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Review of BATs and BEPs for the

Hazardous Waste Treatment Sector

in the Mediterranean Region

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Regional Activity Centre for Cleaner Production (RAC/CP)
Mediterranean Action Plan

UNEP

MAP

Regional Activity Centre for Cleaner Production

Ministry of the Environment Spain

Generalitat de Catalunya
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Please inform us if any point in the study can be improved or if any inaccuracy is found.

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For additional copies or for further information, please contact:

Cleaner Production Regional Activity Centre for (CP/RAC)

Dr. Roux, 80
08017 Barcelona (Spain)
Tel. +34 93 553 87 90 - Fax. +34 93 553 87 95
E-mail cleanpro@cprac.org
Website: http://www.cprac.org

INDEX

INDEX OF TABLES

EXECUTIVE SUMMARY

Introduction

The Plan for the Reduction by 20% by 2010 of the Generation of Hazardous Wastes from Industrial Installations in the Mediterranean Region [7], drawn up within the framework of the Strategic Action Programme (SAP), highlighted the hazardous waste management sector as one of the main industrial sectors generating hazardous waste. In this framework, this review of Best Available Techniques (BATs) and Best Environmental Practices (BEPs) for hazardous waste treatment in the Mediterranean Region aims to provide a reference document to be used by the MAP countries to improve their hazardous waste treatment practices.

The types of hazardous waste treatments considered in this review have been classified into four main categories: treatment, thermal treatment, use of hazardous waste in industrial processes and landfill.

Methodology

The related information on environmental techniques and practices for the hazardous waste treatment sector has been mainly selected from information sources which are focused on the activities and processes currently existing in the European Union. The feasibility of application of such techniques and practices in the Mediterranean hazardous waste treatment sector has been assessed and further studies have been recommended where necessary.

Although the terms “best available technique” and “best environmental practice” have different definitions in Annex IV of the Mediterranean Land-Based Sources Protocol, within the framework of the European Union the term “best available technique” is considered to be broad enough to embrace the concept of “best environmental practice”.

Techniques for the hazardous waste treatment sector

This chapter has been based on the Reference Document on Best Available Techniques (BREF) for Waste Treatment Industries [2]. Environmental techniques and practices have been reviewed for each of the related technique categories: generic techniques, techniques for specific types of waste treatments and techniques for emissions abatement. An assessment of the applicability to the Mediterranean hazardous waste treatment sector has been made. Those techniques or practices considered as Best Available Techniques (BATs) by the BREF have been selected for their environmental benefits and economic assessment.

Techniques for the hazardous waste incineration sector

This chapter has been mainly extracted from the Reference Document on Best Available Techniques for Waste Incineration [3]. It considers the most commonly applied thermal treatment of incineration, but also includes information on gasification and pyrolysis. Techniques and practices considered have been divided according to the main stages of the incineration process. Of the techniques described, those considered as Best Available Techniques (BATs) by the BREF have been organised into tables by section. For each of them, a brief description, an assessment of their applicability to Mediterranean hazardous waste incineration have been included, along with the environmental benefits and an economic assessment.

The utilisation of hazardous waste in industrial processes

This chapter is mainly focused on the use of hazardous waste as secondary fuels. Related information has been gathered principally from two sources: Refuse Derived Fuel, Current Practices and Perspectives -European Commission- Environment Directorate-General [1] and the Reference Document of Best Available Techniques in the Cement and Lime Manufacturing Industries [6]. The main industrial waste used as substitute or secondary fuel and the related industrial processes and technologies are described. Moreover, environmental and economic benefits and an assessment of their applicability to Mediterranean industrial processes have also been taken into account.

Landfill

Criteria on design, operation and closure considered as Best Available Techniques (BATs) have been collected in this chapter. The main information sources were: BAT Guidance Notes for the Waste Sector: Landfill Activities –EPA- [4] and Preparation of a Set of Tools for the Selection, Design and Operation of Hazardous Waste Landfills in Hyper-dry Areas - Basel Convention Regional Centre for Training and Technology Transfer for the Arab States in Cairo- [5]. Related environmental techniques and practices have been classified according to the stages of a landfill installation: management elements for hazardous waste landfill; landfill design; landfills in operation and landfill closure. Full applicability to the Mediterranean Region has been concluded.

Future sector developments

Techniques that may appear in the near future have been described. Information was only available for waste treatment and incineration.

Conclusions and recommendations

Techniques and practices related to the design of the installation and the application of technologies affecting the operating processes are feasible if the installation is still at the project stage. The criteria applied in the design of a landfill and the process design of an incineration facility are representative examples.

The improvement of the Mediterranean hazardous waste treatment sector, in particular existing installations, does not necessarily imply investment in new technologies; the appropriate implementation of management tools and good housekeeping practices in the installation is likely to provide significant environmental benefits at a reasonable cost at the early stages.

Special attention should be paid to techniques for emissions abatement: wastewater treatment, air emissions abatement and residue management with the aim of ensuring compliance with legal requirements (e.g. emission limit values) set by the country and the maximum reduction of emissions. Monitoring and control systems support these types of techniques.

Nevertheless, recommendations addressed to the decision makers at the project stage of a new hazardous waste treatment facility are based on the knowledge and analysis of:

- The characteristics and amounts of the hazardous waste to be treated.
- The waste management hierarchy: reduce, reuse, recycle, energy recovery and, as the last resort, disposal.
- The site and its environment.
- The desired outputs of the activity.
- The economic aspects.
- The legal requirements in the Mediterranean country (e.g. emission limit values).

1. INTRODUCTION

1.1. BACKGROUND

The Strategic Action Programme (SAP) aims to facilitate the implementation of the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (LBS Protocol) by the MAP countries. It establishes timetables for the prevention, reduction, control and/or elimination of impacts on the marine environment from land-based activities, including hazardous waste.

Within the framework of the Strategic Action Programme (SAP), the Plan for the Reduction by 20% by 2010 of the Generation of Hazardous Wastes from Industrial Installations for the Mediterranean Region [7] was produced by the RAC/CP in collaboration with Enviros Spain. According to this Plan, the hazardous waste management sector was highlighted as one of the main industrial sectors generating hazardous waste. A total generation of 20 million tonnes of hazardous waste was estimated within MAP countries for 2002.

In this context, the RAC/CP prepared the present review on Best Available Techniques (BATs) and Best Environmental Practices (BEPs) for hazardous waste treatment in the Mediterranean Region, in order to provide a reference document to be used by the MAP countries to improve their hazardous waste treatment practices.

1.2. DEFINITIONS

In Annex IV of the Mediterranean Land-Based Sources Protocol, criteria have been developed for the definition of best available techniques and best environmental practices:

The term "best available techniques" means the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste. In determining whether a set of processes, facilities and methods of operation constitute the best available techniques in general or individual cases, special consideration shall be given to:

a) comparable processes, facilities or methods of operation which have recently been successfully tried out;

b) technological advances and changes in scientific knowledge and understanding;

c) the economic feasibility of such techniques;

d) time limits for installation in both new and existing plants;

e) the nature and volume of the discharges and emissions concerned.

The term "best environmental practice" means the application of the most appropriate combination of environmental control measures and strategies. In making a selection for individual cases, at least the following graduated range of measures should be considered:

a) the provision of information and education to the public and to users about the environmental consequences of choice of particular activities and choice of products, their use and ultimate disposal;

b) the development and application of codes of good environmental practice which cover all aspects of the activity in the product's life;

c) the mandatory application of labels informing users of environmental risks related to a product, its use and ultimate disposal;

d) saving resources, including energy;

e) Making collection and disposal systems available to the public;

f) avoiding the use of hazardous substances or products and the generation of hazardous waste;

g) recycling, recovery and reuse;

h) the application of economic instruments to activities, products or groups of products;

i) establishing a system of licensing, involving a range of restrictions or a ban.

On the other hand, the term "best available techniques" is defined in Article 2(11) of Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC) as "the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole".

Article 2(11) goes on to clarify further this definition as follows:

- "techniques" shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
- "available" techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;
- "best" shall mean most effective in achieving a high general level of protection of the environment as a whole.

In contrast, the term "best environmental practice" has not been defined within the framework of the European Union; however, it should be understood that the definition of "techniques" is broad enough to embrace the concept of "practices".

1.3. OBJECT AND SCOPE

This review has the following main objectives:

a) to identify information on the best available techniques and best environmental practices related to the different types of hazardous waste treatments;

b) to integrate the available information to produce a reference document on BATs and BEPs for the different options of hazardous waste treatment for the Mediterranean Region;

c) to provide specific considerations on the use of BATs and BEPs in the hazardous waste treatment sector for the Mediterranean countries.

The types of hazardous waste treatments considered in this review have been classified in four main categories: treatment, thermal treatment, use of hazardous waste in industrial processes and landfill.

As in the abovementioned Plan for the Reduction by 20% by 2010 of the Generation of Hazardous Waste from Industrial Installations in the Mediterranean Region [7], the scope of the study comprises countries within the Mediterranean Action Plan (MAP): Albania, Algeria, Bosnia & Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Morocco, Palestine, Serbia & Montenegro, Slovenia, Spain, Syria, Tunisia and Turkey. In this report, the term "Mediterranean Region" refers to the MAP countries.

2. THE HAZARDOUS WASTE TREATMENT SECTOR

The Plan for the Reduction by 20% by 2010 of the Generation of Hazardous Wastes from Industrial Installations in the Mediterranean Region [7], produced within the framework of the Strategic Action Programme (SAP), highlighted the hazardous waste management sector as one of the main industrial sectors generating hazardous waste. Within this framework, this review aims to serve as a reference document on environmental techniques and practices applicable to the hazardous waste treatment sector in the Mediterranean Region.

The structure of the document has been divided into four chapters according to the following classification of hazardous waste management practices:

1. **Hazardous waste treatment**, including installations dealing with treatments resulting in output either for (material) recovery, use as fuel or disposal.

2. **Hazardous waste incineration**, covering waste incineration and some thermal treatments such as pyrolysis or gasification.

3. **Use of hazardous waste in industrial processes**, covering practices of use of refuse derived fuel in industrial processes (co-burning or processes where heat is required).

4. **Landfill**, covering deposit into or onto land.

Each chapter has also been divided into sections according to the characteristics of each category and the information available.

1. **Hazardous waste treatment:** this chapter has been extracted mainly from the Reference Document on Best Available Techniques (BREF)[1] on Waste Treatments Industries [2]. Due to its complexity and heterogeneity, it has been divided into the following categories:

- Generic techniques.
  - Techniques for specific types of waste treatments:
    - Biological treatments.
    - Physicochemical treatments.
    - Treatments applied to exchange waste in order to enable the recycling/regeneration of materials.
    - Treatments applied to turn a waste into a material that can be used as fuel.
  - Techniques for pollution abatement.

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[1] A BREF is the product of an exchange of information organised by the European IPPC Bureau based on the Directive 96/61/EC (the IPPC Directive) and carried out with a dedicated Technical Working Group (TWG) constituted for the purpose. The IPPC Directive lays down a framework requiring Member States to issue operating permits for certain installations carrying on industrial activities described in its Annex 1. These permits must contain conditions based on best available techniques (BAT), to achieve a high level of protection of the environment as a whole.

From the reported techniques and practices, those selected as Best Available Techniques (BATs)[2] by the BREF have been extracted into tables by category. It should be mentioned that for each of them, a brief description, an assessment of their applicability to the Mediterranean hazardous waste treatment sector, the environmental benefits identified and an economic assessment have been included. The original numbering of BATs has been maintained from the BREF throughout this document to facilitate their traceability with respect to the source document.

2. **Hazardous waste incineration:** this chapter has been mainly extracted from the Reference Document on Best Available Techniques for Waste Incineration [3]. It considers the most commonly applied thermal treatment of incineration, but also includes information on gasification and pyrolysis. Techniques and practices considered have been divided according to the main stages of the incineration process:

    - Generic techniques.
    - The thermal treatment stage.
    - The energy recovery stage.
    - Steam generators and quench cooling for hazardous waste incinerators.
    - Applied flue-gas treatment (FGT) and control systems.
    - Wastewater treatment and control techniques.
    - Solid residue treatment and control techniques.
    - Monitoring and control techniques.

Of the described techniques, those considered as Best Available Techniques (BATs) by the BREF have been extracted into tables by section. For each of them, a brief description, an assessment of their applicability to Mediterranean hazardous waste incineration, the environmental benefits and an economic assessment have been included. The original numbering of BATs has been maintained from the BREF along this document to facilitate their traceability with respect to the source document, although in some sections numbers may not be successive.

3. The **utilisation of hazardous waste in industrial processes** is focused mainly on the use of hazardous waste as secondary fuel. Related information has been mainly gathered from two sources: Refuse Derived Fuel, Current Practice and Perspectives -European Commission-Environment Directorate -General- [1] and the Reference Document of Best Available Techniques in the Cement and Lime Manufacturing Industries [6]. The main industrial waste used as substitute or secondary fuels and the related industrial processes and technologies are described. Moreover, environmental and economic benefits and an assessment of the applicability to Mediterranean industrial processes have also been taken into account.

    - Utilisation of secondary fuel.
    - Industrial sectors using hazardous waste.
    - Technologies.
    - Environmental assessment.
    - Economic assessment.

4. **Landfill** has also been considered as a type of hazardous waste treatment, and therefore criteria on landfill design, operation and closure considered as Best Available Techniques (BATs) have been collected in this chapter. The main information sources were: BAT Guidance Notes for the Waste Sector: Landfill Activities –EPA- [4] and Preparation of a Set of Tools for the selection, Design and Operation of Hazardous Waste Landfills in Hyper-dry Areas - Basel Convention

[2] The BREF does not consider the BEP category; however, the term BAT includes both techniques and practices.

Regional Centre for Training and Technology Transfer for the Arab States in Cairo - [5]. Related techniques and practices have been classified according to the stages of a landfill installation:

- Management elements for hazardous waste landfill.
- Landfill design.
- Landfills in operation.
- Landfill closure.

3. TECHNIQUES FOR HAZARDOUS WASTE TREATMENT

This chapter includes techniques and practices concerning hazardous waste treatments which are considered to provide a high level of protection of the environment.

The following sections have been classified according to the categories of techniques established by the BREF [2]. The main related techniques are described and selected BATs are summarised at the end of each section. The description of each BAT includes its environmental benefits and an economic assessment. In addition, their applicability to the hazardous waste treatment sector in the Mediterranean Region has been assessed.

In general, available information on BATs regarding waste treatments does not distinguish between those techniques that are particularly related to hazardous waste, in particular generic techniques, as these are generally applicable to the treatment process regardless of the hazardousness of waste. However, any specific reference to hazardous waste has been stressed throughout the whole review.

3.1. GENERIC TECHNIQUES

Generic techniques are 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). They consider the pre-treatments/activities or post-treatments/activities commonly used in the waste treatment sector. For example, they include techniques used for repackaging, crushing, sieving, drying, blending, homogenisation, scrapping, fluidification, washing, baling, regrouping and storage, transportation, reception and traceability control, as well as management techniques used in waste treatment installations.

3.1.1. Environmental management

Generic techniques and practices related to environmental management principally consist of the implementation of good housekeeping/management techniques/tools and Environmental Management Systems (EMS). An EMS is a tool that operators can use to address design, construction, maintenance, operation and decommissioning issues in a systematic, demonstrable way, preventing emissions and playing a part in improving the environmental performance of the installation.

As these techniques are mainly based on management tools, they are applicable to all sites and types of industrial installations. Hence, considering that their scope and type should be related to the nature, scale and complexity of the installation and the range of environmental impacts it may have, their application to all hazardous waste treatment facilities within the Mediterranean Region is feasible.

The BATs related to environmental management are presented in table 3.1.

Table 3.1: BATs for environmental management

BAT	Environmental benefits	Economics
1.- Implement and adhere to an Environmental Management System (EMS).	The maintenance of and compliance with clear operating procedures ensure that the installation's permit conditions and other environmental targets and objectives are met at all times, specifically by considering environmental impact, cleaner technologies and sectoral benchmarking.	Difficulties for determining the costs and economic benefits.
2.- Ensure the provision of details of the activities carried out on-site.	This helps assess operators' proposals and in particular the opportunities for further improvements.	NA.[3]
3.- Good housekeeping procedure and adequate training programme: a) Sampling. b) Reception facilities. c) Management techniques. d) Utilisation of qualified people. e) Handling activities related to transfers into or from drums/containers. f) Techniques to improve the maintenance of storage.	a) A good knowledge of waste prevents problems during treatment; b) Identification of source, composition and hazardousness of waste prevents acceptance without written information. c) Improvement of environmental awareness. d) Improvement of the environmental performance of the facility. e) Avoidance of fugitive emissions and prevention of releases and reactions. f) Avoidance of fugitive emissions.	Variable costs (for sampling and reception facilities see BATs 9 and 10).
4.- Close relationship with the waste producer/holder.	Trying to influence the waste producer and holder can help to avoid the need to use very expensive solutions for the treatment of waste.	This decreases the cost of waste treatment.
5.- Sufficient staff available and on duty with the requisite qualifications at all times. (See also BAT no. 3)	Environmental protection depends on the good management of the installation and as a result on the good qualification of its workers.	Qualified people are more expensive. Training programmes also incur some costs.

[3] Not available

3.1.2. Knowledge of waste input

Knowledge of waste input is necessary to identify and analyse which type of control can be carried out during the waste treatment process. The final goal is to have a good characterisation of waste types to optimise the effectiveness of the process and to avoid any possible leaks. Waste input controls can be applied from the pre-acceptance and arrival of the waste at the treatment site, to the final dispatch of the waste. The following procedures are included:

- Waste composition characterisation.
- Pre-acceptance procedure.
- Acceptance procedures.
- Sampling.
- Reception facilities.

It is feasible to apply these types of techniques in the Mediterranean countries although the degree of implementation will depend on the resources of each installation. Sampling and analysis procedures usually require significant investment in analytical equipment and operational costs. They are applicable to all types of waste, but are especially recommended for hazardous waste. Table 3.2 shows the related BATs.

Table 3.2: BATs for knowledge of the waste input

BAT	Environmental benefits	Economics
6.- Have a concrete knowledge of the waste IN, e.g.: • Laboratory activities. • Selection of waste oils to be re-refined. • Selection of feedstock for biological systems.	An on-site laboratory provides assurance that the necessary process input controls are in place and a consistent waste OUT is generated. Improvement of the feedstock quality can enhance the environmental performance of an installation as well as the quality of the product. Avoids toxic compounds entering biological systems.	NA.
7.- Implement a pre-acceptance procedure.	This helps operators identify and accept only waste suitable for the specific treatment.	Extra administration cost (packaging, labelling).
8.- Implement an acceptance procedure.	This confirms the characteristics of pre-accepted waste and prevents unsuitable waste being accepted. Moreover, it also prevents waste being rejected and being sent back.	Waste characterisation and analysis costs are high.
9.- Implement different sampling procedures. (See also BAT no. 3)	A good knowledge of waste prevents problems during treatment.	Specific laboratory equipment is necessary for sampling.
10.- Have a reception facility. (See also BAT no. 3)	Identification of source, composition and hazard of waste prevents acceptance without written information.	Operational costs are relatively low and mainly involve administrative costs. EXAMPLE: in a waste oil treatment facility with a capacity of 10,000 t/yr[4], an analytical laboratory has an estimated capital cost of GBP40,000 and an estimated operating cost of GBP20,000; continuous monitoring equipment has a capital cost of GBP10,000 and an operating cost of GBP10,000.

[4] t/yr: tonne/year

3.1.3. Knowledge of waste output

These techniques consist of the analysis of waste output according to the most relevant parameters for the receiving facility. They are generally limited to the analysis of elemental composition and parameters such as energy content, water content, organic and inorganic content, etc.

Other waste characterisation techniques are based on procedures for the identification of primary constituent(s), identification of waste sources, and ensuring appropriate knowledge transfer between holders of the waste.

These types of techniques are applicable to most waste treatment facilities in the Mediterranean countries; the only limitation arises from investment in analytical equipment and operational costs. Table 3.3 shows the related BAT.

Table 3.3: BATs for determining the waste output

BAT	Environmental benefits	Economics
11.- Analyse the waste output according to the relevant parameters important for the receiving facility.	This improves knowledge of the potential environmental issues related to the waste to be treated and reduces the risk of accidents or bad operations.	The investment in analytical equipment for a waste oil treatment facility is around EUR750,000 per site.

3.1.4. Management systems

Management techniques are typically applied to waste treatment installations as a whole. The aim is to optimise the effectiveness of the process as well as to prevent environmental emissions.

They consist of procedures concerning:

- Traceability of waste treatment.
- Mixing/blending rules.
- Segregation and compatibility procedures.
- Improvement of the efficiency of waste treatments.
- Accident management plan.
- Incident diary.
- Noise and vibration management plan.
- Consideration of any future decommissioning.

Some of these practices may be difficult to apply to small installations due to the computer requirements, e.g. traceability systems for waste treatment or improvement of the efficiency of waste treatments by mass balances and material flow analysis, especially within the Mediterranean Region. Others, such as segregation and compatibility procedures, mixing and blending rules can be applied to all installations. In contrast, accident management plans and incident diaries are especially relevant for installations dealing with hazardous waste. The selection of BATs for these techniques is presented in the table 3.4.

Table 3.4: BATs for management systems

BAT	Environmental benefits	Economics
12.- Have a system in place to guarantee the traceability of waste treatment.	This provides documentary evidence of the treatment given to a certain waste.	NA.
13.- Have and apply mixing/blending rules oriented to restrict the types of waste that can be mixed/blended together in order to avoid increasing pollution emission of down-stream waste treatments.	The appropriate separation of waste at the source prevents incidents that could result in the mixing of incompatible waste.	Some solid waste streams can be segregated effectively through minor changes in equipment. The disposal of mixed waste is more expensive than the treatment of a stream composed of a single type of waste.
14.- Have segregation and compatibility procedures in place. (See also BATs no.13 and 24).	See BAT no.13.	See BAT no.13.
15.- Improvement of the efficiency of waste treatments related to the usefulness of the outputs, raw material consumption and material flow analysis.	Optimisation of waste treatment installations helps to achieve lower emissions and consumption.	NA.
16.- Produce a structured accident management plan. (See also 3.1.1 Environmental Management)	The most significant environmental risks associated with WT operations are from the **storage of hazardous waste**, from emissions resulting from waste types reacting together, from leaks or spillages or from treatment processes going out of control.	NA.
17.- Have and properly use an incident diary. (See also BAT nos. 1 and 16)	See BAT nos. 1 and 16.	See BAT nos. 1 and 16.
18.- Have a noise and vibration management plan in place as part of the EMS. (See also BAT no. 1)	Reduction of noise levels generated by the installation.	NA.
19.- Consider any future decommissioning at the design stage. (See also BAT no. 1)	Prevents environmental issues during decommissioning.	NA.

3.1.5. Utilities and raw material management

These techniques are mainly focused on energy management. Heat and power are needed to run an installation. The main uses of energy in a waste treatment facility are:

- Heating, lighting and power in facility buildings.
- Power for treatment processes and facility equipment, such as pumps, air compressors, centrifuges, etc.
- Fuel to power vehicles.

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

Some techniques related to energy and raw materials management are:

- Provision of a breakdown of energy consumption and generation by source.
- Use of cleaner fuels.
- Use of waste as fuel.
- Measures to improve energy efficiency (e.g. establishing an energy efficiency plan, etc.).
- Raw material selection.
- Techniques to reduce water use and prevent water contamination.

In principle, these techniques are applicable throughout the waste treatment sectors; nevertheless, some difficulties can arise from the allocation of energy consumption to single activities or processes in existing installations. Despite the high investment costs, these are particularly appropriate for those Mediterranean countries that are drawing up projects for new installations for hazardous waste treatment. Table 3.5 shows the BATs for this area.

Table 3.5: BATs for utilities and raw materials management

BAT	Environmental benefits	Economics
20.- Provide a breakdown of the energy consumption and generation (including exporting) by the type of source (electricity, gas, liquid conventional fuels, solid conventional fuels and waste). (See also BAT no. 1)	This can help to optimise the match between generation and consumption and hence to optimise the use of energy resources.	The requirements are basic and low-cost.
21.- Continuously increase the energy efficiency of the installation by: • Developing an energy efficiency plan. • Using techniques that reduce energy consumption and thereby reduce direct and indirect emissions. • Defining and calculating the specific energy consumption of the activity. (See also BAT no. 20)	Utilising an energy efficiency plan and switching to cleaner fuels can reduce the energy consumption and environmental emissions from energy use. An increase in the energy efficiency of boilers and heaters reduces emissions of VOCs.	Typically, energy efficiency systems have higher investment costs. However, their operating costs are typically lower (or the revenues higher). Costs are higher for existing installations than for new installations.
22.- Carry out an internal benchmarking (e.g. on an annual basis) of raw materials consumption.	The selection of raw materials can • Reduce the use of chemicals and other materials; • Substitute less harmful materials for those which can be more readily abated; • 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 waste (depending on the volume and contamination of the waste).	NA.
23.- Explore the options for the use of waste as a raw material for the treatment of other waste. If waste is used to treat other waste, then to have a system in place to guarantee that the waste supply is available. (See also BAT no. 22)	If the waste is to be used as a reagent in a treatment process, not having such waste available may delay the treatment process for the waste type to be treated. This delay may cause associated environmental problems.	For example, the guarantee of the long-term performance of anaerobic systems is a key issue for their economical viability.

3.1.6. Storage and handling

The implementation of environmental practices for storage and handling is especially relevant in hazardous waste treatment facilities. The main objectives of environmental practices for storage are:

- Storing the waste safely before its introduction as feed into the treatment.
- Providing 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 the treatment and dispatch of waste.
- Uncoupling the treatment and dispatch of waste.
- Allowing the effective use of classifying procedures to be made during storage/accumulation periods.
- Facilitating 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 levels of tractability of the waste must be achieved and ensured by the immediate storage/accumulation of the waste to be treated.
- Facilitating mixing, blending, and repackaging of the waste as deemed necessary.
- Allowing the staged input of various waste types with reagents to the subsequent unit treatment processes.
- Collecting a reasonable amount of waste prior to sending it for certain treatments (transfer stations).
- Reducing fugitive emissions, leakages, 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, contamination of soil and water from major spillages or incidents involving a loss of containment.

Some common environmental techniques regarding storage and handling are:

- <u>Generic techniques applied to waste storage</u>: specifying storage procedures for special circumstances (such as public holidays), locating storage areas away from watercourses and sensitive perimeters, clearly marking and signposting storage areas with regard to the quality and hazardous characteristics of the waste stored therein, etc. See BAT 24 in table 6.
- <u>Techniques for the storage of drums and other containerised waste</u>: see BAT 24 in table 3.6.
- <u>Techniques to improve the maintenance of storage</u>: putting in place procedures for the regular inspection and maintenance of storage areas including drums, vessels, pavements and bunds; carrying out daily inspection of the condition of containers and pallets and keeping written records of these inspections; having in place and following a routine programmed inspection of tanks, and mixing and reaction vessels.
- <u>Bunds for liquid storage</u>: see BAT 25 in table 3.6.
- <u>Restricting the use of open-topped tanks, vessels or pits</u>.
- <u>Generic techniques applied to waste handling</u>: continuing the waste tracking system that began at the pre-acceptance stage, having in place a management system for the loading and unloading of waste in the installation, having emergency storage for leaking vehicles to minimise acute incidents, etc. See BAT 28 in table 3.6.
- <u>Handling of solid waste</u>: ensuring the bulking of different batches only takes place with compatibility testing, not adding liquid waste to solid waste, using local exhaust ventilation to control odour and dust, unloading solid waste and sludge in a closed and depressurised building, etc.
- Handling activities related to transfers into or from drums and containers: see BAT 31 in table 3.6.

- Automatic unloading of drums (a complete station includes): a drum supply station driven by pneumatic motorisation, a grip station for the drums equipped by a hydraulic clamp, a station for the cutting, scraping, washing and ejection of the drum bottom; a station for the disposal, scraping, and high-pressure cleaning of the shell of the drum, a station for the pressing and removal of the cleaned drums, a control cabin, VOC emissions prevention.
- Techniques to improve stock control in storage: for bulk liquid waste, stock control involves maintaining a record of the route through the entire process, the provision of emergency storage capacity, all containers need to be clearly labelled with the date of arrival, relevant hazard code, use of over-drumming as an emergency measure, automatic monitoring of the storage and treatment tank levels with the tank level indicators, etc.
- Computer controlled high rack storage area for **hazardous waste**. The logistics centre in the compound of different treatment facilities is a computer controlled high rack storage area for hazardous waste. 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 properties of the substance and to determine the appropriate treatment process. The laboratory also produces concepts for clean-up in cooperation with the other departments.
- Tank and process pipework labelling: all vessels need to be clearly labelled with regard to their contents and capacity, and need to have a unique identifier. The label should differentiate between wastewater and process water, combustible liquid and combustible vapour and the direction of flow. Written records need to be kept for all tanks, detailing the unique identifier, using a suitable pipework coding system, tagging all valves with a unique identifier and showing this on the process and instrumentation diagrams and correctly sizing and maintaining all connections in an undamaged state.
- Carrying out a compatibility test prior to transfer: a sample from the receiving tank/vessel/container is mixed in a proportional ratio with a sample from the incoming waste stream, which is intended to be added to the tank/vessel/container, the two samples need to cover the “worst case“ scenario of likely constituents, any evolved gases and the cause of possible odour need to be identified, etc.
- Segregation of storage. 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 in contact with it, and the compatibility of the waste with other waste stored together. See BAT 30 in table 3.6.

The detailed BATs for these techniques are shown in table 3.6. These techniques are highly recommended and feasible to apply in the Mediterranean countries, especially in the hazardous waste treatment sector.

Table 3.6: BATs for storage and handling

BAT	Environmental benefits	Economics
24.- Apply techniques related to storage: • Areas with correct drainage and all necessary measures for the specific risks (odorous, volatile emissions and low flashpoint). • All connections between the vessels are capable of being closed via valves.	The appropriate and safe storage of waste helps to reduce fugitive emissions (e.g. VOC, odours, and dust) and the risk of leakages. Segregated storage is necessary to prevent incidents from incompatible substances reacting and as a means of preventing escalation should an incident occur.	NA.
25.- Separately bund the liquid decanting and storage areas using bunds which are impermeable and resistant to the stored materials.	This reduces the contamination of soil and water from major spillages or incidents involving a loss of containment.	NA.
26.- Apply techniques concerning tank and process pipework labelling: • Clearly labelling all vessels (contents, capacity). • Keeping complete records for all tanks.	These systems make it easier for the operator to maintain a good knowledge of the whole process and help to reduce accidents and to control emissions.	NA.
27.- Take measures to avoid problems that may be generated from the storage/accumulation of waste. May conflict with BAT no. 23 when the waste is used as a reactant.	This prevents emissions during storage activities.	NA.
28.- Apply techniques when handling waste: • Systems and procedures in place, management system for the loading and unloading of waste, qualified personnel and ensuring that damaged hoses, valves and connections are not used. • For liquid waste, collecting the exhaust gas from vessels and tanks. • Unloading solids and sludge in closed areas with extractive vent systems.	The appropriate and safe handling of waste helps to reduce fugitive emissions and the risk of leakages. Segregated storage is necessary to prevent incidents from incompatible substances reacting and as a means of preventing escalation should an incident occur. The appropriate and safe handling of solid waste avoids incidents and fugitive emissions. Common abatement systems can be connected to the venting systems of tanks to reduce solvent losses to the air due to displacement when filling tanks and tankers. Sites handling dusty waste have specific hoods, filters and extraction systems. Most sites have a full concrete base.	NA.

BAT	Environmental benefits	Economics
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 waste, it needs to be carried out under local exhaust ventilation.	This avoids fugitive emissions e.g. by minimising splashes, fumes and odours, health and safety problems; and it prevents unexpected releases or reactions.	NA.
30.- Ensure that the chemical incompatibilities guide the segregation required during storage. (See also chapter 3.1.4 Management Systems)	Carrying out a compatibility test prior to transfer prevents any adverse or unexpected reactions and releases before transfer to storage tanks. It covers tanker discharges to bulk storage, tank-to-tank transfer, and transfer from a container to a bulk tank, bulking into drums/IBCs and bulking solid waste into drums or skips. Oxidiser and flammable liquid containers are stored separately so that they cannot come into contact with one another as a result of leakage. (See also BAT no. 28)	NA.
31.- Apply the following techniques when containerised waste is handled: • Storing of containerised waste under cover (if its necessary: sensitive to light, heat, temperature or water) • 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	Storage under cover reduces 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 techniques 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.	NA.

3.1.7. Segregation and compatibility

These techniques avoid mixing waste with the aim of facilitating later treatment and preventing other problems that could appear. The principle of segregation and compatibility is that mixing 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 hazardous waste. Some principles to consider are:

- Not making the waste a liquid if it is dry.
- Having proper labelling of all lines and containers.
- Only allowing the mixing of polluted waste of different pollution strengths if the mixed waste is treated according to the more polluted waste.
- Keeping the cooling water separate from the waste streams.

- Considering or applying segregation when storing materials.
- Having rules restricting the types of waste that can be mixed together.

This is a key principle that is easy to implement through the establishment of documented procedures and staff training, which largely contribute to the reduction of pollution at source. It is applicable to all hazardous waste treatment plants within the Mediterranean Region. Environmental benefits are significant if hazardous waste is involved.

3.1.8. Techniques for the environmental improvement of other common techniques

This section aims to reduce environmental emissions from two different stages of waste treatment: drum crushing and shredding activities, and washing processes.

The associated BATs for these techniques are detailed in table 3.7. They are generally recommended for installations dealing with these operations.

3.1.8.1. Techniques to reduce emissions from drum crushing and shredding activities.

These techniques reduce VOC (Volatile Organic Compounds) emissions into the air and reduce contamination of watercourses and soil.

Several techniques which can be applied to reduce emissions from drum crushing and shredding activities are:

- Making the drum crushing and shredding plant fully enclosed and fitting it with an extractive vent system linked to abatement equipment.
- Keeping skips for the storage of crushed/cut drums covered.
- Using scaled drainage.
- Avoiding crushing drums that contain flammable and highly flammable waste or volatile substances.

When treating hazardous waste in a shredding facility, the following techniques can also be applied:

- Pressure-surge-proof channel of 12 m high against damage.
- The facility is pressure resistant up to 10 bar.
- Batch-wise operation of the shredder for minimising the exposure.
- Fire alarm systems and sprinkler installations.
- Online connection to the nearest rescue service.
- Explosion-proof switches, aggregates and machines.
- Overpressure cabins with activated carbon filter in all machines.
- Fire water of 50 m^3 in a subsurface basin.
- Permanent nitrogen flooding of the work space inside the shredder.

3.1.8.2. Techniques to reduce emissions from washing processes

These techniques allow the identification and treatment of washing residues, among them:

- Identifying the components that may be present in the items to be washed (e.g. solvents).
- Transferring washed waste to appropriate storage.
- Using treated wastewater from the waste treatment plant.

Table 3.7: BATs for the environmental improvement of other common techniques

BAT	Environmental benefits	Economics
32.- Perform crushing, shedding and sieving operations in areas fitted with extractive vent systems linked to abatement equipment when handling materials that can generate emission to air (e.g. odours, dust, VOCs).	This reduces VOC emissions to air and reduces contamination of watercourses and soil.	An EXAMPLE bin shredding installation: the capacity of the facility is 5,000 Mg/yr[5]. The quantity of **hazardous waste** treated is 1000 t/yr. The investment needed for the treatment plant is EUR 325,000. An EXAMPLE aerosol can shredding installation: the capacity of the facility is 500 t/yr. The investment needed for the treatment plant is EUR 500,000.
33.- Perform crushing/shredding operations 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. (See also BAT no. 32 and the chapter Air Emission Treatments)	See BAT no. 32.	See BAT no. 32.
34.- Perform washing process considering: • Identifying the washed components that may be present in the items to be washed (e.g. solvents). • Transferring washing to appropriate storage. • Using treated wastewater from the WT plant for washing instead of fresh water.	This allows the identification and treatment of washing residues.	NA.

3.1.9. Techniques to prevent accidents and their consequences

These techniques are necessary to prevent accidents which would have environmental consequences, or to reduce their consequences once they have occurred. Some related techniques include:

[5] Mg/y: megagrams/year

- Producing a structured accident management plan: identifying the hazards to the environment posed by the installation; assessing all risks of accident and their possible consequences.
- Having a documented system to identify, assess and minimise the environmental risks and hazards of accidents and their consequences.
- Maintaining an inventory of substances.
- Keeping incompatible waste and substances separate 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.
- Providing adequate storage arrangements for raw materials, products and waste.
- Using an automatic system based on microprocessor control, by-pass valve control or tank level readings: e.g. ultrasonic gauges, high level warnings and process interlocks.
- Documenting the control measures in place, including the evaluation of these measures and a decision about their adequacy.
- Providing appropriate containment: e.g. bunds and catchpots, building containment.
- Implementing techniques and procedures to prevent the overfilling of storage tanks, e.g. level measurements, independent high level alarms, high-level cut-off, and batch metering.
- Keeping an up-to-date installation log/diary to record all incidents, near-misses, changes to procedures, abnormal events, and the finding of maintenance inspections. Leaks, spills and accidents can be recorder in the diary.
- Establishing procedures to identify, respond to and learn from such incidents.
- Identifying the roles and responsibilities of personnel involved in accident management.
- Providing personnel training.

These techniques are general and applicable to all waste treatment sectors; some of them are especially relevant for hazardous waste treatment. As well as environmental reasons, accident prevention is the main driving force for their implementation; they are therefore considered essential in the improvement of the hazardous waste treatment sector in the Mediterranean Region.

3.1.10. Techniques to reduce noise and vibrations

If a company has an EMS in place, normally it will also have a noise management plan. This should include:

- Description of main sources of noise and vibration within the installations (both for normal and infrequent operations).
- Details of the appropriate noise surveys, measurements, investigations or modelling.

As this represents an initial control of the generic parameters of the installation, its application in Mediterranean installations is feasible.

3.1.11. Techniques for decommissioning

These techniques aim to minimise environmental impacts associated with the decommissioning of a plant. Some of them are as follows:

- Considering decommissioning at the design stage, thereby making suitable plans to minimise risks during later decommissioning.
- For existing installations, putting in place a programme of design improvements.

- 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.
- Establishing the measures proposed to avoid 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).
- Establishing plans for the cleaning of deposited residues, waste and any contamination resulting from the waste treatment activities.
- Ensuring that plant and equipment taken out of use are decontaminated and removed from the site.

These techniques are applicable to all stages of a waste treatment installation, from the design and building stage to the site closure. They are especially suitable for those Mediterranean countries which are closing outdated installations and designing new ones.

3.1.12. Common techniques

This section is divided into three different techniques: treatment of small waste, waste size reduction and other common techniques (cleaning, re-packaging, screening, sedimentation, sieving, sorting and scrapping and washing). They are useful for installations which deal with different sizes of waste which need to be homogenised prior to treatment.

3.1.12.1. Treatment of small waste

This is to identify different types of waste for their correct treatment, e.g. treatment of hazardous waste from private households, universities, laboratories and business enterprises.

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.

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 and deposit in underground disposal).
- Packing treatment for emptying fluid containers: small volumes are combined for the purpose of creating large batches (solvents or acids). These are disposed of in downstream high temperature incineration or recovered in the in-house physicochemical treatment plant.
- Treatment of plant protection products, reactive and odour intensive substances in a special cabin.

3.1.12.2. Waste size reduction

The main aim is to adapt the waste's solid granulometry for further treatments or to extract waste which is difficult to pump or decant.

Techniques used in the installations are shredding, sieving, fractionating, conditioning and confectioning.

These techniques are useful for 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.

3.1.12.3. Other common techniques

These consist of generic techniques used in the waste treatment sector. They are mainly mechanical treatments. They are typically used as pre-treatments but some are used as post-treatment, e.g.:

- Cleaning: removes pollution that would otherwise preclude the recovery of waste materials. It is for PCB capacitators and transformers.
- Re-packaging: 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 process. Used for municipal solid waste to be used as a fuel and for plastic, paper and metal bales.
- Screening.
- Sedimentation.
- Sieving: used to separate big particles. Vibrating sieves, static sieves and rotary sieves are used. For preparation of waste to be used as fuel.
- Sorting and scrapping.
- Washing: one purpose of washing may be to enable the re-use of drums in the installation or their sale 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.

3.2. TECHNIQUES FOR SPECIFIC TYPES OF WASTE TREATMENTS

3.2.1. Biological treatments

Biological treatment uses living organisms to decompose organic waste into water, CO_2 and simple inorganics or into simpler organics such as aldehydes and acids. Not all biological treatments are appropriate for hazardous waste as the presence of toxic waste frequently reduces the biological activity. The different types of biological treatments are as follows:

- Activated sludge: decomposes organic waste in water by exposing waste to biological growth. This is classified as a wastewater treatment.
- Aerated lagoons: large lagoons containing high concentrations of microorganisms. This is classified as a wastewater treatment.
- Composting: engineered mounds of waste are built to encourage the biological breakdown of organic solids, producing a humic substance valuable as a soil conditioner.
- Aerobic digestion: reduction of the organic content of waste. Applied to solid waste, non-continuous wastewater, bioremediation and to sludge and soil contaminated with oil.
- Anaerobic digestion: decomposes organic matter in closed vessels in the absence of air. Applied to solid-liquid waste, highly contaminated wastewater (e.g. chlorinated compounds), bioremediation and in the production of biogas to be used as a fuel.

Activated sludge and aerated lagoons are considered as wastewater treatments, while composting and aerobic and anaerobic digestion are appropriate for municipal solid waste treatment (specifically biowaste). However, anaerobic digestion has been tested for hazardous waste disposal as well.

The following techniques and practices are considered to have good environmental operating performance in biological treatments; they are typically used as part of a whole waste treatment:

- Selection of the appropriate biological treatment. A key technical factor is to provide proper contact between the organic constituents of the waste and the microbial population. This depends primarily on the state of the waste and its concentration. It helps to avoid operational problems as well as to extract the greatest benefit from the waste (e.g. use as fuel).

- Specific storage and handling techniques for biological treatments. See BAT 65 in table 3.8.
- Selection of feedstock for biological systems: the presence of substances which are not subject to beneficial treatment, such as toxic metals, needs to be limited for entering into the biological processes; while the process itself is an important aspect, the quality of the feedstock probably has the biggest effect and so it is vital to maximise its quality.
- Generic techniques for anaerobic digestion. See BAT 68 in table 3.8.
- Increasing the retention time in the anaerobic digestion processes. This involves allowing the digestate to spend more time in degradation conditions. A higher retention time will enable more extensive biodegradation and subsequently better quality digestate and can thus increase biogas production.
- Techniques for the reduction of emissions when biogas is used as fuel. See BAT 68 in table 3.8. The biogas generated requires desulphurisation because of the high sulphur content, especially in order to prevent corrosion of the unit using the biogas.
- Increasing the energy efficiency of the electricity generators and anaerobic digestion systems: electrical conversion efficiencies will vary according to the combustion plant; installing biogas engines with efficiencies higher than 30% is essential for achieving good overall energy efficiency.
- Techniques to improve mechanical biological treatments: using filters on the exit air to minimise particulate emissions, reducing emissions of nitrogen compounds by optimising the C-N ratio and using acid scrubbers, avoiding anaerobic conditions in aerobic treatment installations, controlling the air supply using a stabilised air circuit, carefully positioning the windrows to enable proper access for forming and turning, efficient balancing of water to minimise the production of leachates, etc.
- Aerobic digestion of slurries: this is a typical biological treatment applied to slurries.
- Aeration control of biological degradation: applying overpressure operations, applying suction (pressurised) operation, having aeration floors with slit plates and a basement cellar to ensure an even aeration of the complete moving/turning, adapting aeration to the biodegradation activity of the material by segmentation of the biological degradation area into separately controllable aeration fields, ensuring that there is an even flow through the biodegraded material in tunnel system floors, by using embedded punched pipes and relatively high pressures and using heat exchangers to lower the exhaust gas temperature and humidity.
- Management of exhaust gas in Mechanical Biological Treatments (MBTs). See BAT 70 in table 3.8.
- Abatement techniques for biological treatments. See BAT 69 in table 3.8.

In principle, these biological techniques are applicable to the Mediterranean Region as they are not very expensive and are easy to incorporate, use and maintain; however, their applicability is limited by the presence of certain toxic substances such as heavy metals. Anaerobic digestion is the most appropriate biological treatment for hazardous waste but it has a high investment cost. Table 3.8 shows BATs associated with biological treatments.

Table 3.8: BATs for biological treatments

BAT	Environment benefits	Economics
65.- Use the following techniques for storage and handling in biological systems: • For less odour-intensive waste: use automated and rapid action doors in combination with an appropriate exhaust air collection device. • For highly odour-intensive waste: use closed feed bunkers constructed with a vehicle sluice. • House and equip the bunker area with an exhaust air collection device.	It is important in liquid waste bio-treatment systems that the flow of substrate is relatively constant to maintain correct operation; otherwise unexpected emissions can be caused. These techniques prevent emissions into the air. Residual waste may contain large amounts of small-grained particles. Therefore considerable dust emissions can be expected in the bunker due to the tipping and loading processes with mobile tools, which should be retrieved or deposited as close to the source as possible.	NA.
66.- Adjust the admissible waste types and separation processes according to the type of process carried out and the abatement technique applicable (e.g. depending on the content of non-biodegradable components).	It avoids toxic compounds entering the biological system, i.e. toxic in terms of reducing biological activity. If non-biological active parts of the feedstock are separated, such streams can be easily re-used or recycled (e.g. glass, metals).	NA.
67.- Use the following techniques when applying anaerobic digestion: • Close integration between the processes and water management. • A recycling of the maximum amount of wastewater to the reactor. • Operate the system under thermophilic digestion conditions. • Measure TOC, COD, N, P and Cl levels in the inlet and outlet flows. • Maximise the production of biogas (needs to consider the effect on the digestate and biogas quality).	These techniques increase the efficiency of anaerobic digestion; they allow better use of their products and minimise the quantity of potentially toxic materials. Anaerobic systems are effective at breaking down ring compounds (for example, phenols) and generate methane that can be utilised as a fuel. However, not all compounds derived by the anaerobic breakdown of aromatic rings (e.g. xenobiotica) can be mineralised under anaerobic conditions. Odour emissions of 250-500 ou/m[36] from anaerobic treatment can be reached by using an appropriate bio filter and scrubber if the NH3 content is higher than 30 mg/Nm[37]. Increasing the retention time will enable extensive biodegradation and subsequently a better quality digestate and will thus increase biogas production.	Specific investment costs are generally much higher than with aerobic treatment.

[6] ou/m^3: odour unit/cubic metre

[7] Mg/Nm^3: milligram/normal cubic metre

BAT	Environment benefits	Economics
68.- Reduce exhaust gas emissions of dust, NO_x, SO_x, CO, H_2S and VOC when using biogas as a fuel by using an appropriate combination of the following techniques: • Scrubbing the biogas with iron salts. • Using de-NO_x techniques (SCR). • Using a thermal oxidation unit. • Using activated carbon filtration.	Emissions values: Data in mg/Nm^3 at 5% O_2 AOX: <150 biogas. CO: 100-650 exhaust gas. Dust: <10-50 exhaust gas. NO_x: 100-500 exhaust gas. H_2S: <5 exhaust gas. HCl: <10-30 exhaust gas. HF: <2-5 exhaust gas. Hydrocarbons: <50-150 exhaust gas. SO_2: <50-500 exhaust gas.	Secondary measures to reduce emissions from flue-gas when biogas is used as fuel are considered not economically viable nor environmentally justified for small power/heat installations.
69.- Improve the mechanical biological treatment (MBT) by: • Using fully enclosed bioreactors. • Avoiding anaerobic conditions during aerobic treatment by controlling the digestion, the air supply and adapting to biodegradation activity. • Using water efficiently. • Thermally insulating the ceiling of the biological degradation hall in aerobic processes. • Minimising the exhaust gas production to levels of 2500 to 8000 Nm^3/t. • Guaranteeing a uniform feed. • Recycling process waters or muddy residues within the aerobic treatment process to completely avoid water emissions. If wastewater is generated, then this should be treated to reach the values mentioned in BAT no. 56 • Reducing emissions of nitrogen compounds by optimising the C: N ratio	Optimised biological processes combine a reduction of emissions to water and air during treatment in the treatment plant. Furthermore, another environmental benefit is that mechanically biologically pre-treated waste is characterised by a marked reduction in volume, water content and gas formation potential, as well as having a significant improvement in leaching and settlement behaviour in landfills. Another benefit is that a high calorific waste stream is separated which can be incinerated with energy recovery. Mechanical and physical treatments used as a pre-treatment to optimise the conditions for the subsequent biological treatment are adjusted to enhance the separation of valuable materials, inhibiting materials or materials for which a biological treatment is not suitable. See also BATs nos. 65 and 66.	NA.
70.- Reduce the emissions from mechanical biological treatment to the following levels: Odour: <500-600 ouE/m^3 and NH3: <1-20 mg/Nm^3.	Reduction of emissions may be reached by a combination of the following techniques: a) generic prevention, b) adsorption,	a) NA. b) Low operating costs for low concentration s of VOCs.

BAT	Environment benefits	Economics
By using the following techniques: • Maintaining good housekeeping. • Regenerative thermal oxidiser. • Dust removal. For VOC and PM, see BAT no. 41.	c) chemical scrubbing, d) low oxidative process, e) incineration, f) catalytic combustion, g) regenerative thermal oxidiser, h) non-thermal plasma treatment.	c) NA. d) NA. e) The cost-efficiency of the operation is determined by the size of the volume of flow to be treated and by the pollutant concentrations. f) The cost of investment is relatively high. g) NA. h) NA.
71.- Reduce water emissions to the levels (ppm): COD: 20-120 BOD: 2-20 Heavy metals (Cr, Cu, Ni, Pb, Zn): 0.1-1 Highly toxic metals: As:<0.1; Hg: 0.01-0.05: Cd:<0.1-0.2; Cr (IV): <0.1-0.4 As well as restricting the emissions of total nitrogen, ammonia, nitrate and nitrite.	Identifies and assists the monitoring of pollutants that are typically released.	NA.

3.2.2. Physicochemical treatments

These are based on treatments that affect the physicochemical properties of waste. These techniques are highly specific depending on the type of waste and its content and can require high investment. Thus, waste must be characterised and physicochemical treatment options studied carefully; this is critical in the Mediterranean countries where there is a poor knowledge of hazardous waste flows and hazardous waste is typically destined for final disposal installations.

This section has been structured according to the physical conditions of waste, so treatments carried out on liquids and solids have been considered separately.

3.2.2.1. Physicochemical treatments for wastewater

Physicochemical treatments are planned in such a way that the maximum amount of recyclable materials can be separated so that a minimum amount of auxiliary materials are used.

The waste treated in physicochemical plants is aqueous liquid. Ph-c plants generally treat waste liquids or sludges with a relatively high water content (>80 w/w-%). Regardless of its origin and its relationship to its material characteristics, the waste commonly treated by these plants is:

- Emulsions/cooling lubricants.
- Acids.
- Alkaline solutions.
- Concentrates/saline solutions containing metals.
- Wash-water.
- Wastewater containing a petrol/oil separator.
- Solvent mixtures.
- Sludges.
- Aqueous liquid waste with high concentration of biodegradable materials.
- Aqueous marine waste.

Environmental techniques considered in the determination of BATs (BATs are shown in table 3.9) concerning the physicochemical (Ph-c) treatment of wastewater are:

- Planning the operation of a Ph-c plant: all measurement and control installations have to be easily accessible and easy to maintain, control and testing systems have to be established, the reception inspection must be adapted to the information from the declaration analysis of the proof of waste disposal and to the process order provided for each particular treatment, the production of wastewater should be prevented as far as possible by construction measures, e.g. roofing of the reception area, etc.
- Techniques for Ph-c reactors. See BAT 72.
- Neutralisation: preventing the mixing of acidic/basic waste with other streams to be neutralised when the mix contains metals and complexing agents at the same time. Complexing ions to watch out for include, for example, EDTA, NTA and cyanides. Making the necessary neutralisation equipment robust and easy to use can help the equipment stand up to the rigours of use in Ph-c plants dealing with acidic/basic waste needing neutralisation.
- Precipitation of metals. See BAT 75.
- Break-up of emulsions. See BAT 76.
- Oxidation/reduction. See BAT 77.
- Techniques for the treatment of waste containing cyanides. See BAT 78.
- Techniques for the treatment of waste containing chromium (VI) compounds. See BAT 79.
- Techniques when treating wastewater contaminated with nitrites. See BAT 80.
- Treatments of phenolic solutions by oxidation: it is possible to treat aqueous waste containing phenol (3-5 w/w-%) by catalytic oxidation, using an oxidising agent and a metal catalyst or by a strong oxidising reagent (e.g. $KMnO4$).
- Techniques for waste containing ammonia. See BAT 81.
- Filtration/dewatering: extending any air sampling for ammonia in exhaust stacks or filter press areas to cover VOCs, linking the air space above some presses to the main abatement systems at the plant, improving the draining behaviour of mud by the addition of flocculation agents, for example lime, or synthetic flocculation agents. See BAT 82.
- Dissolved air flotation (DAF) system: this generates a supersaturated solution of wastewater and compressed air by raising the pressure of the wastewater stream to that of the compressed air, then mixing the two in a retention tank. See BAT 83.

- Ion exchange processes: using ion exchanges only for salt concentrations of less than 1500 mg/l, using pre-treatments to reduce salt concentration (e.g. precipitation), removing solid materials in solutions by sand filters or activated carbon adsorption before using ion exchange processes, using conductivity measurements to monitor and operate the ion exchanger plant (cation-anion combination).
- Membrane filtration: examining in the laboratory which membrane is suitable for the waste to be treated, submitting permeate and concentrate resulting from ultrafiltration to subsequent treatment and monitoring, pH, electrical conductivity, pressure, temperature, etc.
- Sedimentation: settlement is carried out in a clarifier that needs to be specifically designed with an inlet, outlet, settling zone and sludge blanket. The addition of flocculation agents to the sludge and wastewater to be treated is recommended to accelerate the sedimentation process and to facilitate the further separation of solids.
- Sieving: avoiding overload of the sieving equipment, correctly cleaning the filter apertures as required and ensuring that there is an unimpaired discharge of filter underflow and overflow at all times. See BAT 84.
- Solvent extraction: using well operated and regulated processes, returning the extraction solvent for re-use in a closed loop, using anti-foaming agents when faults occur in the extraction due to surface-active substances (e.g. tensides) resulting from the mixing processes, avoiding using solvents with comparable chemical characteristics to the component to be extracted, in order to avoid poor separation effects, e.g. azeotropic mixtures, improving the separation performance during extraction by increasing the temperature and separating substances which may have negative effects in pre-treatment procedures.
- Techniques when treating wastewater containing precious metals. Photographic liquid waste contains several toxic and not easily degradable compounds. By means of physicochemical and biological treatment, including evaporation, the diffusion of these compounds to the environmental is minimised.
- Techniques for the treatment of aqueous marine waste. This can be distinguished as wastewater containing oil and wastewater containing chemicals. Some techniques are:
  a) applying specific pre-treatment processes in the case of wastewater containing metals,
  b) applying physicochemical pre-treatment and biological treatment in the case of wastewater containing oil,
  c) treating exhaust gases to reduce VOC and odour emissions,
  d) defining acceptance and processing standards for every treatment route, etc.
- Abatement techniques applied in Ph-c treatment plants: bag filters, scrubbers for acids and for NH3, oxidising scrubber, off-gas used during the incineration of hazardous waste, biofilters and biofilters for the organic part.

Some operations carried out with hazardous waste via Ph-c plants are:

- Treatment of emulsions.
- Treatment of emulsions and waste with contents to be detoxified.
- Treatment of liquid, aqueous waste with some organic solvents.
- Treatment of emulsions and oil/water mixtures.
- Treatment of liquid, aqueous waste containing organic solvents and tensides.
- Detoxification (oxidation/reduction) of waste containing nitrites, Cr(VI), cyanide (as pre-treatment).

Usually, the waste processed comes from various industrial and commercial production processes, and from maintenance, repair and cleaning activities. Some specific industrial sectors that use physicochemical treatments are the printing and photographic industries. BATs especially intended to treat hazardous waste have been highlighted in **bold** in table 3.9.

Table 3.9: BATs for the physicochemical treatment of wastewater

BAT	Environmental benefits	Economics
72.- Apply the following techniques in physicochemical reactors: • Clearly defining the objectives and the expected reaction chemistry for each treatment process • Assessing each new set of reactions and proposed mixes of waste and reagents in a laboratory-scale test prior to waste treatment. • Specifically designing and operating the reactor vessel • Enclosing all treatment/reaction vessels and ensuring that they are vented to the air via scrubbing. • Monitoring the reaction to ensure that it is under control and proceeding towards the anticipated result. • Preventing the mixing of waste or other streams that contain metals and complexing agents at the same time.	Control of the reaction/treatment process is crucial to environmental protection and to preventing possible accidents. A yield of 96% removal of metals can be attained.	NA.
73.- Some additional parameters need to be identified for the physicochemical treatment of wastewater (in addition to the generic parameters identified for wastewater in BAT no. 56).	NA.	NA.
74.- Apply the following techniques to the neutralisation process: • Ensuring that the customary measurement methods are used. • Storing the neutralised wastewater separately. • Final inspection of the neutralised wastewater.	Improves the neutralisation process and avoids downstream problems (e.g. preventing the mixing of waste or other streams in a way that further treatment of the wastewater is no longer possible).	NA.
75.- Apply the following techniques to aid precipitation of the metals:	Substances such as chromium, zinc, nickel, lead are usually present	NA.

BAT	Environmental benefits	Economics
• Adjusting the pH to the point of minimum solubility (metals will precipitate). • Avoiding the input of complexing agents, chromates and cyanides. • Avoiding organic materials (interfere with precipitation from entering the process) • Allowing the resulting treated waste to clarify by decantation. • Using sulphide precipitation if complex agents are present.	dissolved in solution or adsorbed onto particulate or colloidal matter; this is relatively simple and robust technology and shows performance of up to 95%.	
76.- Apply the following techniques to break up emulsions: • Testing for the presence of cyanides in the emulsions to be treated. If cyanides are present, the emulsions need a special pre-treatment. • Setting up simulated laboratory tests.	The acid splitting of emulsions is very important for the disposal of waste and for the protection of water, because waste can be used for the treatment of the emulsions. These techniques are important to avoid environmental and operational problems.	NA.
77.- Apply the following techniques to oxidation/ reduction: • Abating the air emissions generated. • Having safety measures and gas detectors in place.	These techniques reduce the emissions that may occur from redox reactions.	NA.
78.- Apply the following techniques to wastewater containing cyanides: • Destroying the cyanides by oxidation. • Adding caustic soda in excess to prevent a decrease in pH. • Avoiding the mixing of cyanide waste with acidic compounds. • Monitoring the progress of the reaction using electropotentials.	The resulting cyanate cannot readily be reduced back to cyanide and any discharge of cyanate into a watercourse will not lead to free cyanide being generated. There are also fewer health risks. The pre-treatment of wastewater containing cyanides is essential to avoid the formation of metal-cyanide complexes. With these techniques, concentrations of less than 0.1 mg/l[8] of cyanide can be achieved.	NA.

[8] Mg/l: milligram/litre

BAT	Environmental benefits	Economics
79.- Apply the following techniques to wastewater containing chromium (VI) compounds: • Avoiding the mixing of Cr(VI) waste with other waste. • Reducing Cr(VI) to Cr(III). • Precipitating the trivalent metal.	Chromium (VI) is the highest oxidation state of the metal. An example of this is chromic acid, or chromium oxide, which is acidic, toxic, water-soluble and used as an oxidising agent. With these treatments, concentrations of less than 0.1mg/l of chromium (VI) are achievable.	NA.
80.- Apply the following techniques to wastewater containing nitrites: • Avoiding mixing nitrite waste with other waste. • Checking and avoiding nitrous fumes during the oxidation/acidification treatment of nitrites.	Concentrations of less than 2.0 mg/l of nitrite can be achieved by good optimisation of the nitrite treatment process.	NA.
81.- Apply the following techniques to wastewater containing ammonia: • Using a dual column air stripping system with an acidic scrubber for waste with ammonia solutions up to 20%. • Recovering the ammonia in the scrubbers and returning it to the process prior to the settlement stage. • Removing the ammonia removed in the gas phase by scrubbing the waste with sulphuric acid to produce ammonium sulphate. • Extending any air sampling of ammonia in exhaust stacks or filter press areas to cover the VOCs in filtration and dewatering.	These techniques prevent major emissions of ammonia gas during the initial neutralisation process when the pH is changing rapidly as the tanks are agitated and the temperature is rising.	The solutions containing ammonia can also be used as de-NO_x-agents. This destination might be less expensive than collection/treatment as a hazardous waste.

BAT	Environmental benefits	Economics
82.- Link the air space above filtration and dewatering processes to the main abatement system of the plant.	Improves the filtration process and reduces fugitive emissions. Filter cake with high concentrations of metals, e.g. nickel and copper, can be used as a raw material in the metallurgical industry.	NA.
83.- Add flocculation agents to the sludge and wastewater to be treated, to accelerate the sedimentation process and to facilitate the further separation of solids. To avoid the use of flocculation agents, evaporation is better in those cases where it is economically viable.	This increases sedimentation efficiency. Sedimentation of solids generally simplifies the waste treatment procedures which follow. However, unintentional sedimentation processes are a disadvantage since processes can be affected and often the build-up of sediment can only be removed at considerable expense.	Applying this technique allows savings to be made on discharge and transport costs, since only the sediment needs to be managed rather than the total aqueous suspension.
84.- Apply rapid cleaning and steam or high-pressure water jet cleaning to the filter apertures used during sieving processes.	The sieving of waste is performed as an initial treatment procedure. The separation out of particles which may harm equipment, processes or products is beneficial for all successive waste treatment measures.	NA.

The specific applicability of some of these techniques is presented below:

- Neutralisation can be applied to all mixable liquid waste.
- Aqueous waste treatment processes treat a variety of compatible aqueous waste materials by precipitating soluble metals and acidic anions out of solution while increasing the particle size of suspended solids, thereby aiding later phase separation between solids and liquids by clarification and filtration. Typical waste includes interceptor waste, paint spray booth waste and process effluents, among others.
- Chemical and thermal treatment methods are most widely used for the destruction of waste streams containing cyanide.
- Waste containing ammonia: such systems are applied to wastewater with a high ammonia content. There is other waste containing ammonia/ ammonium, e.g. landfill leachate, for which a stripping system is inadequate due to the transfer of other substances to the gas phase.
- Addition of flocculation agents: solids may be discrete suspended particles that are self-settling, or there may be a range of sizes and surface characteristics, which then require the formation of flocculating suspensions to coagulate and settle the mass. In certain cases, it is not necessary to use flocculation agents (solids are self-settling or they are not effective).

3.2.2.2. Physicochemical treatment of solid waste and contaminated soil

The main goal in the physicochemical treatment of solid waste is to minimise the long-term release by leaching out the primarily heavy metals and low biodegradable compounds.

In principle, all treatment options can be applied to waste solids and waste sludges. However, the characteristics of the treated material and the effectiveness of treatment technology can vary greatly depending on the specific properties of the original waste IN and on the type of cleaning system applied. The treatment options have been sub-grouped according to the following types:

- extraction and separation,

- thermal treatment,
- mechanical separation,
- conditioning,
- immobilisation,
- dewatering,
- drying,
- thermal desorption,
- vapour extraction from excavated soil,
- solvent extraction from solid waste,
- excavation and removal of excavated soil and
- soil washing.

Environmental techniques considered in the determination of BATs for the physicochemical treatment of solid waste are:

- Pre-treatment before immobilisation: this basically consists of the washing/leaching of salts with water, and the physicochemical pre-treatment of metals (especially insolubilisation of amphoteric metals. See BAT 85 in table 3.10).
- Laboratory activities: having a laboratory on-site, applying quality control, addressing any inhibitors identified in the binder formulation with secondary binders/additives, specifying the length of time that samples need to be kept available for analysis, etc.
- Immobilisation: defining an acceptable range of characteristics of a waste that can be effectively treated by the process, performing these processes within controlled reaction vessels, applying pre-acceptance procedures to assess waste. See BAT 87 in table 3.10.
- Cement solidification: generally waste is mixed with Portland cement and additives to control the properties of the cement, and enough water to ensure that hydration reactions will take place to bind the cement. Cement-based solidification techniques rely on the use of equipment that is typically readily available.
- Use of other reagents in the immobilisation process: encapsulation by bitumen, carbonisation using CO_2 and immobilisation with clay minerals.
- Phosphate stabilisation: chemical stabilisation using phosphate as the stabilisation agent is used. The treatment process is relatively simple, and consists of a mixing device (such as a pugmill) into which the waste IN is fed at a controlled rate.
- Thermal treatments of solid waste: includes vitrification, melting and fusion of solid waste. Applied to solid waste from waste incinerators.
- Recovery of salts by solution/evaporation: when solid waste is produced, the recovery potential can be considered. The recovery of salts may be a possibility, for example. These products could be obtained by evaporation or recrystallisation of the salts from the flue-gas cleaning system of wastewater, either locally or at a centralised evaporation plant. When the scrubber fluid is treated separately and subjected to evaporation, recoverable products like salts or hydrochloric acid can be obtained. The reutilisation potential of such products strongly depends on the product quality.
- Acid extraction: this process combines an acid extraction of soluble heavy metals and salts by using the (acidic) scrubber blowdown. Before using the scrubber liquid, mercury is removed by either filtration (when activated carbon is introduced into the scrubber) and/or a specific ion exchange.
- Excavation and removal of contaminated soil: identifying and implementing ways to reduce fugitive emissions by proper management of the site, enclosing the remediation within a dome

and applying treatment to the air and controlling the rate of excavation, the amount of contaminated soil area that is exposed, and the duration that soil piles are left uncovered.

- Vapour extraction: as the vapours are removed from the solid waste, they are treated to reduce emissions. Direct combustion is theoretically possible if the hydrocarbon content of the exhaust gas is high enough, but the concentration typically drops significantly during removal. For lower levels of hydrocarbons, catalytic oxidation or carbon adsorption may be effective.
- Soil washing: recycling the blowdown water as much as possible, using carbon filters for the treatment of collected air emissions from the waste site or soil washing unit and ensuring that the sludge and solids from wastewater treatment are subjected to appropriate treatment and disposal.
- Solvent extraction: this is much more effective for treating organic compounds than inorganics and metals. Solvent extraction differs from soil washing in that it employs organic solvents (e.g. propane, butane, carbon dioxide, aliphatic amines) rather than aqueous solutions to extract contaminants from the soil. It is a separation process that does not destroy the contaminants.
- Evaporation: this is typically an important part of the Ph-c treatment facility. The evaporation treatment facility concentrates the **hazardous waste**. The concentrate is typically burned. The sewage (condensate) is stored temporarily and after analysis and control, it will be transported to a wastewater treatment plant. The exhaust air will be cleaned with a carbon filter. Before evaporation, certain pre-treatments are carried out in the Ph-c treatment facility. These are flocculation, precipitation, ultrafiltration and organic splitting. After evaporation, flocculation is carried out on the condensate if it is contaminated with oil. The exhaust air is treated by alkali scrubbing and carbon filtration.
- Purification and recycling of Flue-Gas Treatment (FGT) waste: this consists mainly of sodium chloride (as a result of HCl neutralisation), sodium sulphate (as a result of SO2 neutralisation), sodium carbonate (as a result of sodium bicarbonate excess), fly ash and adsorbent (activated carbon or lignite coke). The process include:
  a) mixing the FGT waste with hydraulic binders,
  b) dissolving in water and adding additives,
  c) filtering this suspension and purifying the brine in such a way that it may be re-used in the manufacture of sodium carbonate.

The specific applicability of some of these techniques and the specific references to hazardous waste (in **bold**) are detailed below:

- Insolubilisation of amphoteric metals: waste containing chromates, amphoteric metals (Pb and Zn) and soluble salts, need pre-treatment. These can be applied in municipal waste incinerators with wet flue-gas treatment systems. They can be used only in incinerators with a wet FGT system and with a permit allowing the discharge of treated wastewater. The treatment is applied to monolithic and granular material (e.g. treatment of bottom ash).
- Restricting the acceptance of waste: this is most likely to be effective in the treatment of inorganic waste where solubility is quite low. Waste containing chromates, amphoteric metals and waste with some soluble salts content needs pre-treatment. Some waste is not suitable (but may be accepted if the concentration is very low):
  a) flammable waste,
  b) oxidising agents,
  c) odorous waste,
  d) waste containing volatile substances or highly soluble organic waste and a high COD content or molybdenum,
  e) solid cyanides and chelating agents.
- Solidification, vitrification, melting and fusion and the use of other reagents: these are typically performed at plants located near the final destination of the end material; thus individual

incinerators have no need to install solidification equipment. The technique can be used on all types of FGT waste. Solidification with cement has also been used **on many other types of hazardous waste, including for the disposal of low-level radioactive waste.** Waste IN should comply with certain requirements:

a) water content <5%,

b) unburned content <3%,

c) metal content <20% by weight,

d) ash size <100 mm.

This treatment is used for the treatment of bottom ash, as well as for combinations of bottom ash and FGT waste. Due to the typically high content in salts and **heavy metals of FGT waste, the separate treatment of FGT waste may necessitate a requirement for extensive off-gas treatment, thus reducing the overall benefits of separately treating these materials.** Bitumen encapsulation has been used on fly ash only and not for the residues from dry and semi-dry FGT systems. It can be implemented as an integrated unit at the incinerator or could also be set up to act as a centralised plant treating residues for more than one incinerator.

- Controlling the rate of excavation: enclosure of the remediation within a dome is not a commonly used measure.
- Using a bench-scale test: applicable to soils contaminated with volatile compounds at operating temperature. High molecular weight organic compounds may foul or plug baghouses or condenser systems. Rotary dryers can typically treat soils that have an organic content of less than 2%. Thermal screw units may treat soils that contain up to 50% organic matter.

Table 3.10 shows the selected BATs for the physicochemical treatment of solid waste. Techniques especially designed for hazardous waste have been highlighted in **bold**.

Table 3.10: BATs for the physicochemical treatment of solid waste

BAT	Environmental benefits	Economics
85.-Promote the insolubilisation of amphoteric metals, and reduce the leaching of toxic soluble salts by a combination of: a) Water washing. b) Evaporation and recrystallisation. c) Acid extraction. when immobilisation is used to treat solid waste containing hazardous compounds for landfilling.	a) This produces a filter cake with reduced toxicity and solubility and salted water. It helps to reduce the leachability of the waste OUT and contamination by the leaching out of soluble compounds. b) These techniques avoid the discharge of saline wastewater into the sewerage system. This is achieved by the evaporation of the scrubber liquid from the wet flue-gas treatment system. c) It can remove a significant part of the total amount of heavy metals from the waste IN (Cd and Zn:>85%, Pb and Cu:>33%, Hg:>95%); the leachability of the material is reduced by a factor of 10^2-10^3. Zinc, Cadmium and Mercury are recycled.	a) The investment cost is higher than the solidification process alone. b) These are several times the cost of production of the same salts from natural sources. It is applied for environmental reasons (not economic). c) The process costs of treating the FGT waste are about EUR 150-250/t (including charges for recycling the zinc filter cake).

BAT	Environmental benefits	Economics
86.- Test the leachability of inorganic compounds, by using the standardised CEN leaching procedures and by applying the appropriate testing level: • Basic characterisation, • Compliance testing, or • on-site verification.	An on-site laboratory is the essential element in providing assurance that the necessary process input controls are in place and that a consistent waste OUT is generated.	NA.
87.- Restrict the acceptance of waste to be treated by solidification/immobilisation treatment to waste not containing high levels of VOCs, odorous components, solid cyanides, oxidising agents, chelating agents, high TOC waste and gas cylinders.	This enhances the environmental performance of immobilisation techniques (e.g. reduction of permeability, reduction of specific surface, chemical buffering). Stabilisation is a cold process and consequently does not require energy. The waste OUT of this technique typically has very good physicochemical/ leaching characteristics. As the process is cold, fumes or air pollution are minor. Water permeability of $3.7E10^{-11}$ m/s can be achieved in the final product when cement is used as immobiliser.	Cold processes are considered economically attractive techniques. They typically require simple equipment and incur low investment (concrete mixers, silos, pumps...) and operational costs.
88.- Apply control and enclosure techniques for loading/unloading and enclosed conveyor systems.	See BAT no. 87.	See BAT no. 87.
89.- Have an abatement system(s) in place to handle the flow of air, as well as the peaks associated with loading and unloading.	See BAT no. 87.	See BAT no. 87.
90.- Use at least a) Solidification. b) Vitrification, melting and fusion. c) Other reagents. phosphate stabilisation process before landfilling any solid waste.	a) Cement solidification allows reduced contact between water and waste IN and to some extent the formation of less soluble metal hydroxides or carbonates. **Amphoteric metals can also be treated.** The solidified product is relatively easy to handle, and the risk of dust formation is relatively low. The release of heavy metals from the products in the short term is relatively low. b) An inherent advantage of these processes is the destruction of organic pollutants, i.e**. dioxins**. Thermal treatment facilities reduce the volume to around 30-50% of the input volume. Melting increases the density of the	a) In most cases the waste IN can be delivered to existing plants. Treatment costs for this technique are estimated at about EUR 25/tonne waste IN. EUR 100-500/tonne of input. b) Treatment costs are reported to be in the order of EUR 100-500/tonne of input. Investment costs could be about EUR 20 million for a plant with a capacity to deal with 1-1.5 tonnes/hour.

BAT	Environmental benefits	Economics
	product to typically 2.4-2.9 tonnes/m^3. Vitrification yields the most stable and dense products. c) Fly ash particles can be encapsulated by bitumen, and potential contact with water is thus restricted. This improves the leaching properties of the fly ash; probably allowing less heavy metals to be released than in the case of cement solidification. d) The process retains salts in the waste OUT and produces no wastewater.	c) NA. d) The treatment cost is about EUR 15 per tonne of FGT waste. In addition to this, a royalty is charged for the use of the patented process amounting to EUR 5-10 per tonne. Investment costs are about EUR150,000-500,000 per installation, depending on existing equipment.
91.- Control the rate of excavation; the amount of contaminated soil area that is exposed; and the duration soil piles are left uncovered during the excavation and removal of contaminated soil.	This reduces the fugitive emissions generated by the excavation and removal of contaminated soil. VOC emission control also can be achieved by controlling the operating conditions within present parameters.	NA.
92.- Use a bench-scale test to determine the suitability of the process to be applied and the best operational conditions for its use.	The thermal desorption of soil can treat a wide range of organic contaminants and the systems can be mobile. Thermal desorbers operate at lower temperatures, so significant fuel savings may result when compared to incineration. They also produce smaller volumes of off-gases to be treated.	Typically cheaper than incineration.
93.- Have collection and control equipment in place such as afterburners, thermal oxidisers, fabric filters, activated carbon, or condensers for the treatment of the gases from thermal treatments.	See BAT no. 92.	See BAT no. 92.
94.- Report the efficiency achieved during the processes for the different components reduced and also for those that have not been affected by the process.	See BAT no. 87.	See BAT no. 87.

3.2.3. Recovery of materials from waste

The processes designed to recover the materials or portions of materials contained in waste are typically dependent on the type of waste treated and the materials that are wanted or that need to be produced. The materials produced from these treatments are materials that can be re-used for the same purpose (e.g. lubricant oils) or recovered for other non-energy purposes (e.g. recovery of metals from catalysts). These treatments are called ‘Regeneration’ except for the regeneration of waste oils, where “re-refining” is used.

As these types of techniques are highly specific and they depend on the nature of waste, the type of installation and the possibility of covering costs, an assessment is required prior to their implementation in the Mediterranean Region. However, if a proper collection is carried out, both re-refining of waste oils and regeneration of spent solvents seem to be the most adequate techniques for Mediterranean countries.

3.2.3.1. Recovery of materials from waste: re-refining of waste oils

There are two main options for the treatment of waste oils: the treatment of the waste oils to produce a material that will be used mainly as fuel or for other purposes (e.g. absorbent, mould release oil, flotation oil). In this case, treatments such as the cleaning of waste oils, thermal cracking and gasification are included; the other option is known as re-refining and consists of treating the waste oils to reconvert them into a material that can be used as a base oil to produce lubricants.

The re-use of waste oils requires cleaning or re-refining. The main processes are the following:

- Pre-treatment of waste oils.
- Cleaning of waste oils.
- Fractionation of waste oils.
- Finishing of waste oils.
- Technologies used for the re-refining of waste oils.

The environmental techniques considered in the determination of BATs for re-refining waste oils are as follows. Specific BATs for the re-refining of waste oils are presented in table 3.11:

- Generic techniques to increase the yield of re-refining: sending the residue from the vacuum distillation column to a selectopropane unit, sending the bottom residue from the vacuum distillation column to a thermal cracking unit to produce diesel, selecting the appropriate vacuum in the vacuum distillation units, using a scrubbing unit to reduce VOC emissions and to recover raw material, using sieves to remove matter such as polymer fibre, having in place an intermediate tank between the dehydrotreatment and the distillations.
- Selection of waste oils to be re-refined. Waste oils suitable for recycling are (see BAT 96):
  - a) (Black) engine oils, which have homogeneous characteristics and are sought by re-refining plants,
  - b) black industrial oils are potentially suitable for regeneration but due to the content of additives other substances are not typically preferred by re-refining plants, and
  - c) light industrial oils, which are relatively clean.
- Distillation/clay process. See BAT 100.
- Distillation and chemical treatment or solvent extraction: this consists of a series of vacuum cyclone evaporators followed by the chemical treatment of the lubricating oil cuts obtained.
- Solvent extraction process and distillation: the Interline propane extraction process comprises three stages and no final step is required: chemical pre-treatment with reagents and catalysts, liquid propane extraction of the lubricant bases, separating water and asphalt and atmospheric and vacuum distillation, to separate the light fractions and the base oils for lubricants. See BAT 101.
- Thin film evaporator and different finishing processes: vacuum distillation is a common component in many re-refining plants. A technique to consider is to apply mechanical seals on rotating shafts in wiped thin film evaporators.

- Thermal de-asphalting oil refinery. See BAT 102.
- Hydrotreatment: a technique to consider is to scrub or incinerate the acid off-gases from hydrotreatments.
- Direct contact hydrogenation process.
- Solvent extraction.
- Caustic soda and bleaching earth treatment.
- Treatment in a refinery: there are two possible mixing options in refineries:

  a) Mixing the feedstock (typically crude oil):

  The pre-treated oil is mixed with the crude oil and the blend passes through the desalter before it is fed to the crude oil distillation unit of an existing refinery.

  b) Blending into the vacuum residue:

  Pre-treated waste oil is used as a supplementary component to be mixed with the bottom product in the vacuum column.
- Water management in waste oil re-refining installations: ensuring that any effluent water is treated before discharge, using a wastewater treatment unit, re-using the cleaned wastewater as cooling water by applying a suitable treatment and by generating water products that may be re-used outside the installation and feeding the effluent water to the heater along with the oils in order to incinerate the harmful constituents.
- Waste management in waste oil treatment installations: burning the non-lubricant recovered oils in a heater equipped with a gas scrubber to provide energy for the plant, treating and disposing of all used filters, applying a thermal treatment to all residues and using the residues from the vacuum distillations and evaporators as asphalt products. See BAT 104.

The specific applicability of some of these techniques is as follows:

- Operating a careful control of the incoming materials: this technique is fully applicable to 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.
- Checking at least for chlorinated solvents and PCBs. the following waste oils can be re-recyclable:

  a) engine oils without chlorine,

  b) hydraulic oils without chlorine,

  c) non-chlorinated mineral diathermic oils,

  d) engine oils with chlorine,

  e) hydraulic oils with chlorine.
- Using condensation as a treatment for the gas phase of the flash distillation unit: used where only relatively small volumes or low flows (50-100 Nm^3/h[9]) need to be treated, and when liquid nitrogen is available and the concentration of VOCs is quite high. This technology is available for stable volumes and concentrations.
- Having vapour return lines:

  a) Thermal oxidiser: applications include treating the emissions from oil reprocessing heating vessels, which also incorporates recovery of the oil components. Condensation can be

[9] Nm^3/h: normal cubic metre/hour

used as a pre-treatment for thermal oxidation, reducing the fuel requirement and the overall size of the oxidiser required. Needs prior dilution with air when an explosive concentration may be reached.

b) Activated carbon adsorption: this is used for the reduction of VOCs, odours and fugitive emissions; it is also used as an abatement technique for local extraction points, in the treatment of air emissions from soil washing, soil solvent extraction, from soil flushing, aerosol can treatment, biological treatment plants and Ph-c. It is not suitable for the abatement of air emissions from an oil re-processing heating vessel or for high concentrations or small molecules, or if dust is present, and it cannot be adapted to some molecules (e.g. acetone).

- Directing vent streams to a thermal oxidiser with waste gas treatment:

  a) Condensation: this can be used as pre-treatment for thermal oxidation, reducing the fuel requirements 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[10].

  b) Caustic scrubbing: a common use is the treatment of extracted air from the reactor vessel with scrubber liquor (a caustic solution). The process is extensively applied in Ph-c plants.

- Using a waste oil re-refining process:

  a) Generic techniques: the most suitable are those that are not too heavily polluted, have a high viscosity index and an absence of esters and biolubricants.

  b) Distillation and chemical treatment: medium sized plants (25 kt/yr[11]).

  c) Solvent extraction process: there is a possibility of re-refining in areas with low production of waste oil.

  d) Thin film evaporator: the size of these installations ranges from 25-160 kt/yr.

  e) Thermal de-asphalting process: this is applied in large and small installations (100-108 kt/yr and 40-100 kt/yr).

  f) Solvent extraction: fully applicable in the sector.

  g) Caustic soda: applied to waste oils.

[10] kg/h: kilogram/hour

[11] kt/yr: kiloton/year

Table 3.11: BATs for recovery of materials from waste: re-refining waste oils

BAT	Environmental benefits	Economics
95.- Operate a careful control of the incoming materials supported by analytical equipment (viscometer, infrared, chromatography and mass spectrometry as appropriate), laboratories and resources.	This improves knowledge of the potential environmental issues related to the waste to be treated and reduces the risk of accidents or bad operations. See BAT no. 6.	Estimation shows that the investment in analytical equipment for waste oil treatment facilities is in the order of EUR 75,000 per site. See BAT number 6.
96.- Check at least for chlorinated solvents and PCBs.	Segregated used lubricants can have a higher recovery value as fuel and as a new material for re-refining. If chlorinated compounds are prevented from entering the re-refining process, then operational and environmental problems can be avoided. See also BATs nos. 6 and 95.	NA. See BATs nos. 6 and 95.
97.- Use condensation as a treatment for the gas phase of the flash distillation unit.	The condensed VOC 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.	Typically high operating cost. Operational cost of EUR 2/t solvent treated for a liquid nitrogen condenser.
98.- Have vapour return lines for loading and unloading vehicles, routing all vents to a) A thermal oxidiser/incinerator, or b) An activated carbon adsorption installation.	a) Synergy with existing combustion facilities. It allows energy recovery from burning the VOCs in the combustion. b) The used activated carbon can be recovered several times or may be used as fuel; adsorption on activated carbon presents similar efficiency to those of thermal oxidisers but less risk of flash fire, back into the vehicles being loaded/ unloaded. Emissions of VOCs from the carbon trap (chlorinated solvents) are 8-32 ng/Nm^3 or 215 kg/yr, when cleaning used oils. See also BATs nos. 28 and 63.	a) 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. b) This offers low operating costs for low concentrations of VOC and there is an additional cost for the renewal of the activated carbon. See also BATs numbers 28 and 63.
99.- Direct vent streams to a thermal oxidiser with waste gas treatment if chlorinated species are present in the vent stream. If high levels of chlorinated species are present then	a) Chloroform emissions can be as little as 20 mg/Nm^3. b) This increases the efficiency of pollutant adsorption (particularly relevant for the removal of acid gases by basis particles injected at the scrubber, if applicable). c) See BAT no. 98.	a) Typically high operating cost. b) NA. c) See BAT no. 98.

BAT	Environmental benefits	Economics
a) condensation followed by, b) caustic scrubbing, and activated carbon guard bed is the preferred treatment path.		
100.- Utilise thermal oxidation at 850°C with a two seconds residence time for the vacuum distillation vent of vacuum generators or for the air from process heaters.	NA.	NA.
101.- Use a highly efficient vacuum system.	This increases the efficiency of the waste oil re-refining treatments.	NA.
102.- Use the residues from vacuum distillation or thin film evaporators as asphalt products.	This reduces the amount of residues generated by the treatment.	NA.
103.- Use a re-refining process of waste oil which can achieve a yield higher than 65% on a dry basis.	Yields higher than 65% can be achieved using a suitable combination of the following techniques: a) Generic techniques to increase the yield or re-refining, b) Selection of waste oils to be re-refined, c) Distillation/clay process, d) Distillation and chemical treatment or solvent extraction, e) Solvent extraction process and distillation, f) Thin film evaporator and different finishing processes, g) Thermal de-asphalting process, h) Recycling in a lubricating oil refinery, i) Hydrotreatment, j) Direct contact hydrogenation process, k) Solvent extraction, and l) Caustic soda and bleaching earth treatment.	a) NA. b) NA. c) NA. d) The investment cost of 108 kt/yr installation is USD 29 million. e) Reduced capital and operating costs. f) The investment cost of 108 kt/yr installations is USD 43 million. g) The cost of a TDA clay installation with a capacity of 100 kt/yr is EUR280/t oil for a TDA hydro-installation of EUR304/t oil. h) Capital cost USD45 million. i) The capital cost is very high. j) Economically attractive high quality products and a higher yield per tonne of input. k) Cheaper than the hydrofinishing option. l) There are high quality products and a higher yield per tonne of input.

BAT	Environmental benefits	Economics
104.- Achieve the following values in the discharged wastewater from the re-refining unit: Hydrocarbons: <0.01-5 ppm[12]; Phenols: 0.15-0.45 ppm by using a combination of process-integrated techniques and/or primary, secondary, biological and finishing treatments.	TOC levels variable depending on type of waste treatment.	NA.

3.2.3.2. Recovery of materials from waste: regeneration of waste solvents

There are two main alternatives for the treatment of waste solvents:

a) The utilisation of the calorific value by using them directly as a fuel or blended with other fuels.

b) Treatment of the waste solvent to reconvert it into a material that can be re-used as solvent (regeneration).

Solvent regeneration is a common practice in many industries such as chemical, pharmaceutical and painting; with a wide range of solvents currently being regenerated, the most common are:

- Alcohols: ethyl, isopropyl.
- Aliphatics: hexane, heptane.
- Aromatics: benzene, aromatic naphta, toluene, xylene, turpentine.
- Chlorinated: trichloroethylene, perchloroethylene, methylene chloride.
- Esters: ethyl acetate, butyl acetate.
- Ketones: Methyl ethyl ketone, methyl isobutyl ketone.
- Mixture of solvents: toluene/xylene, alcohols, ketones, phenols, toluene/heptane.

Environmental techniques considered in the determination of BATs (selected BATs for this category are detailed in table 3.12) are as follows:

- Selection of waste solvents to be recycled. Waste solvents composed of monostreams are typically regenerated. A waste solvent can be considered regenerative if, for example, it is a monostream (one batch from one waste generator), it yields a minimum of 60% distillate, it has a certain minimum amount per load and the costs of distillation are the same as or lower than for incineration. See BAT 105.
- Improvement of regeneration treatment of waste solvents: applying azeotropic distillation, applying vacuum distillation, using thin-film evaporators, heating the feed stream with the distillate by means of a heat-exchanger and insulation measures, applying cascade re-use of solvent, using vapour balancing systems and directing the waste gas to abatement techniques

[12] ppm: parts per million

(e.g. activated carbon filtration, enclosed systems and using vapour balance lines during loading), using distillation for the separation of organic solvents from solids, using rectification for the removal of contaminating substances and achieving a certain quality of the waste OUT and dewatering by means of a decanter if the solvents contain water.

- Wastewater treatment in waste solvent facilities: bio-reactors, wastewater staple tanks, wastewater intermediate storage tanks und ultrafiltration facilities.
- Evaporation or distillation residues. Vacuum dryer and other drying techniques are in use for distillation bottoms. See BAT 106.
- Full automation of residue incineration. In a solvent distillation plant the discharge of the distillation sludge is optimised. For working and environmental protection reasons the process of discharge is now fully automated. Because of the high heating value the transfer of the sludge to the in-house incineration plant is fully automated.

Table 3.12: BATs for recovery of materials from waste: regeneration of waste solvents

BAT	Environmental benefits	Economics
105.- Operate a careful control of the incoming materials as supported by analytical equipment, laboratories and resources.	See BAT no. 95.	See BAT no. 95.
106.- Evaporate the residue from the distillation columns and to recuperate the solvents.	This increases the percentage of solvent recovered - 99% of the container solvent. Resins and pigments may also be recovered. At the same time, they may reduce odour and VOC emissions that may be generated by the bottoms.	Investment costs of EUR1.2 million. Operating costs vary between EUR100 and 150 per tonne of residue treated.

3.2.3.3. Recovery of materials from waste: regeneration of waste catalysts

Although there are other alternatives to regenerate spent catalyst, only ex-situ regeneration installations have been considered for this review. This section also includes information on the recovery of components from waste generated by abatement techniques.

Catalysts from the refinery industry such as those used in hydrotreating, hydrocracking, reforming and isomerisation are typically regenerated. The metals that are typically economically interesting to recover are Rh, Cd, Pt, Ir, the Nickel Raney and some petroleum catalysts with Ni-Co, Co-Mo, Co.

The main techniques considered in the determination of BATs (which are presented in table 3.13) for regeneration of waste catalysts are as follows:

- Generic techniques used in the treatment of waste catalysts: applying heat recovery in the form of energy production or recuperation. To this end, recuperative burners, heat-exchanges and boilers can be used to recover heat; using oxygen or oxygen-enriched air or oxygen in the burners, preheating the combustion air used in burners, preheating the material charged to the furnace and automatically controlling the point of extraction using dampers and fan controls so that the systems are deployed when and where they are needed, for example, during charging or during “roll out” of a converter. See BAT 107.
- To improve control of the process: adjusting the temperature levels and residence time of the catalyst in the unit, in order to achieve desired levels of carbon and sulphur, applying cooling prior to a bag filter installation, using sealed furnaces, which can allow very highly efficient capture of the fumes, using ducts and fans to convey the collected gases to abatement or treatment processes, etc.

- Abatement techniques used in the waste catalyst regeneration sector: fabric filter and wet scrubber. See BAT 108.

Fabric filters are typically used as secondary or tertiary gas cleaning devices in combination with a cyclone or a dry scrubber located upstream; they are suitable for high flow, low concentration (e.g. 1-200 mg/Nm^3), low temperature gas streams and when the pollutant is chemically reactive. However, they are not suitable for use in moisture-laden streams or those with acidic, tarry or sticky characteristics.

Table 3.13: BATs for recovery of materials: regeneration of waste catalyst

BAT	Environmental benefits	Economics
107.- Use bag filters to abate particulates from the fumes generated during the regeneration process.	• High collection efficiency for both coarse and fine particles, • Efficient with a high concentration range, • Collected dust may be re-used in the process, and • High collection efficiency at high temperatures, if special materials e.g. Teflon are used.	NA.
108.- Use SO_X abatement system.	Scrubbing reduces emissions to air of VOCs, acids, ammonia, particulates, etc. and increases the efficiency of pollutant adsorption. See BAT no. 107.	The costs vary with chemical use. See BAT no. 107.

3.2.3.4. Recovery of materials from waste: regeneration of waste activated carbon

The purpose of this technique category is to treat the spent activated carbon to produce a material with properties and qualities very similar to the original activated carbon. Thermal treatments are the main processes used for regeneration. During the process, drying, thermal desorption and heat treatment are carried out. This activity is only applicable to extruded or granular activated carbon and is not suitable for powdered carbon.

The techniques to consider in the determination of BATs are as follows:

- Choice of furnace used to regenerate the waste activated carbon: the options are "multiple hearth furnaces", "direct fired rotary kilns" and "indirect heated kilns" (where there is no contact between the kiln content with flue-gases generated from a burner).
- Flue-gas treatment: using an afterburner for the gases exiting the furnace or kiln, designing the regenerator and associated ducting and equipment to operate under reduced pressure, in order to prevent the escape of regenerator gases into the air, applying heat recovery, cooling the flue-gases with a quench section or venture scrubber, etc. See BAT 114 in table 3.14.
- Wastewater treatment plants: these processes need a system for the treatment of the liquid effluent generated in the flue-gas treatment plant. Some techniques include:
  a) Applying two-stage hydroxide precipitation at different pH values,
  b) Utilising sulphide precipitation to remove metals,
  c) Utilising flocculation,
  d) Settlement,
  e) Filtration or centrifuges to separate the suspended materials,

f) Adjusting the pH to promote the precipitation of specific chemicals,

g) Achieving an acceptable effluent, etc. See BAT 116 in table 3.14.

- Pollution control techniques applicable to activated carbon regeneration: primary measures for particulate control (applicability in furnace temperature, turning rate of the rotary furnace and fuel type), secondary measures for particulate and acid gases control (mechanical collectors, wet and dry scrubbers, electrostatic precipitators and fabric filters), primary measures for NO_x control (reduce furnace and combustion temperatures, reduce the excess air and thus lower the concentration of atomic oxygen in higher temperature zones, reduce residence time in all higher temperature areas, control the furnace heat release rate, and eliminate high temperature peaks, etc.) and secondary measures for NO_x control (selective catalytic and non-catalytic reduction, the SO_x, NO_x, RO_x BOX).

The specific applicability of some of the previous techniques (BATs are shown in table 3.14) is as follows:

- Having an effective quality control procedure: waste gas treatment facilities may vary depending on the application for which the carbon has been used. More stringent requirements may be needed for carbon that has been used for industrial applications.
- Requiring a written undertaking: this is widely applied in the WT sector. In small WT plants, traceability systems may be difficult.
- Utilising an indirect fired kiln for industrial carbons: for the treatment of industrial carbons where more onerous temperature criteria apply to the afterburner.
- Having a WWTP containing an appropriate combination of treatments: applied to the effluent from quenching or scrubbing flue-gas treatment.

Table 3.14: BATs for recovery of materials: regeneration of waste activated carbon

BAT	Environmental benefits	Economics
109.- Have an effective quality control procedure in place to ensure that the operator can differentiate between the carbon used for potable water or food grade carbon and other spent carbons (the so-called "industrial carbons").	This reduces the emissions of flue-gas generated.	For carbons used in industrial applications, more expensive abatement measures may be required.
110.- Require a written undertaking from customers indicating what the activated carbon has been used for.	This provides documentary evidence of the treatment given to a certain waste.	NA
111.- Utilise an indirect fired kiln for industrial carbons –it may be argued that this could equally be applied to potable water carbons. However, limits on capacity and corrosion may deem that only multiple hearth or direct fired rotary kilns may be used.	These offer the advantages of eliminating the need for the mixing of burner flue-gases with process gases. The lower volume of gas requiring heating saves on energy and the size of abatement equipment. Burner flue-gas that has indirectly heated the kiln is then directed to the base of the stack where it may be combined with the kiln off-gases to reduce the visibility of the emitted plume.	NA

BAT	Environmental benefits	Economics
112.- Utilise an afterburner with a minimum of 1100°C, two seconds residence time and 6% excess oxygen for the regeneration of industrial carbons where refractory halogenated or other thermally resistant substances are likely to be present.	See BAT no. 109.	See BAT no. 109.
113.- Utilise an afterburner with a minimum heating temperature of 850°C, two seconds residence time and 6% excess oxygen for potable water and food grade active carbons.	See BAT no. 109.	See BAT no. 109.
114.- Apply a flue-gas treatment train consisting of quench and/or venturi and aqueous scrubbing sections, followed by an induced draft fan.	See BAT no. 109.	See BAT no. 109.
115.- Utilise a caustic or soda ash scrubbing solutions to neutralise acid gases for industrial carbon plants.	See BAT no. 109.	See BAT no. 109.
116.- Have a WWTP containing an appropriate combination of flocculation, settlement, filtration and pH adjustment for the treatment of potable water carbons. For effluents of industrial carbons, applying additional treatments (metal hydroxide, sulphide precipitation) are also considered BATs.	The achievable release levels for key substances in the context of the processes concerned are: • suspended solids: 50 mg/l; • cadmium: 5 µg/l[13]; • mercury: 1-10 µg/l; • other heavy metals: <0.5 mg/l; • simazine and atrazine: 1 µg/l.	NA.

3.2.3.5. Recovery of materials from waste: regeneration of resins

Regeneration of ion exchange resins can take place by applying a pH balancing system or by applying hot water. Hot water is only possible for thermally stable resins.

[13] µg/l: microgram/litre

3.2.4. Preparation of waste to be used as fuel

These treatments and processes are mainly applied to obtain a material, prepared from waste, to be used as fuel or to change its physicochemical properties to allow better recovery of its calorific value. Some treatments may produce outputs that may be used for other proposes other than as fuel. These processes are very similar and only depend on the physical properties of the starting waste and the physical properties that the waste OUT needs to have to be able to be burned in a combustion chamber.

Waste which has some calorific value is currently used as fuel in certain combustion processes, e.g. waste incineration, cement or lime kilns, large combustion plants, heating plants, chemical works, industrial boilers, ceramic plants, brick production, iron and steel production, non-ferrous metal production. Some of the sectors using waste as fuel are directly linked to the production of that waste. This implies that some waste may not need any further preparation for its further use in that sector. However, this section considers the transformation of different types of waste into a material suitable for use as fuel in different processes: cement or lime kilns, waste incineration, large combustion plants and other sectors.

The subsequent use as fuel of these types of waste by different industrial sectors has been developed in chapter 5.

In the Mediterranean region, three key issues should be considered prior to the development of facilities preparing waste to be used as fuel: (a) the existence of industrial installations available for the use of hazardous waste as fuel, (b) the calorific value of available waste, and (c) the need for prior treatment for this waste.

3.2.4.1. Preparation of solid waste to be used as fuel

The following techniques are considered to have good environmental operating performance in terms of the preparation of solid waste:

- Drying the solid waste fuel: depending on the water content and the physical characteristics of the waste, a first step of dewatering can be applied. It may consist of one of the following operations:
  a) gravity thickening,
  b) centrifugal thickening,
  c) flotation thickening,
  d) gravity belt,
  e) rotary drum thickening.
- Magnetic separation of ferrous metals: installing an overband magnetic separator lengthwise over the conveyor belts right above the trajectory of the material, re-sorting the material with a magnetic drum separator or with a magnetic pulley, since small ferrous particles could still remain under a non-magnetic layer, increasing the conveyor belt's velocity gaining a low level of the material and using the overfed feed design for the magnetic drum separator.
- Separation of non-ferrous metals: conditioning the grain size of the non-ferrous elements of the waste to be between 3 and 150 mm before their separation by an eddy current separator, using a high frequency alternating magnetic field in order to improve the separation of fine-grained non-ferrous metal, positioning the magnetic pole system eccentrically, etc.
- All-metal separators: in the preparation of solid waste fuel, all-metal separators are applied to plastics processing. High throughputs can be obtained if the material is diversified before auto recognition. Normally, all-metal separators operate with a detection coil which is placed transverse to the direction of transport and cut into single segments.
- Positive and negative sorting: positive sorting means that only the desired materials with high calorific values and low contents of harmful substances are sorted out of the material flow. This

strategy leads to a higher amount of landfill material and often to a higher quality of the solid waste fuel produced. Negative sorting strategies only separate the materials which are not desired in the product. With this strategy the amount of landfill material might be less because other materials which might contain a higher content of harmful substances end up in the product.

- Use of pneumatic assistance for size reduction: the use of pneumatic assistance for processing the material discharged from comminution (size reduction).
- Drum screens: the best results are obtained at a rotational speed of 70% of the critical speed in the cataract mode. The disadvantage of the cascade mode is that the screen will create lumps and fines will not be well liberated.
- Improvements of the dust filters in the cyclones of air classifiers: reuse of the air that has been used for air classifiers and blow-down. Approximately 30% of the air of the circular flow is discharged on the pressure side of the ventilator and cleaned by a dust filter.
- Near infrared spectroscopy: material which has to be separated is often fed on a belt conveyor. The conveyor usually operates at fast velocities so that its function is almost like an isolating device. The detector consists of a near infrared spectroscopy sensor which scans the whole width of the belt conveyor and transmits the characteristic spectrums of the different materials to a data processor.
- Automatic picking: the material passes a vibrating chute which feeds a conveyor belt. A metal detector is located under the conveyor belt, which sends specific data for each particle to the computer unit.
- Pelletising and agglomeration: disc agglomerators consist of a metal housing with one or more discs inside. The inner side of the reactor is filled with material discontinuously. The discs, which have superstructures to stir the material much better, start to rotate, converting frictional energy into frictional heat. At the moment the material begins to plasticize, the energy consumption rises and can provide the signal to empty the reactor.
- Cryogenic grinding: cryogenic grinding is a treatment of size reduction and sieving of deep cooled full and empty packaging in an inert atmosphere. The aim is to separate the used packaging of paint, ink, and similar substances into fractions, e.g. to be used as fuel and as secondary metals and plastic but reducing the emissions of VOCs and volatile compounds due to the low temperatures used.

Some of these techniques are generic, so they can be easily applied; however, others have specific applications:

- Try to have a close relationship with the waste fuel user: the actual blend of waste solvents in particular is set by a good knowledge of the constituents, in order to meet calorific values and limits on pollutants, e.g. chlorine and heavy metals.
- When producing waste fuel from hazardous waste: adsorption is simple and reliable and batch operation is possible.
- When producing waste fuel from hazardous waste: provision of full details on the activities to be carried out: this is fully applicable in all WT plants. Techniques to prevent accidents: Some of the techniques are WT sector specific but others are very general. Some are only relevant for hazardous waste treatment.

Table 3.15 shows BATs selected for preparation of waste to be used as fuel.

Table 3.15: BATs for preparation of waste to be used as fuel

BAT	Environmental benefits	Economics
117.- Try to have a close relationship with the waste fuel user in order that a proper transfer of the knowledge of the waste fuel composition is carried out.	Knowledge of possible emissions and any operational problems that may be generated.	NA.
118.- Have a quality assurance system to guarantee the characteristics of the waste fuel produced.	See BAT no. 117.	See BAT no. 117.
119.- Manufacture different types of waste fuel according to the type of user (e.g. cement kilns), the type of furnace (e.g. grate firing, blow feeding) and the type of waste used to manufacture the waste fuel (e.g. hazardous waste).	This provides the user with the required physicochemical properties of waste fuel.	NA.
120.- When producing waste fuel from hazardous waste, use activated carbon treatment for less polluted water and thermal treatment for highly polluted water. Thermal treatment relates to any thermal treatment or incineration. See BATs on hazardous waste incineration (chapter 4).	The benefits are the final “polishing” of the effluent and the recovery of substances from the effluent before its reuse or its emission to the sewer, surface waters etc. See also BAT no. 104.	NA. See also BAT no. 104.
121.- When producing waste fuel from hazardous waste, ensure correct follow-up of the rules concerning electrostatic and flammability hazards for safety reasons. Use the following techniques: a) Provision of full details on the activities to be carried out. b) Techniques to prevent accidents and their consequences.	a) This helps assess operators’ proposals and in particular the opportunities for further improvements. b) The most significant environmental risk associated with WT is from the storage of HW, from emissions resulting from waste reacting together either from leaks or spillages, or from treatments that are out of control.	a) NA. b) NA.

3.2.4.1.1. Preparation of solid waste fuels from hazardous waste

The goal of the preparation of such fuel is to make a tailor-made, homogeneous, and free-flowing waste fuel, which can be used in combustion processes and this may also make it easier for it to be treated/used. The types of waste used are pasty, powder and solid waste, mainly hazardous and, in some specific cases, some liquid waste. The process consists of mechanical preparation of solid waste fuel by the impregnation of waste over a support. Main users are co-incineration plants such as cement kilns. Table 3.16 shows the BATs selected for preparation of solid waste fuel from hazardous waste.

Table 3.16: BATs for preparation of solid waste fuel from hazardous waste

BAT	Environmental benefits	Economics
122.- Consider emissions and flammability hazards in case a drying or heating operation is required.	This cleans and reduces emissions from the treatment of liquid waste. It is crucial to the sale of the liquid waste fuel that any high solids content that the warm oil retains, is removed. See also BAT no. 121.	NA. See also BAT no. 121.
123.- Consider carrying out the mixing and blending operations in closed areas with appropriate atmosphere control systems.	This reduces fugitive emissions (e.g. VOCs, particulates) and spillages. See also BAT no. 122.	NA. See also BAT no. 122.
124.- Use bag filters for the abatement of particulates.	See BAT no. 107.	See BAT number 107.

3.2.4.2. Preparation of liquid waste to be used as fuel

The aim is to obtain a liquid waste fuel able to become fluid and move when a different of pressure or gravity is applied. Some of the materials produced may be very viscous and can be very difficult and expensive to pump. The waste OUT of these treatments are referred to as 'liquid waste fuel' regardless of whether the fuel is semi-liquid or liquid.

Typically, the materials prepared by this type of treatment are hazardous waste. Several liquid waste fuels can be prepared according to the different waste and market requirements:

- Organic liquid preparation by blending.
- Fluidification.
- Emulsions.
- Sludges (emerging technique).

The techniques considered in the determination of related BATs are:

- Generic techniques for the preparation of liquid waste fuel: using heat-exchange units external to the vessel, using carbon adsorption or condensation to avoid VOC emissions, removing the high solid content from liquid waste to be used as fuel, removing oil from liquid effluent prior to discharge to foul sewers or other water, ensuring that in a multi-chamber oil interceptor every single chamber oil interceptor is large enough to allow six minutes retention at maximum foreseeable flow rates and using a vertical agitator without any bearing inside the tank.
- Thermal cracking of waste oils. See solvent extraction.
- Membrane filtration as a mild processing of waste oils have a pre-treatment to protect the membrane system.

3.2.4.2.1. Preparation of liquid waste fuels from hazardous waste

There are two possible processes: blending and fluidification.

Blending processes are based on the control of mixing by means of the addition of selected chemicals or tensides and they result in emulsions which are typically produced from hazardous waste such as oils and emulsions from the mechanical and metallurgy industries, waste and sludges containing oil from petroleum refining, production failure, etc. Main users are co-incineration plants such as cement kilns.

Fluidification processes are those where liquid, pasty and solid waste is homogenised and shredded together in order to produce a liquid which can be used as fuel. Typical input waste is oil residues, used solvents, residues from organic chemical synthesis, oil and grease, etc.

Main users are co-incineration plants such as cement kilns.

The related BATs are presented in table 3.17.

Table 3.17: BATs for preparation of liquid waste fuel from hazardous waste

BAT	Environmental benefits	Economics
125.- Use heat-exchange units external to the vessel if heating of the liquid fuel is required.	See BAT no. 122.	See BAT number 122.
126.- Adapt the suspended solid content to ensure the homogeneity of the liquid fuel.	See BAT no. 122.	See BAT number 122.

3.2.4.2.2. Treatments of waste oil when waste OUT is basically used as fuel

The treatment of waste oil to reconvert it into a material that can be used as a base oil to produce lubricants, the re-refining process, is described in section 3.2.3.1.

In this section, the treatments covered are those where waste oil, due to its calorific value, is treated to produce a material that will be mainly used as fuel or for other uses (e.g. absorbent, mould release oil, flotation oil).

When used as a substitute fuel, principally for coal, diesel and light fuel oil, used oil has an economic value. A number of different burning applications for used oil exist, distinguishable partly by the temperature at which they burn and partly by the control technology they use to reduce environmental effects. Before its use as fuel (developed in section 5), several cleaning or transformation treatments may need to be applied, e.g.:

- Direct burning of waste oils: cement kilns, waste incinerators, blast furnaces and large combustion plants.
- Mild reprocessing of waste oils: cleaning treatments involving the settling of solids and water, chemical demineralisation, centrifugation and membrane filtration.
- Severe reprocessing: separates the combustible waste oil portion from the less desirable bottom fraction which contains the metals, the non-combustible ash, grit and dirt.
- Thermal cracking: uses heat to break long-chain hydrocarbon molecules into shorter ones, thus generating lighter liquid fuels. This is a refinery process.
- Hydrotreatment: catalytic hydrogenation in the mineral oil industry.

3.2.4.3. Preparation of gaseous fuel from waste

There are two ways of producing gaseous fuel from waste:

- Gasification of the waste at high temperatures by partial oxidation and then conversion of materials containing carbon into synthesis gas (mainly H_2 and CO).
- Production of biogas, mainly methane, by the anaerobic digestion of waste (covered by section 3.2.1 on biological treatments).

This is an option for the reuse of waste oil as well as other types of waste, especially when gas fuel has a use on-site.

3.3. TECHNIQUES FOR THE ABATEMENT OF EMISSIONS

Many non-production techniques exist for the waste treatment sector. In particular, techniques used to control and abate emissions to air, water, residues and soil.

As they consist of end-of-pipe techniques, they should be applicable in the Mediterranean region and, in particular, in the hazardous waste treatment sector.

3.3.1. Air emission 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.

The following techniques are to prevent or control the emissions mainly of dust, odours and VOCs and some inorganic compounds. They consist of restricting the use of open-topped tanks, vessels and pits, using an enclosed system with extraction, or under depression, to a suitable abatement plant, applying a suitably sized extraction system, correctly operating and maintaining the abatement equipment, having a scrubber system, having leak detection and repair procedures and reducing air emissions using preventive and/or abatement techniques.

The specific applicability of some of these BATs (the complete list can be observed in table 3.18) is as follows:

- Restricting the use of open topped tanks: this is typically applied to the storage of waste that may cause fugitive emissions (e.g. VOCs, particulates).
- Using an enclosed system with extraction: there are severe limitations to the use of complete enclosures on the few sites where other control options are not acceptable.
- Correctly operating and maintaining the abatement equipment: this is suitable for high flow, low concentration (1-200 mg/Nm^3 VOC), low temperature gas streams and when the pollutant is chemically reactive (or soluble in the case of VOC pollutants). It is 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 directly to a stack or vent. It can also be used for the treatment of off-gases generated during the loading of storage tanks.
- Having a scrubber system: acid scrubbers are applied to capture 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.
- Having leak detection and repair procedures: 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).
- Reducing air emissions.
    a) Generic prevention techniques: synthetic covers are typically used to control VOC emissions.
    b) Leak detection and repair programme: suitable for sites that contain a large number of piping components.
    c) Cyclones: may only be used in combination with a bag filter and are not efficient at separating small particles.
    d) ESP: not suitable for organic particles.
    e) Fabric filter: used for both fugitive emissions and point source emissions to air.
    f) Lamella separators: only used for the separation of rough dust particles.

g) Adsorption: used for the reduction of VOCs.

h) Condensation: concentration of VOCs is quite high.

i) Temporary and long-term foams: commonly used to control VOC emissions during the remediation of HW sites containing volatile toxic compounds.

j) Biofilters: these are used for scrubbing large volumes of exhaust gas streams which carry low organic loads. Suitable for high flow, low concentration, low temperature gas and when the pollutant is soluble.

k) Incineration: there are no limits on its application.

l) Combined combustion: needs prior dilution with air when an explosive concentration may be reached.

m) Catalytic combustion: given the interfering factors, the practical applicability seems problematic.

Table 3.18: BATs for air emissions treatments

BAT	Environmental benefits	Economics
35.- Restrict the use of open-topped tanks, vessels and pits by: • Not allowing direct venting or discharges to air. • Keeping the waste or raw materials under cover or in waterproof packaging (see also storage and handling). • Connecting the head space above the settlement tanks to the overall site exhaust and scrubber units.	This reduces fugitive emissions (e.g. VOCs, particulates) and spillages.	NA.
36.- Use an enclosed system with extraction, or under depression, to a suitable abatement plant. This technique is especially relevant for processes which involve the transfer of volatile liquids, including during tanker charging/discharging.	The enclosure collects 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.	The capital cost of the structure for total enclosure is relatively high. Operating costs can also be very high if large volumes of air must be treated and exhausted to keep the concentration of pollutants in the internal atmosphere within the dome at levels that are safe for workers' health.
37.- Apply a suitably sized extraction system which can cover: the holding tanks, pre-treatment areas, storage tanks, mixing/ reaction tanks and the filter press areas; or have in place a separate system to treat the vent gases from specific tanks.	Activated carbon filters from tanks holding waste contaminated with solvents reduce fugitive emissions to the air (e.g. VOCs and odour.	See BAT no. 36.
38.- Correctly operate and maintain the abatement equipment, including the handling and treatment/disposal of spent scrubber media.	The scrubber reduces emissions to air of VOCs, acids, ammonia, particulates, etc. Increased efficiency of the 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).	A summary of scrubbing costs for emission controls for area sources applied to excavation and removal are: Emission control technique: water spray: 0.001 (USD/m^2[14]) as material cost. Assuming municipal water cost of 1USD/1000 litres. Water requires constant re-application. Water truck rental: 500 USD/week.

[14] USD/m^2: American dollar/square metre

BAT	Environmental benefits	Economics
		Emission control technique: additives: surfactant: 0.65 USD/m^2; Hygro salt: 2.58 USD/m^2; Bitumen/adhesives: 0.02 USD/m2. Costs vary with chemical use.
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 in certain pre-treatment systems if the discharge is incompatible or too concentrated for the main scrubber. (See also BAT no. 38)	See BAT no. 38.	See BAT no. 38.
40.- Have leak detection and repair procedures in place in installations handling a large number of piping components and storage and compounds that may leak easily and create an environmental problem. This may be seen as an element of the EMS (see also the chapter on Environmental Management).	The leak detection and repair programme detects leak of VOCs from valves, pumps and other piping components.	The cost of a leak detection survey and associated repairs can be partially offset by savings from reduced materials loss to the air. Savings are dependant on the value of the material being lost.
41.- Reduce air emissions to the following levels: EMISSION LEVELS (mg/Nm^3): VOCs: 7-20 (for low VOC loads, the higher end of the range can be extended to 50). PM: 5-20	The reduction of air emissions can be achieved by using a suitable combination of air emission BATs (nos. 35 to 41) and the following techniques: a) Generic prevention techniques. b) Leak detection and repair programme. c) Cyclones. d) Electrostatic precipitators (ESP). e) Fabric filter. f) Lamella separators. g) Adsorption. h) Condensation. i) Temporary and long-term foams. j) Biofilters. k) Scrubbing.	a) NA. b) It can be partially offset by savings from reduced material losses to the air. c) These are relatively cheap. d) NA. e) NA. f) NA. g) Low operating costs for low concentrations of VOCs. h) Typically high operating cost. i) NA. j) They have lower operating costs than other air pollution control technology. k) NA. l) The cost-efficiency of the operation is determined by the size of the flow volume to be treated and by the pollutant concentrations.

BAT	Environmental benefits	Economics
	l) Incineration. m) Combined combustion. n) Catalytic combustion. o) Oxidation treatments. p) Combined treatment of exhaust air.	m) Adaptation costs can be high. n) The cost of investment is relatively high. o) NA. p) NA.

3.3.2. Wastewater management

This section only covers the management of wastewater after it has already been contaminated.

The main purpose of wastewater 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 solid particles, desorption of waste from solid particulates, contact between organic waste and micro-organisms and oxidation of the slurry by aeration.

In general, the treatment and purification of wastewater from waste treatment plants is an important element of these plants, mainly due to the potentially high pollution loads that may be in the wastewater. A distinction can be made between separation and conversion processes.

Separation processes are:

- mechanical treatment,
- evaporation,
- adsorption,
- filtration,
- nano-, ultrafiltration,
- reverse osmosis, and
- centrifugation.

Whereas conversion processes are:

- wet oxidation using H_2O_2,
- ozonisation,
- precipitation/neutralisation, and
- anaerobic and aerobic biological treatments of wastewater.

Wastewater management is an essential step in any hazardous waste treatment facility, including in the Mediterranean region; the techniques required depend on the processes carried out within the installation and water emission limit values.

The specific applicability of some of the techniques identified for wastewater management (BAT list is shown in table 3.19) is as follows:

- Reducing water use and contamination: this is a part of an integrated EMS in the installation. Some techniques are only applied to complex WT plants, to identify the opportunities for maximising the reuse, and for minimising the use of water. These techniques may have some applicability restrictions where water release is continuous or batch and in the case that the WWTP is installed on/off-site.

- Having procedures in place: generally applied in most waste treatment facilities.
- Segregating the water collecting systems: this is typically carried out in two separate systems, one dedicated to rainwater, which is typically not treated and another one collecting all the other aqueous effluents that are typically treated together.
- Maximising the reuse of treated wastewater: this technique can have restrictions to its application due to the increase of the concentration of some soluble components that may interfere with the waste treatment process.
- Conducting daily checks on the effluent management system: the frequency of this technique is sometimes guided by a risk approach.
- Identifying the main chemical constituents: this technique needs to take into consideration the fact that it is not realistic to perform an environmental impact assessment for all variations of the discharge from the WT installation.
- Only discharging the wastewater from its storage after the conclusion of all the treatment measures: this technique may require a further storage tank. This may potentially be costly and space is required, especially for large and continuous flows.
- Achieving water emissions values:
  a) Primary wastewater treatments: air stripping is used to remove halogenated and non-halogenated hydrocarbons from dilute aqueous solution.
  b) Secondary wastewater treatments: chemical precipitation is employed to remove metal ions from wastewater.
  c) Tertiary wastewater treatment: this is very effective for the elimination of nitrogen compounds and of biodegradable organic carbon compounds.

Table 3.19: BATs for wastewater management

BAT	Environmental benefits	Economics
42.- Reduce water use and the contamination of water by: • applying site waterproofing and storage retention methods, • carrying out regular checks of the tanks and pits, • applying separated water drainage according to the pollution load, • applying a security collection basin, • performing regular water audits, and • segregating process water from rainwater. (See also BAT no. 46)	Reducing water use may be a valid environmental (or economic) aim in itself. In addition, from the point of view of reducing pollutant emissions, there are distinct benefits to be gained, in particular: • Associated benefits within the process (reduction in energy requirements for heating and pumping the water). • Reduces dissolution of pollutants in 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 reductions in consumption can be made.	Some economic incentives for applying this technique can be to: • Reduce the necessary size of (a new) wastewater treatment plant. • Reduce costs where water is reused in-house or purchased from or disposed of to another party.

BAT	Environmental benefits	Economics
43.- Have procedures in place to ensure that the effluent specification is suitable for the on-site effluent treatment system or discharge.	These techniques generally minimise emissions to load watercourses. They may also reduce the risk of contamination of process or surface water as well as reducing odour and VOC emissions.	NA.
44.- Avoid the effluent by-passing the treatment plant system.	See BAT no. 43.	See BAT no. 43.
45.- Have in place and operate an enclosure system whereby rainwater falling on the processing areas is collected along with tanker washings and returned to the processing plant or collected in a combined interceptor.	See BAT no. 43.	See BAT no. 43.
46.- Segregate the water collecting systems for potentially more contaminated waters from less contaminated water.	This avoids problems in later treatment and dilution.	NA.
47.- Have a full concrete base in the whole treatment area that drains 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 sewers usually need automatic monitoring systems, such as pH checks, which can shut down the overflow. (See also BAT no. 63).	See BAT no. 42	See BAT no. 42.
48.- Collect rainwater in a special basin for checking, treatment if contaminated and further use.	See BAT no. 43.	See BAT no. 43.
49.- Maximise the reuse of treated wastewater and the use of rainwater in the installation.	See BAT no. 43.	See BAT no. 43.
50.- Conduct daily checks on the effluent management system and maintain a log of all checks carried out, by having a system for monitoring effluent discharge and sludge quality in place.	See BAT no. 43.	See BAT no. 43.
51.- Firstly identify wastewater that may contain **hazardous compounds**. Secondly, segregate the previously identified wastewater streams on-site and, thirdly, specifically treat wastewater on-site or off-site.	See BAT no. 46.	See BAT no. 46.
52.- Ultimately after the application of BAT no. 42, select the appropriate treatment technique for each type of wastewater.	See BAT no. 43.	See BAT no. 43.

BAT	Environmental benefits	Economics
53.- Implement measures to increase the reliability with which the required control and abatement processes can be carried out (for example, optimising the precipitation of metals).	See BAT no. 43.	See BAT no. 43.
54.- Identify the main chemical constituents of the treated effluent (including the make-up of the COD) and make an informed assessment of the fate of these chemicals in the environment.	See BAT no. 43.	See BAT no. 43.
55.- Only discharge the wastewater from its storage after the conclusion of all the treatment measures and a subsequent final inspection.	See BAT no. 43.	See BAT no. 43.
56.- Achieve the following water emission values before discharge. EMISSION VALUE (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 (IV): <0.1-0.4 (See also BATs nos. 42-55)	The reduction of water emissions can be reached by applying a suitable combination of the wastewater management BATs and the following techniques: a) primary wastewater treatments, b) secondary wastewater treatments, c) tertiary wastewater treatments, d) reporting of the components in the effluent generated in waste treatment facilities.	a) NA. b) NA. c) NA. d) NA.

3.3.3. Management of process-generated residues

“Residue” means the solid waste generated by the waste treatment activity and is not directly related to the type of waste treated in the installation.

For management of this residue, the generic techniques for environmental management can be applied (section 3.1.1), so application to Mediterranean installations is feasible provided the characteristics of the installation are taken into account.

This section covers the following types of techniques:

- Techniques for the reduction of waste generated due to the treatment.
- Management of the waste generated due to the treatment.
- Those techniques focused on a reduction of soil contamination.

The specific applicability of some of the techniques for the management of the process generated residues (BATs are shown in table 3.20) is as follows:

- Maximise the use of reusable packaging: the reuse of packaging and pallets depends on whether the packaging is made for reuse or not. In several cases such reuse may conflict with ADR regulations if the packaging is not retrofitted appropriately.
- Reuse drums when they are in good working order: the recycling of drums needs to take into account the contamination of drums with the content. Drums not suitable for direct recycling are typically send for appropriate treatment.
- Re-use the waste from one activity/treatment where possible: this is applicable where synergies are identified and another activity is carrying out.

Table 3.20: BATs for management of process-generated residues

BAT	Environmental benefits	Economics
57.- Have a residue management plan as a part of the EMS including basic housekeeping techniques and internal benchmarking techniques. See also BATs nos. 1 and 3.	This ensures a prudent use of natural resources and can reduce waste generation. It reduces emissions from the management of the residue handled in the installation and minimises the amount of residue arising, as well as helping to identify a good disposal route.	In terms of capital expenditure and operational costs, sludge treatment is a significant component and the management and disposal of solid waste will remain one of the most fundamental issues facing operators.
58.- Maximise the use of reusable packaging (drums, containers, IBCs, pallets, etc.).	See BAT no. 57.	See BAT no. 57.
59.- Reuse drums when they are in a good working state. In other cases, they are to be sent for appropriate treatment.	See BAT number 57.	See BAT number 57.
60.- Keep a monitoring inventory of waste on-site by using records of the amount of waste received on-site and records of the waste processed. See also BAT no. 27.	Avoid large amounts of waste, drums and containers being stored and the loss of identity of the waste.	NA.
61.- Reuse the waste from one activity/treatment possibly as a feedstock for another. See also BAT no. 23.	This can increase energy efficiency, reduce waste generation, reduce water consumption and water emissions for the complex as a whole.	Typically decreases the overall cost of treatments.

3.3.4. Soil contamination

These techniques relate to water spills and other fugitive emissions and to decommissioning. Some specific techniques in this regard are:

- Providing and maintaining the surface of operational areas. See BAT 62 in table 3.21.
- Utilising an impermeable base and internal site drainage. See BAT 63 in table 3.21.

- Applying separate drainage systems and sumps, enabling the isolation of specific areas of the site where waste is handled and bulked, in order to contain possible spills and to protect surface water drainage from contamination. This can help to reduce liquid emissions.
- Minimising the installation site. See BAT 64 in table 3.21.
- Carrying out regular monitoring of subsurface vessels for potential leakages (e.g. vessel level checks during periods of inactivity).
- Designing the areas where water-endangering liquids are transferred as watertight bunds. The bund must be watertight so that in the event of an accident, the hazardous liquid can be contained until security measures are in place.
- Equipping the containers used for the storage/accumulation of water-endangering materials with double walls or standing them in bunded tanks.
- 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.

To prevent soil contamination, three best available techniques have been identified (see table 3.21).

Table 3.21: BATs for soil contamination

BAT	Environmental benefits	Economics
62.- Provide and 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.	This can prevent the short and long-term contamination of the site. Minimisation of underground vessels and pipes makes the maintenance tasks and inspections easier.	NA.
63.- Utilise impermeable base and internal site drainage.	This avoids accidents and fugitive emissions. See also BATs nos. 43 and 62.	See also BATs nos. 43 and 62.
64.- Reduce the installation site and minimise the use of underground vessels and pipework.	See BATs nos. 10, 25, 40 and 63.	See BATs nos. 10, 25, 40 and 63.

4. TECHNIQUES FOR HAZARDOUS WASTE INCINERATION

These techniques focus on the controlled burning of waste.

The following sections have been classified according to the categories of techniques established by the BREF [3]. The main BATs selected are summarised in each section. The description of each BAT includes its environmental benefits and an economic assessment. In addition, applicability to the hazardous waste incineration sector in the Mediterranean region has been assessed. Where available, BATs have been further developed in subsections.

Although incineration is by far the most widely applied, there are three main types of thermal waste treatment relevant to this section:

- Pyrolysis: thermal degradation of organic material in the absence of oxygen.
- Gasification: partial oxidation.
- Incineration: full oxidative combustion.

The basic linear structure of a waste incineration plant (applicable also to hazardous waste) may include the following operations:

- Incoming waste reception.
- Storage of waste and raw materials.
- Pre-treatment of waste (mainly on-site treatments and blending operations).
- Loading of waste into the process.
- Thermal treatment (furnace design etc.).
- Energy recovery (e.g. boiler and energy supply options).
- Flue-gas cleaning.
- Flue-gas cleaning residue management.
- Flue-gas discharge.
- Emissions monitoring and control.
- Wastewater control and treatment (e.g. from site drainage, flue-gas treatment, storage).
- Ash/bottom ash management and treatment (arising from the combustion stage).
- Solid residue discharge/disposal.

Pyrolysis and gasification plants follow a similar basic structure to waste incineration installations, but differ significantly in detail.

4.1. GENERIC TECHNIQUES

These techniques, practices and measures can be applied to all hazardous waste incineration installations due to their general nature. In particular for Mediterranean countries which are planning new incineration facilities, the selection of the most suitable design in each case is considered an essential stage. Management practices are applicable to both new and existing plants; the only restriction is the necessary adaptation to the characteristics of each installation.

The selection of the Best Available Techniques (BATs) is presented in table 4.1. In the following sections, a brief description of each technique considered as a BAT has been developed.

Table 4.1: BATs for generic techniques in the hazardous waste incineration sector

BAT	Environmental benefits	Economics
1.- The selection of an installation design that is suited to the characteristics of the waste received using the following techniques: a) Suitability of process design. b) Combustion chamber design features.	a) There are technologies developed in order to meet the specific waste treatment requirements of particular waste streams. b) These improve combustion results with lower emissions to all media and reduce consumption.	a) NA. b) At new plants these can be optimised at the outset. The additional costs of such design refinements may then be small. At existing plants, the costs of redesigning are very high.
2.- The maintenance of the site in a generally tidy and clean state.	General tidiness and cleanliness contribute to an enhanced working environment and can allow potential operational problems to be identified in advance.	NA.
3.- The maintenance of all equipment in good working order, and carrying out maintenance inspections and preventive maintenance in order to achieve BAT no. 2.	NA.	NA.
4.- Establishing and maintaining quality controls over waste input, according to the types of waste that may be received at the installation using the following techniques: a) Establishing installation input limitations and identifying key risks. b) Communication with waste suppliers to improve incoming waste quality control. c) Controlling waste feed quality on the incinerator site. d) Checking, sampling and testing incoming waste.	a) This ensures smooth and stable operation of the incinerator and reduces requirements for reactive and emergency process intervention. b) Avoiding the receipt of unsuitable waste or controlling the delivery of waste that is difficult to treat or that requires special care can reduce operational difficulties and hence avoid additional releases. c) Reduced emissions in the flue-gas through: smooth process operations, effective combustion, improved energy recovery, more even raw gas	a) These are not precisely quantifiable. b) Savings may arise from avoiding operational difficulties. c) NA. d) These can represent a significant proportion of operational costs at HW plants. e) Investment cost for installing detectors is approx. EUR 25,000 – 50,000.

BAT	Environmental benefits	Economics
e) Detectors for radioactive materials.	concentrations and hence improved operation of the flue-gas cleaning plant and reduced fouling in the boiler by reducing dust release. d) Advanced identification of unsuitable waste, substances or properties can reduce operational difficulties and hence avoid additional releases. e) Prevention of plant contamination and release of radioactive substances.	
5.- The storage of waste according to a risk assessment of its properties, so that the risk of potentially pollutant releases is minimised.	The environmental benefits are: • reduction of risks of releases through secure containment, • prevention of rainwater penetration of the stored waste, • prevention of wind scattering, • allows management of fugitive releases, • reduces: leachate production, mobilisation of pollutants, deterioration of containers, temperature related expansion and contraction of sealed containers and odour releases.	NA
6.- Using techniques and procedures to restrict and manage waste storage times, in order to generally reduce the risk of releases from storage of waste/ container deterioration, and of processing difficulties that may arise.	NA.	NA.
7.- Minimising the release of odours (and other potential fugitive releases) from bulk waste storage areas and waste pre-treatment areas by passing the extracted atmosphere to the incinerator for combustion.	A general reduction in fugitive releases, odours, Greenhouse Gas (GHG) emissions, and sanitary risks is achieved.	Additional ducting costs for retrofits. The provision of a backup system for periods when the incinerator is not available entails the additional cost of that system.
8.- The segregation of the storage of waste according to a risk assessment of its chemical and physical characteristics to allow safe storage and processing.	Segregating incompatible waste reduces risks of emissions by: • Reducing accident risks. • Allowing the balanced feeding of substances.	NA.

BAT	Environmental benefits	Economics
9.- The clear labelling of waste that is stored in containers so that they may continually be identified. This is applicable to hazardous waste.	The benefits are the knowledge of waste content and the increase in the operator's ability to trace sources of problems and then to take steps to eliminate or control them.	NA.
10.- The development of a plan for the prevention, detection and control of fire hazards at the installation, in particular for: • waste storage and pre-treatments areas, • furnace loading areas, • electrical control systems, and • baghouse filters and static bed filters.	This technique reduces the risk of accidental fugitive releases from fires and explosions.	Costs are for installation and maintenance. Nitrogen costs, where used. Prevention of damage by fire can save significant costs. Installation of fire safety measures may reduce insurance premiums.
11.- The mixing or further pre-treatment of heterogeneous waste to the degree required to meet the design specifications of the receiving installation.	The burnability of the waste is improved by making it more homogeneous, thus reducing and stabilising emissions from the furnace, and leading to steadier steam/hot water generation in boilers.	Costs are variable depending on the nature of the waste.
12.- The use of: a) Pre-combustion removal of recyclable metals or b) Bottom ash separation of metals. Remove ferrous and non-ferrous recyclable metals for their recovery either: • after incineration from the bottom ash residues or, • where the waste is shredded, from the shredded waste before the incineration stage.	a) Recovery of recyclable metal streams, improved value of metals that have not been partially oxidised, reduction of content of volatile metals in the flue-gas leading to reduced contamination of flue-gas cleaning residues and improved bottom ash quality by reduction of metal content (non-volatile faction). b) It is necessary to allow recycling of the various ash compounds. See also BAT no. 52.	a) There are investment and operational costs associated with the use of the shredding and separation equipment. b) The metals fractions can be sold to scrap dealers (for ferrous material EUR0.01-0.05/kg and for non-ferrous material EUR0.1-0.6/kg). See also BAT no. 52.
13.- The provision of operators with a means to visually monitor, directly or using television screens or similar, waste storage and loading areas.	NA.	NA.
14.- The minimisation of the uncontrolled ingress of air into the combustion chamber via waste loading or other routes.	NA.	NA.

BAT	Environmental benefits	Economics
55.- The implementation of noise reduction measures to meet local noise requirements.	NA.	NA
56.- Applying environmental management. The scope and nature of EMS will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.	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.	It is difficult to accurately determine the costs and economic benefits of introducing and maintaining a good EMS.
69.- Additional quality controls at HWI: using specific systems and procedures; using a risk-based approach according to the source of the waste, for the labelling, checking, sampling and testing of waste to be stored/ treated. Analytical procedures should be managed by suitably-qualified personnel and using appropriate procedures. See also BAT no. 4	Advanced identification of unsuitable waste, substances or properties can reduce operational difficulties and hence avoid additional releases. Knowledge of the process or origin of the waste is important as certain hazardous characteristics, (for example toxicity or infectiousness) is difficult to determine analytically.	The cost of applying these techniques increases rapidly with the extent and complexity of the procedures adopted. The costs for the sampling, analysis, storage and additional processing time required can represent a significant proportion of operational costs at hazardous waste plants in particular, where the most extensive sampling and analysis regimes are applied.
70.- The mixing, blending and pre-treating of the waste in order to improve its homogeneity, combustion characteristics and burn-out to a suitable degree with due regard to safety considerations. If shredding is carried out then blanketing with an inert atmosphere should be carried out. The techniques that may be used are: a) Shredding of drummed and packaged hazardous waste. b) Pre-treatment and targeted preparation of solid waste for combustion.	a) The use of continuous feed improves the combustion performance and reduces peaks of CO and VOCs; increases average heat recovery due to stable gas flow in boilers; stabilises conditions for operation of flue-gas cleaning equipment; prevents explosions in the kiln and reduces downtime due to refractory damage, etc. b) Improved combustion through homogenisation of the waste. Reduced pollutant loads, reduced heat value fluctuations and reduced emissions and consumptions from smoother operation. The intensive mixing of waste before it enters the bunker can improve fuel qualities.	a) Example: the recycling of packaged steel from a 35 t/d[15] plant produced an additional income of EUR35,000/yr. The number of operators required for handling of packages was reduced from 6 to 3. Construction costs of two lines were reported: 35 t/d packaged liquid line= EUR 2.9 million and 75 t/d packaged and bulk solid line= EUR5.4 million.

[15] t/d: tonne/day

BAT	Environmental benefits	Economics
		b) Cost of separating mixed waste may be significant.
71.- The use of a feed equalisation system for solid **hazardous waste** in order to improve the combustion characteristics of the fed waste and to improve the stability of flue-gas composition, including the improved control of short-term CO peak emissions.	Continuous feeding of solid HW improves controllability of waste feeding and reduces CO peaks. Optimal utilisation of the incineration capacity of the rotary kiln for low calorific solid HW. Homogeneous stream of molten bottom ash is formed. Fire safety is improved in the HW bunker area by the use of automatic fire extinguishing equipment. Installation of video monitoring equipment enables continuous observation of waste feeding.	NA.
72.- The direct injection of liquid and gaseous **hazardous waste**, where this waste requires specific reduction of exposure, releases or odour risk.	Prevention of diffuse air emissions due to the fact that the waste is fed by a complete closed system.	The average investment price for a dedicated line amounts to EUR 100,000-200,000.

4.1.1. Suitability of process design for the waste received

One of the most important decisions to be made by the operator relates to the selection of a combustion stage (or thermal treatment) that is technically suited to the material that will be fed into the process.

The choice of thermal treatment technique generally needs to take into account the following technical criteria (see also BAT 1 in table 4.1):

- Waste chemical composition and variation, e.g. techniques designed to treat a narrow range of specific waste operate within a narrower range of performance limits.
- Waste physical composition, e.g. particle size and variation.
- Waste thermal characteristics, e.g. calorific value, moisture levels.
- Throughput and process availability required.
- Required bottom ash, and other residue(s) quality and composition.
- Possibilities for use of products of partial oxidation, such as syngas or coke.
- Emission level targets and selected abatement system.
- Type of energy recovery (e.g. heat, electrical power, CHP).

In practice, many waste incinerators may have only limited control over the precise content of the waste they receive. Operators receiving such waste thus need to design their processes to be sufficiently flexible to cope with the range of waste inputs that could be fed to the process.

4.1.2. General good housekeeping practices

General tidiness and cleanliness contribute to an enhanced working environment and can allow potential operational problems to be identified in advance. These techniques can be applied to all installations and to all sectors. This is especially important for hazardous waste, despite its dangerous nature.

The main elements of good housekeeping are:

- The use of systems to identify and locate/store waste received according to its risks.
- The prevention of dust emissions from operating equipment.
- Effective wastewater management, and
- Effective preventive maintenance.

The best available practices according to these criteria can be consulted in table 4.1, particularly numbers 2 and 3.

4.1.3. Pre-treatment, storage and handling techniques for hazardous waste

Different types of waste need different types of pre-treatment, storage and handling operations prior to incineration. For this report, only hazardous waste is studied.

Regarding hazardous waste, two types of plants are possible: merchant incineration plants and dedicated incineration plants. The main differences between them are summarised in table 4.2.

Table 4.2: Summary of differences between operators in the hazardous waste incineration market

Criteria	Merchant plants	Dedicated plants
Ownership	Private companies, municipalities or partnerships	Usually private companies (used for their own waste)
Characteristics of waste treated	Very wide range of waste. Knowledge of exact waste composition may be limited in some cases.	Wide range of waste. Often only the waste arising within one company or even from one process. Knowledge of waste composition generally higher.
Combustion technologies applied	Predominantly rotary kilns. Some dedicated technologies for dedicated or restricted specification waste.	Rotary kilns plus. a wide variety of specific techniques for dedicated or restricted specification waste.
Operational and design considerations	Flexibility and wide range of performance required to ensure good process control.	Process can be more closely designed for a narrower specification of feed in some cases.
Flue-gas treatment	Wet scrubbing often applied to give flexibility of performance, as well as a range of FGT techniques applied in combination.	Wet scrubbing often applied to give flexibility of performance, as well as a range of FGT techniques applied in combination.
Cost/market considerations	Operators usually compete in an open (global) market for business. Some plants benefit from national/regional policies regarding the destination of waste produced in that country/region. Movement of hazardous waste in the EU is controlled by Transfrontier Shipment Regulations which limits the scope of an open global market.	Competition more limited or in some cases non-existent. Higher disposal costs tolerated by users in some cases for reasons of waste producer policy on in-house disposal.

This section has been divided into four subsections (waste acceptance, storage, feeding and pre-treatment and waste transfer and loading) for better comprehension.

4.1.3.1. Waste acceptance

Significant effort is required to assess, characterise and trace incoming waste due to the very wide variety of waste types encountered, their high potential hazard and high levels of uncertainty concerning precise knowledge of waste composition.

The exact procedures required for waste acceptance and storage depend on the chemical and physical characteristics of the waste.

For each type of hazardous waste, a declaration of the nature of the waste made by the waste producer is submitted so that the waste manager can then decide whether the treatment of each specific type of waste is possible. When waste composition cannot be described in detail (e.g. small amounts of pesticides), the waste management company may agree with the waste producer on specific packaging requirements, making sure that the waste will not react during transport, when it is accepted for incineration, or within containers.

It is also important to establish the installation's limitations on the characteristics of the waste that can be fed to the incinerator itself. From knowledge of the incineration process input limitations, it is possible to draw up waste input specifications that highlight the maximum and desirable system input rates. It is then possible to identify the key risks (such as, for example, high mercury, iodine or bromide input, leading to high raw flue-gas concentrations; high sulphur loads exceeding FGT capacity, etc.), and procedural control required to prevent or reduce operation outside these limitations.

When the waste received cannot be treated (because this may cause operational problems), the operator's concerns for the people who produce and supply the waste can help in the overall chain of waste management.

Checking, sampling and testing incoming waste involve the use of a suitable regime for the assessment of incoming waste. The assessments carried out are selected to ensure that the waste received is within the range suitable for the installation and to decide whether the waste needs special handling/storage/treatment/removal for off-site transfer and whether the waste is as described by the supplier (for contractual, operational or legal reasons).

Techniques vary from simple visual assessment to full chemical analysis (and tests to detect radioactive materials): nature and composition of waste, heterogeneity of waste, known difficulties with waste, etc.

A priori, these techniques could be applied in all waste incineration plants, (including in the Mediterranean region) particularly those that receive hazardous waste. The specific applicability of the BATs related to this subsection (see table 4.1, numbers 4, 14, 96.1, 69 and 70) is:

- Quality controls:
  - a) Installation inputs: this is applicable to all waste incineration plants, particularly those that receive waste from diverse sources and of a wide or difficult to control specification **(e.g. merchant hazardous waste plants)**.
  - b) Communication with waste suppliers: this can be applied to all waste incineration plants, especially those receiving waste from diverse sources and of a wide or difficult to control specification.
  - c) Controlling waste feed quality: all installations need to produce their own set of key process input limitations and then adopt suitable receipt restrictions and possible pre-treatment to ensure that these limitations are not exceeded. This is especially necessary for **hazardous waste.**
  - d) Checking, sampling and testing incoming waste: these are appropriate where waste composition and sources are most variable **(e.g. merchant HW plants)** or where there are known difficulties.
  - e) Detectors for radioactive material: these are applicable to incineration plants where heterogeneous waste is received from a wide variety of suppliers.
- Additional quality controls for hazardous waste incineration: the most extensive sampling and analysis regimes are appropriate where waste composition and sources are most variable (e.g. merchant hazardous waste plants) or where there are known difficulties.
- Additional quality controls: the most extensive sampling and analysis regimes are appropriate where waste composition and sources are most variable (e.g. merchant hazardous waste plants) or where there are known difficulties.
- Mixing, blending and pre-treatment of waste in order to improve its homogeneity:
  - a) Shredding of drummed and packaged HW: this is applicable to incinerators receiving packaged hazardous waste.

b) Pre-treatment and targeted preparation of solid waste for combustion: this is mainly applicable to waste that can be delivered in various fractions or efficiently treated to separate the fractions required.

c) This technique may be particularly applicable to installation designs that have narrow input specifications, e.g. fluidised beds.

d) The benefits of applying this technique may be more limited where an installation is already designed for "mass burn" e.g. grates and rotary kilns.

- The use of a feed equalisation system for solid hazardous waste: this is applicable to hazardous waste incinerators receiving heterogeneous solid waste.

4.1.3.2. Storage

In general, the storage of waste needs, additionally, to take into account the unknown nature and composition of waste, as this gives rise to additional risks and uncertainties.

The storage of waste in areas that have sealed and resistant surfaces and controlled drainage prevents the release of substances either directly from the waste or by leaching from the waste. The techniques employed vary according to the type of waste, its composition and the vulnerability or risk associated with the release of substances from the waste. In general, the following storage techniques are appropriate:

- Odorous materials stored inside with controlled air systems using the discharged air as combustion air.
- Designated areas for loading/offloading with controlled drainage.
- Clearly marked areas for drainage from potential areas of contamination.
- Limitation of storage times according to waste type and risks.
- Adequate storage capacity.
- Baling or containment of some waste for temporary storage is possible, depending on the waste and location specific risk factors.
- Fire protection measures.

Specific recommendations for hazardous waste are:

- Segregated storage according to risk assessment.
- Special attention to the length of storage times.
- Automatic handling and loading devices.
- Cleaning facilities for surface and containers.

Appropriate waste assessment is an essential element in the selection of storage and loading options. Some issues to note are:

- For the storage of **solid hazardous waste**, many incinerators are equipped with a bunker (500 to 2000 m^3) from which the waste is fed into the installation by cranes or feed hoppers.
- **Liquid hazardous waste and sludges:** these are usually stored in a tank farm. Some tanks have storage under an inert (e.g. N_2) atmosphere. Liquid waste is pumped via pipelines to the burners and introduced into the rotary kilns and/or the Post-Combustion Chamber (PCC). Sludges can be fed to rotary kilns using special "viscous-matter" pumps.
- Some incinerators are able to feed certain substances, such as toxic, odorous, reactive and corrosive liquids, by means of a **direct injection** device, directly from the transport container into either the kiln or PCC.

- Some merchant incinerators, particularly in Europe, are equipped with conveyors and elevators to transport and introduce **drums** and/or small packages directly into the rotary kiln.

The specific applicability of the related BATs (see table 4.1, numbers 5, 6, 7, 8, 9, 10 and 72) is as follows:

- Minimising the release of odour: this is applicable to all incinerators where there is a risk of odour or other substances being released from storage areas. Plants storing volatile solvents can significantly reduce their VOC emissions using this technique.
- Segregation of the storage of waste: this is applicable where waste is already collected and delivered so that further segregation is not required.
- Clear labelling: this is mainly applicable to **hazardous waste, clinical waste plants or other** situations where waste is held in containers and has variable/distinct compositions.
- Development of a plan for prevention: this is applicable in all installations.
- Direct injection of liquid and hazardous waste: this technique is applicable to liquid hazardous waste, particularly waste that presents health and safety handling risks that require minimal worker exposure.

4.1.3.3. Feeding and pre-treatment

To help control the waste feed quality, and hence stabilise the combustion process within design parameters, a set of quality requirements can be produced for the waste fed to the combustor. The waste quality requirements can be obtained from an understanding of the process operational limitations, such as:

- Thermal throughput capacity of the incinerator.
- Physical requirements of the feed (particle size).
- Control used for the incineration process.
- Capacity of the flue-gas treatment system and the resultant maximum raw gas input concentrations/rates.
- The emission limit values that need to be met.
- Bottom ash quality requirements.

The feed equaliser itself consists of two robust screw conveyors capable of crushing and feeding solid waste and a tailor-made feed hopper for receiving various types of waste.

Metal separation can be achieved by using:

- Over-band magnets for large ferrous materials e.g. shredded drums.
- Drum magnets for small and heavy ferrous items such as batteries, nails, coins, etc.
- Eddy current separators for non-ferrous metals (mainly copper and aluminium used for packaging and electrical components).

It may be necessary to wash the removed metals in order to remove contamination from the waste they have been in contact with. Whether this is necessary depends on the type of contamination, subsequent storage, transport and recycling process requirements.

Some incinerators have dedicated and integrated homogenisation installations for the pre-treatment of waste. These include:

- A shredder for bulky solids.
- A dedicated shredder purely for drums.
- A shredder combined with a mechanical mixing device.

Because of the wide range of chemical and physical specifications of some hazardous waste, difficulties may occur in the incineration process. Some degree of waste blending or specific pre-treatment is thus often carried out in order to achieve more even loads. It is also necessary for acceptance criteria to be developed for each installation.

Depending on waste composition and on the incineration plant characteristics, together with the availability of other means of treatment for any waste produced, other pre-treatment may also be carried out (for example: neutralisation, sludge drainage and solidification of sludge with binding agents).

The techniques used for waste pre-treatment and mixing are wide-ranging and may include:

- Mixing of liquid hazardous waste to meet input requirements for the installation.
- Shredding, crushing, and shearing of packaged waste and bulky combustible waste.
- Mixing of waste in a bunker using a grab or other machine.

The pre-treatment of liquid packaged waste and packed or bulk solid waste to produce a mixture for continuous feed to the furnace can be carried out. Suitable waste may be treated to obtain a pumpable state for pumped injection into the kiln or shredded for adding to the storage burner where solids and liquids separate and are then fed into the kiln separately, using grabs and pumping respectively. The general principle of increasing homogeneity through suitable waste preparation can be applied to all incinerators where significant variations in raw gas parameters are seen post combustion.

The specific applicability of some BATs associated with this subsection (see table 4.1, numbers 11, 12 and 58) is as follows:

- Mixing or further pre-treatment: this technique is applicable in all plants receiving heterogeneous solid waste **(e.g. packaged hazardous waste)**. Pre-treatment is most likely to be a requirement where the installation has been designed for narrow specification, homogeneous waste.
- Use of pre-combustion removal and bottom ash separation:
  - a) Bottom ash separation: magnetic separation of ferrous metals is applicable in all new and existing installations.
  - b) Non-ferrous metal separation requires space and sufficient throughput and may be performed by an external bottom ash processing installation. **At some HW plants, shredded drums are removed using magnets prior to combustion.**
- Mixing, blending and pre-treatment:
  - a) Shredding of drummed/packaged waste: this is applicable to incinerators receiving packaged hazardous waste.
  - b) Pre-treatment and targeted preparation: this is mainly applicable to waste that can be delivered in various fractions or efficiently treated to separate the fractions required. This technique may be particularly applicable to installation designs that have narrow input specifications, e.g. fluidised beds. The benefits of applying the technique may be more limited where an installation is already designed for “mass burn”, e.g. grates and rotary kilns.

4.1.3.4. Waste transfer and loading

The operators of waste feed systems need to have a good view of waste storage and loading areas and their mechanisms to monitor them. This can be achieved by positioning the control room with a view of the combustor loading areas and by the use of video monitors or other detection systems. The former is preferable unless there are particular safety or other technical reasons why this cannot be achieved.

Liquid, pasty and gaseous waste can be fed directly to rotary kilns via several direct feeding lines. In general, the direct injection operation is done by connecting the waste container and the feeding line and pressurising the container with nitrogen or in case of sufficiently low viscosity, by emptying the container with appropriate pumps.

The use of systems that prevent air ingress into the combustion chamber helps to maintain process stability and reduce emissions. Such systems include:

- Maintaining a filled hopper for solid waste.
- Use of enclosed screw feeders.
- Use of interlocked double doors for batch loading.
- Use of pumped direct injection for liquid and pasty waste.

The specific applicability of the associated BATs (see BAT 13 and 71 in table 4.1) is as follows:

- Use of bottom ash separator: magnetic separation of ferrous metals is applicable in all new and existing installations. Non-ferrous metal separation requires space and sufficient throughput and may be performed by an external bottom ash processing installation. **At some HW plants, shredded drums are removed using magnets prior to combustion.**
- Direct injection of liquid and gaseous **hazardous waste**: This technique is applicable to liquid hazardous waste, particularly waste that presents health and safety handling risks that require minimal worker exposure.

4.1.4. Pre-treatment, storage and handling techniques for sewage sludge

The composition of sewage sludge varies greatly. Particularly important factors to take into account when incinerating sewage sludge are:

- The dry solids content (this varies from 10% up to 45%).
- Whether the sludge is digested or not.
- The lime, limestone and other conditioning contents of the sludge.
- The composition of the sludge as primary-, secondary-, bio-sludge, etc.
- Odour problems, especially during sludge feeding in storage.

Pre-treatment processes of sewage sludge are presented in the following subsections, and are: physical dewatering, drying and sludge digestion.

4.1.4.1. Physical dewatering

Mechanical drainage before incineration reduces the volume of the sludge mixture by the reduction of the water content, thus increasing the associated heat value of this process. Through mechanical drainage of the sewage sludge in decanters, centrifuges, belt filter presses and chamber filter presses, a dry solids (DS) level of between 10 and 45% can be achieved.

4.1.4.2. Drying

Often a substance that has been dried by mechanical drainage is still insufficiently dry for auto thermal incineration. In this case, a thermal drying plant for additional drying can be used before the incineration furnace, the sewage sludge is further reduced in volume and the heat value is further increased. (See BATs 75 and 76 in table 4.1).

4.1.4.3. Sludge digestion

Sludge digestion decreases the content of organic material in the sludge and produces biogas (at least in the case of anaerobic digestion). Digested sludge can generally be dewatered more easily than non-digested sludge, thus allowing a slightly higher dry solids content to be obtained after mechanical dewatering.

Table 4.3 shows the selection of the best available techniques associated with sewage sludge incineration.

Table 4.3: BATs for sewage sludge incineration.

BAT	Environmental benefits	Economics
76.- The use of fluidised bed technology in installations may generally be a BAT because of the higher combustion efficiency and lower flue-gas volumes that generally result from such systems.	NA.	NA.
77.- The drying of the sewage sludge, preferably by using heat recovered from incineration, to the extent that additional combustion support fuels are not generally required for the normal operation of the installation.	NA.	NA.

4.2. THE THERMAL TREATMENT STAGE

Thermal treatment is a process by which heat is applied to waste in order to reduce its bulk prior to final disposal.

Different types of thermal treatments are applied to the different types of waste. However, not all thermal treatments are suited to all waste. The incineration technologies (these are further detailed in section 4.2.1) are:

- Grate incinerators.
- Rotary kilns.
- Fluidised beds.
- Pyrolysis and gasification systems.

Incineration of sewage sludge: this takes place in rotary kilns, multiple hearth, or fluidised bed incinerators. Co-combustion in grate-firing systems, coal combustion plants and industrial processes is also applied.

Incineration of hazardous and medical waste: rotary kilns are most commonly used, but grate incinerators (including co-firing with other waste) are also applied to solid waste, and fluidised bed incinerators to some pre-treated materials. Static furnaces are also widely applied at on-site facilities in chemical plants.

Other processes have been developed that are based on the de-coupling of the phases which also take place in an incinerator: drying, volatilisation, pyrolysis, carbonisation and oxidation of the waste. Gasification using gasifying agents such as steam, air, carbon-oxides or oxygen is also applied. These processes aim to reduce flue-gas volumes and associated flue-gas treatment costs. Some of these developments met technological and economic problems when they were scaled-up to commercial industrial sizes, and are therefore no longer used.

Table 4.4 shows the selection of the best available techniques associated with the thermal treatment processes. They constitute a selection of the techniques developed in the whole section. A brief description of each of them can be found in each specific subsection. Their applicability to the hazardous waste sector and to the Mediterranean region is also assessed.

Table 4.4: BATs for thermal treatment processes

BAT	Environmental benefits	Economics
15.- The use of flow modelling which may assist in providing information where concerns exist regarding combustion or FGT performance, and in providing information in order to: • Optimise furnace and boiler geometry, • Optimise combustion air injection, and • Where SNCR or SCR is used, to optimise reagent injection points.	This may enhance combustion performance and therefore limit the formation of CO, TOC, PCDD/F and NO_x. There is no effect on other, waste contained, pollutants. Reduction of fouling due to excessive local flue-gas velocities by using CFD modelling can increase the availability of plants and improve energy recovery over time. Improvement in performance of abatement equipment.	Typically, a computer optimisation study will cost EUR 10,000 to 30,000, depending on the scope of the study and the number of modelling runs required.
16.- To adopt operational regimes and implement procedures in order to reduce overall emissions.	Consistent plant operation improves energy efficiency.	Avoiding shutdown can reduce costs at incineration installations by allowing continuous throughput and hence greater installation utilisation.
17.- The identification of a combustion control philosophy and the use of key combustion criteria and a combustion control system to monitor and maintain these criteria within appropriate boundary conditions, in order to maintain effective combustion performance. Techniques to consider are: a) Selection and use of suitable combustion control systems and parameters. b) Use of infrared cameras for combustion monitoring and control.	a) The incineration process has less variation in time (i.e. improved stability) and space (i.e. more homogeneous) thus allowing for improved overall combustion performance and reduced emissions to all media. b) It improves overall combustion performance and reduces emissions to all media.	a) The advantages also result in less maintenance and, therefore, better plant availability. b) The estimated cost of one camera is EUR 50,000.

BAT	Environmental benefits	Economics
18.- The optimisation and control of combustion conditions by: • Control of air supply, distribution and temperature, including gas and oxidant mixing, • Combustion temperature level and distribution, and • Raw gas residence time. The techniques that may be used are: a) Optimisation of air supply stoichiometry, b) Primary air supply optimisation and distribution, c) Secondary air injection, optimisation and distribution, d) Optimisation of time, temperature, turbulence of gases in the combustion zone, and oxygen concentrations, and e) Design to increase turbulence in the secondary combustion chamber (SCC).	a) Reduction of flue-gas volumes (and hence treatment requirements) whilst achieving effective gas burnout are the aim of the optimisation. b) Optimisation of the combustion stage of the incineration process and reduction of overall emissions. c) The benefits are to reduce the quantity of combustion-related substances (e.g. NO_x, CO and/or VOC). CO and VOC levels are not treated in the FGT. d) This reduces NO_x production and hence treatment requirements and/or emissions, reduces flue-gas volumes and improves energy efficiency. e) This improves combustion leading to lower raw gas concentrations of combustion-related parameters. It can reduce the volume of secondary air required, and hence reduce overall flue-gas volumes and NO_x production.	a) NA. b) Provided the initial design is correct and provides systems and equipment for primary air control, additional equipment and costs are not normally incurred. c) The costs will vary according to specific design features. d) NA. e) NA.
19.- In general it is a BAT to use those operating conditions (i.e. temperatures, residence times and turbulence) as specified in Art.6 of Directive 2000/76/EC. The use of other operating conditions may also be a BAT.	If hazardous waste with a content of more than 1% of halogenated organic substances, expressed as chlorine, is incinerated, the temperature has to be raised to 1100°C for at least two seconds.	NA.
21.- The use of auxiliary burner(s) for start-up and shutdown and for maintaining the required operational combustion temperatures at all times when unburned waste is in the combustion chamber.	Ensuring that incineration temperatures are adequate by the use of automatically operated burners ensures that the gases produced are properly combusted, reducing raw gas concentrations of products of incomplete combustion (PICs) at the furnace outlet and hence emissions to all media.	Retrofit costs may be significant owing to difficulties in positioning the burners. The costs will be significantly higher for processes that operate on a batch basis.

BAT	Environmental benefits	Economics
22.- The use of a combination of heat removal close to the furnace and furnace insulation that, according to the net calorific value (NCV) and corrosiveness of the waste incinerated, provides for adequate heat retention in the furnace and additional heat to be transferred for energy recovery. The techniques that may be used are: a) Protection of furnace membrane walls and boiler first pass with refractory or other materials. b) Use of an integral furnace-boiler.	a) The greater plant availability means that the additional risks of emissions associated with start-up and shutdown are reduced. It will also reduce the need to add support fuels to lower LCV waste. The use of water and air-cooled walls allows the heat to be recovered, gas temperature reduction and reduction to be made in secondary air addition. b) This improves heat recovery by reducing heat losses by radiation at the furnace outlet, allows the installation of SNCR de-NO_x systems and reduces the excess air requirement and hence flue-gas volumes.	a) Changing the configuration of the furnace at existing plants may not be practicable due to high costs. b) This is less expensive than a separate boiler for plants above very small capacity furnaces (i.e. 1 or 2 t/h).
23.- The use of furnace dimensions that are large enough to provide for an effective combination of gas residence time and temperature so that combustion reactions may approach completion and result in low and stable CO and VOC emissions.	It enables reduced emissions of organic substances from the combustion stage. It also improves heat exchange in boilers, owing to a reduction in deposits on boiler tubes. This can result in improved energy recovery.	Large furnaces are more expensive to construct.
24.- When gasification or pyrolysis is used, in order to avoid the generation of waste, it is a BAT to combine the gasification or pyrolysis stage with a subsequent combustion stage with energy recovery and flue-gas treatment that provides for operational emissions levels to air and/or recovery or supply to use those substances that are not combusted.	NA.	NA.

BAT	Environmental benefits	Economics
25.- In order to avoid operational problems that may be caused by higher temperature sticky fly ash, using a boiler design that allows gas temperatures to reduce sufficiently before the convective heat exchange bundles. The techniques that may be used are: a) Optimisation of boiler architecture. b) Use of a "platen" type superheater.	a) Greater plant availability and better heat exchange allows increased overall energy recovery possibilities. Design to reduce boiler fouling also reduces the retention of dust within temperature zones that may increase the risk of dioxin formation. b) These "platen" type superheaters allow high superheated steam temperature with good availability and stability. See also BAT no. 23.	a) Operational savings through reduced maintenance and increased energy sales can lead to very short payback periods, and can then justify the adoption of these techniques at new installations. b) Less expensive than bundles for last stage superheaters when installed in areas with hotter flue-gas temperatures. Use may increase construction costs and this needs to be considered against the additional heat exchanger life that may be gained. See also BAT no. 23.
73.- The use of a combustion chamber design that provides for containment, agitation and transport of the waste, for example: rotary kilns - either with or without water cooling. Water cooling for rotary kilns may be favourable in situations where: the LHV of the fed waste is higher (e.g. >15-17 GJ/tonne) or higher temperatures are used.	The main benefit of rotary kilns with water cooling is that higher combustion temperatures may be used where required.	NA.

4.2.1. Combustion technology selection

The selection of combustion technology is closely related to the waste types that can be incinerated in the facility; a detailed explanation of incinerator types and characteristics has been developed along this section.

These technologies are very specific; hence, an assessment of each particular situation (facility, type and amount of waste, etc.) should be developed, especially within the Mediterranean region (see table 4.4, BATs numbers 17 and 73):

- Identification of a combustion control philosophy:
    a) Suitable combustion control system: this is applicable in all incineration installations.
    b) Infrared cameras: this is mainly applicable to grate incinerators. This technique is applicable only if it can be applied when the furnace design is such that the camera can view the relevant areas of the grate. Moreover, application is limited, in general to larger scale furnaces, with several grate lines (e.g. >10 t/h).

- Use of combustion chamber design: this technique is applicable to rotary kiln incinerators with higher LHV inputs. It is mainly applied at hazardous waste plants but could also have wider application to other waste burned in rotary kilns. The technique is especially suited to plants that require high temperatures for the destruction of particular types of waste.

4.2.1.1. Grate incinerators

Grate incinerators are widely used for the incineration of mixed municipal waste. Other waste that is commonly treated includes: commercial and industrial non-hazardous waste, sewage sludge and certain clinical waste.

As the scope of this document encompasses only hazardous waste, this technology will not be developed further.

4.2.1.2. Rotary kilns

Rotary kilns are very robust and almost any waste, regardless of type and composition, can be incinerated.

Operating temperatures of rotary kilns used for waste range from around 500°C (as a gasifier) to 1450°C (as a high temperature ash melting kiln). Higher temperatures are sometimes encountered, but usually in non-waste applications.

When used for conventional oxidative combustion, the temperature is generally above 850°C. Temperatures in the range of 900-1200°C are typical when incinerating hazardous waste.

In order to increase the destruction of toxic compounds, a post-combustion chamber is usually added. Additional firing using liquid waste or additional fuel may be used to maintain the temperatures required to ensure the destruction of the waste being incinerated.

4.2.1.3. Kilns and post-combustion chambers for hazardous waste incineration

The operational kiln temperature of installations for incineration usually varies from 850°C up to 1300°C. The temperature may be maintained by burning waste with higher calorific value, waste oil, heating oil or gas. Higher-temperatures kilns may be fitted with water-based kiln cooling systems, which are preferred for operation at higher temperatures. The operation at higher temperatures may result in molten (vitrified) bottom ash (slag); at lower temperatures the bottom ash is sintered.

Temperatures in the post-combustion chamber (PCC) typically vary between 900-1200°C depending on the installation and the waste feed. Most installations have the ability to inject secondary air into the post-combustion chamber. Due to the high temperatures and the secondary air introduction, the combustion of exhaust gases is complete and organic compounds (e.g. PAHs, PCBs and dioxins) including low molecular weight hydrocarbons, are destroyed.

4.2.1.3.1. Drum kiln *with post-combustion chamber for hazardous waste incineration*

For the incineration of hazardous waste, a combination of drum-type kilns and post-combustion chambers has proven successful, as this combination can treat solid, pasty, liquid and gaseous waste uniformly.

Drum-type kilns between 10 and 15 m in length, and with a length to diameter ratio usually in the range of 3 of 6, and with an inner diameter of between 1 and 5 m are usually deployed for hazardous waste incineration.

4.2.1.4. Fluidised beds

Fluidised bed incinerators are widely applied to the incineration of finely divided waste e.g. RDF and sewage sludge. They have been used mainly for the combustion of homogeneous fuels. Among these are coal, raw lignite, sewage sludge and biomass.

In the fluidised bed, drying, volatilisation, ignition, and combustion take place. The temperature in the free space above the bed is generally between 850 and 950°C. Above the fluidised bed material, the free board is designed to allow retention of the gases in a combustion zone. In the bed itself the temperature is lower (around 650°C).

Because of the well-mixed nature of the reactor, fluidised bed incineration systems generally have a uniform distribution of temperatures and oxygen, which results in stable operation. For heterogeneous waste, fluidised bed combustion requires a preparatory process step for the waste so that it conforms to size specifications.

4.2.1.4.1. Stationary (or bubbling) fluidised bed (BFB) incineration

This type of fluidised bed is commonly used for sewage sludge, as well as for other industrial sludges, e.g. petrochemical and chemical industry sludges.

At start-up, or when sludge quality is low (e.g. with old sludge or a high share of secondary sludge) additional fuel (oil, gas and/or waste fuel) can be used to reach the prescribed furnace temperature (typically 850°C). Water can be injected into the furnace to control the temperature.

4.2.1.4.2. Circulating fluidised bed (CFB) for sewage sludge

The circulating fluidised bed is especially appropriate for the incineration of dried sewage sludge with a high heat value. It works with fine bed material and at high gas speeds that remove the greater part of the solid material particles from the fluidised bed chamber with the flue-gas. The particles are then separated in a downstream cyclone and returned to the incineration chamber. The advantage of this process is that high heat turnovers and more uniform temperature along the height can be reached with low reaction volume. Plant size is generally larger than BFB and a wide range of waste inputs can be treated.

4.2.1.4.3. Spreader-stoker furnace

This system may be considered as an intermediate system between grate and fluidised bed incineration.

Compared to grate incineration, the grate is of less complicated construction due to the relatively smaller thermal and mechanical load. When compared to fluidised bed systems, the uniformity of particle size is less important and there is a lower risk of clogging.

4.2.1.4.4. Rotating fluidised bed

This system is a development of the bubbling bed for waste incineration. Inclined nozzle plates, wide bed ash extraction chutes and upsized feeding and extraction screws are specific features to ensure reliable handling of solid waste. Temperature control within the refractory lined combustion is by flue-gas recirculation. This allows a wide range of calorific values of fuels.

4.2.1.5. Pyrolysis and gasification systems

Alternative technologies for thermal waste treatment have been developed since the 1970s. In general these have been applied to selected waste streams and on a smaller scale than incineration. These technologies attempt to separate the components of the reactions that occur in conventional waste incineration plants by controlling process temperatures and pressures in specially designed reactions.

The additional aims of gasification and pyrolysis processes are to:

- Convert certain fractions of the waste into process gas (called syngas).
- Reduce gas cleaning requirements by reducing flue-gas volumes.

Both pyrolysis and gasification differ from incineration in that they may be used for recovering the chemical value of the waste (rather than its energy value). The chemical products derived may in some cases then be used as feedstock for other processes. However, when applied to waste, it is more common for pyrolysis, gasification and a combustion-based process to be combined, often on the same site as part of an integrated process. When this is the case the installation is generally recovering the energy value rather than the chemical value of the waste, as would a normal incinerator.

In some cases the solid residues from such processes contain pollutants that, in an incineration system, would be transferred to the gas phase, and then with efficient flue-gas cleaning, be removed with the FGT residue.

The typical reaction conditions and products from pyrolysis, gasification and incineration processes are shown in table 4.5.

Table 4.5: Typical reaction conditions for pyrolysis, gasification and incineration processes

	Pyrolysis	Gasification	Combustion
Reaction temperature (°C)	250-700	500-1600	800-1450
Pressure (bar)	1	1-45	1
Atmosphere	Inert/nitrogen	Gasification agent: O2, H_2O	Air
Stoichiometric ratio	0	<1	>1
Products from the process			
Gas phase:	H_2, CO, hydrocarbons, H_2O, Ns	H^2, CO, CO_2, CH_4, H_2O, N_2	CO_2, H_2O, O_2, N_2
Solid phase:	Ash, coke	Slag, ash	Ash, slag
Liquid phase:	Pyrolysis oil and water		

The best available technique for both systems is number 24 in Table 4.4.

4.2.1.5.1. Pyrolysis

Pyrolysis is the degassing of waste in the absence of oxygen, during which pyrolysis gas and a solid coke are formed. The heat value of pyrolysis gas typically lies between 5 and 15 MJ/m3 based on municipal waste and between 15 and 30 MJ/m3 based on RDF. In a broader sense, “pyrolysis” is a generic term including a number of different technology combinations that constitute, in general, the following technological steps:

- Smouldering process: formation of gas from volatile waste particles at temperatures between 400 and 600°C.

- Pyrolysis: thermal decomposition of the organic molecules of the waste between 500 and 800°C resulting in formation of gas and a solid fraction.
- Gasification: conversion of the carbon share remaining in the pyrolysis coke at 800 to 1000°C with the help of a gasification substance in a process gas.
- Incineration: depending on the technology combination, the gas and pyrolysis coke are combusted in a incineration chamber.

In addition to the thermal treatment of some municipal waste and sewage sludge, pyrolysis processes are also used for:

- Decontamination of soil.
- Treatment of synthetic waste and used tyres.
- Treatment of cable tails as well as metal and plastic compound materials for substance recovery.

The potential advantages of pyrolysis processes may include:

- Possibility of recovering the material value of organic fractions e.g. as methanol.
- Possibility of increased electrical generation using gas engines or gas turbines for generation (in place of steam boilers).
- Reduced flue-gas volumes after combustion, which may reduce FGT capital costs to some degree.
- The possibility of meeting specifications for external use of the char produced by washing (e.g. chlorine content).

4.2.1.5.2. Gasification

Gasification is the partial combustion of organic substances to produce gases that can be used as feedstock or as a fuel.

There are several different gasification processes available or being developed which are in principle suitable for the treatment of municipal waste, certain hazardous waste and dried sewage sludge.

It is important that the nature of the waste fed keeps within certain predefined limits. Pre-treatment is necessary, especially for municipal waste. Hazardous waste may be gasified directly if they are liquid, pasty or finely granulated.

The special features of the gasification process are:

- Smaller gas volume compared to the flue-gas volume in incineration (by up to a factor of 10 by using pure oxygen).
- Predominant formation of CO rather than CO_2.
- High operating pressures (in some processes).
- Accumulation of solid residues as slag (in high temperature slagging gasifiers).
- Small and compact aggregates (especially in pressure gasification).
- Material and energetic utilisation of the synthesis gas.
- Smaller wastewater flows from synthesis gas cleaning.

The following gasification reactors are used.

- Fluidised bed gasifier.
- Current flow gasifier.

- Cyclone gasifier.
- Packed bed gasifier.

4.2.1.6. Other techniques

4.2.1.6.1. Stepped and static hearth furnaces

Static hearth furnaces consist of a refractory lined box in which the waste is burned on the base of the furnace, often with the injection of support fuels above the burning waste to help maintain temperatures. Such systems have been used in some cases to provide a means for the disposal of dead animals, animal parts, packaging waste and some clinical waste.

Stepped hearth systems are a development from static hearths. They usually consist of 2 to 4 static hearths arranged as a series of steps. Such systems are capable of reaching modern legislative requirements with some waste types. Burnout of the waste may be variable and highly dependent on the waste type.

4.2.1.6.2. Multiple hearth furnaces

Multiple hearth furnaces are mainly used for the incineration of sludges (e.g. sewage sludge).

The number of trays for drying, incineration and cooling is determined based on the residual material characteristics. The multiple hearth furnace is also equipped with a start-up burner, sludge dosing mechanism, circulation, sleeve shaft and fresh air blowers.

The incineration temperature is limited to 980°C, as above this temperature the sludge ash fusion temperature will be reached and clinker will be formed. In order to prevent leakage of hot toxic flue-gases, multiple hearth furnaces are always operated at a slight vacuum pressure.

4.2.1.6.3. Multiple hearth fluidised bed furnace

Several layers are installed into the freeboard of a stationary fluidised bed, enabling the sludge to be pre-dried with flue-gas. Using this pre-drying process, only a small amount of water must be evaporated in the actual fluidised bed, meaning that the grate surface and entire furnace can be reduced.

Uniform incineration is promoted in the multiple hearth fluidised bed furnace by optimising air supply, sand addition and evaporation in the layers and in the fluidised bed. Higher temperatures (temperature differences between the furnace head and foot) can be avoided, leading to a lower formation of NO_x.

4.2.1.6.4. Incineration chamber for liquid and gaseous waste

Incineration chambers are designed specifically for the incineration of liquid and gaseous waste, as well as solids dispersed in liquids. A common application of incineration chambers is in the chemical industry for the incineration of liquid and process off-gas. With chloride-containing waste, HCl may be recovered for use.

All post-combustion chambers in hazardous waste incineration plants are essentially incineration chambers. In one plant (Ravenna, Italy) the post-combustion chamber is so large that the total thermal process can occur there.

Operation temperatures are usually chosen to ensure good destruction of the waste fed into the chamber. Some catalytic systems are used for specific waste streams, these run at reduced temperatures of 400-600°C.

4.2.1.6.5. Cycloid incineration chamber for sewage sludge

A cycloid incineration chamber is now used for the thermal disposal of sewage sludge. The optimal particle size for fuel ignition lies between 1 and 5 mm, therefore only dried sewage sludge granules can be used.

4.2.1.6.6. Wastewater incineration

Wastewater can be cleaned through the incineration of its organic content. This is a special technology for the treatment of industrial wastewater where organic and sometimes inorganic wastewater content material is chemically oxidised with the help of atmospheric oxygen with the evaporation of the water, at high temperatures. The term “gas phase oxidation” is used to differentiate this type of incineration from other technologies, such as wet oxidation. The process of gas phase oxidation is used if the organic substances in the water cannot be reused or if their recovery is not economical or another technique is not applied.

4.2.1.6.7. Plasma technologies

Plasma is a mixture of electrons, ions and neutral particles. This high temperature, ionised, conductive gas can be created by the interaction of a gas with an electric or magnetic field. Plasmas are a source of reactive species, and the high temperatures promote rapid chemical reactions.

Plasma processes utilise high temperatures (5000 to 15000°C), resulting from the conversion of electrical energy to heat, to produce a plasma. They involve passing a large electric current though an inert gas stream.

Under these conditions, hazardous contaminants, such as PCBs, dioxins, furans, pesticides, etc., are broken into their atomic constituents, by injection into the plasma. The process is used to treat organics, metals, PCBs (including small-scale equipment) and HCB. In many cases the pre-treatment of waste may be required.

An off-gas treatment system depending on the type of waste treated is required, and the residue is a vitrified solid or ash. The destruction efficiency for this technology is quite high (>99.99%). Plasma is an established commercial technology; however, the process can be very complex, expensive and operator intensive.

4.2.2. Use of flow modelling

Physical and/or computer models may be used to investigate the effect of design features. Various parameters may be investigated, including gas velocities and temperatures inside the furnace and boilers. Gas flow through FGT systems may also be studied with a view to improving their efficiency, e.g. SCR units.

Modelling has been successfully used at both new and existing incineration plants to optimise:

- Furnace and boiler geometry.
- The positioning of secondary and/or flue-gas recirculation air (if used).
- The reagent injection points for SNCR NO_x reduction.
- Gas flow through SCR units.

More information can be found in BAT number 15 (table 4.4). The specific applicability of this technique is as follows:

- Flow modelling: this is applicable to new waste incineration projects, existing plants where concerns exist regarding combustion and boiler design, existing plants undergoing alterations in the furnace/boiler, new and existing plants investigating the positioning of secondary/flue-gas recirculation air injection equipment and installations installing or using SCR.

For the Mediterranean region, this technique may be useful; however, as the costs are medium-high, its global advantage must be carefully studied.

4.2.3. Use of continuous rather than batch operation

Emissions at incineration plants are easier to control during routine operation than during start-up and shutdown operations. Reducing the number of start-ups and shutdowns required is an important operational strategy that can reduce overall emissions and consumption. Sizing and maintaining plants to maximise continuous running is also important.

Factors that help to achieve continuous throughput include:

- The process design throughput rate being similar to the rate at which waste is received.
- Waste storage (where possible) may cover slow periods (seasonal waste generation fluctuations).
- Organisation of the supply chain to prevent slow periods.
- Supplementing waste feed with additional fuels.
- Use of online cleaning.

Further details are described in BAT 16 (table 4.4); the specific applicability is as follows:

- Adopt operational regimes: planning for and achieving a reduced number of shutdowns is likely to reduce the annual mass emission levels of any plant.

4.2.4. Controlling combustion conditions

This section has been divided into three parts (optimisation of air supply stoichiometry, primary and secondary air supply optimisation and distribution). In general, control techniques are a key part of the combustion process as they ensure the adequate conditions are provided. Due to their value in preventing incidents and abnormal situations, they are strongly recommended within the Mediterranean region.

The specific applicability of these techniques is as follows (See BAT 18, table 4.4):

- Optimisation and control of combustion conditions:
  a) Primary air supply: this technique is applied at every plant.
  b) Secondary air injection: this is applicable to all waste incineration plants.
  c) Design to increase turbulence: the SCC is designed by the supplier at the design stage. Additional features might be necessary with some furnace designs for some types of waste. The use of additional physical features to increase mixing is currently mainly applied in the **HWI industry.**

4.2.4.1. Optimisation of air supply stoichiometry

In combustion systems, sufficient oxygen (usually from air) must be supplied to ensure that combustion reactions reach completion; the supply of air therefore has the following roles:

- Cooling.
- Prevention of slag formation in the combustion chamber/boiler.
- Mixing of gases to improve efficiency.
- Influencing burnout quality.

The precise amount of air required is dependent upon the waste type and characteristics and the type of combustor.

In general, the over-supply of air should be avoided, but it must still be sufficient to ensure effective combustion (as demonstrated by low and stable CO concentrations downstream of the furnace).

4.2.4.2. Primary air supply optimisation and distribution

Primary air is that which is supplied into, or directly above, the waste bed to provide the oxygen necessary for combustion. The manner of primary air supply is directly related to the incineration technology.

In grate systems it is supplied through the grate into the waste bed to bring the necessary air to the different zones of the grate where the reactions occur and ensure homogeneous and sufficient distribution inside the waste bed. This improves bottom ash burnout and cooling of the grate bars to prevent slagging and corrosion. The cooling of fluid-cooled grates is typically achieved by means of a separate water circuit and the effect of the primary air on cooling is therefore irrelevant.

4.2.4.3. Secondary air injection, optimisation and distribution

During drying, gasification, incineration, and burnout, combustible waste materials are transformed into gaseous form. These gases are a mixture of many volatile components, which must be further oxidised. For this purpose, additional air (so-called secondary air) is introduced into the furnace.

Another main function of the secondary air is to mix the hot flue-gases. For this purpose it is blown into the furnace through a large number of nozzles, which ensures that the furnace's entire cross-section is sufficiently covered.

4.2.5. Use of automatically operated auxiliary burners

During start-up, auxiliary burners are used to create a zone above the required minimum temperature, through which the flue-gases are fed from the furnace zone to the secondary incinerator. This is the predominant operational condition for the burner design. In order to ensure a sufficient temperature under extreme conditions, auxiliary burners are installed. These are used when the temperature falls under the required minimum temperature.

The BAT associated with this practice is number 21 (table 4.4). It can be applied in all waste incinerators, particularly those receiving waste of low heat value (LHV) and/or waste of inconsistent quality.

4.2.6. Protection of furnace membrane walls and boiler first pass with refractory or other materials

The furnace is formed by membrane walls consisting of rows of vertical tubes, connected by strips, welded together in order to form a closed (membrane) wall, which is part of the boiler's evaporation section. In the lower section of the furnace in particular, the membrane walls must be protected against the corrosive and abrasive effect of the flue-gases, which are not yet fully incinerated at that point. For this purpose, the furnace walls of the lower section are covered with a layer of ceramic refractory material or other protective materials. An additional advantage of this wall protection for lower calorific value waste is the reduction of heat transfer to the boiler, which is beneficial where temperatures need to be maintained.

The related best available technique is number 22 (table 4.4). Its specific applicability is described below:

- Use of a combination of heat removal close to the furnace insulation:

  a) Protection of the furnace membrane walls: this technique is mainly applied to municipal grate incinerators.

b) Use of an integral furnace-boiler: this is applicable to all types of grates except rotary and oscillating kilns. The capacity of furnaces must be above 10 t/h of waste.

4.2.7. Use of low gas velocities in the furnace and the inclusion of empty passes before the boiler convection section

The furnaces of waste incinerators are normally designed large enough to provide low gas velocities and long gas residence times. This allows combustion gases to be fully burned out, and prevents boiler tube fouling.

Heat-exchanger fouling may also be reduced by including empty passes between the main furnace area and the heat-exchange bundles to allow gas temperature, and hence fly ash stickiness, to be reduced.

See BATs 23 and 25 (table 4.4) for further information on these techniques. They can be applied in the Mediterranean region wherever they are necessary and related benefits compensate the additional costs. Specific applicability for each of them is as follows:

- Use of furnace dimensions that are large enough to provide an effective combination of gas residence: this technique is mainly applicable to the design of new plants and where substantial re-fits of existing furnaces and boilers are being carried out. It is also applicable to nearly all types of incinerators.
- Use of a boiler design that allows gas temperatures to reduce sufficiently: this is applicable at the design stage to all incineration plants with energy recovery boilers, when concerns exist for improving operating life and efficiency. Use of a "platen" type superheater: this can be installed in any boiler with two or three open passes.

4.3. THE ENERGY RECOVERY STAGE

Energy recovery is an important issue in these types of installations, as it saves energy problems and costs. In the following section, a description of the main techniques associated with the improvement of the energy recovery stage has been developed. In table 4.6 the best available techniques and practices have been summarised. Specific applicability is presented in each section; however, these techniques are generally applicable to all hazardous waste incinerators.

Particular assessments focused on each installation should be made in the Mediterranean region to ensure expected improvements.

Table 4.6: BATs for energy recovery

BAT	Environmental benefits	Economics
26.- The overall optimisation of installation energy efficiency and energy recovery, in general: • To reduce energy losses with flue-gases. • The use of a boiler to transfer the flue-gas energy for the production of electricity and/or supply of steam/heat with a thermal conversion efficiency for **hazardous waste** giving rise to increased boiler corrosion risks (typically from chlorine/sulphur content), of above 60 to 70%. • For gasification and pyrolysis processes, the use of a boiler with a thermal conversion efficiency of at least 80% or the use of a gas engine or other electrical generation technology.	Increasing the recovery and effective supply/use of the energy value of the waste replaces the need for the external generation of this energy, resulting both in a saving of resources and in avoiding the emissions and consumption of the avoided external energy generation plant.	Higher relative treatment costs at smaller plants and the lack of an economy of scale tend to lead to a lower availability of capital for investment in the most sophisticated energy recovery techniques. This, in turn, means that lower efficiencies can be expected at smaller installations.
27.- To secure, where practicable, long-term base-load heat/steam supply contracts with large heat/steam users so that a more regular demand for the recovered energy exists and therefore a larger proportion of the energy value of the incinerated waste may be used.	See BAT no. 26.	See BAT no. 26.
28.- The location of new installations so that the use of the heat and/or steam generated in the boiler can be maximised through any combination of: • Electricity generation with heat or steam supply for use. • The supply of heat or steam for use in district heating distribution networks. • The supply of process steam for various, mainly industrial, uses. • The supply of heat or steam for use as the driving force for cooling/air conditioning systems.	This improves overall energy efficiency by supplying heat to a synergistic user.	High electricity prices encourage the adoption of techniques that increase electrical generation efficiency.

BAT	Environmental benefits	Economics
29.- In cases where electricity is generated, the optimisation of steam parameters, including consideration of the use of higher steam parameters to increase electrical generation and the protection of boiler materials using suitably resistant materials.	Higher electrical output per tonne of waste burned can be achieved by the increase of steam pressure and/or temperature. This higher efficiency reduces external use of fossil fuel and the related CO_2 emissions.	The cost of cladding can be discounted against reduced maintenance costs and income from electricity sales and improved plant availability. The cost of cladding has been reported to be approx. EUR 3,000/m^2. The range of increase in income depends on the energy price obtained.
30.- The selection of a turbine suited to: • The electricity and heat supply regime. • High electrical efficiency.	This has an influence on electricity production and energy output. Steam tapping results in optimised energy use. Savings in fossil fuels lower pollutant and greenhouse gas emissions.	NA.
31.- At new or upgrading installations, where electricity generation is the priority over heat supply, the minimisation of condenser pressure.	Increased electrical energy generation is possible by improving the vacuum.	The use of larger pressure reduction techniques will be more economic where electrical energy has a higher price. For air-cooled condensers (ACC), larger pressure drops require larger surface area equipment and higher performance of the fan motors, which then increases costs.
32.- The general minimisation of overall installation energy demand, including the following: • For the performance level required, the selection of techniques with lower overall energy demand. • Ordering flue-gas treatment systems in such a way that flue-gas reheating is avoided. • Using heat exchangers to heat the SCR inlet flue-gas with the flue-gas energy at the SCR outlet. • The use of heat exchange systems to minimise flue-gas reheating energy demand. • Avoiding the use of primary fuels by using self produced energy.	Reducing the process demand reduces the need for external energy generation or allows the export of greater quantities of energy. The additional energy recovered may be supplied for use.	Operational cost savings may be made by reducing the external process energy demand. Where the energy saved can be exported, this can result in additional income. Capital costs of significant re-design at existing plants may be large in relation to the benefits that can be achieved.

BAT	Environmental benefits	Economics
33.- Where cooling systems are required, the selection of the steam condenser cooling system technical option that is best suited to the local environmental conditions.	The environmental benefits depend on the type chosen; it is possible to decrease installation parasitic electricity demand, thermal impacts, noise impacts or visual impacts.	NA.
34.- The use of a combination of on-line and off-line boiler cleaning techniques to reduce dust residence and accumulation in the boiler.	Improved heat-exchange increases energy recovery. Although flue-gas treatment (FGT) systems can be used to absorb or **destroy PCDD/F**, the reformation risk may be reduced by effective cleaning.	NA.
37.- When selecting between wet, semi-wet and dry FGT systems, taking into account the general selection criteria as given as an example in table 5.3. (Waste Incineration BREF [3]).	Example of assessment of some IPPC relevant criteria that may be taken into account. (Waste Incineration BREF [3],table 5.3)	NA.
38.- To prevent the associated increased electrical consumption, to generally (i.e. unless there is a specific local driver) avoid the use of two bag filters in one FGT line. The techniques that may be used are: a) Application of an additional flue-gas polishing system. b) Application of double bag filtration.	a) Further reduction of emissions to the air of dust (below 1 mg/m^3), heavy metals, mercury and PCDD/F and acid gases. b) Additional reduction in dust emissions to air. 24 hour average levels of below 1 mg/m^3 can be achieved in nearly all situations. Separation of FGT residues is possible, i.e. separation of fly ash from the FG neutralisation residues. This may then allow the recovery of one or other fraction where suitable outlets exist.	a) The key cost aspects of this technique are: increased capital investment costs of additional process unit and increased operational costs (mainly due to the energy requirements for pressure drop, provision of compressed air for back pulsing of bag filter, and additional maintenance costs). b) Additional cost and extra process units. Additional energy costs and maintenance.
72.- The direct injection of liquid and gaseous hazardous waste, where this waste requires specific reduction of exposure, releases or odour risk.	Prevention of diffuse air emissions due to the fact that the waste is fed by a complete closed system.	An average investment price for a dedicated line amounts to EUR 100,000-200,000.

BAT	Environmental benefits	Economics
74.- To reduce installation energy demand and to achieve an average installation electrical demand of generally below 0.3-0.5 MWh/tonne of waste processed.	Reducing the process demand reduces the need for external energy generation or allows the export of greater quantities of energy. The additional energy recovered may be supplied for use.	Operational cost savings may be made by reducing the external process energy demand. Where the energy saved can be exported, this can result in additional income. Capital costs of significant re-design at existing plants may be large in relation to the benefits that can be achieved.

4.3.1. Introduction and general principles

Incineration plants can liberate the energy value of waste and can supply electricity, steam and hot water. Where a plant is located so that the supply and use of these outputs can be maximised, this will allow better use of the energy value of the waste.

Energy input to incineration plants is mainly from the calorific content of the waste, but may also come from additional fuel added to support the combustion process, and also from imported power (electricity). Optimising the efficiency of the plant consists of optimising the whole process. The optimal energy efficiency technique depends on the particular location and on operational factors. Examples of factors that need to be taken into account when determining the optimal energy efficiency are:

- Location. If is there a user/distribution network for the energy.
- Demand for the energy recovered. There is little point in recovering energy that will not be used. This is a particular issue with heat but generally less of an issue with electricity.
- Variability of demand.
- Climate. In general heat will be of greater value in colder climates.
- Reliability of fuel/power supply. Isolated plants may experience unreliable waste deliveries or even electrical supply interruptions that can result in shutdowns or greater dependence on the use of self-generated power.
- Waste composition. Higher concentrations of corrosive substances can result in an increased corrosion risk, thus limiting steam parameters if process availability is to be maintained.
- Waste variability. Rapid and extensive fluctuations in composition can give rise to fouling and corrosion problems that limit steam pressure and hence electricity generation.
- High electrical efficiency conversion plants may be attractive when electrical power prices are high; however, frequently more sophisticated technology has to be used with a possible negative effect on availability.

Combustion is an exothermic (heat generating) process. The majority of the energy produced during combustion is transferred to the flue-gases. Cooling down the flue-gas allows:

- The recovery of the energy from the hot flue-gases, and
- Cleaning the flue-gases before they are released to the atmosphere.

In plants without heat recovery, the gases are normally cooled by the injection of water, air, or both. In the majority of cases a boiler is used.

In waste incineration plants, the boiler has two interconnected functions:

- To cool the flue-gases.

- To transfer the heat from the flue-gases to another fluid, usually water which is usually transformed inside the boiler into steam.

The design of the boiler will mainly depend on the stream and the flue-gas characteristics. The flue-gas characteristics are themselves highly dependent on waste content. **Hazardous waste**, for example, tends to have very wide variations in composition and, at times, very high concentrations of corrosive substances in the raw gas. This has a significant impact on the possible energy recovery techniques that may be employed. In particular, the boiler can suffer significant corrosion, and steam pressure may need to be reduced with such waste.

The principal uses of the energy transferred to the boiler are:

- Production and supply of heat (as steam or hot water).
- Production and supply of electricity.
- Combinations of the above.

The specific applicability is as follows (BATs 26, 27 and 73 in table 4.6):

- The overall optimisation of installation energy efficiency: the efficiency range that can be achieved depends on the chemical and physical nature of the waste being burned as well as its calorific content. In general, higher electrical efficiency can be achieved where the waste contains lower and/or less variable concentrations of substances that may enhance corrosion in boilers. As high temperature corrosion becomes an increasing problem at higher steam parameters, the need for high plant availability can become a limiting factor.
- Reducing energy installation demand: options for optimisation are greatest at new installations, but at existing plants options may be more limited.

4.3.2. Reduction of overall process energy consumption

The reduction of energy consumption is an important good practice due to its environmental benefits and costs savings. This is fully applicable in the Mediterranean region provided that the particularities of each installation are taken into account.

The reduction of installation energy requirements needs to be balanced against the need to ensure effective incineration, to achieve treatment of the waste and control of emissions (particularly to air).

Some of the common sources of significant process energy consumption are:

- Induced and forced draught fans to overcome pressure drops and for combustion air.
- Waste transfer/loading equipment (e.g. pumps/cranes and grabs/screw feeders).
- Air-cooled condensers.
- Waste pre-treatment (shredders, etc.)
- Flue-gas heating for specific air pollution control devices (e.g. bag filters, SCR systems).
- Flue-gas reheating for reduction in plume visibility.
- Fuels for combustion support and start-up/shutdown.
- Wet flue-gas treatments, which cool flue-gases better than semi-wet and dry systems.
- Electricity demand from other devices.

The following techniques and measures can reduce process demand in the abovementioned sources:

- Avoiding the use of unnecessary equipment.
- Using an integrated approach to target overall installation energy optimisation rather than optimising each separated process unit.

- Placing high temperature equipment upstream of lower temperature or high temperature drop equipment.
- The use of heat-exchangers to reduce energy inputs.
- The use of energy generated by the WI plant that would otherwise not be used or supplied, to replace the import of external energy sources.
- The use of frequency-controlled rotating equipment for those equipment parts which operate at variable speeds, such as fans and pumps, where they are effectively often operated at reduced load.

The selected BAT is 32, as shown in table 4.6 and its applicability is:

- General minimisation of overall installation energy demand: options for optimisation are greatest at new installations – where it will be possible to examine and select from a variety of overall designs in order to achieve a solution that balances emissions reduction against energy consumption. At existing installations, options may be more limited, owing to the expense (and additional technical risk) associated with complete re-design. Plants that have been retrofitted to achieve particular emission limit values generally have to fit tail-end gas cleaning equipment and will therefore have higher energy consumption figures.

4.3.3. External factors affecting energy efficiency: waste type and nature

The characteristics of the waste delivered to the installation will determine the techniques that are appropriate and the degree to which energy can be effectively recovered. Both chemical and physical characteristics are considered when selecting processes.

4.3.4. External factors affecting energy efficiency: influence of plant location on energy recovery

In addition to waste quality and technical aspects, the possible efficiency of a waste incineration process is influenced to a large extent by the output options for the energy produced. Processes with the option to supply electricity, steam or heat will be able to use more of the heat generated during incineration for this purpose and will not be required to cool away the heat, which otherwise results in reduced efficiency.

The highest waste energy utilisation efficiency can usually be obtained where the heat recovered from the incineration process can be supplied continuously as district heat, process steam etc., or in combination with electricity generation. However, the adoption of such systems is very dependent on plant location, in particular the availability of a reliable user for the energy supplied.

The generation of electricity alone (i.e. no heat supply) is common, and generally provides a means of recovering energy from the waste that is less dependent on local circumstances.

The specific applicability of the related BAT (no. 28 in table 4.6) is:

- Location of new installations: this is only applicable where a synergistic operation is situated conveniently and suitable commercial agreements are in place. Mainly applicable where the focus of energy recovery is the production of electricity. Less applicable to plants that can supply steam or heat directly to a user.

4.3.5. Factors taken into account when selecting the design of the energy cycle

The following factors are reported to be taken into account when determining the local design of a new waste incineration plant.

Factor to consider	Detailed aspects to consider
Waste feed	• Quantity and quality. • Availability, regularity, delivery variation with seasons. • Prospect of change in both the nature and the quantity of waste. • Effects of waste separation and recycling.
Energy sales possibilities	Heat: • To communities. • To private industries. • Heat use. • Geographical constraints; delivery piping feasibility. • Duration of the demand, duration of the supply contract. • Obligations for the availability of the supply. • Steam/hot water conditions: pressure, temperature, flow rate, condensate return or not? • Season demand curve. • Subsidies can influence economics significantly. • Heat customer holdings in the plant financing. Electricity: • National grid or industrial network, plant self-consumption, customer self-consumption. • Price of electricity significantly influences investment. • Subsidies or loans at reduced rates can increase investment. • Technical requirements: voltage, power, availability of distribution network connection.
Local conditions	• Cooling medium selected: air or water. • Meteorological conditions in time. • Acceptability of a “plume” of water vapour. • Availability of cold water source.
Combined heat and power	• Apportionment according to the season. • Evolution of the apportionment in future.
Other	• Choice between: increasing energy output, reducing investment cost, operational complexity, availability requirements, etc. • Acceptable noise level. • Available space. • Architectural constraints.

Some have been selected as best available techniques (numbers 29 and 31 in table 4.6). The specific applicability of these BATs is:

- Optimisation of steam parameters: this is applicable to all incinerators recovering electricity only, or where the heat proportion of combined heat and power plants (CHP) is low, to increase electricity outputs. The technique has limited applicability to processes that have reliable options for the supply of steam or heat.
- Where electricity generation is the priority: where electricity generation is of lower priority, the turbine outlet pressure can be above atmospheric. Air-cooled condensers (ACC) are often the only possible type applicable. Open loop hydro-condensers are only suited to locations where there is an abundant water supply that can tolerate the heating effect of the subsequent discharge.

4.3.6. Selection of turbines

The incineration process can take place with different types of turbine. The more common are:

- Back pressure turbines: used when a significant and possibly constant amount of heat can be supplied to customers.
- Condensing turbines: used when there are few or no possibilities to supply heat to customers and the recovered energy is to be converted into electricity.
- Extraction condensing turbines: these are condensing turbines with a significant extraction of steam at intermediate pressure for some purpose. There are nearly always some extraction(s) so that significant and varying amounts of heat or steam can be supplied to customers.
- Double stage condensing turbines: these heat up the steam between the two stages by using some of the input steam for superheating the steam in the second stage to reach higher energy production at low condensation temperatures.

There is one BAT selected (number 30 in table 4.6), in relation to this:

- Selection of a turbine: turbine selection must be made at the same time as the other steam cycle characteristics and depends more on external aspects than the incineration process.

4.3.7. Energy efficiency of waste incinerators

Energy input and output are involved in energy efficiency:

Energy input to the incinerators that needs to be taken into account when considering energy efficiency is as follows:

- Electricity input: plants may choose to export all of the electricity generated by the incinerator, particularly when economic incentives support the production of electrical energy from incineration, and import from the grid the energy required to run the incineration process itself.
- Steam/heat/hot water input: steam (heat or hot water) can be used in the process. The source can be external or circulated.
- Conventional fuels are consumed in order to: ensure that the required combustion chamber temperatures are maintained; increase the temperature in the combustion chamber to the required level before the plant is fed with waste; increase flue-gas temperature in order to avoid bag house filter and stack corrosion, and to suppress plume visibility; preheat the combustion air and heat up the flue-gas for treatment in specific devices, such as selective catalytic reduction (SCR) or fabric filters.

Energy output from waste incinerators is:

- Electricity: the incineration process itself may use some of the electricity produced.

- Fuel: fuel (e.g. syngas) is produced in gasification/pyrolysis plants and may be exported or combusted on-site with or without energy recovery.
- Steam/hot water: the heat released in the combustion of waste is often recovered for a beneficial purpose e.g. to provide steam or hot water for industrial or domestic users, for external electricity generation or even as a driving force for cooling systems. Combined heat and power (CHP) plants provide both heat and electricity.

4.3.8. Applied techniques for improving energy recovery: waste feed pre-treatment

There are two main categories of pre-treatment techniques of relevance to energy recovery: homogenisation and extraction/separation:

Homogenisation of waste feedstock mixes the waste received at the plant using the physical techniques in order to supply a feed with consistent combustion qualities.

Extraction/separation involves the removal of certain fractions from the waste before it is sent to the combustion chamber. Techniques range from extensive physical processes for the production of refuse derived fuels (RDF) and the blending of liquid waste to meet specific quality criteria, to the simple spotting and removal by crane operators of large items that are not suitable for combustion, such as concrete blocks or large metal objects.

4.3.9. Applied techniques for improving energy recovery: boilers and heat transfer

Tubular water boilers are generally used for steam and hot water generation from the energy potential of hot flue-gases. The steam or hot water is generally produced in tube bundles in the flue-gas path. The envelopment of the furnace, the following empty passes and the space where evaporator and super-heater tube bundles are located are generally designed with water-cooled membrane walls.

Higher steam parameters increase turbine efficiency and result in higher electricity production per tonne of waste burned. However, because of the corrosive nature of the gases emitted by the waste when it is burned, incinerators cannot use the same temperatures and pressures as some primary power generators.

Spray coolers and surface coolers are used in circulation boilers in order to maintain the exact required steam temperature. It is their function to balance the fluctuations of the steam temperature, these fluctuations being the consequences of load fluctuations, changes in the waste quality, surplus air, as well as contamination of the heat surfaces.

The preparation of boiler feed water and make-up water is essential for effective operation and to reduce corrosion (inside the tubes) or risk of turbine damage. The quality of boiler water must be higher when increased steam parameters are used.

4.3.10. Applied techniques for improving energy recovery: combustion air preheating

Preheating the combustion air is particularly beneficial for assisting the combustion of high moisture content waste. The pre-warmed air supply dries the waste, thus facilitating its ignition. The supply heat can be taken from the combustion of the waste by means of heat-exchange systems.

4.3.11. Applied techniques for improving energy recovery: water cooled grates

Water cooling of grates is used to protect the grate. Water is used as a cooling medium to capture heat from the burning waste bed and use it elsewhere in the process. It is common that the heat removed is fed back into the process for preheating the combustion air or heating the condensate.

Another option is to directly integrate the water cooling into the boiler circuit, operating it as an evaporator.

These grates are applied where the net calorific value of the waste is higher, typically above 10MJ/kg. At lower calorific values their application is more limited.

The specific applicability of the best available technique (number 33 in table 4.6):

- Cooling systems: The selection of cooling system depends upon main local environmental and health issues and relative importance of associated cross-media effects. Water cooling by convection is not applicable in dry inland situations.

4.3.12. Reduction of condenser pressure

After leaving the low-pressure section of the steam turbine, the steam is condensed in condensers and the heat is then passed into a cooling fluid. The condensed water from steam is generally re-circulated and used as boiler feed water.

The temperature of the cold source at the turbine outlet is important for turbine productivity. The colder the source, the higher the enthalpy drop and, therefore, the higher the energy generation. For reasons of climatic conditions, it is obvious that it is easier to achieve this low pressure in cooler climates. Therefore this is not a technique that could be widely used in the Mediterranean Region.

4.3.13. Applied techniques for improving energy recovery: flue-gas condensation

Water in the flue-gas from combustion comprises evaporated free water from the fuel and reaction water from the oxidation of hydrogen, as well as water vapour in the combustion air. When burning waste, the water content in the flue-gas after the boiler and economiser normally varies between 10 and 20% in volume, corresponding to water dew points of about 50-60°C. During cleaning of the boiler with steam, the water content in the flue-gas increases to about 25%.

The minimum possible dry gas temperature at this point is 130-140°C using normal boiler construction material. This temperature is mostly determined in order to be above the acid dew point, linked to the SO_3 content and the H_2O content of the flue-gas.

4.3.14. Applied techniques for improving energy recovery: heat pumps

The main purpose of heat pumps is to transform energy from one temperature level to a higher level. There are three different types of heat pumps in operation at incineration installations: compressor-driven heat pumps, absorption heat pumps and open heat pumps.

Compressor-driven heat pumps are, for instance, installed in refrigerators, air conditioners, chillers, dehumidifiers, and heat pumps used for heating with energy from rock, soil, water and air. An electrical motor normally drives the pump, but for big installations, steam turbine-driven compressors can be used. In a closed circuit, a refrigerant substance is circulated through a condenser, expander, evaporator and compressor. The ratio between output heat and compressor power can be as high as 5.

Absorption heat pumps are similar to the compressor type pump. They operate with water in a closed loop through a generator, condenser, evaporator and absorber. Instead of compression, circulation is maintained by water absorption in a salt solution, normally lithium bromide, in the absorber. The ratio between the output heat and absorber power is normally about 1:6.

Open heat pumps: the principle is to decrease the water content of the flue-gas downstream of the condenser using a heat and humidity exchanger with air as the intermediate medium. The higher water content in the flue-gas in the condenser means a higher water dew point, and a bigger difference between the water dew point and the dew point of the return water from the district heating system.

4.3.15. Applied techniques for improving energy recovery: flue-gas recirculation

A proportion (approximately 10-20% by volume) of the flue-gases is re-circulated, normally after pre-dedusting, to replace secondary air feeds in the combustion chamber. This technique is reported to reduce heat losses in the flue-gas and to increase the process energy by around 0.75-2%. Additional benefits of primary NO_x reduction are also reported. Lagging of the recirculation ducting is reported to provide an effective remedy for corrosion concerns in this area.

These are applicable to all waste incinerators with boilers, including in the Mediterranean Region (BAT 34 in table 4.6).

4.3.16. Applied techniques for improving energy recovery: reheating of flue-gases to the operation temperatures of FGT devices

Some air pollution control equipment requires the flue-gases to be reheated to enable their effective operation. Examples include SCR systems and bag filters that generally require temperatures in the region of 250°C and 120°C respectively. The energy for heating the gases can be obtained from external energy sources and the use of process-generated heat or power. The use of heat exchanges to recapture the heat after the equipment reduces the need for external energy input. This is carried out where the next stage of the process does not require the flue-gas temperature to be as high as that emitted from the earlier equipment.

The specific applicability of some of theses BATs (numbers 38 and 39 in table 4.6) is:

- To prevent the associated increased electrical consumption:
  a) Application of an additional flue-gas polishing system: the additional abatement of heavy metals increases suitability where these require further reduction. Larger plants with higher flows can achieve greater reductions in local contributions to emissions. This is an end-of-pipe technique, well-suited to retrofits where dust requires reduction. Existing plants already achieving low emission levels through other means may not benefit greatly from the addition of this technique.
  b) Application of double bag filtration: This can be applied to any incineration process, but is most applicable where very low dust emission limit values are applied or separation of FGT residue components is desired.
- The reduction of FGT reagent consumption and of FGT residue production:
  a) Use of acid gas monitoring for FGT process optimisation: this is particularly suited to dry, semi-wet and intermediate FGT processes with high variability inlet concentrations of acid gases. Smaller plants may benefit the most as rogue waste input can exert greater influence on smaller throughput systems. It is suited to new and existing processes but particularly suited to retrofits where acid gas control could be further optimised.
  b) Recirculation of FGT residues in the FGT system: this is applicable to all waste types except where inlet concentrations are highly variable e.g. merchant hazardous waste, unless in combination with another system for these pollutants. There are no specific restrictions for new/existing plants.

4.3.17. Applied techniques for improving energy recovery: plume visibility reduction

In some locations sensitivity to visible plumes is high. Certain techniques (e.g. wet scrubbing) also give rise to higher levels of moisture in the flue-gas and therefore increase the possibility of high-visibility plumes. Lower ambient temperature and higher humidity levels increase the risk of plume condensation, and hence visibility. Increasing the temperature of the flue-gases provides one way of reducing plume visibility, as well as improving the dispersion characteristics of the release. Depending on flue-gas moisture content and atmospheric conditions, plume visibility is greatly reduced above stack release temperatures of 140°C. This can be achieved by selecting alternative flue-gas treatments or by the use of condensing scrubbers to remove water from the flue-gas.

4.3.18. Applied techniques for improving energy recovery: steam water cycle improvement

The selection of the steam water cycle will generally have a much greater impact on the energy efficiency of the installation than improving individual elements of the system, and therefore provides the greatest opportunity for increased use of energy in the waste. It should be applied in the Mediterranean Region.

4.3.19. Efficient cleaning of the convection bundles

Clean boiler tubes and other heat-exchange surfaces result in better heat exchange. This may also reduce the risk of dioxin formation in the boiler.

Cleaning may be carried out on-line (during boiler operation) and off-line (during boiler shutdowns and maintenance periods). Dimensions of the boiler and heat exchanger design (e.g. tube spacings) influence the cleaning regime.

Techniques for on-line cleaning include:

- Mechanical rapping.
- Soot-blowing by steam injection.
- High or low pressure water spraying (mainly on the wall in the empty passes of the boiler).
- Ultra/infra/sonic cleaning.
- Shot cleaning or mechanical pellet scouring.
- Explosive cleaning.
- High-pressure air injection with movable lances.

Off-line techniques include:

- Periodic manual cleaning.
- Chemical cleaning.

In addition to these techniques, it can also beneficial to prevent higher temperature gases (when fly ash is stickier and hence more likely to adhere to surfaces it comes into contact with) coming into contact with convective heat-exchange bundles by:

- Including empty passes with water walls only.
- Using large furnace dimensions and hence lower gas velocities before the bundles.

4.4. STEAM GENERATORS AND QUENCH COOLING FOR HAZARDOUS WASTE INCINERATORS

There are two main approaches adopted for cooling the combustion gases from hazardous waste incinerators: heat recovery boilers and rapid quench cooling.

Heat recovery boilers in hazardous waste incineration installations: the hot combustion gases are cooled in a steam generator (or boiler) with a capacity of between 16MW and 35MW depending on the installation. The steam that is produced has a pressure of 13 bar to 40 bar with a temperature of between 207 and 385°C. A range of factors influence the efficiency of the steam generators used in hazardous waste incinerators, including the composition of the gas and the potential for deposition to occur on the heat-exchange surfaces. This has a significant influence on the construction materials used and on the design, as well as on the operational life and performance of the equipment. For some installations, the steam is used in a turbine to produce electricity. Alternatively, steam may be transported for direct use in industrial processes, e.g. the production of chemicals, or to other waste treatment processes, or fed into a district heating system. Combinations of these are also applied.

Rapid quench cooling: some installations are not equipped with a boiler, but the combustion gases are reduced in temperature by means of very quick quench cooling. This is performed to prevent the formation of dioxins and to avoid the installation of an extra end-of-pipe dioxin removal technique. These installations are referred to as “quenchers”, and have been adopted in some plants where a very wide range of highly halogenated waste inputs have to be treated. This limits the potential options for energy recovery.

The main advantages and disadvantages of both approaches are described in table 4.7:

Table 4.7: Advantages and disadvantages of gas cooling systems

Gas cooling system	Advantages	Disadvantages
Heat recovery boiler	• High energy recovery efficiency possible (70-80% can be converted to steam). • Lower water consumption and water treatment volumes.	• Possible increased risk of dioxin reformation in boiler. • Additional capital and maintenance costs of boiler system.
Rapid quench cooling	• Reduced risk of dioxin re-formation. • Need for additional dioxin controls on emissions to air may be reduced. • It may be possible to treat waste with a more variable range and higher halogen or salts loads if this technique is used.	• Very limited energy recovery. • Water consumption may be higher. • Water treatment volumes may be higher.

4.5. APPLIED FLUE-GAS TREATMENT (FGT) AND CONTROL SYSTEMS

This chapter is divided into two parts. One refers to flue-gas treatment and the other to the techniques to control emissions (including particulates, acid gases, NO_x, dioxins and furans, mercury and heavy metals, organic compounds and greenhouse gases). The following table (table 4.8) presents the selection of the related best available techniques.

Techniques and practices focused on the reduction of flue-gas treatment, and especially PCDD/F emissions, are considered critical for all incineration installations, thus the application of the most appropriate is essential, including in the Mediterranean region.

Table 4.8: BATs for flue-gas treatment and control systems

BAT	Environmental benefits	Economics
35.- The use of an overall flue-gas treatment (FGT) system that, when combined with the installation as a whole, generally provides the operational emission levels listed in Table 5.2 (Waste Incineration BREF [3]) for releases to air associated with the use of BAT.	Operational emission level ranges associated with the use of the BAT for releases to air (Waste Incineration BREF [3],Table 5.2)	NA.
36.- When selecting the overall FGT system, taking into account: the general factors, the potential impacts on energy consumption of the installation and the additional overall system compatibility issues that may arise when retrofitting existing installations.	See BAT no. 15	See BAT no. 15
37.- When selecting between wet, semi-wet and dry FGT systems, taking into account the general selection criteria as given as an example in Table 5.3. (Waste Incineration BREF [3])	Example of assessment of some IPPC relevant criteria that may be taken into account (Waste Incineration BREF [3], Table 5.3)	NA.
40.- The use of primary NO_x reduction measures to reduce NO_x production, together with either SCR or SNCR, according to the efficiency of flue-gas reduction required.	See BAT no. 36.	See BAT no. 36.
41.- For the reduction of overall PCDD/F emissions to all environmental media, the use of: • Techniques for improving knowledge of and control of the waste. • Primary techniques to destroy PCDD/F in the waste and possible precursors. • The use of installation designs and operational controls that avoid those conditions that may give rise to PCDD/F reformation or generation. The techniques that may be used are:	a) NA. b) This reduces the risk of PCDD/F production in the process and, hence, subsequent emissions. c) PCDD/F is adsorbed on the activated carbon to result in emissions of below 0.1 mg/Nm^3 TEQ. Metallic mercury is also adsorbed. d) Reduction of emissions to air as follows: PCDD/F is adsorbed to give clean gas emissions below 0.1 ng/Nm^3 TEQ, Hg is adsorbed to give emissions below 50 µg/Nm^3, typically below 30 µg/Nm^3 and dust is collected by the filter.	a) NA. b) No significant cost implications for new processes but very significant capital investments may be required for some existing processes for the replacement of boiler and flue-gas treatment systems. c) Lignite coke is reported to be more economical than activated carbon. It is also reported that in general the consumption of lignite coke is higher than activated carbon (up to twice the ratio).

BAT	Environmental benefits	Economics
a) Primary techniques for prevention of PCDD/F. b) Prevention of reformation of PCDD/Fin the FGT system. c) Adsorption of PCDD/F by activated carbon injection or other reagents. d) Adsorption of PCDD/F in static beds, and e) Destruction of PCDD/F using Selective Catalytic Reduction (SCR). f) Destruction of PCDD/F using catalytic filter bags.	e) Destruction efficiency for gas phase PCDD/F of 98 to 99.9% is seen, giving PCDD/F emissions below 0.1 ng/Nm^3 TEQ and more often in the range of 0.5-0.02 ng/Nm^3 TEQ. f) Destruction efficiency of PCDD/F entering the catalytic filter bags at a MSWI of above 99% are reported. Emission concentrations of PCDD/F of below 0.02 ng/Nm^3 TEQ resulting from inlet concentrations of 1.9 ng/Nm^3. The filters also provide dust removal. The total release of dioxins from the installation (to all media) is also reported to be reduced by destruction, rather than adsorption (with activated carbon).	d) The investment cost of a coke filter for 100,000 t/y is estimated at EUR 1.2 million. The investment cost for one static bed wet filter (empty) (incineration line of 50,000 t/yr) is approximately EUR 1 million (equipment and civil work). e) NA. f) The key cost aspects of this technique are: increased investment cost of the bags compared with non-catalytic bags. The cost of the media is EUR 300/m^2, lower investment costs than SCR but with similar destruction efficiency and the need to make additional provisions for Hg removal.
42.- Where wet scrubbers are used, carrying out an assessment of PCDD/F build-up in the scrubber and adopting suitable measures to deal with this build-up and prevent scrubber breakthrough releases.	NA.	NA.
44.- For the control of Hg emissions, where scrubbers are applied as the only or main effective means of total Hg emission control: • The use of a low pH first stage with the addition of specific reagents for ionic Hg removal. • Activated carbon injection, or • Activated carbon or coke filters. The techniques that may be used are: a) Low pH wet scrubbing and additive addition. b) Addition of hydrogen peroxide to wet scrubbers. c) Chlorite injection for elemental Hg control.	a) Overall Hg removal efficiency is around 85%. The impact of the concentration of Hg in the incinerated waste and the content of Cl are decisive in the determination of the final emission levels achieved. b) Additional reduction of concentration of all types of mercury in flue-gas (together with activated carbon usually at about 99.5% removal efficiency) as well as the reduction of HCl and SO_2. c) This reduces Hg emissions. Side benefits: NO_x reduction. d) Metallic Hg is adsorbed (usually at about 95% removal efficiency) to result in emissions to air of below 30 µg/Nm^3. Ionic mercury is also removed by chemi-adsorption resulting from the sulphur content in the flue-gas or from sulphur impregnated	a) NA. b) The cost of an installation is approx. EUR4 million for a capacity of 200,000 tonnes of waste. H_2O_2 is reported to be costly and its consumption may prove difficult to control. c) The cost of the reagent is the limiting factor. d) Additional capital costs of the technique for processes that already have, or intend to use, reagent injection and bag filters are minimal. Additional operational costs are from reagent consumption and disposal of residues. **The cost of operations (carbon cost) is approx. EUR 125,000/yr for a facility treating 65,000 tonnes of HW per year.**

BAT	Environmental benefits	Economics
d) Activated carbon injection for Hg adsorption, and e) Use of static activated carbon or coke filters.	in some types of activated carbon. The carbon also adsorbs dioxins. e) Reduction of emissions to air as follows: Hg is adsorbed to give emissions below 50 µg/Nm^3, typically below 30 µg/Nm^3 and dust is collected by the filter.	e) The investment cost of a coke filter for a 100,000 t/yr MSWI was estimated at EUR 1.2 million.
45.- For the control of Hg emissions where semi-wet and dry FGT systems are applied, the use of activated carbon or other effective adsorptive reagents for the adsorption of PCDD/F and Hg, with the reagent dose rate controlled so that final air emissions are within the BAT emission ranges given for Hg.	See BAT no. 44.	See BAT no. 44.
48.- Where wet flue-gas treatment is used: a) The use of on-site physicochemical treatment of the scrubber effluent prior to its discharge. b) The separate treatment of the acid and alkaline wastewater streams resulting from the scrubber stages when there are particular drivers for the additional reduction of releases to water, and/or HCl or gypsum recovery is to be carried out. c) The recirculation of wet scrubber effluent within the scrubber system, and the use of the electrical conductivity of the re-circulated water as a control measure. d) The provision of storage/ buffering capacity for scrubber effluent, to provide a more stable wastewater treatment process. e) The use of sulphides or other Hg binders to reduce Hg (and other heavy metals) in the final effluent. f) When SNCR is used with wet scrubbing, the NH_3 levels in the effluent discharge may be reduced using NH_3 stripping	a) With the application of sulphides to increase heavy metal precipitation from wet-scrubbing effluent, a reduction of Hg levels in effluents treated of 99.9% and emissions levels to water of Hg below 0.003 mg/l can be achieved. b) Emissions to water can be reduced further than with combined treatment. Optimisation of separated streams reduces reagent consumption and allows targeted treatment. Gypsum can be recovered from sulphur scrubbers; this reduces sulphur discharges with the wastewater and the sulphur content of solid residues from the effluent treatment plant (ETP). HCl may be regenerated from first stage acid scrubbers. c) Reduction in water consumption by wet scrubbers. It also reduces demand for fresh water and effluent to the sewer plant. d) Lower emissions to water, improved stability and confidence in the treatment process and optimisation of treatment can lead to reduced	a) The additives and reagents can be costly. b) Operational and capital costs for the second ETP may be partially offset by reduced disposal cost when gypsum and salts like NaCl or CaCl are recovered. c) NA. d) It is necessary to provide higher volumes for buffering and throughput capacity of wastewater treatment. e) NA. f) Operational and capital costs for ammonia stripper may be partially offset by reduction in reagent costs when the recovered ammonia is re-circulated to the SNCR reagent injection.

BAT	Environmental benefits	Economics
and the recovered NH_3 re-circulated for use as a NO_x reduction reagent.	consumption for effluent treatment. e) NA. f) Reduction of NH_3 in the discharged scrubber effluent and reduction of NH_3 consumption where re-circulated to the NO_x reduction reagent.	
49.- The use of a suitable combination of the techniques for improving waste burnout to achieve a TOC value in the ash residues of below 3 wt% includes: • The use of a combination of furnace design, operation and waste throughput rate that provides sufficient agitation and residence time at sufficiently high temperatures. • The use of furnace designs that physically retain the waste within the combustion chamber to allow its combustion. • The use of techniques for mixing and pre-treatment of the waste (BAT no. 11). • The optimisation and control of combustion conditions. The techniques that may be used are: a) Improving the burnout of bottom ash. b) Selection of combustion technology. c) Increased agitation and residence time. d) Adjustment of throughput to maintain good burnout and combustion conditions. e) Reduction of grate riddling rate and/or return of cooled riddling to the combustion chamber.	a) This will lower the residual carbon content and thus the TOC. b) NA. c) Effective waste destruction, improved characteristics of solid residue and increased extraction of the energy value from the waste. d) This ensures waste is properly destroyed and that the residues produced are of better quality. e) Improved burnout of the waste and improved ash quality.	a) Basic pre-treatment of waste may not be expensive. b) NA. c) At new installations, this is not expensive but at existing plants it is. d) Restricting the waste throughput can result in lower income from waste disposal. e) There can be significant investment costs for retrofitting existing plants and extra operational costs.

BAT	Environmental benefits	Economics
51.- Where a pre-dedusting stage is in use, an assessment of the composition of the fly ash so collected should be carried out to assess whether it may be recovered, either directly or after treatment, rather than disposed of. The techniques that may be used are: a) Separation of the dust removal stage from other flue-gas treatment, and b) application of an additional flue-gas polishing system.	a) It is possible to reduce overall dioxin (PCDD/F) output from the process by reducing output in solid residues by fly ash recirculation to the combustor. Non-thermal treatments for fly ash generally do not change the overall PCDD/F mass balance but concentrate the PCDD/F into smaller amounts of residue. b) Reduction of emissions to flue-gas stream by reducing particulate load on later FGT processes. Separation of the fly ash from the FGT residue allows reductions in the quantity of FGT residue produced and separate treatment of fly ash for possible recycling uses.	a) Cost of additional process may be offset by reduced FGT residue disposal costs. b) The key economic aspects are: • Increased capital and investment costs for additional process units. • increased energy costs, particularly for bag filtration. • possible cost reductions for disposal where outlets are available for segregated fly ash. • possible increased cost of handling additional residue streams.
75.- For merchant HWI and other hazardous waste incinerators feeding waste of highly varying composition and sources, the use of: a) Wet FGT is generally a BAT to provide for improved control of short-term air emissions. b) Specific techniques for the reduction of elemental iodine and bromine emissions where such substances exist in the waste at appreciable concentrations.	a) This reduces the emissions to air and wet FGT systems provide the highest removal efficiencies (for soluble acid gases) of all FGT systems with lowest excess stoichiometric factors. b) A yellow/brown or purple coloured flue-gas can be seen in some cases when appreciable concentrations of bromine or iodine (respectively) pass through the FGT system. The use of targeted or regular $Na_2S_2O_3$ addition prevents this effect.	c) Higher capital investment costs than other systems, mainly due to the effluent treatment plant and the higher number of process units required; operational costs associated with the disposal of residues may be lower. d) The construction costs for a third scrubber step at an existing HWI are approx. EUR600,000. The yearly consumption of $Na_2S_2O_3$ for each incinerator line is approx. 50 tonnes (EUR 0.5/tonne).

4.5.1. Application of FGT techniques

Flue-gas treatment systems are constructed from a combination of individual process units that together provide an overall treatment system for the flue-gases.

The individual components of a FGT system are combined to provide an effective overall system for the treatment of the pollutants that are found in the flue-gases. There are many individual components and designs, and they may be combined in many ways.

In the following subsections some indications regarding these treatments are developed. There are some selected BATs (numbers 35, 36, 74 and 48 in table 4.8) such as measures relating to flue-gas treatment. In principle, these techniques can be applied within the Mediterranean Region. The specific applicability is described below:

- For merchant HWI and other hazardous waste incinerators feeding waste:
  a) Wet FGT is generally a BAT to provide for improved control of short-term air emissions: it can be applied to any waste type, but it is particularly suited to highly variable inlet gas compositions (e.g. hazardous waste). It can also be applied to all plant sizes, but is generally applied in medium to larger plants where economies of scale exist.
  b) Specific techniques for the reduction of elemental iodine and bromine emissions: this technique is mainly applicable to HWIs or other installations where concentrations of bromine/iodine in the waste incinerated are highly variable and/or difficult to predict/control.
- Where wet flue-gas treatment is used:
  a) The use of on-site physicochemical treatment: this is applicable to all waste incinerator installations with wet scrubbing. May also be applicable to other wastewater streams that require such treatment prior to their discharge.
  b) The separate treatment of the acid and alkaline wastewater streams arising from the scrubber stages: this technique is only applicable in WI installations with wet scrubbers. In general it is only suited to new installations where there are special driving forces for effluent purity etc. It is most applicable where there is a need for final effluent of the highest quality and/or where there are outlets for the beneficial use of the recovered HCl/gypsum.
  c) The recirculation of wet scrubber effluent: This is only of use in wet scrubbing systems or for sewage sludge dewatering.
  d) The provision of storage/buffering capacity for scrubber effluents: this system is of greater importance where waste is highly heterogeneous or of uncertain composition as this leads to greater variations in the effluent content.
  e) When SNCR is used with wet scrubbing: this technique can be applied to all WI installations with wet scrubbers downstream of ammonia/urea reagent injection for NO_x reduction. The technique is of particular benefit where ammonia slip levels downstream of the boiler are higher.

4.5.1.1. General factors to consider when selecting flue-gas treatment systems

The following list of general factors requires consideration when selecting flue-gas treatment (FGT) systems (see also BAT number 37 in table 4.8):

- Type of waste: composition and variation.
- Type of combustion process and its size.
- Flue-gas flow and temperature.
- Flue-gas content, size and rate of fluctuations in composition.
- Target emission limit values.
- Land and space availability.
- Availability and cost of outlets for residues accumulated/recovered, of water and other reagents.
- Energy supply possibilities (e.g. supply of heat from condensing scrubbers).
- Tolerable disposal charge for the incoming waste (both market and political factors exist).
- Noise emissions.
- Arrange different flue-gas cleaning devices if possible with decreasing flue-gas temperatures from boiler to stack.

4.5.1.2. Energy optimisation

Some flue-gas treatment techniques can add significantly to the overall energy requirements of the incineration process. It is necessary to consider the additional energy requirements imposed by law.

4.5.1.3. Overall optimisation and the “whole system” approach

As well as considering the energy aspects, there are benefits in considering the FGT system as a whole unit. This is particularly relevant to the removal of pollutants because the units often interact, providing primary abatement for some pollutants and an additional effect on others. Depending on the composition in the cleaning sequence, different cleaning efficiency values are obtained.

4.5.1.4. Technique selection for existing or new installations

Overall optimisation and the interface between FGT systems components (as well as the rest of the incineration process) is important for both new and existing installations. With existing installations the number of options may be more severely restricted than with new installations. Comments regarding inter-process compatibility may be found in the sections that deal with individual FGT techniques.

4.5.2. Overview of flue-gas treatments at hazardous waste incinerators

Different techniques are used to reduce the concentration of polluting components in the flue-gases:

- Scrubber systems are used to reduce the acid components in the flue-gases. To decrease the amount of dust and heavy metals in the flue-gas, electrostatic precipitators (ESPs) and bag-house filters are used. ESP systems are normally installed at the front end of wet scrubbers to reduce the solid input to the washing liquid, but not generally for dry or semi-dry treatment systems where bag filters are used. The bag filters themselves provide a dust control system
- To reduce the release of dioxins into air, the following techniques are used: activated carbon, fixed-bed activated carbon filters and selective catalytic reduction.
- To reduce NO_x emissions: Selective Catalytic (SCR) or Non-Selective Catalytic Reduction (NSCR).

4.5.3. Flue-gas treatment for sludge incinerators

The type of FGT systems used depends largely on the composition of the waste, and will often be similar to those applied to municipal waste incinerators. However, special attention may be required for removing nitrogen oxides and mercury.

4.5.4. Techniques for reducing particulate emissions

The selection of gas cleaning equipment for particulates from the flue-gas is mainly determined by:

- Particle load in the gas stream.
- Average particle size.
- Particle size distribution.
- Flow rate of gas.
- Flue-gas temperature.
- Compatibility with other components of the entire FGT system.
- Required outlet concentrations.

Some parameters are rarely known (such as particle size distribution or average size) and are empirical figures. Available treatment or disposal options for the deposited substances may also influence FGT system selection, i.e. if an outlet exists for the treatment and use of fly ash, this may be separately collected rather than the fly ash being collected with FGT residues.

The application of a system to remove dust from the flue-gas is generally considered essential for all waste incineration installations.

4.5.4.1. Pre-dedusting stage before other flue-gas treatments

This section considers the location of a dust removal stage, generally after pre-dedusting at the boiler stage, but before other subsequent FGT stages.

The following pre-dedusting systems are used for waste incineration:

- Cyclones and multi-cyclones.
- Electrostatic precipitators.
- Bag (fabric) filters.

4.5.4.1.1. Cyclones and multi-cyclones

These use centrifugal force to separate particulate matter from the gas stream. Multi-cyclones differ from single cyclones in that they consist of many small cyclone units.

In general, cyclones on their own cannot achieve the emission levels now applied to modern waste incinerators. They can, however, have an important role to play when applied as a pre-deduster before other flue-gas treatment stages. Energy requirements are generally low, as there is no pressure drop across the cyclone. These are considered appropriate for application in the Mediterranean region.

The specific applicability of the BAT related to cyclones (number 51 in table 4.8) is:

- Where a pre-dedusting stage is in use, an assessment of the composition of the fly ash:
    a) Separation of the dust removal stage from other flue-gas treatment: this is applicable to all new installations and existing processes replacing flue-gas treatment systems.
    b) Application of an additional flue-gas polishing system: this is applicable to all waste types (it may not be required for low raw gas dust concentrations). Space may be a limiting factor for existing plants.

4.5.4.1.2. Electrostatic Precipitators (ESP)

Electrostatic precipitators are sometimes also called electrostatic filters. The efficiency of dust removal of electrostatic precipitators is mostly influenced by the electrical resistance of the dust. If the dust layer resistance rises to values above approx. 10^{11} to 10^{12} Ωcm, removal efficiency is reduced. The dust layer resistance is influenced by waste composition. It may thus change rapidly with changing waste composition, particularly in **hazardous waste incineration**. Sulphur in the waste (and water content at operational temperatures below 200°C) often reduces the dust layer resistance as SO2 in the flue-gas and therefore facilitates deposition in the electric field.

For the deposition of fine dust and aerosols, installations that maintain the effect of the electrostatic field by drop formation in the flue-gas can improve removal efficiency.

Typical operational temperatures for electrostatic precipitators are 160-260°C. Operations at higher temperatures (e.g. above 250°C) are generally avoided as this may increase the risk of PCDD/F formation (and hence releases).

4.5.4.1.3. Fabric filters

These are also called bag filters and are widely used in waste incineration plants. Filtration efficiency is very high across a wide range of particle sizes. At particle sizes below 0.1 microns, efficiency is reduced, but the fraction of these that exist in the flue-gas flow from waste incineration plants is relatively low. Low dust emissions are achieved with this technology. It can also be used following an ESP and wet scrubbers.

Compatibility of the filter medium with the characteristics of the flue-gas and the dust and the process temperature of the filter are important for effective performance. The filter medium should have suitable properties for thermal, physical and chemical resistance. The gas flow rate determines the appropriate filtering surface.

Mechanical and thermal stress on the filter material determines service life, energy and maintenance requirements.

4.5.4.2. Additional flue-gas polishing system

This technique relates to the application of flue-gas polishing systems for the final reduction of dust emissions after other FGT has been applied, but before the final release of stack gases to the atmosphere. The main systems applied are:

- Bag (fabric) filters.
- Wet-ESP.
- Electrodynamic venture scrubbers.
- Agglo-filtering modules.
- Ionizing wet scrubber.

It is possible to consider the addition of a final wet flue-gas treatment system as a polishing treatment after other systems that deal with acid gases, etc. This addition is generally made to specifically control HCl emissions where they are highly variable.

These are in general, expensive and very specific techniques, so, within the Mediterranean region it may be better to use a generic technique (more economical).

4.5.4.2.1. Wet electrostatic precipitators (Wet-ESP)

These are based on the same technological working principle as electrostatic precipitators. With this design, however, the precipitated dust on the collector plates is washed off using a liquid (water). This technique operates satisfactorily in cases where moist or cooler flue-gas enters the electrostatic precipitator.

4.5.4.2.2. Condensation electrostatic precipitator

This is used to deposit very fine, solid, liquid or sticky particles, for example, in the flue-gas from **hazardous waste** incineration plants. It consists of vertical plastic tubes arranged in bundles, which are externally water-cooled.

The dust-containing flue-gas is first cooled down to dew-point temperature in a quench by direct injection of water and then saturated with vapour. By cooling the gases in the collecting pipes further down, a thin, smooth liquid layer forms on the inner surface of the tubes as a result of condensation of the vapour. This is electrically earthed and thus serves as the passive electrode.

4.5.4.2.3. Ionisation wet scrubbers (IWS)

These remove various pollutants from the flue-gas. The IWS combines the principles of electrostatic charging of particles, electrostatic attraction and deposition for aerosols, vertical deposition for coarse, liquid and solid particles and absorption of hazardous, corrosive and malodorous gases.

4.5.5. Techniques for the reduction of acid gases

Acid gases (e.g. HCl, HF and SO_x emissions) are generally cleaned from the flue-gas using alkaline reagents. The following flue-gas cleaning processes are applied:

<u>Dry processes</u>: a dry sorption agent (e.g. lime, sodium bicarbonate) is added to the flue-gas flow. The reaction product is also dry.

<u>Semi-wet processes</u>: also called semi-dry, the sorption agent added to the flue-gas flow is an aqueous solution (e.g. lime milk) or suspension (e.g. as a slurry). The water solution evaporates and the reaction products are dry. The residue may be re-circulated to improve reagent utilisation. A sub-set of this technique is flash-dry processes which consist of the injection of water (giving fast gas cooling) and reagent at the filter inlet.

<u>Wet processes</u>: the flue-gas flow is fed into water, hydrogen peroxide, and/or a washing solution containing part of the reagent (e.g. sodium hydroxide solution). The reaction product is aqueous.

4.5.5.1. Recirculation of FGT residues in the FGT system

Residues collected in the fabric filter used for dry, semi-wet and similar (but not wet) FGT systems usually contain a significant proportion of unreacted flue-gas treatment reagents, as well as the fly ash and other pollutants removed from the gas stream. A proportion of the accumulated residues can be re-circulated within the FGT system.

Because of the recirculation, the size of the FGT is generally increased to accommodate the additional volume of re-circulation material.

4.5.5.2. Removal of sulphur dioxide and halogens

Sulphur dioxide and gaseous halogens are cleaned from flue-gases by the injection of chemical or physical sorption agents which are brought into contact with the flue-gas. In this technique, the reaction products are dissolved or dry salts. There are three systems: dry, semi-wet and wet. Below is a short explanation of each one.

<u>Dry systems</u>: in dry sorption processes the absorption agent (usually lime or sodium bicarbonate) is fed into the reactor as a dry powder. The dose rate of reagent may depend on the temperature as well as on reagent type. With lime this rate is typically two or three times the stoichiometric amount of the substance to be deposited; with sodium bicarbonate the ratio is lower. This is required to ensure emission limits are complied with over a range of inlet concentrations. The reaction products generated are solid and need to be deposited from the flue-gas as dust in a subsequent stage, normally a bag filter.

<u>Semi-wet systems</u>: in spray absorption, the absorption agent is injected either as a suspension or solution into the hot flue-gas flow in a spray reactor. This type of process utilises the heat of the flue-gas for the evaporation of the solvent (water). The reaction products generated are solid and need to be deposited from the flue-gas as dust in a subsequent stage.

<u>Wet systems</u>: wet flue-gas cleaning processes use different types of scrubber design. The scrubber solution is strongly acidic (typically pH 0-1) due to acids forming in the deposition process. HCl and HF are mainly removed at the first stage of the wet scrubber. The effluent from the first stage is recycled many times, with small fresh water addition and a bleed from the scrubber to maintain acid gas

removal efficiency. In this acidic medium, deposition of SO_2 is low, so a second stage scrubber is required for its removal.

4.5.5.3. Direct desulphurisation (direct addition of alkaline reagents to the waste)

Desulphurisation in fluidised bed processes can be carried out by adding absorbents (e.g. calcium/magnesium compounds) directly into the incineration chamber. Additives such as limestone dust, calcium hydrate and dolomite dust are used. The system can be used in combination with downstream flue-gas desulphurisation.

Ideal conditions for direct desulphurisation exist in a cycloid furnace due to the constant temperature level.

Absorption (and adsorption) of pollutants can also be performed in a fluid bed reactor into which residues and reagents are re-circulated in combustion at a high rate. Recirculation of flue-gas keeps the gas flow above a minimum level in order to maintain fluidisation of the bed. The bed material is separated in a bag filter. Injection of water reduces the consumption of absorbents (and hence the production of residues) significantly.

4.5.5.4. Use of acid gas monitoring for FGT process optimisation

By using fast-response gas HCl monitoring upstream and/or downstream of dry and semi-wet FGT systems, it is possible to adjust the operation of the FGT system so that the quality of alkaline reagent used is optimised for the emission set point of the operation. This technique is generally applied as an additional method to control peak concentrations, with the build-up of a layer of reagent on the bag filters also providing an important buffering effect for reagent fluctuations.

4.5.6. Techniques for the reduction of emissions of oxides of nitrogen

NO_x production may be reduced with primary and/or secondary techniques.

Primary techniques: NO_x production can be reduced using furnace control measures that prevent oversupply of air (i.e. prevention of the supply of additional nitrogen) or prevent the use of unnecessarily high furnace temperatures (including local hot spots). The techniques that may be used are: air supply, gas mixing and temperature control, flue-gas recirculation, oxygen injection, staged combustion, natural gas injection (re-burn) and injection of water into furnace/flame.

Secondary techniques: these are applied to comply with a daily average NO_x value (e.g. 200mg/Nm^3 in EU). For most processes the application of ammonia or ammonia derivatives (e.g. urea) as reduction agents has proved successful. The nitrogen oxides in the flue-gas basically consist of NO and NO_2 and are reduced to nitrogen N_2 and water vapour by the reduction agent. Two processes are important for the removal of nitrogen from flue-gases: Selective Non-Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR). Both NH_3 and urea are applied in aqueous solutions. NH_3 is normally, for safety reasons, delivered as a 25% solution.

The selected best available technique (number 40) is shown in table 4.8.

4.5.6.1. Selective catalytic reduction (SCR)

Selective catalytic reduction (SCR) is a catalytic process during which ammonia mixed with air (the reduction agent) is added to the flue-gas and passed over a catalyst, usually a mesh (e.g. platinum, rhodium, TiO_2, zeolites). When passing through the catalyst, the ammonia reacts with NO_x to give nitrogen and water vapour.

4.5.6.2. Selective Non-Catalytic Reduction (SNCR)

In this process, nitrogen oxides are removed by selective non-catalytic reduction. With this type of process the reducing agent (typically ammonia or urea) is injected into the furnace and reacts with the nitrogen oxides.

4.5.6.3. Optimisation of reagent selection for SNCR NO_x reduction

The reagents used for SNCR are ammonia and urea. The reagents selection needs to take account of a variety of process operational, cost and performance factors to ensure that the optimal one is selected for the installation concerned.

New processes can be specifically designed to achieve stable and predictable combustion conditions and select the optimal injection locations for the reagent, which then allows the benefits of the ammonia to be secured. Existing processes with difficulties in stabilising combustion conditions (e.g. for design, control or waste type reasons) are less likely to be in a position to optimise reagent injection and may therefore benefit from the use of urea.

4.5.7. Techniques for the reduction of PCDD/F emissions

In general, to achieve a good level (low emissions) it is necessary to use a combination of primary techniques to reduce PCDD/F production, with secondary measures to further reduce the air emissions level.

The techniques that can be used are:

- Adsorption on activated carbon reagents in an entrained flow system: the carbon is filtered from the gas flow using bag filters. Activated carbon shows high absorption efficiency for mercury as well as for PCDD/F.
- SCR systems: SCR systems are used for NO_x reduction, and they also destroy gaseous PCDD/F through catalytic oxidation.
- Catalytic bag filters: filter bags are either impregnated with a catalyst, or the catalyst is directly mixed with organic material in the production of fibres. Such filters have been used to reduce PCDD/F emissions.
- Re-burn of carbon adsorbents: carbon is used to adsorb dioxins (and mercury) at many waste incinerators.
- Use of carbon-impregnated plastics for PCDD/F adsorption: plastics are widely used in the construction of flue-gas cleaning equipment due to their excellent corrosion resistance. PCDD/F is adsorbed on these plastics in wet scrubbers.
- Static bed filters: activated coke moving bed filters are used as a secondary cleaning process in the flue-gas of municipal and hazardous waste incineration. It is possible to deposit substances contained in the flue-gas at extremely low concentrations with high efficiency.
- Rapid quenching of flue-gases: this involves the use of a water scrubber to cool flue-gases directly from their combustion temperature to below 100°C. it is used in some HWI. The action of rapid quenching reduces the residence of flue-gases in temperature zones that may give rise to additional de novo PCDD/F synthesis.
- Adsorption on activated carbon reagents in an entrained flow system: activated carbon is injected into the gas flow. The carbon is filtered from the gas flow using bag filters. The activated carbon shows a high absorption efficiency for mercury as well as for PCDD/F.
- Use of carbon slurries in wet scrubbers: this can reduce emissions to the flue-gas stream and prevent the accumulation of dioxins in the scrubber material. The dioxin or furan molecules are transferred to the liquid sprayed in the scrubber and the dioxins are subsequently adsorbed on the carbon, where a catalytic reaction takes place.

As has already been noted, some of these techniques (may vary from country to country) have to be applied in the Mediterranean region due to their performance against persistent organic pollutants such as dioxins and furans.

The best available techniques regarding dioxins and furans (PCDD/F) are numbers 41 and 42 (table 4.8). The specific application for them is as follows:

- Reduction of overall PCDD/F emissions to all environmental media:
  a) Primary techniques: these are applicable for improving the combustion-related aspects that will lead to generally improved incineration performance, including a reduction in the risk of PCCDD/F production.
  b) Prevention of reformation of PCDD/F: particularly an issue with PCBs or other waste where risk of PCDD/F formation is believed to be higher. It is applicable to all plant size ranges and it is more difficult to re-design in existing processes.
  c) Adsorption of PCDD/F by activated carbon: this is applicable to all waste types, all plant size ranges and to new and existing plants (easily retrofitted in most cases).
  d) Adsorption of PCDD/F in static beds: this is applicable to all waste types, but is particularly suited to highly heterogeneous **and hazardous waste** where PCDD/F may be high due to difficult combustion conditions.
  e) Destruction of PCDD/F using DCR: this can be applied to any waste type and to any plant size, but it is most economical for medium to large installations due to capital costs.
  f) Destruction of PCDD/F using catalytic filters: this is applicable to all waste types and all plant size ranges. It is also applicable to new and existing processes.

4.5.8. Techniques for the reduction of mercury emissions

There are two types of techniques for the reduction of mercury (Hg) emissions: primary and secondary. Primary techniques are general (fully applicable in the Mediterranean Region) and secondary techniques are specific.

Primary techniques: mercury is highly volatile and therefore almost exclusively passes into the flue-gas stream. The only relevant primary techniques for preventing emissions of mercury into air are those which prevent or control, if possible, the inclusion of mercury in the waste: efficient separate collection of waste that may contain heavy metals, e.g. cells, batteries, dental amalgams…; notification of waste producers of the need to segregate mercury; identification and/or restriction of receipt of potentially mercury-contaminated waste and where such waste is known to be received, controlled addition to avoid overload of abatement system capacity.

Secondary techniques: mercury vaporises completely at a temperature of 357°C and remains gaseous in the flue-gas after passing through furnace and boiler. Inorganic mercury and elemental mercury are affected differently by FGT systems and detailed consideration of the results for both is required. The selection of a process for mercury abatement depends on the load fed in and on the chlorine content of the burning material. With higher chlorine content, mercury in the crude flue-gas will increasingly be in ionic form, which can be deposited in wet scrubbers. This is a particular consideration at sewage sludge incineration plants where raw gas chlorine levels may be quite low. If, however, the chlorine content in the (dry) sewage sludge is 0.3% mass or higher, only 10% of the mercury in the clean gas is elemental; and the elimination of only the ionic mercury may achieve a total Hg emission level of 0.03 mg/Nm^3. Metallic mercury can be removed from the flue-gas stream by: transformation into ionic mercury by adding oxidants and then depositing in the scrubber or direct deposition on sulphur-doped activated carbon, hearth furnace coke or zeolites.

The following four subsections develop four different cases for mercury reduction.

Best available techniques regarding this category are shown in table 4.8 (nos. 44 and 45). The specific applicability of BAT 44 is:

- For the control of Hg emissions:

   a) Low pH wet scrubbing and additive addition: this can only meet the emission limits set in Directive 2000/76/EC on the incineration of waste. This technique is only applicable for Hg air emission control as an Hg pre-treatment step, or where input waste concentrations are low enough (e.g. below 4 mg/kg[16]). Otherwise emissions to air of above 50 µg/Nm^3 may result.

   b) Addition of hydrogen peroxide to wet scrubbers: this method is applicable to all types of waste incinerators using scrubbing. The best effect is reached if the scrubber is situated downstream from the baghouse filter with carbon injection.

   c) Chlorite injection for elemental Hg control: incineration of waste; mercury abatement of flue-gas containing at least 400 mg/Nm^3 of hydrogen chloride. Compatible only with wet scrubbing systems.

   d) Activated carbon injection for Hg adsorption: this provides effective emission reductions across a range of waste types. It is applicable to new installations and as a retrofit.

   e) Use of static activated carbon or coke filters: this is particularly suited to highly heterogeneous and HW. Independent of the plant size, it can be applied to existing and new processes.

4.5.8.1. Low pH wet scrubbing and additive addition

The use of wet scrubbers for acid gas removal causes the pH of the scrubber to reduce. Most wet scrubbers have at least two stages. The first removes mainly HCl, HF and some SO_2. A second stage, maintained at a pH of 6-8, serves to remove SO_2. If the first stage is kept at a pH of below 1, the removal efficiency of ionic Hg as $HgCl_2$, which is generally the main compound of mercury after waste combustion, is over 95%. However, the removal rates of metallic Hg are only in the order of 0-10%, mainly as a result of condensation at the scrubber operational temperature of around 60 to 70°C.

Metallic mercury adsorption can be improved up to a maximum of 20-30% by the:

- Addition of sulphur compounds to the scrubber liquor.
- Addition of activated carbon to the scrubber liquor.
- Addition of oxidants, e.g. hydrogen peroxide, to scrubber liquor. This technique converts metallic mercury to the ionic form as $HgCl_2$ to facilitate its precipitation, and has the most significant effect.

4.5.8.2. Activated carbon injection for Hg adsorption

This technique involves the injection of activated carbon upstream of a bag filter or other de-dusting device. Mercury metal is adsorbed in the stream and where barrier filters such as bag filters are used, also on the reagent that is retained on the bag surface.

4.5.8.3. Separation of mercury using a resin filter

After dust separation and the first acidic wet rinse, the raw acids in the ionically-bound heavy metal are carried off through an Hg ion exchanger. Mercury is separated off in a resin filter. Then the acid is neutralised using lime milk.

[16] mg/kg: milligram/kilogram

4.5.8.4. Chlorite injection for elemental Hg control

The injection of a strong oxidising agent will convert the elemental mercury into oxidised mercury and make its scrubbing possible in the wet scrubber. To avoid this agent being used up by reaction with other compounds, it is introduced just before the spray nozzles of the first acidic scrubber. The pH of the scrubber is kept between 0.5 and 2.

When the sprayed liquid comes into contact with the acidic fumes containing hydrogen chloride, chlorite is transformed into chlorine dioxide, which is the actual active species.

4.5.9. Techniques for the reduction of other emissions of heavy metals

Other heavy metals in incineration are converted mainly into non-volatile oxides and deposited with flue ash. Thus, the main relevant techniques are those applicable to dust removal. Activated carbon is also reported to be used for reducing heavy metals emissions.

4.5.10. Techniques for the reduction of emissions of organic carbon compounds

Effective combustion provides the most important means of reducing emissions to air of organic carbon compounds. Flue-gas from waste incineration plants can contain trace quantities of a very wide range of organic species including: halogenated aromatic hydrocarbons; polycyclic aromatic hydrocarbons (PAH); benzene, toluene and xylene (BTX) and polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF). PCDD/F may form after the furnace from precursor compounds. Precursor compounds are: PCB, polychlorinated diphenylmethanes (PCDM), chlorobenzenes and chlorohydroxybenzenes.

PCDD and PCDF may also form in catalytic reactions of carbon or carbon compounds with inorganic chlorine compounds over metal oxides. These reactions will occur especially on fly ash or filter dust at temperatures between 200 and 450°C.

The following three mechanisms are believed to lead to the formation of dioxin/furan in waste incineration:

- Formation of PCDD/F from chlorinated hydrocarbons already in, or formed in, the furnace (such as chlorohydrobenzene or chlorobenzene).
- De novo synthesis in the low-temperature range (boilers, dry ESPs).
- Incomplete destruction of the PCDD/F supplied with the waste.

Optimum flue-gas incineration largely destroys the precursor compounds. The formation of PCDD/PCDF from the precursor compounds is, therefore, suppressed.

Emissions of organic hydrocarbon compounds can be reduced by further dust and aerosol deposition, since this pollutant preferably adsorbs onto the fine fraction of dust, and by enforced flue-gas cooling (condensation).

The specific applicability of this technique (BAT number 49 in table 4.8) is:

- <u>The use of a suitable combination of the techniques for improving waste burnout</u>:
  a) The use of a combination of furnace designs: this is applicable both in new and existing installations.
  b) Increased agitation and residence time: the nature of the waste received may restrict the actual combustion technology selection. However, these techniques are applied in all cases.
  c) Adjustment of throughput to maintain good burnout and combustion conditions: this is applicable to all WI plants.

d) Reduction of grate riddling rate and/or return of cooled riddling to the combustion chamber: this is applicable to all grate incinerators, particularly to those where:

- Particular concerns or requirements exist that require improved burnout.
- Clinical or other infectious waste is co-combusted that can go through the grate.
- Grates with larger spacing between grate bars and high riddlings or in other systems where riddling levels may be relatively higher.

4.5.11. Reduction of greenhouse gases (CO_2, N_2O)

There are essentially two ways of reducing greenhouse gas emissions:

- Increasing the efficiency of energy recovery and supply.
- Controlling CO_2 emissions using flue-gas treatment.

Production of sodium carbonate by reacting CO_2 in the flue-gases with NaOH is possible.

4.5.11.1. Prevention of nitrous oxide emissions

Emissions of nitrous oxide from waste incineration can arise from:

- Use of lower combustion temperatures- typically this becomes of interest below 850°C.
- The use of SNCR for NO_x reduction (particularly where urea is the reagent chosen).

The optimum temperature for the simultaneous minimisation of both NO_x and N_2O production is reported to be in the range of 850-900°C. Under conditions where the temperature in the post-combustion chamber is above 900°C, N_2O emissions are reported to be low. N_2O emissions from the use of SCR are also low. Thus, provided combustion temperatures are above 850°C, in general, SNCR represents the only significant source of N_2O emissions from modern waste incinerators.

To avoid nitrous oxide emissions, the following techniques are used:

- Reducing SNCR reagent dosing by SNCR process optimisation.
- Selecting the optimised temperature window for SNCR reagent injection.
- Using flow modelling methods to optimise injection nozzle locations.
- Designing to ensure effective gas/reagent mixing in the appropriate temperature.
- Over-stoichiometric burnout zones to ensure oxidation of nitrous oxide.
- Using ammonia instead of urea in SNCR.

4.6. WASTEWATER TREATMENT AND CONTROL TECHNIQUES

This section includes the techniques needed to treat wastewater from flue-gas treatment and hazardous waste incineration plants. Table 4.9 presents the selection of the best available techniques and practices. The application of some type of wastewater treatment is essential in hazardous waste incinerators, including in the Mediterranean region.

Table 4.9: BATs for wastewater treatment and control techniques

BAT	Environmental benefits	Economics
46.- The general optimisation of the recirculation and reuse of wastewater produced on the site within the installation. The techniques that may be used are: a) Re-circulation of effluents to the process in place of their discharge. b) Use of boiler drain water as a water supply for scrubbers.	a) This can allow the waste incinerator to concentrate inorganic pollutants into solid waste, reduce water consumption and eliminate (or limit) the need for effluent discharges. b) Reduction in water consumption by replacement of scrubber feed-water.	a) Costs will increase if interim effluent treatment is required. Savings may be made by reducing water consumption and discharge costs. b) NA.
47.- The use of separate systems for the drainage, treatment and discharge of rainwater that falls on the site, including roof water, so that it does not mix with potential or actual contaminated wastewater streams. Some such wastewater streams may require only little or no treatment prior to their discharge, depending on contamination risk and local discharge factors.	The environmental benefits are a reduction in the volume of wastewater requiring treatment; the remaining polluted fraction is of higher concentration and can be more effectively treated.	Retrofit costs can be significant at existing sites, but these can be installed efficiently at new sites. Savings may be made from the reduction in water holding capacity needed on the site.

4.6.1. Potential sources of wastewater

Potential emissions to water from waste incineration plants are: process wastewater, wastewater from collection, treatment and storage of bottom ash, sanitary wastewater, clean rainwater, polluted rainwater, used cooling water and condensed wastewater from the partial pre-drying of sewage sludge.

4.6.2. Basic design principles for wastewater control

The following basic principles are applied to incineration wastewater control: application of optimal incineration technology, reduction of water consumption and discharge of wastewater in compliance with relevant water emission standards, and optimal operation of the water treatment system.

The specific applicability for the selected best practices (numbers 46 and 47 in table 4.9) is:

- The use of separate systems for the drainage, treatment and discharge of rainwater that falls on the site: this technique may be applied in all WI installations. If the incinerator is located in a community with only one sewer for both polluted wastewater and rainwater, the separate collection of unpolluted streams is of limited sense, unless it can be suitably treated for direct discharge to the environment.

4.6.3. Processing of wastewater from wet flue-gas treatment systems

The process wastewater resulting from wet flue-gas treatment contains a wide variety of polluting components. The amounts of wastewater and concentrations depend on the composition of the waste and on the design of the flue-gas system. The recirculation of wastewater in wet FGT systems can result in a substantial reduction in the amount of wastewater, and as a consequence, in higher concentrations of pollutants.

Three main methods are applied for treatment of wastewater from wet flue-gas treatment systems:

- Physicochemical treatment: based on pH correction and sedimentation. With this system, a treated wastewater stream containing dissolved salts is produced, and if not evaporated requires discharge.
- Evaporation in the waste incineration process line by means of a spray drier, into semi-wet FGT systems, or other system that uses a bag filter. In this case, the dissolved salts are incorporated into the residue of the flue-gas treatment system. There is no emission of wastewater, other than that evaporated with the flue-gases.
- Separate evaporation of wastewater. In this case, the evaporated water is condensed, but as it is generally very clean can often be discharged (or reused) without special measures.

4.6.3.1. Physicochemical treatment

The process shown consists of the following steps. Some or all of these may be in use:

- Neutralisation of the polluted wastewater: lime is often used. This results in the precipitation of sulphites and sulphates.
- Flocculation of pollutants: removal of heavy metal compounds is based on flocculation followed by precipitation. It needs a different pH range according to the metal.
- Settlement of the formed sludge.
- Dewatering of the sludge.
- Filtration of the effluent: this can use sand filters and/or active carbon filters. These reduce heavy metal concentrations and PCDD/F-compounds, PAHs, etc.

Other steps can also be included:

- Precipitation.
- Coagulation.
- pH and temperature control.

4.6.3.2. Application of sulphides

In order to carry out flocculation, organic agents (e.g. polyelectrolytes) are commonly used. The addition of complex-builders and sulphides allows further reductions in mercury and other heavy metal discharges.

The use of sulphides requires special safety regulations.

4.6.3.3. Application of membrane technology

This is especially efficient for large water flows with low salt concentrations.

4.6.3.4. Stripping of ammonia

For the application of SNCR de-NO_x, the wastewater from the wet scrubber contains ammonia compounds. Depending on the actual ammonia concentration, stripping the ammonia from the effluent may be an option.

4.6.3.5. Separate treatment of wastewater from the first and the last steps of the scrubber systems

The first steps of wet scrubber systems are typically operated at a very low pH level. Under these process conditions, specifically HCl is removed from flue-gas streams. The removal of SO_2 takes place in the final step, at a neutral pH.

4.6.3.6. Anaerobic biological treatment (conversion of sulphates into elementary sulphur)

The sulphates in the wastewater can be reduced to sulphides in a reactor by the activity of anaerobic bacteria. The effluent of this reactor, which has a high content of sulphides, is treated in a second reactor. In this, the sulphides are biologically oxidised in an aerobic atmosphere into elemental sulphur.

It is reported that this technology may be difficult to apply in the hazardous waste field.

4.6.3.7. Evaporation systems for process wastewater

If the discharge of soluble salts is not acceptable, the process wastewater needs to be evaporated. For this purpose there are two main options:

- In-line evaporation: the waste is recycled in the process by means of a spray dryer (comparable with the spray absorber).
- Separate evaporation: this is based on evaporation in steam-heated evaporation systems.

4.6.3.8. Recirculation of polluted wastewater in wet cleaning systems

Polluted wastewater from wet scrubbers is re-circulated as much as possible before any treatment, so that it may be reused as a feed for the scrubbers or as dilution water for organic flocculants for sewage sludge dewatering.

4.6.3.9. Recirculation of effluents in the process in place of their discharge

Because the incineration process itself provides a means of concentration and removal of pollutants from waste streams, it is possible for low to medium volume wastewater effluents to be fed into the incineration process at appropriate points. This can be done in such a way that it does not affect the operation of the incineration plant, nor its environmental performance.

4.6.3.10. Separate discharge of rainwater from roofs and other clean surfaces

This technique involves the separation of the drainage of clean rainwater so that it does not mix with potential and actual contaminated streams.

4.6.3.11. Provision of storage/buffering capacity for wastewater

The larger the volume of storage that is provided, the greater the homogeneity of the wastewater composition. This, in turn, allows improved optimisation and process control at the treatment stage.

4.6.3.12. Separate treatment of effluents arising from different wet scrubbing stages

This technique involves the separation and separate treatment of the acid and alkaline wet scrubber streams in order to allow improved optimisation of the effluent and increased options for the recovery of components of the effluents streams.

4.6.4. Wastewater treatment at hazardous waste incinerators

HWI installations that discharge wastewater have a wastewater treatment facility. The current situation can be summarised as follows:

- A general distinction can be made between the incinerators equipped with a boiler and the other HWI installations equipped with a quick quench-cooling system, with the flow of discharged effluent being greater for the latter for technical reasons. Installations equipped with a boiler discharge between <1 and 5 l/kg[17] incinerated waste. Installations with only quench-cooling systems discharge between 10 and 20 l/kg incinerated waste, although they can reduce their water flow to 5 l/kg by re-circulating the effluent of the wastewater treatment plant or recycling within the quench unit itself.
- Normally the effluent of the acidic section of the wet gas cleaning (containing NaCl, $CaCl_2$, Hg, CaF2 and SO_3) is mixed with the effluent of the alkaline section (containing Na_2SO_4) in order to precipitate part of the gypsum (and to decrease the sulphate content of the effluent to less than 2 g/l, which is the solubility concentration of gypsum) before further treatment. There is, however, one installation where the effluents of acidic and alkali scrubbers are treated separately.

The main elements of wastewater treatment plant for the treatment of effluent from the wet flue-gas cleaning section from hazardous waste incineration are:

- Neutralisation (e.g. addition of lime, NaOH/HCl).
- The addition of reagents specifically for the precipitation of metals as hydroxides or metal sulphides (e.g. flocculation agents, tri-mercapto-tri-azine, sulphides, polyelectrolyte).
- The removal of sediment: either using sedimentation by gravity and decantation, or using mechanical techniques such as filter presses, centrifuges.

In some wastewater treatment plants the wastewater is polished by passing it through a sand filter, followed by an activated carbon filter.

4.7. SOLID RESIDUE TREATMENT AND CONTROL TECHNIQUES

This section describes the types of residues generated by a hazardous waste incineration plant and existing techniques to reduce them (in solid and in gas). The selected best available techniques that can be applied are shown in table 4.10.

The application of some type of solid residue treatment and control techniques is essential in hazardous waste incinerators; in addition, benefits can be obtained from some waste fractions and the reduction of disposal costs. Likewise, it is significant for installations within the Mediterranean Region.

[17] l/kg: litre/kilogram

Table 4.10: BATs for solid residue treatment and control techniques

BAT	Environmental benefits	Economics
43.- If re-burn of FGT residues is applied, then suitable measures should be taken to avoid the recirculation and accumulation of Hg in the installation.	NA.	NA.
50.- The separate management of bottom ash from fly ash and other FGT residues, so as to avoid contamination of the bottom ash and thereby to improve the potential for bottom ash recovery. It is also a BAT to assess the levels of contaminants in the boiler ash, and to assess whether separation or mixing with bottom ash is appropriate.	Segregation of FGT residue from the bottom ash enables further treatment of the bottom ash to yield a material for use. A mixed stream does not allow processing into a material for recovery and need landfilling. Natural building materials are replaced.	Cost reductions may be seen where markets exist for bottom ash use. FGT residue disposal may be higher, but volumes are greatly reduced (FGT residue volumes on their own are typically 2-3% of mass of waste input, combined with bottom ash this will be around 15%).
52.- The separation of remaining ferrous and non-ferrous metals from bottom ash, as far as practicably and economically viable, for their recovery.	The ferrous fraction can be recycled, after separation of impurities, as steel scrap for blast furnaces. The non-ferrous metals are processed externally by further separation according to metal type, and may be re-melted. The resulting ash fraction may be processed to yield an inert secondary construction material.	The metal fractions can be sold to scrap dealers (for ferrous material EUR 0.01-0.05/kg and for non-ferrous material EUR 0.1-0.6/kg).
53.- The treatment of bottom ash (on or off-site), by a suitable combination of: a) bottom ash treatment using ageing, b) bottom ash treatment using dry treatment systems, c) bottom ash treatment using wet treatment systems, d) bottom ash treatment using thermal systems, e) high temperature (slagging) rotary kiln (1100-1400°C), and f) bottom ash screening and crushing to the extent that is required to meet the specifications set for its use or at the receiving treatment or disposal site.	a) Ageing is performed to reduce both the residual reactivity and the leachability of metals. b) This produces a material that may be used and reduces the amount of residue for disposal. c) Wet bottom ash treatment aims to remove metals, in order to reduce both the metal content and metal leaching. Approx. 50% of chloride content can be reduced by washing the ashes. d) This reduces volume (reduced by 33-50%); it produces very low leaching, and an extremely stable residue that can be readily recycled as an aggregate. PCDD/F levels in ash are reduced.	a) The cost of ageing is low. Savings in disposal costs by recycling. b) The main benefit is to avoid disposal costs; the economy of the bottom ash treatment operation depends on the market price of the produced fractions. c) It depends on the market price of the produced fractions. d) External thermal treatment costs are reported to be high. e) Additional costs arise from: the need to use a water-cooled kiln in order to avoid high maintenance costs; support fuels may be needed to maintain high temperatures; modifications

BAT	Environmental benefits	Economics
	e) All organic materials are completely incinerated (organic matter content in bottom ash after incineration is typically less than 1%); lower hydrocarbon and CO content in flue-gases; higher destruction of PCB molecules and a molten bottom ash is formed in the rotary kiln. f) The main environmental benefit of installing a mechanical treatment process is a reduction of the volume of rejects and waste, and therefore, a higher global recovery rate.	to furnace may be required to retain heat; addition of inorganic materials, producing more bottom ash and scrubbing of heavy metals which evaporate more at higher temperatures. In some cases the use of higher temperatures has been abandoned on account of costs associated with refractory maintenance. f) The cost-effectiveness of installing a system for breaking up heavy rejects is to be evaluated on the basis of projected quantities and disposal costs.
54.- The treatment of FGT residues (on or off-site) to the extent required to meet the acceptance requirements for the waste management option selected for them, including consideration of the use of the FGT residue treatment techniques. These techniques are: a) Cement solidification of FGT residues. b) Vitrification and melting of FGT residues. c) Acid extraction of boiler and fly ash.	a) This reduces contact between water and the residue and to some extent the possible formation of less soluble metal hydroxides or carbonates. b) Melted and vitrified products generally have very good leaching properties. c) The process removes a significant part of the total amount of heavy metals from the residues. The leachability of the residue is reduced by a factor of 10^2-10^3. Zinc, cadmium and mercury are recycled. Ecotoxicity tests are reported to be positive.	a) The residues can be delivered to existing plants. Treatment costs may vary according to the country. b) Treatment costs are reported to be around EUR100-6,000/t residue. Investment costs can be about EUR10-20 million for a plant with a capacity of 1-2 t/hr. c) Process costs of treating FGT residues: about EUR150-205/t (including charges for recycling the zinc filter cake, equivalent to EUR10-13/t of waste).

4.7.1. Types of solid residue

Waste incineration results in various types of solid residue. A distinction can be made between those residues directly resulting from the incineration process and those resulting from the FGT system. FGT residues may be fine fly ash and/or reaction products and unreacted additives from the FGT system (or associated wastewater treatment system). The latter category is often called Flue-Gas Treatment (FGT) or Air Pollution Control (APC) residues. The solid residues from (wet) scrubber effluent treatment processes are often pressed to form a solid called a filter cake or mixed with fly ash to minimise volume or for better dewatering with gypsum from the plant. In addition, gypsum and salts may be recovered from wet flue-gas treatment systems if specific processes are used.

The following subsections give a short explanation of the types of residue (classified according to the source).

4.7.1.1. Residues arising from the combustion stage of the incinerator:

Hazardous waste and specific clinical waste:

- Slag: resulting from rotary kiln incineration of hazardous waste. In general, this type of residue is disposed of by landfill without further treatment, or may be recycled if locally permitted.
- Other ash is similar to ash from MSWI but in as it may contain higher levels of pollutants, in general the practice has been mostly to dispose of it.

Sewage sludge:

- Fly ash: resulting from fluidised bed incineration of sewage sludge. This type of waste can be used as a filling material for bound applications in civil construction, in countries where this practice is permitted.
- Bed ash: resulting from fluidised bed incineration of sewage sludge. This is a relatively small category. It is often added to the fly ash or landfilled without further treatment.

RDF:

- Bed ash: resulting from fluidised bed incineration of RDF. Depending on the specific characteristics of the material, bed ash amounts may be substantially higher than for sewage sludge incineration. There is little experience of its re-use.
- Ash: resulting from small and medium scale incineration of waste wood. This concerns relatively small quantities.

Some installations operate at especially high temperature with the specific aim of melting the ash in order to form a slag. Such slag may have improved use options owing to lower leachability. High temperature slagging rotary kilns and combined gasification combustion process provide examples of such systems.

4.7.1.2. FGT residues

FGT residues contains concentrated amounts of pollutants (e.g. hazardous compounds and salts) and therefore is normally not considered appropriate for recycling purposes. The main objective is then to find an environmentally safe final disposal option. The following types of flue-gas treatment residues can be distinguished:

- Residues from dry and semi-wet flue-gas treatment: these residues are a mixture of calcium and/or sodium salts, mainly as chlorides and sulphites/sulphates. There are also some fluorides and unreacted reagent chemicals. This mixture also includes some fly ash that has not been removed by any preceding dust removal step. It can, therefore, also include polluting heavy metals and PCDD/F. The normal way of disposal is landfilling as hazardous waste, (e.g. big bags). Leachability of the residues is an important aspect for subsequent landfill disposal, therefore treatments to lower the leachability of these residues prior to landfilling is used. FGT residue from the dry sodium bicarbonate process can be purified and recycled in an industrial process, e.g. as a raw material in the chemical industry; this can require segregation of fly ash and salts residues in order to reduce the inert content.
- Improvement of the properties for landfilling by cold solidification.
- Filter cake: form the physicochemical treatment of wastewater from wet flue-gas treatment. This material is characterised by a very high heavy metals content, but can also include salts of limited solubility, such as gypsum. The normal means of disposal is landfilling. This residue may be concentrated in PCCD/F and is therefore sometimes pre-treated before landfilling.
- Gypsum: this may also be recovered with or without cleaning depending on the process parameters and quality requirements. Recovery of gypsum is possible when limestone or hydrated lime is used in a two-stage wet scrubber with an efficient droplet separator.

- Salts: resulting from in-line evaporation of wastewater. This residue is comparable with the residue from dry flue-gas treatment.
- Salts: resulting from separate evaporation of wastewater. Salts use or disposal depends on the composition of the residue. It is usually more pure than where in-line evaporation has been carried out.
- Residues from flue-gas polishing: options for use depend on the adsorbent used. The residue of carbon from fixed bed reactors is sometimes permitted to be incinerated in the waste incineration plant itself, if certain process conditions are fulfilled. The residue of entrained bed systems can also be incinerated, if the applied adsorbent is activated carbon or oven cokes only. If a mixture of other reagents and activated carbon is used, the residue is generally sent for external treatment or disposal, since there might be a risk of corrosion.
- Use as filler material in salt mines.

4.7.2. Treatment techniques for solid residues

The possibility of recovering the solid residues from waste incinerators is typically determined by:

- The content of organic compounds in the residues.
- The total content of heavy metals in the residues.
- The leachability of metals, salts, and heavy metals in the residues.
- Physical suitability e.g. particle size and strength, of residues.
- Market factors, regulations and polices.

The specific applicability of selected BATs (50, 52 and 53 in table 4.10) is as follows:

- The separate management of bottom ash from fly ash and other FGT residues: this technique is applied to both new and existing plants.
- <u>The separation of remaining ferrous and non-ferrous metals from bottom ash</u>: magnetic separation of ferrous metals is applicable in all new and existing installations. Non-ferrous metals separation requires space and sufficient throughput and may be performed by an external (centralised) bottom ash processing installation.
- <u>The treatment of bottom ash</u>:
  a) Bottom ash treatment using ageing: this can be applied to all new and existing installations producing bottom ashes.
  b) Bottom ash treatment using dry treatment systems: this is applicable to new and existing installations. In order to be economically viable, a minimal throughput is needed.
  c) Bottom ash treatment using wet treatment systems: this is applicable to new and existing installations.
  d) Bottom ash treatment using thermal systems: plasma treatment is applied to the treatment of combined incinerator and fly ash. If the chemical residues of FGT are added, increased FGT is required.
  e) High temperature (slagging) rotary kiln (1100-1400°C): Mainly applicable to rotary kilns burning **hazardous waste of** higher caloric values e.g. those that include various solvents and waste oils.
  f) Bottom ash screening and crushing: this is applicable to all incineration installations producing an ash requiring treatment before it can be used, or where such treatment may allow increased use.

The following subsections present a selection of these techniques according to the type of residue.

4.7.2.1. Treatment and recycling of solid residues

The high mineral content of incineration ash residues can make them potentially suitable for use as road or other construction material. Use is possible if the material complies with a set of environmental and technical criteria. This requires an optimisation of the ash quality through primary or secondary measures. The general parameters of interest are:

- Burn-out (BAT 43 in table 4.10).
- Mineral reactivity.
- Metal leaching.
- Salt content.
- Particle size and particle size distribution.

Primary measures for controlling residue outputs involve optimising control of the combustion process in order to:

- Guarantee an excellent burn-out of carbon compounds.
- Promote the volatilisation of heavy metals out of the fuel bed, and
- Fix lithophilic elements in the bottom ash, thus reducing their leachability.

They could be applied in the Mediterranean Region despite their generic nature. The secondary treatments that are possible must be studied by each installation.

Secondary treatment systems involve one or more of the following actions:

- Size reduction, to allow metal segregation and improve technical quality.
- Segregation of ferrous and non-ferrous metals, which may be recycled in the metals industry.
- Washing, in order to remove soluble salts.
- Ageing, to stabilise the matrix structure and reduce reactivity.
- Treatment with a hydraulic or hydrocarbon binder, for reuse as road base.
- Thermal treatment, to make and contain inert metals in a glassy matrix.

4.7.2.2. Segregation of the bottom ash from flue-gas treatment residues

The mixing of flue-gas treatment residues with bottom ash causes contamination of the bottom ash. Due to the higher metal content, metal leachability and organic content of the FGT residues, the environmental quality of the bottom ash is reduced. This limits the options for the subsequent use of the bottom ash.

This technique consists of the separate collection, storage and transport of both residue streams. This involves dedicated storage silos and containers, and specific handling systems for the fine and dusty FGT residue.

4.7.2.3. Bottom ash - separation of metals

Both ferrous and non-ferrous metals may be extracted from bottom ash. Ferrous metals separation is performed using a magnet. The ash is spread out on a moving belt or vibrating conveyor and all magnetic particles are attracted by a suspended magnet. This ferrous metals separation may be performed on the raw ash after leaving the ash extractor.

Non-ferrous metal separation is performed using an Eddy Current Separator. A rapidly rotating coil induces a magnetic field in non-ferrous particles, which causes them to be ejected from the material flow. This technique is effective for particle sizes of 4-30 mm and requires a good spreading of the material on the moving belt. Separation is performed after ferrous metal segregation, particle size reduction and screening.

4.7.2.4. Bottom ash screening and crushing

The various mechanical treatment operations for bottom ash are intended to prepare materials for road and earthworks construction that possess satisfactory geotechnical characteristics and do not cause damage to the road works. Several operations can occur during the preparation process:

- Granulometric separation by screening.
- Size reduction by crushing large elements or otherwise breaking them up.
- Air-stream separation to eliminate light unburned fractions.

Three types of screen are encountered:

- Rotary or drum screens.
- Flat screens (vibrating or not).
- Star screens: screening is achieved by movement over a series of rollers equipped with star-shaped arms on each axis.

A crusher can be installed in the treatment line to break up large chunks, generally at the exit of the fist screening. Half of the facilities are equipped with crushing apparatus, some use equipment on-site to smash blocks.

4.7.2.5. Bottom ash treatment using ageing

After metals separation, bottom ash may be stored in the open air or in specific covered buildings for several weeks. Storage is generally in stockpiles on a concrete floor. Drainage and runoff water are collected for treatment. The stockpiles may be wet, if required, using a sprinkler or hose system in order to prevent dust formation and emissions and to favour the leaching of salts and carbonisation if the bottom ashes are not sufficiently wet.

The stockpiles may be turned regularly to ensure homogeneity of the processes that occur during the ageing process (uptake of CO_2 from the air due to moisture, draining of excess water, oxidation, etc.) and to reduce the residence time of every batch of bottom ash in the dedicated facilities.

4.7.2.6. Bottom ash treatment using dry treatment systems

Dry bottom ash treatment installations combine the techniques of ferrous metals separation, size reduction and screening, non-ferrous metals separation, and ageing of the treated bottom ash. The product is a dry aggregate with controlled grain size, which may be used as a secondary construction material.

4.7.3. Treatments applied to flue-gas residues

The following techniques are identified to treat the flue-gas residue. They are specific and the applicability of the best available technique (number 54 in table 4.10) is as follows:

- Treatment of flue-gas residues:
    a) Cement solidification: this is typically performed at dedicated plants located near the end-destination of the product; thus, individual incinerators have no need to install solidification equipment. It can be used for all types of FGT residue. It is also used in many other types of **hazardous waste.**

b) Acid extraction of boiler and fly ash: this system can be used only on incinerators with a wet FGT system that can discharge the treated wastewater.

4.7.3.1. Solidification and chemical stabilisation

The main purpose of solidification is to produce a material with physical and mechanical properties that promote a reduction in contaminant release from the residue matrix. The addition of cement, for example, generally decreases hydraulic conductivity and porosity of the residue, and on the other hand increases durability, strength and volume. In addition, it usually increases the alkalinity of the mixture, therefore improving the leaching behaviour of the product, although the solubility of amphoteric metals such as lead and zinc may be increased as a result.

The solidified product is usually cast into blocks or landfilled directly. A major consideration here is reducing the interaction between water and the residue.

Solidification methods commonly make use of several, mostly inorganic, binder reagents, although some organic binders can also be used. Combinations of binders and various types of proprietary or non-proprietary additives are used as well. The most prevalent solidification technique is by far cement stabilisation.

Several of the stabilisation methods incorporate an initial washing step where a major part of soluble salts and to some extent metals are extracted before the chemical binding of the remaining metals.

4.7.3.2. Thermal treatment of FGT residue

The thermal treatment of incineration residue aims to reduce the volume of the residue, but also to reduce its organic and heavy metal content and to improve its leaching behaviour before landfilling.

Thermal treatment can be grouped into three categories: vitrification, melting and sintering.

- Vitrification is a process where residues are treated at high temperatures (currently 1300°C to 1500°C) and then quickly quenched (with air or water) to obtain an amorphous glassy matrix. After cooling down, the melt forms a single phase product called a vitrificate. This can be a glass-like or stone-like product, depending on the melt composition.
- Melting is similar to vitrifying, but the quenching step is controlled to allow crystallisation of the melt as much as possible. It results in a multi-phase product. Temperatures and the possible separations of specific metal phases are similar to those used in vitrifying.
- Sintering involves the heating of residues to a level where particle bonding occurs and the chemical phases in the residues reconfigure. This leads to a denser product with less porosity and a higher strength than the original product. Typical temperatures are around 900°C.

Regardless of the actual process, the thermal treatment of residues in most cases results in a more homogeneous, denser product with improved leaching properties. Vitrifying also adds the benefits of the physical containment of contaminants in the glass matrix.

The energy requirements of stand-alone treatments of this type are generally very high. The main problem is the heat transport into the melting reactor.

The flue-gas issued from the thermal treatment of solid residues may contain high levels of pollutants such as NO_x, TOC, SO_x, dust and heavy metals. Therefore appropriate flue-gas treatment is required. Sometimes the flue-gas produced is fed into the FGT of the incinerator if nearby. The high salt concentrations in FGT residues can cause corrosion problems in the flue-gas treatment from such processes. Sintering is not used as a dedicated treatment option for FGT residues, although some combined treatments do involve this.

4.7.3.3. Extraction and separation of FGT residues

Treatment options using extraction and separation processes can, in principle, cover all types of processes extracting specific components from the residue. However, most emphasis has been put on processes involving the extraction of heavy metals and salts with acid.

4.7.3.4. Chemical stabilisation of FGT residues

The main concept of chemical stabilisation is to bind heavy metals in more insoluble forms than they are present in the original untreated residue. These stabilisation methods make use of both the precipitation of metals in new minerals as well as the binding of metals to minerals by sorption. This process includes the solubilisation of heavy metals in the residues and a subsequent precipitation in, or sorption to, new minerals.

4.7.3.5. Other methods or practices for FGT residues

A commonly-used management option at incinerators with wet cleaning systems is to combine the fly ash with the sludge produced by treating the scrubber solutions; the resulting product is called a Bamberg cake. This method has been used for more than a decade to improve residue properties before landfilling.

4.8. MONITORING AND CONTROL TECHNIQUES

Monitoring and control are important parts of the incineration process. They help to guarantee the optimum conditions of the process and thereby prevent possible incidents and consequent impacts on the environment. These techniques and practices are of particular interest for installations within the Mediterranean Region.

4.8.1. Incineration control systems

One of the main challenges of waste incineration stems from the often wide variation in waste composition. Because of these differences, incineration processes have been developed to cope with large variations in process conditions. However, when unfavourable process conditions occur, interventions in operations are still required.

Sophisticated control systems result in an incineration process that has fewer variations in time (improved stability) and space (more homogeneous). Improved process control has many potential advantages, such as:

- Better bottom ash quality (due to sufficient primary air distribution and a better positioning of the incineration process on the grate).
- Less fly ash production (due to fewer variations in the amount of primary incineration air).
- Better fly ash quality (less unburned material, due to more stable process conditions in the furnace).
- Less CO and CxHy-formation (due to more stable process conditions in the furnace).
- Less NO_x formation (due to more stable process conditions in the furnace).
- Better utilisation of the capacity (because the loss of thermal capacity by variations is reduced).
- Better energy efficiency (because the average amount of incineration air is reduced).
- Better boiler operation (because the temperature is more stable, there are fewer temperature “peaks” and thus less risk of corrosion and clogging fly ash formations).
- Better operation of the flue-gas treatment system (because the amount and the composition of the flue-gases is more stable).

- Less maintenance and better plant availability.

In order to be able to control the incineration process, detailed process information is required. This may include: grate temperatures for various positions; thickness of waste layer on the grate; pressure drop over the grate; furnace and flue-gas temperatures at various positions; determination of temperature distribution over the grate surface by optical or infrared measurement systems, CO-, O_2,-CO_2- and/or H_2O-measurements (at various positions) and steam production.

4.8.2. Overview of emissions monitoring carried out

The following emission compounds are to be measured on a continuous basis: dust, HCl, SO_2, CO, C_xH_y, NO_x and HF.

Additionally, the following process parameters need to be monitored continuously: furnace temperature, O_2, pressure, flue-gas outlet temperature, water vapour content, heavy metals and PCDD/F. Measurement techniques for mercury and dioxins are difficult and expensive.

4.8.3. Overview of safety devices and measures

Plant safety is an important aspect in the planning, establishment and operation of waste incineration plants. The safety-relevant parts of the installation are equipped with protective systems. These parts are:

- The waste bunker and other areas for the storage of potentially hazardous waste.
- The combustion and flue-gas purification plants, and
- Storage facilities for necessary auxiliaries (e.g. ammonia, activated carbon, etc.).

Protective systems used to control risk include:

- Systems for controlling the release of pollutants, such as retention systems for used fire-fighting water, bunding tanks for substances that are a hazard to water.
- Fire protection systems and devices such as fire walls, fire detectors, fire extinguishing systems.
- Systems for protection against explosions, such as pressure relief systems, bypasses, arrangements for avoiding sources of ignition, inert gas systems, earthing systems, etc.
- Systems for protection against sabotage.
- Systems for protection against lightning strike.
- Fire dividing walls to separate the transformers and retention devices.
- Fire detection and protection where low voltage power distribution panels are located.
- Pollutant detection near corresponding storage, distribution, etc.
- Machines and equipment designed to ensure input and output of energy.
- Components for the discharge, removal or retention of hazardous substances or mixtures of hazardous substances, such as holding tanks, emergency relief and emptying systems.
- Warning, alarm and safety systems which trigger when there is a disruption of normal operations, prevent disruption of normal operations or restore normal operations.

5. USE OF HAZARDOUS WASTE IN INDUSTRIAL PROCESSES

5.1. UTILISATION OF SECONDARY FUEL

A wide range of industrial waste types are used as substitute or secondary fuels in Europe and this experience can be reproduced within the Mediterranean region.

The waste includes plastics and paper/cardboard from commercial and industrial activities (e.g. packaging waste or rejects from manufacturing), waste tyres, biomass waste (e.g. straw, untreated waste wood, dried sewage sludge), waste textiles, waste from car dismantling operations and hazardous industrial waste with high calorific value (for example, waste oils, industrial sludge, impregnated sawdust and spent solvents). This waste may require size reduction or simple screening, but usually does not require advanced physical processing, so its use as fuel is feasible in the Mediterranean region. [1]

Industrial waste used as secondary fuel has to be processed, generally outside the final industry plant, to meet industry specifications (preparation treatments of waste to be used as fuel have been developed in section 3.2.4) e.g. homogenisation to provide a consistent calorific value and the limiting of compounds such as chlorine or phosphorous for clinker production.

Waste only needs to be stored at the final industry plant and then proportioned for feeding to the kiln. Since supplies of waste suitable for use as fuel tend to be variable, while waste material markets are rapidly developing, it is advisable to design storage/preparation plants to be multi-purpose.

Refuse derived fuels cover a wide range of waste materials which have been processed to fulfil guideline, regulatory or industry specifications mainly to achieve a high calorific value. The main industrial waste which is used as substitute or secondary fuel and the type of industry that generally uses them are described below. The hazardous properties of some of them, e.g. plastics, paper, waste wood will depend on their content in toxic substances.

5.1.1. Tyres

Tyres have a typical high calorific value of 28.5 to 35 MJ/kg[18]. They contain relatively high levels of iron, sulphur (≈1.6%) and zinc (≈1.5%). In the cement industry, tyres are one of the most commonly-used solid secondary fuels with regular utilisation.

5.1.2. Used oils

Untreated waste oils (Approximately 31% of waste oil generated by the EU -this quantity should be extrapolated to the Mediterranean region-) are commonly used as secondary fuels in cement kilns and other industries as power and smelter. This type of waste is also reported to be used in district heating plants, power plants and the production of bitumen.

[18] MJ/kg: megajoules/kilogram

Approximately 32% (this should be also extrapolated) receives limited treatment (separation of water and sediment) and is used as a fuel in cement kilns, the stone industry and power plants.

5.1.3. Plastics

Plastics usually have a high calorific value (29 to 40 MJ/kg). They are usually shredded and mixed with other waste before injection. The principal limiting factor in plastics is chlorine content, mainly in PVC.

Plastic waste processed into secondary fuels in cement kilns includes non-recyclable plastics such as plastic bags from retail outlets or rejects from industrial processes.

Before injection and co-firing, plastics have been trialled by shredding and mixing with other waste. Plastics are also reported to be used in other types of combustion plants and as reducing agents in blast furnaces. Plastics from end-of-life vehicles (ASR - automotive shredder residue) are reported to be co-incinerated as secondary fuels in cement kilns and in a power plant.

5.1.4. Biomass

5.1.4.1. Waste wood

Waste wood has a calorific value ranging between 15 and 17 MJ/kg at 10 to 15% residual water. If the wood has been treated or painted, concentrations of heavy metals (As, Cr, Cu), chlorine compounds and other toxic substances may be high.

Waste wood can have many origins: waste wood from mills, panel production (MDF) and furniture production is usually re-used in panel production or burned to generate process energy on site. This is usually not available for energy recovery in other sectors. Waste wood from households or industrial sectors, on the contrary, is potentially available for energy recovery.

Waste wood is commonly co-combusted in multi-fuel boilers for district heating production, in coal-fired power plants and other industrial plants, in brick kilns and also in cement kilns.

5.1.4.2. Sewage sludge

Dried sewage sludge (more than 90% dry solids (ds)) can be used as fuel in cement kilns in conjunction with other solid waste types. Dried sewage sludge has a calorific value of 16 to 17 MJ/kg.

Dried sewage sludge is co-incinerated in cement kilns. There are plans to co-combust dried sewage sludge in a power plant and in a brick kiln.

5.1.4.3. Straw

Sawdust is mixed with organic compounds to produce a more consistent secondary fuel for the cement industry in most European kilns. It is also used as a pore agent in the brick industry.

5.1.5. Paper and paper sludge

Waste paper is used as alternative fuel in cement kilns, usually together with plastic and other waste. Paper has a typical calorific value of 12.5 to 22 MJ/kg. Sludge or residues from the production of paper are also used as secondary fuels, mainly by the paper industry itself. Paper sludge has a lower Calorific Value (CV) of about 8.5 MJ/kg.; however, it is also used as secondary fuel in cement kilns. Paper sludge and other residues from the production of paper are also co-combusted by the paper industry itself across Europe.

5.1.6. Animal Waste

Animal waste (bone meal and animal fats) has a typical CV of 16 to 17 MJ/kg. Rendered animal meal and fats are prepared at approved processing facilities. Animal carcasses from non-BSE (Bovine Spongiform Encephalopathy) infected animals undergo extraction of the spinal cord, nervous systems, tonsils and eyes, sterilisation (at 133°C under a pressure of 3 bars for at least 20 minutes) and then grinding. This waste is reported to have a high calorific value and is of stable composition. Pre-treatment can either be carried out off-site by the supplier, or on-site by the industry themselves or a site-based subsidiary.

Bone meal and animal fats are used as alternative fuels in cement kilns; some are co-combusted in other combustion plants, in coal-fired power plants and on a temporary basis in a power and district plant. Straw and chicken manure are or will also be co-incinerated as secondary fuel in power plants.

5.1.7. Spent solvents

These are widely used as secondary fuel by the cement industry. Solvents are also used in coal-fired power plants and other industrial plants. They can be mixed with sawdust before being injected into the kiln.

5.1.8. Other waste

Other waste fractions processed as secondary fuels are:

- Substitute Liquid Fuel (SLF) mixed with sawdust (i.e. spent solvents).
- Automotive shredder residue (ASR).
- Carpet residues and off-cuts: these could also be used as secondary fuels in the cement industry.
- Textiles.
- Nappy manufacturing waste.
- Anode waste, etc.

To summarise, typical hazardous waste used as substitute or secondary fuels in the industrial sectors is shown in table 5.1:

Table 5.1: Hazardous waste used as substitute or secondary fuels in Europe

Hazardous waste	Industrial sector
Spent solvents	Cement kilns, coal-fired power plants, and other industrial plants.
Waste oils	Cement kilns, power plants, stone industry, district heating plants, production of bitumen
Sewage sludge	Cement kilns, power plant, brick kiln

5.2. INDUSTRIAL SECTORS USING HAZARDOUS WASTE

The three main industrial sectors using secondary fuels from industrial waste (both hazardous and non-hazardous) are:

- Cement industry.

- Paper industry.
- Power industry.

The most reliable and detailed information was collected for the cement industry while it proved more difficult to obtain clear information concerning the other sectors. For the paper industry, it was difficult to quantify Refuse Derived Fuel (RDF) that was co-incinerated, as it was not possible to distinguish between waste generated on-site such as bark, paper rejects or paper sludge and traded RDF. In the power sector, the changes in the energy market made it difficult to collect reliable and up-to-date information.

Other sectors (i.e. the brick and blast furnace industries) could also be co-incinerating refuse derived fuels but these sectors argue that this is not primarily for energy substitution but for material substitution. RDF from industrial waste is used in processes that do not rely on combustion, such as biodigestion, gasification and pyrolysis (gasification and pyrolysis have been developed in section 4.2.1.5).

The following sections contain a description of the industries that can use hazardous waste as fuel. These also include the industries located in the Mediterranean region.

5.2.1. Cement industry

Cement kilns consist of a rotary kiln in which clinker sintering takes place. The length of the kiln varies from 70 to 200 m with one burner at the hot end of the kiln. Flue-gas cleaning is via electrostatic precipitator(s).

Fossil fuels (e.g. coal, petroleum coke, oil or natural gas) are the predominant fuels used in the cement and lime industries. However, low-grade fuels such as shales, coal washings, petrol coke and waste fuels (traditionally waste oils, spent solvent, waste tyres) have been increasingly utilised. More recently, the cement industry has co-incinerated bone meal and animal fats.

A general assumption is that cement quality is not affected by using waste, as waste composition is monitored and adjusted to comply with cement requirements. Similarly, the cement industry claims that emissions are mainly determined by raw materials and are not influenced by the type of fuel. For example, high NO_x emissions are inherent to the process because of the high temperatures of combustion. Emissions of sulphur dioxide, ammonia and ammonium compounds are mainly due to raw material content. Other emissions, such as dioxins, are not affected by the type of alternative fuel. [6]

The fuel is generally added in the main burner, or with the raw materials, or in the decarbonation zone (wet process only) or in the precalciner (dry process only). Solid fuel is crushed prior to its firing into the burner. Pulverisation is necessary to ensure the complete burn-out of the residual ash. The flame temperature is very high (between 1800 and 2000°C) and retention time is of more than 5 sec at a temperature above 1200°C, ensuring the total destruction of organic matter.

Waste fed to a secondary burner, preheater or precalciner will be burnt at lower temperatures, which is not always enough to decompose halogenated organic substances.

Volatile components in material that is fed into the upper end of the kiln or as lump fuel can evaporate. These components do not pass the primary burning zone and may not be decomposed or bound in the cement clinker. Therefore the use of waste containing volatile metals (mercury, thallium) or volatile organic compounds can result in an increase in the emissions of mercury, thallium or VOCs when improperly used.

Table 5.2: Main characteristics of the cement production process (RDC/Kema, 1999 in [1])

Parameter	Conditions
Flame temperature	1800-2000°C
Gas retention time	> 5sec at a temperature above 1200°C
Oxygen excess	Low
Efficiency	44%
Other	Oxidising atmosphere High thermal inertia Alkaline environment
Residue	Ash retention in clinker

To ensure additional energy transfer to the decarbonation zone, it is also possible to add solid fuel to the raw material. However, this is not best practice as it results in a greatly increased emission of organics in the flue gases.

It is also possible to add solid waste in the middle of the wet kiln at the level of the decarbonation phase. The waste does not have to be pulverised. However, such a discontinuous method of supply requires special control of the quantities of fuel and oxygen to ensure complete combustion and avoid increased organics and carbon monoxide in the flue-gas. In a dry process, it is possible to inject pulverised fuels at the transition zone of the rotary kiln and pre-cyclones and the oxygen supply must be properly adjusted to ensure complete burnout.

As the process requires temperature of about 2000°C, the cement industry has a very high energy demand. Information on energy consumption including secondary fuels in the cement industry is known.

The cement industry is the largest consumer of secondary fuels from industrial waste, with about 105 kilns across Europe; more than 2.5 million tpa of secondary fuels, mainly hazardous waste such as spent solvents, used oils and tyres have been reported to be co-incinerated in cement plants.

Hazardous waste such as waste oils and spent solvents mixed with sawdust or injected in liquid form at the flame are one of the most common RDFs co-incinerated in cement kilns. Tyres are also commonly used as whole tyres or after shredding. They are typically introduced at mid-kiln or calcination stage. They can also be added into pre-heater systems or into the firing system.

The European average energy substitution rate for secondary fuels in the cement industry is reported to range between 1 and 40%. It was reported that in 1995, fuel usage in the cement industry in Europe was about 10% for refuse derived fuels.

Table 5.3: Quantities of waste used as secondary fuels in Europe (RDC/Kema, 1999 in [1])

Waste type	Quantity in 1997 ($x10^3$ tonnes per annum)	Expected quantities 2003 ($x10^3$ tonnes per annum)
Tyres/rubber	413	496
Household RDF	115	132
Sewage sludge	81	99
Used oils	446	<1140
Spent solvent and hazardous waste	592	(included in used oils)
Plastics	71	85
Waste paper	27	31
Waste wood	9	12
Other	44	53
Total	**1800**	**2050**

The recycling of collected particulate matter in the process wherever practicable is considered to constitute a best available technique. When the collected dusts are not recyclable, the use of these dusts in other commercial products where possible is considered also a BAT.

5.2.2. Power industry

In conventional coal-fired power plants, fine coal powder is burned in a furnace at about 1600°C. The retention time of the combustion gas is at least 4 seconds at >1200°C. Electrostatic precipitators and flue-gas desulphurisation were reported to be commonly used, together with NO_x reduction by selective catalytic reduction (SCR). Table 5.4 shows the main characteristics of coal-fired power plants.

Table 5.4: Main characteristics of coal-fired power plants (RDC/Kema, 1999 in [1])

Parameter	Conditions
Flame temperature	1600-2000°C
Gas retention time	> 4sec at temperature above 1200°C
Oxygen excess	3 Vol %
Efficiency	40-45%
Residue	Slag, fly, gypsum

Co-firing refuse derived fuels in coal-fired power and district heating plants is relatively common in Northern Europe; however, it is not common in the Mediterranean region.

Power plants and district heating plants co-combust mainly non-hazardous secondary fuels such as waste wood, straw and dried sewage sludge.

The residue from coal-fired power plants is slag, fly ash and gypsum, which can be reused. Production of electricity from coal requires about 300 kg coal per MWh produced. It is argued that the co-firing of waste with coal has the advantages of saving fossil resources and is more efficient than waste incineration. Co-firing with waste potentially impacts on atmospheric emissions and residue quality. The main emissions influenced by co-incineration are linked to heavy metal content such as mercury (Hg) and thallium (Tl). However, emissions limits will only be exceeded if the content of Hg and/or Tl in waste is high (at levels up to grams per kg). The quality of fly ash will be influenced to a limited extent by co-firing, depending on the quantities of alkali elements (K and Na) in the waste (RDC & Kema 1999 in [1]).

5.2.3. Pulp and paper

The production of pulp and paper requires considerable amounts of steam and power. Most mills produce their own steam in one or more industrial boilers which can burn fossil fuels and/or wood/bark waste. Mills that use chemical processes also burn their spent liquor in a boiler to recover chemicals and generate electricity. Other waste can also be burnt, such as mercaptans, paper sludge, non-recyclable recovered paper, etc. Some mills also have on-site lime kilns to generate quicklime, in which waste can also be burnt.

Constraints on co-incineration in the pulp and paper industry are not related to product quality except when co-firing spent liquor. The main types of waste used are paper sludge, de-inking sludge, and residue from waste paper (often containing plastics), bark and wood waste and sawdust. The majority of this waste is produced on-site.

5.2.4. Lime kilns

The production of quicklime (CaO) from burning limestone in a kiln is a very energy-demanding process requiring between 900 and 1800 kcal/kg[19]. Temperatures are as high as 1300°C with more than 5 seconds residence time for carbon dioxide to be driven off from limestone. There are two main types of kilns; blast shaft kilns and rotary kilns.

It was reported in 1995 (European Lime Association as reported in RDC and Kema 1999 [1]) that about 1% of fuel consumed by industry was derived from waste, compared to 48% of gas, 36% of coal and 15% of heavy fuel. The range and quantities of refuse derived fuels are very low because waste can influence the quality of the final product and only low ash waste-derived fuels can be co-incinerated, such as sawdust, shredded tyres, methanol and other low grade solvents, plastics and used oils.

5.2.5. Brick kilns

Industrial waste is also reported to be co-incinerated in brick kilns in some countries. The temperature reached here is lower than in cement kilns. It is however argued by the industry that the use of secondary materials such as straw, sawdust, paper sludge and polystyrol is not for energy requirements but as pore agents and thus constitutes recycling and not combustion/incineration.

[19] kcal/kg: kilocalories/kilogram

5.2.6. Iron production plants

Most waste/residues used in the iron industry are by-products of the process or waste recycled in-house in the sintering plant for material recycling rather than energy substitution. However, there are recent reports of the use of granulated plastics as a fuel substitute for coke in some blast furnaces.

5.3. TECHNOLOGIES

In this section, a description of the types of technologies applied to the different sectors has been included. These technologies represent case studies for the development of industrial facilities available for the use of hazardous waste in the Mediterranean Region.

5.3.1. Brown coal-fired power station

This uses a rehabilitated crude brown coal-fired power station with steam turbine for brown coal. A gas desulphurisation plant (GDP) is connected to reduce sulphur dioxide emissions. This operates using the wet process: the additive limestone meal ($CaCO_3$) is blown into the flue-gas with water. The limestone meal is added in a stoichiometric ratio to the SO_2. The resulting GDP-gypsum can be used in the building construction industry. The GDP plant reduces SO_2 by 95% and dust by 90%. NO_x emissions are reduced solely by primary measures. The power station has an electrical efficiency of 39%.

5.3.2. Hard coal-fired power station

This uses a hard coal-fired power station for imported coal. The power station has a power rating of 500 MW and a net electrical generation ratio of 43.5%. A gas desulphurisation plant (GDP), a $DeNO_x$ plant and an electrostatic precipitator are connected to reduce emissions. The GDP operates using the wet method, which relies on a stoichiometric ratio of limestone-SO_2. This reduces SO_2 emissions by 90%, dust emissions by 90% and HCl and HF emissions by 95% each. The $DeNO_x$ plant operates in accordance with the SCR-process (selective catalytic reduction) with ammonia as sorbent at a stoichiometric ratio. NO_x emissions are thus reduced by 85%. The electrostatic precipitator reduces dust emissions by a further 99.5%. For this assessment, compliance with the threshold values specified in the Waste Incineration Directive (2000/76/EC) cannot be guaranteed.

5.3.3. Cement works

The cement process chosen is a dry kiln equipped with cyclone or grid preheater. Dust is minimised by an electrostatic precipitator. The basic primary fuel used in the cement process is hard coal. The technology used in this module can be considered to be typical for a large number of cement kilns in Europe.

5.3.4. Waste incinerator

The waste incinerator process chosen is a municipal solid waste incineration plant with grate firing and energy recovery. It represents a standard average. The flue-gas cleaning technology ensures compliance with the threshold values of the new EC Waste Incineration Directive. Flue-gas emissions via the chimney are the main emission pathway. Other material flows are incineration residues and the by-products resulting from flue-gas cleaning. The plant works without any process wastewater. Flue-gas cleaning is divided into several steps. Firstly an electrostatic precipitator (three cells) is installed to minimise dust and ashes. Furthermore, a spray-dryer, a fabric filter, an acid scrubber for HCl reduction, a gas desulphurisation plan and a SCR for NO_x reduction are installed. It is assumed that a modern boiler system is used, with 90% of the furnace heat transformed to steam. In general, the gross efficiency of power generation from waste incineration is no higher than 25%. After plant consumption, it can be assumed that there will be an electricity surplus of 10% that is fed into the public grid. There are also MSWI with combined heat and power (CHP) generation with a lower electricity output but a feed to district heating systems.

5.3.5. Co-incineration

A wide range of industrial waste is also processed to be co-incinerated in industrial processes as secondary fuel. This waste includes plastics and paper/card from commercial and industrial activities (e.g. packaging waste or rejects from manufacturing), waste tyres, biomass waste (e.g. straw, untreated waste wood, dried sewage sludge), waste textiles, waste from car dismantling operations (Automotive Shredder Residues - ASR) and hazardous industrial waste such as waste oils, industrial sludge, impregnated sawdust and spent solvents. This waste must have a high calorific value, be consistent in quality and be cheap or even support a gate fee. In the past few years, the market for substitute fuels has been very buoyant with the arrival of cheaper fuel substitutes such as meat and bone meal following the BSE and dioxins crises.

5.4. ENVIRONMENTAL ASSESSMENT

The DG Environment report on refuse derived fuel [1] undertook the assessment of the environmental impacts of the production and use of RDF by comparing the use of RDF in brown and hard coal-fired power plants, cement plants and hazardous waste incineration plants by using a multiple approach including:

- A Life-Cycle Analysis (LCA) considering general benefits or disadvantages of the total recovery system of RDF.
- An Environmental Impact Assessment (EIA) estimating local impacts of the production and use of RDF.
- An assessment of impacts on the products from industries co-incinerating RDF.

Calculations were based on the assumptions that the materials (both RDF and fossil fuel) were of average quality and that the technology modelled for the installations was of average to advanced level (with respect to BATs) for the production and use of RDF.

A short description of LCA and EIA follows. These could be utilised as a tool for the hazardous waste sector.

A Life-Cycle Analysis (LCA) assesses the environmental effects generated throughout the service life of a human activity. It analyses the environmental impacts of a product, its system or service life (from cradle to grave), or more exactly, what is required so that a product acts in a certain way.

An Environmental Impact Assessment (EIA) analyses the environmental impacts of investments and plants in specific locations, considering possible alternatives. It is applied to decision-making for public activities and for granting permission for some private activities.

5.5. ECONOMIC ASSESSMENT

The use of secondary fuels is an important economical option. Depending on the raw materials and the process technology used (wet, dry or semi dry/wet processes), the energy demand varies between 2.8 GJ[20] and 5.5 GJ to produce one tonne of clinker. The energy conversion efficiency defined as the

[20] GJ: gigajoules

energy content of the clinker divided by the total energy input amounts, on average, to 44% for European cement kilns.

For co-incineration facilities, if the requirement for investment in additional flue-gas cleaning equipment arises from the use of MSW, it is clear that the co-incineration facility might take the view that the use of MSW as fuel is not cost-effective.

Alternatively, it would seem quite possible that the local authority or waste management company could enter into an agreement with the co-incineration facility in which, rather than paying for a dedicated energy recovery facility, the local authority or waste management company itself makes the necessary investment (fully or in part) to enable the plant to make use of MSW whilst adhering to limit values established.

If, on the other hand, co-incineration facilities were required to make the investment irrespective of the use of MSW (and this would seem quite reasonable from an environmental perspective) the issue would be one of the competitiveness and survival of the co-incineration facility. The incremental cost of using RDF would be zero. Greater use of RDF would probably become more of an imperative for the industry than it already is.

6. LANDFILL OF HAZARDOUS WASTE

6.1. INTRODUCTION

Landfills are common final disposal options for hazardous waste. They are essentially an engineered construction activity where waste forms the input for the process. All waste received at a landfill site must be pre-treated or separated, because landfill is a finalist treatment (it is the last step of the treatment).

A generic description of the process of landfilling starts with the delivery of materials entering the facility at a reception and handling area, where other waste management activities may also take place. Following checking and acceptance, the waste is transported to the disposal point. The landfill development activity is phased and, at any one time, cells can be in preparation, in operation or in the process of restoration.

In certain categories of landfill, waste may decompose over time and change in nature. Therefore, where relevant, the provision of measures to control emissions from the products of decomposition, including leachate and landfill gas, forms an integral part of the activity [4].

In the following sections, environmental techniques and practices applicable to landfills have been developed. They consist of general criteria for their design, operation and closure, which are strongly recommended for the Mediterranean Region. It should be noted that uncontrolled landfilling may have critical environmental impacts.

6.2. MANAGEMENT ELEMENTS FOR HAZARDOUS WASTE LANDFILL

There are different types of landfills. The objectives of landfill classification are:

- To consider waste disposal situations and needs in terms of combinations of waste type, size of waste stream and potential for significant leachate generation.
- To develop landfill classes which reflect the spectrum of waste disposal needs.
- To use landfill classes as the basis for setting graded Minimum Requirements for the cost-effective selection, investigation, design, operation and closure of landfills.

Council Directive 99/31/EC of 26 April 1999 on the landfill of waste defines categories of waste (municipal, hazardous, non-hazardous and inert waste) and applies to all landfills. Landfills are divided into three categories:

- Landfill for hazardous waste.
- Landfill for non-hazardous waste.
- Landfill for inert waste.

A standard waste acceptance procedure is laid down so as to avoid any risks:

- Waste must be treated before being landfilled.
- Hazardous waste must be assigned to a hazardous waste landfill.
- Landfills for non-hazardous waste must be used for municipal waste and for non-hazardous waste.

- Landfill sites for inert waste must be used only for inert waste.
- Criteria for the acceptance of waste of each landfill class must be adopted by each department of environment of each country.

The following information is based on a guideline on the determination of Best Available Techniques (BAT) for landfill activities developed by the Environmental Protection Agency (EPA) of Ireland [4] for compliance with Council Directive 99/31/EC on the landfill of waste and Council Directive 96/61/EC concerning integrated pollution prevention and control. Furthermore, guidelines on landfill design and operation prepared by Basel Convention Regional Centre for Training and Technology Transfer for Arab States in Cairo (Cairo-BCRC) have also been taken into account [5] for the framework of the Mediterranean Region.

In the identification of BATs, emphasis is placed on pollution prevention techniques rather than end-of-pipe treatment.

6.3. LANDFILL DESIGN

The general objective of landfill design is to provide a cost-effective, environmentally acceptable waste disposal facility. The specific objectives are:

- The mitigation of any adverse impacts identified in the site investigation and in the Environmental Impact Assessment (EIA).
- The prevention of leachate-related pollution to adjacent ground and surface water.
- The provision of sufficient cover material to ensure an environmentally and aesthetically acceptable operation.

In order to do this, the design must be based on a sound knowledge of the environmental setting including (see also table 6.1):

- Waste quality projections and site life requirements.
- Liner requirements.
- Leachate disposal requirements.
- Landfill support facilities and covers and closure material requirements.
- Surface water and drainage management system requirements.
- Gas control requirements.
- Determination of the disposal of waste material already onsite.
- Local dimensional and construction methods requirements.
- Availability of local material, power and water, other utilities.
- Climate.
- Economic and social factors.

Table 6.1: Considerations for landfill design

Consideration	Design Issue
The nature and quantity of waste	This directly affects environmental control measures
Water control	Rainfall, surface water runoff and groundwater protection
Protection of soil and water	Selection of type of liner system
Stability	Stability of the site base, liner system, waste mass and capping
Development aspects	Facility design, planning and applied processes, construction, operation, closure and aftercare
Monitoring requirements	Provision and installation of monitoring points within and outside the facility
Landfill afteruse	Compatibility with the proposed afteruse
Landfill phasing	Operational and restoration requirements, location of facility infrastructure
Leachate management	Leachate collection system and treatment/disposal facility
Landfill gas control	Potential for gas migration, gas collection, gas burning/utilisation
Environmental nuisance	(a) during construction e.g. noise, dust, mud (b) during operation, e.g. noise, odours, dust, litter, birds, vermin and fires

Design variations are most notably implemented in arid regions (some countries within the Mediterranean region, such as Egypt).

To ensure soil foundation support and establish site civil and environmental limitations, the following must take place:

- Conducting hydro-geologic investigations.
- Defining geological stratigraphy.
- Establishing groundwater depths and flow directions.
- Defining characteristics of on-site soils.
- Preparing base and topographical maps.
- Obtaining available precipitation data.

Special services needed to accomplish this are as follows:

- A survey of the site for property boundary and topographic information.
- Geotechnical investigation, consisting of soil borings and soil tests.
- Geological studies including surface and subsurface investigations.
- Geo-hydrological investigations including groundwater modelling.
- Geophysical investigations including ground penetrating radar studies.

Below, is a selection of the specific measures to take into account, the specific explanation and the selection of BATs according to them.

6.3.1. Location

Landfill location must have minimal impact on environmental components as well as on lifeline utilities like transportation and social and economic factors.

A Feasibility Study involving a preliminary environmental impact assessment and geo-hydrological investigation must be carried out for each candidate site. This will determine whether the potential impact of the site is environmentally and socially acceptable.

This study has to be done for each landfill project in every country. The following three subsections outline certain points to be taken account with regard to landfill site location.

6.3.1.1. Access Roads

An appropriately constructed and maintained access road to and a road system within the hazardous waste landfill site capable of supporting all vehicles hauling waste are required during the operating life of the landfill. Access to disposal sites is a notorious problem in a number of communities in economically developing countries. Poor accessibility leads to congestion and under-utilisation of collection equipment. Road access to the site should be sufficient to permit safe and orderly entrance and exit, even during periods of inclement weather.

The site should be made accessible through the use of a properly graded, all-weather road, and the road should be sufficiently wide to allow access for fire-fighting equipment at all times.

6.3.1.2. Distance and Capacity

The selected site should provide sufficient capacity to meet current and projected needs for hazardous waste disposal in the area being serviced for a minimum of ten years. This length of time justifies the investments made in the site (such as acquisition, studies, access roads and equipment).

The site should be located reasonably close to the centre of hazardous waste generation or to the transfer station. Typically, the maximum recommended distance is 50 km as a radius from the waste generation node. An alternative, and perhaps preferable, suggestion is that the average length of time required to reach the site should be considered, rather than the distance. This takes into account variables as well as distance, such as traffic and the quality of roads. The maximum length of time for a single journey should be in the order of 30-45 minutes for typical collection vehicles (i.e. vehicles with capacities of about 5 tonnes). An exception to this is for transport vehicles of large capacity such as transfer trailers; in this case, one-way trips of up to 2 hours may be economically feasible, although this will depend on local circumstances.

6.3.1.3. Outlines of Environmental Impact Assessment

Once a candidate landfill site has been selected for development location criteria, further detailed investigation and reporting are required before starting site development. The assessment of the potential environmental impacts of a landfill usually takes place in parallel with the detailed site investigation. The objectives of the assessment of potential environmental impacts are:

- To identify the various ways in which an existing, proposed or closed landfill will affect its receiving environment.
- To ensure that the identified impacts can be eliminated or mitigated (minimised) by means of proper design and operation, combined with ongoing monitoring.

There are two stages in assessing the potential impact of a landfill on the environment:

- Environmental Impact Assessment (EIA): this makes use of accepted methodology to assess the potential impact of a site on the environment. Since the environment includes the social environment, the EIA must include wide consultation with all stakeholders, including the local community.
- Assessment of the Environmental Consequences of Failure: this assesses the consequences of the escape of contaminants from a landfill site in the event of design failure.

Most EIA methods depend on, or have as their starting point, a checklist of considerations that should form part of the design process. This checklist may be used to identify interactions between site characteristics, design and operation, and their potential impacts on the environment.

In order to identify interactions, use is often made of a two-dimensional environmental impact identification matrix. Actions and impacts would include those linked to the following phases of the project:

- Site preparation and construction.
- Operation.
- Closure and rehabilitation.
- After-use.

The actions and impacts that make up the axes of the matrix must be selected by a qualified team with multi-disciplinary representation.

6.3.2. Property boundary

The objective is to maintain a separation area between the landfill site and other civil structures, to and minimise the potential for the accumulation of methane gas originating in landfill and other sources of pollutants (such as leachate) in structures near the landfill. Another objective is to minimise the visual impact associated with landfill sites from nearby roadways

There should be no residential development, either existing or planned, within 500 meters of the disposal site's boundary. The fill should also have a buffer zone of unused land. The buffer zone between the discharged solid and/or hazardous waste landfill and the property boundary should be at least 50 meters of which the 15 meters closest to the property boundary must be reserved for natural or landscaped screening (berms or plant screens). The distance between the discharged solid or the hazardous waste landfill and the nearest residence, water supply well, water supply intake, hotel, restaurant, food processing facility, school, or public park varies from a radius of 300 meters to 1.6 kilometres.

6.3.3. Geology

The objective is to minimise the potential for the landfill to be located in areas like karst terrains, avalanche areas or areas with mass movement, susceptible to events or forces that are capable of damaging the landfill containment system and having an impact on the environmental monitoring system.

Waste facilities should not be located on poorly drained or very poorly drained soils, such as those common to wetlands, nor should they be sited on excessively well-drained soils. Upon excavation to the base of the future landfill, a minimum of two meter-deep test pits should be dug per hectare of the site, and the soils tested and photographed to confirm their suitability for supporting the facility.

The following subsections provide specific explanations of the important geological characteristics for landfill sites.

6.3.3.1. Karst terrains

Karst terrains mean areas where karst topography, with its characteristic surface and subterranean features, has developed as a result of the dissolution of limestone, dolomite, or other soluble rock. Characteristic physiographical features present in karst terrains include, but are not limited to, sinkholes, sinking streams, caves, large springs, and blind valleys. Other rocks such as dolomite or gypsum may also be subject to solution effects.

6.3.3.2. Areas susceptible to mass movement

These are those areas of influence (i.e. areas characterised as having an active or substantial possibility of mass movement) where the movement of earth material at, beneath, or adjacent to the landfill unit, because of natural or human-induced events, results in the downhill transportation of soil and rock material by means of gravitational influence. Areas of mass movement include, but are not limited to, landslides, debris slides and flows, solifluction, block sliding, and rock fall.

6.3.3.3. Avalanche Areas

The objective of this criterion is to minimise the potential that areas associated with avalanches (steep slopes and areas with occasional heavy rainfall) will damage the landfill containment system and negatively affect its performance. Since there is only limited data on avalanche prone areas, for the purpose of this evaluation, steep topography shall be used as a surrogate for avalanche prone areas.

6.3.3.4. Soils

Waste facilities should not be located on poorly drained or very poorly drained soils, such as those common to wetlands, nor should they be sited on excessively well-drained soils. Upon excavation to the base of the future landfill, a minimum of two, two-meter deep test pits should be dug per hectare of the site, and the soils tested and photographed to confirm their suitability for supporting the facility.

6.3.4. Nature

The site should be selected so that no known living or breeding areas of environmentally endangered or rare species are present within the site boundaries; neither should the perimeter of a site be located within 250 meters of protected areas.

6.3.4.1. Endangered Species

The objective of this criterion is to minimise the threat posed by a landfill of causing destruction or adverse modification to critical habitat of an endangered or threatened species, jeopardising the continued existence of endangered or threatened species or contributing to the taking of endangered or threatened species. Property containing critical habitat of an endangered or threatened species listed pursuant to acts by local Environmental Affairs Agencies shall be excluded from the facility siting process where the landfill may cause destruction or adverse modification to critical habitat of an endangered or threatened species, jeopardise the continued existence of endangered or threatened species, or contribute to the taking of endangered or threatened species.

6.3.5. Drainage

Surface water diversion to prevent storm water runoff from making contact with the waste is required. Runon and runoff from the site should be minimised. All drainage ditches, evaporation ponds and swales (low, trough-like tracts of land) should be suitably designed and sufficiently distant from the waste to prevent it absorbing the collected water.

For the minimisation of groundwater emissions, the applicant should put in place procedures to ensure that the lining system is not damaged and to ensure that continuing emplacement of waste does not compromise the stability of the lining system. For all landfill sites, trigger levels need to be agreed and set for groundwater quality, based on the specific hydro-geological conditions of the area, taking into account the direction and gradient of groundwater flow [5].

6.3.5.1. Distance to Surface Water and Environmentally Sensitive Areas

The objective of this criterion is to minimise deficiencies in monitoring storm water runoff, as well as the input of contaminated groundwater that leads to impairment of the beneficial uses of nearby surface water due to site-derived hazardous and deleterious chemicals. The inevitable failure of hazardous waste landfill liner/containment systems and the unreliability of the groundwater monitoring systems that are used at some landfills mean that ultimately, where shallow groundwater flow paths exist from the base of the landfill to surface water systems, on-site landfills will not only pollute groundwater with hazardous/deleterious chemicals, but also surface waters. Since this pollution may occur for many decades after closure of the landfill, it is essential that appropriate measures be taken to monitor shallow groundwater for the transport of hazardous and deleterious chemicals to surface water.

6.3.5.2. Distance to lakes or ponds

The objective of this criterion is to minimise the potential for surface water runoff from a landfill to impact a perennial lake or pond with contaminated runoff, sediment load, and/or waste. Property within 200 meters of ponds, marshes and swamps or around any perennial lakes that are either naturally occurring or contain non-industrial use water shall be excluded from the facility siting process.

6.3.5.3. Distance to rivers or streams

The objective of this criterion is to minimise the potential for surface water runoff from a landfill site to impact a perennial river or stream with contaminated runoff, sediment load, and/or waste. Property within a distance of 100 meters from the waterline of any perennial river or stream (both sides) shall be excluded from the facility siting process. The following minimum distances are recommended: 250 meters from flowing bodies of water less than 3 meters wide, 300 meters from flowing bodies of water greater than or equal to 3 meters wide.

6.3.5.4. Wetlands

The objective of this criterion is to minimise the potential for impact to wetland habitats or species, water quality, or degradation of the wetlands associated with a hazardous landfill. Any property that is designated a wetland by a National Wetlands Inventory map shall be excluded from the facility siting process. Hazardous waste should not be placed in environmentally important wetlands with significant biodiversity.

6.3.5.5. Coastal Features

The landfill boundary should be at least 150 meters from a marine shoreline.

6.3.5.6. Distance to Industrial Process Water

The objective of this criterion is to minimise the potential for surface water runoff from a landfill to impact a process water or storm water pond with contaminated runoff, sediment load and/or waste. Property within a radius of 100 meters around any process water or storm water management pond shall be excluded from the facility siting process.

6.3.5.7. Floodplains

The objective of this criterion is to minimise the potential for storm water flows associated with the 100-year flood event to (1) disturb and erode the landfill cover, (2) disturb and wash out in-place waste, or (3) impact environmental monitoring systems. Also, the objective is to minimise the potential for the landfill site to restrict the flows associated with the 100-year flood event or reduce the water storage capacity of the floodplain. Property located on 100-year floodplains shall be excluded from the facility siting process.

6.3.6. Final Cover

Final cover for landfill sites is to consist of a minimum of 1.5 meters of low permeability (<1 x 10^{-5} cm/s[21]) compacted soil plus a minimum of 0.15 meters of topsoil with approved vegetation established. The depth of the topsoil layer should be related to the type of vegetation proposed.

Soils of higher permeability may be approved based on leachate generation potential at the landfill site. Final cover is to be constructed with slopes of between 4% and 33% with appropriate runon/runoff drainage controls and erosion controls.

Final cover is to be installed within 90 days of landfill site closure or on any areas of the landfill site which will not receive any more refuse within the next year. Completed portions of the landfill site are to receive final cover progressively during the active life of the landfill site [5].

6.3.7. Gas Venting or Recovery and Management Systems

These are required for landfills of a total capacity exceeding 100,000 tonnes. An assessment of the potential emissions of non-methane organic compounds (NMOCs), the surrogate group of gaseous compounds associated with landfill gas, shall be carried out. If the assessment indicates that emissions of NMOCs exceed or are expected to exceed 150 tonnes/year, the installation and operation of landfill gas recovery and management systems are mandatory. Where a gas recovery and management system is installed, direct venting to the air of gases collected must be avoided; rather, subsequent utilisation for energy recovery is recommended. Combustion, even by incineration or flaring, should be encouraged over direct venting to the atmosphere to reduce odours and greenhouse gas emissions [5].

6.3.8. Final Contour of the Site

Drainage patterns of the surrounding area require the temporary structures base of each fill area and the top of each lift to have ramp access to working areas with a minimum 3% gradient (internal roads) the area's ten-year, 24-hour rainfall. Ramps should be designed and maintained to prevent erosion, especially erosion of the bottom liner and of the final cover material. Protection of permanent slopes with vegetation is also worth considering, especially in areas prone to soil erosion. The final contours of the completed fill should be a minimum of 3% and a maximum of 20% slope, and should take into account the final use of the site. Care should be taken to maintain adequate slopes when settling occurs after closure of the landfill site [5].

6.3.9. Use of energy

Landfill facilities use relatively small quantities of energy and the main uses are:

[21] cm/s: centimetres/second

- Heating, lighting and power in facility buildings.
- Power to facility equipment such as wheel wash, weighbridge, pumps, treatment processes, lighting etc.
- Fuel to power vehicles.

The applicant should: quantify the energy consumption at the facility by the source of energy, demonstrate that energy efficiency has been considered in the design and that purchasing, operating and maintenance procedures optimise the energy use of the facility [4].

6.3.10. Raw materials

The requirement to describe the raw materials relates to the quantity and nature of residual waste that will be disposed of and any ancillary materials that will be used in the facility [4].

6.3.11. Dust/Fine Particulates (PM10) and odours

Fine particulate (PM10) impact is generally restricted to very fine waste types or very fine dust generated during construction phases. It is not considered a significant risk for landfills. Some control techniques are, for example, the pre-treatment of dusty waste using water.

Offensive odours are emitted at landfill sites from a number of sources, particularly:

- Malodorous waste;
- Leachate and landfill gas.

The control techniques are:

- Minimisation of open tipping face area;
- prompt replacement, compaction and covering of waste;
- immediate burial of odorous waste;
- restriction of loads known to be particularly odorous;
- restriction of tipping activities during periods of adverse weather;
- upgrading and sealing of sump covers;
- aeration of leachate storage areas;
- improvements in landfill gas collection and combustion systems;
- covering or burial of waste excavated during the installation of leachate or landfill gas management systems and the use of odour-neutralising sprays/aerosols at times when either climatic or waste acceptance site monitoring indicates a heightened risk to identified receptors [5].

6.4. LANDFILLS IN OPERATION

Hazardous Waste Landfills (HWLF) have a series of operating requirements related to routine operation, management, and environmental monitoring [5].

The operating requirements pertain to new HWLF units, existing HWLF units, and lateral expansions of existing HWLF units. The objectives of minimum operating requirements are:

- To ensure that all waste is disposed of in an environmentally and socially sound manner.
- To ensure that disposal operations are acceptable to those they affect.

There are some guidelines and BATs that must be considered (in the Mediterranean Region) for landfills in operation:

6.4.1. Primary requirements

BATs for the handling and disposal of waste at a landfill refer to [4] an Environmental Management System (EMS) that incorporates the following features:

- Management and Reporting Structure.
- Schedule of Environmental Objectives and Targets.
- Annual Environmental Report (AER).
- Environmental Management Programme (EMP).
- Documentation System.
- Corrective Action Procedures.
- Awareness and Training Programme.
- Communications Programme.
- Waste acceptance procedure.
- Waste management system for all waste.
- Appropriate storage and handling.
- Leachate and Landfill Gas management.

The manner in which a facility is managed is a critical element in ensuring emissions from a landfill are minimised. Therefore management of facilities must ensure that:

- Staff are competent to manage and operate the facility, i.e. a Fit and Proper Person;
- There is a environmental management system in place to ensure standards are maintained, including incident and complaints management procedures.

Another important aspect is waste acceptance. The nature of the waste deposited in a landfill and the way in which that waste is handled can have a significant effect on the potential for a landfill facility to cause pollution or harm to health.

Controlling the waste input to the facility is one of the most important operational matters. The deposit of waste for which the facility is designed, and therefore permitted to accept, can have a direct effect upon the pollution/nuisance potential of the facility. It is essential that measures be implemented to ensure that only waste for which the facility is designed and which is permitted by the licence is deposited and contain at least the following items:

- Measures in place to fully document the waste arriving onsite.
- Clear criteria for the reception of waste.

6.4.2. Water

Wastewater at landfill facilities originates from the landfill, such as contaminated rainfall run-off, leachate and landfill gas condensate and from ancillary activities and site infrastructure, such as foul drainage, wheel wash and hard standing.

BATs relate to water discharged directly into surface water or to sewers as trade effluents. The treatment required will depend on the permitted emission limits specified in the waste licence. Treatment provisions would typically include silt traps/oil interceptors for surface run-off through to biological and physicochemical treatment for leachate, dependent on the discharge receptor [4].

This section has been divided into two parts: one for discharge and the other for leachate effluent.

6.4.2.1. Discharge to surface water, sewer and to groundwater

Only roof water and water from unpaved areas (not in the landfill footprint) are appropriate for direct discharge to surface waters.

For discharge to foul sewers, final effluent quality must meet standards set by the receiving sewage authority for the adequate treatment of the wastewater it receives.

The legislation of each country should prohibit the direct emission to groundwater of effluents containing certain hazardous substances and require strict controls to prevent indirect emissions of pollutant substances. Removal of the risk of emissions to groundwater through appropriate controls is a BAT for the facility and also requires the provision of groundwater monitoring to enable early detection of any contamination of groundwater that may arise from the facility and the setting of its upper limits.

6.4.2.2. Leachate effluent

Discharge from leachate treatment plants may enter either surface watercourses or sewers or be disposed of by spray irrigation to land. In applying the best environmental practices to discharge from treatment systems the following assumptions have been applied:

- The discharge will not have a significant impact on the receiving water body or sewer system.
- Systems discharging to surface waters are robust and deliver a consistently high-quality effluent.
- The discharge meets the EQS, taking into account the assimilative capacity of the receiving water.
- The pollutant load of water discharges from hazardous waste landfills will be entirely dependent on the waste deposited.

6.4.3. Air

Emissions to air can occur as either process gases from abatement plants or fugitive emissions from waste degradation. BAT guidance seeks to regulate both as each can be effectively managed.

As for vehicle emissions, procedures to ensure that vehicles are well maintained and hence operating efficiently need to be implemented. As part of assessing the energy efficiency of the facility, procedures to review fuel use by all vehicles on sites should be put in place.

Potential emissions to air and elimination/control technique guidance will be similar to the following list:

- odours from waste, gas, leachate and contaminated surface water;
- direct emission of landfill gas;
- combustion/oxidation products from flaring landfill gas, utilisation of landfill gas, burning waste gas and biological treatment of landfill gas;
- dust from waste and from operational/engineering activities;
- noise from fixed plant – flares/engines/leachate treatment plant; and from vehicles & machinery used in waste operations;
- litter;
- vehicle emissions;
- VOC, asbestos fibres emissions.

6.4.3.1. Fugitive gas emissions

These include gas emissions to soil surrounding the waste body, the open atmosphere and within buildings.

6.4.3.2. Process gas emissions

Different emission limit values (ELVs) have been prepared for landfill gas flares and landfill gas utilisation plants as they emit different ranges of gases and under optimum conditions achieve different limits.

The principal process regulated is the oxidation, or combustion, of methane to carbon dioxide. Other minor gas components are also destroyed during this process.

Control of the combustion conditions, in terms of carbon monoxide concentration, temperature and retention time, rather than the emissions, is considered by many regulatory authorities to be the most effective way to define the BAT i.e. by ensuring that combustion occurs at 1000°C with a product retention time of 0.3 seconds within the combustion zone.

6.4.3.3. Odours

There is a general licensing requirement that odours shall not result in significant impairment of amenities or the environment beyond the site boundary.

6.4.3.4. Noise

On a landfill facility, noise can be generated that is ongoing (i.e. the operation of equipment and vehicles) and intermittent (i.e. gas cannons for bird scaring and blasting).

Some control techniques are:

- Constructing permanent and temporary acoustic screening bunds at the facility perimeter.
- Constructing a buffer zone between the facility and the external environment, selection of equipment.
- Fitting silencing equipment to operational plant and equipment.
- Selection of equipment that conforms to EU Noise Standards.
- Use of acoustic screens around fixed/mobile plant and equipment.
- Use of buildings to contain inherently noisy fixed plant and equipment.
- Prediction of noise impact at specified noise sensitive locations, using standardised sound power levels for construction plant.
- Locating noisy and tonal plant, such as flares, utilisation plants and leachate pumping stations, away from residential locations, taking into consideration the topography of the site and surrounding areas.
- Assessment of the severity of noise impact on residential areas due to a new development. This specifically refers to industrial developments, but is commonly used for other applications and is currently being reviewed.

6.4.3.5. Vibration

Vibration emissions may arise where a landfill is developed on the site of a quarry where blasting is still being carried out. However, generally this does not apply.

6.4.4. Waste compaction and soil cover

Waste is to be spread in thin layers (0.6 m or less) on the working face and compacted. Normally, 3-5 passes of the compacting equipment over the waste are sufficient to achieve an appropriate density. Where a landfill operates continuously 24 hours per day, 0.15 m of cover material is to be applied at the approved frequency [5].

6.4.5. Pre-treatment of hazardous waste

The properties of certain hazardous waste are such that they cannot be safely deposited directly into a landfill. In such cases, the waste must be pre-treated to render it immobile, less toxic or less reactive.

A variety of treatment options exist. These are often interrelated but may be generally categorised into physical, chemical and biological treatment methods. Chemical processes include neutralisation, precipitation, fixation and oxidation. Physical processes include incineration, blending and encapsulation. Biological processes include aerobic and anaerobic degradation of organic materials.

6.4.6. Delisting of hazardous waste

Delisting of hazardous waste involves treatment and/or hazard rating tests to confirm that the waste is of such low mobility or concentration that it can be reclassified with a lower hazard rating.

6.4.7. Co-disposal and prohibited waste

The co-disposal of different solid and liquid hazardous waste must be controlled and prohibited unless specifically approved by the manager. The following waste is subject to co-disposal:

- Bulk liquids and semisolid sludges which contain free liquid.
- Liquid or semisolid waste including septage, black water, sewage treatment sludge, etc.
- Automobiles, white goods, other large metallic objects and tyres (unless recycling options are available or feasible).
- Biomedical waste as defined by local Environmental Affairs Agencies.
- Dead animals and slaughterhouse, fish hatchery and farming waste or cannery waste and by-products.

6.4.8. Scavenging

Scavenging of waste should be prevented. The salvaging of waste should be encouraged by providing areas and facilities for separation of recyclable or reusable materials.

6.4.9. Litter Control

Litter is to be controlled by compacting the waste, minimising the working face area, applying cover at appropriate frequencies, providing litter control fences and instituting a regular litter pickup and general good housekeeping program or any other required measures.

There are some elimination techniques, such as the segregation of waste to remove the light fraction from the waste stream, pre-sorting of waste prior to deposit at the landfill and shredding or treatment of waste under cover and prior to deposit.

6.4.10. Open Burning

Open burning of typical hazardous waste at landfills is prohibited.

6.4.11. Signs

All landfill sites should have signs posted at each entrance with all the information, such as site name, contact phone number and address for the owner and operator or phone number in case of emergency.

6.5. LANDFILL CLOSURE

6.5.1. Cessation of waste disposal

The cessation of waste acceptance at a landfill facility initiates a review of the waste licence. This review allows the licence to be amended to reflect the change in activities on-site as the facility moves from the operational stage to the restoration and aftercare stage. Licence amendments will reflect the Agency's assessment of the licensee's requirements to ensure that the site continues to be properly managed.

6.5.2. Restoration and aftercare

Restoration is a process that will return a site to a condition suitable for the selected afteruse. Restoration includes soil spreading, final landform construction, landscaping works and aftercare.

Aftercare involves any measures that are necessary to be taken in relation to the facility for the purposes of preventing environmental pollution following the cessation of landfill activities at the facility and the capping and restoration of the site. The length of this aftercare period will vary from site to site and the licence holder remains responsible for the aftercare until the Agency accepts the surrender of the waste licence (Waste Management Acts 1996-2003, S48).

6.5.3. Maintenance of environmental pollution control systems

Until the EPA accepts surrender of the licence, the licence holder/operator is responsible for environmental management of the facility. During aftercare the licence holder/operator must ensure that the following pollution control systems are maintained and remain effective:

- the landfill gas control system;
- the leachate collection, treatment and disposal system;
- the landfill cap;
- groundwater monitoring;
- all above ground components such as gas wellheads, leachate pumping manholes and monitoring boreholes.

7. FUTURE SECTOR DEVELOPMENT

In this section, emerging techniques have been analysed. An emerging technique is a novel technique that has not yet been applied in any industrial sector on a commercial basis. These techniques may appear in the near future.

Information on these techniques was only available for waste treatment and incineration.

7.1. WASTE TREATMENT

7.1.1. On-line analysis

This can be used for all applications in the field of preparation of solid recovered fuels. It is used for crushed and/or for non-crushed materials with automatic elimination of materials which do not comply with the quality criteria for solid recovered fuels- especially when the chlorine and/or bromine values are exceeded. The mode of operation is based on a new N-ray fluorescence analysis with high-speed analysis, so that a large quantity of crushed or non-crushed materials per hour can be analysed and/or detected and can be automatically eliminated by overdraw nominal stock. This tool now seems to be the fastest and most exact handheld analysis tool for practically all recycling of metal, plastic, old wood, glass, ground, waste, mud and non-ferrous metal.

7.1.2. Biological degradation times in MBT processes

The minimal biological degradation times required to comply with the landfill criteria with sufficient operational reliability will have to be determined by future experience with the new, optimised MBT plants.

7.1.3. Immobilisation of heavy metal chlorides

A method for the stabilisation of heavy metal waste generated in the fly ash vitrification process is based on the batch conversion of heavy metal chlorides with ammonium dihydrogenphosphate, conversion of heavy metal chlorides into phosphate and its immobilisation in a phosphate glass matrix.

7.1.4. Ferrous sulphate stabilisation of FGT waste

This stabilisation involves a five-step procedure, where the solid materials are first mixed with a $FeSO_4$ solution and then aerated with atmospheric air at L/S 3 l/kg in order to oxidise Fe(II) to Fe(III) and precipitate iron oxides. This step also includes the extraction of soluble salts. The pH of the suspension is then maintained at basic pH for about 1 hour to allow dissolved heavy metals to bind to precipitated iron oxides. The fourth step of the process is dewatering and finally a washing step to exchange remaining water and remove remaining salts. The final stabilised product has a water content of about 50%. The main advantage of this stabilisation process is the improved leaching properties of the final product. It can be implemented as an integrated part of the incinerator but may also exist as a centralised treatment plant handling residues from several incinerators. The treatment cost is estimated to be about EUR 65/tonne with a plant capacity of 20,000 tonnes/year including investment costs.

7.1.5. Carbon dioxide and phosphate stabilisation of FGT waste

Chemical agents used here are CO_2 and/or H_3PO_4. This process involves a two-step procedure where waste IN is first washed at L/S 3 l/kg in order to extract soluble salts. After this the material is dewatered and washed again in a plate and frame filter press at L/S 3 l/kg. The residues are then re-suspended and CO_2 and/or H_3PO_4 are added. The stabilisation reactions are allowed to occur for 1-1.5 hours while pH decreases. Finally, the residues are dewatered again and washed at the filter press with another 3 l/kg. The final product has a water content of about 50%. The use of CO_2 and H_3PO_4 as stabilizing agents ensures that heavy metals are bound as carbonates or phosphates.

This shows very good leaching properties similar to Ferrox stabilisation. The stabilisation unit can be implemented as an integrated part of the incinerator but may also exist as a centralised treatment plant handling residues from several incinerators. Treatment cost for stabilisation is estimated to be about EUR80/tonne with a plant capacity of 20,000 tonnes/year, including investment costs.

7.1.6. 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.

7.1.7. Phytoextraction of metals from the soil

In the field of environmental reclamation through biological processes, the methodology known as phytoremediation has recently received mounting attention from operators in the field. Phytoremediation encompasses various techniques used for cleaning up both soil and water. For metal-contaminated soil, phytoextraction represents one of the best solutions from the environmental point of view.

7.1.8. Treatment of waste contaminated with POPs

Such types of waste are at present mainly treated by incineration. However, other types of technique are emerging, as shown in table 7.1.

Table 7.1: Treatment of waste contaminated with POPs

Technique	Comment
Base catalysed dechlorination	Organochlorines are reacted with an alkaline polyethylene glycol, forming a glycol ether and/or hydroxylated compound, which require further treatment, and a salt. Dioxins have been identified in process residues. Destruction efficiency is not high.
Catalytic hydrogenation	Organochlorines are reacted with hydrogen in the presence of noble metal catalysts, yielding hydrogen chloride and light hydrocarbons.
Electrochemical oxidation	At low temperature and atmospheric pressure, electrochemically-generated oxidants react with organochlorines to form carbon dioxide, water and inorganic ions with high destruction efficiencies.
Electron beam oxidation	
Mediated electro-chemical oxidation by cerium	This technique uses electrochemical cells for the generation of the active Cerium (IV) oxidant at the anode, a liquid phase reactor for primary organic destruction, a gas phase reactor to destroy any fugitive emissions from the liquid reactor and an acid gas scrubber for the removal of acid gases prior to venting to the air.
Mediated electro-chemical oxidation by silver	This process uses silver (II) to oxidise organic waste streams. Reactions take place in an electro-chemical cell similar to the type utilised in the chlor-alkali industry.
Molten metal	Organochlorines and other materials are oxidised in a vat of molten metal, yielding hydrogen, carbon monoxide, ceramic slag and metal by-products.
Molten salts	Organochlorines and other materials are oxidised in a vat of molten salt, yielding carbon dioxide, water, molecular nitrogen, molecular oxygen, and neutral salts. Destruction efficiency may be high. This is suitable for the destruction of pesticides but not for treatment of contaminated soils.
Photocatalysis	Use light to activate a catalyst that oxidise/reduce the compounds. A wide range of compounds can be destroyed.
Ultraviolet oxidation	

7.1.9. Emerging techniques for treatment of waste oil

At present, around the world, there are many activities to improve the existing used oil recycling technologies and to develop new ones. Some techniques under development are:

- FILEA Process by C.E.A.: supercritical CO_2 filtration.
- MRD solvent extraction: solvent extraction of used oil vacuum distillates produced by TFE with a highly efficient and selective solvent.
- New Meinken technology: apply a novel absorbent to vacuum distillates. The catalyst absorbent seems to be activated clay. No industrial application is currently known.
- ROBYS ^{TM} Process: catalytic cracking and stabilisation for diesel production.
- Supercritical treatments: this applies to the deasphalting and also to fractionation.

7.1.10. Regeneration of activated carbon

Activated carbon regeneration technologies (biological regeneration and oxidative regeneration of spent activated carbon) are currently at the research and development stage. There are some novel pollution control techniques for the abatement of emissions, but the stage of development is unknown. These are the following: circulating fluidised bed absorber, electrocatalytic oxidation of sulphur dioxide, electrochemical processes, flue-gas irradiation and methanol injection.

7.1.11. Preparation of solid fuel from organic/water mixtures

This process consists of the preparation of a fuel for use in cement kilns. The process is the mixing of the organic/water mixtures with a lime hydrate porous structure in order to capture the organics and use the product as raw material in the cement industry. This technique is able to deal with clinical waste, municipal waste, hazardous/chemical waste and non-hazardous industrial and commercial waste.

7.1.12. Emerging techniques for hazardous waste preparation for energy recovery

New adsorbents for the preparation of solid waste fuel from hazardous waste. There is permanent research into other absorbents in order to replace the fresh sawdust.

7.1.13. Cracking of polymer materials

Liquid or gaseous fuels like diesel oils or heavy fuel oils can also be substituted with a prior step to crack the waste polymer into a liquid or a gas. Efforts in this field have mainly not progressed further than pilot-scale tests.

7.2. WASTE INCINERATION

7.2.1. Use of steam as a spraying agent in post-combustion chamber burners instead of air

NA.

7.2.2. Application involving the reheating of turbine steam

Another option to increase the efficiency of electricity production is the reheating of turbine steam after its first passage through the turbine. For this application, steam temperature is limited to 400°C, but steam pressure increases. This technique increases electrical efficiency by approximately 2-3%. The application may be influenced by economic feasibility, which is mainly determined by the additional investment costs and by electricity prices.

7.2.3. Other measures in the crude flue-gas area for reducing dioxin emissions

A reduction in dioxins can be achieved through the following measures in the crude flue-gas area, which seek to reduce dioxin formation by inhibiting reactions or reducing the presence of dust in the temperature range 450-200°C:

- Addition of inhibitors to the waste - efficiency is limited and secondary reactions require consideration.
- Employment of hot gas dedusters.

- Reduction of deposits of airborne dust in the flue-gas path by effective cleaning of flue-gas vents, boilers, heating plates- a well-proven maintenance-related issue.

7.2.4. Oil scrubber for the reduction of polyhalogenated aromatics and polyaromatic hydrocarbons (PAHs) in the flue-gases from incineration

Dioxins and furans have very low solubility in water and therefore they are not removed in wet scrubbers to a significant and reliable extent. Any removal which does take place is generally due to the removal of PCDD/F that is adsorbed onto particulate matter removed in the wet scrubber. At best, there is some depletion by condensation of, predominantly, the higher molecular weight Hexa-to Octa-species from the gas phase into the relatively cold wash liquor. However, dioxins and furans are more lipophilic. High boiling partly unsaturated oil or oil-water emulsions of such oil therefore provide suitable scrubbing media.

7.2.5. Use of CO_2 in flue-gases for the production of sodium carbonate

If the flue-gas is brought into contact with caustic soda solution, the carbon dioxide reacts with the sodium hydroxide to form sodium carbonate. The liquid is odourless and colourless. The carbonate solution may be used as a raw material.

7.2.6. Increased bed temperature, combustion control and oxygen addition in a grate incinerator

The basis concept of this process (know as the SYNCOM plus process) is the integrated sintering of ash in the waste bed of a grate-based energy from the waste incinerator. Higher bed temperatures are used to melt or sinter 50-80% of the bottom ash. The unmelted fraction protects the grate from clogging. A completely sintered, well burned out, low leaching residue is produced.

Table 7.2: Comparison between conventional WTE plants and SYNCOM processes

	Conventional waste to energy (WTE) plants	SYNCOM	SYNCOM plus
Loss on ignition	2%	1%	0.1%
Leaching of lead (mg/l)	0.2	0.05	0.01
PCDD/F content (ng TEQ/kg)	15	8	0.3

The system also reduces:

- Overall plant dioxin discharges (<5µg I-TEQ/t of waste input),
- Volumes of fly ash,
- Flue-gas volumes by approx. 35%.

This technique is applicable to grate incinerators. There is a 5-10% increase in overall plant investment costs. Reductions in disposal costs for residues, with income possible from sales of granulate as an aggregate replacement.

7.2.7. The PECK combination process for MSW treatment

The main features of this process are:

- Use of a first stage sub-stoichiometric, gasifying grate at 950°C.
- Recycling of treated fly ash to the grate.
- Followed by a rotary kiln at 1400°C gas temperature with excess air ratio of 1.1 to 1.3 over stoichiometric.
- The high temperature in the rotary kiln melts the mineral materials.
- Water quench of residues to form a glass-like phase.

The key environmental benefits over and above conventional MSWI processes are:

- Production of a semi-vitrified lower leaching bottom ash residue.
- Vitrification is an internal process- no external energy is required.
- Reduced fly ash volumes.
- Reduction in overall dioxin outputs by destruction in the incinerator.
- Concentration of heavy metals into a smaller volume of solid waste.
- Emissions of oxides of nitrogen to air are reduced by the air-staging process.

The process has been developed for municipal solid waste but could in principle be applied to other waste. The process is preferably equipped with a conventional wet flue-gas purification unit. For the treatment of the fly ash, HCl is needed which can be recovered from the washing water.

7.2.8. $FeSO_4$ stabilisation of FGT residues

This stabilisation involves a five-step procedure, where the residues are first mixed with a $FeSO_4$ solution and then aerated with atmospheric air at liquid/solid ratio of 3 l/kg, in order to oxidise Fe(II) to Fe(III) and precipitate iron oxides. This step also includes the extraction of soluble salts. The pH of the suspension is maintained at pH 10-11 to allow dissolved heavy metals to bind to the precipitated iron oxides. The fourth step of the process is dewatering the treated residues and finally a washing step to exchange remaining water and remove remaining salts. The final stabilised product has a water content of about 50%.

The main advantage is improved leaching properties of the final product. The process reduces the amount of residue by about 10% of dry weight.

The stabilisation unit can be implemented as an integrated part of the incinerator but may also exist as a centralised treatment plant handling residues from several incinerators. The technique has been demonstrated on semi-dry FGT residues as well as fly ash alone and fly ash combined with sludge from the wet scrubbers, all with good results.

Treatment cost for a stabilisation process (Ferrox stabilisation) is estimated to be about EUR 65/tonne with a plant capacity of 20,000 tonnes/year; including investment costs.

7.2.9. CO_2 stabilisation of FGT residues

This stabilisation resembles in many respects the $FeSO_4$ stabilisation process. However, the chemical agents used here are CO_2 and/or H_3PO_4.

CO_2 stabilisation shows very good leaching properties similar to Ferrox stabilisation. The CO_2 stabilisation process reduces the amount of residue by about 15% of dry weight.

The stabilisation unit can be implemented as an integrated part of the incinerator but may also exist as a centralised treatment plant handling residues from several incinerators.

The treatment cost for CO_2 stabilisation using this process is estimated to be about EUR 80/tonne ash with a plant capacity of 200,000 tonnes/year, including investment costs.

7.2.10. Overview of some other emerging FGT residue treatment techniques

7.2.10.1. Treatment for supply to the cement industry

Current utilisation of waste as secondary fuel in the cement industry has been developed in depth in 5.2.1. This system converts bottom ash, fly ash and neutralisation residues into a material that can be used in cement kilns.

Another process (only at the pilot plant stage) also aims to supply materials to the cement industry. In this case, residue form lime-based dry and semi-dry FGT systems are separated to give an inert fraction (approx. 70 wt%) that is mainly oxides for use in the cement kiln, a further fraction (approx 25 wt%) of sodium and calcium chlorides, and the remaining fraction that contains the heavy metals.

7.2.10.2. Heavy metal evaporation process

Fly ash is heated to around 900°C in an atmosphere enriched with hydrochloric acid. The heavy metals are volatilised as chlorides and then condensed on a filter where they concentrate to such an extend that recycling may be possible.

7.2.10.3. Hydro-metallurgical treatment + vitrification

In this process, hydrometallurgical treatment allows the removal of heavy metals and salts. The subsequent vitrification of the fly ash produces a slag which may be used for construction. The process is reported to be applicable to several ash compositions and to have been demonstrated on a semi-industrial scale. The process is applied at one MSWI in France burning 120,000 tonnes MSW/yr and producing 3,500 tonnes/yr of treated FGT residue from this treatment process.

7.2.11. Combined dry sodium bicarbonate + SCR + scrubber FGT systems

This technique consists of combining dry FGT with sodium bicarbonate with a SCR system and a scrubber.

As sodium bicarbonate presents a wide operating temperature range (140-300°C) and leads to SO_x emissions below 20 mg/Nm^3, it ideally combines with a SCR without reheating the FG; although FG reheat may be needed if stack temperature is too low after the wet scrubber. A scrubber placed after the SCR will remove the remaining HCl. As the amount of HCl removed is very low, the purge can be easily re-injected upstream where it is completely vaporised. The result is a FGT system without intermediate reheating steps and without liquid effluents.

The system combines two well known FGT technologies and has the following characteristics:

- SO_2 and HCl emissions at the stack are low.
- The sodium bicarbonate excess is reduced because of the downstream scrubber; no gas reheating is generally needed; there are no liquid effluents to treat because the purge is re-injected upstream.
- Emissions are low even under fluctuating inlet concentrations.

The applicability of this technique is assessed in table 7.3.

Table 7.3: Applicability of combined dry sodium bicarbonate + SCR + scrubber FGT systems

Criteria	Evaluation/comment
Waste type	Can be applied to any waste type: particularly suited to highly variable inlet gas compositions (e.g. hazardous waste).
Plant size range	Not restricted but generally applied to medium/large plants.
New/existing	Not restricted.
Inter- process compatibility	High operating temperatures make the process very compatible with SCR as no reheating of FG is needed.
Key location factors	Low plume visibility; no liquid effluent is produced; residue can be recycled and safe reagent.

This technique has higher capital costs than dry systems due to the addition of a scrubber. Capital costs are similar if a scrubber in good condition is already in place. However, it has low operational costs.

7.2.12. Combination of thermal processes

This term is used for processes consisting of a combination of different thermal processes (pyrolysis, incineration, gasification).

7.2.12.1. Pyrolysis- incineration

The following techniques are at various stages of development:

- Pyrolysis in a drum-type kiln with subsequent high temperature incineration of pyrolysis gas and pyrolysis coke.
- Pyrolysis in a drum-type kiln, followed by condensation of the gaseous tars and oils, subsequent high-temperature incineration of pyrolysis gas, pyrolysis oil and pyrolysis coke.
- Pyrolysis on a grate with directly connected high-temperature incineration.

The solid residues from these processes are granular, which can be advantageous for later reutilisation or disposal. Sewage sludge (dehydrated or dried) may be co-treated with the municipal waste fractions.

The recycled clean products (RCP) process is a development of the pyrolysis on a grate with a directly connected high-temperature incineration process. The molten bottom ash is depleted of metallic components and upgraded to a cement additive in a special secondary treatment stage. In Germany, the RCP process concept is now being applied for the first time on an industrial scale.

The flue-gas cleaning techniques applied for the three pyrolysis combination processes named above do not, in principle, differ from the systems used in municipal waste incineration plants.

7.2.12.2. Pyrolysis- gasification

Two different types of pyrolysis-gasification processes can be distinguished:

Disconnected (pyrolysis with subsequent gasification = conversion process) and directly connected processes.

1. Conversion process:

   In such processes, metals and, if required, inert material may be removed after the pyrolysis step. As pyrolysis gas and pyrolysis coke require reheating in the gasification process, the technical and energy requirements are higher than with connected processes. The condensed exhaust vapour is treated as wastewater and discharged. This process is only used for municipal waste to date.

2. Combined gasification-pyrolysis and melting process:

   In such processes, the un-shredded waste is dried in a push furnace and partially pyrolysed. From this furnace they are transferred directly and without interruption into a standing packed-bed gasifier. Here they are gasified (in the lower part) at temperatures of up to 2000°C with the addition of oxygen. Pure oxygen is also added in the upper part of the gasification reactor to destroy the remaining organic components in generated synthesis gas, through oxidation, gasification and cracking reactions.

   Although reported to be capable of treating a wider range of waste, this process is mainly used for municipal and non-hazardous industrial waste.

7.2.12.3. Gasification-combustion

Shredding residues, waste plastic or shredded MSW is gasified in an internally circulating bubbling fluidised bed, which is operated at about 580°C.

Different from other gasification processes, this is operated at atmospheric pressure and with air rather than oxygen. Pre-treatment of MSW by shredding is necessary to reduce particle size to 300 mm in diameter. Waste already within this specification can be treated without shredding. In the various plants in operation, other waste like sewage sludge, bone meal, clinical waste and industrial slags and sludges are treated in addition to MSW.

8. CONCLUSIONS AND RECOMMENDATIONS

- Most of the sources consulted concerning environmental techniques and practices for the hazardous waste treatment sector are based on European Union experiences. The techniques and practices considered throughout this document have been mainly selected from activities and processes that currently exist in the European Union.
- Although the terms “best available technique” and “best environmental practice” have different definitions in Annex IV of the Mediterranean Land-Based Sources Protocol, within the framework of the European Union the term “best available technique” is considered to be broad enough to embrace the concept of “best environmental practice”.
- The feasibility of application of such techniques and practices in the Mediterranean hazardous waste treatment sector has been assessed where possible; however, particular studies focused on each installation are strongly recommended prior to the implementation of any specific technique, especially if a high investment cost is associated.
- Techniques and practices related to the design of the installation and the application of technologies affecting operating processes are feasible if the installation is still at the project stage. The criteria applied in the design of a landfill and the process design of an incineration facility are representative examples.
- Nevertheless, the improvement of the Mediterranean hazardous waste treatment sector, in particular of existing installations, does not necessarily imply investment in new technologies; an appropriate implementation of management tools and good housekeeping practices in the installation is likely to provide significant environmental benefits at reasonable costs at the early stages.
- Special attention should be paid to techniques for the abatement of emissions: wastewater treatment, air emissions abatement and residue management with the aim of ensuring compliance with legal requirements (i.e. emission limit values) set by the country and to obtain the maximum reduction of emissions. Monitoring and control systems support these types of techniques.
- The techniques that involve most technological requirements are those related to hazardous waste thermal treatments, in particular, the thermal treatment stage, the energy recovery stage and flue-gas treatment. As a consequence, viability studies are essential.
- To facilitate the use of hazardous waste in industrial processes in Mediterranean installations, two key issues are to be considered: waste should be selected according to its calorific values and techniques for the abatement of air emissions should be implemented.
- BATs identified for landfilling are feasible and strongly recommended for Mediterranean facilities. It should be noted that uncontrolled landfilling has critical environmental impacts in the Mediterranean region.

Recommendations addressed to decision makers at the project stage of new hazardous waste treatment facilities are based on the knowledge and analysis of:

- The characteristics and amounts of the hazardous waste to be treated.
- The waste management hierarchy: reduce, reuse, recycle, energy recovery and, as the last alternative, disposal.
- The site and its environment.
- The desired outputs of the activity.

- The economic aspects.
- The legal requirements in the Mediterranean country (e.g. emission limit values).

General recommendations for national authorities to promote the improvement of the environmental performance of the hazardous waste treatment sector have been selected as follows:

- To facilitate the knowledge of feasible alternatives to current processes and the instruments that industries can use to improve efficiency (e.g. information networks between universities and technological institutions).
- To drive waste treatment enterprises to increase managerial expertise, incorporating the environment as a key issue.
- To introduce specific financial and other incentives to encourage enterprises to invest and/or to receive external capital for environmental protection projects.
- To promote material and energy recovery prior to final treatment and/or disposal.
- As public installations generally receive international assistance, they should become BAT references for other installations.
- A calendar which enables the installation to adapt to new technologies or to close the activity in the case where no feasible alternative exists.

Once the waste treatment facility is about to implement a certain environmental technique or practice, it has to take into consideration the following steps aimed at pollution prevention:

1. Measure

The first and basic step is to measure not only the volume and characteristics of the effluents (wastewater, emissions, waste) but also the normal operation conditions, the balance between input of energy, raw materials (input waste) and other materials used directly or indirectly in the process, and the final product (output waste).

2. Identification of sources of pollution

As a consequence of the measurement process, the relevant steps of the activity generating pollution are clearly identified.

3. Identification of potential alternatives

By identifying the appropriate techniques from the ones developed throughout this report.

4. Analysis of technical feasibility of the alternatives

For both phases, different elements must be taken into consideration depending on each particular case. For example: availability of technologies, adaptability to local conditions, employee skills & technical capacities, adaptability and/or limitation of input waste, analytical requirements, the rational use of water and energy, land facilities, waste output disposal requirements, recovered materials quality requirements, maintenance & repair, etc.

5. Analysis of economic feasibility of the alternatives

The most common financial instruments that can be used to analyse any investment: Differential Cash Flow, Investment Payback Period (IPP), Internal Rate of Return (IRR), Net Present Value (NPV).

The context must be a medium- to long-term analysis, taking into consideration: the previewed increases in the cost of treatment/deposit, energy, water, changes in input or output waste, analysis, labour, maintenance, increases/decreases in productivity, investment and operating costs, intangible cost/benefit etc.

6. Implementation

At this stage, the role of environmental authorities becomes essential to ensuring the adoption of environmentally friendly techniques and practices, as well as discouraging those not adopting a proactive attitude. Again, public installations should take on a reference role.

7. Check results

The results of implementation could be identified and evaluated through monitoring indicators or schemes. In a similar procedure to quality programs, those results become the source of the identification of new targets and provides new benchmarking information. Furthermore, this information can be published so as that other enterprises, in turn, can use it as reference.

9. ANNEX I - SUMMARY OF BATS

9.1. BATS FOR HAZARDOUS WASTE TREATMENT

BAT	PAGE
1. Implement and adhere to an Environmental Management System (EMS).	24
2. Ensure the provision details of the activities carried out on-site.	24
3. Good housekeeping procedure and adequate training programme: a) Sampling. b) Reception facilities. c) Management techniques. d) Utilisation of qualified people. e) Handling activities related to transfers to or from drums/containers. f) Techniques to improve the maintenance of storage.	24
4. Close relationship with the waste producer/holder.	24
5. Sufficient staff available and on duty with the necessary qualifications at all times. (See also BAT 3).	24
6. Have specific knowledge of the waste input, e.g.: • Laboratory activities. • Selection of waste oils to be re-refined. • Selection of feedstock for biological systems.	26
7. Implement a pre-acceptance procedure.	26
8. Implement an acceptance procedure.	26
9. Implement different sampling procedures. (See also BAT 3).	26
10. Have a reception facility. (See also BAT 3).	26
11. Analyse the waste out according to the relevant parameters important for the receiving facility.	27
12. Have a system in place to guarantee the traceability of waste treatment.	28

13. Have and apply mixing/blending rules aimed at resctricting the types of wastes that can be mixed/blended together in order to avoid increasing pollution emission of down-stream waste treatments.	28
14. Segregation and compatibility procedures in place. (See also BATs num. 13 and 24).	28
15. Improvement of the efficiency of waste treatments related to the usefulness of the outputs, raw materials consumption and material flow analysis.	28
16. Produce a structured accident management plan. (See also 3.1.1 Environmental Management).	28
17. Have and properly use an incident diary. (See also BAT 1 and 16).	28
18. Have a noise and vibration management plan in place as part of the EMS. (See also BAT 1).	28
19. Consider any future de-commissioning at the design stage. (See also BAT 1).	28
20. Provide a breakdown of energy consumption and generation (including exporting) by the type of source (electricity, gas, liquid conventional fuels, solid conventional fuels and waste). (See also BAT 1).	30
21. Continuously increase the energy efficiency of the installation, by: • Developing an energy efficiency plan. • Using techniques that reduce energy consumption and thereby reduce direct and indirect emissions . • Defining and calculating the specific energy consumption of the activity. (See also BAT 20).	30
22. Carry out an internal benchmarking (e.g. on an annual basis) of raw material consumption.	30
23. Explore the options for the use of waste as a raw material for the treatment of other wastes. If waste is used to treat other wastes, then to have a system in place to guarantee that the waste supply is available. (See also BAT 22).	30
24. Apply techniques related to storage: • Areas with correct drainage and all necessary measures to the specific risks (odorous, volatile emissions and low flashpoint). All connections between the vessels can be closed via valves.	33
25. Separately bund the liquid decanting and storage areas using bunds which are impermeable and resistant to the stored materials.	33
26. Apply techniques concerning tank and process pipework labelling: • Clearly labelling all vessels (contents, capacity). • Keeping complete records for all tanks.	33

27. Take measures to avoid problems that may be generated from the storage/accumulation of waste. May conflict with BAT 23 when the waste is used as a reactant.	33
28. Apply techniques when handling waste: • Systems and procedures in place, management system for the loading and unloading of waste, qualified personnel and ensuring that damaged hoses, valves and connections are not used. • For liquid wastes collecting the exhaust gas from vessels and tanks. • Unloading solid and sludge in closed areas with extractive vent systems.	33
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, it must be carried out under local exhaust ventilation.	34
30. Ensure that chemical incompatibilities guide the segregation required during storage. (See also Chapter 3.1.4 Management System).	34
31. Apply the following techniques when containerised wastes are handled: • Storing of containerised wastes under cover (if necessary: sensitive to light, heat, temperature or water ingress); • Maintaining 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.	34
32. Perform crushing, shedding and sieving operations in areas fitted with extractive vent systems linked to abatement equipment when handling materials that can generate emission to air (e.g. odours, dust, VOCs).	36
33. Perform crushing/shredding operations 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. (See also BAT 32 and Chapter on Air Emission Treatments).	36
34. Perform washing process considering: • Identifying the washed components that may be present in the items to be washed (e.g. solvents). • Transferring washing waters to appropriate storage. • Using treated wastewater from the WT plant for washing instead of fresh water.	36
35. Restrict the use of open topped tanks, vessels and pits by: • Not allowing direct venting or discharges to air. • Keeping the waste or raw materials under cover or in waterproof packaging (see also storage and handling). • Connecting the head space above the settlement tanks to the overall site exhaust and scrubber units.	72
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.	72

37. Apply a suitably sized extraction system which can cover: the holding tanks, pre-treatment areas, storage tanks, mixing/ reaction tanks and the filter press areas; or have in place a separate system to treat the vent gases from specific tanks.	72
38. Correctly operate and maintain the abatement equipment, including the handling and treatment/disposal of spent scrubber media.	72
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 pre-treatment systems if the discharge is incompatible or too concentrated for the main scrubber. (See also BAT 38).	73
40. Have leak detection and repair procedures in place in facilities handling a large number of piping components and storage and compounds that may leak easily and create an environmental problem. This may be seen as an element of the EMS (see also chapter on Environmental Management).	73
41. Reduce air emission to the following levels: EMISSION LEVELS (mg/Nm^3): VOC: 7-20 (for low VOC loads, the higher end of the range can be extended to 50) PM: 5-20	73
42. Reduce the water use and the contamination of water by: • applying site waterproofing and storage retention methods, • carry out regular checks of the tanks and pits • applying separate water drainage according to the pollutant load • applying a security collection basin, • performing regular water audits, • segregating process water from rainwater. (See also BAT 46).	75
43. Have procedures in place to ensure that the effluent specification is suitable for the on-site effluent treatment system or discharge.	76
44. Avoid the effluent by-passing the treatment plant system.	76
45. Have in place and operate an enclosure system whereby rainwater falling on the processing areas is collected along with tanker washings and returned to the processing plant or collected in a combined interceptor.	76
46. Segregate the water collecting systems to separate potentially more contaminated waters from less contaminated water.	76
47. Have a full concrete base in the whole treatment area that slopes toward 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 also BAT 63).	76
48. Collect the rainwater in a special basin for checking, treatment if contaminated and further use.	76

49. Maximise the re-use of treated wastewater and use of rainwater in the facility.	76
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.	76
51. Firstly, identify wastewater that may contain **hazardous compounds**; secondly,, segregate the previously identified wastewater streams on-site; and thirdly, specifically treat wastewater on-site or off-site.	76
52. Ultimately after the application of BAT 42, select the appropriate treatment technique for each type of wastewater.	76
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).	77
54. Identify the main chemical constituents of the treated effluent (including the make-up of the COD) and make an informed assessment of the fate of these chemicals in the environment.	77
55. Only discharge wastewater from storage after the conclusion of all the treatment measures and a subsequent final inspection.	77
56. Achieve the following water emission values before discharge. EMISSION VALUE (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 (IV): <0.1-0.4 (See also BATs 42-55).	77
57. Have a residue management plan as a part of the EMS including basic housekeeping techniques and an internal benchmarking technique. See also BATs 1 and 3.	78
58. Maximise the use of re-usable packaging (drums, containers, IBCs, palettes, etc.).	78
59. Re-use drums when they are in a good working state. In other cases, they are to be sent for appropriate treatment.	78
60. Keep a monitoring inventory of the waste on-site by using records of the amount of waste received on-site and records of the waste processed. See also BAT 27.	78
61. Re-use the waste from one activity/treatment possibly as a feedstock for another. See also BAT 23.	78
62. Provide and 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.	79

63. Utilise impermeable base and internal site drainage.	79
64. Reduce the installation site and minimise the use of underground vessel and pipework.	79
65. Use the following techniques for storage and handling in biological systems for: • Less odour-intensive wastes: use automated and rapid action doors in combination with an appropriate exhaust air collection device. • Highly odour-intensive wastes: use closed feed bunkers constructed with a vehicle sluice. • House and equip the bunker area with an exhaust air collection device.	41
66. Adjust the admissible waste types and separation processes according to the type of process carried out and the abatement technique applicable (e.g. depending on the content of non-biodegradable components).	41
67. Use the following techniques when applying anaerobic digestion: • Close integration between the processes and the water management. • A recycling of the maximum amount of wastewater to the reactor. • Operate the system under thermophilic digestion conditions. • Measure TOC, COD, N, P and Cl levels in the inlet and outlet flows. • Maximise the production of biogas (needs to consider the effect on the digestate and biogas quality).	41
68. Reduce exhaust gas emissions of dust, NOx, SOx, CO, H_2S and VOC when using biogas as a fuel by using an appropriate combination of the following techniques: • Scrubbing biogas with iron salts. • Using de-NOx techniques (SCR). • Using a thermal oxidation unit. • Using activated carbon filtration.	42
69. Improve the mechanical biological treatment (MBT) by: • Using fully enclosed bioreactors. • Avoiding anaerobic conditions during aerobic treatment by controlling the digestion, the air supply and adapting to biodegradation activity. • Using water efficiently. • Thermally insulating the ceiling of the biological degradation hall in aerobic processes. • Minimising the exhaust gas production to levels of 2500 to 8000 Nm^3/t. • Guaranteeing a uniform feed. • Recycling process waters or muddy residues within the aerobic treatment process to completely avoid water emissions. If wastewater is generated, then this should be treated to reach the values mentioned in BAT 56. • Reducing emissions of nitrogen compounds by optimising the C: N ratio.	42
70. Reduce the emissions from mechanical biological treatment to the following levels: Odour: <500-600 ouE/m^3 and NH3: <1-20 mg/Nm^3. By using the following techniques:	42

• Maintaining good housekeeping. • Regenerative thermal oxidiser. • Dust removal. For VOC and PM; see BAT 41.	
71. Reduce water emissions to the levels (ppm): COD: 20-120 BOD: 2-20 Heavy metals (Cr, Cu, Ni, Pb, Zn): 0.1-1 Highly toxic metals: As:<0.1; Hg: 0.01-0.05; Cd:<0.1-0.2; Cr (IV): <0.1-0.4 As well as restricting the emissions of total nitrogen, ammonia, nitrate and nitrite.	43
72. Apply the following techniques in physico-chemical reactors: • Clearly defining the objectives and the expected reaction chemistry for each treatment process. • Assessing each new set of reactions and proposed mixes of wastes and reagents in a laboratory-scale test prior to waste treatment. • Specifically designing and operating the reactor vessel. • Enclosing all treatment/reaction vessels and ensuring that they are vented to the air via scrubbing. • Monitoring the reaction to ensure that it is under control and proceeding towards the anticipated result. • Preventing the mixing of wastes or other streams that contain metals and complexing agents at the same time.	46
73. Some additional parameter need to be identified for the physico-chemical treatment of wastewaters (in addition to the generic parameters identified for wastewater in BAT 56).	46
74. Apply the following techniques for the neutralisation process: • Ensuring that the customary measurement methods are used. • Separately storing the neutralised wastewater. • Final inspection of the neutralised wastewater.	46
75. Apply the following techniques to aid precipitation of the metals: • Adjusting the pH to the point of minimum solubility (metals will precipitate). • Avoiding the input of complexing agents, chromates and cyanides. • Avoiding organic materials (interfere with precipitation from entering the process). • Allowing the resulting treated waste to clarify by decantation. • Using sulphidic precipitation if complex agents are present.	46
76. Apply the following techniques to break-up emulsions: • Testing for the presence of cyanides in the emulsions to be treated. If cyanides are present, the emulsions need a special pre-treatment. • Setting up simulated laboratory tests.	46

77. Apply the following techniques to oxidation/ reduction: • Abating the air emissions generated. • Having safety measures and gas detectors in place.	47
78. Apply the following techniques to wastewaters containing cyanides: • Destroying the cyanides by oxidation. • Adding caustic soda in excess to prevent a decrease in pH. • Avoiding the mixing of cyanide wastes with acidic compounds. • Monitoring the progress of the reaction using electropotentials.	47
79. Apply the following techniques to wastewaters containing chromium (VI) compounds: • Avoiding the mixing of Cr (VI) wastes with other wastes. • Reducing Cr (VI) to Cr (III). • Precipitating the trivalent metal.	47
80. Apply the following techniques to wastewaters containing nitrites: • Avoiding mixing nitrite wastes with other wastes. • Checking and avoiding nitrous fumes during the oxidation/acidification treatment of nitrites.	48
81. Apply the following techniques to wastewaters containing ammonia: • Using a dual column air stripping system with an acidic scrubber for waste with ammonia solutions up to 20 w/w-%. • Recovering the ammonia in the scrubbers and returning it to the process prior to the settlement stage. • Removing the ammonia separated in the gas phase by scrubbing the waste with sulphuric acid to produce ammonium sulphate. • Extending any air sampling of ammonia in exhaust stacks or filter press areas to cover the VOCs in filtration and dewatering.	48
82. Link the air space above filtration and dewatering processes to the main abatement system of the plant.	49
83. Add flocculants to the sludge and wastewater to be treated, to accelerate the sedimentation process and to facilitate the further separation of solids. To avoid the use of flocculants, evaporation is preferable in those cases where it is economically viable.	49
84. Apply rapid cleaning and steam or high pressure water jet cleaning to the filter apertures used during sieving processes.	49
85. Promote the insolubilisation of amphoteric metals, and reduce the leaching of toxic soluble salts by a combination of: a) Water washing. b) Evaporation and recrystallisation. c) Acid extraction. When immobilisation is used to treat solid waste containing hazardous compounds for landfilling.	52

86. Test the leachability of inorganic compounds, by using the standardised CEN leaching procedures and by applying the appropriate testing level: • Basic characterisation. • Compliance testing. • On-site verification.	53
87. Restrict the acceptance of wastes to be treated by solidification/immobilisation treatment to those not containing high levels of VOCs, odorous components, solid cyanides, oxidising agents, chelating agents, high TOC wastes and gas cylinders.	53
88. Apply control and enclosure techniques for loading/unloading and enclosed conveyor systems.	53
89. Have an abatement system(s) in place to handle the flow of air, as well as the peak loadings associated with charging and unloading.	53
90. Use at least a) Solidification. b) Vitrification, melting and fusion. c) Use of other reagents. Phosphate stabilisation process before landfilling any solid waste.	53
91. Control the rate of excavation, the amount of contaminated soil area that is exposed, and the duration soil piles are left uncovered during the excavation and removal of contaminated soil.	54
92. Use a bench-scale test to determine the suitability of the process to be applied and the best operational conditions for its use.	54
93. Have collection and control equipment in place such as afterburners, thermal oxidisers, fabric filters, activated carbon, or condensers for the treatment of gases from thermal treatments.	54
94. Report the efficiency achieved during the processes for the different components reduced and also for those that have not been affected by the process.	54
95. Operate a careful control of the incoming materials supported by analytical equipment (viscometer, infrared, chromatography and mass spectrometry as appropriate), laboratories and resources.	58
96. Check at least for chlorinated solvents and PCBs.	58
97. Use condensation as a treatment for the gas phase of the flash distillation unit.	58
98. Have vapour return lines for loading and unloading vehicles, routing all vents to a a) Thermal oxidiser/incinerator or b) An activated carbon adsorption installation.	58
99. Direct vent streams to a thermal oxidiser with waste gas treatment if chlorinated species are present in the vent stream. If high levels of chlorinated species are present then	58

a) condensation followed by b) caustic scrubbing, and c) activated carbon guard bed is the preferred treatment path.	
100. Utilise a thermal oxidation at 850ºC with a two-second residence time for the vacuum distillation vent of vacuum generators or for the air from process heaters.	59
101. Use a highly efficient vacuum system.	59
102. Use the residues from vacuum distillation or thin film evaporators as asphalt products.	59
103. Use a re-refining process of waste oil which can achieve a yield higher than 65% on a dry basis.	59
104. Achieve the following values in the discharged wastewater from the re-refining unit: Hydrocarbons: <0.01-5 ppm; Phenols: 0.15-0.45 ppm by using a combination of process-integrated techniques and/or primary, secondary, biological and finishing treatments.	60
105. Operate a careful control of the incoming materials as supported by analytical equipment, laboratories and resources.	61
106. Evaporate the residue from the distillation columns and recuperate the solvents.	61
107. Use bag filters to abate particulates from the fumes generated during the regeneration process.	62
108. Use SO_X abatement system.	62
109. Have an effective quality control procedure in place to ensure that the operator can differentiate between the carbon used for potable water or food grade carbon and the rest of spent carbons (the so-called “industrial carbons”).	63
110. Require a written undertaking from customers indicating what the activated carbon has been used for.	63
111. Utilise an indirect fired kiln for industrial carbons . It may be argued that this could equally be applied to potable water carbons; however, limits on capacity and corrosion may determine that only multiple hearth or direct fired rotary kilns may be used.	63
112. Utilise an afterburner with a minimum of 1100ºC, two seconds residence time and 6% excess oxygen for the regeneration of industrial carbons where refractory halogenated or other thermally resistant substances are likely to be present.	64
113. Utilise an afterburner with a minimum heating temperature of 850ºC, two seconds residence time and 6% excess oxygen for potable water and food grade active carbons.	64
114. Apply a flue-gas treatment train consisting of quench and/or venturi and aqueous scrubbing sections, followed by an induced draft fan.	64
115. Utilise caustic or soda ash scrubbing solutions to neutralise acid gases for industrial carbon plants.	64

116. Have a WWTP containing an appropriate combination of flocculation, settlement, filtration and pH adjustment for the treatment of potable water carbons. For effluents of industrial carbons, applying additional treatments (metal hydroxide, sulphide precipitation) are also considered BATs.	64
117. Try to maintain a close relationship with the waste fuel user to ensure that knowledge on the waste fuel composition is transferred effectively.	67
118. Have a quality assurance system to guarantee the characteristics of the waste fuel produced.	67
119. Manufacture different types of waste fuels according to the type of user (e.g. cement kilns), the type of furnace (e.g. grate firing, blow feeding) and the type of waste used to manufacture the waste (e.g. hazardous waste).	67
120. When producing waste fuel from hazardous residue, use activated carbon treatment for low polluted water and thermal treatment for highly polluted water. Thermal treatment relates to any type of thermal treatment or incineration. See BATs on Hazardous Waste Incineration (Chapter 4).	67
121. When producing waste fuel from hazardous waste, ensure correct follow-up of the rules concerning electrostatic and flammability hazards for safety reasons. Use the following techniques: a) Provision of full details on the activities to be carried out, b) Techniques to prevent accidents and their consequences.	67
122. Consider emissions and flammability hazards in case a drying or heating operation is required.	68
123. Consider carrying out the mixing and blending operations in closed areas with appropriate atmosphere control systems.	68
124. Use bag filters for the abatement of particulates.	68
125. Use heat-exchange units external to the vessel liquid fuel must be heated.	69
126. Adapt the suspended solid content to ensure the homogeneity of the liquid fuel.	69

9.2. BATS FOR HAZARDOUS WASTE INCINERATION

BAT	PAGE
1. The selection of an installation design suited to the characteristics of the waste received using the following techniques: a) Suitability of process design. b) Combustion chamber design features.	82
2. Keep the site generally clean and tidy.	82

3. To maintain all equipment in good working order, and to carry out maintenance inspections and preventive maintenance in order to comply with BAT 2.	82
4. To establish and maintain quality controls over the waste input, according to the types of waste that may be received at the installation using the followings techniques: a) Establishing installation input limitations and identifying key risks. b) Communication with waste suppliers to improve incoming waste quality control. c) Controlling waste feed quality on the incinerator site. d) Checking, sampling and testing incoming wastes. e) Detectors for radioactive materials.	82
5. The storage of wastes according to a risk assessment of their properties, to minimise the risk of potentially polluting emissions .	83
6. To use techniques and procedures to restrict and manage waste storage times, in order to generally reduce the risk of releases from storage of waste/container deterioration, and of processing difficulties that may arise.	83
7. To minimise the release of odour (and other potential fugitive releases) from bulk waste storage areas and waste pre-treatment areas by passing the extracted atmosphere to the incinerator for combustion.	83
8. The segregation of stored wastes according to a risk assessment of their chemical and physical characteristics to allow safe storage and processing.	83
9. The clear labelling of waste stored in containers for their permanent identification. This is applicable to hazardous waste.	84
10. The development of a plan for the prevention, detection and control of fire hazards at the installation, in particular for: • Waste storage and pre-treatments areas. • Furnace loading areas. • Electrical control systems. • Bag house filters and static bed filters.	84
11. The mixing or further pre-treatment of heterogeneous wastes to the degree required to meet the design specifications of the receiving installation.	84
12. The use of: a) Pre-combustion removal of recyclable metals. b) Bottom ash-separation of metals. c) Remove ferrous and non- ferrous recyclable metals for their recovery either: after incineration from the bottom ash residues or where the waste is shredded from the shredded wastes before the incineration stage.	84
13. The provision of operators with a means to visually monitor, directly or using television screens or similar, waste storage and loading areas.	84

14. The minimisation of the uncontrolled intake of air into the combustion chamber via waste loading or other routes.	84
15. The use of flow modelling which may assist in providing information where concerns exist regarding the combustion or FGT performance, and to provide information in order to: • Optimise furnace and boiler geometry. • Optimise combustion air injection. • Optimise reagent injection points where SNCR or SCR is used.	95
16. To adopt operational regimes and implement procedures in order to reduce overall emissions.	95
17. The identification of a combustion control philosophy, and the use of key combustion criteria and a combustion control system to monitor and maintain these criteria within appropriate boundary conditions, in order to maintain effective combustion performance. Techniques to consider are: a) Selection and use of suitable combustion control systems and parameters, b) use of infrared cameras for combustion monitoring and control.	95
18. The optimisation and control of combustion conditions by: • control of air supply, distribution and temperature, including gas and oxidant mixing, • combustion temperature level and distribution, • raw gas residence time. The techniques that may be used are: a) Optimisation of air supply stoichiometry. b) Primary air supply optimisation and distribution. c) Secondary air injection, optimisation and distribution, d) optimisation of time, temperature, turbulence of gases in the combustion zone, and oxygen concentrations. e) Design to increase turbulence in the secondary combustion chamber (SCC).	96
19. In general it is BAT to use those operating conditions (i.e. temperatures, residence times and turbulence) as specified in Art.6 of Directive 2000/76. The use of other operating conditions may also be BAT.	96
21. The use of auxiliary burner(s) for start-up and shut-down and for maintaining the required operational combustion temperatures at all times when unburned waste is in the combustion chamber.	97
22. The use of a combination of heat removal close to the furnace and furnace insulation that, according to the net calorific value (NCV) and corrosiveness of the waste incinerated, provides for adequate heat retention in furnace and additional heat to be transferred for energy recovery. The techniques that may be used are: a) Protection of furnace membrane walls and boiler first pass with refractory or other materials. b) Use of an integral furnace-boiler.	97

23. The use of furnaces that are sufficiently large to allow an effective combination of gas residence time and temperature such that combustion reactions may approach completion and result in low and stable CO and VOC emissions.	97
24. When gasification or pyrolysis is used, in order to avoid the generation of waste, it is BAT to combine the gasification or pyrolysis stage with a subsequent combustion stage with energy recovery and flue-gas treatment that provides for operational emission levels to air and recover or supply for use of the substances that are not combusted.	97
25. In order to avoid operational problems that may be caused by higher temperature sticky fly ashes, to use a boiler design that allows gas temperatures to reduce sufficiently before the convective heat exchange bundles. The techniques that may be used are: a) Optimisation of boiler architecture. b) Use of a platen-type superheater.	98
26. The overall optimisation of installation energy efficiency and energy recovery, as in general: • to reduce energy losses with flue-gases, • the use of a boiler to transfer the flue-gas energy for the production of electricity and/or supply of steam/heat with a thermal conversion efficiency: for hazardous wastes giving rise to increased boiler corrosion risks (typically from chlorine/sulphur content), above 60 to 70%. • For gasification and pyrolysis processes, the use of a boiler with a thermal conversion efficiency of at least 80% or the use of a gas engine or other electrical generation technology.	18
27. To secure, where practicable, long-term base-load heat/steam supply contracts to large heat/steam users so that a more regular demand for the recovered energy exists and therefore a larger proportion of the energy value of the incinerated waste may be used.	108
28. The location of new installations so that the use of the heat and/or steam generated in the boiler can be maximised through any combination of: • Electricity generation with heat or steam supply for use. • The supply of heat or steam for use in district heating distribution networks. • The supply of process steam for various, mainly industrial, uses. • The supply of heat or steam for use as the driving force for cooling/air conditioning systems.	108
29. In cases where electricity is generated, the optimisation of steam parameters including consideration of the use of higher steam parameters to increase electrical generation and the protection of boiler materials using suitably resistant materials.	109
30. The selection of a turbine suited to: • The electricity and heat supply regime. • High electrical efficiency.	109
31. In new plants or when upgrading installations, the minimisation of condenser pressure when electricity generation takes priority over heat supply.	109

32. The general minimisation of overall installation energy demand, including the following: • For the performance level required, the selection of techniques with lower overall energy demand. • Ordering flue-gas treatment systems to avoid flue-gas reheating . • To use heat exchangers to heat the SCR inlet flue-gas with the flue-gas energy at the SCR outlet. • The use of heat exchange systems to minimise flue-gas reheating energy demand. • Avoiding the use of primary fuels by using self-produced energy.	109
33. Where cooling systems are required, the selection of the steam condenser cooling system technical option that is best suited to the local environmental conditions.	110
34. The use of a combination of on-line and off-line boiler cleaning techniques to reduce dust residence and accumulation in the boiler.	110
35. The use of an overall flue-gas treatment (FGT) system that, when combined with the installation as a whole, generally provides for the operational emission levels listed in Table 5.2 (Waste Incineration BREF [3]) for releases to air associated with the use of BAT.	121
36. When selecting the overall FGT system, to take into account the general factors, the potential impacts on energy consumption of the installation and the additional overall-system compatibility issues that may arise when retrofitting existing installations.	121
37. When selecting between wet/ semi-wet/ and dry FGT systems, to take into account the general selection criteria as given in Table 5.3. (Waste Incineration BREF).	110
38. To prevent the associated increased electrical consumption, to generally (i.e. unless there is a specific local driver) avoid the use of two bag filters in one FGT line. The techniques that may be used are: a) Application of an additional flue-gas polishing system. b) Application of double bag filtration.	110
40. The use of primary NO_x reduction measures to reduce NO_x production, together with either SCR or SNCR, according to the efficiency of flue-gas reduction required.	121
41. For the reduction of overall PCDD/F emissions to all environmental media, the use of: • Techniques for improving knowledge and control of the waste. • Primary techniques to destroy PCDD/F in the waste and possible precursors. • The use of installation designs and operational controls that avoid those conditions that may give rise to PCDD/F reformation or generation. The techniques that may be used are: a) Primary techniques for prevention of PCDD/F. b) Prevention of reformation of PCDD/Fin the FGT system. c) Adsorption of PCDD/F by activated carbon injection or other reagents. d) Adsorption of PCDD/F in static beds.	122

e) Destruction of PCDD/F using Selective Catalytic Reduction (SCR). f) Destruction of PCDD/F using catalytic filter bags.	
42.- Where wet scrubbers are used, to carry out an assessment of PCDD/F build up in the scrubber and adopt suitable measures to deal with this build up and prevent scrubber breakthrough releases.	122
43. If re-burn of FGT residues is applied, then suitable measures should be taken to avoid the re-circulation and accumulation of Hg in the installation.	141
44. For the control of Hg emissions, where scrubbers are applied as the only or main effective means of total Hg emission control: • The use of an initial low pH stage with the addition of specific reagents for ionic Hg removal. • Activated carbon injection. • Activated carbon or coke filters. The techniques that may be used are: a) Low pH wet scrubbing and additive addition. b) Addition of hydrogen peroxide to wet scrubbers. c) Chlorite injection for elemental Hg control. d) Activated carbon injection for Hg adsorption. e) Use of static activated carbon or coke filters.	1122
45.- For the control of Hg emissions where semi-wet and dry FGT systems are applied, the use of activated carbon or other effective adsorptive reagents for the adsorption of PCDD/F and Hg, with the reagent dose rate controlled so that final air emission are within the BAT emission ranges given for Hg.	123
46. The general optimisation of the re-circulation and re-use of wastewater arising on the site within the installation. The techniques that may be used are: a) Re-circulation of effluents to the process in place of their discharge. b) Use of boiler drain water as a water supply for scrubbers.	137
47. The use of separate systems for the drainage, treatment and discharge of rainwater that falls on the site, including roof water, so that it does not mix with potential or actual contaminated wastewater streams. Some such wastewater streams may require only little or no treatment prior to their discharge, depending on contamination risk and local discharge factors.	139
48. Where wet flue-gas treatment is used: a) The use of on-site physico-chemical treatment of the scrubber effluents prior to their discharge. b) The separate treatment of the acid and alkaline wastewater streams arising from the scrubber stages when there are particular drivers for the additional reduction of releases to water, and/or HCl or gypsum recovery is to be carried out. c) The re-circulation of wet scrubber effluent within the scrubber system, and the use of the electrical conductivity of the re-circulated water as a control measure.	123

d) The provision of storage/buffering capacity for scrubber effluents, to provide a more stable wastewater treatment process. e) The use of sulphides or other Hg binders to reduce Hg (and other heavy metals) in the final effluent. f) When SNCR is used with wet scrubbing the NH_3 levels in the effluent discharge may be reduced using NH_3 stripping and the recovered NH_3 re-circulated for use as a NO_x reduction reagent.	
49. The use of a suitable combination of the techniques for improving waste burnout to achieve a TOC value in the ash residues of below 3 wt% includes: • The use of a combination of furnace design, operation and waste throughput rate that provides sufficient agitation and residence time at sufficiently high temperatures. • The use of furnace designs that physically retain the waste within the combustion chamber to allow its combustion. • The use of techniques for mixing and pre-treatment of waste (BAT 11). • The optimisation and control of combustion conditions. The techniques that may be used are: a) Improving the burnout of bottom ash. b) Selection of combustion technology. c) Increased agitation and residence time. d) Adjustment of throughput to maintain good burnout and combustion conditions. e) Reduction of grate riddling rate and/or return of cooled riddling to the combustion chamber.	124
50. The separate management of bottom ash from fly ash and other FGT residues, so as to avoid contamination of the bottom ash and thereby improve the potential for bottom ash recovery. It is also a BAT to assess the levels of contaminants in the boiler ash, and to assess whether separation or mixing with bottom ash is appropriate.	141
51. Where a pre-dedusting stage is employed, an assessment of the composition of the fly ash so collected should be carried out to assess whether it may be recovered, either directly or after treatment, rather than disposed of. The techniques that may be used are: a) Separation of the dust removal stage from other flue-gas treatment. b) Application of an additional flue-gas polishing system.	125
52. The separation of remaining ferrous and non-ferrous metals from bottom ash, as far as practicably and economically viable, for their recovery.	141
53. The treatment of bottom ash (on or off-site), by a suitable combination of: a) Bottom ash treatment using ageing. b) Bottom ash treatment using dry treatment systems. c) Bottom ash treatment using wet treatment systems. d) Bottom ash treatment using thermal systems.	141

e) High temperature (slagging) rotary kiln (110-1400ºC). f) Bottom ash screening and crushing. g) To the extent that is required to meet the specifications set for its use or at the receiving treatment or disposal site.	
54. The treatment of FGT residues (on or off-site) to the extent required to meet the acceptance requirements for the waste management option selected for them, including consideration of the use of the FGT residue treatment techniques. These techniques are: a) Cement solidification of FGT residues. b) Vitrification and melting of FGT residues. c) Acid extraction of boiler and fly ash.	142
55. The implementation of noise reduction measures to meet local noise requirements.	85
56. Apply environmental management. The scope and nature of EMS will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.	85
69. Additional quality controls at HWI: to use specific systems and procedures; using a risk-based approach according to the source of the waste, for the labelling, checking, sampling and testing of waste to be stored/ treated. Analytical procedures should be managed by suitable qualified personnel and using appropriate procedures. See also BAT 4.	85
70. The mixing, blending and pre-treating of waste in order to improve its homogeneity, combustion characteristics and burn-out to a suitable degree with due regard to safety considerations. If shredding is carried out then blanketing with an inert atmosphere should be implemented. The techniques that may be used are: a) Shredding or drummed and packaged hazardous wastes. b) Pre-treatment and targeted preparation of solid waste for combustion.	85
71. – The use of a feed equalisation system for solid **hazardous wastes** in order to improve the combustion characteristics of the fed waste and to improve the stability of flue-gas composition including the improved control of short-term CO peak emissions.	86
72. The direct injection of liquid and gaseous **hazardous wastes**, where those wastes require specific reduction of exposure, releases or odour risk.	86
73. The use of a combustion chamber design that provides for containment, agitation and transport of the waste, for example: rotary kilns - either with or without water cooling. Water cooling for rotary kilns, may be favourable in situations where: the LHV of the fed waste is higher (e.g. >15-17 GJ/t) or higher temperatures are used.	98
74. To reduce installation energy demand and to achieve an average installation electrical demand of generally below 0.3-0.5 MWh/tonne of waste processed.	111
75. For merchant HWI and other hazardous waste incinerators feeding wastes of highly varying composition and sources, the use of: a) Wet FGT is generally BAT to provide for improved control of short-term air emissions.	125

b) Specific techniques for the reduction of elemental iodine and bromine emissions where such substances exist in the waste at appreciable concentrations.	
76. The use of fluidised bed technology at installations may generally be BAT because of the higher combustion efficiency and lower flue-gas volumes that generally result from such systems.	94
77. The drying of the sewage sludge, preferably by using heat recovered from the incineration, to the extent that additional combustion support fuels are not generally required for the normal operation of the installation.	94

10. ANNEX II - GLOSSARY

A
ACC: Air-Cooled Condensers
AER: Annual Environmental Report
APC: Air Pollution Control
As: Arsenic
ASR: Automotive Shredder Residues

B
BAT: Best Available Technique
BEP: Best Environmental Practice
BFB: Stationary Fluidised Bed
BOD: Biological Oxygen Demand
BREF: Reference Document on Best Available Techniques
BTX: Benzene, Toluene and Xilene

C
$CaCl_2$: Calcium Chloride
CaF_2: Calcium Fluoride
CaO: Quicklime
Cd: Cadmium
CEN: European Committee for Normalisation
CFB: Circulation Fluidised Bed
CFD: Computerised Fluid Dynamics
CHP: Combined Heat and Power
Cl: Chlorine
Co: Cobalt
CO: Carbon Monoxide
CO_2: Carbon Dioxide
COD: Chemical Oxygen Demand
Cr: Chromium
Cu: Copper
CV: Calorific Value

D
DAF: Dissolved Air Flotation

E
EIA: Environmental Impact Assessment
ELVs: Emission Limits Value
EMP: Environmental Management Programme
EMS: Environmental Management System
EPA: Environmental Protection Agency
ESP: Electrostatic Precipitator
ETP: Effluent Treatment Plant
EU: European Union
EQS: Environmental Quality Standard

F
Fe: Iron

$FeSO_4$: Ferrous Sulphate
FGT: Flue Gas Treatment

G
GBP: Great Britain Pound
GDP: Desulphurisation Plant
GHG: Greenhouse Gas

H
HC: Hydrocarbons
HCBs: Hexachlorobenzene
HCl: Hydrochloric acid
HF: Hydrogen fluoride
Hg: Mercury
H_3PO_4: Phosphoric acid
H_2S: Hydrogen sulphide
HW: Hazardous Waste
HWI: Hazardous Waste Incineration/incinerator
HWLF: Hazardous Waste Landfill

I
IBC: Intermediate Bulk Container
IPP: Investment Payback Period
IPPC: Integrated Pollution Prevention and Control
Ir: Iridium
IRR: Internal Rate of Return

K
K: Potassium

L
LCA: Life-Cycle Analysis
LCV: Lower Calorific Value
LHV: Low Heat Value

M
MAP: Mediterranean Action Plan
MBT: Mechanical Biological Treatment
MDF: Medium Density Fibreboard
Mo: Molybdenum
MSWI: Municipal Solid Waste Incinerator/incineration

N
N: Nitrogen
Na: Sodium
NaCl: Sodium Chloride
NOx: Nitrogen oxides
NaOH: Sodium Hydroxide
Na_2SO_4: Sodium Sulphate
NCV: Net Calorific Value
Ni: Nickel
NMOCs: Non-Methane Organic Compounds
Non-BSENon-Bovine Spongiform Encephalopathy
NPV: Net Present Value

P
P: Phosphorus
PAH: Polycyclic Aromatic Hydrocarbon

Pb: Lead
PCB: Polychlorinated Biphenyl
Ph-c: Physico-chemical
PCC: Post Combustion Chamber
PCDD/F: Polychlorinated Dibenzodioxin and Dibenzofuran
PCDM: Polychlorinated Diphenylmethanes
PICs: Products of Incomplete combustion
PM10: Fine Particulate
POP: Persistent Organic Pollutant
Pt: Platinum
PVC: Poly Vinyl Chloride

R
RAC/CP: Regional Activity Centre for the Clean Production
RCP: Recycled Clean Products
RDF: Refused Derived Fuel
Rh: Rhodium

S
SAP: Strategic Action Programme
SCC: Secondary Combustion Chamber
SCR: Selective Catalytic Reduction
SLF: Substitute Liquid Fuel
SNCR: Non Selective Catalytic Reduction
SO_2: Sulfur Dioxide
SO_3: Sulfur Trioxide
SOx: Sulfur Oxides

T
TDA: Thermal de-asphalting
TEQ: Toxic Equivalent
Tl: Thallium
TOC: Total Organic Carbon

V
VOCs: Volatile Organic Compounds

W
Waste IN: Waste Input
Waste OUT: Waste Output
WT: Waste Treatment
WTE: Waste to Energy Plant
WWTP: Wastewater Treatment Plant

Z
Zn: Zinc

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Regional Activity Centre
for Cleaner Production (RAC/CP)

Dr. Roux, 80 - 08017 Barcelona (Spain)
Tel.: + 34 93 553 87 90 - Fax: + 34 93 553 87 95
E-mail: cleanpro@cprac.org
http://www.cprac.org

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