MINI BREF 1
COMMON TECHNIQUES
[extract from *BREF for the Waste Treatments Industries* from August 2006]

Note: Text in blue corresponds to references also mentioned in MINI-BREF 1-Common techniques

1. General information

[5, Concawe, 1996], [7, Monier and Labouze, 2001], [13, Marshall, et al., 1999], [14, Ministry for the Environment, 2000], [36, Viscolube, 2002], [39, Militon, et al., 2000], [40, Militon and Becaud, 1998], [41, UK, 1991], [42, UK, 1995], [53, LaGrega, et al., 1994], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [100, UNEP, 2000], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [124, Iswa, 2003], [125, Ruiz, 2002], [126, Pretz, et al., 2003], [128, Ribi, 2003], [150, TWG, 2004], [152, 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 re-used by other means and may become not marketable. These materials are typically given to third parties for further treatment.

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 waste treatment processes may involve the displacement and transfer of substances between media. For example, some treatment processes results in a liquid effluent sent to sewer and a solid waste sent to landfill, and others result in emissions to air mainly due to incineration. Alternatively, the waste may be rendered suitable for another treatment route, such as in the combustion of recovered fuel oil. There are also a number of important ancillary activities associated with treatment, such as waste acceptance and storage, either pending treatment on site or removal off site.

1.2. Installations for the treatment of waste

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 Section **Error! Reference source not found.** of 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
- 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.

1.2.1. 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 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 1.1 below shows the number of waste transfer installations and capacity in different European countries.

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	0[1]	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.

Table 1.1: Waste transfer installations
[39, Militon, et al., 2000], [60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [86, TWG, 2003], [150, TWG, 2004]

1.3. Economic 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 supraregional, 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. 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. This will require the development of dedicated plants and, probably, equipment for the treatment of specific wastes.

Whilst restrictions on landfilling, which will be introduced by the Landfill Directive, will require more treatment of waste either prior to or instead of landfill, this may lead to the continuing development of sites utilising stabilisation and fixation 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 the entire facility. 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.

1.4. 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 1.2 shows the main air emissions from waste treatment operations.

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.	

Table 1.2: Main air pollutants emitted by waste treatments and their main sources

Water emissions
Most waste installations declare an emission of total nitrogen, total organic carbon, total phosphorus and chloride to water. Table 1.3 gives a summary of the main water emissions from waste treatment operations.

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.	

Table 1.3: Main water pollutants (parameters) emitted by waste treatments and their main sources

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 re-used 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.

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.

Table 1.4: Installations for the biological treatment of waste
[39, Militon, et al., 2000], [60, Azkona and Tsotsos, 2000], [61, Weibenbach, 2001], [86, TWG, 2003], [150, 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 1.4, 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.

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 interpret IPPC Directive or any EC waste legislation. These are:

- common techniques. This covers those stages found in the waste sector that are generally applied and that are not specific to any individual type of waste treatment (e.g. reception, blending, sorting, storage, energy system, management). The unit operations associated with these treatments are also covered. Figure 2.2 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
- 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 and centrifuging, solvent recovery and any thermal treatments not included in the WI BREF. The unit operations associated to these treatments are also covered
- 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.

Figure 2.1 and Figure 2.2 illustrate 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.

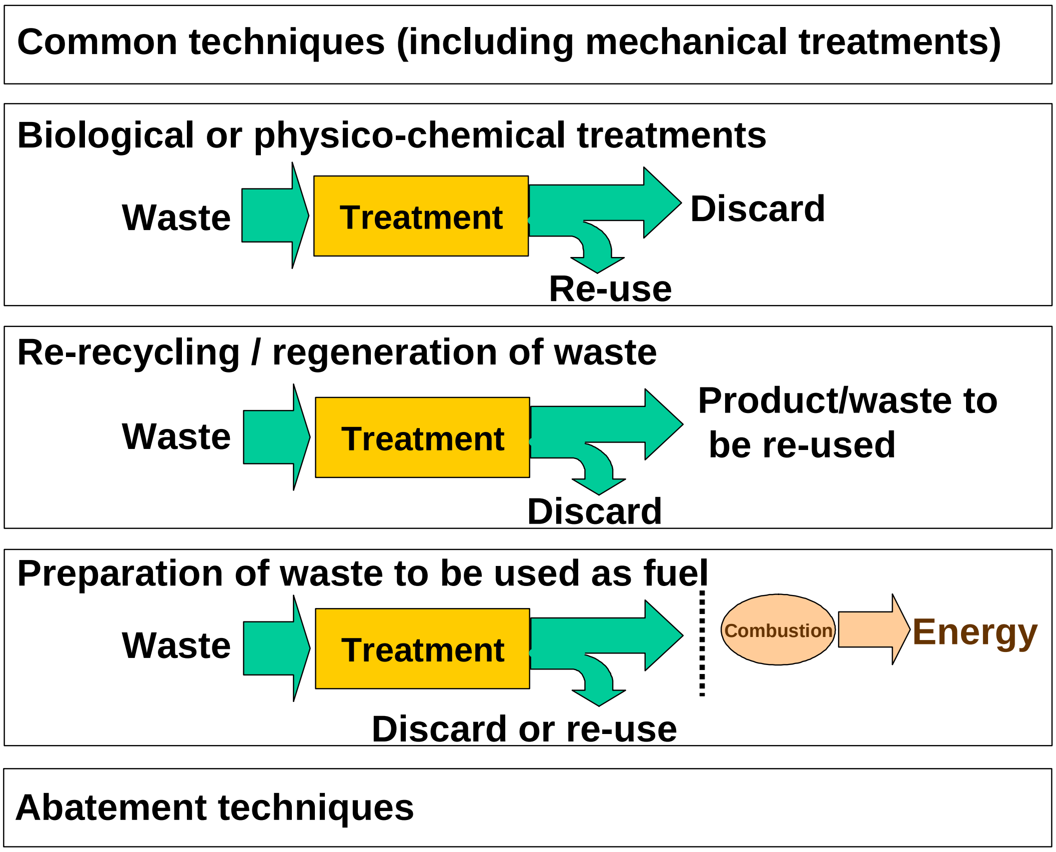


Figure 2.1: Structure of the chapters

Note: This figure only tries to give a snapshot of how information is structured in this document. Exceptions to any of these categories might be present and sometimes it is difficult to classify a treatment under certain block.

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.

Such structure should not be interpreted as any attempt to give guidance if a waste treatment is Recovery or Disposal under the EC waste legislation.

[150, TWG, 2004]

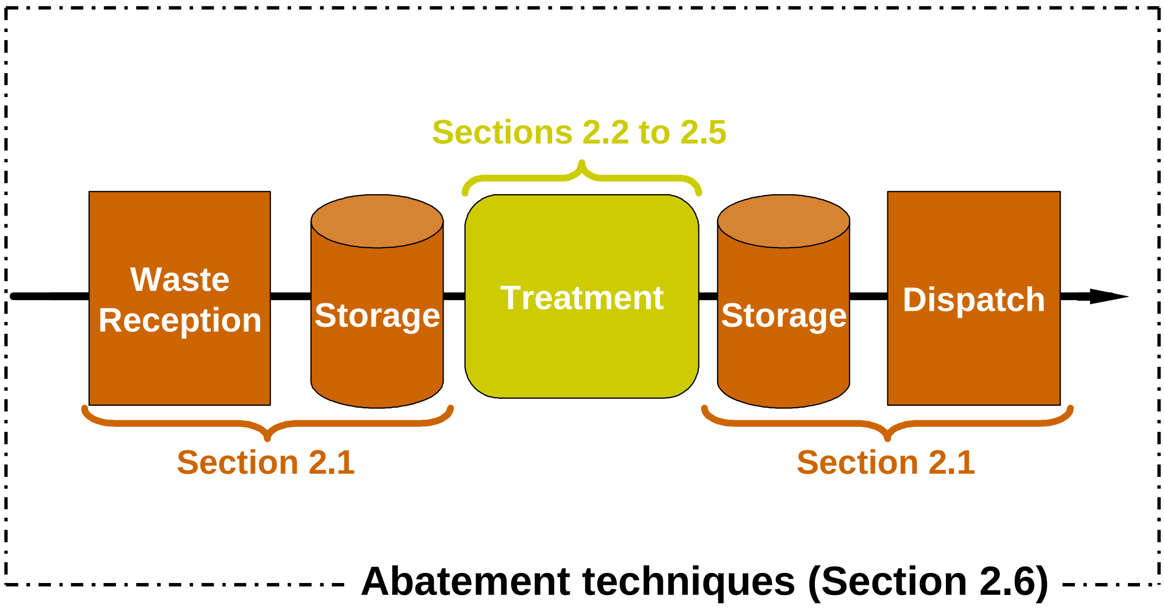


Figure 2.2: Typical operations in waste treatments and how these have been distributed in this and subsequent chapters

Many 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 technique, to help the reader to easily assess the information within this document.

Name of the type of information	Type of information included
Purpose	A brief explanation of what this type of WT 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 uses this type of technique

Table 2.1: Information contained in the description of each technique included in Chapter 2 [150, TWG, 2004]

<u>Waste treatment installations</u>
While the waste is in storage, a treatment schedule is developed that identifies 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 2.3 is one example of such a complex installation.

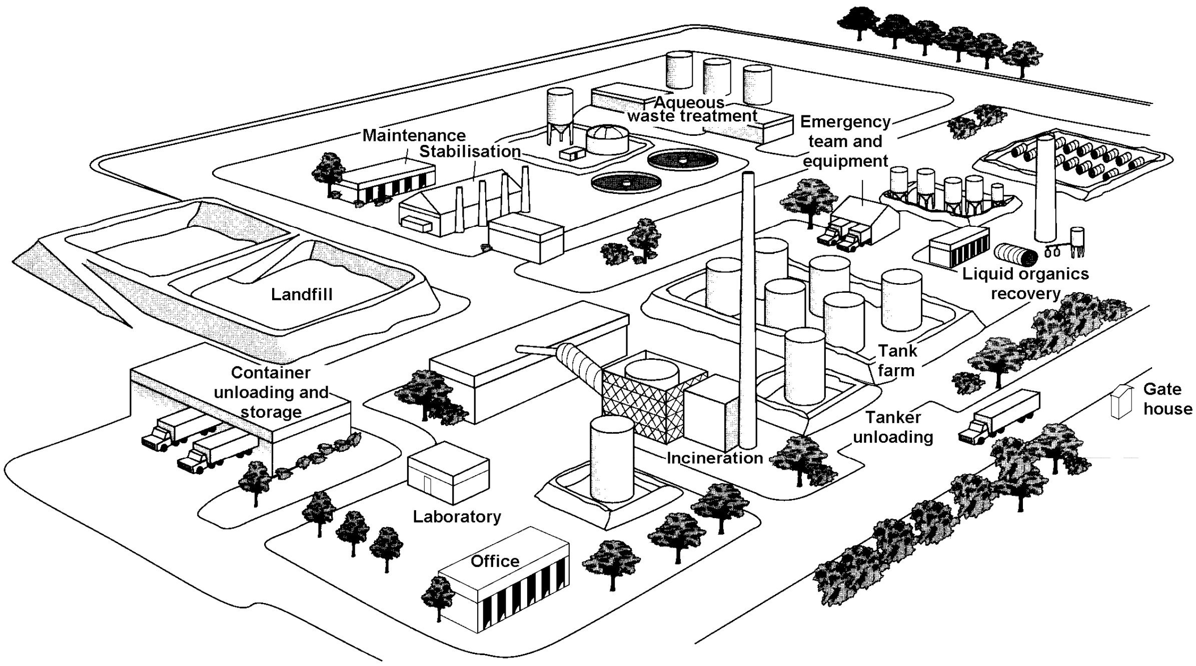


Figure 2.3: Example of an integrated waste treatment installation
[53, LaGrega, et al., 1994]

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.

	Operations subsystems				
Facility components	**Pre-shipment waste analysis**	**Waste receiving**	**Waste storage and preparation**	**Waste treatment**	**Solid outputs managemen t**
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					

Table 2.2: Examples of operations subsystems and their components
[53, LaGrega, et al., 1994], [150, TWG, 2004], [152, 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.

2.1. Common techniques applied in the sector

[40, Militon and Becaud, 1998], [50, Scori, 2002], [51, Inertec, et al., 2002], [53, LaGrega, et al., 1994], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [100, UNEP, 2000], [116, Irish EPA, 2003], [119, Watco, 2002], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004], [156, VROM, 2004] [157, UBA, 2004].

This section discusses the pretreatments/activities or post-treatments/activities (see the introduction to Chapter 2 and Figure 2.2) commonly used in the WT sector and included under the scope of this document. It also includes some treatment activities that are commonly used in the whole sector. For example, it includes 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 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 0. Those techniques applied for the abatement of emissions (e.g. air filters, biofilters, waste water treatments) are briefly mentioned in Section 2.2 and are widely analysed in the last three sections of Chapter 4.

2.1.1. Reception, acceptance, traceability and quality assurance

For most WT plants, the following order is relevant: a) acceptance b) storage c) treatment d) storage of residues and emissions. Each of the 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, where 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.

Pre-acceptance

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.

Acceptance

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.

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 provides information on sampling and sample preparation. Some more information is also available in Section 3.3.

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 2.4.

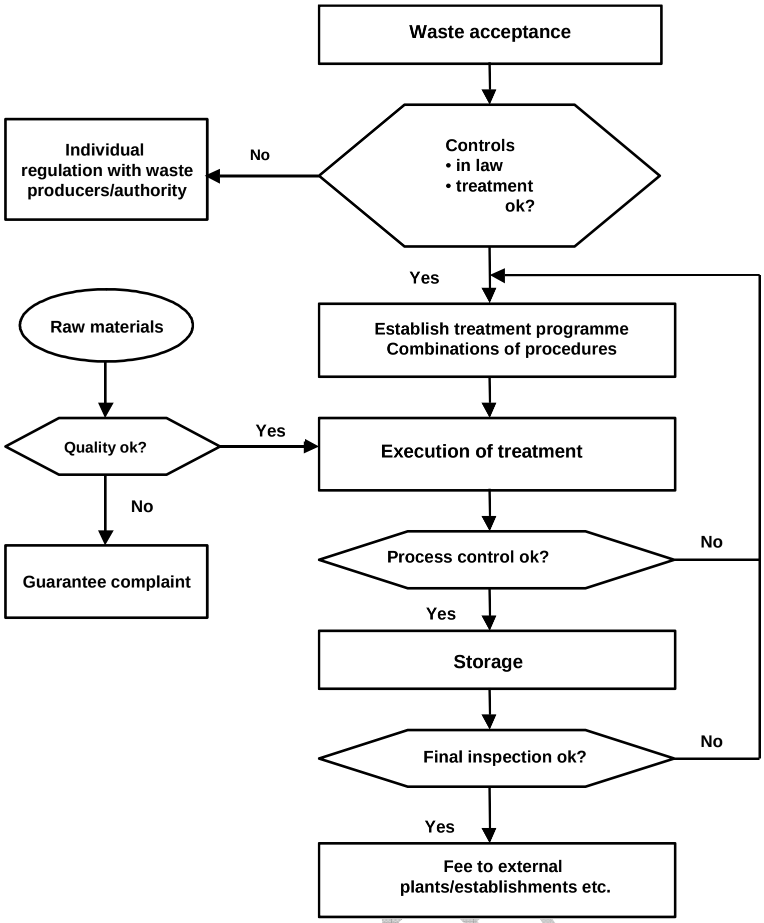


Figure 2.4: Simplified flow chart of an example of checking/inspection in a physico-chemical treatment plant of waste waters
[121, Schmidt and Institute for environmental and waste management, 2002]

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 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.

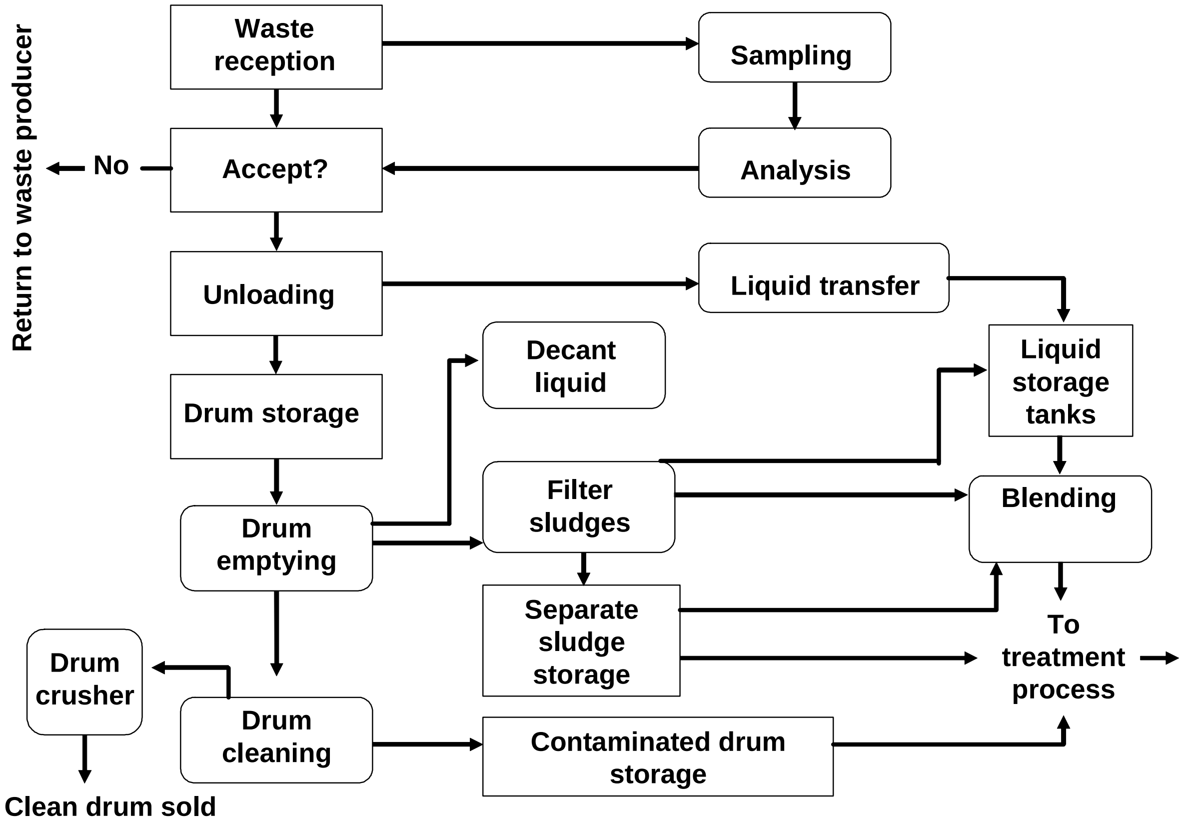


Figure 2.5: Example of waste reception and acceptance at a facility handling bulk liquids and drums [80, Petts and Eduljee, 1994]

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.

2.1.2. Management techniques

This section covers operational management and emission management in the installation. Some special precautionary measures need to be applied regarding:

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

2.1.3. 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 fork-lift 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 electrically or even pneumatically powered. 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, centrifugues, 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.

2.1.4. Storage and handling

The objectives of storage are to:

- store the waste safely before its introduction as feed into the treatment
- 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.
- uncouple the treatment and dispatch of waste
- allow effective use of classifying procedures to be made during storage/accumulation periods
- facilitate continuous treatment processes. Continuous treatment processes are not capable of reacting to sudden and significant changes in 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
- facilitate mixing, blending, and repackaging of the waste as deemed necessary
- allow the staged input of various wastes with reagents to the subsequent unit treatment processes
- collect a reasonable amount of waste prior to sending for certain treatments (e.g. transfer stations).

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 packer 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 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, that may need a controlled and checked stream of material for their process.

One role of waste solvent facilities is to regroup and recondition of small volumes (drums, etc.) to prepare then as fuels or to regenerate a solvent that can be re-used. The goal of a solvent regroupment/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 involve different techniques. Solids are transported by: conveyor belts, fork lift 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 approx. 1 m³, 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.

Washing and cleaning of vehicles and receptacles/containers
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 re-use 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 chlorine-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 left over concentration in the 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 wash-water is run in a closed loop over the existing water treatment system.

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 re-use within the transfer operations and others are washed (or vented) prior to re-use or sale.

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.

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, as for example 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.

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 litre or other sizes depending on the further treatment) in either designated enclosed buildings with positive ventilation and flameproof lighting, or within open-sided roofed areas.

Tanks are also used to store wastes. This may be part of a medium scale bulking operation to ensure that part 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 hard-standing 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-treatment functions are not separated but rather take place in the same container. A batch treatment process is used.

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

Emptying of containers
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 by a handling device, transported to the pre-selected 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 pre-selected by a control system.

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.
Handling of materials from a Ph-c plant
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. Large quantities in containers of, e.g. 100 to 12000 litres content volume. Prior to treatment, the units/containers have to be 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 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 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
- 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.

2.1.5. Blending and mixing

Wastes, once produced, should in principle be kept separate from other wastes. The reasons for this are that the re-use/recovery of homogenous streams are generally easier than that for 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 explored the different rules that may be applied on whether or not mixing/blending may be allowed and under what conditions this should be carried out.

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. 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).

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
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 mixing of substances that react strongly with each other (heat, fire, gas formation) or explosive substances (explosion) must be prevented. Mixing must be prevented from giving rise to risks to human health and the environment, both during the mixing operation itself, and 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
- the mixing of wastes must be prevented from leading 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 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 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 POP content below the defined low POP content is not allowed because this is not environmentally sound
- the mixing of wastes must be prevented from leading to the undesired diffuse dispersal of environmentally hazardous substances. The effects of diffuse dispersal are determined by the type 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 assessed 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 take into consideration the cyclical character of future re-use.

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.

Users
Blending and mixing is typically applied only when 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.

2.1.6. Decommissioning

Purpose
The purpose of decommissioning is to return the facility, on surrender of the waste licence, to a condition suitable for the selected afteuse. The importance of a proper closure is such that development of a closure plan is a necessity, since it will provide and document a plan for the final closure of a site prior to the startup of operation. This also fits in with a life cycle assessment of a planned site.

Principle of operation
For the decommissioning, the operator typically needs to demonstrate that, following decommissioning, the condition of the site will not cause, or be likely to cause, environmental pollution.

A closure plan needs to provide a clear and orderly set of actions and methods to be followed upon cessation of all operations at a facility. The steps need to be designed to ensure that the closed facility (a) poses a minimal risk to human health and the environment, and (b) requires minimal post-closure maintenance.

Feed and output streams
Not applicable.

Process description
The extent of the decommissioning/restoration will be dependent on the types of materials accepted, the design of the facility and the selected afteruse.

The cessation of waste acceptance at a facility typically initiates a review of the waste licence. This review allows the licence to be surrendered or amended to reflect the change in activities on site.

A closure plan requires assurance that funds are available to close the facility even if the facility owner starts bankruptcy proceedings. This assurance can be in the form of a bond, corporate guarantee, or some other financial instrument. The monetary amount is determined based on a cost estimate prepared as part of the closure plan. For example, the cost estimate may be equal to the maximum costs of closing all the waste management units ever activated at the facility.

Closure of a storage or treatment facility requires removal of all the remaining waste to another facility. All equipment and structures that had been in contact with waste must also be decontaminated. This may entail removal of concrete pads used to hold waste containers, as well as contaminated soil where leaks have occurred.

Users
Applicable to the whole WT sector.

2.1.7. Treatment of smalls

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

Principle of operation

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.

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 to 200 l. The small volumes are combined for the purpose of creating large batches (solvents or acids). These are disposed 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 an special cabin.

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

2.1.8. Size reduction

Purpose
Adapt the waste solid granulometry for further treatments or to extract wastes which are difficult to pump or decant. Reduces the particle size.

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:

<u>Bin shredder</u>
The treatment facility consists of a shredder for the comminution of empty, half empty and full bins with sizes ranging from 1l to 1000 litres. The feed system works with an electronic wheel loader. The shredder itself is placed in a pressure surge-proof channel of 12 m 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.

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 (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).

Users

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

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 pretreatments but some are also used as post-treatments (e.g. sieves). They are shown in Table 2.3, which also states the purpose of the treatments and where they are used.

Technique	Purpose	Users
Cleaning	Remove contamination that would otherwise prohibit waste materials being recovered	PCB capacitors and transformers
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		
Sedimentation	Solid components within the fluid wastes are separated and the wastes are pretreated for further processing	Preparation of liquid waste fuel
Sieving	Used to separate big particles. Vibrating sieves, static sieves and rotary sieves are used	Preparation of waste to be used as fuel
Sorting and scrapping		
Washing	One purpose for washing may be to enable the re-use of drums into the installation or for selling to other installations for re-use. 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. Ph-c treatment plants

Table 2.3: Common techniques applied in waste treatment
[86, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

2.1.10. 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.

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 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.

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.
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 industry glass. Sites typically do not take coated glass from electronic equipment.

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.

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.

2.2. Techniques for the abatement of emissions

[126, Pretz, et al., 2003], [150, 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.

3. Current consumption and emission levels

This chapter provides data and information about current consumption and emission levels in existing installations at the time of writing. Because it covers many types and sizes of waste treatment installations, data is very wide-ranging. The aim of this chapter is to bring together, as far as possible, consumption and emission levels for different waste treatment installations as a whole and as far as possible from each specific process/activity. The data quoted should, in most cases, enable estimates to be made of the concentration and loads of emissions from WT sites. This will in turn help a competent authority issuing a permit to verify the information provided by the applicant in the permit application.

The structure of this chapter is similar to that of Chapter 2, with the sections being divided into:

- Section 3.1: an overview of the emissions and consumptions from common waste treatment processes/activities
- Sections 3.2 to 3.5: the emissions and consumptions from the different processes/activities covered by this document. Again, such structure/classification should not be interpreted as any attempt to interpret IPPC Directive or any EC waste legislation
- Section 3.6: the emissions and consumptions generated by the techniques used to abate emissions
- Section 3.7: the monitoring systems typically applied in waste treatment installations.

Sections 3.1 to 3.6 follow the order laid out in Chapter 2 so as to make it easier to cross reference between chapters. In addition, each of these sections have been structured in the same way following the material flow logical steps, i.e. waste IN (input), consumptions (input), emissions (output) and finally waste OUT (output). Table 3.1 explains this layout further.

Section	Title of the section	Information included
3.X.1	Waste IN	Description of the type of wastes that may be treated as well as their physico-chemical properties. This section is important because the type of waste input is relevant for the determination of eventual emissions, residual wastes and the composition of the waste outputs
3.X.2	Consumptions	Consumption of energy (i.e. fuel, heat, electricity) and chemicals (i.e. water, air, additives, catalysts)
3.X.3	Emissions	This includes emissions to air and water of any component as a result of the process operation or related to the waste input. Residues (also waste in many cases) related to the type of process are also covered in this section
3.X.4	Waste OUT	When the outcome of a certain process is to be used as input into another process, it is also important to know the physico-chemical properties of the output. In some cases, this detail is not important and is then omitted
X being from 1 to 6: 1 Common techniques, 2 Biological treatments, 3 Physico-chemical treatments, 4 Regeneration treatments, 5 Preparation of waste fuel and 6 Abatement techniques.		

Table 3.1: Structure of each section of Chapter 3

Figure 3.1 shows a diagram of the mass/energy balance of a typical operation/process/activity. A waste input (called in this document waste IN) is treated in an installation, producing a processed/treated output (called in this document waste OUT). To change the physico-chemical properties of the waste IN, it is necessary to provide to the system, energy and chemicals (e.g. water, air, acids, etc.) as required to support the particular treatment. Application/operation of the waste treatment then generates emissions to air and water, as well as a unusable waste and possibly a usable waste OUT. The unusable waste (e.g. waste lime, bottoms of storage tanks, sludges) is generated by the process/operations and is different from the target waste OUT. The reason for differentiating between the wastes is that the waste OUT may be used for different purposes, but process generated waste/residues is typically not re-used.

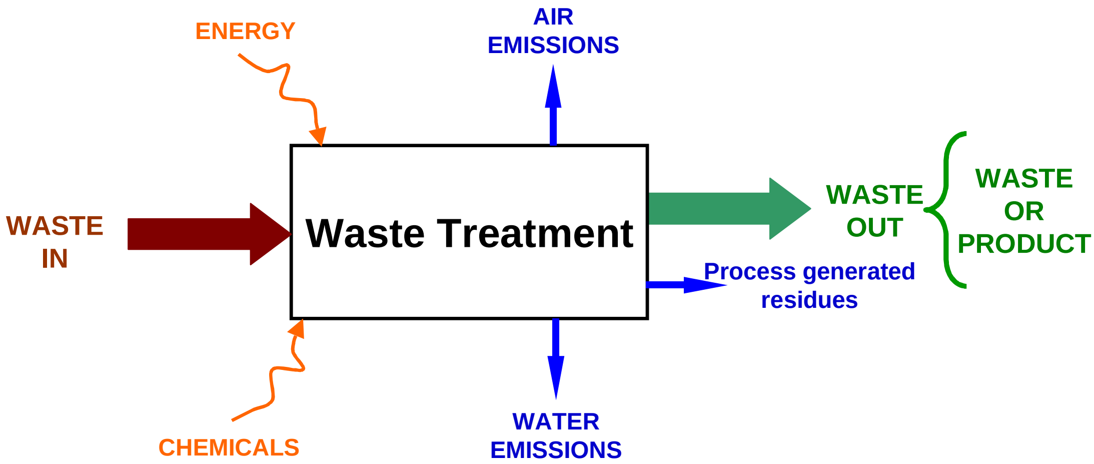


Figure 3.1: Inputs and outputs in a waste treatment operation
Note: Sections 3.X.1: Analysis of the waste to be treated, brown arrow; Sections 3.X.2: Analysis of the consumptions, orange arrows; Sections 3.X.3: Analysis of the emissions, blue arrows; Sections 3.X.4: Analysis of the waste treated, green arrow

Table 3.2 shows a summary of the main releases to the environment generated by WT activities.

	Substances released										
Source	**Particulates**	**NO_x, SO_x, HCl**	**NH_3,Amines**	**H_2S**	**HCN**	**VOCs**	**Odours**	**Other organics**	**Metals**	**Suspended solids**	**COD**
Common activities											
Acceptance (sampling/vehicle waiting)	A,W,L	A	A			A	A				
Transfer (pipework/pumps/valves)		A	A	A	A	A	A	W,L	W,L	W	W
Storage of solids (e.g. lime)	A,W,L										
Drum storage, bulk liquid storage and treatment vessels		A	A			A	A	A	W	W	W
Transfer and storage of wastes	A,W,L					A	A	A	A,W,L	W	W
Charging and mixing of treatment vessels	A,W,L					A	A	A	A,W,L	W	W
Removal of solid residues from vessel	A,W,L					A	A	A	A,W,L	W	W
Biological			A	A		A	A		W	W	W

Physico-chemical											
Precipitation/settlement and dewatering	W						A	W	W	W	W
Acid neutralisation		A	A(1)	A		A(2)	A(2)	A(2) W	W		W
Alkali neutralisation			A				A	W	W		W
Chromic acid neutralisation									W		
Cyanide treatment					A		A				
Stabilisation	A,W,L		A			A	A			W	W
Waste oil treatment						A	A	A			W
Notes: (1) There is a specific problem with the treatment of sulphuric acid that has been used to scrub an amine release (2) Conventional treatment of acidic wastes contaminated with solvents KEY: To air (A) To water (W) To land (L)											

Table 3.2: Summary of typical releases to the environment generated by waste treatment activities [55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004]

In order to complement the information directly provided by the TWG on emissions and consumptions of WT installations, a questionnaire was prepared and sent to TWG members (see Annex II). This was then forwarded by TWG members to WT facilities all over Europe. As a result more than 70 'filled-in' questionnaires were returned to the EIPPCB. A compilation of the data arising from this survey has been incorporated in this chapter and it has been referred as [66, TWG, 2003]. The consolidated analysis of the survey does not identify names, companies or specific figures or even identify individual comments from any specific company/site provider. Thus, data have been used in such a way so as to maintain confidentiality of the providers and preventing identification to any particular source.

3.1. Emissions and consumptions from common waste treatment processes/activities

[29, UK Environment Agency, 1996], [42, UK, 1995], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [150, TWG, 2004], [156, VROM, 2004], [157, UBA, 2004]

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 0. This covers those sites that transfer, bulk and store wastes.

3.1.1. Waste IN in common treatments

The type of wastes that may be involved in these processes is very wide especially for hazardous waste. Table 3.3 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.

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	

Table 3.3: Common waste streams processed at hazardous waste transfer stations in the UK [56, 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.

3.1.2. Consumptions of common treatments

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 3.4.

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 0)
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

Table 3.4: Examples of commonly used raw materials in waste treatments [55, UK EA, 2001], [150, TWG, 2004]

3.1.3. Emissions from common treatments

Following the same structure as followed in Section 0, 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.

	Type of fuel		
	Distillate	**Residual fuel**	**Diesel**
Air emissions			
CO_2[1]	3142	3112	3036 – 3142
PM			2.564
PM_{10}[1]	0.2	2.85	2.83
NO_x[1]	3.46	7.54	33.9 – 48.8
N_2O			0.041 – 1.3
CH_4			0.17 – 0.336
NM-VOC[1]	0.09	0.12	7.08 – 10.898
CO[1]	0.06	0.5	15.8 – 26.548
SO_2[1]	3.6	47.4	0.8 – 10.106
SO_x	19.56 x S[2]	20.42 x S[2]	
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 m^3 fuel) and European Environment Agency • [2] S is the % of sulphur in the fuel • [@] as benzo (a) pyrene			

Table 3.5: Summary of data for small boilers using a distillate (gas), a residual oil (fuel oils 5,6) or diesel engines
[56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [65, EEA, 2003], [150, 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 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
- 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 3.6 shows 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.

Table 3.6: Potential emissions from transfer stations, bulking processes and storage
[56, Babtie Group Ltd, 2002], [86, TWG, 2003]

Emissions from some other common waste treatments
Table 3.7 summarises the most frequent activities/equipment found in common waste treatment processes and the emissions that may be generated.

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

Table 3.7: Activities/equipment that may lead to emissions from some common waste treatments [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [113, COWI A/S, 2002], [116, Irish EPA, 2003], [121, Schmidt and Institute for environmental and waste management, 2002]

<u>Shredding</u>

• Parameter	• Concentration	• Unit
• Dust	• 0.1	• mg/Nm^3
• SO_2	• <0.06	• mg/Nm^3
• NO_x	• 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.		

Table 3.8: Exhaust air from shredding treatment of solid hazardous waste [157, UBA, 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.

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

Procedure	Hazard	Hazardous event	Cause/possible initiating event
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
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.

Table 3.9: Example of most frequent accidents that may occur in WT installations
[80, Petts and Eduljee, 1994], [126, Pretz, et al., 2003], [150, 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:

- 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.

<u>Particulate emissions</u>
Sites handling powders and wastes giving rise to dusts (e.g. fly ashes) often have particulates to emit to the air.

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

<u>Odour emissions</u>
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:

- 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 3.10:

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

Table 3.10: Point source emissions to water
[55, 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 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

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

Operation	Emissions to air (kg/yr)	Emissions to sewer (kg/yr)
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

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.

Table 3.11: Example of total estimated emissions from a waste transfer facility [56, Babtie Group Ltd, 2002], [86, TWG, 2003]

Emissions from specific waste treatments

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

Specific waste treatments	Air	Water	Waste
	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		
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.		

Table 3.12: Emissions from specific waste treatment processes
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [100, UNEP, 2000], [150, TWG, 2004]

3.1.4. Waste OUT from common waste treatments

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.

3.2. Emissions and consumptions from end-of-pipe treatments (abatement)

[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, 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.

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 3.13 or depending on the waste water treatment plant step.

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.

Table 3.13: Emissions from the different steps of a waste water treatment plant
[56, Babtie Group Ltd, 2002]

Table 3.14 gives some qualitative values of the emissions from waste water treatments and advises how these can be calculated.

	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

Table 3.14: Relevant emissions for waste water treatment [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, 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 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.

3.3. Monitoring

[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004]

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). Table 3.15 and Table 3.16 indicate some monitoring practices applied in some EU countries.

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
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

Table 3.15: Monitoring practices applied to waste treatment plants in the EU
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004]

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.

Table 3.16: Monitoring practices for some waste treatment processes used in the EU [56, Babtie Group Ltd, 2002], [86, 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.

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 2.1.1. Each type of waste needs a specific sampling protocol based on the physico-chemical properties of the waste [150, 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.

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.

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

Table 3.17: Examples of parameters and analysis principles used in sampling [122, Eucopro, 2003], [150, 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
- 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.

4. Techniques to consider in the determination of BAT

This chapter sets out techniques considered generally to have potential for achieving a high level of environmental protection in the industries within the scope of this document. Management systems, process-integrated techniques and end-of-pipe measures are included, but a certain amount of overlap exists between these three when seeking the optimum results.

Prevention, control, minimisation and recycling procedures are considered as well as the re-use of materials and energy.

Techniques may be presented singly or as combinations to achieve the objectives of IPPC. Annex IV to the Directive lists a number of general considerations to be taken into account when determining BAT and techniques within this chapter will address one or more of these considerations. As far as possible a standard structure is used to outline each technique, to enable comparison of techniques and an objective assessment against the definition of BAT given in the Directive.

The content of this chapter is not an exhaustive list of techniques and others may exist or be developed which may be equally valid within the framework of BAT.

Generally a standard structure is used to outline each technique, as shown in Table 4.1:

Name of the type of information	*Type of information included*
Description	Technical description of the technique
Achieved environmental benefits	Main environmental impact(s) to be addressed by the technique (process or abatement), including emission values (normally a range) achieved and efficiency performance. Environmental benefits of the technique in comparison with others
Cross-media effects	Any side-effects and disadvantages to other media caused by implementation. Environmental problems of the technique in comparison with others and how to prevent or solve them
Operational data	Performance data on emissions/wastes and consumption (raw materials, water and energy). Any other useful information on how to operate, maintain and control the technique, including safety aspects and operability constraints of the technique
Applicability	Techno-economic applicability. Consideration of plant age (new or existing), plant size (large or small) and factors involved in retrofitting (e.g. space availability). Also included is information on which waste treatment activity is applied in each case
Economics	Information on costs (investment and operation) and any savings (e.g. reduced raw material consumption, waste charges) related to the capacity of the technique (e.g. EUR/tonne). Values in currencies different to EUR have been converted according to 2002 annual average conversion factors for the EUR. In such cases, the original cost data along with the year and the currency have been also included (between brackets)
Driving force for implementation	Local conditions or requirements which have led to implementation of the technique. Information on the reasons other than environmental ones for implementation (e.g. improvement in product quality, increased yield)
Example plants	Reference to the plants operating the technique in Europe and in the rest of the world. If the technique has not yet been applied in the sector or in the EU, a brief explanation as to why
Reference literature	Literature source for more detailed information on the technique

Table 4.1: Information breakdown for each technique included in Chapter 4

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.

Organisation of the chapter
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 0 to **Error! Reference source not found.** 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 describe 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.

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.

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.

Waste composition characterisation

Description
The varied nature of the waste industry and the large differences in waste generated by each economic sector dictates that most waste streams handled on a site for treatment will usually be varied. Waste consists of complex mixtures of sometimes unknown constituents. For this reason, it is important to have an improved knowledge of the primary constituent(s) as well as the source of the waste. Besides the direct way of determining waste composition, e.g. by analysing the waste, there are other indirect approaches that can be taken, including:

- analysing market research data. This technique focuses on the goods after production; on the basis that all goods result in waste sooner or later and by considering certain influencing facts, and by utilising market research it is possible to calculate the amount of goods that end up as MSW, for example. A similar method can be applied by looking at the input into private households
- analysing waste treatment outputs. According to the balance principle, elemental input equals elemental output. By focusing on the products of waste treatments, it should thus be possible to determine the input waste composition in terms of substances by carrying out routine measurements
- in addition it is worth noting that there are, of course, some wastes that are composed of a mix of wastes mixed at the source where they originate. Usually, the waste producer will know the composition of this waste stream. If the waste producer adopts a good waste management system, he will inform the waste collector of the waste composition. This is important as the classification and identification of the waste should not be first given to the waste collector, but should primarily be the responsibility of the waste producer. This system is related with the one mentioned in Section 0.

Indirect analysis methods for determining the waste composition can supplement the direct analysis method. Some techniques to particularly consider are noted in Table 4.2 below:

Technique	Information
Identify the primary constituent(s)	Where the main constituents of the waste stream are known, it is possible to categorise it as having a 'high', 'medium' or 'low' emission potential. An example of this could be to base the assessment on the volatility of the constituent elements as notified by the waste producer
Identify the waste source	Knowledge of the waste source (e.g. paint industry, pharmaceutical, automotive, etc.) provides a good guide to the type of components that may be present in the waste. This will allow adoption of a simpler method to categorise the waste. EWL uses this system. However, available data are usually insufficient to allow this method to be developed at present. It would be necessary to undertake further research to establish the most common sources of waste streams; their compositions; and the consistency of that composition
Knowledge of the organic content of the waste	Some colorimetric methods, for example, may provide an indication of the organic content of incoming wastes. However, these may not be suitable for organic solvents (in such cases, gas chromatography is more adequate)
Ensure adequate transfer of knowledge between holders of the waste	As with other waste streams, a crucial control measure is to ensure an adequate transfer of knowledge between holders of the waste. This should ensure that the constituents of all wastes bulked together to form a blend are known and recorded

Table 4.2: Waste composition characterisation techniques
[56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

The type of analysis required to accurately characterise the waste will vary depending upon the nature of the waste, the process to be used and what is known about the waste already. The results of all analyses need to be kept within the tracking system. These details can include information on:

- checks carried out on the constituents declared by the waste producer/holder to ensure permit compliance, and that it is suitable for the treatment plant specification and final disposal option. This check will also

cover checks on the presence of any constituents that may be potentially damaging to the treatment process
- all hazardous characteristics (e.g. flammability, explosivity, infectivity)
- physical appearance (e.g. consistency)
- compatibility assessment (e.g. reactions with water and other substances)
- colour
- acidity or alkalinity
- presence, strength and description of odour assessment
- presence of oxidants
- TOC
- COD
- ammonia
- flashpoint and combustion properties under normal conditions
- presence of sulphide(s)
- presence of cyanide(s)
- compounds containing halogen
- sulphur
- metals (e.g. heavy metals)
- VOCs
- POPs (e.g. PCBs).

A list of the parameters which may be analysed for the production of fuel from hazardous wastes is shown in Table 4.3.

Parameters	**Pre-acceptance**	**Acceptance**	**Waste fuel preparation process[1]**	**Dispatch**
Density	Yes	Optional	Optional	Optional
Viscosity	Optional	Optional	Optional	Optional
Flashpoint	Yes	Yes	Optional	Yes
LHV	Yes	Yes	Yes	Yes
Vapour pressure	Optional	Optional	Optional	Optional
Water content	Yes	Yes	Optional	Yes
pH	Yes	Yes	Optional	Yes
Ash contents	Yes	Optional	Optional	Yes
Ash composition	Optional	Optional	Optional	Optional
Chlorine	Yes	Yes	Yes	Yes
Fluorine	Optional	Optional	Optional	Optional
Bromine	Optional	Optional	Optional	Optional
Iodine	Optional	Optional	Optional	Optional
Heavy metals				
• volatile (Cd, Hg, Tl)	Yes	Yes	Optional	Yes
• others	Yes	Yes	Optional	Yes
PCB	Yes	Yes	Optional	Yes
Pentachlorophenol (PCP)	Optional	Optional	Optional	Optional
Sulphur	Yes	Optional	Optional	Optional
Alkalis	Optional	Optional	Optional	Optional
Corrosion test	Optional	Optional	Optional	Optional
Compatibility test	Yes	Yes	-	-
Radioactivity	Optional	Yes	-	Optional

Notes:
[1] depends on the type of production
Optional depends on the type of wastes, operating processes (liquid or solid substituted fuel preparation) and according to the requirements / specifications of the final users.
In italics minimum controls required in standard procedure

Table 4.3: List of analysis parameters typically considered in the production of fuel from hazardous waste [122, Eucopro, 2003]

Typically a good acceptance criterion includes the knowledge of the following parameters for waste oils.

Parameter	Acceptance	Dispatch
Water content	Yes	
Solid content	Yes	
Flashpoint	Yes	
Distillation curve	Yes	
PCB	Yes	
Total Cl	Yes	
S	Yes	
Pb, Cr, V, Cu, Ni	Yes	
Synthetic esters and fatty oils	Yes	
Colour		Yes
Viscosity		Yes
Viscosity index		Yes

Table 4.4: List of analysis parameters typically considered in the treatment of waste oils
[42, UK, 1995], [55, UK EA, 2001], [119, Watco, 2002]

Achieved environmental benefits
It improves the knowledge of the potential environmental issues related with the waste to be treated and reduces the risk of accidents or bad operations.

Cross-media effects
Not identified.

Operational data
Sites undertake screening tests to confirm that the waste is within plant parameters, but usually these cannot identify all the potential contaminants in the waste stream. Therefore, characterisation by waste producers and WT operators is part of a general requirement for all sites, and provides guidance on effective screening methods. For example, a full set of analysis for waste oils takes around 2 hours.

Applicability
This technique is fully applicable for all waste treatment facilities receiving waste. The disadvantage of the waste product analysis is the fact that full determination of the constituent materials is generally not accomplished, e.g. it is not possible to calculate the contents of paper, plastic or organic substances from the composition of the products of combustion. This method is limited to the analysis of elemental composition and parameters such as energy content, water content and the content of inorganic and organic matter.

Economics
An estimation shows that the investment in analytical equipment for a waste oil treatment facility is in the order of EUR 75000 (GBP 50000) per site.

Driving force for implementation
Better operability reduces process and economic risks. The water and solid content is analysed in waste oils because of quality and payment purposes. This has been encouraged in part by the quality requirements of the users of the treated oil, but this is not always a uniform requirement.

Example plants
The analysis of waste treatment products has already been applied in many countries. In some cases there is a first initial analysis (e.g. sulphur, total chlorine, water and flashpoint for waste oil treatments). If the oil passes these tests, it is quarantined before further analyses are performed. These include viscometry and infrared analysis to check for certain compounds including synthetic esters and fatty oils. Within the work carried out by CEN/TC 343, WG 2 'Specifications and classes' some extra information can be found for solid recovered fuels (SRF). Also more specific information for waste fuels can be found in Section **Error! Reference source not found.** of this document.

Reference literature
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [81, VDI and Dechema, 2002], [86, TWG, 2003], [119, Watco, 2002], [131, UBA, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [152, TWG, 2004]

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:

a. carrying out suitable checks before any decision is made to accept the waste
b. 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
c. 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
d. providing the chemical composition of the waste, its handling requirements and its hazards
e. providing and analysing a representative sample(s) of the waste from the production process producing such waste from the current holder
f. undertaking a comprehensive characterisation of the waste for each new waste enquiry
g. 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
h. 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
i. 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
j. 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
k. providing and checking details of the waste code according to the European Waste List (EWL)
l. 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)
m. carrying out a procedure for risk assessment
n. 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
- 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:

Pre-acceptance for waste oil treatment
As a general requirement, this step is not critical for a waste oils treatment plant, but it would be required if the waste is 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 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 installations are not set up for dealing with flammable materials. Petrol contamination often occurs, this significantly reduces the flashpoint of the material and will thus significantly increase the risk of accidents. Care should be 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 bottoms 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:

- aqueous wastes containing solvents that may then be emitted due to the heat of the process
- high nitrogen wastes with a potential for ammonia emissions to the 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 data rather than to extend the monitoring programme.

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.

Reference literature
[16, ÖWAV Working Commitee, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [131, UBA, 2003], [150, TWG, 2004], [153, TWG, 2005]

Acceptance procedures when the waste arrives at the WT installation

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 (see Section 0)
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:

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 checking 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.
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.

	Percentage of plants where this practice occurs (%)
Site enclosed or on a fully impermeable base	77
Return of rainwater (except 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
Note: Data correspond to 13 different physico-chemical treatment sites that were analysed.	

Table 4.5: Control procedures identified at physico-chemical treatment plants
[56, Babtie Group Ltd, 2002], [86, 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 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.

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 should set out clearly the types of contaminant on the activated carbon that it is intended to be regenerated.

Economics

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.

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

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.

Reference literature

[29, UK Environment Agency, 1996], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [125, Ruiz, 2002], [131, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

Sampling

Description

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
c. the number of samples and sample sizes for waste materials delivered in containers
d. sampling procedures for all incoming wastes including bulk (liquids and solid) wastes and wastes in drums and containers, and laboratory smalls. The number of samples taken increases with the number of containers. In extreme situations, small containers must all be checked against the accompanying paperwork. The procedure should include a system for recording the number of samples and degree of consolidation
e. having a system to ensure that the waste samples are analysed
f. details of the sampling of wastes in drums within designated storage, e.g. the time-scale after receipt
g. verification and compliance testing to confirm the identity and description of the waste
h. maintenance at the installation of a record of the sampling regime for each load, together with the justification for the selection of each option
i. sampling tankered wastes prior to acceptance. This way there is no storage pending sampling
j. retaining samples on-site 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
k. 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 specific issues to note are:

l. 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
m. samples are usually taken from one of three points on the tanker:
   - top hatch
   - back valve
   - sight glass

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. 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. gantries can be constructed to avoid the need for taking samples from the back valve of tankers, which would likely result in small spillages.

For sampling drummed waste (depending on the type of packaging), some specific 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. visual controls for every container and the sampling procedure need to be defined under the supervision of the operator
s. utilising the opening, visual control and adapted sampling of all drums above a certain capacity, for example of more than 200 litres
t. sampling packaged wastes in closed areas kept in depression or inside dedicated chambers with extractor hoods in case that waste contains fugitive materials.

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 should ensure 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.

Achieved environmental benefits
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.

Operational data
Specific laboratory equipment is necessary to practice sampling.

Applicability
Some sort of sampling is applicable to all types of waste.

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.

Example plants
All waste plants do some kind of sampling.

Reference literature
[16, ÖWAV Working Commitee, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [122, Eucopro, 2003], [131, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004]

Reception facilities

Description
There is usually a reception area for incoming waste where visual checks are made against the special waste consignment note and where some further sampling is undertaken before the waste is allocated. Sites tend to sample specific waste streams. Some good environmental practices applied to reception facilities are:

a. to have an accreditated laboratory on site to analyse the waste samples for pre-acceptance and acceptance. This may be accomplished by ensuring that the laboratory carrying out the analysis has a roboust quality assurance system, quality control methods and suitable record keeping of the analysis
b. to equip laboratories with the control equipment and devices necessary for quality assurance. Self-regulation is commonly not officially recognised
c. to have a dedicated quarantine waste storage area, so that if the inspection or analysis indicates that the wastes fail to meet the acceptance criteria (including, e.g. damaged, corroded or unlabelled drums) then the wastes can be safely temporarily stored. Such storage needs to be for a maximum of five working days. In the case of cold ambient temperatures, this storage time may exceed five working days to allow for sampling after defrosting. After acceptance, the waste can be moved to another storage area (for bulk waste, this is typically a bulking area). Written procedures need to be in place for dealing with wastes held in quarantine, and also for detailing and monitoring the maximum storage volume. Written procedures need to be put in place for the repackaging of the waste before return to the waste holder, as well as for the packaging procedures
d. to mark on a site plan the inspection, unloading and sampling areas and having a suitably sealed drainage system. Having a separate collection system for spills which is separated from rainwater collection drains and having a sealed underground area which is safely protected against the wastes needing to be treated (related with techniques in Section 4.5.2)

e. 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
f. to immediately assess the wastes deposited within the reception area
g. to immediately segregate wastes, to remove possible hazards due to incompatibility, which could result in the waste failing to meet acceptance criteria
h. 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
i. 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
j. to ensure 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
k. 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
l. 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
m. 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
n. to have a designed storage area at the facility that is suitable for the wastes received
o. 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:

p. weighing all incoming loads, unless alternative reliable volumetric systems linked to specific gravity data are available
q. not accepting any load on the site unless sufficient storage capacity exists
r. ensuring that all documents are checked and approved, and that any discrepancies need to be resolved before the waste is accepted
s. visually inspecting the load - where possible inspection checks need to be undertaken before off-loading. In any event though, the inspections need to be carried out immediately upon the arrival of the load at the installation
t. 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
u. 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 information may contain any necessary data regarding health and safety, further treatment, waste code, original producer, date of arrival on site, etc.
v. 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
Identifies the source, composition and hazard of the waste. Prevents wastes being accepted without written information.

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.
Operational data

A laboratory for chemically analysing the samples is needed. Related to technique a (see description above), some samples are not taken for immediate controls and analysis. Some samples, for example, are kept in case authorities require further controls.

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
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.

Techniques	Capital cost (GBP)	Operating cost (GBP)
Analytical laboratory [1,2]	40000	20000
Continuous monitoring equipment [2]	10000	1000
Technical Specification		
Capacity Oil types Process operation Waste gas flow Age of plant Age of pollution control equipment	10000 t/yr used lubricating oils batch 0 – 50 Nm^3/hr 10 years old 2 years old	
Notes: 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.		

Table 4.6: Economics of laboratory and monitoring equipment in a waste oil treatment facility
[42, UK, 1995], [150, TWG, 2004]

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.

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. 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.

The receiving area is normally covered and the doors are often closed because of odour, dust and 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.

Reference literature
[29, UK Environment Agency, 1996], [55, UK EA, 2001], [86, TWG, 2003], [119, Watco, 2002], [121, Schmidt and Institute for environmental and waste management, 2002], [126, Pretz, et al., 2003], [131, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.1.2. Management systems

Managerial techniques typically applied to the waste treatment installations as a whole are included in this section.

Techniques to determine the type of waste treatment applied to each waste

Description

Once the composition and characteristics (e.g. content of hazardous compounds) of the waste has been established, and it is confirmed that the waste is as described in the delivery/reception area (acceptance procedure), a treatment method or option for the waste should be determined. There are three fundamental principles for selecting the appropriate waste treatment for a specific waste: 1) to adequately characterise the waste, 2) to ensure that the waste is suitable for the proposed treatment activity and 3) to ensure operational control of the treatment process, including inputs and reaction monitoring and to have clear end-point objectives. Some techniques applicable to help achieve these goals are to:

a. describe and consider the installation's activities and the proposed techniques to prevent and reduce the waste arisings, the emissions of substances and heat (including during periods of start-up or shutdown, momentary stoppages, leaks or malfunctions)
b. identify the waste types subject to each process, including all the contaminants
c. identify the chemistry of the process and the fate of all the waste components and any reaction products
d. identify suitable recovery or abatement options, especially for components which may be harmful to the environment and which are not destroyed in the treatment but are displaced from one medium to the other. This can involve tracking those substances capable of pollution and that may be released unchanged from the treatment process
e. identify a suitable treatment method for each new waste enquiry
f. be sure that the process feedstock does not include substances such as solvents that could be recovered at a subsequent stage, by, for example, drying and subsequent distillation to separate components
g. have a clear methology to assess the treatment of waste, considering the physico-chemical properties of the individual waste and the specifications for the treated waste
h. report if there is any advice on preferable waste treatment (e.g related to waste treatment hierarchy) pursuant to the type of waste to be treated (e.g. EWL).

Achieved environmental benefits

The selection of a suitable treatment for a certain waste is vital to ensure that environmental emissions are reduced and that the waste is properly treated.

Operational data

Frequently, several procedures must be used for the correct treatment of waste. The procedure followed, or rather the combination (types of procedures, sequence of their application, applied controls, etc.) will be specified by typically a company/installation coordination procedure. In such a procedure, the laboratory results on the basis of the composition of the waste and its reaction behaviour have some impact on the type of waste treatment to be selected.

Driving force for implementation

The selection of a treatment is not only a function of the type of waste, but other issues such as local constraints (e.g. waste strategy), logistic considerations and what type of treatments are available in the region are also important issues to consider.

Sometimes and wherever possible, waste material is required to be processed by chemical, physical or biological treatment if it contains unacceptable quantities of environmentally hazardous substances or compounds which can be separated, converted, or immobilised, and thus rendered less harmful.

Example plants
Technique applied to all WT facilities.

Reference literature
[53, LaGrega, et al., 1994], [55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [131, UBA, 2003], [150, TWG, 2004]

Guaranteed supply of waste

Description
Waste can be seen as the 'raw' material used by WT facilities. In some cases the waste can be used as a reagent to treat other wastes. In any case, the guarantee to have the waste/material will be available at the right time for the continuing and proper performance of the installation is important.

Achieved environmental benefits
If the waste is to be used as a reagent in a treatment process, not having such a waste available may delay the treatment process for the waste type to be treated. This delay may incur associated environmental problems.

Applicability
For example, the guarantee of long term performance of anaerobic systems is a key issue for their economical feasibility (see Section **Error! Reference source not found.**)

Example plants
The main area of concern in anaerobic digestion is the guarantee of the long term performance of a plant which is key to its economical feasibility. This risk can be reduced through technological developments but the associated costs may affect the economics in the short term. Another example is the guarantee of having a sufficient supply of waste bases available in physico-chemical plants in order to neutralise acidic materials in the case that those are used as neutralisation processes.

The bunker or the equipment to feed the process should allow a constant feeding to abate overloads of machines.

Reference literature
[55, UK EA, 2001], [86, TWG, 2003], [126, Pretz, et al., 2003]

Techniques to increase the traceability of waste

Description
Any 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, that is, awaiting onward transfer
- breakdown of waste quantities by hazard classification
- indicate where the waste is located on site relative to a site plan
- compare the quantity on site against total permitted
- compare the time the waste has been on site against 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 0)
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 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
i. for bulk liquid wastes, 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
j. 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
- manage the throughput of wastes.

Cross-media effects
Not identified.

Operational data
Typically, computer databases are required. Implementation of an effective system also requires additional administrative work. Traceability systems need to question what exactly has to be traced and when.

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.

Reference literature
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

Improvement of the efficiency of waste treatments

Description
Waste treatment efficiency in this section relates to the improvement of the usefulness of the outputs, raw material consumption and material flow analysis. The techniques related to energy efficiency are included in Section 0. Some techniques which can be applied to increase the efficiency of waste treatment are:

a. to provide an assessment of the efficiency of the treatment process in relation to pollutants, i.e. in terms of the removal or partition of substances within the process, for example:
   - 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, for example pesticides or solvents)
   - the utilisation of heat vapour used to preheat waste oil
b. to analyse efficiency parameters using the following steps:
   - process mapping – identifying the pathways within the process for the specific substance or substances
   - mass balance
c. to analyse the effect variability of the waste composition may have on the performance of WT units
d. to monitor efficiency. Operational efficiency monitoring may be carried out by instrumentation, direct operator observation, and chemical analysis. Any monitoring programme will typically involve extensive record keeping, using a combination of computers, chart recorders, and manually completed paper logs
e. to have in place procedures for waste material separation, and in such a way that the recyclability of the separated materials will not be impaired.

Some of these techniques are sometimes part of ISO 9000 and ISO 14001.

Achieved environmental benefits
A facility must monitor operations carefully to assure that its performance achieves the desired results. Optimisation of the waste treatment installations typically helps to achieve lower emissions and lower consumptions.

Operational data
It is recognised that to be commercially viable, waste treatment facilities need to deal with variable waste streams, but that it may not always be desirable or effective to overcomplicate the design and operation of a waste treatment process by trying to accommodate every component of the varied waste stream. Therefore, monitoring the waste and applying suitable separation can help to achieve a higher efficiency and economy of operation.

Some waste treatments have to deal with a wide and variable range of wastes. This requires the plant and equipment to be versatile and usable for a number of wastes. This contrasts with treatment techniques used for 'in-house' treatment on waste producer premises, where the number of waste streams is limited and well characterised. This characteristics of in-house treatments may lend themselves to the development of dedicated single stream treatment techniques.

Applicability
Even where the site weighs all the input wastes and outgoing waste streams and products, it is not always easy to perform a sensible mass balance on the system. Mass balances and material flow analysis for each single material fractions or ingredient are difficult and sometimes the results are questionable. The main reason is the inherent variations in the waste IN.

Examples of recyclable materials in Ph-c plants are principally oil, grease, organic solvent, metal, metal salts.

Driving force for implementation
Typically undertaken indirectly to reduce the operational cost of the installation or the disposal cost of the waste.

Example plants
There are still a large number of sites that do not have a weighbridge, or do not use the weighbridge for each load.

Reference literature
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004], [153, TWG, 2005]

Management techniques

Description
Some techniques are:

a. operational control of the treatment process
b. provision and maintenance of suitable infrastructure (good housekeeping)
c. management of effluents (developed in Section 4.4.1)
d. control of the plant based on laboratory-determined analyses, which also determine treatment programmes, the required controls and documentation
e. to have the plant operation carried out exclusively by specialised and expert personnel (e.g. management level: with university qualification, relevant degree and/or working specialism; operative level: skilled worker, laboratory assistant). Personnel qualifications can be assured by a mix of a relevant time of studying, a continuing education measures; with the requisite specialist technical personnel knowledge being determined and controlled within the context of plant certification. Related with techniques described in Section 0
f. to have all the necessary peripheral structures required for a correctly functioning enterprise. This includes, for example, property boundaries, signs designating the location of parking places and storage facilities, lighting, scales, a workshop, etc.

Achieved environmental benefits
General improvement of the environmental awareness of the installation.

Applicability
Regular training is common in the waste treatment sector.

Reference literature
[50, Scori, 2002], [55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

Identification of economies of scale and synergies

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 4.1.3)
c. combining combustible wastes to justify a combined waste-to-energy (see energy sections within Section 4.1.3)
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

[55, UK EA, 2001], [86, TWG, 2003]

Provision of full details on the activities to be carried out

Description

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.

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 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
[55, UK EA, 2001], [86, TWG, 2003], [131, UBA, 2003], [150, TWG, 2004], [153, TWG, 2005]

Environmental management tools

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
   - 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)
- 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) [68, 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.:
- 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
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.

A number of studies ([77, Klemisch and Holger, 2002], [78, Clausen, et al., 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 [69, Schaltegger and Wagner, 2002] shows the following costs (see Table 4.7) 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.

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

Table 4.7: Cost of application of EMAS

A study by the German Institute of Entrepreneurs [70, 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 [71, 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.

Reference literature
[66, TWG, 2003], [72, EC, 2001], [73, ISO, 1996], [150, TWG, 2004]

Promote good collaboration between waste producer and holder

Description
Generally it can be said that options taken early in the chain can have the most benefits and that prevention is better than treatment. Thus, actions taken by the waste producer and holder can have a big effect on the waste. This technique thus focuses on trying to influence the waste producer and holder and if there are problems trying to change the bad waste management habits of the producer and holder.

Achieved environmental benefits
Waste treatment plants significantly rely on the linkages with the preceding logistics, actions and companies especially if it can help to avoid the need to use very expensive solutions for the treatment of waste.

Applicability
Sometimes it is very difficult to to persuade waste producers and holders to change their habits. Moreover, the control of the waste producer is carried out by the authorities.

Economics
Normally, this decreases the cost of the waste treatment.

Driving force for implementation
To try to decrease the cost of the treatment. This technique is related to Article 3(c) obligations of waste producers in sectors subject to IPPC and for producers not subject to IPPC, Article 2 of Directive on hazardous waste (91/689/EEC).

Example plants
Physico-chemical treatment plants of waste waters. The waste water arising during the treatment of waste in a Ph-c plant contains inadmissibly high levels of organic materials, depicted as AOX. Technically expensive and, in part, energy intensive procedures such as adsorption or oxidation must be used to separate these organic materials from, or to convert into, waste water.

A process-independent solution to this task is the separate collection of the organic materials – depicted as AOX – directly at the point where these arise, so that they are then not mixed with the waste to be treated and cannot contaminate the waste water produced in the course of the waste treatment. This, therefore, eliminates the need to apply the above-mentioned procedures to reduce the proportion of organic materials, depicted as AOX.

AOX cannot be separated by adsorption with activated carbon. It becomes clear that a separate collection of the materials shown in the AOX is certainly more effective. In practice, these types of substance are kept strictly separate.

The distillation operation should work together logistically in order to accomplish the separate collection of the materials to be prepared according to the distillation criteria. This co-operation is implemented in practice and has proved its worth.

Reference literature
[121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

Utilisation of qualified personnel in the facility

Description
Some examples are:

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 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 also be recognised on the basis of comparable training or on many years of practical experience
c. other staff: other staff must be reliable and technically skilled. This technical skill may be based, for example, on formal qualifications in such areas as community services and waste disposal, on many years of practical experience, or on comparable training.

Achieved environmental benefits
Improves 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 good management of the installation and as a result of workers qualifications.

Cross-media effects
Not known.

Operational data
This is a management tool.

Applicability
Fully applicable to the whole WT sector.

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.

Example plants
There are many examples in the sector**.** It might happen that delivered wastes might cause problems, so it is advantageous if the staff in charge are alert on problematic wastes. However, staff should be aware of all materials which might cause problems during processing. Depending on the applied machines these might be large bulky parts or other components like metals. If these staff are highly alert, an almost continuous processing with a small range of quality fluctuations might be guaranteed.

Reference literature
[126, Pretz, et al., 2003], [131, UBA, 2003], [150, TWG, 2004]

4.1.3. Utilities and raw material management

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 4.8 below:

Energy source	Energy consumption		
	Delivered (MWh)	Primary (MWh)	% of total
Electricity*			
Gas			
Liquid fuels			
Waste			
Other (operator to specify)			
* specify source			

Table 4.8: Energy consumption reporting
Based on [55, UK EA, 2001]

b. reporting the energy exported from the installation
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 installation.

Achieved environmental benefits

Evaluating the reduction of emissions from the energy system can only be carried out with a proper accounting of the actual emissions generated. The breakdown between generation and consumption can help to optimise the match 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 rather limited, and possible efforts to decrease consumption need to be balanced against possible higher emissions from the treatment.

Applicability

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 consumptions to each single process/treatment carried out within the overall WT process. These reports are typically carried out every year or every half a year. Higher frequencies may be applied in the case of a higher variation in the types of waste treated.

Economics

The requirements are basic and low cost.

Driving force for implementation

To reduce energy costs.

Reference literature
[55, UK EA, 2001], [116, Irish EPA, 2003], [150, TWG, 2004], [153, TWG, 2005]

Use of cleaner fuels

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 0), 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
[86, TWG, 2003], [116, Irish EPA, 2003], [150, TWG, 2004]

Use of waste as fuel

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 4.3).

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 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
[14, Ministry for the Environment, 2000], [42, UK, 1995], [116, Irish EPA, 2003], [150, TWG, 2004]

Measures to improve energy efficiency

Description
Some techniques applicable to increase the energy efficiency of WT installations are:

a. developing an energy efficiency plan which appraises 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 and the targeting of areas for reductions
c. using combined heat and power (CHP)
d. applying operating, maintenance and housekeeping measures to the most relevant energy consumption installations, 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, for example, optimising excess air
   - other maintenance relevant to the activities within the installation
   - 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
e. 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

f. 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)
g. applying energy efficiency techniques to building services
h. setting the time of operation of the high energy equipment to off-peak periods
i. 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). For example, based on primary energy consumption for the products or raw material inputs which most closely match the main purpose or production capacity of the installation
j. minimising the emissions of diesel engines
k. using landfill gas to produce electricity and heat
l. making an energy survey to identify the opportunities of further energy savings
m. using heat of the furnaces and engines for vaporisation processing, drying and for preheating activities
n. selectingthe appropriate waste to be treated in the installation. Typically, installations not designed to treat a certain type of waste consumes 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 4.8, together with supporting information from any appraisal procedure carried out. The plan is required to ensure that the operator has considered all relevant 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.

Table 4.9: CO_2 saving from the integration of different improvement energy efficiency techniques [55, UK EA, 2001]

Utilising an energy efficiency plan and switching to cleaner fuels can reduce the energy consumption and the environmental emissions from 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.

Operational data
The place within the existing WT installation where the improvement is applied typically dependent on the existing installation.

Applicability
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 make 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
Typically energy efficient systems have higher investment costs. However, their operation costs are typically lower (or the revenues higher). Costs are typically higher for existing installations than for new installations. Some examples are shown in Table 4.10.

Energy efficiency option	NPV EUR'000	NPV/CO_2 saved EUR/tonne
7MW CHP plant	2058	15
High efficiency motor	0.75	52.5

Compressed air	n.a.	n.a.
Indicative only, based on cost/benefit appraisal.		

Table 4.10: Economics of the integration of different improvement energy efficiency techniques [55, UK EA, 2001]

The improvement of the energy efficiency needs to be balanced with the cost to achieve this. WT 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.

Reference literature

[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [66, TWG, 2003], [116, Irish EPA, 2003], [132, UBA, 2003], [150, TWG, 2004], [153, TWG, 2005]

Raw material selection

Description
This section deals with the selection and substitution of the raw materials used. Some techniques are to:

a. identify the raw and auxiliary materials, other substances and water that have been proposed for use. This involves gathering a list together of the materials used (including, i.e. generic information about 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, approximate percentages going to each media and to the product)
    - the environmental impact where known (for example degradability, bioaccumulation potential, toxicity to relevant species)
    - 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. re-use the spent lime from incinerator lime injection acid gas abatement systems
g. re-use waste strong acids in those treatments where acid is needed.

Achieved environmental benefits
These measures can:

- reduce 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 an understanding of the fate of by-products and contaminants and their environmental impact
- be seen as a preferred option for some acid wastes, but depends on the volume and contamination of the waste.

Cross-media effects
Possible, for example in the re-use of spent lime, attention should be given to the level of metal and organic contamination that may be present.

Operational data
Due to the nature of the WT processes, the consumption of raw material is influenced by the variation of the 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 in relation to the size of reactor vessel. This requires a similar scale up with mixing tanks to produce the lime solution.

Applicability
The scope to minimise the potential environmental impact of the use of raw materials is sometime limited in terms of the quantity used (waste minimisation) or of their nature (for example, presence of contaminants, use of less harmful alternatives).

Driving force for implementation
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
The following raw material substitutions are considered for application in the UK:

Raw material	Possible substitute
Sodium hydroxide	Only 'mercury free' NaOH should be used[1]
Demulsifiers	Only fully biodegradable products with known, safe degradation products should be used
[1] Industry producers of NaOH consider that mercury free NaOH should contain less than 50 µg/kg	

Table 4.11: Examples of raw material substitution
[55, UK EA, 2001], [86, TWG, 2003]

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.

Reference literature
[55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

Techniques to reduce water use and prevent water contamination

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 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:

a. performing regular water audits, with the aim of reducing water consumption and preventing water contamination. 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 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. recycling water within the process. 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

d. separately discharging uncontaminated roof and surface water, which cannot be used
e. ultimately carrying out some form of treatment on the waste water. 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
f. 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
g. 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 re-using wash-water
    - using trigger controls on all hoses, hand lances and washing equipment
h. discharging rainwater to interceptors
i. undercovering some parts of the site to avoid contamination of rainwater (e.g. in the main waste treatment plant)
j. protecting systems to avoid liquid and solid spills being discharged directly to watercourses or to sewer
k. 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
l. 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
    - 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

m. 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
n. applying the techniques to bunds mentioned in Section 0.

Achieved environmental benefits

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.

Applicability
Typically this is a part of an integral EMS (Section 0) in the installation. 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 that water releases are continuous or batch and in the case that the WWTP is installed on-site or off-site.

Economics
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
Economic incentives to reduce waste water generation and water consumption. In some EU countries, there are incentive systems in place which have the aim of encouraging a reduction in water consumption.

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. Some installations have reported that it is possible to reduce up to 90 % of the water consumption.

Reference literature
[54, Vrancken, et al., 2001], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

4.1.4. Storage and handling

This section covers techniques to consider in the determination of BAT for storage and handling activities in a WT installation. However, it needs to be pointed out that a horizontal BREF entitled 'Emissions from Storage' is available and provides more information on the issue.

Generic techniques applied to waste storage

Description
Some general techniques are:

a. 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
b. locating storage areas away from watercourses and sensitive perimeters and in such a way so as to eliminate or minimise the double handling of wastes within the installation
c. clearly marking and signposting storage areas with regard to the quantity and hazardous characteristics of the wastes stored therein

d. 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
e. ensuring that the storage area drainage infrastructure can contain all possible contaminated run-off and that drainage from incompatible wastes cannot come into contact with each other
f. 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
g. using a dedicated area/store for sorting and repackaging laboratory smalls. Once the wastes have been sorted according to their hazard classification, with due consideration for any potential incompatibility problems, and repackaged then these drums do need not to be stored within their dedicated laboratory smalls area but can be and indeed need to be removed to the appropriate storage area
h. 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
i. ensuring that all connections between vessels are capable of being closed via suitable valves. Overflow pipes need to be directed to a contained drainage system, which may be the relevant bunded area or to another vessel provided suitable control measures are in place
j. equipping tanks and vessels with suitable abatement systems, together with level meters with audible and visual high level alarms. These systems need to be sufficiently robust and regularly maintained to prevent foaming and sludge build-up affecting the reliability of the gauges
k. ensuring that storage vessels holding flammable or highly flammable wastes meet special requirements
l. preferably routing pipework above ground, although if it is underground the pipework needs to be contained within suitable inspection channels
m. replacing underground or partially underground vessels without secondary containment, for example, double skinned with leakage detection, by aboveground structures
n. equipping silos with abatement systems, level monitors and high level alarms
o. ensuring that incorporate storage bunkers extraction systems for particulate abatement or spray damping

p. locating bulk storage vessels on an impervious surface which is resistant to the material being stored. The 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
q. ensuring that the vessels supporting structures, pipes, hoses and connections are resistant to the substances (and mix of substances) being stored
r. 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
s. 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
t. storing organic waste liquid (e.g. with a flashpoint of less than 21 °C) under a nitrogen atmosphere to keep it inertised. Each storage tank is put in a waterproof retention area and equipped with a level indicator. Gas effluent from events are collected and treated.
u. using polymer sheeting to cover open solids storage facilities that may generate particulates
v. having an appropriate number of tanks for the different kinds of incoming and outgoing streams
w. 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
x. dealing with waste streams containing VOCs separately and using plants dedicated to these waste streams
y. having measures available to prevent the build up of sludges higher than a certain level and the emergence of foams that may affect such measures in liquid tanks, e.g. by regularly controlling the tanks, sucking out the sludges for appropriate further treatment and using anti-foaming agents
z. equipping tanks and vessels with suitable abatement systems when volatile emissions may be generated, together with level meters and alarms. These systems need to be sufficiently robust (e.g. able to work if sludge and foam is present) and regularly maintained

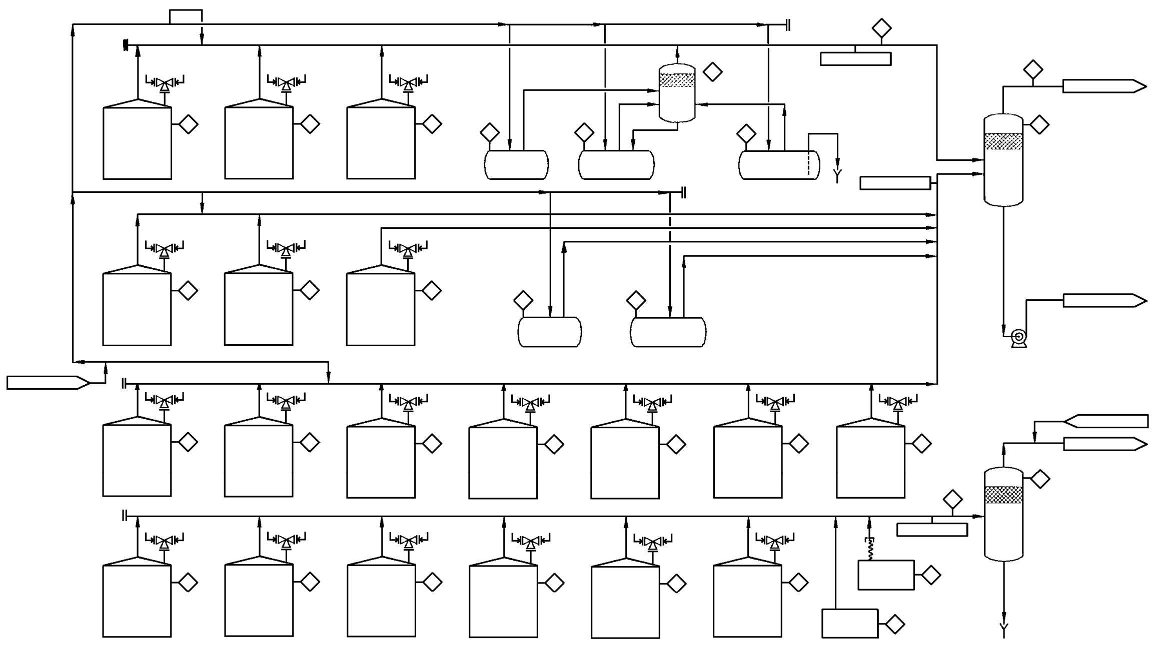
Some generic techniques in the reduction of odour related to storage are:

aa. optimising the controlling time lapse and temperature in the settling processes
bb. controlling the decanting of settled layers by visual assessment of samples from different levels
cc. handling odorous compounds in fully enclosed, suitably abated vessels
dd. storing drums and containers of odorous materials in enclosed buildings
ee. 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).

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. Segregated storage is necessary to prevent incidents from incompatible substances reacting and as a means of preventing escalation should an incident occur.

Some justification of technique p (see descripton above) for a volume of 110 % is that takes into account the build-up of rainfall with the bund.

Example plants
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 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. The amount of displacement to vent during transfer of contents is minimised in some cases by connected vent pipes. See an example in the Figure 4.1 below.



APPAREC.	UNITA' DI MISURA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PRODOTTO	/	S-5 VISCOFLEX MC 38	S-102 VISCOFLEX MC 33	S-101 VISCOFLEX MC 33	V-201 RICEVITORE IMP. TCT	02-B2 RIC. BAROIL VACUUM	/	02-V1 RICEV. IMP. STRIPP. 100	C-303 SEPAR. GAS CONDENSE "A"	CORR. "A" A 10 DRUM 08-V1	S-33 GASOLIO MC 80	S-34 GASOLIO MC 80	TK-401 OL. DISIDR. MC 750	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. DISIDR. MC 60
CORRENTI	/	CORR. "A1"	CORR. "A1"	CORR. "A1"	CORR. "A1"	CORR. "A1"	/	CORR. "A1"	CORR. "A1"	CORR. "A1"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"
STATO	/	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	/	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	GASSOSO IDROC+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2
TEMPERATURA	°C	140	140	140	35	58	/	35	40	40	30	30	120	30	30	30	30	50
PRESSIONE	mm/H20	/	/	/	1000	400	/	400	80	80	/	/	100	200	100	/	/	/

APPAREC.	UNITA' DI MISURA	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
PRODOTTO	/	S-60 VISCOFLEX MC 150	S-59 VISCOFLEX MC 150	S-56 VISCOFLEX MC 150	S-58 GASOLIO MC 150	CORR. "A2" A 10 DRUM 08-V1	08-V1 SEPAR. GAS A COMBUST.	08-V1 GAS A COMBUST.	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 H2O DI PROC. MC 120	VASCA V-1 H2O PROC. DA CENTR.	BRACCIO DI CARICO DENSONE	COLLETTORE CORR. "B" A 08-V2	08-V2 SEP. A CORR. A COMBUST.
CORRENTI	/	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	CORR. "A2"	COR."A1+A2" A COMBUSTIONE	COR."A1+A2"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"	CORR. "B"
STATO	/	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	LIQUIDO+ GAS+N2	GASSOSO IDROC+N2	GASSOSO IDROC+N2	GASSOSO IDROC+N2	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	140	140	140	30	30	30	30	30	40	30	30	30	35	30	SALTUARIO	/	30
PRESSIONE	mm/H20	/	/	/	/	/	20	-10	/	/	/	/	/	/	/	/	-30 mm/H20	-35 mm/H20

Figure 4.1: Blanketing system in a storage system used in a waste oil re-refining facility
[36, Viscolube, 2002]

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 gasoil (different kinds) and water. Another EU installation has blanketed all the storage tanks of output and intermediate materials of the process. Traps of VOCs and odours 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

[30, Eklund, et al., 1997], [36, Viscolube, 2002], [50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [128, Ribi, 2003], [150, TWG, 2004], [153, TWG, 2005]

Techniques for the storage of drums and other containerised wastes

Description

Some techniques are:

a. storing containerised wastes under cover. This can also be applied to any container that is held in storage pending sampling and the emptying of containers. Covered areas need to have adequate provision for ventilation. The air is treated before it is released depending on the type of contamination if any (see Section 4.3)
b. storing containers with well fitting lids, caps and/or with valves secure and in place
c. maintaining the availablity 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
d. strictly following regulations related to the storage areas for containers holding flammable or highly flammable wastes, as these areas are highly regulated
e. 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
f. applying positive ventilation or keeping the storage area below atmospheric pressure
g. utilising open sided roofed areas
h. utilising flameproof lighting
i. 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
j. storing containers in such a way that leaks and spillages could not escape over bunds or the edge of the sealed drainage area
k. 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 filter. The system is not air-tight, 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 the air during the decanting of solvents at minimum cost
l. producing and following written procedures for the segregation and packing of laboratory smalls
m. avoiding storing incompatible substances within the same drum/container (e.g. laboratory smalls)
n. using a dedicated area/store for sorting and repackaging laboratory smalls
o. once the wastes have been sorted according to hazard classification, with due consideration for any potential incompatibility problems, and repackaged, ensuring that these drums are not stored within the dedicated laboratory smalls area but are removed to the appropriate storage area
p. where laboratory smalls are decanted into larger containers, carrying out this in a closed building with a ventilation system and exhaust air treatment and a bunding system without drainage

q. storing drums and containers including hazardous waste in basins which are impermeable and have a double construction
r. storing completely closed containers like IBC and bigger, that may be stored outside halls, over a surface protected ground.

Achieved environmental benefits
The storage under cover of drummed waste has the advantage of reducing 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. Some of the techniques presented also prevent the emissions which could be caused by storing incompatible substances together which might then react together. Other benefits are related to avoiding soil contamination.

Cross-media effects
Related with technique a (see description above), 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 emission to the air.

Operational data
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 installations also need also to consider the access requirements for fire fighting.

Applicability
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 typically enough to ensure an effective environmental protection.

Reference literature
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

Techniques to improve the maintenance of storage

Description
Some techniques are:

a. putting in place procedures for the regular inspection and maintenance of storage areas including drums, vessels, pavements and bunds. Inspections need to pay particular attention to any signs of damage, deterioration and leakage. Records need to be kept detailing action taken. Faults should be repaired as soon as practicable. If the containment capacity or the capability of bund, sump or pavement is compromised then the waste needs to be removed until the repair is completed
b. carrying out daily inspection of the condition of containers and pallets and keeping written records of these inspections. If a container is found to be damaged, leaking, or in a state of deterioration, provision needs to be made to either over-drum or transfer the contents to another container. Pallets damaged to the extent that the stability of the containers is or may become compromised need to be replaced. ‘Plastic shrink wrap’ needs to only be used to provide secondary stability to drum/container storage, in addition to the use of pallets of an appropriate condition
c. having in place and following a routine programmed inspection of tanks, and mixing and reaction vessels, including periodic thickness testing. In the event of damage or deterioration being detected, the contents need to be transferred to an appropriate alternative storage. These inspections need to preferably be carried out by independent expert staff and written records need to be maintained of the inspection and of any remedial action taken.

Achieved environmental benefits
Reduces storage problems and avoids fugitive emissions.

Example plants

Many examples exist in the sector.

Reference literature
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [150, TWG, 2004]

Bunds for liquid storage

Description
All tanks containing liquids whose spillage could be harmful to the environment need to be bunded. Some issues to consider for these bunds are that they need to:

a. be impermeable and resistant to the stored materials
b. have no outlet (that is, no drains or taps), but should drain to a collection point for treatment
c. have the pipework routed within bunded areas with no penetration into contained surfaces
d. be designed to catch leaks from tanks or fittings
e. have a sufficient bund capacity. See point p in Section 0
f. be subject to regular visual inspections and any contents pumped out or otherwise removed under manual control should be checked first for contamination. Where not frequently inspected, the bunds should be fitted with a high level probe and an alarm as appropriate. There needs to be a routine programmed inspection of bunds (normally visual but extending to water testing where structural integrity is in doubt)
g. have fill points within the bund.

Note, the working areas for liquid decanting and storage areas need to be separately bunded.

Achieved environmental benefits
Reduces contamination of soil and water from major spillages or incidents, involving a loss of containment.
Applicability
Storage of liquids.

Driving force for implementation
These issues are typically regulated in the different EU countries.

Reference literature
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

Restricting the use of open topped tanks, vessels or pits

Description
Some techniques are:

a. not allowing direct venting or discharges to the air by linking all vents to suitable abatement systems
b. keeping the waste or raw materials under cover in waterproof packaging.

Achieved environmental benefits
Reduces fugitive emissions (e.g. VOC, particulates) and spillages.

Operational data
During accidental events discharges to the air may be permited to avoid more severe damage.
Applicability
Typically applied to the storage of waste that may cause fugitive emissions (e.g. VOC, particulates).

Reference literature
[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004]

Generic techniques applied to waste handling

Description

Some general techniques are:

a. having in place systems and procedures to ensure that wastes are transferred to the appropriate storage safely
b. 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 0)
c. having in place a management system for the loading and unloading of waste in the installation, also taking into consideration any risks that these activities may incur (for example, in the transfer of bulk liquid waste from tanker to storage vessels). This might involve:
    - having in place systems to prevent 'tanker drive off', i.e. a vehicle pulling away whilst still coupled
    - 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
    - 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:
        - 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 of the transfer hose may not be necessary 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
    - providing of routine maintenance, so that a more acute accident situation does not arise due to the failure of plant or equipment. This may include the failure of a pump seal or the blockage of a filter pot commonly used at transfer points
    - having an emergency storage for leaking vehicles, to minimise an acute incident associated with the failure of the seal on the road tanker
    - back balancing the vapour system when loading road tankers
    - 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. In order to prevent an unauthorised discharge, a lockable isolating valve needs to be fitted to the loading connection. This needs to be kept locked during periods when there is no supervision of the unloading points
d. 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. VOC)
e. 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
f. packing containers of chemicals into separate drums based on their hazard classification. Chemicals which are incompatible (e.g. oxidisers and flammable liquids) should not be stored in the same drum
g. 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
h. 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
i. 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
j. using rotary type pumps equipped with a pressure control system and safety valve

k. collecting the exhaust gas from vessels and tanks when handling liquid waste that may generate fugitive emissions
l. selecting the adequate packaging material considering what material/waste is intended to be contained (e.g. dangerous material)
m. having in place systems and procedures to ensure that waste subjected to be transferred is packaged and transported in accordance with legislation concerning the safe carriage of dangerous goods.

Achieved environmental benefits
An appropriate and safe storage of wastes helps to reduce fugitive emissions, the risks of leakages and prevention of accidents. Segregated storage is necessary to prevent incidents from incompatible substances and as a means of preventing escalation should an incident occur. A transfer of damaged pallets may lead to other pallets being stored on top, resulting in further damage and possible collapse of the stack.

Applicability
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.

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 spillage. Interceptors with overflows to sewers usually have automatic monitoring systems, such as a check on pH, which can shut down the overflow.

Driving force for implementation
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
[50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [152, TWG, 2004]

Handling of solid waste

Description
Some techniques are:

a. ensuring the bulking of different batches only takes place with compatibility testing
b. not adding liquid wastes to solid wastes other than in purpose designed and built reaction vessels, and only after the appropriate compatibility tests
c. using local exhaust ventilation to control odour and dust
d. unloading solid and sludge in a closed and depressurised building
e. balancing of air between tanks and different areas
f. using pumping of sludges instead of open movement.

Achieved environmental benefits
Avoids accidents and fugitive emissions.

Cross-media effects
When pumping sludges or liquids from one container to another, some emissions may be generated in the area where the material is pumped due to the displacement of the air.

Applicability
Techniques noted as c) and d) of the description section above are typically applicable to wastes that may generate fugitive emissions.

Example plants
Preparation of waste fuel.

Reference literature
[29, UK Environment Agency, 1996], [55, UK EA, 2001], [86, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [152, TWG, 2004]

Handling activities related to transfers into or from drums and containers

Description
This section includes drum, tank, tanker or small container transfers into or from drums. Some techniques are:

a. 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
b. bulking up odorous materials only under controlled conditions (e.g. not in the open air) to avoid odour emissions
c. keeping the container lidded/sealed as much as possible
d. transferring wastes in containers into storage vessels using a dip pipe
e. during bulking to tankers, using vapour balance lines connected to appropriate abatement equipment
f. ensuring that the transfer from a tanker to a drum or viceversa uses a minimum of two people to check the pipes and valves at all times
g. manipulating drums using mechanical means, for example a fork-lift truck with rotating drum handling fitting
h. ensuring that transfers/discharges only take place after compatibility testing has been completed (see Section 0) and then only with the sanction of an appropriate manager. The approval should specify 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
i. ensuring that tankers are not used as reaction vessels as this is not their designed purpose
j. blending by bulking into tankers needs to only take place once suitable verification and compatibility testing has been carried out
k. decanting larger individual containers of waste into IBCs or 205 litre drums and generally bunding these areas to protect site drainage
l. taking suitable precautions against the hazards of static electricity when handling flammable liquids
m. securing together the drums by shrink-wrap
n. training fork-lift drivers in the handling of palletised goods, to minimise fork-lift truck damage to the integrity of drums
o. using sound and undamaged pallets
p. replacing any damaged pallets on arrival and not transferring them into storage
q. providing adequate space needs within drum storage areas
r. 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.

Achieved environmental benefits
Avoids fugitive emissions, e.g. by minimising splash, fume and odour, health and safety problems; and prevents unexpected releases or reactions.
Applicability
Technique r (see description above) is typically applied to locations within the installation.

Reference literature
[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004], [153, TWG, 2005]

Automatic unloading of drums

Description
The unloading station includes (from upstream to downstream):

a. a drum supply station driven by pneumatic motorisation. The drums, transported by means of a fork-lift, are placed onto a set of conveyors with motorised rollers, ensuring that the containers are then directed to the grip station
b. 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
c. 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 flowrate principle, permitting a reduced consumption of water, is assured by nozzles placed inside metal sheaths
d. 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
e. a station for the pressing and removal of the cleaned drums
f. a control cabin.
g. 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.

Achieved environmental benefits
Reduces the length of time that the conditioned waste remains on site and optimises the process of cleaning the containers. The purpose of such a system is to unload waste from drums without human intervention avoiding accidents.

Applicability
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.

Driving force for implementation
The automated station for the unloading of conditioned waste shall meet the following dual objective:

- to improve the working conditions of the operatives
- to reduce the length of time that the conditioned waste remains on site and to optimise the process of cleaning the containers.

Example plants
Applied to the preparation of fuel from hazardous waste.

Reference literature
[91, Syke, 2003], [122, Eucopro, 2003], [150, TWG, 2004]

Techniques to improve stock control in storage

Description
Some issues to consider are:

a. for bulk liquid wastes, stock control involves maintaining a record of the route through the entire process. For drummed waste, the control needs to utilise the individual labelling of each drum to record the location and duration of storage

b. the 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
c. all containers need to be clearly labelled with the date of arrival, relevant hazard code(s) and a unique reference number or code 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
d. 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
e. automatic monitoring of the storage and treatment tanks levels with the tank level indicators
f. 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
g. limiting the reception storage area to a maximum of one week only (see Section 0)
h. taking measures (e.g acceptance planning, identififying 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.

Achieved environmental benefits
Prevents emissions during storage activities.

Operational data
A management system is required as the above techniques relate to a quality management system (QMS).

Example plants
Many examples exist in the sector.

Reference literature
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004]

Computer controlled high rack storage area for hazardous wastes

Description
The logistic centre in the compound of different treatment facilities is a computer controlled high rack storage area for hazardous wastes. Here, all substances are identified, weighed, photographed and sampled before storage.

Of special importance is the in-house laboratory, where samples of the individual waste substances are analysed before disposal or recovery in order to identify the exact substance properties and to determine the appropriate treatment process. The laboratory also produces concepts for clean-up in cooperation with the other departments.

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.

Achieved environmental benefits
It separates different types of hazardous wastes and ensures its appropriate treatment process.

Operational data
Before storage of the containers in the high rack area, administrative and technical controls take place (e.g. sampling and photographic documentation). Storage of the containers is then carried out by means of a

programmed stock control system. Transport of the container within the high rack area is carried out by computer-controlled shelf access equipment. Programming ensures that all transport processes of the container are planned in advance and thus predefined, and that all associated information (e.g. documents and sampling results) and executed transport processes of the container are registered, which allows for comprehensive control. In order to enable reception and storage of wastes in varying containers, every container is put on a standardised pallet. This pallet is designed as a collecting tray that collects spill-overs, e.g. from sampling.

Applicability
This technique is applicable to waste treatment facilities receiving hazardous wastes.

Example plants
An example waste disposal plant in Germany.

Reference literature
[157, UBA, 2004]

Tank and process pipework labelling

Description
Some issues to consider related to labelling requirements are:

a. all vessels need to be clearly labelled with regard to their contents and capacity, and need to have an unique identifier. Tanks need to be appropriately labelled depending on their use and contents, for example:

Content	Example label
Solvent	Highly flammable
Effluent	Waste water

b. 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)
c. 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
d. 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	Fire fighting water
Blue	5012	Compressed air

e. tagging all valves with an unique identifier and showing this on the process and instrumentation diagrams
f. correctly sizing and maintaining all connections in an undamaged state.

Achieved environmental benefits
The systems make it easier for the operator to maintain a good knowledge of the whole process and help to reduce accidents and control emissions.

Applicability
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.

Reference literature
[55, UK EA, 2001], [86, TWG, 2003]

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
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.

Table 4.12 presents an example of a compatibility chart and indicates that careful planning must be given to chemical storage. For example, 'acids, minerals, non-oxidising' (number 1) can generate heat and violent polymerisation reactions when mixed/blend with aldehydes (number 5).

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	Flourides, 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, modings, etc.	GF H F	GF H F						H F G									H F						23

No.	Name of reactivity group	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
24	Metals and metal compounds, toxic	S	S	S			S	S			S														24																	
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 agentes, 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

Note 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**

Table 4.12: Example of a compatibility chart for the storage of hazardous waste [53, LaGrega, et al., 1994]

Achieved environmental benefits
Prevents any adverse or unexpected reactions and releases before transfer to storage tanks.

Applicability
Testing is necessary prior to transfer. This needs to cover:

- tanker discharges to bulk storage
- tank to tank transfers
- transfers from a container to a bulk tank
- bulking into drums/IBCs
- bulking of solid waste into drums or skips.

Reference literature
[53, LaGrega, et al., 1994], [55, UK EA, 2001], [86, TWG, 2003]

Segregation of storage

Description
A key issue in providing safe storage is compatibility. This has two independent considerations:

- the compatibility of the waste with the material used to construct the container, tank, or liner in contact with the waste (e.g. certain solvents should not be stored in plastic containers)
- the compatibility of the waste with other wastes stored together (e.g. containers of cyanide waste should not be located near acid waste).

After wastes have been checked on arrival, they are split into different groups based on the chemical content and the size of the containers. Some techniques are:

a. consideration of any chemical incompatibilities to guide the segregation criteria (e.g. avoid placing acids with cyanides). The Seveso Directive and Chemical law provide guides for this segregation. The storage BREF also provides some guidances
b. not to mix waste oils with waste solvents. Some commonly used automotive products such as degreasing solvents, aerosol brake cleaners and aerosol carburetor cleaners may contain halogen compounds containing chlorine, bromine and iodine. If mixed with waste oil the entire mixture can become more difficult to treat
c. differentiation of storage according to the hazardness of the waste (e.g. flashpoint limit at 55 °C)
d. to have fire protection walls between storage sectors or a security distance large enough to avoid fire propagation.

Achieved environmental benefits
Segregated storage is necessary to prevent incidents from incompatible substances reacting together and as a means of preventing escalation should an incident occur. Another possible secondary benefit may be related to the fact that mixing wastes may make overall waste management more difficult.

Cross-media effects
Typically more space is necessary for segregated storage.

Applicability
The storage of oxidisers and flammable liquid containers is carried out separately so that they cannot come into contact with one another as a result of leakage.

Driving force for implementation
To prevent incidents due to incompatible reactions occurring. Some legislation and guidances are available on this issue in some Member States (e.g. UK).

Reference literature
[15, Pennsylvania Department of Environmental Protection, 2001], [53, LaGrega, et al., 1994], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004], [151, EIPPCB, 2003]

4.1.5. Segregation and compatibility testing

Description

A primary aid for source reduction 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. More information can be found in Section 2.1.5. Some techniques and principles to consider are:

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
c. only allowing the mixing of polluted wastes of different pollution strengths if the mixed waste is treated according to 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 Section 0)
f. having rules restricting the types of wastes that can be mixed together. Some purposes of such rules are to reduce the environmental risk, for safety reasons or to prevent dilution.

Achieved environmental benefits

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.

Cross-media effects

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.

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) sometimes is considered not applicable for reasons of safety.

Application of the basic principles of mixing an blending as described in Section 2.1.5 (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 0.

Economics
Some solid waste streams can be segregated effectively through minor changes in equipment. Typically, the disposal of a 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).

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
Some examples of compatibility test typically applied in the waste sector are:

- compatibility tests for storage (see Section 0)
- 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 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 4.13) when evaporation/distillation systems need to be applied.

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 phase
Water vapour-volatile ingredients	With 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

Table 4.13: Ingredients affecting evaporation
[121, Schmidt and Institute for environmental and waste management, 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.

Segregation of waste oils in order to produce a material with a higher value than fuel oil is a common practice.

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

<u>Thermal processes</u>
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.

<u>Treatment of wastes contaminated with POPs</u>
Mixing and blending of wastes for recovery could be allowed if the concentration of POPs does not exceed the low POP content 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 4.14 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.

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

Table 4.14: Maximum concentrations allowed for mixing wastes for recovery
[156, VROM, 2004]

Heavy metals - Cd, Hg, Tl

When the three basic principles on mixing and blending and their elaboration are taken into account, competent authorities may allow the following maximum concentrations in wastes for mixing for co-firing or co-incineration, as presented in Table 4.15. Emissions of the heavy metals mercury, cadmium and thallium into the air will occur when waste 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.

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

Table 4.15: Maximum concentrations allowed for mixing for co-firing or co-incineration
[156, 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

[53, LaGrega, et al., 1994], [86, TWG, 2003], [89, Germany, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [126, Pretz, et al., 2003], [150, TWG, 2004], [152, TWG, 2004], [156, VROM, 2004]

4.1.6. Techniques for the environmental improvement of other common techniques

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. The abatement system can be interlocked with the plant operation, so that the plant cannot operate unless the abatement system is working
b. keeping skips for the storage of crushed/cut drums covered
c. using sealed system, e.g. chutes, for the containment of residues
d. using sealed drainage
e. avoiding crushing drums that contain (or which have contained) flammable and highly flammable wastes or volatile substances, unless the residues have first been removed and the drum then cleaned.

In a shredding facility, the following techniques can also be applied:

f. 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
g. storing of acids, bases, photographic chemicals, chemicals from households, pesticides and lab chemicals
h. storage for flammable liquids like waste solvents, with a flashpoint of <21 ºC
i. decomposition of the aerosol cans into the following components: propellants, liquid ingredients, metals and plastics
j. 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
k. 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:

l. pressure-surge-proof channel of 12 m high against damages
m. the facility is pressure resistant up to 10 bar
n. batch-wise operating of the shredder for minimising the exposure
o. using fire alarm systems and sprinkler installations; furthermore, boxes are equipped with a sprinkler installation for the reduction of dust
p. having an online connection to the rescue service; in case of a fire, the fire department is immediately notified
q. using explosion-proof switches, aggregates and machines in the entire hall
r. using overpressurised cabins with activated carbon filters in all machines, for the safety of the workers
s. fire water of 50 m^3 in a subsurface basin
t. 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:

u. 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

v. 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 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
[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004], [152, TWG, 2004], [157, UBA, 2004]

Techniques to reduce emissions from washing processes

Description
Some techniques include:

a. identifying the components that may be present in the items to be washed (e.g. solvents)
b. transferring washed waste to appropriate storage and then treating this in the same way as the waste from which it was derived

c. 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.

Achieved environmental benefits
Allows the identification and treatment of washing residues.

Applicability
The washing of drums and IBCs is usually only carried out where there is an adjacent treatment plant to accept the wash-waters 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 installation.

Reference literature
[55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

4.1.7. Techniques to prevent accidents and their consequences

Description
IPPC requires, as a general principle, that necessary measures should be taken to prevent accidents which may have environmental consequences, and to limit those consequences. Some techniques include:

a. producing a structured accident management plan within a time-scale, which includes:
    - identifying the hazards to the environment posed by the installation. Particular areas to consider may include waste types, overfilling of vessels, failure of plant and/or equipment (for example, over-pressure of vessels and pipework, blocked drains), failure of containment (for example, bund and/or overfilling of drainage sumps), failure to contain fire-waters, making the wrong connections in drains or other systems, preventing incompatible substances coming into contact, unwanted reactions and/or runaway 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 x 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 to? (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 to 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 installation and its location. The main factors which should be taken into account are:
        - the scale and nature of the accident hazard presented by the installation and the activities
        - the risks to areas of population and the environment (receptors)
        - the nature of the installation and complexity or otherwise of the activities and the relative difficulty in deciding 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 4.1.1)

d. maintaining an inventory of substances, 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 spilled into a watercourse could destroy its ecosystem). (The inventory is also related with traceability, see Section 0)
e. 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 compatibility Section 0)
f. 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 curbed perimeter and separate drainage collection. Measures also need to be in place to prevent containers falling over into other storage areas
g. providing adequate storage arrangements for raw materials, products and wastes
h. 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
i. ensuring that 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
j. documenting the control measures in place, including the evaluation of these measures and a decision about their adequacy
k. 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
l. applying, as appropriate, preventative techniques, such as suitable barriers, to prevent damage to equipment from the movement of vehicles (see Section 0)
m. providing appropriate containment, e.g. bunds and catchpots, building containment (see Section 0)
n. 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 0)
o. keeping an up-to-date installation 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 is then available to estimate notifiable releases for the annual report
p. establishing procedures to identify, respond to and learn from such incidents
q. 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
r. putting in place procedures to avoid incidents occurring as a result of poor communication among operation staff during shift changes and following maintenance or other engineering work
s. identifying and providing personnel training requirements as required
t. systems already applied for the prevention of fugitive emissions are generally relevant in addition to drainage systems (see also Section 0):
    - procedures need to be 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 equipped with a high level alarm or sensor with a pump to suitable storage (not to discharge);
    - there needs to be a system in place to ensure that the sump levels are kept to a minimum at all times
    - high level alarms, etc. should not be routinely used as the primary method of level control
u. ensuring that process waters, site drainage waters, emergency fire-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 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 fire-water collection system needs to also take account of the additional fire-water flows or fire-fighting foams. Emergency storage lagoons may be needed to prevent contaminated fire-water reaching controlled waters (see also Section 0):
v. applying maintenance and testing to the same standards as the main plant or stand-by plants

w. 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
x. applying suitable procedures and provisions for, e.g. the storage of certain types of hazardous waste which may require automatic alarms and possibly sprinklers. The facility must provide adequate water supply for extinguishing fires plus the capability to collect and store fire-water run-off. The storage or treatment of any water-reactive waste will necessitate an alternative type of fire protection system
y. putting in place safe shutdown procedures
z. 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 caused and steps need to be developed to redress this
aa. having in place sufficient security measures, including personnel, to prevent vandals and inadvertent intruders who could become exposed from 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
bb. 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
cc. 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
dd. having in place a fire protection and explosion protection system, containing prevention and detection equipment, and extinction equipment.

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.

Cross-media effects
Not known.

Operational data
Technique o (see Description section above) typically is a computer-based system.

Applicability
Some of the techniques are WT sector specific but others are very general. Some are only relevant for hazardous waste treatments.

Driving force for implementation

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.

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
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004], [152, TWG, 2004]

4.1.8. Techniques to reduce noise and vibrations

Description
A noise management plan is typically part of the environmental management system (EMS in Section 0). Such a plan normally:

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. provides the above information also 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 may be necessary for either new or existing installations taking into consideration the potential for noise problems.

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
Reduces noise levels generated by the installation.

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.

Driving force for implementation
A reduction of noise and vibrations.

Reference literature
[55, UK EA, 2001], [150, TWG, 2004]

4.1.9. Techniques for de-commissioning

Description

To minimise de-commissioning problems and any associated environmental impacts, some techniques include:

a. considering the de-commissioning at the design stage, thereby making suitable plans to minimise risks during later de-commissioning
b. for existing installations 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 economically not possible to replace, then operators should protect 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 plan to demonstrate that, in its current state, the installation can be decommissioned to avoid any pollution risk and to return the site of operation to a satisfactory state. The plan should be kept updated as material changes occur. However, even at an early stage, the closure 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 resource 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- 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
d. 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 installation)
e. describing plans for the clearing of deposited residues, waste and any contamination resulting from the waste treatment activities
f. ensuring that plant and equipment taken out of use are decontaminated and removed from the site.

Achieved environmental benefits

Prevents environmental issues during de-commissioning.

Applicability

The techniques mentioned here are applicable to the installation operation lifetime, the design and build 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.

Example plants

The decomissioning of whole plants or parts of them occur frequently in the sector.

Reference literature

4.2. [55, UK EA, 2001], [116, Irish EPA, 2003], [150, TWG, 2004]

4.3. Waste gas treatments

This section contains techniques used in the waste treatment sector to 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 techniques have already been described and analysed in other BREFs (special reference is made to the 'Waste water and waste gas treatment and management' BREF and waste incineration BREF). For this reason, it is not intended in of this section to provide a complete analysis of each of the different techniques. Instead, 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 covered in the previous section since they are very dependent on the type of process/activity carried out.

4.3.1. Generic prevention techniques

Description
Some techniques include:

a. using an enclosed system with extraction, or under depression, to a suitable abatement plant, especially during processes involving the transfer of volatile liquids or handling wastes that generate VOC emissions, including during tanker charging/discharging
b. applying a suitably sized extraction system which can cover the holding tanks, pretreatment areas, storage tanks, mixing/reaction tanks and the filter press areas, or 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)
c. completely enclosing the entire site (e.g. in a dome)
d. 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
e. using wind barriers.

Achieved environmental benefits
Reduces fugitive emissions to the air (e.g. 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
A positive side effect of enclosure is the reduction of noise for workers on site.

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 0)
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.

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

Table 4.16: Summary of emission control costs for area sources applied to excavation and removal [30, Eklund, 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 the air. Most WT plants have some abatement systems in place to control emissions to the air, but the type and level of control varies widely.

Reference literature
[30, Eklund, et al., 1997], [50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.3.2. Leak detection and repair programme

Description
A leak detection and repair (LDAR) programme for installations handling solvents and similar volatile materials may include:

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. using non-intrusive tank volume measurements
c. replacing filter pot lids when cleaning filters
d. storing filter slops in sealed drums
e. storing contaminated waters which have a potential for odours in covered tanks
f. using drum storage (see Section 0)
g. ensuring that regular cleaning/desludging of tanks is carried out, using maintenance schedules to avoid large scale decontamination activities
h. tanker washing if the load is likely to give rise to odour. The wash-water/aqueous waste from the washing needs to be directly discharged to abated storage systems before opening the tankers. Open tankers for the least amount of time possible
i. direct monitoring of valves, pump seals, etc. using a portable organic vapour analysing instrument to check for leaks
j. undertaking maintenance activities for fixing any detected leaks, e.g. replacing valve packing.

Achieved environmental benefits
Detects leaks of VOCs from valves, pumps and other piping components.

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
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.

Reference literature
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [150, TWG, 2004]

4.3.3. Cyclones

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.

Achieved environmental benefits
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 re-used in the process.

Cross-media effects
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. High wear with abrasive dust.

Operational data
Cyclones are relatively reliable. Operational conditions include:

- monitoring of pH, flowrate 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.

Applicability
This technique may be only used in combination with a bag filter. It is not efficient at separating small particles.
Economics
Cyclones are relatively cheap.

Example plants
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 Ph-c plants.

Reference literature
[55, UK EA, 2001], [122, Eucopro, 2003], [126, Pretz, et al., 2003]

4.3.4. Electrostatic precipitators (ESP)

Description
Electrostatic precipitators use high voltages to attract and remove particulate matter from the flue-gases. 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.

Achieved environmental benefits
Reduces particulate emissions. High collection efficiency for both coarse and small particles. Efficient at high temperatures and efficient for the collection of liquid particles.

Applicability
This technique is not suitable for organic particles due to the high explosion risk they present.

Example plants
It is used for the treatment of the exhaust gases of Ph-c plants.

Reference literature
[122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.3.5. Fabric filters

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. Filter efficiency may be enhanced by pre-coating the filter cloth prior to being brought online.

Achieved environmental benefits
- high collection efficiency for both coarse and small particles
- efficient with a large concentration range
- collected dust may be re-used in the process
- high collection efficiency at high temperatures, if special materials, e.g. teflon, are used.

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 (per tonne waste fuel produced)	
Electricity (kWh)	2.5 to 3.5
Fuel/gas (litre)	-
Reactant (nature and kg)	-
Residues	-
Costs (EUR/t waste fuel produced per year)	
Investment cost	Up to 4
Operation cost	0.15
Maintenance cost	0.1

Table 4.17: Dust filtration by a fabric filter
[122, Eucopro, 2003]

Cross-media effects
Cyclones and fabric filters create a pressure drop in the gasflow 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.

Operational data
Insitu cleaning can be achieved by air pulse, counter flow air or mechanical tapping. The reliability highly depends on the filter material. Fabric filters may create a risk of explosion. 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 need to be a programme in place for the regular cleaning of physical filters.

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.

Example plants
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 Ph-c plants.

Reference literature
[53, LaGrega, et al., 1994], [55, UK EA, 2001], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.3.6. Lamella separators

Description
In lamella separators, the air stream flows through several parallel plates which have hooked bumps, which force the air stream to change its direction. Because of the inertia of the particles, they are separated in the dust trap and split from the air stream.

Achieved environmental benefits
Reduces particulate emissions.

Applicability
Lamella separators are only applied for the separation of rough dust particles.

Reference literature
[126, Pretz, et al., 2003]

4.3.7. Adsorption

Description
In adsorption processes, the pollutant is removed from the waste gas flow and specifically adsorbed to the adsorbent. Exhaust air purification by adsorption basically consists of two treatment steps:

a. reduction of the pollutant by adsorption and accumulation in an adsorbent
b. regeneration of the adsorbent.

The pollutants from the waste gas stream accumulate in the adsorber. When the charging capacity of the adsorbent is reached, the adsorbed pollutants are desorbed in order to allow for a re-use of the adsorbent. Desorption is usually carried out with a hot air stream, the volume of which is considerably less than the waste gas stream. The concentrated desorbed harmful gas is eliminated in a further treatment step.

Adsorption is based on the principle of active centres in a porous matrix. Different adsorbents can be distinguished mainly by their ability to adsorb water. Thus they can be divided into hydrophilic and hydrophobic adsorbents.

Recently, plants for the treatment of gases with a low content of solvents have been developed. These, are based on new adsorbing materials presenting high chemical and mechanical stability and able to adsorb at low temperatures and desorb at a set temperature. The concentrated solvents can then be burned without fuel addition *in situ*.

Although activated carbon is the most widely used adsorption material, other alternatives include silica gel, alumina and zeolites. In waste gas treatment, adsorption is carried out using an activated carbon filter. Activated carbon has a large volume of very small pores which create a large surface area. Typical activated carbons have surface areas from 600 to 1200 m^2/g. The exhaust gas can be purified by an activated carbon fill or by an injection of activated carbon into the air stream followed by a downstream separation by a textile filter.

Achieved environmental benefits
Some benefits of this technique are:

- applicable for a wide range of components
- the used activated carbon can be recovered several times or may be used as fuel
- adsorption on activated carbon presents similar efficiencies to those of thermal oxidisers but less risk of flash fire, back into the vehicles being loaded/unloaded.

Characteristics	Level

Input flow range (Nm^3/h)	<50000
Input VOC concentration (g/Nm^3)	<0.5
Output VOC concentration (mg/Nm^3)	40 – 110
Need for preliminary de-dusting	yes
Risks	Quick saturation
Residues	
Consumption (per tonne waste fuel produced)	
Electricity (kWh)	25 – 75
Fuel/gas (kWh)	-
Other fuels or biogas	
Reactant (kg)	0.1 – 0.5 g/VOC (for activated carbon)
Costs	
Investment costs (EUR/t capacity)	10 – 30
Operational costs (EUR/t waste fuel produced) Electricity Fuel/gas Others	1.65 1 – 3 0
Maintenance costs (EUR/t waste fuel produced)	0.5

Table 4.18: Techno-economic data for adsorption
[122, Eucopro, 2003]

Emissions of VOCs from the carbon trap (chlorinated solvents) are 8 – 32 mg/Nm^3 or 215 kg/yr, when cleaning used oils.

Cross-media effects
Limited performance because of incomplete capture of some organic molecules. May also present fire and explosion risks. This method captures but does not destroy organic compounds. Saturated carbon filters need further treatment.

Operational data
The abatement can easily become overloaded and thus ineffective. The use of activated carbon is efficient for the capture of the VOCs, which mainly arise from storage facilities. The absorption capacity of the activated carbon depends on the nature of the particular VOCs, but is limited to a maximum 300 g/kg activated carbon. Some points to note are:

- simple design
- stability over time
- acceptance of high spot concentrations
- that at some (high) VOC concentrations, the adsorption is exothermic and needs to be controlled in order to avoid fire/explosions.

The lifetime of the carbon used in abatement for storage at waste oil treatment facilities is expected to be long. This is because in this application it will only be catering for breathing rather than displacement losses.

If an activated carbon filter is applied, the exhaust air has to be purified of dust first, as the dust can cause clogging and can lead to an increasing pressure gradient.

The charging capacity of the adsorbents is influence by a number of factors:

- physico-chemical properties of the substances that are to be adsorbed (especially the boiling point)
- concentration of the substance
- competing adsorption of other substances
- co-adsorption of water
- adsorption temperature
- pore structure and size of the inner surfaces of the adsorbent.

Applicability
Carbon adsorption is used for the reduction of VOCs, odour and fugitive emissions. Carbon adsorption is commonly used as an abatement technique for local extraction points e.g. at bulking up and sampling points. Care must be taken to avoid the air steam becoming moist as the polar nature of the common adsorbents will preferentially adsorb water vapour. For this reason carbon adsorption is not suitable for the abatement of air emissions from an oil re-processing heating vessel.

There are several different applications for activated carbon, for instance activated carbon is applied for the purification and removal of trace organic contaminants from liquid and vapour streams.

Carbon adsorption systems are often used in soil vapour extraction, but they may be costly to implement and are generally not acceptable for high humidity gas streams. They are also common in the treatment of air emissions from soil washing, soil solvent extraction, from soil flushing, aerosol can treatment, biological treatment plants and Ph-c plants (e.g. for the adsorption of the volatile components).

Carbon adsorption is not suitable for high concentrations or small molecules, or if dust is present. Also, carbon adsorption cannot be adapted to some molecules, e.g. acetone.

Economics
Some points to note are:

- this offers low operating costs for low concentrations of VOC
- there is an additional cost for the renewal of the activated carbon.

The following two tables (Table 4.19 and Table 4.20) show cost data for adsorption.

Treatment	Maximum flow (Nm^3/h)	Capital Cost (USD)
Carbon adsorption (regenerative)	170	20000[a]
	400	24000[a]
	800	33000[a]
	1770	12000[b]
Carbon canisters	160	700
	800	8000[c]
	1600	6000
	6400	23000[c]
	160	50000

[a] Includes blowers, demisters, controls, gauges, valves, and flow ammeters
[b] Includes blowers, flexible connectors, and dampers
[c] Deep bed units

Table 4.19: Capital costs to control VOC emissions from soil venting extraction systems [30, Eklund, et al., 1997]

Technical specification	
Capacity	10000 t/yr
Oil types	Used lubricating oils

Process operation Waste gas flow Age of plant Age of pollution control equipment	Batch 0 – 50 Nm^3/hr 10 years old 2 years old	
Possible Control Techniques	**Capital cost**	**Operating cost (GBP)**
Activated carbon drums*	Low	1100
*Assumes three 60 kg drums on site requiring replacement three times a year.		

Table 4.20: Cost of controlling releases to air from a typical oil recycling plant
[42, UK, 1995]

Example plants
Preparation of waste fuel from hazardous waste. Operational experience from biological treatment plants (MBT) is currently not available.

Reference literature
[30, Eklund, et al., 1997], [42, UK, 1995], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [150, TWG, 2004]

4.3.8. Condensation

Description
VOCs can be removed by condensation with liquid nitrogen or other cooling agents (e.g. cooling water). The condenser is a vessel incorporating a heat-exchanger where a gas is cooled to change to the liquid phase (i.e. condensation). VOC recovery by nitrogen cryogenic condensation in solvent (-130 ºC). More information on this issue can be found in the BREFs on Large Volume Organic Chemicals (LVOC) and on Common Waste Water and Waste Gas Treatment (CWW).

Achieved environmental benefits
The condensed VOCs can be recovered. VOC emissions achievable can be as little as 10 to 50 g/h. Efficiencies of 99.3 % can be achieved. Chloroform emissions can be as little as 20 mg/Nm^3. Nitrogen is re-usable for other means in the plant.

Characteristics	Value
Input flow range (Nm^3/h)	<100
Input VOC concentration (g/Nm^3)	2 – 500
Efficiency (%)	>95
Need for preliminary de-dusting	no
Residues	no
Consumption (per tonne waste fuel produced)	
Electricity (kWh)	25
Fuel/gas (kWh)	-
Other fuels or biogas	
Reactant (kg)	Nitrogen
Costs	
Investment cost (EUR/t capacity)	20 to 60
Operational costs (EUR/t waste fuel produced)	2 to 6
Maintenance costs (EUR/t waste fuel produced)	<0.5

Table 4.21: Data on liquid nitrogen condensation
[122, Eucopro, 2003]

Cross-media effects

Consumption of nitrogen and electricity. Direct discharge of nitrogen contaminated with other compounds may occur.

Operational data
Sensitivity to water presence. The presence of water vapour in the air can block the system and the water condenses to ice, which could then frost or ice up the flow systems. A defrosting period is then necessary. Consumption of nitrogen of 18 kg/t solvent recovered. Elimination of the security risks. Temperature and pressure controls are simple.

Applicability
Used in cases where only relatively small volumes or low flows need to be treated, and when liquid nitrogen is available and the concentration of VOC is quite high. This technology is available for stable volumes and compositions. Applications typically include treating the emissions from oil reprocessing heating vessels, which also incorporates a recovery of the oil components. Condensation can be used as a pretreatment for thermal oxidation, reducing the fuel requirement and the overall size of the oxidiser required. Applicable to flows of between 50 - 100 Nm^3/h and loads from 1 to 10 kg/h. It is easily applicable to existing plants and it is very flexible to adapt to changes in flow and concentration.

In Ph-c plants, the volatile components are cooled and condensed for their treatment.

Economics
Typically high operating cost. Operational cost of EUR 2/t solvent treated for a liquid nitrogen condensator.

Technical specification		
Capacity	10000 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	
Possible Control Techniques	**Capital Cost (GBP)**	**Operating Cost (GBP)**
Glycol chiller	30000	8000

Table 4.22: Cost of controlling releases to air from a typical oil recycling plant
[42, UK, 1995]

Driving force for implementation
Safety regulations.

Example plants
Preparation of waste fuel from hazardous waste and solvent recovery. At an example waste oil re-refining plant, the dehydration and defuelling units use air-cooled, condensing heat-exchangers for vapour recovery. The vacuum-distillation vapour recovery uses oil and cooling-water condensers. Vapour and non-condensable streams are then routed to the process heater for destruction of the organics and any odorous substances that may be present. There are at least eight plants in the EU.

Reference literature
[42, UK, 1995], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [66, TWG, 2003], [122, Eucopro, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.3.9. Temporary and long term foams

Description

At least six types of foam products are available. The foams vary in their compatibility and effectiveness for various classes of contaminants. Specialised equipment is available for applying foams over large areas. The foam is applied to a depth of 15 – 76 cm, at coverage rates of up to 100 m^2/min. The liquid foam concentrate is applied via an air-aspirating nozzle or chute. The degree of expansion (i.e. the number of litres of foam produced from one litre of liquid concentrate) can be classed as high (250:1), low (20:1), or medium.

Two general types of foams are used: temporary or long term. Temporary foams provide coverage for up to an hour, at which time 25 % or more of the liquid incorporated in the foam will have been released. Long term foams contain a stabilising additive to extend the useful life of the foam to days or even weeks.

Achieved environmental benefits

Reduction of VOC emissions. The effectiveness of foams is quite high for the areas that are covered. Short term emission reductions of 75 to 95 % for total paraffin and total aromatics, respectively have been measured in the field over 20 minute time periods. Emission reductions for total VOCs of 99 to 100 % using stabilised foam have been measured in the field over 24-hour time periods.

The two primary advantages of foams are that they can be highly effective and they can be applied directly to the backhoe bucket and the exposed contaminated soil.

Cross-media effects

There are several disadvantages of foams to consider. The thick layers of foam required for the control of emissions can be applied more effectively to horizontal surfaces than to vertical surfaces such as the sides of the excavation pit. Incomplete coverage of the emitting surfaces will markedly decrease the effectiveness of the controls. As foam concentrates are usually over 90 % water, the addition of this water to the soil increases the weight of the soil, making it more difficult to handle, and making it less amenable to thermal treatment. The foam is difficult to apply on windy days and, under any conditions, frequent application or re-application of the foam may be necessary.

Applicability

Modified fire-fighting foams are commonly used to control VOC emissions during the remediation of hazardous waste sites containing volatile toxic compounds.

Reference literature

[30, Eklund, et al., 1997]

4.3.10. Biofilters

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).

The biofilter consists of an apparatus filled with decomposable material such as compost, bark or a mixture of turf and heather, etc. Micro-organisms (fungi, bacteria, viruses and algae) are resident on the material. The exhaust airflows through the material while the micro-organisms decompose the harmful substances. Water and airflow normally run countercurrently. A biofilter is not a filter in the mechanical sense (i.e. it does not lead to a separation of particles), but it is a reactor where a certain range of harmful substances are metabolised to harmless substances. The desired qualities of a biofilter are outlined in Table 4.23.

Characteristic	Description
Filter media	Biologically active, but reasonably stable
	Organic matter content >60 %
	Porous and friable with 75 – 90 % void volume
	Resistant to water logging and compaction
	Relatively low fines content to reduce gas headloss

	Relatively free of residual odour
	Specifically designed mixtures of materials may be desirable to achieve the above characteristics
Moisture content	50 – 80 % by weight
	Provisions must be made to add water and remove bed drainage
Nutrients	Must be adequate to avoid limitations
	Usually not a problem with aerobic digestion gases because of the high NH_3 content
pH	7 to 8.5
Temperature	Near ambient, 15 – 35 or 40 °C
Gas pretreatment	Humidification could prove to be useful in order to achieve near 100 % inlet gas humidity
	Dust and aerosols may be removed to avoid media plugging, but for most biofilters this is not a problem (unless they have a tissue layer in the bottom)
Gas loading rate	<100 $m^3/h\text{-}m^3$, unless testing supports higher loadings
Gas residence time	30 - 60 seconds, unless testing supports shorter residence time
Media depth	>1m, <2 m
Elimination capacity	Depends on media and compound (typically in the range 10 – 160 $g.m^{-3}.h^{-1}$)
Gas distribution	The manifold must be properly designed to present a uniform gas flow to the media

Table 4.23: Qualities of biofilter media
[59, Hogg, et al., 2002]

In contrast to the biofilter, in bioscrubbers the micro-organisms are not fixed in the bioscrubber on organic materials. The biomass swims quasi free in the suspension, which is sprayed on the exhaust gas in a countercurrent flow. The principal difference this brings about is that the absorption of the harmful substances is local and is separated from the metabolism.

In an aerosol can treatment facility, the exhaust air from the different operational parts is led through an air-permeable filter layer by means of ventilators. While the airflows through the filter layer, the degradable contents are decomposed by micro-organisms that populate the filter. In order to ensure that the filter layer remains air-permeable, which is essential for the supply of air oxygen to the micro-organisms, the exhaust air is cleaned beforehand so that solids (dusts) are removed. Simultaneously, cleaning moisturises the exhaust air, which is necessary to prevent drying of the filter layer. The biofilter, thus, represents an aerobic fixed bed reactor for the biochemical decomposition of organic substances. The biofilter, e.g. with an area of 1800 m^2, can treat an exhaust air stream of approximately 200000 m^3/h, which results in a specific filter load area of 111 $m^3/m^2/h$. Below the biofilter, there are supply areas that are utilised by the different treatment facilities (provision for treatment and dispatch). This area is designed as a collection tray. Moreover, a stationary foam extinguishing installation is present.

Achieved environmental benefits
Reduces odour and VOC emissions from natural compounds and from the synthesis of inorganic compounds (e.g. H_2S and NH_3), aromatic and aliphatic compounds (e.g. acids, alcohols, hydrocarbons). Other compounds that may be degraded are non-chlorinated solvents, mercaptans, amines, amides, aldehydes and ketones. The treatment capacity ranges from 50 - 150 $Nm^3/h/m^2$ depending on the type of pollutant.

Substance (group)	**Input concentration (mg/Nm^3)**	**Output concentration (mg/Nm^3)**	**Biofilter efficiency (%)**
Aldehydes, alkanes			75
Alcohols			90
AOX, aromatic hydrocarbons			40

(benzene)			
Aromatic hydrocarbons (toluene, xylene)			80
NMVOC			83
PCDD/F			40
Odour			95 – 99
NMVOC (Values in total carbon)	30 – 70	10 – 40	80

Table 4.24: Biofilter efficiency in MBT waste gas treatment
[81, VDI and Dechema, 2002]

The removal efficiency of a biofilter is determined by the gas residence time in the media bed. Effective residence times typically range from 30 to 60 seconds for most aerobic digestion applications. Studies have reported high removal efficiencies for specific compounds such as H_2S (>99 %), methyl mercaptan, dimethyl disulphide, dimethyl sulphide (>90 %) and various terpenes (>98 %).

Environmental benefits include low energy requirements and the avoidance of potential cross-media transfer of pollutants. Measurements in the practical application of biofilters in physico-chemical treatment plants have shown results of approx. 95 to 98 % degradation for organic solvents, with concentrations in exhaust air to be purified from 400 to 1600 mg/Nm³.

In biological treatment plants, malodorous gases will be fed through a scrubber (e.g. acidic wet scrubber), which reduces the ammonia content to an acceptable level for the biofilter. The biofilter removes odours and any remaining ammonia. The filtering process does not create any compounds that are harmful to the environment and after use, the filter can be treated by composting and additional waste will not be generated. The levels of ammonia and odour after treatment are <1 mg/m^3 and 1000 – 6000 ouE/m^3 (90 % reduction), respectively.

Table 4.25 and Table 4.26 show the effectiveness of biofilters applied to MBTs.

Parameter	Concentration (µg/m³) min – max	Effectiveness (%) min – max	Concentration (µg/m³) min – max	Effectiveness (%) min – max	Concentration (µg/m³) min – max	Effectiveness (%) min – max
Acetaldeyde	2100 – 2500	78 – 89	46 – 740	89 – 96	4900 – 6100	99
n-Butylacetate	150 – 425	97 – 99	30 – 120	83 – 96	170 – 980	73 – 99
Ethylbenzene	250 – 310	12 – 42	60 – 190	27 – 61	250 – 740	16 – 43
2-Ethyltoluene	180 – 220	33 – 41	25 – 105	14 – 89	80 – 270	25 – 55
3,4-Ethyltoluene	480 – 640	23 – 45	70 – 260	38 – 96	230 – 1000	48 – 77
Limonane	1700 – 4300	29 – 40	810 – 2200	94 – 98	1300 – 3700	30 – 63
Toluene	490 – 550	16 – 39	130 – 280		460 – 1000	7 – 36
m/p-Xylene	850 – 1400	9 – 42	280 – 620	30 – 71	720 – 2000	19 – 45
o-Xylene	260 – 290	23 – 41	60 – 150	7 – 63	160 – 650	20 – 45
Acetone	2450 – 2900	99 – 100	1200 – 2800	99 – 100	4700 – 8200	93 – 97
2-Butanone	960 – 2800	99 – 100	80 – 770	94 – 99	370 – 11000	95 – 100
Ethanol	5200 – 5300	100	88 – 750	94 – 99	14000 – 18000	100
α-Pinene	370 – 700	8 – 44	280 – 790	53 – 83	560 – 930	5 – 39
β-Pinene	330 – 800	12 – 44	120 – 300	53 – 81	230 – 490	38 – 49

Table 4.25: Concentration ranges for some parameters of the exhaust air from MBTs, showing the retention efficiency of the biofilter for these compounds
[132, UBA, 2003], [150, TWG, 2004]

Biological exhaust gas purification processes are able to reduce the exhaust air/exhaust gas contents from municipal waste treatment plants only to a limited extent (typically NMVOC of more than 300 g/t waste). Table 4.26 shows some measurement results from well maintained biofilters with upstream air humidifiers.

Compounds of the exhaust air	Separation efficiency (%)		
	Facility A	Facility B	Facility C
Acetaldehyde	-18 to -99	99	99
n-Butylacetate	83 – 96	73 – 99	97 – 99
Camphor	60 – 88	60 – 90	88 – 91
Dichloromethane	-53 to -80	-300 to -33	43 – 62
Dimethyldisulphide	44 – 78	-55 to -89	10 – 31
2-Hexanone	75 – 80	-	80 – 82
Naphthalene	50 – 75	38 – 93	58 – 82
Phenol	-25 to - 79	75 – 88	47 – 94
1,4-Dichlorbenzene	0 – 73	-1900 to -89	-130 to -13
Ethyl benzene	27 – 61	16 – 43	12 – 42
2-Ethyl toluene	14 – 89	25 – 55	33 – 41
3/4-Ethyl toluene	38 – 96	45 – 77	23 – 45
Limonene	94 – 98	30 – 63	29 – 40
Styrene	64 – 89	44 – 66	21 – 50
Toluene	29 – 50	7 – 36	16 – 39
m/p-Xylene	30 – 71	19 – 45	9 – 42
o-Xylene	7 – 63	20 – 45	23 – 41
Acetone	99 – 100	93 – 97	94 – 97
2-Butanone	94 – 99	95 – 100	99 – 100
Ethanol	94 – 99	100	100
Ethylacetate	74 – 93	82	97 – 99
α-Pinene	59 – 83	5 – 39	8 – 44
β- Pinene	53 – 81	38 – 49	12 – 44
Benzene	0 – 17	-	0 – 20
Trichlorethene	-108 to -3	67 – 90	20 – 46
Combinations of air humidifiers and biofilters may provide varying purification power for organic substances of the first and second group			

Table 4.26: Separation efficiency of organic compounds in the biofilter
[132, UBA, 2003]

Table 4.27 gives a summary of current measurement results from the biofilter of an aerosol can treatment facility. Note that other parts of the exhaust air of the treatment process are treated by the in-house high temperature incineration facility.

Component	Average concentration of raw gas	Average concentration of cleaned gas
Total carbon (FID)	206	49
CHC/CFC	9.69	8.17
Benzene	1.07	0.35
Aromatic compounds	35.4	8.07
Ester, alcohols	80.8	0.57
Results from 2003 and data in mg/m^3		

Table 4.27: Raw gas and treated gas by a biofilter in an aerosol can treatment facility
[157, UBA, 2004]

Cross-media effects

N_2O and NO emissions are typically increased. However, it has been demonstrated that the use of an acid scrubber for ammonia (NH_3) removal prior to biofiltration can reduce potential N_2O and NO emissions.

Methane is neither biodegradated nor produced by the biofilter. Terpenes are produced by the biofilter itself and arise from the degradation of any wooden materials in the biofiltering media. Some references question whether biofilters really decrease VOCs since, they claim, VOCs are actually produced by the biofilter itself.

The degrees of decomposition of the studied biofilters in MBT plants for single compounds are not as high as for several special applications in industry (80 % or >90 %). For non-methane TOC (NMTOC) they achieve on average an efficiency rate of only 40 – 70 %. For methane, the efficiency is close to 0 %. The decomposition efficiency for single compounds in the exhaust gas of MBT plants exhibit good values for NMTOC (e.g. acetone, acetaldehyde, limonene and ethanol), moderate values for BTEX and no reduction for CFCs.

The partly low degradation efficiencies for NH_3 also with a potential inhibition of carbon decomposition, may be improved by the use of acid scrubbers (e.g. sulphuric acid for the absorption of ammonia) instead of neutral scrubbers. The NH_3 emissions will be minimised not only because they are odorous but also because, in the biofilter, close C/N relations of the MBT exhaust air may lead to the formation of NO and N_2O.

Operational data

Biofilters are typically one metre thick of porous material. The material used in the biofilter is usually a mix of green compost typically mounted over a certain structure. These systems are very easy to be built and maintained. High porosity (80 – 90 %), the humidity (60 – 70 %), pH, temperature, and the contact time between the nutrients need to be controlled for good biofilter performance. The humidity in the biofilter can be maintained with a special water system or by humidifying the gas to be purified before it is passed pass through the biofilter.

The NMVOC removal in biofilters strongly depends on the temperature (e.g. weather conditions), which can reduce the efficiency of the biofilter.

In some cases, the materials used for the biofilter media may not be able to fully satisfy the demands for all the essential nutrients of the micro organisms in the biofilter for a longer time. In these cases supplying additional nutrients can significantly increase the efficiency of the biofilter.

The pressure drop is less than 50 mm H_2O. The surface load per unit area of the biofilters should not exceed approx. 80 $Nm^3/m^2 \times h$.

Some issues to consider include:

- incoming air must have a relative humidity of >90 % (this may require the use of a humidifier)
- particulates must be removed
- hot gases may need to be cooled closer to the optimal activity temperature for aerobic micro-organisms, generally 25 to 35 °C and the potential temperature rise across the bed of up to 20 °C needs to be taken into account
- the major operating parameters, such as the off-gas temperature and the back-pressure, need to be checked daily
- the moisture content in the filters needs to be monitored regularly
- a low temperature alarm needs to be fitted to warn of freezing, which can damage the filter and could affect the growth of the microbes
- the packing media must be supported to allow a fast, even airflow without any pressure drop
- the media needs to be removed when it starts to disintegrate, thus affecting the airflow (bark is less resistant than, for example, heather)
- the choice of media and supporting system affects the power requirement for maintaining the airflow, with the power needed to overcome the bed resistance being the largest operational cost
- consideration needs to be given to the effect of a loss of biomass due to the introduction of toxic compounds and a stand-by procedure needs to be developed for such an event.

Even in the case of optimisations (combinations with bio-scrubbers instead of water scrubbers) a low and reliable emission cannot be permanently achieved. For the odorous emissions, a strong reduction can be achieved (with only the filter's innate smell remaining) if an appropriate conditioning of the exhaust air is carried out.

In the case of flue-gas treatment from aerobic digestion of the digestate generated in anaerobic treatments, the concentration of ammonia is rather high (>30 mg/Nm^3) being in this case necessary to chemically pretreat the flue-gas before it is guided to the biofilter.

Applicability
Biofilters are applied for great volumes of exhaust gas streams which carry low organic loads in the particular exhaust gases but which have intensive odours. Concentrations of components to be treated need to be relatively stable for a good performance. Biobeds have been installed on waste treatment sites for the abatement of odorous emissions. Applicable to all types of WWTP.

Biofilters are used for the treatment of exhaust gases in aerosol can treatment facilities, thermal distillative drying of sludge, biological treatment (MBT) plants and Ph-c plants. In Ph-c plants, biofilters are used for the adsorption of the volatile components to compost material and for the biological decomposition of the adsorbed components by micro-organisms in the compost material. If the biofilter is in danger of desiccating, the exhaust air that is to be cleaned has to be moisturised.

Biofilters are suitable only for low polluted exhaust gas streams and are thus only used for the purification of the hall exhaust air streams. Flue-gas cleaning by biofilters or biological cleaning generated in anaerobic digestion plants has been proven to be of value.

Economics
Biofiltration and bioscrubbing have lower operating costs than many other air pollution control technologies for treating low concentrations of biodegradable organic pollutants. Bioscrubbers have the higher maintenance cost of the two. Treatment gas flows of more than 1500 Nm^3/h are considered cost-effective. Investment cost of EUR 550000 for a biofilter applied to treatment of WWTP odours with a flow of 1800 Nm^3/h.

Characteristics	**Value**
Input flow range (Nm^3/h)	<100000
Input VOC concentration (g/Nm^3)	<1
Efficiency (%)	<90 %

Need for preliminary de-dusting	No
Risks	Destruction of micro-organism
Residues	Yes
Consumption (per tonne waste fuel produced)	
Electricity (kWh)	15
Fuel/gas (kWh)	-
Alternative fuel or biogas	
Reactant (kg)	Barks
Costs	
Investment costs (EUR/t capacity)	10 to 20
Operational costs (EUR/t waste fuel produced)	<1
Maintenance costs (EUR/t waste fuel produced)	<0.25

Table 4.28: Consumptions and costs of biofilters
[122, Eucopro, 2003]

Driving force for implementation
Reduction of odour emissions. The German and Austrian Governments have set limit values for MBT facilities for odour emissions with 500 GE/Nm³ and for VOCs (Austria: 100 g/t treated waste, Germany: 55 g/t treated waste). Furthermore, such systems cannot achieve the TOC emission limit values demanded by some German standards (e.g. less than 55g TOC per tonne of MBT input and a TOC concentration of less than 20 mg/Nm^3).

Example plants
Widely used in the sector. Applied in the treatment of flue-gases from biological treatment plants and from physico-chemical treatment of waste waters and immobilisation. It is also commonly used in other industrial sectors, such as in the chemical, iron and steel, and food industries and in waste water treatment plants. Many examples of the use of biofilters exist in the EU.

Reference literature
[52, Ecodeco, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [66, TWG, 2003], [81, VDI and Dechema, 2002], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [135, UBA, 2003], [150, TWG, 2004], [157, UBA, 2004]

4.3.11. Scrubbing

Description
Absorption techniques are typically called scrubbers. Some techniques include:

a. having in place a scrubber system for the major inorganic gaseous releases (e.g. Cl_2, ClCN, HCl, H_2S, NH_3, NO_x), organic compounds (e.g. VOC) and odour from some unit operations treating certain types of waste (containing these volatile compounds), which have a point discharge for process emissions. In circumstances of highly variable emissions, the installation of a secondary scrubber unit to certain pretreatment systems may be a solution if the discharge is incompatible, or too concentrated for the main scrubbers
b. correctly operating and maintaining the abatement equipment, including the handling and disposal of spent scrubber medium.

Water sprays are a commonly used control method for particulate matter emissions. The addition of dust control chemicals such as polymers or acrylics to the water increases the effectiveness of the spraying.

Achieved environmental benefits

Reduces emissions to air of VOC, acids, ammonia, particulates, etc. Increases the efficiency of pollutant adsorption, due to the particle-gas contact (particularly relevant for the removal of acid gases by basic particles injected at the scrubber, if applicable).

Cross-media effects
This technique generates liquid effluents and sludge that require further treatment.

Wet scrubbers generate steam plumes. Releases from wet scrubber vents need to be hot enough to avoid visible plume formation in the vicinity of the vent. This is to prevent the condensation or adsorption of environmentally harmful substances by the condensing water vapour. Exhaust gases from a wet scrubber can be heated by the use of waste heat to raise the temperature of the exhaust gases and to prevent immediate condensation on the exit from the vent. This procedure also aids the thermal buoyancy of the plume.

Operational data
Usually some level of air monitoring will be carried out, either at the scrubber discharge or at the site boundary. Typically the monitoring of the exit gases from the scrubber systems/filter systems is spasmodic. The assumption is that the abatement systems are fit for this purpose and will reduce the emission to an acceptable background release. Discharge points may be monitored on a quarterly or monthly basis for those acid gases that are expected to be collected.

Water supply and effluent disposal facilities must be available. Monitoring provisions include:

- pH, flowrate and level of scrubber liquors and scrubber pressure drop
- pressure drop monitoring with alarms
- periodically monitoring the exit concentrations under different operating conditions.

There also needs to be a programme in place for the regular changing of absorbent in the absorption units.

Applicability
Suitable for high flow, low concentrations (e.g. 1 – 200 mg/Nm^3 VOC), low temperature gas streams and when the pollutant is chemically reactive (or soluble in the case of VOC contaminants).

These techniques are typically applied to point source emissions related to those compounds which result from the collection of gas from a vessel or area and which are passed on either via abatement or direct to a stack or vent. This technique can be used for the treatments of off-gases generated during the loading of storage tanks.

Acid scrubbers are applied to capture the ammonia emissions liberated during the acidic treatment in the re-refining of waste oils. Mineral oil scrubbers are also used to trap VOCs and odours in waste oil treatment facilities.

Hypochlorite or hydrogen peroxide may be used for cyanide scrubbing and odour control. A two-stage system could be utilised, e.g. alkali and oxidiser scrubbers in series. Water supply and effluent disposal facilities need to be available to run these systems. There needs to be a programme for the regular changing of absorbent in the absorption units.

Alkaline potassium permanganate or hypochlorite can be used as oxidisers for the treatment of cyanide compounds.

Economics
Table 4.29 below shows a summary of scrubbing costs for emission controls for area sources applied to excavation and removal.

Emission control technique	Material cost (USD/m^2)	Comments
Water spray	0.001 (varies)	Assuming municipal water cost of 1 USD/1000 litres. Water requires constant re-application. Water

		truck rental: 500 USD/week.
Additives: Surfactant Hygro salt Bitumen/adhesives	 0.65 2.58 0.02	Costs vary with chemical use

Table 4.29: Summary of costs for emission controls for area sources applied to excavation and removal [30, Eklund, et al., 1997]

Example plants
A common use is the treatment of extracted air from the reactor vessel with a scrubber liquor, typically a caustic solution. The process is extensively applied in Ph-c plants (e.g. wet scrubbing). Used as a pretreatment, e.g. before biofilters, for the treatment of the exhaust gases of biological treatment plants.

Pretreatment processes capable of liberating toxic gases tend to have their own scrubbing systems, with the scrubber vent leading into the main site exhaust system, and with the aqueous liquors being treated in the plant.

All of the oxidation systems seen in the UK have their own local scrubber systems, and the residues from both the oxidation and the scrubber solutions are treated in the main plant. Where the plant has a total exhaust system for the site, the exhaust from the oxidation scrubbers typically goes through the main plant exhaust scrubbing system prior to discharge to the air.

Caustic scrubbing is employed to strip hydrogen sulphide in plants treating waste oil.

Reference literature
[30, Eklund, et al., 1997], [42, UK, 1995], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.3.12. Chemical scrubbing

Description
Chemical exhaust gas treatment can be one-step or multi-step scrubbing with chemical scrubbers. Up to now, plants of this type have been produced, e.g. as one-step or multi-step carrier material cleaners with controlled pH values in each step or with an addition of oxidants.

Achieved environmental benefits
Scrubbers of this type are well suitable for removing single components (e.g. ammonia).

Cross-media effects
This scrubber is required for the reduction of N-compounds prior to the subsequent treatment. Multistage exhaust air scrubbers (acid-alkaline), or scrubbing with H_2O_2, can only reduce the concentration of certain components (e.g. VOCs) due to the high crude gas concentrations generated especially by recirculating treatments.

Applicability
A state-of-the-art technique in biological treatment (MBT) plants is a combination of acid scrubbers and thermal regenerative exhaust gas treatment. The release of the treated exhaust air is carried out via a stack.

Driving force for implementation
It is reported that scrubbed gas concentrations required by a German regulation cannot be reached by these systems alone.

Example plants

Currently no information is available on its use as an independent treatment step in biological treatment (MBT) plants. All information in this section corresponds to experiences in other types of plants.

Reference literature
[132, UBA, 2003], [150, TWG, 2004]

4.3.13. Low oxidative processes

Description
Among the low oxidative processes commonly used are ionisation and UV processes. These are based on the principle that sometimes the adsorption of a single O or OH radical can significantly reduce the odorous properties of a substance.

Achieved environmental benefits
The effect of the low oxidative processes is very substance-group specific and can be impaired considerably by the presence of certain noxious gases (e.g. formation of amines in the presence of ammonia).

Cross-media effects
This treatment however does not lead to a significant decomposition of organically bound carbon. According to experiences gained so far, there is often only a partial oxidation and no break-up of the ring of aromatic hydrocarbons. Styrole may be polymerised. Methane is only slightly reduced.

Operational data
The specific energy demand is usually below 1 kW/1000 Nm^3 of air.

Applicability
These processes are often used for odour neutralisation in different areas.

Example plants
Used in biological treatment plants, nevertheless, operational experience is not available.

Reference literature
[132, UBA, 2003]

4.3.14. Incineration

Description
In the decontamination of thermal exhaust air, the exhaust air is treated in a combustion chamber at temperatures of up to 850 ºC and for a minimum residence time of at least 2 seconds. Within this space of time, the harmful substances will be totally oxidised and the cleaned gas can then be released to the air.

In biological treatment plants, incineration can be differentiated into post-combustion, with or without heat recovery. As in thermal post-combustion, the carbohydrates are oxidised to carbon dioxide and water in a combustion chamber.

Achieved environmental benefits

Used for VOC control and will usually require the addition of supplementary fuel to support the combustion process. The operator can offset the cost of the supplementary fuel when there is a requirement elsewhere on site for the waste heat that is generated. Values of less than 50 g of VOC per tonne of waste can be achieved with this technique.

In biological treatment plants, by using special heat-exchangers, high quality heat recovery of up to 98 % may be achieved. These high rates of heat recovery are based on the use of special ceramic heat-exchangers, which combine a high mass and a large surface area in an ideal way.

Operational data
Usually requires the addition of supplementary fuel to support the combustion process. The flowrate is 1500 Nm^3/h and the operating temperature is 1050 – 1200 ºC. The specification of 850 ºC with 2 seconds residence time may be justified in waste incineration when a complete flue-gas treatment installation achieves the full removal of residual contaminants. The burning conditions are more extreme (e.g. 1100 ºC with 2 seconds residence time) to completely destroy some odorous and VOC components as well as destroy dioxins and dioxin pre-cursors.

Table 4.30 shows the energy requirements of incineration for different hydrocarbon concentrations in the gas.

Parameter				
Hydrocarbon concentration in the gas (g/Nm^3)	0.5	1.5	3	6
Incineration	9	8	6.2	3.2
Heating energy in kWh required for the treatment of 100 Nm^3/h of gas contaminated with VOCs The flows that have been treated range from 500 Nm^3/h up to 11000 Nm^3/h				

Table 4.30: Energy requirements of incineration for different hydrocarbon concentrations in the gas [30, Eklund, et al., 1997]

Applicability
There are no limits for its application.

Economics
The following two tables (Table 4.31 and Table 4.32) show cost data for incineration.

Treatment	**Maximum flow (Nm^3/h)**	**Capital cost (USD)**
Incineration	110	13000[1]
	160	25000[1]
	915	44000[1]
Internal combustion engine	96	62000
	160	50000
[1] The cost includes blower, sampling valves, and controls. Heat recovery systems are not included		

Table 4.31: Capital costs for controlling VOC emissions from soil venting extraction systems

[30, Eklund, et al., 1997]

Capital cost (GBP)	Operating cost (GBP)
30000	3000
Incineration of 2.5 kg fuel oil/hour @ GBP 0.13p/litre Capacity: 10000 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	

Table 4.32: Cost of controlling releases for air from a typical oil recycling plant using incineration [42, UK, 1995]

In biological treatment plants, cost-efficiency of the operation is determined by the size of the volume flow to be treated and by the pollutant concentrations. The ideal conditions are autothermal operation, where the amount of energy released by the combustion of the pollutants exactly corresponds to the energy demand for maintaining the combustion temperature. The necessary heating energy can, in this case, be gained completely from the combustion of the carbohydrates. This energy demand is directly dependent on the degree of heat recovery. Pollutant concentrations are low making heat supply necessary and, consequently, generating high operation costs.

Driving force for implementation
Waste Incineration Directive (2000/76/EC).

Example plants
At least two waste oil treatment plants use such a system. Used in biological treatment plants.

Reference literature
[30, Eklund, et al., 1997], [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [150, TWG, 2004]

4.3.15. Combined combustion

Description
In some plants where combustion takes place, it is possible to inject polluted air collected in the workshop directly into the secondary air circuit of the burner or into the primary air that goes into the burner. This might require a specific adaptation of the combustion process (modification of gas cleaning and stability of combustion).

Achieved environmental benefits
- synergy with existing combustion facilities
- allows an energy recovery from burning the VOCs in the combustion.

Table 4.33 shows VOC removal data using combined combustion.

Characteristics	Value
Input flow range (Nm^3/h)	<50000
Input VOC concentration (g/Nm^3)	~ 3 <explosion limit of the compounds
Output VOC concentration (mg/Nm^3)	10 – 50
Need for preliminary de-dusting	no
Residues	no
Consumption (per tonne waste fuel produced)	
Electricity (kWh)	*
Fuel/gas (kWh)	*
Costs	
Investment cost (EUR/t capacity)	*
Operational costs (EUR/t waste fuel produced)	*
Maintenance costs (EUR/t waste fuel produced)	*
*depends on each case	

Table 4.33: VOC removal using combined combustion
[122, Eucopro, 2003]

Cross-media effects

- not available during maintenance of the burner
- specific instrumentation and valves must be installed to prevent a 'domino effect' between each process
- fluctuations in quality or quantity of the VOC could cause some trouble in the combustion system.

Applicability
Needs prior dilution with air when an explosive concentration may be reached.

Economics
Adaptation costs can be high. The operator can offset the cost of the supplementary fuel when there is a requirement elsewhere on site for the waste heat that is generated.

Driving force for implementation
Waste Incineration Directive (2000/76/EC).

Example plants
Used for the preparation of waste fuel from hazardous waste and laundering of waste oils.

Reference literature
[30, Eklund, et al., 1997], [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.3.16. Catalytic combustion

Description
The polluted air is burned but, in this technique, the combustion temperature is reduced by the use of a catalyst. The catalyst allows the same destruction efficiency of the VOC at a lower temperature.

In biological treatment plants, catalytic combustion may be used to remove TOC from the exhaust gas. The pollutants are oxidised at temperatures between 200 and 500 ºC using noble-metal or metal oxide catalysts.

Achieved environmental benefits

- low fuel consumption
- complete destruction of VOC

- efficiencies range from 95 to 99.9 %
- output concentrations of 5 – 50 mg C/Nm^3 are achievable. The actual range depends on the type of compound and the input concentration.

Table 4.34 shows VOC removal data using catalytic combustion.

Characteristics	Value
Input flow range (Nm^3/h)	20000 – 50000
Input VOC concentration (g/Nm^3)	1 – 3
Output VOC concentration (mg/Nm^3)	10 – 50
Need for preliminary de-dusting	Yes
Risks	Catalyst poisoning
Residues	no
Consumption (per tonne waste fuel produced)	
Electricity (kWh)	25 – 75
Fuel/gas (kWh)	70 – 140
Reactant (kg)	Catalyst
Costs	
Investment costs (EUR/t capacity)	20 – 30
Operational costs (EUR/tonne waste fuel produced)	
Electricity	1 – 3
Fuel/gas	1 – 2
Maintenance costs (EUR/t waste fuel produced)	<1

Table 4.34: VOC removal using catalytic combustion
[122, Eucopro, 2003]

In biological treatment plants, purification efficiencies of more than 99 % can be achieved.

Cross-media effects
The catalyst is sensitive to some compounds (e.g. metal and organic), and their build up may progressively decrease their efficiency.

In biological treatment plants, among the disrupting substances are catalyst toxins, such as organometallic compounds, organic silicon compounds and arsenic compounds. The treatment of halogenated compounds, organic sulphur compounds and organic nitrogen compounds is possible only to a limited degree. Methane can be catalytically reduced to CO_2 only under certain conditions. High temperatures of over 600 ºC are necessary for the catalytic oxidation of methane. The energy use of a thermal treatment without heat recovery is very high. The catalytic-thermal oxidation in biological treatment (MBT) is, therefore, questioned under both an economical and environmental point of view.

Operational data
- needs a gas pretreatment in some cases (e.g. ESP, bagfilters and gas scrubber)
- needs prior dilution with air when explosive concentrations are reached
- the energy consumption is lower than for incineration.

Table 4.35 shows the energy requirements of catalytic combustion for different hydrocarbon concentrations in the gas.

Parameter				
Hydrocarbon concentration in the gas (g/Nm^3)	0.5	1.5	3	6
Catalytic combustion	2	1.2	0	0
Heating energy in kWh required for the treatment of 100 Nm^3/h of gas contaminated with VOCs.				

The flows that have been treated range from 500 Nm^3/h up to 11000 Nm^3/h

Table 4.35: Energy requirements with catalytic combustion for different hydrocarbon concentrations in the gas
[122, Eucopro, 2003]

In biological treatment plants, the operating life of such catalysts may be more than 30000 operating hours, depending on the operating temperature and on the disrupting substances in the process gas.

Applicability
Given the numerous interfering factors, the practical applicability of catalytic oxidation in biological treatment plants seems problematic. Furthermore, operational experience from biological treatment (MBT) plants is not available.

Economics
The cost of investment is relatively high. Table 4.36 shows the capital costs for controlling VOC emissions from soil venting extraction systems.

Treatment	Maximum flow (Nm^3/h)	Capital cost (USD)
Internal combustion engine	96	62000
	160	50000
Catalytic oxidation	160	25000[a]
	320	31000 – 69000[a]
	800	44000 – 86000[a]
	1600	77000[b]
	8000	140000
[a] Includes burner, blower, flame arrestor, gauges, filters, knockout pot, sampling port, controls, and skid mounting [b] Dilution system available for an additional 22000 USD.		

Table 4.36: Capital costs for controlling VOC emissions from soil venting extraction systems
[30, Eklund, et al., 1997]

Driving force for implementation
Waste Incineration Directive (2000/76/EC).

Reference literature
[30, Eklund, et al., 1997], [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [132, UBA, 2003], [150, TWG, 2004]

4.3.17. Regenerative catalytic oxidiser

Description
VOCs are burned in combustion chambers at a temperature ranging from 750 to 950 °C. The energy produced by the combustion of the VOCs is used to preheat the polluted air on the ceramic bed before combustion. The combustion temperature can be adapted according to the VOC concentration. The polluted process air is heated to the necessary reaction temperature by a heating system and then guided over a combined catalyst and heat accumulating bed reactor. In this reactor, the process air is decomposed to CO_2 and water. The heat from this reactor is then guided over a second combined bed reactor and accumulated there. After this reactor's accumulator bed has been heated, the process air stream is switched so that it enters the second reactor. The heat from the second reactor is then used to preheat the process air, whilst the pollutant

oxidation takes place in the first reactor. During further operation, the unit is switched cyclically between the two stages described above.

Achieved environmental benefits

- high VOC destruction rate (>99 %)
- reduced use of fossil fuel or waste fuel (high energy efficiency)
- at high VOC concentrations (>3 g TOC/Nm^3), it is possible to operate in an autothermal zone. This means that minimum external energy is needed to be added to sustain the reaction.

Table 4.37 shows VOC removal data using regenerative catalytic oxidation.

Characteristic	Value
Input flow range (Nm^3/h)	20000 – 80000
Input VOC concentration (g/Nm^3)	2 – 4 with peaks of up to 10
Output VOC concentration (mg/Nm^3)	15 – 50
Efficiency (%)	>99 %
Need for preliminary de-dusting	Yes
Risks	
Residues	No
Consumption (per tonne waste fuel produced)	
Electricity (kWh)	10 – 50
Fuel/gas (kWh)	50 – 200*
Alternative fuel or biogas	Yes
Reactant (kg)	-
Costs	
Investment costs (EUR/t capacity)	10 – 25
Operational costs (EUR/t waste fuel produced) Electricity Fuel/gas	 1 – 3 2 – 6
Maintenance costs (EUR/t waste fuel produced)	<1
*according to the VOC concentration	

Table 4.37: VOC removal using regenerative catalytic oxidation
[122, Eucopro, 2003]

Cross-media effects

High energy consumption if there is only a low VOC concentration.

Operational data

- accepts fluctuations of VOC concentrations
- needs prior dilution with air when an explosive concentration may be reached
- needs a de-dusting when dust concentration inlet is higher than 20 mg/Nm^3.

Table 4.38 shows the energy requirements of regenerative catalytic oxidation for different hydrocarbon concentrations in the gas.

Parameter				
Hydrocarbon concentration in the gas (g/Nm^3)	0.5	1.5	3	6
Regenerative catalytic oxidation	0	0	0	0
Heating energy in kWh required for the treatment of 100 Nm^3/h of gas contaminated with VOCs. The flows that have been treated range from 500 Nm^3/h up to 11000 Nm^3/h				

Table 4.38: Energy requirements with regenerative catalytic oxidation for different hydrocarbon concentrations in the gas

[122, Eucopro, 2003]

Applicability
It is designed for low to medium VOC concentrations because of its low energy costs.

Economics
Low operation costs and high investment cost.

Driving force for implementation
Waste Incineration Directive (2000/76/EC).

Reference literature
[30, Eklund, et al., 1997], [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004]

4.3.18. Regenerative thermal oxidiser

Description
The aim of a regenerative thermal oxidiser is the permanent and high quality recovery of a large part of the heat energy that is necessary for heating the waste gas stream to the required oxidation temperatures for treatment.

This heat energy is stored in flow-through heat-exchangers. Such heat-exchangers consist either of a ceramics fill material or are fin heat exchangers. The performance of this recuperative process is expressed by the degree of heat recovery achieved, which is defined as follows:

$$\text{Performance} = 1 - \frac{T_{\text{scrubbed gas}} - T_{\text{crude gas}}}{T_{\text{combustion chamber}}} \qquad T = \text{temperature}$$

The incoming exhaust air is heated up in the 'hot' heat-exchanger bed. The air is heated up to a temperature a few degrees below that of the combustion chamber, depending on the heat storage capacity. In the combustion chamber, oxidation takes place. In the case of low pollutant concentrations in the process air, the missing energy has to be brought in by primary energy sources. After passage through the combustion chamber the exhaust gas, which is now at the reaction temperature, gives off its heat to a 'cold' heat-exchanger bed.

Due to the high energy demand for heating up the exhaust gas and due to the optimal heat exchange the greatest part of the heat stored in the 'hot' heat-exchanger bed is given off to the exhaust gas after appox. 120 seconds. Conversely the hot exhaust gas heats up the 'cold' heat-exchanger bed.

Achieved environmental benefits
The realised heat recovery rates vary between 90 and 98 % depending on the pollutant content of the exhaust gas. An additional supply of energy in this case is not necessary. With regards to the required values for the scrubbed gas, the systems currently available on the market differ in the technical method utilised for ensuring the lowest scrubber gas values. This is necessary because at the stream reversal point, remnants of the crude gas may pollute the scrubbed gas. Systems optimised with respect to this problem can achieve scrubbed gas concentrations of less than 10 mg/Nm^3.

Operational data

In order to maintain permanent operation, the stream direction has to be controlled in such a way that the heat-exchanger bed when heated up at a given time can be used for heating up the waste gas. This results in an alternating heating and cooling of the respective heat-exchanger beds.

Also crucial for the design of the plant is the amount of the enthalpy chemically bound in the pollutants that are to be oxidised. The operation is autothermic if the sum of the heat stored in the heat-exchanger beds and the reaction enthalpy released is sufficient to maintain the necessary temperature in the combustion chamber.

If the enthalpy bound in the pollutants is not sufficient to reach oxidation temperature, this has to be achieved and ensured by the use of an external energy supply. Some individual providers realise this by the installation of controlled burners in the combustion chamber, others enrich the exhaust gas with the additional combustibles so that the system can be kept in autothermic conditions. In this case, the plant can be operated flamelessly. In energy-optimised plants, an energy consumption of 8 kWh heat output per 1000 Nm^3 of waste gas can be expected.

For the starting period until reaching operational temperature and during operation with low organic substance concentrations (<2 g C/Nm^3), an external energy supply is necessary due to the as yet insufficient energy storage in the heat-exchanger beds. In the starting phase of flameless systems electrical heating is usually used, otherwise the heat energy can be brought in by natural gas or propane gas burners.

For operation with gaseous waste fuels such as landfill gas or biogas, it needs to be taken into account that these gases may be contaminated by pollutants. For starting an operation that has not yet reached the required combustion chamber temperatures, these gases should not be used. This can only be done with conventional fuels such as natural gas or propane gas. Additionally it has to be ensured in the safety chain that in the event of any service interruption and the resulting decrease of the temperature in the combustion chamber, the supply of the waste fuels is regulated and thus always available.

Applicability
In the context of research projects and for plant operation, combinations of acid scrubbers and regenerative thermal oxidisers have proven valuable. This process combination has advantages in terms of cleaning capacity as well as in terms of operational costs.

Example plants
In practice, there are several different designs of regenerative thermal oxidisers, which differ primarily in the design of the individual heat-exchanger beds and in the selection of the heat-exchanger material. For low concentrations, these processes have become widely used in post-combustion with heat recovery.

Regenerative thermal oxidisers have been used in Germany for several years for the purification of biological treatment (MBT) plants' exhaust gas. In Austria, an MBT plant has also recently installed and started operation of these types of systems.

Reference literature
[132, UBA, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.3.19. Oxidation treatments

The type of oxidation treatment related to the following two tables (Table 4.39 and Table 4.40) has not been specified. It could be any of the four techniques described in Sections 4.3.14 to 4.3.17. These tables show air emissions data after treatment.

Air emission parameter	Value	Units
Fume temperature	140	ºC
PM	10 – 27	mg/Nm^3
Heavy metals	0.03	mg/Nm^3

TOC	8	mg/Nm^3
SO_x	10	mg/Nm^3
NO_x	350	mg/Nm^3
HCl	2.3 – 10	mg/Nm^3
HF	<0.1	mg/Nm^3
HBr	<0.1	mg/Nm^3
HCN	<0.1	mg/Nm^3
P	0.019	mg/Nm^3
$CO_2/(CO+CO_2)$	<1	mg/Nm^3
CO_2	9.5	%
CO	50	mg/Nm^3
PAH	<0.1	ng/Nm^3
PCDD + PCDF	<0.01	ng/Nm^3
TCDD + TCDF	<0.01	ng/Nm^3
PCB + PCN + PCT	<1	ng/Nm^3
Values referred to 10 % O_2 in the fumes		

Table 4.39: Air emissions from off-gas thermal destruction plants from several waste oil treatment plants [42, UK, 1995], [66, TWG, 2003], [86, TWG, 2003]

Air parameter	Units	INPUT streams		OUTPUT
		Off-gas from process plants	Off-gas from tanks blanketing	
Flow	Nm^3/h	101	1400	2700[1]
Temperature	°C	18	27	146
Dust	mg/Nm^3	58.6	1.1	28.4
H_2S	mg/Nm^3	101600	<1	<0.1
Mercaptans	mg/Nm^3	2153	1.7	0.7
SO_x	mg/Nm^3	30000	1.3	3
HCl	mg/Nm^3	308	0.9	0.8
VOC	mg/Nm^3			3
NO_x	mg/Nm^3			181
PAH	mg/Nm^3			<0.1
[1]Combustion air included				

Table 4.40: Thermal treatment of contaminated streams [66, TWG, 2003]

4.3.20. Non-thermal plasma treatment

Description

The non-thermal plasma technique is one of the highly oxidative processes. It is a physical process that activates the molecules in a changing electric field and thus facilitates attack by a radical reaction. Non-thermal plasma denotes a condition of atoms and molecules which are activated by electric fields and which are thus subject to dissipation of the electrons or a shift of the electrical charge to energy-richer orbits. Thereby energy potentials, whose energy level corresponds to temperature equivalents of up to 100000 °C of thermal activated plasma can be reached.

Achieved environmental benefits

Organically bound carbon can be degraded to a high extent. The advantage of non-thermal plasma is that with sufficiently high field strengths and a precise energy supply, dosing can cause a reaction within fractions of seconds. Hereby increased quantities of different radicals are produced, which due to their high oxidative capacity are able to attack organic molecules and to break up compounds.

Cross-media effects
Due to the radical reaction in the reactor, ozone is released at rates of several grams per hour. The plant concept, therefore, has to ensure elimination of this ozone. For this special metal, a catalyst or activated carbon is suitable. When choosing the catalyst it needs to be ensured that there are no secondary odorous emissions from unfinished catalytic processes. The danger of self-ignition of the activated carbon in reactions with ozone has to be taken into account. Moreover it also needs to be taken into account that N_2O is produced to a greater extent.

Example plants
Used in biological treatment plants, nevertheless, operational experience is not available.

Reference literature
[132, UBA, 2003]

4.3.21. NO_x abatement techniques

Description
More information can be found in the Common Waste Water and Waste Gas Treatment (CWW) and waste incineration BREFs. Some techniques include:

a. good process control, which can prevent the actual emission of NO_x
b. good combustion chamber design
c. low NO_x burners
d. SCR
e. SNCR
f. internal flue-gas recirculation
g. oscillating combustion
h. chemical scrubbing (see Section 4.3.12).

Achieved environmental benefits
Reduces NO_x emissions to air.

Cross-media effects
The injection of ammonia or urea in the flue-gas when using SCR or SNCR stream induces the risk of NO_x formation rather than removal, if the temperature is too high and there is excess oxygen present.

Applicability

Basis for the benchmark	Activity
Using sound process control to prevent the emission of NO_x	Waste acid treatment
Using a good combustion chamber design	Combustion plant
Using low NO_x burners	Combustion plants

Economics
SCR and SNCR have higher operational costs than other techniques such as good process control and low NO_x burners.

Reference literature

[55, UK EA, 2001], [86, TWG, 2003], [150, TWG, 2004]

4.3.22. Odour reduction techniques

More information can be found in Section 4.3.23.

Description
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
f. cover the maintenance requirements of the containment and the management of the operations where odour can be contained, for example within buildings
g. place emphasis on pre-acceptance screening (see Section 0) 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 to abatement equipment
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.

Achieved environmental benefits
Prevents the emissions of those odorous releases that may be offensive and detectable beyond the boundaries of the site.

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.

Reference literature
[50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [81, VDI and Dechema, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [120, Prantner, 2002]

4.3.23. Odour management in biological treatment plants

More information can be found in Section 4.3.22.

Description
Effective operational management can help control the formation of odours. This includes:

a. processing incoming feedstock as soon as possible
b. ensuring proper stabilisation of the biomass within the retention time in enclosed buildings, so as to ensure only odourless materials are present in the open curing stage
c. 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 to lose structure and make anaerobic decomposition more likely)
d. preventing the formation of leakage puddles (e.g. ensuring proper slopes to paved surfaces)

e. avoiding the external stockpiling of coarse rejects from pre-process screening steps, as these would also contain a certain percentage of fermentable materials
f. withdrawing the exhaust air from the odorous sections of the process (tipping, deep bunkers storage of input fermentable materials, pretreatment, early process steps. Sometimes also the curing section can be enclosed and exhaust air treated)
g. designing the withdrawal system to prevent any loss of exhaust air from windows, doors, etc.
h. fitting the facility with properly dimensioned abatement systems
i. ensuring proper maintenance of odour abatement technologies is carried out
j. using surfactant reagents
k. providing enclosed leachate collection/storage tank(s), to minimise odour emissions while holding liquor prior to recirculation and/or off-site disposal
l. providing stored leachate treatment, such as aeration, to prevent septic conditions causing odour
m. providing odour abatement, to control emissions from specific sources, such as odour masking atomisers
n. designing the enclosed buildings in such a way so as to have a negative air pressure, to prevent odour emissions from doorways.

Achieved environmental benefits
Prevents or decreases 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.

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.

Applicability
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.

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.

Reference literature
[59, Hogg, et al., 2002], [116, Irish EPA, 2003], [150, TWG, 2004]

4.3.24. Some examples of waste gas treatment applied to different waste treatments

Table 4.41 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 4.3.25.

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

Table 4.41: Applicability of waste gas treatments
[30, Eklund, et al., 1997], [55, UK EA, 2001], [121, Schmidt and Institute for environmental and waste management, 2002], [135, UBA, 2003], [150, TWG, 2004]

4.3.25. Some examples of combined treatment of exhaust air

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.

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

Table 4.42: Exhaust air treatment facility of a waste solvent treatment plant
[130, UBA, 2003]

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_x. 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

Table 4.43: Combined abatement of particulates and VOCs in a hazardous waste treatment plant
[50, Scori, 2002]

4.3.26. Some examples of abatement techniques comparisons applied to the preparation of waste fuel from hazardous waste

Table 4.44 and Table 4.45 compare some abatement techniques when applied to one specific waste treatment.

Criteria	Bag filter	Wet scrubber
Dust treatment performance	+	-
Flexibility	+	+
Consumption	++	-
Costs	++	-

Risks (fire, explosion, etc)	+	++
Cross-media effects	+	-
Note: (-) poor, (+) acceptable and (++) well adapted		

Table 4.44: Comparison of bag filters and wet scrubbers for the abatement of dust emissions [122, Eucopro, 2003]

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						

Table 4.45: Comparison of VOC abatement techniques
[122, Eucopro, 2003]

4.4. 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 0.

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 [63, 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.

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). 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 micro-organisms
- oxidation of the slurry by aeration.

Waste water treatments 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 micro-organisms (sludge) and a cleaner final effluent. Biological degradation only occurs on organics that are dissolved in water and not 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
- nano-, 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.

4.4.1. Management on the waste water within the waste treatment sector

Description
Figure 4.2 shows an effluent management system for a WT installation.

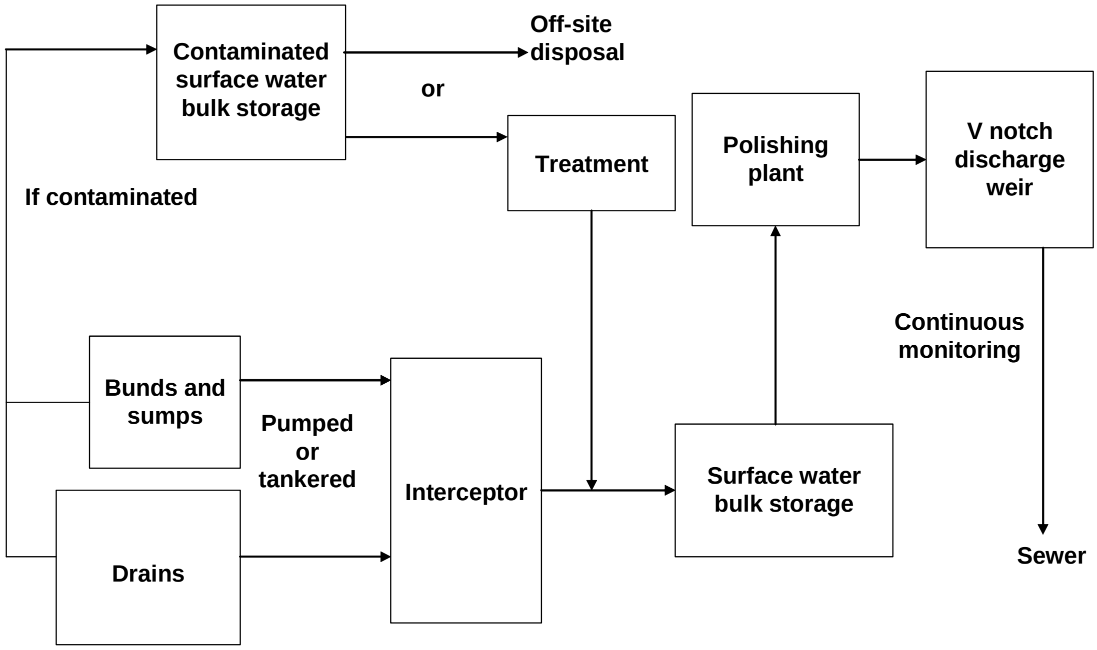


Figure 4.2: Effluent management within a waste treatment installation, which can be classified as shown in Table 4.46 below
[55, UK EA, 2001]

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	4.1.1 4.4.2
Primary treatment	Removal or reduction of target substances from wastes		4.4.3
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	4.4.4
Tertiary treatment	Elimination of biodegradable organic and nitrogen compounds	Biological treatment Settlement Thickening and dewatering	4.4.5
Final treatment	'Polishing' of effluent Recovery of substances from effluent	Filtration Membranes	4.4.6

		Wet air oxidation Adsorption	

Table 4.46: Effluent management techniques

Some techniques for effective waste water management include:

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
h. having in place and operating an enclosure system whereby rainwater falling on the processing areas is collected along with tanker washings, occasional spillages, drum washings, etc., and returned to the processing plant or collected in a combined interceptor
i. collecting the raining water in a special basin for further treatment in the case it is detected that it is contaminated
j. having a full concrete base, with falls to internal site drainage systems which lead to storage tanks or to interceptors that can collect rainwater and any spillage. Interceptors with an overflow to sewer usually need automatic monitoring systems, such as a pH checks, which can shut down the overflow
k. reusing treated waste waters and rainwater in the process (e.g. cooling water)
l. only discharging the waste water from its storage only after the conclusion of all the treatment measures and a subsequent final inspection
m. use of landfill leachate as water input for the aerobic digestion
n. process and run-off water is handled by means of a closed circulation system
o. partial re-use of the water used for the production of polymer solution
p. displacement methods of treating chemical process waters containing VOC (another specific example is contaminated groundwater), resulting in a lower COD content.

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.

Operational data

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

Generally 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.

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

[50, Scori, 2002], [51, Inertec, et al., 2002], [52, Ecodeco, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [66, TWG, 2003], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [122, Eucopro, 2003], [126, Pretz, et al., 2003], [150, TWG, 2004], [152, TWG, 2004], [153, TWG, 2005]

4.4.2. Parameters to consider before mixing waste waters

Description

Some techniques before mixing waste waters that are to be further treated include:

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 specification. Incidents of this nature need to be 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)
e. to isolate drainage systems from flammable waste storage areas to prevent fire being spread along the drainage system by solvents or other flammable hydrocarbons.

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
The procedures conducted by Ph-c plants are hydraulically separated into contaminated waste water and uncontaminated rainwater. Ph-c plants have two separate technical dewatering systems.

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
[121, Schmidt and Institute for environmental and waste management, 2002], [134, UBA, 2003], [150, TWG, 2004]

4.4.3. Primary waste water treatments

Description
Some techniques include:

a. ensuring that the effluent is free of visible oil. This cheek 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.

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
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [150, TWG, 2004]

4.4.4. Secondary waste water treatments

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 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
[55, UK EA, 2001], [134, UBA, 2003]

4.4.5. Tertiary waste water treatments

Description
For the elimination of biodegradable organic compounds and nitrogen compounds biological treatment processes have repeatedly been shown to be effective. In contrast to other treatment techniques biological treatment makes use of micro-organisms 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.

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

Table 4.47: Effluent concentration of a Ph-c plant before and after tertiary waste water treatment [150, 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

[55, UK EA, 2001], [134, UBA, 2003], [150, TWG, 2004]

4.4.6. Final waste water treatments

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 4.48:

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

Table 4.48: Final waste water treatments

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.

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

[41, UK, 1991], [42, UK, 1995], [55, UK EA, 2001], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [150, TWG, 2004]

Evaporation

Description
The aim of the treatment is to concentrate the waste water contents into more manageable volumes.

By splitting the evaporation into several smaller steps and by using a vacuum (in order to lower the boiling temperature), the energy use can be optimised.

Depending on the temperature, the evaporation usually takes place without the chemical conversion of substances. During concentration, phases might be created which favour further separation (e.g. crystallisation).

Achieved environmental benefits
Reduces the amount of waste water to be treated.

Cross-media effects
There is an increased energy consumption. If the materials are not suitable for recovery, the residues from evaporation can be landfilled after an appropriate after-treatment (such as drying, dewatering, conditioning) according to their contents. Since evaporation will only lead to a lightly polluted vapour condensate in the ideal case, the condensate will usually have to be subjected to an after-treatment and purification according to its contents.

Operational data
Limits of the treatment:

- for the selection of input material for the evaporation facility the contents of the waste water need to be taken into account
- if the waste water contains surface-active substances which could lead to foaming during the evaporation process, measures have to be taken to reduce the foam. In addition to the installation of separators, the use of defoamers may be necessary.

Facilities for the mechanical removal of 'crusts' or for the discharge of solid substances which accumulate during evaporation need to be available.

Applicability
The treatment is suitable for highly polluted waste waters from which all inorganic and organic contents that are not volatile need to be eliminated. Evaporation is suitable for instance to further concentrate waste waters already thickened by reverse osmosis or ultrafiltration.

Example plants
Physico-chemical treatment of waste waters.

Reference literature
[134, UBA, 2003], [150, TWG, 2004]

Adsorption

Description
Adsorption to activated carbon is mainly applied for the separation of organic substances from waste waters. Two different approaches are currently in use:

- adding mostly powdery activated carbon to the waste water that is to be treated

- running the waste water over several adsorption columns arranged in series, and which are filled with granulated activated coal.

Achieved environmental benefits
Reduces of organic substances in the waste water.

Cross-media effects
When using powdery carbon, the carbon must be separated from the waste water after use. Depending on the substances adsorbed, it can be incinerated or disposed of at suitable landfill sites. Granulated carbon is usually recovered in external plants.

Applicability
This treatment process is mainly suitable for removing organic substances from waste waters. If individual pollutants or groups of pollutants (e.g. AOX) are to be removed selectively, the process can be optimised by visiting the special properties of the waste water (type and quantity of substances) and thereby the adsorption can be adapted to individual cases (form and properties of the carbon, adsorption time, column size and arrangement, etc.).

As solids can occupy the surface of the activated carbon and thus block the pores they need to be removed before the treatment with activated carbon.

Example plants
Activated carbon adsorption is frequently used in order to enable the operator to meet the permissible maximum value of AOX ≤ 1 mg/l. Activated carbon adsorption however does not selectively separate the AOX-forming materials, but rather a multitude of other organic substances.

Reference literature
[134, UBA, 2003]

Membrane filtration

Description
The separation of substances in membrane processes is brought about by the differential permeabilities of the membrane for different chemical components. There at least one component of the substance mix that is to be separated - usually the solvent – will be able to pass the membrane without resistance, while the other elements are held back to a higher or lesser extent. The fraction that is retained represents the concentrate; the material that passes the membrane is called the permeate.

The following treatment processes, grouped according to their pore sizes, are currently in technical use:

- microfiltration (MF) (>0.6 µm, >500000 g/mol)
- ultrafiltration (UF) (0.1 – 0.01 µm, 1000 – 500000 g/mol)
- nanofiltration (NF) (0.01 – 0.001 µm, 100 – 1000 g/mol)
- reverse osmosis (RO) (<0.001 µm, <100 g/mol)

Some issues to consider include:

a. the pH value in the waste water to be treated can be shifted in order to accelerate the reactions and/or to improve the charge values
b. a fine filter can be connected in front of the activated carbon adsorbent to retain the harmful solids
c. dampening the activated carbon, using fine granulates instead of powders, and feeding it in below the water level in the reactor/basin can help to overcome problems due to dust formation in stirring.

Achieved environmental benefits

By using membrane techniques waste waters with organic and inorganic pollutants can be treated without any considerable addition of chemicals.

Cross-media effects
Through process optimisation, the permeate of a membrane facility should usually be purified sufficiently to be recycled into the industrial process or to comply with minimum quality standards for discharge into water bodies. The concentrate is usually subjected to further treatment, such as:

- re-use
- disposal
- evaporation
- immobilisation.

Applicability
Membrane techniques as used for substance separation and accumulation have become a key technology in water and waste water treatment because no chemicals are necessary, - except for the cleaning of the membrane, - due to the purely technical nature of the separation. As a consequence, the separating components are neither chemically nor thermally polluted. Due to those factors, the economics of the treatment even make it efficient in smaller plants and decentralised treatment of waters at the place of origin is also possible.

The applicability of membrane techniques is influenced both by the construction and design of the modules/membrane systems and by a number of additional limiting factors.

Some of these are:

- damaging factors: free chloride, organic solvents, strong oxidants
- blocking factors
- fouling (metal hydroxides, colloids, biological substances, organic substances)
- scaling (precipitation of salts with low solubility)
- performance-impairing factors
- osmotic pressure, viscosity.

However, these factors are usually not exclusive just to membrane techniques. Nevertheless they generally require a detailed pre-assessment of the water that is to be treated with respect to:

- choice of membrane (polymer or keramics)
- selection of material (synthetic, steal)
- necessary pretreatment (filtration, inhibition, biocides etc.)
- purification programme (acid, alkaline).

Example plants

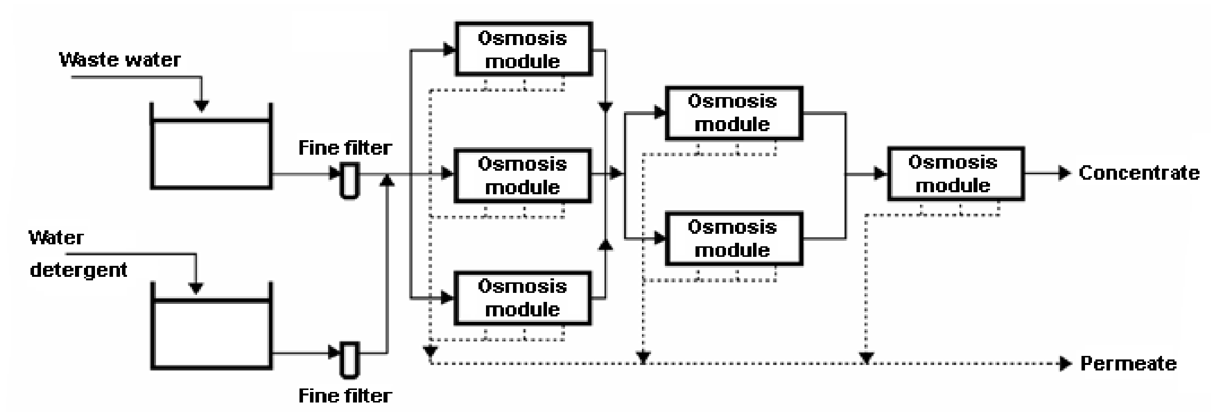


Figure 4.3: Example of a diagram showing a three-step reverse osmosis plant
[150, TWG, 2004]

Reference literature
[134, UBA, 2003], [150, TWG, 2004]

Ozone/UV treatment

Description
Highly polluted waste waters can be treated with ozone alone or with ozone and UV-light in combination with biological treatment processes.

The ozone reaction is a wet chemical reaction. At pH-values below 9 ozone reacts ioniccally by decomposition, leaving one active oxygen atom behind, or as a radical by adsorption of the whole molecule to organic carbon double bonds, breaking them up at pH-values above 9. Oxygen radicals or hydroxyl radicals can also be created from ozone by the exposure to UV-light. These radicals are even more reactive than ozone.

Additionally Nitrogen compounds can be degraded through a combination of the ozone treatment with biological procedures. There the waste water is transported from the influx pump to the denitrification container. Phosphoric acid is added to the influx. Before the fluid enters the denitrification container the runback from the nitrification is added.

In ozone reactors, the ozone can react with the oxidisable substances contained in the waste water. In downstream UV-reactors, the ozone that still remains in the water is destroyed or converted into radicals, which then also react with organic substances.

The remaining oxygen is utilised by aerobic bacteria for nitrification.

After the treatment with ozone and UV-light, part of the cycling water is discharged from the process into the outflow as purified waste water.

Achieved environmental benefits
The wet chemical oxidation with ozone alone or with ozone in combination with UV-light reduces the concentration of:

- dissolved organic hydrocarbons (DOC)
- halogenated hydrocarbons
- polycyclic aromatic carbohydrates (PAC)
- pesticides
- dioxins

- (pathogenic) micro-organisms.

The aim of wet chemical oxidation is the direct degradation of pollutants at a low pressure and temperature. Ozone reacts with all organic substances that contain carbon-carbon double bonds.

Some short-chained aliphatic compounds and carbon-halogen compounds do not easily react with ozone. The bonds of these molecules can be more easily broken if ozone and UV-light are applied in combination.

Depending on the boundary conditions (type of waste water contents, ozone entry, reaction time) the reaction can produce carbon dioxide at the complete oxidation point, and biologically degradable substances (increase of BOD_5) or substances that are not readily biodegradable.

Cross-media effects
If ozone/UV-treatment is combined with a biological step, sludges are produced by the biological treatment which then have to be subjected to further treatment.

Applicability
Some issues to note are:

- longer-chained aliphatic compounds without double bonds are not altered by ozone/UV treatment
- with coloured or turbid waste water, treatment is possible only if UV-treatment is not necessary for the degradation of the contents
- inorganic substances contained in the waste water are not modified and at high salt concentrations can lead to disruption of the process.

Example plants

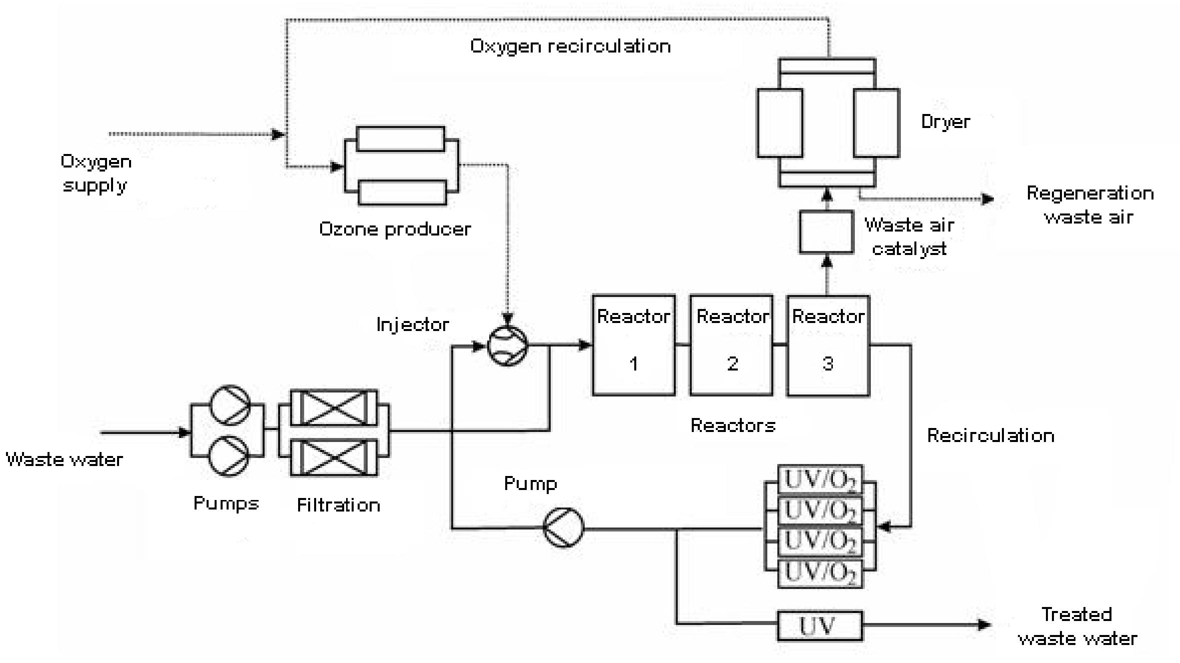


Figure 4.4: Example of a flow sheet showing ozone/UV treatment of waste water
[150, TWG, 2004]

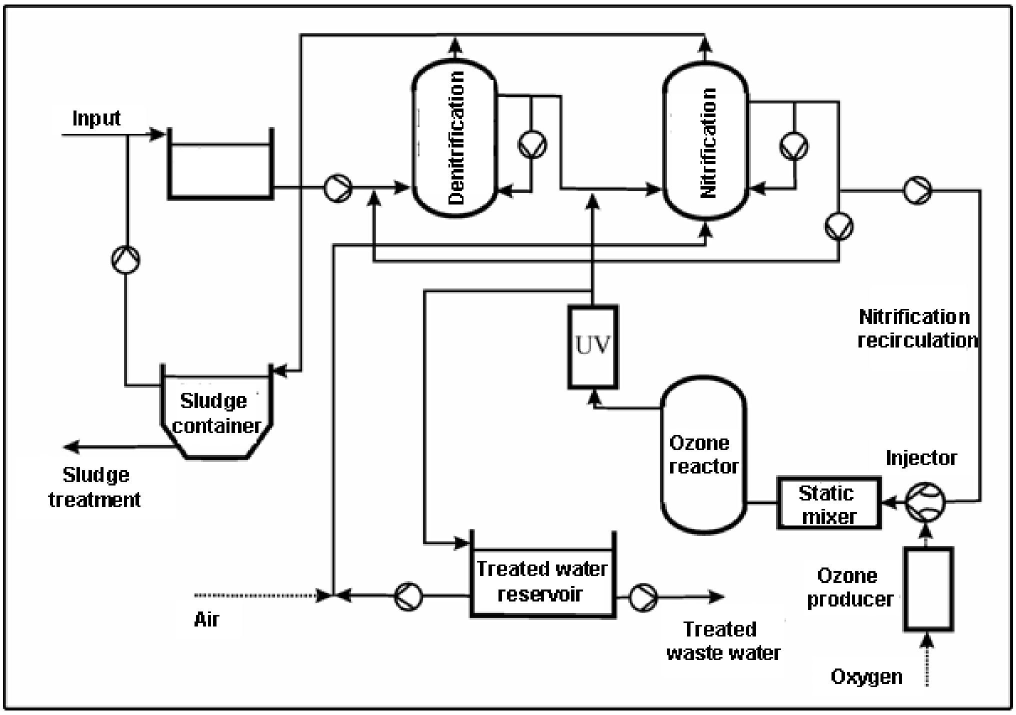


Figure 4.5: Example of a flow sheet showing a biological and UV treatment
[150, TWG, 2004]

Reference literature
[134, UBA, 2003], [150, TWG, 2004]

4.4.7. 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 Table 4.49 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.

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

Table 4.49: Water parameters monitored in waste treatment facilities
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [134, UBA, 2003], [59, Hogg, et al., 2002], [150, 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
[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [59, Hogg, et al., 2002], [86, TWG, 2003], [116, Irish EPA, 2003], [134, UBA, 2003], [150, TWG, 2004]

4.4.8. Examples of some waste water treatment plants in the sector

[56, 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.

4.5. Residue management

The word 'residue' is used in this section to mean the solid waste generated by the waste treatment activity and is not directly related with the type of waste treated in the installation. This is the same type of convention used in Chapter 3 and throughout this document (see also 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 Figure 3.1. 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.

4.5.1. Residue management plan

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 of waste minimisation and they range:

- from basic housekeeping techniques
- through statistical measurement techniques
- to application of clean technologies
- to the use of waste as fuel.

In particular, some techniques include:

a. undertaking an analysis of the sludge/filter cake to ensure 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 streams generated and that need to be removed from the installation. Maintaining a waste 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 which is disposed of or recovered on that side
c. identifying the current or proposed handling arrangements
d. fully describing how each waste stream is proposed to be recovered or disposed of. If it is to be disposed of, the explanation needs to cover why recovery is technically and economically not possible and then describe/explain the measures planned to avoid or reduce impact on the environment
e. ensuring that the dry solids content are not less than 15 w/w-%, to facilitate 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:

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 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 re-use or recycling

i. using multiusable containers instead of drums for all purposes if available
j. utilising the waste with sufficient heat content and low contamination values (see Energy System Sections) as primary/secondary fuel
k. applying housekeeping operations, these can be as simple as sweeping prior to washing floors, these measures can substantially reduce waste volumes.

Achieved environmental benefits

The steps above help to ensure the prudent use of natural resources and can reduce waste generation in the WT installation. Reduces emissions from the management of the residues handled in the installations and minimises 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.

Cross-media effects

The burning of residues can lead to higher air emissions than from the use of conventional fuels.

Operational data

Related with technique h (in the description section above), before re-using drums, the labels and inscriptions need to be removed.

Applicability

The use of residues as fuel is common in waste oil treatment facilities.

The re-use of packaging and palettes depends also whether the packaging is made for re-use or not. In several cases such a re-use may conflict with ADR regulations if the packaging is not retrofitted appropriately.

Related with technique h (in the description section above), the recycle of drums need to take into account the contamination of the drums with the content. Drums not being suitable for direct recycling are typically send to appropriate treatment e.g. incineration. For example, polyethylene drums are completely incinerated, steel drums are cleaned and typically are sorted out from the slags and recycled afterwards. Landfilling of contaminated drums is typically excluded.

Economics

In terms of capital expenditure and operating costs, sludge treatment is a significant component and the management and disposal of solid waste will remain as 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.

Re-using 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 re-used.

Example plants

In Germany, the use of drums has been reduced as much as possible.

Reference literature

[55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [150, TWG, 2004], [152, TWG, 2004]

4.5.2. Techniques to prevent the contamination of soil

Description

These techniques relate to water spills and other fugitive emissions as already dealt with in Section 0 and todecommissioning as already dealt with in Section 4.1.9. Some specific techniques include:

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
b. utilising an impermeable base and internal site drainage
c. applying separate drainage systems and sumps enable the isolation of specific areas of the site where waste is handled and bulked, in order to to contain possible spills and to protect surface water drainage from contamination. These can help to reduce liquid emissions
d. minimising the installation site and minimising the use of underground vessels and pipework
e. carrying out regular monitoring of subsurface vessels for potential leakages (e.g vessel level checks during periods of inactivity)
f. designing the areas where water-endangering liquids are transferred as watertight bunds. Then, the bund must be watertight so that in the event of accident, the hazardous liquid can be contained until security measures are in place
g. ensuring that the areas where water-endangering substances are handled, as well as bunded areas, are specially sealed against seepage by e.g. painting, coatings, concrete quality, sealing systems applied on the inside. There, the sealing system needs to be capable of being inspected at any time
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

Can prevent the short- and long-term contamination of the site. Minimisation of underground vessels and pipes makes easier the tasks of maintenance as well as inspections.

Cross-media effects

Problems such as cracks, blocked outlets on drains, drainage channels of gravel between concrete slabs have all been identified in some cases.

Applicability

Most sites have an impermeable base and operate an internal site drainage (e.g. full concrete base).

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 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 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, organic solvents (depending on the application).

Reference literature

[50, Scori, 2002], [55, UK EA, 2001], [56, Babtie Group Ltd, 2002], [86, TWG, 2003], [121, Schmidt and Institute for environmental and waste management, 2002], [135, UBA, 2003], [150, TWG, 2004]

4.5.3. 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
b. avoiding an accumulation of waste, which may in turn lead to a deterioration or deformation of the container
c. 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
d. conducting a monthy inventory of all the waste on-site to monitor stock levels and to identify any ageing waste on-site
e. ensuring that any accumulations of liquids in bunds, sumps etc, are dealt with promptly.

Achieved environmental benefits

In some reported plants, failure to ensure an adequate throughput of wastes has lead 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

[55, UK EA, 2001], [86, TWG, 2003]

4.5.4. Promoting the external residue exchange

Description

Whilst re-using a residue inside a manufacturing facility is the most desirable form of recycling, it is not always possible to find another department or process that can effectively utilise the residue. An alternative therefore may be to locate another company that can make use of the residue. A waste exchange is a regional clearing-house for such transactions. Waste exchanges maintain computer databases and/or publish periodic lists of wastes available or materials sought by various industries. The waste exchange information base typically includes:

a. company ID code
b. category (e.g., acid, solvent, etc.)
c. description of the primary usable constituents

d. contaminants
e. physical state
f. quantity
g. geographic area
h. packaging.

Achieved environmental benefits
Allows a more appropriate use or disposal of a waste.

Reference literature
[53, LaGrega, et al., 1994]

5. Best available techniques

In understanding this chapter and its contents, the attention of the reader is drawn back to the preface of this document and in particular the fifth section of the preface: ‘How to understand and use this document’. The techniques and associated emission and/or consumption levels, or ranges of levels, presented in this chapter have been assessed through an iterative process involving the following steps:

- identification of the key environmental issues for the waste treatment sector. These are related with air emissions, emission to water, waste, soil contamination as well as energy. However, due to the variety of waste treatments and types of waste involved in this document not all types of emissions are relevant for all waste treatments
- examination of the techniques most relevant to address those 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 performance levels were achieved; such as costs, cross-media effects, main driving forces involved in implementation of these techniques
- selection of the best available techniques (BAT) and the associated emission and/or consumption levels for this sector in a general sense all according to Article 2(11) and Annex IV of the Directive.

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

On the basis of this assessment, techniques, and as far as possible consumption and emission levels associated with the use of BAT, are presented in this chapter that are considered to be appropriate to the sector as a whole and in many cases reflect current performance of some installations within the sector. Where emission or consumption levels ‘associated with best available techniques’ are presented, this is to be understood as meaning that those levels represent the environmental performance that could be anticipated as a result of the application, in this sector, of the techniques described, bearing in mind the balance of costs and advantages inherent within the definition of BAT. However, they are neither emission nor consumption limit values and should not be understood as such. In some cases it may be technically possible to achieve better emission or consumption levels but due to the costs involved or cross-media considerations, they are not considered to be appropriate as BAT for the sector as a whole. However, such levels may be considered to be justified in more specific cases where there are special driving forces.

The consumption and emission levels associated with the use of BAT have to be seen together with any specified reference conditions (e.g. averaging periods).

The concept of ‘levels associated with BAT’ described above is to be distinguished from the term ‘achievable level’ used elsewhere in this document. Where a level is described as ‘achievable’ using a particular technique or combination of techniques, this should be understood to mean that the level may be expected to be achieved over a substantial period of time in a well maintained and operated installation or process using those techniques.

Where available, data concerning costs have been given together with the description of the techniques presented in the previous chapters. These give a rough indication about the magnitude of costs involved. However, the actual cost of applying a technique will depend strongly on the specific situation regarding, for example, taxes, fees, and the technical characteristics of the installation concerned. It is not possible to evaluate such site-specific factors fully in this document. In the absence of data concerning costs, conclusions on economic viability of techniques are drawn from observations on existing installations.

It is intended that the general BAT in this chapter are a reference point against which to judge the current performance of an existing installation or to judge a proposal for a new installation. In this way they will assist in the determination of appropriate ‘BAT-based’ conditions for the installation or in the establishment of general binding rules under Article 9(8). It is foreseen that new installations can be designed to perform at or even better than the general BAT levels presented here. It is also considered that existing installations could move towards the general BAT levels or do better, subject to the technical and economic applicability of the techniques in each case.

While the BREFs do not set legally binding standards, they are meant to give information for the guidance of industry, Member States and the public on achievable consumption and emission levels when using specified techniques. The appropriate limit values for any specific case will need to be determined taking into account the objectives of the IPPC Directive and the local considerations.

Some key findings to help users/readers of this document
During the preparation of this document, several important issues were raised and considered by the TWG; a knowledge of these issues may help users/readers of this document.

- due to the complex nature of the sector, it is strongly recomended to read Chapter 5 in conjunction with Chapter 4. To help the user/reader in this subject, cross-references to Chapter 4 have been included in Chapter 5
- many factors influence decisions about whether or not a waste treatment facility should apply a certain process technique or pollution abatement technique. Factors such as the type of treatment and type of waste processed need to be taken into account when using this document at local level
- in addition to the BAT referenced in this chapter, BAT for a waste treatment facility will also contain elements from other IPPC documents and international regulations. In this context, special attention is drawn to the BAT Reference Document on Emissions from Storage, Industrial Cooling Systems, Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector, Waste Incineration and the Reference Document on the General Principles of Monitoring
- a waste treatment installation covered in this document is only a part of the whole waste management chain. Issues occurring upstream and downstream of a waste treatment installation have a huge impact on the installation, consequently influencing their environmental performance
- overall waste management involves many different kinds of treatment operations (chains of operations) which will ultimately lead to recovery or disposal, actions which may be outside of the scope of this BREF. For instance, according to waste hierarchy, operations aiming for recovery prevail over disposal. However, it has been reported that in certain situations this hierachy may not be the best environmental choice especially when the effect on a complete waste management chain (outside of the scope of this document) is taken into account. These considerations, together with non-environmental aspects, can influence the choice of waste treatment applied.

Some aids to understand the remainder of this chapter
In this chapter, the BAT conclusions for the waste treatment sector are set out on two levels. Section **Error! Reference source not found.** deals with generic BAT conclusions, i.e. these are generally applicable to the whole sector. If there are exceptions when the BAT is not applicable in certain circumstances or cases, this issue is mentioned in the BAT conclusion. Section **Error! Reference source not found.** contains more specific BAT conclusions, e.g. those for the various types of specific processes and activities defined in the scope. So, BAT for any specific type of waste treatment facility is the combination of the non-activity specific elements applied to waste treatment (generic or common issues) and the activity specific elements applicable to the particular case and the other BREFs mentioned above. Emission values associated to the use of BAT in this chapter correspond to daily averages.
Due to the huge variation in the different types of wastes that are covered in this document, it is practically impossible to consider all the differences that may be found in the EU. For this reason, wastes are categorised into two types in this chapter. One deals with non-hazardous waste which represents the general basis for BAT for the waste sector. The other type corresponds to more dangerous waste (e.g hazardous waste) where further measures may be included as BAT. *To help the user/reader, BAT related to hazardous waste have been presented in italics.*

Particularly for this document, BAT is described as qualitative and mainly based on current practice. This is due to the lack of information on quantification of environmental performance parameters (e.g. emissions, consumptions) due to the fact that the majority of information provided corresponds to emission limit values applied in certain countries or regions.

5.1. Generic BAT

Environmental management

These are techniques related to the continuous improvement of environmental performance. They provide the framework for ensuring the identification, adoption and adherence to BAT options that nevertheless remain important and can play a role in improving environmental performance of the installation. Indeed, these good house housekeeping/management techniques/tools often prevent emissions.

A number of environmental management techniques are determined as BAT. The scope (e.g. level of detail) and nature of the Environmental Management System (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. BAT is to:

1. implement and adhere to an EMS that incorporates, as appropriate to individual circumstances, the following features (see Section 0).
    a. definition of an environmental policy for the installation by top management (commitment of the top management is regarded as a precondition for a successful application of other features of the EMS)
    b. planning and establishing the necessary procedures
    c. implementation of the procedures, paying particular attention to
        - structure and responsibility
        - training, awareness and competence
        - communication
        - employee involvement
        - documentation
        - efficient process control
        - maintenance programme
        - emergency preparedness and response
        - safeguarding compliance with environmental legislation.
    d. checking performance and taking corrective action, paying particular attention to
        - monitoring and measurement (see also the Reference document on General Principles of Monitoring)
        - corrective and preventive action
        - maintenance of records
        - independent (where practicable) internal auditing in order to determine whether or not the environmental management system conforms to planned arrangements and has been properly implemented and maintained.
    e. review by top management.

Three further features, which can complement the above stepwise, are considered as supporting measures. However, their absence is generally not inconsistent with BAT. These three additional steps are:

f. having the management system and audit procedure examined and validated by an accredited certification body or an external EMS verifier
g. preparation and publication (and possibly external validation) of a regular environmental statement describing all the significant environmental aspects of the installation, allowing for year-by-year comparison against environmental objectives and targets as well as with sector benchmarks as appropriate
h. implementation and adherence to an internationally accepted voluntary system such as EMAS or EN ISO 14001:1996. This voluntary step could give higher credibility to the EMS. In particular EMAS, which embodies all the above-mentioned features, gives higher credibility. However, non-standardised systems can in principle be equally effective provided that they are properly designed and implemented.

Specifically for this industry sector, it is also important to consider the following potential features of the EMS:

i. giving consideration to the environmental impact from the eventual decommissioning of the unit at the stage of designing a new plant
j. giving consideration to the development of cleaner technologies
k. where practicable, sectoral benchmarking on a regular basis, including energy efficiency and energy conservation activities, choice of input materials, emissions to air, discharges to water, consumption of water and generation of waste.

2. ensure the provision of full details of the activities carried out on-site. A good detail of that is contained in the following documentation (see Section 0 and related to BAT number 1.g)
   a. descriptions of the waste treatment methods and procedures in place in the installation
   b. diagrams of the main plant items where they have some environmental relevance, together with process flow diagrams (schematics)
   c. details of the chemical reactions and their reaction kinetics/energy balance
   d. details on the control system philosophy and how the control system incorporates the environmental monitoring information
   e. details on how protection is provided during abnormal operating conditions such as momentary stoppages, start-ups, and shutdowns
   f. an instruction manual
   g. an operational diary (related to BAT number 3)
   h. an annual survey of the activities carried out and the waste treated. The annual survey should also contain a quarterly balance sheet of the waste and residue streams, including the auxiliary materials used for each site (related to BAT number 1.g).

3. have a good housekeeping procedure in place, which will also cover the maintenance procedure, and an adequate training programme, covering the preventive actions that workers need to take on health and safety issues and environmental risks (see Sections 0, 0, 0, 0, 0 and 0)

4. try to have a close relationship with the waste producer/holder in order that the customers sites implement measures to produce the required quality of waste necessary for the waste treatment process to be carried out (see Section 0)

5. have sufficient staff available and on duty with the requisite qualifications at all times. All personnel should undergo specific job training and further education (see Section 0. This is also related to BAT number 3)

Waste IN

To improve the knowledge of the waste IN, BAT is to:

6. have a concrete knowledge of the waste IN. Such knowledge needs to take into account the waste OUT, the treatment to be carried out, the type of waste, the origin of the waste, the procedure under consideration (see BAT number 7 and 8) and the risk (related to waste OUT and the treatment) (see Section 0). Guidance on some of these issues is provided in Sections **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**

7. implement a pre-acceptance procedure containing at least the following items (see Section 0):
   a. tests for the incoming waste with respect to the planned treatment
   b. making sure that all necessary information is received on the nature of the process(es) producing the waste, including the variability of the process. The personnel having to deal with the pre-acceptance procedure need to be able due to his profession and/or experience to deal with all necessary questions relevant for the treatment of the wastes in the WT facility
   c. a system for providing and analysing a representative sample(s) of the waste from the production process producing such waste from the current holder
   d. a system for carefully verifying, if not dealing directly with the waste producer, the information received at the pre-acceptance stage, including the contact details for the waste producer and an appropriate description of the waste regarding its composition and hazardousness
   e. making sure that the waste code according to the European Waste List (EWL) is provided

f. identifying the appropriate treatment for each waste to be received at the installation (see Section 0) by identifying a suitable treatment method for each new waste enquiry and having a clear methodology in place to assess the treatment of waste, that considers the physico-chemical properties of the individual waste and the specifications for the treated waste.

8. implement an acceptance procedure containing at least the following items (see Section 0):
   a. a clear and specified system allowing the operator to accept wastes at the receiving plant only if a defined treatment method and disposal/recovery route for the ouput of the treatment is determined (see pre-acceptance in BAT number 7). Regarding the planning for the acceptance, it needs to be guaranteed that the necessary storage (see Section 0), treatment capacity and dispatch conditions (e.g. acceptance criteria of the output by the other installation) are also respected
   b. measures in place 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
   c. clear and unambiguous criteria for the rejection of wastes and the reporting of all non conformances
   d. a system for identifying the maximum capacity limit of waste that can be stored at the facility (related to BAT number 10.b, 10.c, 27 and 24.f)
   e. visually inspect the waste IN to check compliance with the description received during the pre-acceptance procedure. *For some liquid and hazardous waste, this BAT is not applicable* (see Section 0).

9. implement different sampling procedures for all different incoming waste vessels delivered in bulk and/or containers. These sample procedures may contain the following items (see Section 0):
   a. sampling procedures based on a risk approach. Some elements to consider are the type of waste (e.g. *hazardous* or non-hazardous) and the knowledge of the customer (e.g. waste producer)
   b. check on the relevant physico-chemical parameters. The relevant parameters are related to the knowledge of the waste needed in each case (see BAT number 6)
   c. registration of all waste materials
   d. have different sampling procedures for bulk (liquid and solids), large and small containers and laboratory smalls. The number of samples taken should increase with the number of containers. In extreme situations, small containers must all be checked against the accompanying paperwork. The procedure should contain a system for recording the number of samples and degree of consolidation
   e. details of the sampling of wastes in drums within designated storage, e.g. the time-scale after receipt
   f. sample prior to acceptance
   g. maintenance of a record at the installation of the sampling regime for each load, together with a record of the justification for the selection of each option
   h. a system for determining and recording:
      - a suitable location for the sampling points
      - the capacity of the vessel sampled (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.
   i. a system to ensure that the waste samples are analysed (see Section 0)
   j. in the case of cold ambient temperatures, a temporary storage may be needed in order to allow sampling after defrosting. This may affect the applicability of some of the above items in this BAT (see Section 0).

10. have a reception facility covering at least the following issues (see Section 0):
   a. have a laboratory to analyse all the samples at the speed required by BAT. Typically this requires having a robust quality assurance system, quality control methods and maintaining suitable records for storing the analyses results. *Particularly for hazardous wastes, this often means that the laboratory needs to be on-site*
   b. have a dedicated quarantine waste storage area as well as written procedures to manage non-accepted waste. If the inspection or analysis indicates that the wastes fail to meet the acceptance

criteria (including, e.g. damaged, corroded or unlabelled drums) then the wastes can be temporarily stored there safely. Such storage and procedures should be designed and managed to promote the rapid management (typically a matter of days or less) to find a solution for that waste

c. 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. The procedure should include all measures as required by the permit 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
d. move waste to the storage area only after acceptance of the waste (related to BAT number 8)
e. mark the inspection, unloading and sampling areas on a site plan
f. have a sealed drainage system (related to BAT number 63)
g. a system 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 (related to BAT number 5)
h. the application of a waste tracking system unique identifier (label/code) to each container at this stage. The identifier will contain at least the date of arrival on-site and the waste code (related to BAT number 9 and 12).

Waste OUT

To improve the knowledge of the waste OUT, BAT is to:

11. analyse the waste OUT according to the relevant parameters important for the receiving facility (e.g. landfill, incinerator) (see Section 0)

Management systems

BAT is to:

12. have a system in place to guarantee the traceability of waste treatment. Different procedures may be needed to take into account the physico-chemical properties of the waste (e.g. liquid, solid), type of WT process (e.g. continuous, batch) as well as the changes that may occur to the physico-chemical properties of the wastes when the WT is carried out. A good traceability system contains the following items (see Section 0):
    a. documenting the treatments by flow charts and mass balances (see Section 0 and this is also related to BAT number 2.a)
    b. carrying out data traceability through several operational steps (e.g pre-acceptance/acceptance/storage/treatment/dispatch). Records can be made and kept up-to-date on an ongoing basis to reflect deliveries, on-site treatment and dispatches. Records are typically held for a minimum of six months after the waste has been dispatched
    c. recording and referencing 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 to enable 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
    d. having 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 details on where the waste is physically located in relation to a site plan, at which point in the designated disposal route the waste is currently positioned
    e. only moving drums and other mobile containers between different locations (or loaded for removal off site) under instructions from the appropriate manager, ensuring that the waste tracking system is amended to record these changes (see Section 0).

13. have and apply mixing/blending rules oriented to restrict the types of wastes that can be mixed/blended together in order to avoid increasing pollution emission of down-stream waste treatments. These rules

need to consider the type of waste (e.g. *hazardous,* non-hazardous), waste treatment to be applied as well as the following steps that will be carried out to the waste OUT (see Section 4.1.5)

14. have a segregation and compatibility procedure in place (see Section 4.1.5 and this is also related to BAT number 13 and 24.c), including:
    a. keeping records of the testing, including any reaction giving rise to safety parameters (increase in temperature, generation of gases or raising of pressure); a record of the operating parameters (viscosity change and separation or precipitation of solids) and any other relevant parameters, such as generation of odours (see Sections 0 and 0)
    b. packing containers of chemicals into separate drums based on their hazard classification. Chemicals which are incompatible (e.g. oxidisers and flammable liquids) should not be stored in the same drum (see Section 0).

15. have an approach for improving waste treatment efficiency. This typically includes the finding of suitable indicators to report WT efficiency and a monitoring programme (see Section 0 and this is also related to BAT number 1)

16. produce a structured accident management plan (see Section 4.1.7)

17. have and properly use an incident diary (see Section 4.1.7 and related to BAT number 1 and to quality management system)
18. have a noise and vibration management plant in place as part of the EMS (see Section 4.1.8 and this is also related to BAT number 1). For some WT installations, noise and vibration may not be an environmental problem

19. consider any future decommissioning at the design stage. For existing installations and where decommissioning problems are identified, put a programme to minimise these problems in place (see Section 4.1.9 and this is also related to BAT number 1.i).

Utilities and raw material management

BAT is to:

20. provide a breakdown of the energy consumption and generation (including exporting) by the type of source (i.e. electricity, gas, liquid conventional fuels, solid conventional fuels and waste) (see Section 0 and related to BAT number 1.k). This involves:
    a. reporting the energy consumption information in terms of delivered energy
    b. reporting the energy exported from the installation
    c. providing energy flow information (for example, diagrams or energy balances) showing how the energy is used throughout the process.

21. continuously increase the energy efficiency of the installation, by (see Section 0):
    a. developing an energy efficiency plan
    b. 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
    c. 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) (related to BAT number 1.k and 20).

22. carry out an internal benchmarking (e.g. on an annual basis) of raw materials consumption (related to BAT number 1.k). Some applicability limitations have been identified and these are mentioned in Section 0

23. explore the options for the use of waste as a raw material for the treatment of other wastes (see Section 0). If waste is used to treat other wastes, then to have a system in place to guarantee that the waste supply is available. If this cannot be guaranteed, a secondary treatment or other raw materials should be in place in order to avoid any unnecessary waiting treatment time (see Section 0)

Storage and handling

BAT is to:

24. apply the following techniques related to storage (see Section 0):
    a. locating storage areas:
        - away from watercourses and sensitive perimeters, and
        - in such a way so as to eliminate or minimise the double handling of wastes within the installation
    b. ensuring that the storage area drainage infrastructure can contain all possible contaminated run-off and that drainage from incompatible wastes cannot come into contact with each other
    c. 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 removed to the appropriate storage area
    d. handling odorous materials in fully enclosed or suitably abated vessels and storing them in enclosed buildings connected to abatement
    e. ensuring that all connections between the vessels are capable of being closed via valves. Overflow pipes need to be directed to a contained drainage system (i.e. the relevant bunded area or another vessel)
    f. having measures available to prevent the building up of sludges higher than a certain level and the emergence of foams that may affect such measures in liquid tanks, e.g. by regularly controlling the tanks, sucking out the sludges for appropriate further treatment and using anti-foaming agents
    g. equipping tanks and vessels with suitable abatement systems when volatile emissions may be generated, together with level meters and alarms. These systems need to be sufficiently robust (able to work if sludge and foam is present) and regularly maintained
    h. storing organic waste liquid with a low flashpoint under a nitrogen atmosphere to keep it inertised. Each storage tank is put in a waterproof retention area. Gas effluents are collected and treated.

25. separately bund the liquid decanting and storage areas using bunds which are impermeable and resistant to the stored materials (see Section 0)

26. apply the following techniques concerning tank and process pipework labelling (see Section 0):
    a. clearly labelling all vessels with regard to their contents and capacity, and applying an unique identifier. Tanks need to have an appropriately labelled system depending on their use and contents
    b. ensuring that the label differentiates between waste water and process water, combustible liquid and combustible vapour and the direction of flow (i.e. in or outflow)
    c. keeping records 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 limits.

27. take measures to avoid problems that may be generated from the storage/accumulation of waste. This may conflict with BAT number 23 when waste is used as a reactant (see Section 0)

28. apply the following techniques when handling waste (see Section 0):
    a. having systems and procedures in place to ensure that wastes are transferred to the appropriate storage safely
    b. having in place a management system for the loading and unloading of waste in the installation, which also takes into consideration any risks that these activities may incur. Some options for this include ticketing systems, supervision by site staff, keys or colour-coded points/hoses or fittings of a specific size
    c. ensuring that a qualified person attends the waste holder site to check the laboratory smalls, the old original waste, waste from an unclear origin or undefined waste (especially if drummed), to classify the substances accordingly and to package into specific containers. In some cases, the individual packages may need to be protected from mechanical damage in the drum with fillers adapted to the packaged waste properties
    d. ensuring that damaged hoses, valves and connections are not used
    e. collecting the exhaust gas from vessels and tanks when handling liquid waste

f. unloading solids and sludge in closed areas which are fitted with extractive vent systems linked to abatement equipment when the handled waste can potentially generate emission to air (e.g. odours, dust, VOCs) (see Section 0)
g. using a system to ensure the bulking of different batches only takes place with compatibility testing (see Section 0 and 4.1.5 and this is also related to BAT number 13, 14 and 30).

29. ensure that the bulking/mixing to or from packaged waste only takes place under instruction and supervision and is carried out by trained personnel. For certain types of wastes, such a bulking/mixing needs to be carried out under local exhaust ventilation (see Section 0)
30. ensure that chemical incompatibilities guide the segregation required during storage (see Section 0 and 0 and this is also related to BAT number 14)

31. apply the following techniques when containerised wastes are handled (see Section 0):
    a. storing of containerised wastes under cover. This can also be applied to any container that is held in storage pending sampling and emptying. Some exceptions on the applicability of this technique related to containers or waste not affected by ambient conditions (e.g. sunlight, temperature, water) have been identified (see Section 0). Covered areas need to have adequate provision for ventilation
    b. maintaining the availability and access to storage areas for containers holding substances that are known to be sensitive to heat, light and water, under cover and protected from heat and direct sunlight.

Other common techniques not mentioned above

BAT is to:

32. perform crushing, shredding and sieving operations in areas fitted with extractive vent systems linked to abatement equipment (see Section 0) when handling materials that can generate emission to air (e.g. odours, dust, VOCs)

33. perform crushing/shredding operations (see Sections 0 and 4.3) under full encapsulation and under an inert atmosphere for drums/containers containing flammable or highly volatile substances. This will avoid ignition. The inert atmosphere is to be abated

34. perform washing processes considering (see Section 0):
    a. identifying the washed components that may be present in the items to be washed (e.g. solvents)
    b. transfering washings to appropriate storage and then treating them in the same way as the waste from which they were derived
    c. using treated waste water from the WT plant for washing instead of fresh water. The resultant waste water can then be treated in the WWTP or re-used in the installation.

Air emission treatments

To prevent or control the emissions mainly of dust, odours and VOC and some inorganic compounds, BAT is to:

35. restrict the use of open topped tanks, vessels and pits by:
    a. not allowing direct venting or discharges to air by linking all the vents to suitable abatement systems when storing materials that can generate emissions to the air (e.g. odours, dust, VOCs) (see Section 0)
    b. keeping the waste or raw materials under cover or in waterproof packaging (see Section 0 and this is also related to BAT number 31.a)
    c. connecting the head space above the settlement tanks (e.g. where oil treatment is a pretreatment process within a chemical treatment plant) to the overall site exhaust and scrubber units (see Section 0).

36. use an enclosed system with extraction, or under depression, to a suitable abatement plant. This technique is especially relevant to processes which involve the transfer of volatile liquids, including during tanker charging/discharging (see Section 4.3.1)

37. apply a suitably sized extraction system which can cover the holding tanks, pretreatment areas, storage tanks, mixing/reaction tanks and the filter press areas, or to have in place a separate system to treat the vent gases from specific tanks (for example, activated carbon filters from tanks holding waste contaminated with solvents) (see Section 4.3.1)

38. correctly operate and maintain the abatement equipment, including the handling and treatment/disposal of spent scrubber media (see Section 4.3.11)
39. have a scrubber system in place for the major inorganic gaseous releases from those unit operations which have a point discharge for process emissions. Install a secondary scrubber unit to certain pretreatment systems if the discharge is incompatible, or too concentrated for the main scrubbers (see Section 4.3.11)

40. have leak detection and repair procedures in place in installations a) handling a large number of piping components and storage and b) compounds that may leak easily and create an environmental problem (e.g. fugitive emissions, soil contamination) (see Section 4.3.2). This may be seen as an element of the EMS (see BAT number 1)

41. reduce air emission to the following levels

Air parameter	***Emission levels associated to the use of BAT (mg/Nm^3)***
VOC	*7 – 20*[1]
PM	*5 – 20*

[1] For low VOC loads, the higher end of the range can be extended to 50

by using a suitable combination of preventive and/or abatement techniques (see Section 4.3). The techniques mentioned above in the BAT 'Air emission treatments' section (BAT numbers 35 – 41) also contribute to achieve these values

Waste water management

BAT is to:

42. reduce the water use and the contamination of water by (see Sections 0 and 4.4.1):
    a. applying site waterproofing and storage retention methods
    b. carrying out regular checks of the tanks and pits especially when they are underground
    c. applying separated water drainage according to the pollution load (roof water, road water, process water)
    d. applying a security collection basin
    e. performing regular water audits, with the aim of reducing water consumption and preventing water contamination
    f. segregating process water from rainwater (see Section 4.4.2 and this is also related to BAT number 46).

43. have procedures in place to ensure that the effluent specification is suitable for the on-site effluent treatment system or discharge (see Section 4.4.1)

44. avoid the effluent by-passing the treatment plant systems (see Section 4.4.1)

45. have in place and operate an enclosure system whereby rainwater falling on the processing areas is collected along with tanker washings, occasional spillages, drum washings, etc. and returned to the processing plant or collected in a combined interceptor (see Section 4.4.1)

46. segregrate the water collecting systems for potentially more contaminated waters from less contaminated water (see Section 4.4.2)

47. have a full concrete base in the whole treatment area, that falls to internal site drainage systems which lead to storage tanks or to interceptors that can collect rainwater and any spillage. Interceptors with an

overflow to sewer usually need automatic monitoring systems, such as pH checks, which can shut down the overflow (see Section 0 and this is also related to BAT number 63),

48. collect the rainwater in a special basin for checking, treatment if contaminated and further use (see Section 4.4.1)
49. maximise the re-use of treated waste waters and use of rainwater in the installation (see Section 4.4.1)

50. conduct daily checks on the effluent management system and to maintain a log of all checks carried out, by having a system for monitoring the effluent discharge and sludge quality in place (see Section 4.4.1)

51. firstly identify waste waters that may contain hazardous compounds (e.g. adsorbable organically bound halogens (AOX); cyanides; sulphides; aromatic compounds; benzene or hydrocarbons (dissolved, emulsified or undissolved); and metals, such as mercury, cadmium, lead, copper, nickel, chromium, arsenic and zinc) (see Section 4.4.2). Secondly, segregate the previously identified waste water streams on-site and thirdly, specifically treat waste water on-site or off-site.

52. ultimately after the application of BAT number 42, select and carry out the appropriate treatment technique for each type of waste water (see Section 4.4.1)

53. implement measures to increase the reliability with which the required control and abatement performance can be carried out (for example, optimising the precipitation of metals) (see Section 4.4.1)

54. identify the main chemical constituents of the treated effluent (including the make-up of the COD) and to then make an informed assessment of the fate of these chemicals in the environment (see Section 4.4.1 and their applicability restrictions identified)

55. only discharge the waste water from its storage after the conclusion of all the treatment measures and a subsequent final inspection (see Section 4.4.1)

56. achieve the following water emission values before discharge

Water parameter	Emission values associated with the use of BAT (ppm)
COD	20 – 120
BOD	2 – 20
Heavy metals (Cr, Cu, Ni, Pb, Zn)	0.1 – 1
Highly toxic heavy metals:	
As	<0.1
Hg	0.01 – 0.05
Cd	<0.1 – 0.2
Cr(VI)	<0.1 – 0.4

by applying a suitable combination of techniques mentioned in Sections **Error! Reference source not found.** and 4.4. The techniques mentioned above in this section on 'waste water management' (BAT number 42 – 55) also contribute to reach these values.

Management of the process generated residues

BAT is to:

57. have a residue management plan (see Section 4.5.1) as part of the EMS including:
    a. basic housekeeping techniques (related to BAT number 3)
    b. internal benchmarking techniques (see Section 0 and this is also related to BAT numbers 1.k and 22).

58. maximise the use of re-usable packaging (drums, containers, IBCs, palettes, etc.) (see Section 4.5.1)

59. re-use drums when they are in a good working state. In other cases, they are to be sent for appropriate treatment (see Section 4.5.1)

60. keep 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 (see Section 4.5.3 and this is also related to BAT number 27)

61. re-use the waste from one activity/treatment possibly as a feedstock for another (see Section 0 and this is also related to BAT number 23)

Soil contamination

To prevent soil contamination, BAT is to:

62. provide and then maintain the surfaces of operational areas, including applying measures to prevent or quickly clear away leaks and spillages, and ensuring that maintenance of drainage systems and other subsurface structures is carried out (see Section 4.5.2)

63. utilise an impermeable base and internal site drainage (see Section 0, 4.4.1 and 4.5.2)

64. reduce the installation site and minimise the use of underground vessels and pipework (see Section 4.5.2 and this is also related to BAT number 10.f, 25, and 40)

6. Emerging techniques

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. This chapter contains those techniques that may appear in the near future and that may be applicable to the waste treatment sector.

[5, Concawe, 1996], [36, Viscolube, 2002], [30, Eklund, et al., 1997], [41, UK, 1991], [81, VDI and Dechema, 2002], [90, Rogut, 2003], [101, Greenpeace, 1998], [122, Eucopro, 2003], [132, UBA, 2003], [141, Magistrelli, et al., 2002], [150, TWG, 2004], [152, TWG, 2004], [154, UNEP, 2004]

On-line analysis

Description
The technique of the online-analysis is one of the latest developments on the field of analysis and quality assurance. It can be used for all applications in the field of preparation of solid recovered fuels.

On-line analysis is used for crushed and/or for non-crushed materials with automatically elimination of materials which do not comply with the quality criteria for e.g solid recovered fuels - especially when the chlorine- and/or bromine values are exceeded.

The mode of function is based on a new X-ray fluorescence-analysis with high speed analysis, so that a large quantity of crushed or not crushed materials (it depends on technical performance and determination) per hour can be analysed and/or detected and it can be automatically eliminate by overdraw 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 electronically signal (digital or analogue) follows. There upon controlled through a software and/or electronics-unit the objectionable material is automatically (mechanically, hydraulically, pneumatically, electrostatically or magnetically 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 a additional control and quality assurance for the material input, also a handheld-unit can be used. The handheld-unit is also based on the X-ray fluorescence-method and it can ecspecially used for the analyse and/or detection from chlorine, bromine and heavymetals.

Achieved environmental benefits
Following elements can be analysed and detected 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, Re.

Cross-media effects

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.

Applicability
This tool seems to be now the fastest and exact handheld analysis tool for practically all recycling metal – plastic – oldwood – glass – ground – waste – mud – non-ferrous metal.

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.