conclusion is based on information given in Section 5.2.3.4]

Table 6.11: BAT-associated emission levels (BAT-AELs) for VOC emissions to air from re-refining of waste oil

Parameter	**Unit**	**BAT-AEL (Average of samples obtained during one year)**
TVOC	mg/Nm^3	5–15

The associated monitoring is given in BAT 4

6.4.2.3 Emissions to water and water usage

BAT 42. In order to reduce water usage and emissions to water, BAT is to use one or both of the techniques given below.

Technique		Description
a	Waste water pretreatment	This includes pretreatment of waste water such as evaporation and steam stripping (see description in Section 6.6.2) prior to the WWTP.
b	Reuse of water	Reusing the cleaned waste water as cooling water after appropriate treatment.

[This BAT conclusion is based on information given in Section 5.2.3.2]

WORKING DRAFT IN PROGRESS

6.4.3 BAT conclusions for the physico-chemical treatment of waste with calorific value

6.4.3.1 Emissions to air

BAT 43. In order to reduce VOC emissions to air from plants performing physico-chemical treatment of liquid and semi-liquid waste with calorific value, BAT is to use one or a combination of the techniques given below.

Technique		Description
•	Adsorption	See Section 6.6.1
•	Thermal oxidation	
•	Wet scrubber	

[This BAT conclusion is based on information given in Section 5.3.4.1]

Table 6.12: BAT-associated emission levels (BAT-AELs) for VOC emissions to air from plants performing physico-chemical treatment of liquid and semi-liquid waste with calorific value

Parameter	**Unit**	**BAT-AEL (Average of samples obtained during one year)**
TVOC	mg/Nm^3	5-15

The associated monitoring is given in BAT 4.

6.4.4 BAT conclusions for the regeneration of spent solvents

6.4.4.1 General environmental performance

BAT 44. In order to improve the general environmental performance of regeneration of spent solvents, BAT is to use the technique given below.

Technique		Description
a	Recover solvents from distillation residues	Vacuum drying and other drying techniques are used to evaporate the residues from the distillation columns and recover the solvents.

[This BAT conclusion is based on information given in Section 5.4.3.1]

WORKING DRAFT IN PROGRESS

6.4.4.2 Emissions to air

BAT 45. In order to prevent or, where that is not practicable, to reduce VOC emissions to air, BAT is to use a suitable combination of the techniques given below.

Technique		Description	Applicability
a	Recirculation of waste gas from solvent regeneration process in steam boiler	Collected waste gas is cooled and chilled to condense and partially separate solvents. This waste gas with remaining solvents is fed to the steam boiler supplying the plant. If the steam boiler is not in operation or the waste gas volume would exceed the steam boiler air demand, the pretreated waste gas is treated by activated carbon filters before release.	Not applicable to the treatment of halogenated solvent wastes, in order to avoid generating and emitting PCBs.
b	Condensation/ Cryogenic condensation	See Section 6.6.1 for the description of the techniques. Adequate control of condenser parameters is essential to minimise VOC emissions from the condenser vents. Condenser (cooling) failure results in an automatic process shutdown.	Generally applicable.
c	Activated carbon adsorption	See Section 6.6.1 for the description of the technique.	There may be limitations to the applicability of the technique due to safety reasons (e.g. activated carbon beds tend to self-ignite when loaded with ketones).
d	Wet scrubber	See Section 6.6.1 for the description of the technique.	Generally applicable.

[This BAT conclusion is based on information given in Sections 5.4.3.3 and 5.4.3.4]

Table 6.13: BAT-associated emission levels (BAT-AELs) for VOC emissions to air from plants performing regeneration of spent solvents

Parameter	Unit	BAT-AEL (Average of samples obtained during one year)
TVOC	kg per tonne of spent solvent treated	0.02-0.36

The associated monitoring is given in BAT 4

BAT 46. In order to reduce the generation of waste water and to reduce water usage, BAT is to use the technique given below.

Technique		Description
a	Liquid ring pumps with high boiling point liquids	Solvent vapours generated by the distillation process carried out under vacuum are absorbed into liquids with high boiling points. The liquid used is alternately cooled and heated in a continuous process. When becoming hot, the condensed and soluble solvents are desorbed and the liquid ring fluid is returned to the vacuum pump for the next reuse. Desorbed solvents are condensed and recovered.

[This BAT conclusion is based on information given in Section 5.4.3.5]

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6.4.5 BAT conclusions for the thermal treatment of spent activated carbon, waste catalysts and excavated contaminated soil

6.4.5.1 General environmental performance

BAT 47. In order to improve the general environmental performance of the thermal treatment of spent activated carbon, waste catalysts and excavated contaminated soil, BAT is to use all of the techniques given below.

Technique		Description	Applicability
a	Heat recovery	This involves gas/gas heat exchangers to allow the preheating of combustion air and waste gas reheating. There may also be a waste heat boiler used for the generation of steam, which is also used in the reactivation of the carbon.	Generally applicable.
b	Reduction of waste gas to be treated	Use an indirectly fired kiln to avoid contact between the kiln content and waste gases generated by the burner(s).	Indirectly fired kilns are normally constructed with a metal tube and applicability may be restricted due to corrosion problems that may appear during treatment of some activated carbons used in industrial applications.
c	Primary measures for reducing particulate and acid gas emissions	This includes: - control of furnace temperature, turning rate of the rotary furnace, fuel type; - design of the regenerator and associated ducting and equipment to operate under a reduced pressure, in order to prevent the escape of regenerator gases into the air; - use of a sealed furnace.	Design measure are generally only applicable to new plants.

[This BAT conclusion is based on information given in Sections 5.5.3.1 and 5.5.4.1]

WORKING DRAFT IN PROGRESS

6.4.5.2 Emissions to air

BAT 48. In order to reduce emissions to air, BAT is to use one or a combination of the techniques given below.

	Technique	Description
a	Thermal oxidation (1)	See Section 6.6.1.
b	Cyclone	
c	Wet scrubber (2)	
d	ESP	
e	Fabric filter (3)	
f	Adsorption	
g	Condensation of waste gas	

(1) Thermal oxidation is carried out with a minimum temperature of 1100 °C and two-second residence time for the regeneration of activated carbons used in industrial applications where refractory halogenated or other thermally resistant substances are likely to be present. In the case of activated carbon used for potable water- and food-grade applications, an afterburner with a minimum heating temperature of 850 °C and two-second residence time is sufficient (see Section Section 6.6.1).
(2) Caustic or soda ash scrubbing solutions are used to neutralise acid gases for thermal treatment of activated carbon used in industrial applications.
(3) Cooling the waste gas prior to a fabric filter is an important technique as it provides temperature protection for the filter and allows a wider choice of fabric.

[This BAT conclusion is based on information given in Sections 5.5.3.1 and 5.5.4.1]

6.4.6 BAT conclusions for the water washing of excavated contaminated soil

6.4.6.1 Emissions to air

BAT 49. In order to reduce dust and VOC emissions to air, BAT is to use one or a combination of the techniques given below.

	Technique	Description
a	Wet scrubber	See Section Section 6.6.1.
b	Fabric filter	
c	Adsorption	

[This BAT conclusion is based on information given in Section 5.6.3.2.2]

WORKING DRAFT IN PROGRESS

6.4.7 BAT conclusions for the decontamination of equipment containing POPs

6.4.7.1 General environmental performance

BAT 50. In order to improve the general environmental performance of PCB decontamination, BAT is to apply all of the techniques given below.

	Technique	Description
a	Design measures to prevent dispersion of PCBs from the storage and treatment areas	• Dedicated storm and run-off water collection system. • Resin coating applied to the whole concrete floor of the storage and treatment areas.
b	Implementation of staff access rules to prevent dispersion of contamination	• Accesses to storage and treatment areas are locked. • Special qualification is required to access the area where the waste or polluted equipment is handled. • Separate 'clean' and 'dirty' cloakrooms to put on/take off individual protective outfit.
c	Prevention of liquid PCB dispersion during the decontamination process	• External surfaces of the contaminated electrical equipment are cleaned with anionic liquid. • Pumping the PCB oil out of the electrical equipment with a pump or under vacuum instead of gravity emptying. • Procedures are defined and used for filling, emptying and (dis)connecting the vacuum vessel. • Long period of dripping (at least 12 hours) to avoid any PCB drop during further treatment operations, after the separation of the core from the casing of an electrical transformer.
d	Control of emissions to air	• The ambient air of the decontamination workshop is treated on activated carbon filters. • The exhaust of the vacuum pump mentioned in technique (c) above is connected to an end-of-pipe abatement system (e.g. a high temperature kiln or activated carbon filters).
e	Management of waste treatment residues	• Porous contaminated parts of the electrical transformer (wood and paper) are fed into a high temperature kiln (≥ 1100 °C). • Destruction of the PCBs in the oils (dechlorination, hydrogenation, solvated electron processes).

[This BAT conclusion is based on information given in Section 5.8.1.3.1]

WORKING DRAFT IN PROGRESS

6.4.7.2 Emissions to air

BAT 51. When solvent washing is used for PCB decontamination, and in order to prevent or, where that is not practicable, to reduce VOC emissions to air and to recover solvent, BAT is to use all of the techniques given below.

	Technique	Description
a	Recovery of solvent	Solvent emissions are collected and distilled in order to recover solvent and reuse it in the process
b	Control of VOC emissions	Airstreams over the whole working zone are collected (see BAT 10) and treated by activated carbon adsorption (for airstreams with low pollutant content) or thermal oxidation (see Section 6.6.1) for gas streams with high pollutant contents (typically solvent vents, etc.).

[This BAT conclusion is based on information given in Section 5.8.1.3.2]

WORKING DRAFT IN PROGRESS

6.5 BAT conclusions for the physico-chemical and/or biological treatment of water-based liquid waste

Unless stated otherwise, the BAT conclusions presented in this section apply to physico-chemical and/or biological treatment of water-based liquid waste, in addition to the general BAT mentioned in Section 6.1

6.5.1 Emissions to air

BAT 52. In order to reduce HCl, NH_3 and VOC channelled emissions to air, BAT is to use one or a combination of the techniques given below.

	Technique	Description
a	Adsorption	See Section 6.6.1
b	Wet scrubber	
c	Biofilter	

[This BAT conclusion is based on information given in Section 5.7.3.1]

Table 6.14: BAT-associated emission levels (BAT-AELs) for HCl, NH_3, and VOC emissions to air from physico-chemical and/or biological treatment of water-based liquid waste

Parameter	Unit	BAT-AEL (Average of samples obtained during one year)
Hydrogen chloride (HCl)	mg/Nm^3	1–3 (1)
Ammonia (NH_3)		0.1–5
TVOC		3–20
(1) This BAT-AEL does not apply if only biological treatment is carried out.		

The associated monitoring is given in BAT 4.

WORKING DRAFT IN PROGRESS

6.6 Descriptions of techniques

6.6.1 Emissions to air

Technique	Typical pollutant(s) abated	Description
Absolute filter	Dust	In absolute filters (e.g. HEPA = high-efficiency particle air filter, ULPA = ultra-low penetration air filter), the filter medium is paper or matted glass fibre with a high packing density. The waste gas stream is passed through the filter medium, where particulate matter is collected.
Adsorption	Mercury, volatile organic compounds, hydrogen sulphide odorous compounds	Adsorption is a heterogeneous reaction in which gas molecules are retained on a solid or liquid surface (adsorbent also referred to as a molecular sieve) that prefers specific compounds to others and thus removes them from effluent streams. When the surface has adsorbed as much as it can, the adsorbed content is desorbed as part of the regeneration of the adsorbent. When desorbed, the contaminants are usually at a higher concentration and can either be recovered or disposed of. The most common adsorbent is granular activated carbon.
Fabric filter	Dust	Bag or fabric filters are constructed from porous woven or felted fabric through which gases are passed to remove particles. The use of a bag filter requires the selection of a fabric suitable for the characteristics of the waste gas and the maximum operating temperature.
Biofilter	Ammonia, hydrogen sulphide, volatile organic compounds, odorous compounds	The waste gas stream is passed through a bed of organic material (such as peat, heather, compost, root, tree bark, compost, softwood and different kinds of combinations) or some inert material (such as clay, activated carbon, and polyurethane), where it is biologically oxidised by naturally occurring microorganisms into carbon dioxide, water, inorganic salts and biomass.
Condensation and cryogenic condensation	Volatile organic compounds	Condensation is a technique that eliminates solvent vapours from a waste gas stream by reducing its temperature below its dew point. Cryogenic condensation can cope with all VOCs and volatile inorganic pollutants, irrespective of their individual vapour pressures. The low temperatures applied allow for very high condensation efficiencies in such a way that it is well-suited as a final VOC emission control technique.
Cyclone	Dust	Cyclone filters are used to remove heavier particulates, which ‘fall out’ as the waste gases are forced into a rotating motion before they leave the separator again. Cyclones are used to control particulate material, primarily PM_{10}. There are high-efficiency cyclones (e.g. multi-cyclones) designed to be effective even for $PM_{2.5}$.

WORKING DRAFT IN PROGRESS

Electrostatic precipitator (ESP)	Dust	Electrostatic precipitators operate such that particles are charged and separated under the influence of an electrical field. Electrostatic precipitators are capable of operating under a wide range of conditions. In a dry ESP, the collected material is mechanically removed (e.g. by shaking, vibration, compressed air), while in a wet ESP it is flushed with a suitable liquid, usually water.
Leak detection and repair (LDAR) programme	Volatile organic compounds	A structured approach to reduce fugitive VOC emissions by detection and subsequent repair or replacement of leaking components. Currently, sniffing (described by EN 15446) and optical gas imaging methods are available for the identification of leaks. **Sniffing method**: The first step is the detection using hand-held VOC analysers measuring the concentration adjacent to the equipment (e.g. by using flame ionisation or photo-ionisation). The second step consists of enclosing the component in an impermeable bag to carry out a direct measurement at the source of the emission. This second step is sometimes replaced by mathematical correlation curves derived from statistical results obtained from a large number of previous measurements made on similar components. **Optical gas imaging methods**: Optical imaging uses small lightweight hand-held cameras which enable the visualisation of gas leaks in real time, so that they appear as 'smoke' on a video recorder together with the normal image of the component concerned, to easily and rapidly locate significant VOC leaks. Active systems produce an image with a back-scattered infrared laser light reflected on the component and its surroundings. Passive systems are based on the natural infrared radiation of the equipment and its surroundings.
Thermal oxidation	Volatile organic compounds	The oxidation of combustible gases and odorants in a waste gas stream by heating the mixture of contaminants with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water.

WORKING DRAFT IN PROGRESS

VOC diffuse emissions monitoring	Volatile organic compounds	Sniffing and optical gas imaging methods are described under leak detection and repair programme. Full screening and quantification of emissions from the installation can be undertaken with an appropriate combination of complementary methods, e.g. Solar occultation flux (SOF) or Differential absorption LIDAR (DIAL) campaigns. These results can be used for trend evaluation in time, cross-checking and updating/validation of the ongoing LDAR programme. Solar occultation flux (SOF): The technique is based on the recording and spectrometric Fourier Transform analysis of a broadband infrared or ultraviolet/visible sunlight spectrum along a given geographical itinerary, crossing the wind direction and cutting through VOC plumes. Differential absorption LIDAR (DIAL): This is a laser-based technique using differential absorption LIDAR (light detection and ranging), which is the optical analogue of radio wave-based RADAR. The technique relies on the back-scattering of laser beam pulses by atmospheric aerosols, and the analysis of the spectral properties of the returned light collected with a telescope.
Wet scrubbing	Dust, volatile organic compounds, gaseous acids (basic scrubber), gaseous alkalis (acid scrubber)	Wet scrubbing (or absorption) is a mass transfer between a soluble gas and a solvent – often water – in contact with each other. Physical scrubbing is preferred for chemical recovery, whereas chemical scrubbing is restricted to removing and abating gaseous compounds. Physico-chemical scrubbing takes an intermediate position. The component is dissolved in the absorbing liquid and involved in a reversible chemical reaction, which enables the recovery of the gaseous component.

WORKING DRAFT IN PROGRESS

6.6.2 Emissions to water

Technique	Typical pollutant(s) targeted	Description
Equalisation	All pollutants	Balancing of flows and pollutant loads by using tanks or other management techniques.
Neutralisation	Acids, alkalis	The adjustment of the pH of waste water to a neutral level (approximately 7) by the addition of chemicals. Sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) may be used to increase the pH; whereas, sulphuric acid (H_2SO_4), hydrochloric acid (HCl) or carbon dioxide (CO_2) may be used to decrease the pH. The precipitation of some substances may occur during neutralisation.
Oil-water separation	Oil/grease	The separation of oil and water and subsequent oil removal by gravity separation of free oil, using separation equipment or emulsion breaking, using emulsion breaking chemicals such as metal salts, mineral acids, adsorbents and organic polymers.
Coagulation and flocculation	Suspended solids	Coagulation and flocculation are used to separate suspended solids from waste water and are often carried out in successive steps. Coagulation is carried out by adding coagulants with charges opposite to those of the suspended solids. Flocculation is carried out by adding polymers, so that collisions of microfloc particles cause them to bond to produce larger flocs.
Electrocoagulation		The release of coagulants in the waste water to be treated is realised by electrolytically dissolving an electrode (i.e. anode, normally made of Fe or Al). When the electrode is dissolved, gas is released (i.e. O_2, H_2) which results in a flotation effect. If necessary, a (support) flocculant can be added to improve the flotation yield.
Filtration		The separation of solids from waste water by passing them through a porous medium, e.g. sand filtration, microfiltration and ultrafiltration.
Flotation		The separation of solid or liquid particles from waste water by attaching them to fine gas bubbles, usually air. The buoyant particles accumulate at the water surface and are collected with skimmers.
Membrane filtration		Microfiltration (MF) and ultrafiltration (UF) are membrane processes that retain and concentrate on one side of the membrane substances such as suspended particles and colloidal particles contained in waste waters.
Sedimentation		The separation of suspended particles by gravitational settling.

WORKING DRAFT IN PROGRESS

Adsorption	Soluble non-biodegradable or inhibitory contaminants, e.g. organics	Adsorption is the transfer of soluble substances (solutes) from the waste water phase to the surface of solid, highly porous particles (the adsorbent). The adsorbent most commonly used is activated carbon.
Distillation/rectification	Soluble non-biodegradable or inhibitory contaminants	Distillation or rectification is the separation of waste water from its contaminants by transferring them into the vapour phase. The enriched vapour phase is condensed afterwards.
Chemical precipitation	Soluble non-biodegradable or inhibitory contaminants, e.g. metals, phosphorus	The conversion of dissolved pollutants into insoluble compounds by adding chemical precipitants. The solid precipitates formed are subsequently separated by sedimentation, air flotation or filtration. If necessary, this may be followed by microfiltration or ultrafiltration.
Chemical oxidation	Soluble non-biodegradable or inhibitory contaminants, e.g. nitrite, cyanide	Chemical oxidation is the conversion of pollutants by chemical oxidising agents other than oxygen/air, or by bacteria, into similar but less harmful or hazardous compounds and/or to short-chained and more easily degradable or biodegradable organic components. Chemical oxidation is also used to degrade organic compounds causing odour, taste, colour and for disinfection purposes
Chemical reduction	Soluble non-biodegradable or inhibitory contaminants, e.g. chromium (VI)	Chemical reduction is the conversion of pollutants by chemical reducing agents into similar but less harmful or hazardous compounds
Evaporation	Soluble non-biodegradable or inhibitory contaminants	Evaporation of waste water is a distillation process where water forms the vapour phase, leaving the concentrate as bottom residue to be disposed of. The volatile steam is collected in a condenser and the condensed water is, if needed after subsequent treatment, recycled.
Ion exchange process	Soluble non-biodegradable or inhibitory contaminants, e.g. metals	Ion exchange is the removal of undesired or hazardous ionic constituents of waste water and their replacement by more acceptable ions from an ion exchange resin, where they are temporarily retained and afterwards released into a regeneration or backwashing liquid.
Nanofiltration and reverse osmosis	Soluble non-biodegradable or inhibitory contaminants	A membrane process is the permeation of a liquid through a membrane, to be segregated into permeate that passes through the membrane and concentrate that is retained. The driving force of this process is the pressure difference across the membrane. Nanofiltration and reverse osmosis membranes can hold back all particles down to the size of organic molecules and even ions.

WORKING DRAFT IN PROGRESS

Stripping	Soluble non-biodegradable or inhibitory contaminants, e.g. hydrogen sulphide (H_2S), ammonia (NH_3), adsordable organically bound halogens (AOX), hydrocarbons	The removal of volatile pollutants from waste water by bringing them into contact with a high volume flow of a gas current in order to transfer them to the gas phase. The pollutants are removed from the stripping gas in a downstream treatment such as condensation and phase separation, and may potentially be reused.
Activated sludge process	Biodegradable organic compounds	The biological oxidation of dissolved organic substances with oxygen using the metabolism of microorganisms. In the presence of dissolved oxygen (injected as air or pure oxygen), the organic components are transformed into carbon dioxide, water or other metabolites and biomass (i.e. the activated sludge). The microorganisms are maintained in suspension in the waste water and the whole mixture is mechanically aerated. The activated sludge mixture is sent to a separation facility from where the sludge is recycled to the aeration tank.
Anaerobic treatment		Anaerobic waste water treatment converts the organic content of waste water, with the help of microorganisms and without entry of air, to a variety of products such as methane, carbon dioxide, sulphide, etc.
Membrane bioreactor		A combination of activated sludge treatment and membrane filtration. Two variants are used: a) an external recirculation loop between the activated sludge tank and the membrane module; and b) immersion of the membrane module into the aerated activated sludge tank, where the effluent is filtered through a hollow fibre membrane, the biomass remaining in the tank.
Nitrification/denitrification	Total nitrogen, ammonia	A two-step process that is typically incorporated into biological waste water treatment plants. The first step is the aerobic nitrification where microorganisms oxidise ammonium (NH_4^+) to the intermediate nitrite (NO_2^-), which is then further oxidised to nitrate (NO_3^-). In the subsequent anoxic denitrification step, microorganisms chemically reduce nitrate to nitrogen gas.

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6.6.3 Sorting techniques

Technique	Description
Air classification	Air classification (or air separation, or aeraulic separation) is a process of approximate sizing of dry mixtures of different particle sizes into groups or grades at cut points ranging from 10 mesh to sub-mesh sizes. Air classifiers (also called windshifters) complement screens in applications requiring cut points below commercial screen sizes, and supplement sieves and screens for coarser cuts where the special advantages of air classification warrant it.
All metal separator	Metals (ferrous and non-ferrous) are sorted by means of a detection coil in which the magnetic field is influenced by metal particles, linked to a processor that controls the air jet for ejecting the materials that have been detected.
Ballistic separation	Materials are separated in a ballistic separator, or ballistic sieve, composed of a series of parallel paddles, with orbital motion, arranged with a variable angle with respect to the horizontal. The materials fed into the ballistic separator, having different physical characteristics (weight, shape, surface…), assume different trajectories following the orbital movement of the paddles.
Electromagnetic separation of non-ferrous metals	Non-ferrous metals are sorted by means of eddy current separators. An eddy current is induced by a series of rare earth magnetic or ceramic rotors at the head of a conveyor that spins at high speed independently of the conveyor. This process induces temporary magnetic forces in non-magnetic metals of the same polarity as the rotor, causing the metals to be repelled away and then separated from the other feedstock.
Manual separation	Material is manually separated by means of visual examination by staff on a picking line to either selectively remove a target material from a general waste stream, or to remove contamination from an output stream to increase purity. This technique generally targets recyclables (glass, plastic, etc.) and any contaminants, hazardous materials and oversize materials such as WEEE. Manual separation takes place within a covered cabin isolated from the rest of the mechanical treatment hall, to limit staff exposure, e.g. to dust and particulates, vehicle movements, and vibration.
Magnetic separation	Ferrous metals are sorted by means of a magnet which attracts ferrous metal materials. This can be carried out, for example, by an overband magnetic separator, or a magnetic drum.
Near infrared spectroscopy (NIS)	Materials are sorted by means of a near infrared sensor which scans the whole width of the belt conveyor and transmits the characteristic spectra of the different materials to a data processor which controls an air jet for ejecting the materials that have been detected.
Sink-float tanks	Solid materials are separated into two flows by exploiting the different material densities..
Size separation	Materials are sorted according to their particle size. This can be carried out by drum screens, linear and circular oscillating screens, flip-flop screens, flat screens, tumbler screens and moving grates.
Vibration table	Materials are separated according to their density and size, moving (in slurry in the case of wet tables, or wet density separators) across an inclined table, which oscillates backwards and forwards.

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X-ray systems	Metal composites are sorted according to various material densities, halogen components, or organic components, with the aid of x-rays.

6.6.4 Management techniques

Accident management plan	The accident management plan is part of the EMS (see BAT 1) and identifies hazards posed by the plant and the associated risks and defines measures to address these risks. It considers the inventory of substances present or likely to be present which could have environmental consequences if they escape.
Residue management plan	A residue management plan is a set of measures aiming to 1) minimise the generation of residues arising from the treatment of waste; 2) optimise the reuse or regeneration of the residues; and 3) ensure the proper disposal of internal residues or waste

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7 EMERGING TECHNIQUES

From ex-Chapter 6

~~Emerging technique is understood in this document as a novel technique that has not yet been applied in any industrial sector on a commercial basis.~~
Article 3(14) of Directive 2010/75/EU defines an ‘emerging technique’ as a 'novel technique for an industrial activity that, if commercially developed, could provide either a higher general level of protection of the environment or at least the same level of protection of the environment and higher cost savings than existing best available techniques'. This chapter contains those techniques that may appear in the near future and that may be applicable to the waste treatment sector.

Note for TWG: this chapter does not contain those emerging techniques which aim only to improve a given waste treatment process (for instance to improve productivity or output quality) without leading to a higher general level of protection of the environment for the process concerned (for instance reduction of emissions or residues from the process).

[2, Concawe 1996] [21, Viscolube 2002] [17, Eklund, B.; Thompson, P.; Inglis, A.; Wheeless, W., et al. 1997] [25, UK Department of the Environment 1991] [58, VDI and Dechema 2002] [62, Rogut, S. 2003] [70, Greenpeace 1998] [78, Eucopro 2003] [88, UBA Germany 2003] [94, Magistrelli et al. 2002] [98, WT TWG 2004][100, WT TWG 2004] [102, UNEP 2004]

7.1 General techniques

7.1.1 Combination of vibration and air separation

TWG, please confirm the technique described below is still an emerging technique

Description
The basic principle is an air separation table, based on a combination of vibration and air sorting technology.

Technical description
The heavy fractions are conveyed upwards by the vibration and discharged at the upper end of the separation table. Lighter components are suspended by the air introduced through the screen mat and float downwards to the other end of the system (see Figure 7.1).

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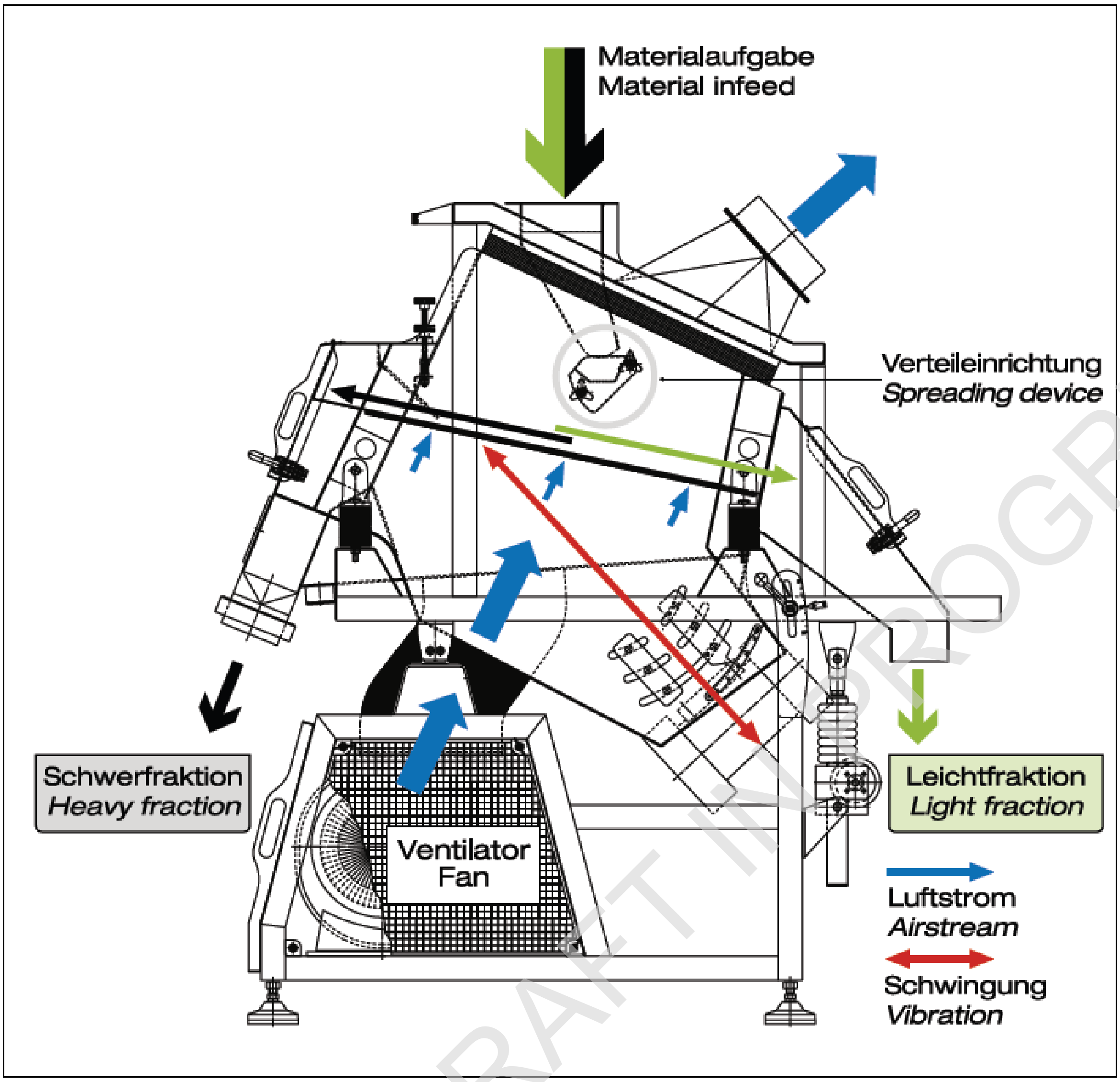

Figure 7.1: Basic principle of the separation table, based on a combination of vibration and air technology

The basic principle is already applied for several applications:

- copper enrichment of dust resulting from shredding of cables (10–250 µm);
- extraction of chromite for reuse in the foundry industry.

Adaptation of the described technique for the following applications is considered an emerging technique:

- separation of rubber and plastic in windows fractions;
- demetallisation of wood chips;
- mechanical treatment of dusts (de-stoning, demetallisation);
- separation of dry household waste (heavy/light density separation);
- separation of construction waste (heavy/light density separation);
- separation of minerals (primary resources) (heavy/light density separation.

Achieved environmental benefits
No water usage.

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Potential performance compared to existing best available techniques

The new applications of the technique are focused (at least partially) on substituting existing wet separation techniques, like pulsating jigs or other gravity separation processes. The major benefit is that there is no water usage and therefore no need for waste water and sludge treatment.

Preliminary cost-benefit estimate

Costs of the technique are derived from existing installations performing copper enrichment and are described in Table 7.1

Table 7.1: Economics associated with the combination of vibration and air sorting

Type of costs	Costs	Comments
Investment/capital costs:		
Machine	EUR 40 000	
Auxiliary equipment (screening, conveying)	EUR 150 000	
Dedusting	EUR 25 000	Only for specific applications, often not necessary because a central dedusting unit is installed.
Operation and maintenance costs (labour utilities, consumables, etc.)		
Energy	5 kW	
Labour	1 supervisor	
Maintenance	EUR 5 000 per year	
Revenues, avoided costs and benefits	No or reduced cost for waste water and sludge treatment compared to wet density separation techniques	
Cost-determining factors	Feed rate, material preparation, particle sizes, difference of gravity	

Technical considerations related to applicability

Table 7.2 shows the application limits of the technique.

Table 7.2: Application limits and restrictions of the combination of vibration and air sorting

Parameter	Limit/Restriction
Particle size	< 10 mm
Throughput	< 8 m^3/h (depending on material)
Humidity of material	< 1 %

Cross-media effects

TWG, please provide information

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Driving force for implementation
No investment needed for treatment of waste water and sludges.

Indication of when the technique might become commercially available'
As described, some forms of the application already exist. New applications like separation of window fractions or wood chips may be applied with minimum modifications within one year at the maximum. Applications for household waste and mineral processing with higher feed rates per machine are at the R&D stage and should be launched in 2016/2017.

Example plants
Austrian reference plants for the described technique are SMK and Schaufler (copper recovery from cable scrap). One prototype exists for wood chips and one for window treatment. Another prototype exists for the separation of rubber and sand for the recycling of stable floors.

Reference literature
[156]

WORKING DRAFT IN PROGRESS

7.2 Mechanical treatments

7.2.1 Mechanical treatment in shredders of metal waste

[107, Mech. subgroup 2014]

TWG, please provide more information on the following emerging techniques by using the 10-heading structure of the BAT candidates

7.2.1.1 Activated carbon

Activated carbon filters belong to adsorption filtration technology, by means of which gases and vapours are adsorbed independently on the surface of solid materials due to physical or chemical reactions. The quantity of adsorbed material depends on the surface and surface structure. Activated carbon has a very large internal surface and is able, by the use of different coatings, to bind all harmful gases except for carbon monoxide and carbon dioxide.

If the basic conditions are right, activated carbon tends to auto-ignite. Furthermore, dust fractions in the exhaust gas flow can clog the filter bed prematurely, i.e. before its intake capacity has been exhausted, making its replacement necessary.

Status: The activated carbon filter technique has been tested for some months in two metal shredder plants in Europe after different preliminary treatments of the air flow for protection against deflagration risk, elimination of dust and/or heating to reduce humidity content.

7.2.1.2 Ultrafiltration

The principle of such an automated filtration system originated for use by paint shops and comprises cells with PTFE membrane filtration, with prior absorption of PCBs and VOCs by a porous additive. The additive prevents the VOCs and PCBs from arriving directly at the membrane. Nevertheless, the surface of the membrane is required to capture residual chemicals. The additive is regenerated in a fluidised bed and, when no longer suitable to be returned to the system, captured in big bags for disposal or energy recovery. This system is compatible with the first cyclone flow. Six cells would be necessary to handle an airflow of some 60 000 m^3/hr.

Status: This technology is used in one shredder only, in Belgium. The ultrafiltration increases production costs by 3 % to 5 %.

7.2.1.3 Dissolution of VOCs

VOCs come from oil, grease and wax present in the shredder infeed. In the past these VOCs came from EoLVs, nowadays EoLVs are depolluted with oil fuel and other removed liquid. It follows that enforcing depollution prevents most sources of VOCs from entering the shredder in the first place. EoLVs account for 30 % of scrap, the remainder is mixed scrap, and more mixed scrap means lower VOCs. VOCs in mixed scrap can come from residues in aerosol cans, paint tins and oil residues. Other sources can be plastics, rubber and hardened glues.

There are several technical approaches for VOC removal from shredder air systems. In principle, there are four solutions:

- liquidation of VOCs by forced cooling;
- adsorption of VOCs by activated carbon;
- destruction of VOCs in regenerative thermal oxidisers;
- dissolution of VOCs in liquids.

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The first three have been proven to be uneconomical. TWG, please confirm However, dissolution of VOCs in wash water can easily be integrated into the current filter configuration since the dust removal already includes a wet scrubber.

The set-up comprises a modified wet Venturi scrubber and a flue-gas scrubber followed by water treatment through flotation (Figure 7.2). Tests have been conducted and have resulted in collection of VOCs in the flotation agent residue, and, depending on the input, more than 60 % of VOCs were removed. Peak emissions can therefore be reduced. Investment costs for the VOC reduction are in the order of EUR 500 000 per installation. The increase in operating costs is negligible, whilst residues for disposal increase by 1–2 m^3 per day and may be disposed of with other residues. The quality of the wash water is substantially improved.

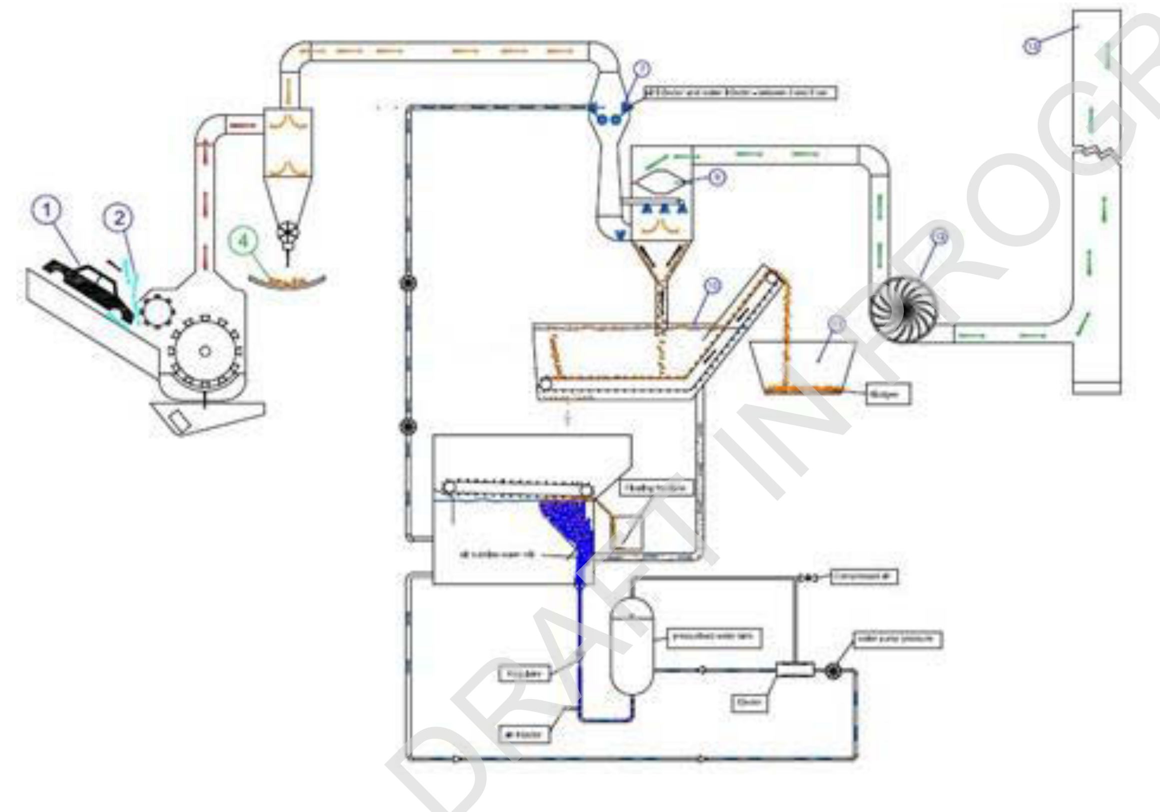

Figure 7.2: Dissolution of VOCs, Patent METSO N° EP 2 552 416 A1

TWG, please provide the original file of the figure

Status: The dissolution of VOCs is still in the test phase concerning water additives, water cleanliness and expected emission limit performance.

7.2.1.4 VOC abatement of exhaust air from shredders by ionisation in combination with activated carbon adsorption

Description
The technique consists of a combination of ionisation (oxidation of organic molecules by injection of ionised air) and activated carbon adsorption for abatement of VOC emissions.

It is usually combined with the continuous monitoring of VOC emissions.

Technical description
Fresh air is ionised in a chamber where electrodes generate a strong electrical field. The ionisation chamber is equipped with a pre-filter (filter class G4) to allow sufficiently low dust levels in the extracted air.

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In a subsequent (mixing) chamber the ionised air stream is combined with the raw gas stream from the shredder (15–20 % ionised air compared to the total exhaust air), which has passed through a filter to ensure the required dust levels. Finally the air passes through an activated carbon filter. Regeneration of the activated carbon is performed by loading it with ionised air only, to oxidise (partly) the adsorbed molecules, after each operational period of the shredder (at night, when no exhaust air stream is generated).

Figure 7.3 shows a diagram of the technique as tested in the pilot plant.

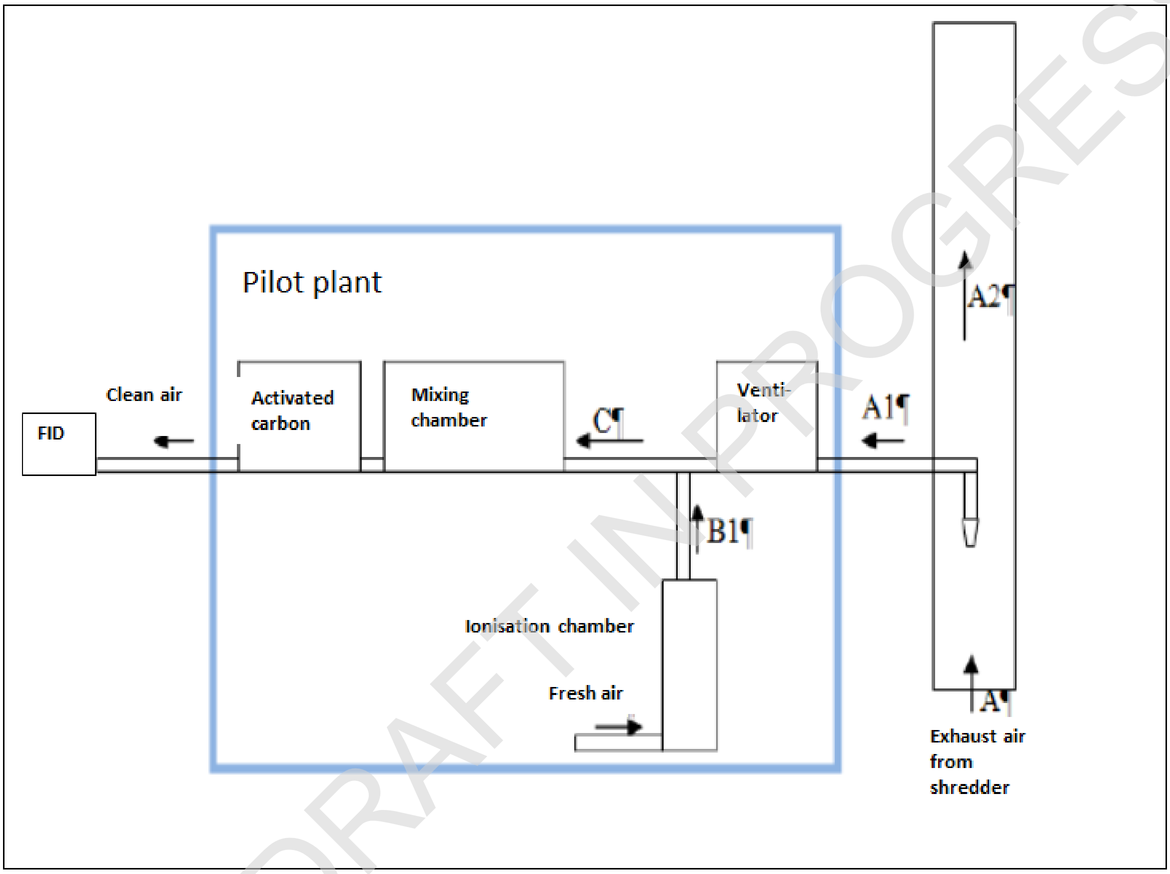

Figure 7.3: Diagram of the pilot installation performing ionisation and activated carbon adsorption

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Indication of when the technique might become commercially available

The technique described was tested in a one-month pilot test at an Austrian shredder plant of Loacker Recycling GmbH in 2014, and based on the results a project is currently under way for the realisation of a large-scale filter unit at the plant. Currently, optimisation with regard to the service time of the activated carbon filter is performed. At the German shredder plant of SRP Saarländische Rohprodukte GmbH the technique is currently being tested at full scale.

Potential performance compared to existing best available techniques

- Reduced VOC emissions: abatement efficiency for VOC has been found to be > 95 %.
- Reduced odour emissions: no measurable odour after the filter.
- Reduced emissions of particulates: considerably lower levels compared to state-of-the-art exhaust air treatment using cyclones and wet scrubbers.

Cross-media effects

- Increase in energy use and use of raw materials (activated carbon).
- Generation of ozone in the electrical field of the ionisation chamber. If it is not completely reacted in the activated carbon unit it may lead to ozone emissions.
- Generation of hazardous waste – saturated activated carbon to be treated.

Preliminary cost-benefit estimate

The investment costs for a typical shredder plant are estimated at approximately EUR 1 million. Cost-determining factors are the applied dedusting technique, air flows and the type of explosion decoupling.

Driving force for implementation
Local emission requirements.

Example plants
The technique has been tested in a one-month pilot test at the Austrian shredder plant of Loacker Recycling GmbH and is applied at full scale by the German shredder plant of SRP Saarländische Rohprodukte GmbH.

Reference literature
[156]

7.2.2 Mechanical treatment in shredders of VFC/VHC-containing equipment

TWG, please provide information on the following emerging techniques by using the 10-heading structure of the BAT candidates

7.2.2.1 Thermal oxidation of CFCs

Description
The aim of thermal oxidation is to destroy oxidising pollutants in the air.

Technical description
According to the IC (impact catalyst) process, the gas purification takes place in two catalytic converters connected in series. The hydrocarbon compounds such as isobutene and pentane are oxidised in the first converter to form water and carbon dioxide. In the second reactor, the CFCs are converted into the components hydrogen chloride (HCl), hydrogen fluoride (HF), and carbon dioxide (CO_2). As the process in the first reactor is exothermic, it simultaneously acts as a preheater for the second catalytic converter stage. Similarly, the thermal energy in the gases emitted from the second reactor is used to preheat the untreated gases before they enter the first reactor.

Achieved environmental benefits
Reduction of energy consumption.

Environmental performance
This system lowers the overall energy requirements of the plant. This process layout even results in the catalytic oxidation becoming fully self-sufficient in terms of energy once the proportion of pentane refrigeration units passes a certain threshold. Furthermore, due to the reduced energy requirements, the IC process produces around 10–20 times less CO_2 emissions (depending on the proportion of pentane refrigeration units) than conventional freeze condensation.

Cross-media effects

TWG, please provide information

Economics

TWG, please provide information

Technical considerations related to applicability

WORKING DRAFT IN PROGRESS

TWG, please provide information

Driving force for implementation

Reduction of energy consumption.

Example plants

TWG, please provide information

Reference literature

[126, Mech. subgroup 2014]

WORKING DRAFT IN PROGRESS

7.3 Biological treatments

7.3.1 Composting

7.3.1.1 Monitoring of air emissions - Inverse dispersion technique using Lagrangian modelling

Description
Quantification of the complete fugitive emissions from a full-scale composting plant by an inverse dispersion technique using concentration information at points upwind and downwind of the source combined with meteorological data and an atmospheric dispersion model.

Technical description
The technique can determine emission rates from well-defined source areas of any shape over large spatial and temporal scales. The concentration measurement could be a point or a line average obtained with closed- or open-path analysers. Typically, line sensors are used since they provide a better average over the source plume and reduce sensitivity to changes in wind direction. The acquisition of path-integrated concentration data can be accomplished with several types of ground-based optical remote sensing (ORS) instruments covering spectral ranges from ultraviolet to infrared, such as open-path Fourier transform infrared (OP-FTIR), ultraviolet differential absorption spectroscopy (UV-DOAS) or open-path tunable diode laser spectroscopy (OP-TDLS). A three-dimensional ultrasonic anemometer provides key wind and turbulence parameters needed for the dispersion model.

The inverse dispersion technique uses atmospheric dispersion models to calculate the theoretical relationship between a source emission rate (e.g. composting plant) and downwind concentration (the ‘C–Q relationship’) at a given state of the atmosphere. The key element of this method is an accurate and user-friendly dispersion model. Lagrangian stochastic models provide the most natural and accurate means of calculating atmospheric dispersion. Such models can be employed in forward or backward mode to derive C-Q (sensor-source) relationships. In the forward case, individual particles are released from a prescribed source area, and the particles dispersion is modelled with a stochastic turbulent flow field (e.g. LASAT - Lagrangian Simulation of Aerosol Transport; Janicke Consulting, 2011). In the backward case, the same formalism is applied, but the particles are modelled backward in time as they travel upwind from the concentration sensor. By analysing the backward trajectories, the locations where the particles touch down within the source area are recorded (e.g. Windtrax – bLS dispersion model; Flesch et al., 1995). The choice of an appropriate dispersion model depends, among others, on the site conditions (e.g. complexity of buildings and topography). While the bLS dispersion model proved to be a particularly good choice for calculating the C–Q relationship for ground-level sources and for concentration observations taken near the source in ideal conditions, LASAT includes a mass-consistent diagnostic wind field model which takes into account turbulence in complex terrain and recirculation effects around buildings.

The following aspects should be considered when applying this method.

- The inverse dispersion technique to estimate the source strength depends on a good description of atmospheric dispersion, which is known to be difficult in unstable conditions.
- The concentration should be measured far enough downwind of a plant to avoid wind turbulence, but close enough so as to meaningfully measure concentration rise. The threshold distance should be more than 10 times the height of the dominant wind obstacle h.

Achieved environmental benefits
Quantification of the complete fugitive emissions from a full-scale composting plant.

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Environmental performance and operational data
Emission rates can be quantified with an uncertainty of less than 10–20 % (Flesch et al., 2004, 2005). Until now, the inverse dispersion technique has been mainly used in the field of research. However, it is on its way to becoming a standardised method, e.g. for landfills (associate standard VDI 4285). There is also a guide available for its application at biogas plants (Liebetrau et al., 2013).

It should be mentioned that there is still a need for research on the limits of the dispersion models for specific applications. Furthermore, the measurements and modelling require appropriate technical expertise.

Economics

TWG, please provide information

Technical considerations related to applicability
The method has been used to characterise fugitive emissions from large area sources including landfills (Zhu et al., 2013), agricultural operations (Flesch et al., 2005; McGinn et al., 2006, 2011), biogas plants (Flesch et al., 2011; Hrad et al., 2014) and full-scale open windrow composting (Hrad et al., 2014b).

Cross-media effects
None identified.

Driving force for implementation
Quantification of emission rates with reduced uncertainty.

Example plants

TWG, please provide information

Reference literature
[Subgroup BIO, 157]

- Flesch, T.K., Wilson, J.D., Yee, E. (1995). Backward-time Lagrangian stochastic dispersion models, and their application to estimate gaseous emissions. J. Appl. Meteorol. 34, 1320–1332.
- Flesch, T.K., Wilson, J.D., Harper, L.A., Crenna, B.P. & Sharpe, R.R. (2004). Deducing ground-air emissions from observed trace gas concentrations: a field trial. Journal of Applied Meteorology, 43, 487–502.
- Flesch, T. K., Wilson, J. D, Harper, L. A. & Crenna, B. P (2005). Estimating gas emissions from a farm with an inverse-dispersion technique. Atmospheric Environment, 39, 4863 – 4874.
- Flesch, T. K., Dejardins, R. L. & Worth, D. (2011). Fugitive methane emissions from an agricultural biodigester. Biomass and Bioenergy, 35, 3927 – 3935.
- Hrad, M., Piringer, M., Kamarad, L., Baumann-Stanzer, K., Huber-Humer, M. (2014). Multisource emission retrieval within a biogas plant based on inverse dispersion calculations—a real-life example, Environmental Monitoring and Assessment, pp. 1-12.
- Hrad, M., Binner, E., Piringer, M., Huber-Humer, M. (2014b). Quantification of methane emissions from full-scale open windrow composting of biowaste using an inverse dispersion technique. Waste Management (2014), http://dx.doi.org/10.1016/j.wasman.2014.08.013 (in press).
- Janicke Consulting, (2011). Dispersion Model LASAT Version 3.2 Reference book.
- Liebetrau, J., Pfeiffer, D., Thrän, D. (Hrsg.) (2013). Messmethodensammlung Biogas – Methoden zur Bestimmung von analytischen und prozessbeschreibenden

WORKING DRAFT IN PROGRESS

Parametern im Biogasbereich. Schriftenreihe des BMU-Förderprogramms, Energetische Biomassenutzung“ Band 7, 2. Auflage, Available online under: https://www.energetische-biomassenutzung.de/fileadmin/user_upload/Downloads/Ver%C3%B6ffentlichungen/07_Messmethodensamm_Biogas_web.pdf (30.09.2014).

- McGinn, S.M., Flesch, T.K., Harper L.A. & Beauchemin, K.A. (2006). An approach for measuring methane emissions from whole farms. J Environ Qual, 35, 14-20.
- McGinn, S.M., Turner, D., Tomkins, N., Charmley, E., Bishop-Hurley, G. & Chen, D. (2011). Methane Emissions from Grazing Cattle Using Point-Source Dispersion. J. Environ. Qual., 40, 22–27.
- VDI 4285: BLATT 1: Messtechnische Bestimmung der Emissionen diffuser Quellen – Grundlagen, 2005.
- Zhu, H., Letzel, M. O., Reiser, M., Kranert, M., Bächling, W., Flassak, T. (2013). A new approach to estimation of methane emission rates from landfills. Waste Management 33, 2713 – 2719.

7.3.1.2 Container composting

TWG, please confirm this is an emerging technique.

Description

Container composting is a composting method that takes place in closed containers allowing a natural supply of oxygen (aerobic process). The method may be applied to organic domestic waste, sewage sludge, garden waste, livestock manure and other organics.

Technical description

The plant consists of a covered space with storage facilities for the different waste fractions so that odours and uncontrolled water ingress can be avoided.

A front-loader loads the different fractions into a mixing plant where they are layered. Any impurities such as stones and plastics are removed manually. The mixing plant is equipped with load cells that keep track of how much of each fraction is entering the mixer so as to optimise the aerobic biological process. A bacterial culture is added to the mixture to accelerate and improve the biological process. Depending on the desired bio-compost to be produced, additives are added, for example in the form of structural material, straw, bio-ash or sand.

A conveyor leads the blended material into a container where the actual composting takes place. Composting can be done under a roof or in the open air.
The container is equipped with top tilt or lid, ventilation in the gable, and provided with a pyramid-shaped double perforated plate bottom. The structure makes it possible to let the air coming in through the tube at the bottom pass freely through the material without the use of energy. A wireless temperature probe records the temperature every half hour. The temperature is about 60 °C after a two-day stay.

TWG, please provide a schema of the plant

After approximatively 30 days, the compost is sanitised, by maintaining the temperature at 70 °C for one hour during the process.

Then the compost is piled in windrows for another 30 days before it is analysed and declared ready for marketing as bio-compost - an organic fertiliser and soil conditioner. The total processing time is typically two months. The process is shown Figure 7.4 below.

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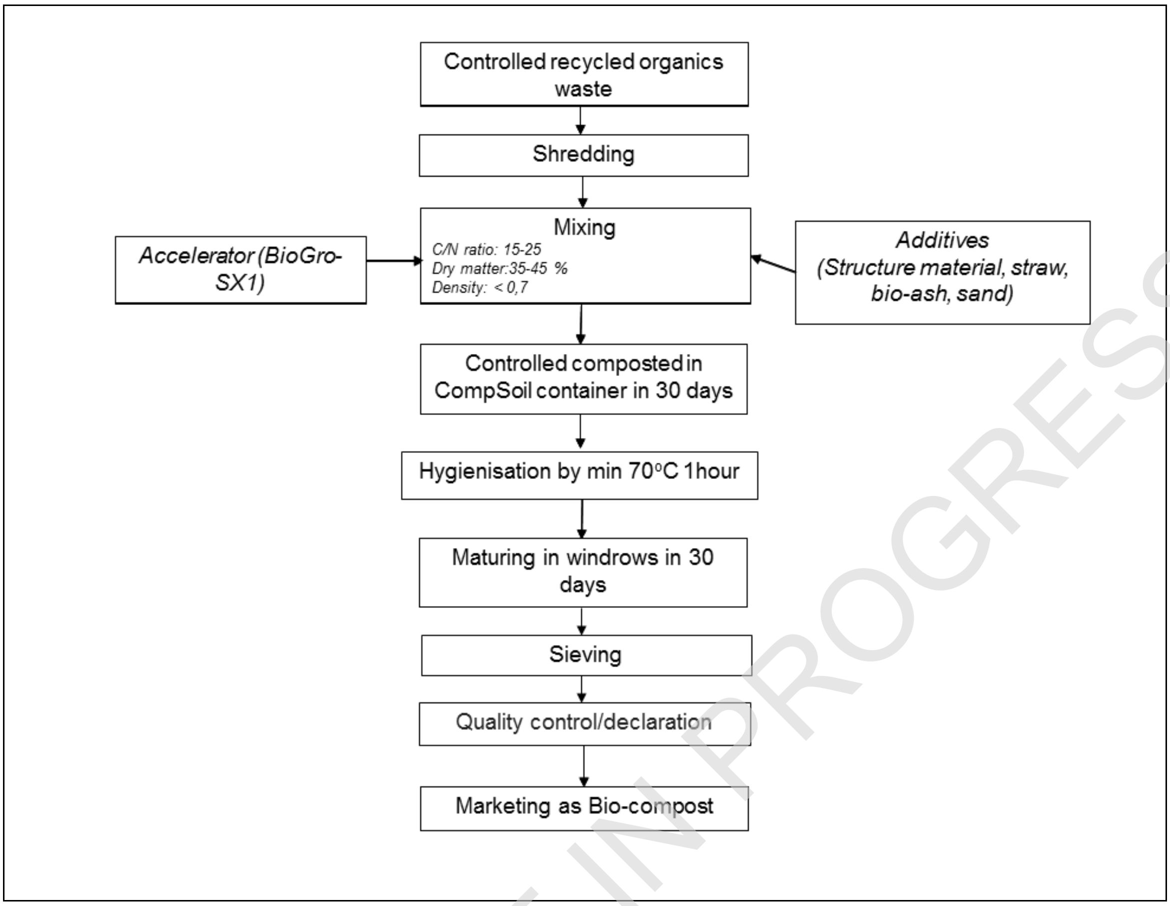

Figure 7.4: Compsoil process

Potential performance compared to existing BAT (environment, use of resources, operational data, etc.)
The aerobic degradation by microorganism is accelerated by use of a bacterial culture so the processing time is much shorter than windrow composting (two months compared to four months).

Compared to composting in windrows, the odour emissions are very low: full-scale measurement has shown 0.66 OU_E/s per tonne on average. The loss of nitrogen in container composting is lower than in windrow composting (6 % compared to 25 %).

The energy consumption is much lower than composting in windrows or box/tunnel composting: 25 kWh per tonne of waste input compared to 30 kWh for windrow composting.

The process allows the breakdown of xenobiotics, pharmaceuticals and personal care products by aerobic degradation.

Preliminary cost-benefit estimate
The operation cost is less than that of windrow composting (DKK 150 versus DKK 300 per tonne of input waste).

Applicability
The method is based on well-known processes and the size of the plant can be adapted continuously as needed by investment in containers and space for the plant.

Cross-media effects
The composting process is a net consumer of energy to run machinery, etc.

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Driving force for implementation

- Environmental benefits.
- Reduction of landfilling and incineration of waste.
- Recycling of organics in a biological circuit.

Timescale for availability

Application for funds from MUDP 2014 for Technological development and test and demonstration of technology. The technique is expected to be available mid-2015. TWG please confirm.

Example plants

CompSoil A/S, Trinderupvej 10, 9500 Hobro, Denmark.

Reference literature

- Petersen P.H. and Clowes L. (2000). Nedbrydning af organiske miljøfremmede stoffer ved kompostering. Vand og Jord, 7, no. 4, 151-155
- Andersen, F. et. al. Fate of pharmaceuticals and personal care products (PCPs) by composting of biosolids. Proceedings from Sardinia 2009.

[184, Danish EPA]

7.3.2 Anaerobic treatment

7.3.2.1 Dry anaerobic digestion of organic household waste

Description

Removal, collection and recycling of nitrogen and phosphorus from the waste water of a dry anaerobic digestion (DAD) plant treating unsorted municipal solid waste.

Technical description

A new, compact plant (AMRECO) was developed for the chemical removal and recycling of nitrogen and phosphorus from liquid from a combined MSW biogas/composting plant in Thailand, based on the dry anaerobic process (DAD). The process is shown in Figure 7.5 below.

Removal of nitrogen and phosphorus is based on magnesium ammonium phosphate (MAP) precipitation.

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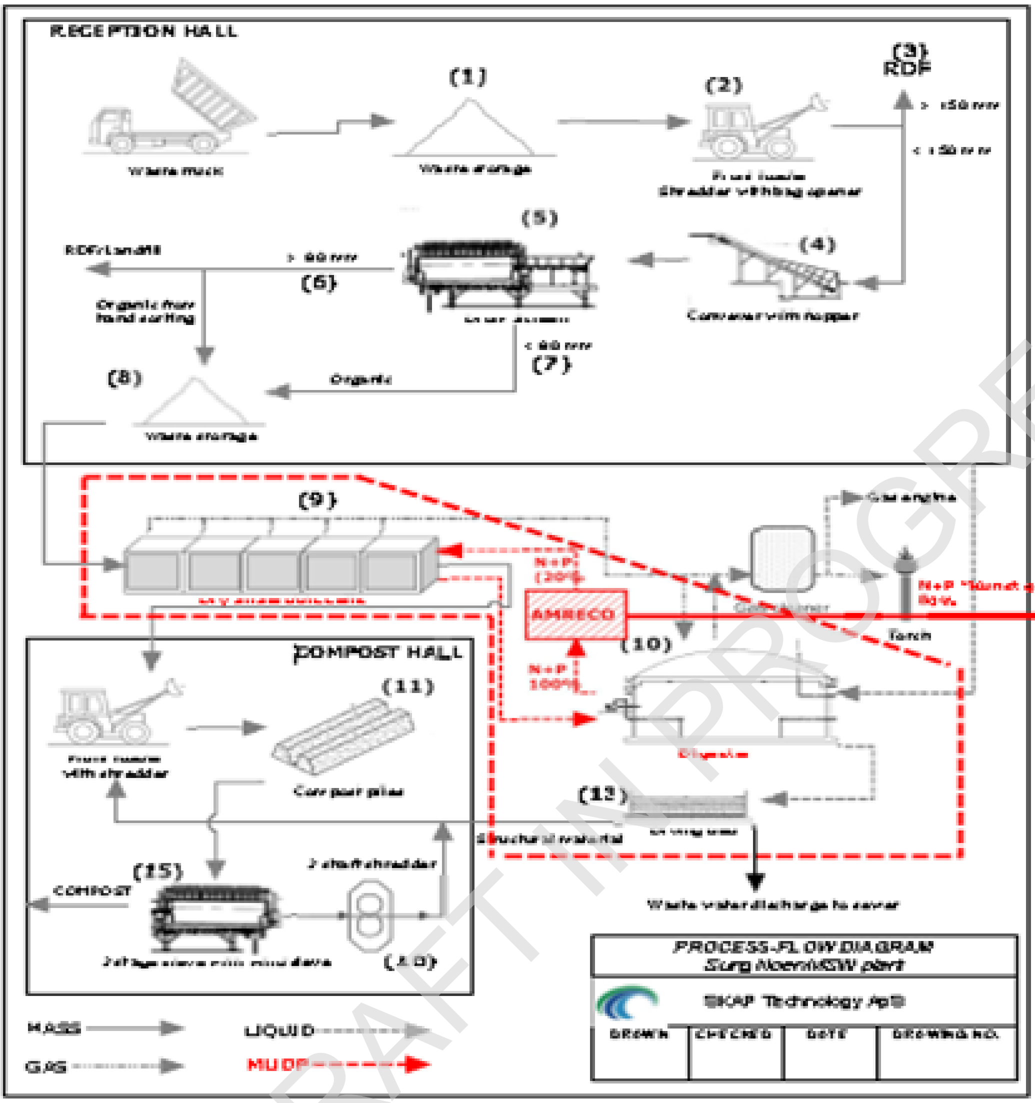

TWG, please provide the original file of the figure

Figure 7.5: The DAD process

The result will be improved gas yield and recovery and conversion of nutrients from the waste to a valuable 'clean' fertiliser. The purposes of the technique are:

1. to optimise the biogas production by reducing the N load on the anaerobic process;
2. to recover/utilise N and P by a new chemical precipitation process;
3. to produce plant and process test documentation that can be used for cleaning/regeneration of NP from other types of fluids too (waste water, landfill leachate, etc.)

Compared to traditional wet anaerobic biogas plants, DAD plants have low requirements for the physical structure and composition of the waste, making this process optimal for the digestion of unsorted municipal waste.

Environmental performance and operational data
The environmental effects are as follows:

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1. Increased biogas production due to the reduced inhibiting effect of ammonia. The biogas production target of the pilot plant is 1.1 million m^3/year. An increased yield of 10 % approximately, i.e. 100 000 m^3 of biogas/year (60 TOE/year) is expected for this plant.
2. Extraction of N and P from water. The estimated annual quantities from the pilot plant are 15–20 tonnes of nitrogen and 3–5 tonnes of phosphorus.

Similarly, environmental benefits are expected for sludge treatment plants. A high nitrogen concentration in the waste water from anaerobic sludge digestion tanks often leads to excessive loads on the existing biological treatment, and may complicate the plants' biological treatment process. Removing nitrogen and phosphorus from waste water can increase the capacity of the waste water treatment and may be a serious alternative to a plant expansion. It also means the collection of nitrogen and phosphorus instead of 'evaporation' of nitrogen to the atmosphere.

The technique is not yet commercially available and a final test of the pilot plant is planned for 2015.

Technical considerations related to applicability

TWG, please provide information

Cross-media effects

TWG, please provide information

Driving force for implementation

The objective of this project is also to be cost-efficient. AMRECO used with other anaerobic process technologies (e.g. UASB) will be able to reduce the cost associated to waste water treatment, e.g. within the food industry.
Recovery of nitrogen and phosphorus from waste streams is also a driving force.

Economics

TWG, please provide information

Example plants

Demonstration plant AMRECO, Thailand.

Reference literature

- http://skaptech.dk/da/amreco-3/anvendelse/8-category-all.html
- SKAP Technology, Denmark: http://skaptech.dk/da/

[Subgroup BIO, 157]

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7.4 Physico-chemical treatments

From ex-Chapter 6

7.4.1 Online analysis

TWG, please confirm this technique is still "emerging".

Description

The technique of online analysis is one of the latest developments in the field of analysis and quality assurance. It can be used for all applications in the preparation of solid recovered fuels.

Technical description

Online analysis is used for crushed and/or non-crushed materials, with automatic elimination of materials that do not comply with the quality criteria, e.g. for solid recovered fuels - especially when the chlorine and/or bromine values are exceeded.

The ~~mode of function~~ technique is based on a new high-speed X-ray fluorescence analysis ~~with high speed analysis~~, ~~so that~~ whereby a large quantity of crushed or uncrushed materials (it depends on technical performance and ~~determination~~ definition) ~~per hour~~ can be analysed and/or detected every hour and can be automatically eliminated by overdrawing nominal stock.

The configuration of the measuring unit and/or analyser takes place directly above a conveyor. A material stream as uniform as possible is directed under the measuring unit and/or analyser and is analysed and/or measured.

If a limit value is exceeded an electronic signal (digital or analogue) follows. ~~There upon controlled through~~ Using a software and/or electronics unit, the objectionable material is automatically (mechanically, hydraulically, pneumatically, electrostatically or magnetically) discharged. The measuring unit and/or analyser can be equipped with one or more X-ray tubes or with one or more detectors.

As an additional control and quality assurance for the material input, a hand-held unit can be used too. The hand-held unit is also based on the X-ray fluorescence method and it can especially used for the analysis and/or detection of chlorine, bromine and heavy metals.

Achieved environmental benefits

The following elements can be detected and analysed with this tool (depending on equipment and software): Cl, Br, Cd, Hg, Pb, As, Se, Ni, Sb, Cu, Ba, Cr, Sn, Mo, Zn, Sr, Fe, Co, Ti, V, Rb, Ir, Pt, Au, Ag, Pd, Nb, W, Bi, Mn, Ta, Zr, Hf, and Re.

Cross-media effects

No information available.

Environmental performance and operational data

~~The tool is developed for the highest analyse quality under hardest attendance (dirt, rain, dust – are no problems!) The most fasted electronic deliver analyse quality as in the laboratory, nevertheless on the spot, measurement for measurement, equal what material, no standards or re-calibrations.~~

TWG please provide more specific information.

Economics

No information available.

Technical considerations related to applicability

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This tool ~~seems to be now the fastest and exact handheld analysis tool~~ is applicable for practically all recycling metal – plastic – ~~old~~ wood – glass – ground – waste – mud – non-ferrous metal.

Example plants
No information available.

Reference literature
[98, WT TWG 2004]

Deleted: unclear

~~**Biological degradation times in MBT processes**~~
~~The minimal biological degradation times required to comply with the landfill criteria with sufficient operational reliability will have to be determined by future experience with the new optimised MBT plants.~~

Deleted: vitrification is outside the scope

~~**Immobilisation of heavy metal chlorides**~~
~~A method for the stabilisation of heavy metals wastes generated in the fly ashes vitrification process is based on the batch conversion of heavy metal chlorides with ammonium dihydrogenphosphate ($NH_4H_2PO_4$). Conversion of heavy metal chlorides into phosphate and its immobilisation in phosphate glass matrix.~~

Deleted: there are no data on better environmental performance of the process

~~**Ferrous sulphate stabilisation of FGT waste**~~

~~*Description*~~
~~This stabilization involves a five step procedure, where the solid material are first mixed with a $FeSO_4$ solution and then aerated with atmospheric air at L/S 3 l/kg in order to oxidise Fe(II) to Fe(III) and precipitate iron oxides. This step also includes extraction of soluble salts. The pH of the suspension is then maintained at pH 10 - 11 for about 0.5 to 1 hour to allow dissolved heavy metals to bind to the precipitated iron oxides. The fourth step of the process is dewatering and finally a washing step to exchange remaining water and remove remaining salts. The final stabilised product has a water content of about 50 %.~~

~~*Achieved environmental benefits*~~
~~The main advantage of this stabilization process is the improved leaching properties of the final product. The leaching characteristics of waste OUT are shown to be very good, and it is expected that low release of heavy metals can be maintained for extended periods of time, as iron oxides are known to endure in geological time frames. The pollution potential of the waste OUT is documented rather detailed and the waste OUT are expected to be less prone to physical disintegration than cement stabilised products because of the fact that most salts are removed. This process stabilises FGT waste and typically have far better leaching properties than cement solidified wastes. This process reduces the amount of waste OUT by about 10 % per dry weight.~~

~~*Cross-media effects*~~
~~No reutilization strategies have yet been demonstrated, however it has been suggested that the waste OUT can be utilised in road construction after thermal treatment in the combustion chamber of the incinerator. Research activities are currently addressing this issue.~~

~~The process produces waste water with high content of salts and relatively low concentrations of metals because Fe(II) is present in the extraction step. The waste water can in most cases be discharged to a marine recipient after a simple treatment or can be deionised by crystallization.~~
~~*Operational data*~~

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~~The process has been demonstrated in pilot scale at a batch plant of about 200 kg dry weight. Parameters like water consumption, mixing of water and materials, Fe(II) oxidation rate, reaction time, pH and pH controlling additive have been optimised. It has been demonstrated that the process is robust with respect to the properties of the waste IN, although some variations in process parameters arise. Typical process data are for one tonne of waste IN: 10 - 50 kg Fe, 20 - 50 minutes aeration, 30 - 60 minutes reaction time, H_2SO_4 or $FeSO_4$ as pH controlling additive, optimum pH of 10 - 11, and a water consumption of 3 - 4 m^3. In the current setup, dewatering of the treated material was done with a plate and frame filter press.~~

~~*Applicability*~~
~~The stabilization unit can be implemented as an integrated part of the incinerator but may also exist as a centralised treatment plant handling residues from several incinerators. The technique has been demonstrated on semidry FGT waste as well as fly ash alone and fly ash combined with sludge from the wet scrubbers (Bamberg product); all with good results.~~

~~*Economics*~~
~~Treatment cost is estimated to about EUR 65/tonne with a plant capacity of 20000 tonne/year including investment costs.~~

~~*Driving force for implementation*~~
~~The main reason for implementing this technology is the very good leaching properties of the waste OUT and the fact that this is expected to last in a long-term perspective.~~

~~*Example plants*~~
~~The process has only been demonstrated in pilot-scale, however it has also been designed in full-scale. No full-scale plants have yet been implemented.~~

~~*Reference literature*~~
~~**[80, Iswa 2003]**~~

Deleted: there are no data on better environmental performance of the process

~~**Carbon dioxide and phosphate stabilisation of FGT waste**~~

~~*Technical description*~~
~~Chemical agents used here are CO_2 and/or H_3PO_4. This process involves a two-step procedure where the waste IN are first washed at L/S 3 l/kg in order to extract soluble salts. After this the material are dewatered and washed again in a plate and frame filter press at L/S 3 l/kg. The residues are then re-suspended, and CO_2 and/or H_3PO_4 is added. The stabilization reactions are allowed to occur for 1 - 1.5 hours while pH decreases, and another hour where pH is maintained around pH 7. Finally, the residues are dewatered again and washed at the filter press with another 3 l/kg. The final product has a water content of about 50 %. The use of CO_2 and H_3PO_4 as stabilizing agent ensures that heavy metals are bound as carbonates or phosphates.~~

~~*Achieved environmental benefits*~~
~~It shows very good leaching properties similar to the Ferrox stabilization. Metal carbonates and phosphates are known to generally have low solubilities, and the leaching characteristics of the waste OUT are expected to remain good for extended periods of time. The pollution potential of the waste OUT is documented rather detailed and physical disintegration of the waste OUT in a long-term perspective is expected to be less important than in the case of cement stabilization, because of the fact that most salts are removed. Waste OUTs typically have far better leaching properties than the ones treated with cement. The process reduces the amount of material by about 15 % per dry weight.~~

~~*Cross-media effects*~~
~~No reutilization strategies have yet been demonstrated. The process produces waste water from first dewatering step. All other process water is recycled in the process. The waste water needs~~

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~~to be treated for dissolved heavy metals in a standard unit, for example using pH adjustment and TMT addition.~~

~~*Operational information*~~

~~The process has been demonstrated in pilot scale at a batch plant of about 200 kg dry weight. Parameters like water consumption, mixing of water and solid material, CO_2 and H_3PO_4 addition, reaction time, pH and pH controlling approach have been optimised. It has been demonstrated that the process is robust with respect to the properties of the waste IN, although some variations in process parameters arise. Depending on waste IN composition, either CO_2 or H_3PO_4 or both have been used. It has also been demonstrated that flue-gas can be used as CO_2 source.~~

~~Typical process data for 1 tonne of waste IN are: 5 - 20 kg of CO_2, 0 - 40 kg H_3PO_4 and 3 m^3 H_2O.~~

~~*Applicability of technique*~~

~~The stabilization unit can be implemented as an integrated part of the incinerator but may also exist as a centralised treatment plant handling residues from several incinerators. The technique has been demonstrated on semidry FGT waste as well as fly ash alone and fly ash combined with sludge from the wet scrubbers (Bamberg product); all with good results.~~

~~*Economics*~~

~~Treatment cost for stabilization is estimated to about EUR 80/tonne with a plant capacity of 20000 tonne/year; including investment costs.~~

~~*Driving force of implementation*~~

~~The main reason for implementing this technology is the very good leaching properties of the waste OUT and the fact that this is expected to last in a long-term perspective.~~

~~*Examples*~~

~~The process has only been demonstrated in pilot scale, however it has also been designed in full-scale. No full-scale plants have yet been implemented.~~

~~*References*~~

~~**[80, Iswa 2003] [100, WT TWG 2004]**~~

Deleted: there are no data on better environmental performance of the process

~~**Emerging techniques for soil vapour extraction for soil remediation**~~

~~Approaches such as microwave, radio frequency, and electrical heating have been tested at the pilot scale, but full-scale results are not yet available.~~

Deleted: there are no data on better environmental performance of the process

~~**Phytoextraction of metals from the soil**~~

~~In the field of environmental reclamation through biological process, the methodology known as phytoremediation has recently received mounting attention from operators in the field. Phytoremediation encompasses various techniques used for cleaning up both soil and water. For metal contaminated soil, phytoextraction represents one of the best solutions from the eco-environmental point of view. Through this technique, metals are absorbed and transported from the soil to the harvestable tissues of plants.~~

Deleted: there are no data on better environmental performance of the process

~~**Treatments of waste contaminated with POPs**~~

~~Such type of waste is actually mostly treated by incineration. However other types of technique are emerging as shown in next~~

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Table 7.3: Emerging destruction techniques of POPs

Technique	Comment
~~Base catalyzed dechlorination~~	~~Organochlorines are reacted with an alkaline polyethylene glycol, forming a glycol ether and/or a hydroxylated compound, which requires further treatment, and a salt. Dioxins have been identified in process residues. Destruction efficiencies are not high~~
~~Catalytic hydrogenation~~	~~Organochlorines are reacted with hydrogen in the presence of noble metal catalysts, yielding hydrogen chloride and light hydrocarbons.~~
~~Electrochemical oxidation~~	~~At low temperature and atmospheric pressure, electrochemically-generated oxidants react with organochlorines to form carbon dioxide, water and inorganic ions with high destruction efficiencies. All emissions and residues can be captured for assay and re-processing, if needed.~~ ~~An electrochemical cell is used to generate oxidising species at the anode in an acid solution, typically nitric acid. These oxidisers and the acid then attack any organic compounds, converting most of them to carbon dioxide, water and inorganic ions at low temperature (<80 °C) and atmospheric pressure. Compounds that have been destroyed by this process include aliphatic and aromatic hydrocarbons, phenols, organophosphorous and organosulphur compounds, and chlorinated aliphatic and aromatic compounds.~~ ~~Data describing concentrations in gaseous, liquid and solid residues of dioxins and other POPs potentially formed by this process were not available for review.~~ ~~No industrial application is currently known~~
~~Electron beam oxidation~~	
~~Mediated electro-chemical oxidation by cerium~~	~~This technique uses electrochemical cells for the generation of the active Cerium(IV) oxidant at the anode, a liquid phase reactor for primary organic destruction, a gas phase reactor to destroy any fugitive emissions from the liquid reactor and an acid gas scrubber for removal of acid gases prior to venting to the air. The process operates at low temperature (90 – 95 °C) and at atmosphere pressure~~
~~Mediated electro-chemical oxidation by silver~~	~~This process uses silver (II) to oxidise organic waste streams. Reactions take place in an electro-chemical cell similar to the type utilised in the chlor-alkali industry. The process operates at low temperature (~90 °C) and at atmospheric pressure~~
~~Molten metal~~	~~Organochlorines and other materials are oxidised in a vat of molten metal, yielding hydrogen, carbon monoxide, ceramic slag and metal by-products.~~ ~~There is currently designing facilities for four commercial customers in US~~
~~Molten salt~~	~~Organochlorines and other materials are oxidised in a vat of molten salt, yielding carbon dioxide, water, molecular nitrogen, molecular oxygen, and neutral salts. Destruction efficiencies may be high. It is suitable for the destruction of pesticides but not for treatment of contaminated soils~~
~~Photocatalysis~~	~~Use light to activate a catalyst that oxidise/reduce the compounds. A wide range of compounds can be destroyed. Useful for liquid and gaseous wastes~~
~~Ultraviolet oxidation~~	
~~*Source*:[70, Greenpeace 1998] [98, WT TWG 2004] [102, UNEP 2004]~~	

7.4.2 Emerging techniques for treatment of waste oil

~~Presently, around the world, there are~~ Many activities are currently in progress worldwide to improve existing used oil recycling ~~technologies~~ techniques and to develop new ones. The table below summarises those techniques under development

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Table 7.4: Waste oil treatment techniques under development

Technique	Comment
~~FILEA Process by C.E.A.~~	~~Supercritical CO_2 filtration~~
MRD solvent extraction	Solvent extraction of used oil vacuum distillates produced by TFE with a high efficient and selective solvent (e.g. NMP). Complete waste free technology with high efficiency and flexibility and production of high quality base oils. Their major advantages are: • quantitative reduction of PNAs to a level not achievable by any other re-refining technology (ppb level); • complete retention of the high valued synthetic base oil components more and more present in used oils resulting in very high qualities of the produced base oils. It is expected that a unit will be in operation in Germany by March 2005. TWG, please confirm this is still an emerging technique.
~~New Meinken technology~~	~~It has been developed a new process applying a novel absorbent to vacuum distillates.~~ ~~The catalyst absorbent seems to be an activated clay.~~ ~~No industrial application is currently known~~
~~Probex Process)~~	
~~ROBYS™ Process~~	~~Catalytic cracking and stabilisation for diesel production~~
~~Supercritical treatments~~	~~This technology applies to the deasphalting and also the fractionation. Pre-flash and hydrotreating do not change with respect to the standard assembly of a PDA unit.~~ • ~~*Supercritical Deasphalting:* the asphaltic fraction is separated by extraction with light hydrocarbons (C_2/C_3) under supercritical conditions. The clarified oil is separated from the extraction medium and fractionated in a standard column under vacuum conditions.~~ • ~~*Supercritical Fractionation:* the clarified oil from the supercritical deasphalting unit. still mixed with the extraction medium. is directly separated into two or more cuts by varying the physical conditions of the mixture.~~ ~~Both technologies reduce the investment and operating costs when compared with the standard PDA technologies (1 and 2 stages).~~ ~~Two independent pilot plant projects have been developed~~

Source: [2, Concawe 1996] [21, Viscolube 2002] [98, WT TWG 2004]

Deleted: there are no data on better environmental performance of the process

~~Regeneration of activated carbon~~

~~Table 7.5: Emerging techniques that may be applied to activated carbon regeneration~~

	~~**Stage of development**~~
~~*Activated carbon regeneration technologies*~~	
~~Biological regeneration of spent activated carbon~~	~~Currently at the research and development stage~~
~~Oxidative regeneration~~	~~Currently at the research and development stage~~
~~*Novel pollution control techniques for the abatement of emissions*~~	
~~Circulating fluidised bed absorber~~	
~~Electrocatalytic oxidation of sulphur dioxide (the ELCOX process)~~	
~~Electrochemical processes~~	
~~Flue-gas irradiation~~	
~~Methanol injection~~	

~~*Source*: [25, UK Department of the Environment 1991] [98, WT TWG 2004]~~

Deleted: there are no data on better environmental performance of the process

~~Preparation of solid fuel from organic/water mixtures~~

~~The process consists in preparation of a fuel for the use in cement kilns. The process is the mixing of the organic-water mixtures with a lime hydrate porous structure in order to capture the organics and use such product as raw material in the cement industry. This technique is able~~

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~~to deal with clinical waste, municipal waste, hazardous/chemical waste and non-hazardous industrial and commercial waste.~~

Deleted: there are no data on better environmental performance of the process

~~**Emerging techniques for hazardous waste preparation for energy recovery**~~
~~New adsorbents for the preparation of solid waste fuel from hazardous waste. There is a permanent research for other absorbents in order to replace the fresh sawdust.~~

Deleted: there are no data on better environmental performance of the process

~~**Cracking of polymer materials**~~
~~Liquid or gaseous fuels like gas oils or heavy fuel oils can be also substituted with a prior step to crack the waste polymer into a liquid or a gas. Efforts in this field have mostly not progressed further than pilot scale tests.~~

7.4.3 Sterilisation of healthcare waste with ozone

TWG please confirm this is an emerging technique

Description
Waste is treated at room temperature using a high concentration of ozone to attain a 6 log 10 reduction (99.9999 %) sterilisation. The waste is shredded with up to 90% reduction in volume and treated with a high concentration of ozone (sterilised) and then compacted into a stainless steel transport bin for disposal or for energy recovery (see Figure 7.6).

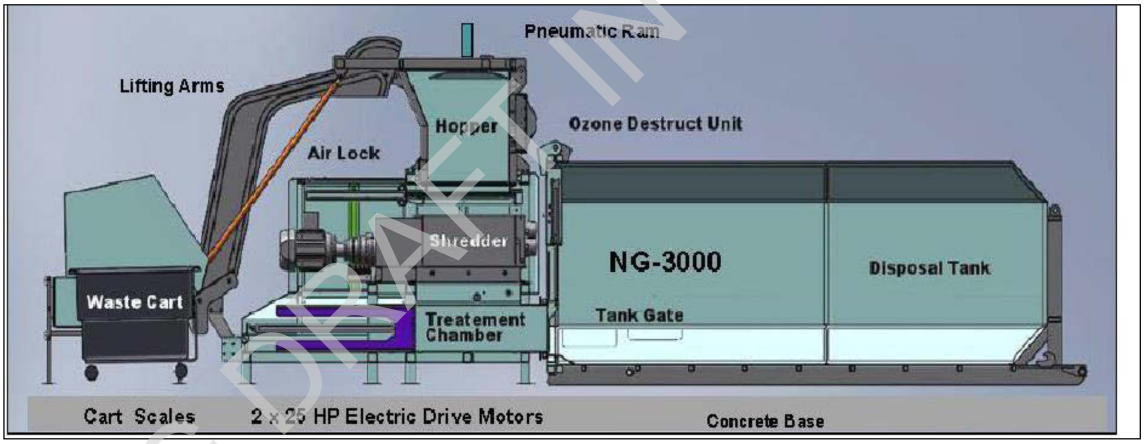

Figure 7.6: OZONATOR installation

Achieved environmental benefit
Reduced emissions to air and water, compared to thermal treatments.

Cross-media effect
None identified

Environmental performance and operational data
No information available at this stage

Economics
No information available at this stage

Technical considerations related to applicability
No information available at this stage

Example plant
Union Hospital located in Terre Haute, Indiana, USA since 2008.

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Reference literature

www.ozonatorindustries.com

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8 CONCLUDING REMARKS

This chapter will be updated at a later stage

From the first meeting onwards, it has been difficult to have a common understanding within the TWG of which waste treatment activities need to be covered by this document. These different views on what should or should not be covered by this document have made the process more difficult and has probably restricted the development of the BAT chapter further (see 'Recommendations for future work' below).

There are some views that the scope of this document should cover all waste treatment installations now available in the waste sector. Their view was based on three rationales: first, the technical characteristics of such additional treatments are very similar if not equal to some of the treatments covered in this document; secondly they maintain that such issues may benefit the competitiveness of some waste treatments not covered by IPPC because such installations may be allowed to operate at less stringent environmental standards than required by BAT; and third it may be interpreted that because these treatments are not covered, no BAT can be determined and that they cannot run under BAT conditions. Scope of this document should not be interpreted as any attempt to interpret IPPC Directive or any waste legislation.

Annex I of the IPPC Directive lists the installations that are covered by the IPPC Directive. The installations are derived from the Recovery/Disposal (R/D) codes mentioned in the the Waste Framework Directive (75/442/EEC). However, it is difficult to distinguish between the R and the D codes ad they are so closely related. For example, there are waste treatments that are not covered when an 'R' treatment is carried out to a certain waste (e.g. aerobic digestion to produce compost) but covered when a 'D' treatment is carried out (e.g. aerobic digestion to landfill). This issue will create difficulties on the implementation of the Directive to certain waste treatment installations and may create market conflicts because some installations will be required to have an IPPC permit and others will not.

Some readers have tried to interpret the structure of the document as the tool to try to distinguish between some R and D codes. One example showing this can be the interpretation of R1, R9 and D10 codes for treatment of waste oils. There are two main options (see Section) for the treatment of waste oils. One is the re-refining of waste oil (covered in Section under the section on recovery of materials) and the other one is the treatment of the waste oil to produce a material that will be mainly used as fuel. This latter option, in some cases, generates materials that can be used as naphthalene absorbant in coke oven gas cleaning, mould release oil or flotation oil. These treatments are covered in Section 5.3.2.4 when used as fuel. It must be stressed that this document does not in any way interpret any legislation.

Annex I of the IPPC Directive also makes the distintion for treatment of hazardous and non-hazardous waste. This issue creates an extra difficulty on a clear scope for this document as well as for the structure of this document. The point is that the same type of installations treating hazardous waste are included but not those treating non-hazardous waste.

Some information considered not to be within of the scope of this document has been included whereas other information provided has not been included at all (e.g. composting). In order to avoid confusion, it has been considered appropriate to maintain the information on these issues that were in the second draft but restricting such information from being included in Chapter 1 to Chapter 3. An example is the bottom ash (slag) treatment to be used as a construction material in ~~Section~~ Some information provided was also agreed to be reviewed by some TWG members after the second TWG meeting. However, the TWG was not able to reach the deadline agreed at the meeting so the information is not available in this document. The information was related to pickling acid for waste water treatments, thermal purification sludge containing oil, thermal treatment of contaminated soil, treatment of blasting grit and treatment of asphalt containing tar.

WORKING DRAFT IN PROGRESS

Some information was given together with the comments to the second draft of this document (see timing of the work section below). As a consequence, there has not been enough time for a full peer review. This means that some techniques in Chapter 4 have not been properly peer reviewed and assessed to decide if they are elements of BAT for the sector. However, some of this new information is now included in the document. Some of this information was probably not provided earlier in the process because of the lack of clarity in the scope of the work. The information that is included in this category is some of the information that was provided by the Netherlands, Germany and Cefic.

This IPPC industrial sector is highly regulated and the terminology used is not the same throughout the EU. Moreover, there are different interpretations of the same wording in the different countries, especially that related to the qualification of Recovery and Disposal. To solve this difficulty, the glossary of this document plays an important role. It informs the user/reader in which sense each conflicting word identified by the TWG has been used in this document. This glossary should not be understood as an interpretation of any legislation and it may conflict with some national legislation definitions. To prevent some difficulties that have been encountered, this document has tried to use ‘neutral’ words with the intention to avoid waste related debates such as waste vs. non-waste, recovery vs. disposal, and hazardous vs. non-hazardous.

Techniques analysed in this document are the most relevant ones for the sector, however as is the case with all BREFs, they are restricted to the information provided.

Timing of the work

The work on this document started with the first plenary meeting of the TWG in February 2002. A first draft was issued in February 2003 followed by a second draft in January 2004. A final plenary meeting of the TWG was held in two sessions in Septerber and October 2004 after which the document was completed. All parts of this final document have thus been subjected to peer review by the TWG.

Sources of information

More than 150 items of information were used for the preparation of this document. Several reports from industry and MS authorities were used as main sources of information and assisted in the drafting, some of them were specifically prepared for this document. Only three Member States actively delivered documents. The others only provided some information when sending comments for the two drafts. The reports submitted mainly focused on specific waste treatments and some covered only some type of wastes, thus partially covering the WT sector. Complementary to that information, 35 site visits to eight EU countries (Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain), 10 meetings with permit writers and technology providers and attendance at six conferences were carried out. The formal consultations on drafts also prompted the submission of new and additional information, as well as providing opportunities for the TWG to verify information already submitted.

On the analysis of information provided, it needs to be emphasised that especially in the case of specific treatments, the core information came from one source. This issue meant that some of the sections of this document may be seen as representative for one country or as partial view of some TWG members. This has created criticism from a few TWG members that some conclusions are based on very little information or are not even representative of the entire EU sector. However, the BAT conclusions could only be achieved on information provided and rely on the expert judgement of the TWG.

110 experts form the TWG, 52 from EU Member States, 47 from Industry, two from Environmental NGO, two from non-Member States and seven from different services of the Commission. However, the attendance at the second TWG meeting was low considering the number of TWG members. Some MSs chose not to participate in the final meeting.

WORKING DRAFT IN PROGRESS

Degree of consensus reached

The conclusions of the work were agreed at the final plenary meeting in September – October 2004 and a high level of consensus was reached. There was full agreement on all the BAT conclusions as presented in this document. However, it needs to be emphasised that there is disagreement from Industry (except one Industry association) and one Member State on the scope of this document (see also first paragraphs of the Concluding remarks chapter). They claim that the coverage of this document should be enlarged to cover the entire WT sector ignoring whether the treatment is formally covered by IPPC or not. Their view was based on the developments on the waste sector since the Waste Framework and IPPC Directives were issued as well as market distorsions that may be generated because only a part of the sector is covered. Composting installations were mentioned as a good illustrative example on the previous points.

Recommendations for future work

The information exchange and the result of this exchange, i.e. this document, present an important step forward in achieving the integrated prevention and control of pollution from the waste treatment industry. On a few topics, however, the information is incomplete and did not allow BAT conclusions to be reached. As a consequence, this is considered as an important issue to focus on during the revision of this document. Future work could usefully focus on collecting the following information:

1. clarification and enlargement of the *scope* to include the majority, if not all, of the waste treatment activities. It would be advisable to clarify the installations to be covered by IPPC and to restrict the use of R/D codes as well as reference to hazardous and non-hazardous waste. Some waste treatments highlighted that may be good candidates for enlarging the scope of this document have been composting, end-of-life materials (including vehicles, fridges, electronic waste, cathode ray tubes, glass preparation, fluorescents containing mercury, batteries, switches) and treatment of slag from combustion processes (e.g. from incineration) to be used for example as construction material. As a consequence of such a decision, this actual document does not contain specific BAT for such processes. However, it needs to be noted that some of these processes are relatively similar to some of the processes already covered

2. *on-site remediation* is not included in this document because it was seen to be outside the scope of IPPC. Clarification as to whether on-site remediation needs to be covered by this document has been proposed.

3. the document does not give guidance of what '*dilution*' is considered to be. A better analysis of what is understood by 'dilution' is required as this can have a big impact on other waste policies. However, at the same time it should be determined whether this guidance is possible to be given under the framework of the IPPC Directive because, as is mentioned in the Scope chapter, IPPC focuses on installations and not the full chain of waste management. It may be possible that when analysing 'dilution', other considerations outside the scope of IPPC may be taken into account

4. there is a shortage of *current consumption and emission levels* and on the performance of techniques to be considered in the determination of BAT. This was generally true throughtout the whole document. Thus, it is proposed to collect data on this issue to generate a better base document and enlarge the BAT chapter

5. this document does not include emission levels associated with the use of BAT for *physico-chemical treatment of waste waters*. These waste streams have some of the largest volumes in Europe, however there is a lack of identification of values for these treatments. The number of generic waste water parameters identified (i.e. COD, BOD and heavy metals) for this sector are considered to be insufficient for this particular treatment
6. some *lack of information* have been identified on some issues covered by this document and some have limited the BAT conclusions. These are:

WORKING DRAFT IN PROGRESS

off-site remediation treatments
mixing and blending treatments. This issue is identified as very important in the sector but it has not been well developed. The BAT chapter lacks further conclusions on this issue
emission levels when biogas is used as the fuel (some information is actually available in the LCP BREF for installations larger than 50 MWth)
waste water emission levels from biological treatments
dioxins, nitrous oxide and mercury emission levels to the air from mechanical biological treatments. One member state considered important to include the dioxins parameter in table of BAT of Chapter 5
destruction of POPs. Basel convention provides technical guidelines for environmental sound management of waste consisting of, containing or contaminated with PCBs, PCTs and PBBs
treatments of waste containing mercury
treatment of asbestos
recovery of components from abatement techniques.

Suggested topics for future R&D projects
The information exchange has also exposed some areas where additional useful knowledge could be gained from research and development projects. These relate to the following subjects:

- studies to build on the knowledge of the definition of dilution
- clarify the distinction between Recovery and Disposal of waste and to define, if possible, the stage where recovery is completed and when the waste turns into a tradeable product.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).

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9 ANNEXES

The previous annexes have been removed or relocated according to the decisions taken at the KOM, as follows:

Removed:

Annex I. Environmental legislation and emission limit values applied to the waste treatment sector

Annex II. Questionnaire used to gather environmental information of European waste treatment plants

Annex III: Types of waste and waste production in the EU: some information moved to Chapter 1

Annex IV. Quality assurance systems for secondary recovered fuel: some information moved to SRF process description

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GLOSSARY

Glossary Section was entirely rewritten according to Standard Texts.

This glossary is meant to facilitate the understanding of the information contained in this document. The definitions of terms in this glossary are not legal definitions (even if some of them may coincide with definitions given in European legislation), they are meant to help the reader understand some key terms in the context of their use in the specific sector covered by this document.

This glossary is divided into the following sections:

I. ISO country codes
II. Monetary units
III. Unit prefixes, number separators and notations
IV. Units and measures
V. Chemical elements
VI. Chemical formulae commonly used in this document
VII. Acronyms
VIII. Definitions

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I. ISO country codes

ISO code	Country
Member States (*)	
AT	Austria
BE	Belgium
BG	Bulgaria
CZ	Czech Republic
CY	Cyprus
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom
Non-member countries	
NO	Norway
(*) The protocol order of the Member States is based on the alphabetical order of their geographical names in the original language(s).	

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II. Monetary units

Code([1])	**Country/territory**	**Currency**
Member State currencies		
EUR	Euro area ([2])	euro (pl. euros)
DKK	Denmark	Danish krone (pl. kroner)
GBP	United Kingdom	pound sterling (inv.)
Other currencies		
USD	United States	US dollar

([1]) ISO 4217 codes.

([2]) Includes Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia and Spain.

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III. Unit prefixes, number separators and notations

Numbers in this document are written using the '.' character as the decimal separator and the space as the separator for thousands.

The symbol ~ (around; about) is the notation used to indicate approximation.

The symbol Δ (delta) is the notation used to indicate a difference.

The following table contains the frequently used prefixes:

Symbol	**Prefix**	**10^n**	**Word**	**Decimal Number**
M	mega	10^6	Million	1 000 000
k	kilo	10^3	Thousand	1 000
-------	-------	1	One	1
m	milli	10^{-3}	Thousandth	0.001
µ	micro	10^{-6}	Millionth	0.000 001
n	nano	10^{-9}	Billionth	0.000 000 001

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IV. Units and measures

Unit Symbol	Unit Name	Measure name (measure symbol)	Conversion and comment
atm	normal atmosphere	Pressure (P)	1 atm = 101 325 N/m^2
bar	bar	Pressure (P)	1.013 bar = 100 kPa = 1 atm
°C	degree Celsius	Temperature (T) temperature difference (ΔT)	
d	day	Time	
g	gram	Weight	
h	hour	Time	
J	joule	Energy	
K	Kelvin	Temperature (T) temperature difference (ΔT)	0 °C = 273.15 K
kcal	kilocalorie	Energy	1 kcal = 4.1868 kJ
kg	kilogram	Weight	
kJ	kilojoule	Energy	
kPa	kilopascal	Pressure	
kWh	kilowatt-hour	Energy	1 kWh = 3 600 kJ
l	litre	Volume	
m	metre	Length	
m^2	square metre	Area	
m^3	cubic metre	Volume	
mg	milligram	Weight	1 mg = 10^{-3} g
mm	millimetre		1 mm = 10^{-3} m
min	minute		
MW$_e$	megawatts electric (energy)	Electric energy	
MW$_{th}$	megawatts thermal (energy)	Thermal energy Heat	
nm	nanometre		1 nm = 10^{-9} m
Nm^3	normal cubic metre	Volume	at 101.325 kPa, 273.15 K
OU$_E$	European odour unit	Odour	
Pa	pascal		1 Pa = 1 N/m^2
ppb	parts per billion	Composition of mixtures	1 ppb = 10^{-9}
ppm	parts per million	Composition of mixtures	1 ppm = 10^{-6}
ppmv	parts per million by volume	Composition of mixtures	
rpm RPM	Revolutions per minute	Rotational speed, frequency	
s	second	Time	
St	stokes	Kinematic viscosity	1 St = 10^{-4} m^2/s; old, cgs unit
t	metric tonne	Weight	1 t = 1 000 kg or 10^6 g
t/d	tonnes per day	Mass flow Materials consumption	
t/yr	tonnes per year	Mass flow Materials consumption	
vol-% % v/v	percentage by volume	Composition of mixtures	
wt-% % w/w	percentage by weight	Composition of mixtures	
W	watt	Power	1 W = 1 J/s
yr	year	Time	
µm	micrometre	Length	1 µm = 10^{-6} m

WORKING DRAFT IN PROGRESS

V. Chemical elements

Symbol	Name	Symbol	Name
Ac	Actinium	Mn	Manganese
Ag	Silver	Mo	Molybdenum
Al	Aluminium	N	Nitrogen
Am	Americium	Na	Sodium
Ar	Argon	Nb	Niobium
As	Arsenic	Nd	Neodymium
At	Astatine	Ne	Neon
Au	Gold	Ni	Nickel
B	Boron	No	Nobelium
Ba	Barium	Np	Neptunium
Be	Beryllium	O	Oxygen
Bi	Bismuth	Os	Osmium
Bk	Berkelium	P	Phosphorus
Br	Bromine	Pa	Protactinium
C	Carbon	Pb	Lead
Ca	Calcium	Pd	Palladium
Cd	Cadmium	Pm	Promethium
Ce	Cerium	Po	Polonium
Cf	Californium	Pr	Praseodymium
Cl	Chlorine	Pt	Platinum
Cm	Curium	Pu	Plutonium
Co	Cobalt	Ra	Radium
Cr	Chromium	Rb	Rubidium
Cs	Caesium	Re	Rhenium
Cu	Copper	Rf	Rutherfordium
Dy	Dysprosium	Rh	Rhodium
Er	Erbium	Rn	Radon
Es	Einsteinium	Ru	Ruthenium
Eu	Europium	S	Sulphur
F	Fluorine	Sb	Antimony
Fe	Iron	Sc	Scandium
Fm	Fermium	Se	Selenium
Fr	Francium	Si	Silicon
Ga	Gallium	Sm	Samarium
Gd	Gadolinium	Sn	Tin
Ge	Germanium	Sr	Strontium
H	Hydrogen	Ta	Tantalum
He	Helium	Tb	Terbium
Hf	Hafnium	Tc	Technetium
Hg	Mercury	Te	Tellurium
Ho	Holmium	Th	Thorium
I	Iodine	Ti	Titanium
In	Indium	Tl	Thallium
Ir	Iridium	Tm	Thulium
K	Potassium	U	Uranium
Kr	Krypton	V	Vanadium
La	Lanthanum	W	Tungsten
Li	Lithium	Xe	Xenon
Lr	Lawrencium	Y	Yttrium
Lu	Lutetium	Yb	Ytterbium
Md	Mendelevium	Zn	Zinc
Mg	Magnesium	Zr	Zirconium

WORKING DRAFT IN PROGRESS

VI. Chemical formulae commonly used in this document

Chemical formula	Name (explanation)
CH_4	Methane
Cl^-	Chloride ion
CN^-	Cyanide ion
CO	Carbon monoxide
F^-	Fluoride ion
HCl	Hydrogen chloride
HF	Hydrogen fluoride
H_2S	Hydrogen sulphide
H_2SO_4	Sulphuric acid
NaOH	Sodium hydroxide. Also called caustic soda
NH_3	Ammonia
N_2O	Nitrous oxide
NO^{2-}	Nitrite ion
NO^{3-}	Nitrate ion
NO_X	Nitrogen oxides (mixture of NO and NO_2)
SO_3^{2-}	Suphite ion
SO_X	Sulphur oxides (mixture of SO_2 and SO_3)

WORKING DRAFT IN PROGRESS

VII. Acronyms

Acronym	Full phrase
AD	Anaerobic digestion
ADR	European agreement concerning the international carriage of dangerous goods by road
AMS	Automated measuring system
AOX	Adsorbable organically bound halogens
APC	Air pollution control
APME TEC	Association of Plastic Manufacturers in Europe, Technical Centre
ASTM	American Society for Testing and Materials
BAT	Best Available Techniques
BAT-AEL	Best Available Techniques - associated emission level
BAT-AEPL	Best Available Techniques - associated performance emission level
BOD	Biochemical oxygen demand
BTEX	Benzene, toluene, ethylbenzene, xylene
BTX	Benzene, toluene, xylene
CAS	Chemical abstracts service (chemicals registry number)
CEFIC	Conseil Européen de l'Industrie Chimique (European Chemical Industry Council)
CEMS	Continuous emissions monitoring system
CEN	Comité Européen de Normalisation (European Committee for standardisation)
CFC	Chlorofluorocarbon
CHP	Combined heat and power (cogeneration).
COD	Chemical oxygen demand
CPI	Corrugated plate interceptor
CV	Calorific value, e.g. in MJ/kg or MJ/m^3
DAF	Dissolved air flotation
DCH	Direct contact hydrogenation process of waste oils
DCM	Dichloro methane
DIN	Deutsches Institut für Normung (German national organisation for standardisation)
DM	Dry matter. The matter after drying of its moisture content
DRE	Destruction and removal efficiency
DS	Dry solids (content)
EA	Environment Agency (England and Wales)
EAF	Electric arc furnace
EDTA	Ethylenediaminetetraacetic acid
EDTMA	Ethylenediaminetetra (methylenephosphonic) acid
EEA	European Environment Agency
EFTA	European Free Trade Association
ELV	Emission limit value
EMAS	Eco-Management and Audit Scheme (Council Regulation (EC) No 1221/2009)
EMS	Environmental management system.
EN	European Norming (EN standards)
EoLV	End-of-life vehicles (as defined in Article 2(2) of Directive 2000/53/EC)
EOP	End-of-pipe (measure)
EOX	Extractable organic halogens
EPA	Environmental Protection Agency (US)
ESP	Electrostatic precipitator
EQS	Environmental quality standard
ETBE	Ethyl tert-butyl ether
EWL	European waste list (from the European Waste Framework Directive, 2008/98/EC)
FGT	Flue-gas treatment
FID	Flame ionisation detector
GAC	Granular activated carbon

WORKING DRAFT IN PROGRESS

Acronym	Full phrase
HCB	Hexachlorobenzene
HCFC	Hydrogen chloro fluoro carbons
HEPA	High-efficiency particle air filter
HFO	Heavy fuel oil
HP	High pressure
IBC	Intermediate bulk container
IED	Industrial Emission Directive (2010/75/EU)
IPPC	Integrated pollution prevention and control
IR	Infrared
ISO	International Organisation for Standardisation
KOH	Potassium hydroxide
L/S	Liquid/solid ratio
LCA	Life cycle assessment.
LCP	Large combustion plant
LDAR	Leak detection and repair
LEV	Local exhaust ventilation system
LFO	Light fuel oil
LPG	Liquefied petroleum gas
LOQ	Limit of quatification
MBR	Membrane bioreactor
MBT	Mechanical biological treatment
MEK	Methyl ethylketone
MIBK	Methyl isobutyl ketone
MF	Microfiltration
MP	Medium pressure
MS	(European Union) Member State
MSW	Municipal solid waste
N	Normal – refers to volume of gases under normal operating conditions with a temperature of 273.15 K and pressure of 101.325 kPa
NA	Not applicable
ND	Not determined / Not detectable
NF	Nanofiltration
NGO	non-Governmental organisation
NI	No information
NIR	Near-infrared spectroscopy
NMVOC	non-Methane Volatile Organic Compound
NOC	Normal Operating Conditions
ODS	Ozone depletion substance
OTNOC	Other Than Normal Operating Conditions
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyl
PCDD/Fs	Polychlorinated dibenzodioxins/dibenzofurans
PCT	Physico-chemical treatment
PDA	Propane de-asphalting (for waste oils)
PEMS	Predictive emissions monitoring system
PID	Piping and instrumentation diagrams
PLC	Programmable logic controller
PM	Particulate matter
POPs	Persistent organic pollutants
PSA	Pressure swing adsorption
RDF	Refuse derived fuel
RH	Relative humidity
RO	Reverse osmosis
RTO	Regenerative thermal oxidiser
SBR	Sequencing batch reactor
SCR	Selective catalytic reduction
SNCR	Selective non-catalytic reduction
SRF	Solid recovered fuel
TDA	Thermal de-asphalting (for waste oils)

WORKING DRAFT IN PROGRESS

Acronym	Full phrase
TDS	Total dissolved solids
TEQ	Toxicity equivalents (iTEQ: international toxicity equivalents)
TFE	Thin film evaporator
TKN	Total Kjeldahl nitrogen
TOC	Total organic carbon
TSS	Total suspended solids
TWG	Technical Working Group
UF	Ultrafiltration
UBA	Umweltbundesamt – Federal Environment Agency, i.e. from Germany or Austria
VOC	Volatile organic compound
VHC	Volatile hydrocarbon
VFC	Volatile fluorocarbon
WFD	Waste Framework Directive (2008/98/EC)
WWT(P)	Waste water treatment (plant)

WORKING DRAFT IN PROGRESS

VIII. Definitions

Activated sludge process	A biological process for treating municipal and industrial waste waters by the use of microorganisms under aerobic conditions.
Aerobic processes	Biological processes that occur in the presence of oxygen.
Anaerobic processes	Biological processes that occur in the absence of oxygen and other electron accepting substances except carbon dioxide/carbonate.
Annual capital cost	An equal or uniform payment made each year over the useful life of the proposed technique. The sum of all the payments has the same 'present value' as the initial investment expenditure. The annual capital cost of an asset reflects the opportunity cost to the investor of owning the asset.
Assimilative capacity	The capacity of a natural body of water to receive waste waters or toxic materials without harmful effects and without damage to aquatic life or humans who consume the water.
Biodegradability	A measure of the ease with which a substance will degrade as a result of biological metabolism..
Biofuel	Biofuel as defined in Article 2(i) of Directive 2009/28/EC.
Biological nutrient removal	The removal of nitrogen and/or phosphorus from aqueous effluents in biological treatment processes.
Biomass	Biomass as defined in Article 2(e) of Directive 2009/28/EC.
Bioremediation	The use of living organisms, e.g. bacteria, to remove pollutants from contaminated sites.
Biowaste	Biowaste as defined in Article 3(4) of Directive 2008/98/EC.
Bottom ash	Solid residues from a combustion process
Breathing	Emissions from a tank resulting from an increase in its head space pressure (due to the evaporation and/or expansion of the tank's contents), and air ingress into a tank resulting from a reduction in its headspace pressure (due to the condensation and/or contraction of the tank's contents).
By-product	A substance or object, resulting from a production process, the primary aim of which is not the production of that item and which is not regarded as being waste, and which meets the requirements of Article 5 of Directive 2008/98/EC on waste.
Cake	Solid or semisolid material remaining on a filter after pressure filtration.
CAS	Chemical abstracts service (registry number). A division of the American Chemical Society holds registries of chemical substances; providing a unique numerical identifier for chemical compounds, polymers, biological sequences, mixtures and alloys which designates only one substance.
Certification	Procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements. Certification can apply to instruments, equipment and/or personnel.
Channelled emissions	Emissions of pollutants into the environment through any kind of pipe, regardless of the shape of its cross-section.
Chelating agent	A compound capable of chelation with metal ions.
Chelation	The formation of a closed ring of atoms by the attachment of compounds or radicals to a central polyvalent metal ion (occasionally non-metallic).
Complexing agent	See chelating agent.
Component	Substance embedded in a mixture, e.g. in waste water, waste gas, solid waste.
Composite sample	A composite sample refers to a water sample which is taken continuously over a given period, or a sample consisting of several samples taken either continuously or discontinuously over a given period (e.g. during 24 hours) and blended.

WORKING DRAFT IN PROGRESS

Continuous measurement	Measurement with an automated measuring system (AMS) permanently installed on site for continuous monitoring of emissions, according to EN 14181:2004.
Control of emissions	Techniques used to limit, reduce, minimise, or prevent emissions.
Cooling water	Water used for energy transfer (heat removal from components and industrial equipment), which is kept in a network separated from industrial water and which can be released back to receiving waters without further treatment.
Co-product	Any of two or more products coming from the same unit process or product system.
Decommissioning	The shutdown of an installation including decontamination and/or dismantling.
Diffuse emissions	Emissions arising from direct contact of volatile or light dusty substances with the environment under normal operating circumstances. These can result from: • inherent design of the equipment (e.g. filters, dryers); • operating conditions (e.g. during transfer of material between containers); • type of operation (e.g. maintenance activities); • a gradual release to other media (e.g. to cooling water or waste water).
Diffuse emissions sources	Multiple sources of similar diffuse or direct emissions distributed inside a defined area; they can be point, linear, surface or volume sources.
Digestate	The solid residue remaining after anaerobic digestion.
Dioxins	Polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).
Direct measurements	Specific quantitative determination of the emitted compounds at source.
Discharge	Physical release of a pollutant through a defined outlet, (i.e. channelled), system, (e.g. sewer, stack, vent, curbing area, outfall).
Discrete	Not continuous, i.e. having gaps between all possible values.
Drainage	Natural or artificial removal of surface and sub-surface water from an area, including surface streams and groundwater pathways.
Draining	Emptying the liquid contents of a system to a collection system or other storage system, creating a possible liquid waste stream.
Emission	The direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into the air, water or land (from Directive 2010/75/EU)
Emissions factors	Numbers that can be multiplied by known data such as plant/process activity data or throughput data to estimate emissions
EOP	End-of-pipe, device or treatment system applied to waste water or channelled exhaust or flue gas at the outlet of a collection system prior to release into the environment.
EWL	European waste list from the European Waste Framework Directive (Directive 2008/98/EC on waste) – hierarchical list of waste descriptions. This List classifies waste materials and categorises them by: (a) the activity from which they are produced, and (b) their characteristics.
Exhaust gas (or exhaust air)	Gas/air stream coming off a combustion or extraction process; it may contain gaseous or particulate components.
Existing plant	A plant that is not a new plant.
Fly ash	The fine fraction of the ash that leaves the combustion chamber with the flue-gas
Fouling	A process of becoming dusty or clogged, e.g. by undesirable foreign matter, such as dirt and other material, accumulating and clogging pores and coating surfaces.

WORKING DRAFT IN PROGRESS

Fugitive emissions	Diffuse emissions from 'point' sources. Fugitive emissions are a subset of diffuse emissions.
Flaring	High-temperature oxidation to burn combustible compounds of waste gases from industrial operations with an open flame. Flaring is primarily used for burning off flammable gas for safety reasons or during non-routine operating conditions.
Hazardous waste	Hazardous waste as defined in Article 3(2) of Directive 2008/98/EC..
IED	Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).
IPPC Directive	Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (IPPC Directive) that has been replaced by Directive 2010/75/EU on industrial emissions (→IED).
Laboratory smalls	Laboratory chemicals in containers of a small capacity
Leachate	Solution obtained by leaching. The solution consists of liquid that, in passing through matter, extracts solutes, suspended solids or any other component of the material through which it has passed.
Leakage	Gaseous or liquid spills out of system/equipment due to system/equipment failure.
Limestone	Mineral rock consisting merely of $CaCO_3$ used as $CaCO_3$ or as raw material for producing quicklime (calcium oxide) by decarburisation and hydrated lime (calcium hydroxide) by the hydration of quicklime.
Make-up water	Water added to a process or a circuit to replace water that is lost by e.g. leakage or evaporation.
Mechanical Biological Treatment (MBT)	Treatment of solid waste combining mechanical treatment (e.g. shredding) with biological treatment such as aerobic or anaerobic treatment
Monitoring	Systematic surveillance of the variations of a certain chemical or physical characteristic of emissions, discharges, consumptions, equivalent parameters or technical measures, etc.
New plant	A plant first operated at the installation following the publication of these BAT conclusions.
Output	The treated material coming out of the waste treatment plant
Pasty waste	Non-pumpable waste (e.g. sludge)
Periodic measurement	Determination of a measure (particular quantity subject to measurement) at specified time intervals using manual or automated methods
Periodic sampling	Discrete/ individual/ separate/ discontinuous/ grab/ spot sampling - individual samples taken in batched, time or effluent-volume dependent. Three formats can be identified: • periodic time dependent sampling – discrete samples of equal volume are taken at equal time intervals; • periodic flow proportional sampling – discrete samples are taken of variable volumes at equal time intervals; • periodic samples taken at fixed flow intervals – discrete samples of equal volume are taken after the passage of a constant volume.
PLC	Programmable logic controller: digital computer used for the automation of industrial processes.
Plume	Visible or measurable discharge of a contaminant from a given point of origin, usually a channelled emission from the stack at an industrial site.

WORKING DRAFT IN PROGRESS

Pollution source	The emissions source. Pollution sources can be categorised as: • point, or concentrated sources; • dispersed sources; • line sources, including mobile (transport) and stationary sources • area sources.
Precision	Refers to the ability of a measurement to be consistently reproduced.
Primary measure/technique	A measure/technique that changes the way in which the core process operates thereby reducing raw emissions or consumptions (see also the counterpart: end-of-pipe technique).
PSA	Pressure swing adsorption: technique used to separate some gas species from a mixture of gases under pressure according to the species molecular characteristics and affinity for an adsorbent material (e.g. for hydrogen production).
Purging	Replacement of the gaseous contents of a system by air or inert gases.
Recovery	Recovery as defined in Article 3(15) of Directive 2008/98/EC.
Recycling	Recycling as defined in Article 3(17) of Directive 2008/98/EC.
Reuse	Reuse as defined in Article 3(13) of Directive 2008/98/EC.
Re-refining	Treatments carried out to waste oil to be transformed to base oil
Reference conditions	Conditions that are specified, e.g. in connection with operating a process, collecting samples.
Regeneration	Treatments and processes mainly designed to make the treated equipment (e.g. activated carbon) or material (e.g. spent solvent) usable again
Release	Actual discharge (routine, usual or accidental) of emissions into the environment.
Remediation	The containment and/or decontamination of contaminated environmental media such as soil, groundwater, sediment, or surface water from a contaminated site intended for further use. The area of the site may be larger than the fenced area.
Reporting	A process of periodic transmission of information about environmental performance, including emissions and compliance with permit conditions, to authorities or to the internal management of the installation and other agencies, such as the general public.
Residue	Material generated by the activities covered by the scope of this document, as waste or by-products.
R-phrases	R-phrases are standard phrases indicating the special risk arising from the dangers involved in using the dangerous substance. The wording of the R-phrases is laid down in Annex III to Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances.
Run-off	Part of the precipitation and snowmelt that does not infiltrate but moves as overland flow.
Sampling, sample	Sampling is the process by which a portion of substance is collected to form a representative part (the sample) of the whole, for the purpose of examination of the substance or material under consideration. (see also continuous sampling, periodic sampling)
Sankey diagram	A specific type of diagram used for displaying flows through a system, e.g. to show mass, energy, material, money flows.
SBR	Sequencing batch reactor - a variation of the conventional activated sludge system to treat waste waters containing organic material whereby the aeration and settlement take place in the same vessel (no need for a secondary clarifier).

WORKING DRAFT IN PROGRESS

Sensitive receptor	Area which needs special protection, such as: - residential areas; - areas where human activities are carried out (e.g. schools, daycare centres, recreational areas, hospitals or nursing homes).
Slag	A vitrified or partially vitrified residue.
Sludge	A suspension with high solids content, such as the type precipitated by sewage treatment.
Slurry	A suspension of solid particles in a liquid but at a lower concentration than found in a sludge.
Specific emissions/consumption	Emissions/consumption related to a reference basis, such as production capacity, or actual production.
Spot measurement	A measurement relating to a specific point in time – not a continuous measurement.
Spot sample	A sample related to a single point in time. [to update once new MON REF is out]
Standard conditions	Referring to a temperature of 273.15 K a pressure of 101.325 kPa and a specified oxygen content.
Surrogate parameter	Measurable or calculable quantities which can be closely related, directly or indirectly, to conventional direct measurements of pollutants, and which may therefore be monitored and used instead of the direct pollutant values for some practical purposes. Also called proxy parameter.
TA Luft	Technical Instructions on Air Quality Control. German Federal Regulation for the control of pollution to air.
Thickening	Liquid-solid separation process to increase the concentration of a suspension by sedimentation, accompanied by the formation of a clear solid.
Treatment of waste with calorific value	Treatment of waste wood, waste oil, waste plastics, waste solvents, etc. to obtain a fuel or to allow a better recovery of its calorific value
Unit	A part of the plant in which a specific processing operation is conducted.
Vitrification	The transformation of a substance or a mixture of substances into glass or an amorphous glassy matrix.
Waste fuel	Any type of waste or material prepared from waste that is used as fuel in any combustion process.
Waste gas	Any gas leaving a process which is not a product (includes exhaust gas, off-gas and flue-gas).
Waste hierarchy	Priority order in waste prevention and management legislation and policy as stipulated in Article 4 of Directive 2008/98/EC.
Waste holder	Waste holder as defined in Article 3(6) of Directive 2008/98/EC.
Waste input	The incoming waste to be treated in the waste treatment plant
Waste oil	Waste oil as defined in Article 3(3) of Directive 2008/98/EC.
Waste treatment	Treatment as defined in Article 3(14) of Directive 2008/98/EC.
Zeolites	Microporous, aluminosilicate minerals commonly used as commercial adsorbents.

WORKING DRAFT IN PROGRESS

WORKING DRAFT IN PROGRESS

JRC Mission

As the Commission's
in-house science service,
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throughout the whole
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Working in close
cooperation with policy
Directorates-General,
the JRC addresses key
societal challenges while
stimulating innovation
through developing
new methods, tools
and standards, and sharing
its know-how with
the Member States,
the scientific community
and international partners.

Serving society
Stimulating innovation
Supporting legislation