MWAN مـــوان
المركز الوطني لإدارة النفايات
National Center for Waste Management

الضوابط والأدلة الفنية
لتصميم مرافق حرق النفايات وإنشائها وتشغيلها

Technical Guidelines
Design, Construction and Operation of Waste Incineration Facilities

17 August 2023

REF# TG-WM-06

Eng Vs.01

TABLE OF CONTENTS

1 PURPOSE AND SCOPE 10
1.1 **Purpose** 10
1.2 **Scope** 10
2 LEGAL REQUIREMENTS 12
3 ROLES AND RESPONSIBILITIES 14
4 OVERVIEW ON WASTE INCINERATION 16
4.1 **Treatment technology overview** 18
4.2 **General Environmental Considerations** 20
5 SITE SPECIFICATIONS AND INFRASTRUCTURE REQUIREMENTS 22
5.1 **Site Infrastructure Guidelines for Waste Incineration facilities** 22
5.1.1 Siting – General Considerations 22
5.1.2 Surface Water Drainage 23
5.1.3 Utilities and Facilities....23
5.1.4 Fencing and Security 24
5.1.5 Waste Rejects Area 24
6 DESIGN REQUIREMENTS & BEST SUITABLE TECHNIQUES APPLICABLE FOR WASTE INCINERATION FACILITIES 25
6.1 **Introduction** 25
6.2 **Techniques for pre-treatment storage and handling** 25
6.2.1 Municipal solid waste and similar (MSW) 26
6.2.2 Hazardous waste 26
6.2.3 Sewage sludge 29
6.3 **Comparison of different processes and techniques for the thermal stage**....30
6.4 **Techniques to increase energy recovery**....33
6.5 **Techniques for the prevention reduction and control of emissions** 36
6.5.1 Techniques for the reduction of emissions to air....36
6.5.2 Techniques for the reduction of discharge to water....53
6.5.3 Treatment techniques for solid residues....57
6.5.4 Odour management plan 61
6.5.5 Management of outputs 62
6.5.6 Material efficiency....62
6.5.7 Techniques for the prevention and control of noise and vibration emissions....63

6.6 Best suitable techniques to improve economic, energy and environmental performance 65

7 EMERGING TECHNIQUES 65

7.1 Reheating of turbine steam 65

7.2 Oil scrubber for the reduction of polyhalogenated aromatics and polyaromatic hydrocarbons (PAHs) in the flue-gases from incineration plants 66

7.3 Flameless pressurised oxycombustion 66

7.4 Phosphorus recovery from sewage sludge incineration ashes 66

7.4.1 Wet-chemical processes 67

7.4.2 Thermal processes 67

8 OPERATION AND MAINTENANCE 68

8.1 Operational techniques to improve environmental performance of Waste Incineration Facilities 68

8.1.1 Quality control of incoming wastes 68

8.1.2 Waste storage 73

8.1.3 Pre-treatment of incoming waste, waste transfer and loading 77

8.2 Training 80

8.2.1 Training requirements 80

8.2.2 Emergency training 81

9 HEALTH AND SAFETY CONSIDERATIONS 82

9.1 Safety devices and measures 82

9.2 Fencing and Security 83

9.3 Accident Management Plans 83

10 MONITORING, RECORDKEEPING AND REPORTING 86

10.1 Environmental management system (EMS) 86

10.2 Waste input monitoring and recordkeeping 87

10.3 Monitoring and recordkeeping of identified emissions 87

10.4 Reporting 91

TABLE INDEX

Table 4-1: Purpose of various components of a waste incinerator 17

Table 4-2: Waste Incineration methods, technology summary, and type of waste treated....19

Table 6-1: Typical reaction conditions and products of combustion, pyrolysis and gasification processes 30

Table 6-2:Comparison of different Waste Incineration processes....32

Table 6-3:Techniques to prevent or reduce dust emissions to air from the treatment of slags and bottom ashes 37

Table 6-4: Techniques to reduce emissions to air of dust, metals, and metalloids from the incineration of waste....39

Table 6-5: NCEC established limits for channelled emissions to air of dust, metals, and metalloids from the incineration of waste: 41

Table 6-6: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of dust, metals, and metalloids from the incineration of waste:....42

Table 6-7: BAT-associated emission levels (BAT-AELs) for channelled dust emissions to air from the enclosed treatment of slags and bottom ashes with extraction of air....42

Table 6-8: Techniques to reduce emissions of HCl, HF and SO2 to air from the incineration of waste....42

Table 6-9: NCEC established limits for channelled emissions to air of HCl, HF and SO2 from the incineration of waste....43

Table 6-10: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of HCl, HF and SO2 from the incineration of waste 44

Table 6-11:Techniques to reduce NOx emissions to air from the incineration of waste and NH3 emissions to air from the use of SNCR and/or SCR....45

Table 6-12: NCEC established limits for channelled NOx and CO emissions to air from the incineration of waste 47

Table 6-13: BAT-associated emission levels (BAT-AELs) for channelled NOx and CO emissions to air from the incineration of waste and for channelled NH3 emissions to air from the use of SNCR and/or SCR 47

Table 6-14: Techniques to reduce emissions to air from organic compounds including PCDD/F and PCBs from the incineration of waste 48

Table 6-15: NCEC established limits for channelled emissions to air of organic compounds from the incineration of waste 49

Table 6-16: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of TVOC, PCDD/F and dioxin-like PCBs from the incineration of waste 50

Table 6-17: Techniques to reduce mercury emissions to air (including mercury emission peaks) from the incineration of waste 51

Table 6-18: NCEC established limits for channelled mercury emissions to air from the incineration of waste .52

Table 6-19: BAT-associated emission levels (BAT-AELs) for channelled mercury emissions to air from the incineration of waste 52

Table 6-20: Techniques to reduce discharge to water from FGC and/or from the storage and treatment of slags and bottom ashes....54

Table 6-21: BAT-AELs for direct emissions to a receiving water body 56

Table 6-22: BAT-AELs for indirect emissions to a receiving water body 57

Table 8-1: Techniques applied for the checking and sampling of various waste types 71
Table 8-2: Some examples of applied storage techniques for various waste types 73
Table 8-3: Main techniques for reducing fugitive diffuse emissions to air, odour releases and GHG emissions75
Table 8-4: Some segregation techniques applied for various waste types 76
Table 8-5: Summary of the current application of thermal treatment processes applied to different waste types...78
Table 10-1: Parameters and minimum monitoring frequency of channelled emissions to air...........................88
Table 10-2: Parameters and minimum monitoring frequency of channelled emissions to air...........................88
Table 10-3: Parameters and minimum monitoring frequency of discharge to water from FGC and/or bottom ash treatment 90

FIGURE INDEX

Figure 1: Example of a MSW incineration plant...25

LIST OF ACRONYMS

BAT	Best Available Techniques
BAT-AELs	BAT Associated Emission Levels
BREF	BAT Reference Documents
CEMS	Continuous Emission Monitoring System
CPR	Cardiopulmonary Resuscitation
CV	Calorific Value
DCP	Dicalcium Phosphate
DS	Dry Solids
EMS	Environmental management system
ESPs	Electrostatic Precipitators
FGC	Flue-Gas Cleaning
GHG	Greenhouse Gas
HCW	Healthcare Waste
IBA	Incinerator Bottom Ash
IBCs	Intermediate Bulk Containers
IED	Industrial Emissions Directive
IR	Implementing Regulations
ISO	International Organization for Standardization
KSA	Kingdom of Saudi Arabia
MSW	Municipal Solid Waste
MWAN / The centre	National Centre for Waste Management
NCEC	National Centre for Environmental Compliance
PAHs	Polyaromatic Hydrocarbons
PCBs	Polychlorinated Biphenyl

PCC	Post-combustion chamber
PCDF	Polychlorinated Dibenzo-p-dioxins
PCDD/F	Polychlorinated Dibenzodioxins and Furans
PEMs	Predictive Emission Monitoring System
PM	Particulate matter
POPs	Persistent organic pollutants
PPE	Personal Protective Equipment
RDF	Refuse Derived Fuel
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
TG	Technical Guideline
TOC	Total organic carbon
TSS	Total suspended solids
TVOC	Total volatile organic carbon, expressed as C (in air).
US EPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WI	Waste incinerator/incineration
WM	Waste Management
WML	Waste Management Law
WT BREF	Waste Treatment Best Available Techniques Reference Document

DEFINITIONS

Boiler ash	The part of the fly ash that is removed from the boiler.
Centre	The National Centre for Waste Management.
Channelled emissions	Emissions of pollutants into the environment through any kind of duct, pipe, stack, chimney, funnel, flue, etc.
Competent Authority	The government entity responsible for operationally managing waste in accordance with a special regulatory provision.
Discharge	Physical release of a pollutant through a defined outlet (i.e., channelled) of the system (e.g., sewer, stack, vent, curbing area, outfall).
Drainage	Natural or artificial removal of surface and subsurface water from an area, including surface streams and groundwater pathways.
Emission	The direct or indirect release of substances, vibrations, heat, or noise from individual or diffuse sources in the installation into the air, water or land.
Flue-gas	A mixture of combustion products and air leaving a combustion chamber and being directed up a stack to be emitted.
Fly ashes	Particles from the combustion chamber or formed within the flue-gas stream that are transported in the flue-gas.
Fugitive emissions	Emissions of pollutants into the environment resulting from a gradual loss of tightness of a piece of equipment designed to contain an enclosed fluid (gaseous or liquid). Fugitive emissions are a subset of diffuse emissions.
Hazardous Waste	Waste classified as hazardous based upon the provisions of the Law and Regulations, which is resulting from industrial or non-industrial activities that contain toxic, flammable, or reactive materials, or corrosives, solvents, degreasers, oils, colorants, paste residuals, acids and alkalis
Inspectors	Persons designated by a decision of the Minister to take charge of detecting, proving and investigating violations of the provisions of the Law and Regulation, jointly or individually
Leachate	Solution obtained by leaching. The solution consists of liquid that, in passing through matter, extracts solutes, suspended solids or any other component of the material through which it has passed.
Licence	A written permission issued by the Centre for the purpose of carrying out any activity related to waste management in accordance with the controls determined by the Law and Regulations.

Other non-hazardous waste	Non-hazardous waste that is neither municipal solid waste nor sewage sludge.
Regulation	The Implementing Regulation of the Law.
Residues	Any liquid or solid waste which is generated by an incineration plant or by a bottom ash treatment plant
Slags and/or bottom ashes	Solid residues removed from the furnace once wastes have been incinerated.
Sludge	Residual sludge from municipal or industrial wastewaters treatment plants and from any other wastewater treatment plants that are similar in composition to municipal, industrial, or residual sludge from septic tanks and other similar installations for the treatment of sewage; or any other residual sludge from sewage treatment plants or septic tanks or any other similar arrangements that are similar to wastewater treatment.
Storage	Storing the waste components or some of them temporarily for transfer or later use.
The Minister	Minister of Environment, Water and Agriculture, and Chairman of the Board of Directors of the Centre.
Treatment	It means the use of physical, biological or chemical means, or a combination of these means, or others to bring about a change in the specifications of waste in order to reduce its volume, or facilitate the processes of treating it when reusing or recycling, or extracting some products from it or to remove organic pollutants and others in order to reduce or utilize some of the waste components or eliminate the possibility of harm to humans or the environment.
Waste Management	Organizing any activity or practice related to waste commencing from waste collection, transportation, sorting, storage, treatment, recycling, import, export, and safe disposal, including aftercare at waste disposal sites.
Waste Producer-Generator	Every person who produces classified waste according to the provisions of the Law.
Waste Service Provider	The person licensed or authorized to engage in one of the Waste Management activities.

1 PURPOSE AND SCOPE

1.1 Purpose

This Technical Guideline (TG) has been developed to provide a range of options and guidance on the selection of the best appropriate techniques and practices related to Waste Incineration (WI) based on local KSA economic, environmental, and social context. For the selection of the best option, the following criteria are taken into consideration:

- Compliance with the new Waste Management Law (WML) and its Regulations;
- Minimum operational and capital cost;
- Sustainability of operations;
- Technical feasibility;
- Circularity; and
- Environmental Impacts & Risks.

This document is intended to provide technical guidance to all stakeholders with respect to Waste Incineration activities that include but are not limited to:

- Design, construction, and operation of treatment facilities;
- Environmental pollution prevention, reduction, and control measures;
- Design and implementation of environmental monitoring program; and
- Proper management of by-products and waste streams produced.

1.2 Scope

Efficient and proper waste management is an essential part of the transition to a circular economy and is based on the "waste hierarchy" which sets the following priority order: prevention, (preparing for) reuse, recycling, recovery and, as the least preferred option, disposal. However, secondary products are inherent to any industrial process and normally cannot be avoided. In many cases, these types of materials (both secondary products and residues) cannot be reused by other means and may become unmarketable. These materials are typically considered for further treatment. In this document, the basic reasons for treating waste are:

- To reduce the hazardous nature of the waste;
- To recover inherent resources and material;
- To reduce the amount of waste which must be finally sent for disposal; and
- To transform the waste into energy (electricity, heat, or both).

This guidance document covers waste incineration (WI). Due to the nature of incineration process, it is mainly applied to the following categories of waste:

- Municipal wastes (residual wastes - not pre-treated);
- Pre-treated municipal wastes (e.g., selected fractions or RDF);
- Non-hazardous industrial wastes and packaging;

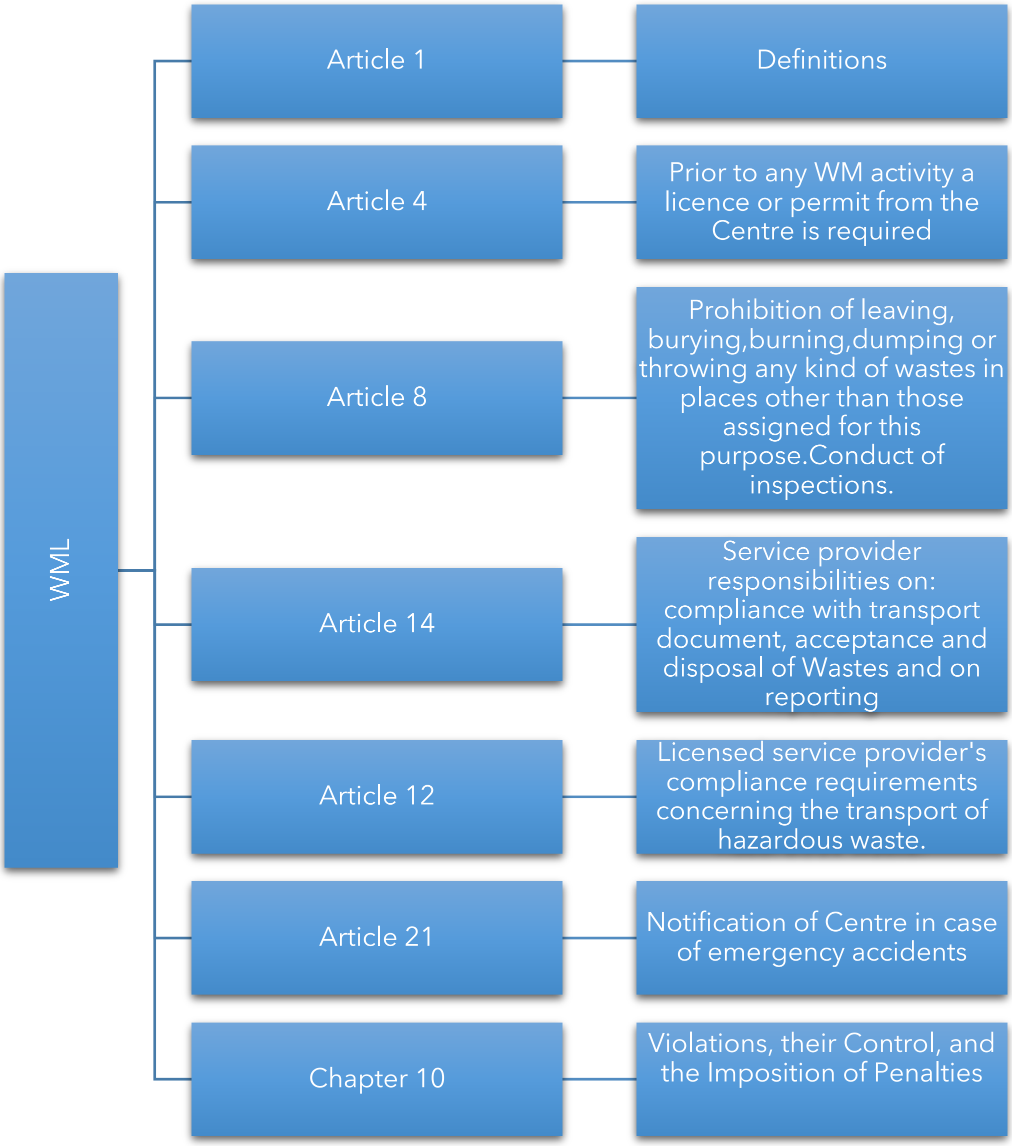
- Agricultural Waste;
- Hazardous wastes;
- Sewage sludges;
- Healthcare waste. [1]

Wastewater, radioactive, nuclear, or military wastes are not included in the scope of the mandate of the National Center for Waste Management and accordingly, are also not included in the scope of this document.

[1]HWC is mentioned for completeness only. It is analysed in detail in the corresponding TG.

2 LEGAL REQUIREMENTS

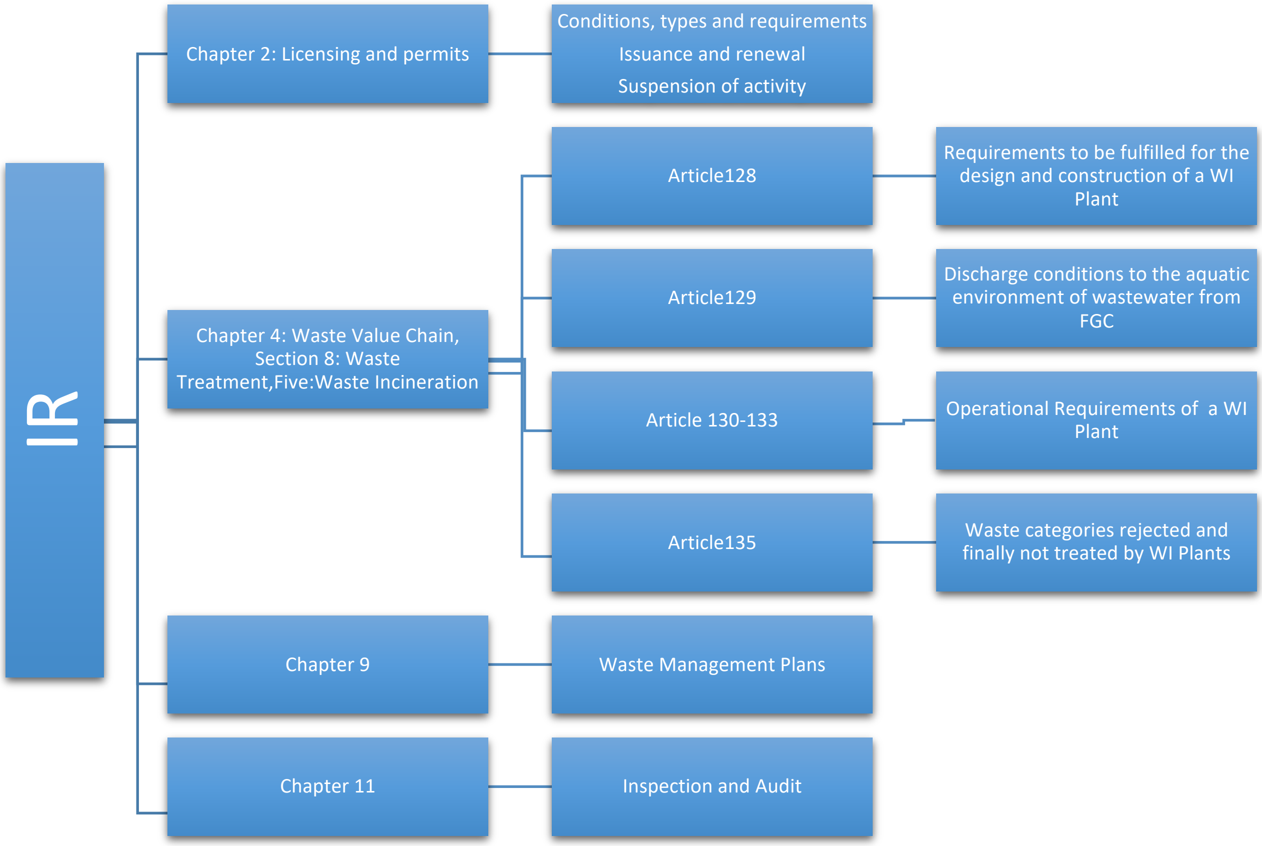
This TG for Waste Incineration complements the information provided by the Waste Management Law (WML) and the corresponding Implementing Regulations (IR) so as to focus on the application of "best available techniques" and "best available practices" based on the local Saudi economic, environmental, and social context. Within this framework, users of this TG, should also consult the WML and the IR, particularly the following provisions[2] [3]:



The terms used in this guidance document have the same meanings as in the WML. Specifically, the term treatment, according to the WML, has the meaning of bringing about a change in the specifications of Waste. These changes occur in order to:

[2] (Waste Management Law.Kingdom of Saudi Arabia, 2021)
[3] (The Implementing Regulations of the Waste Management Law, 2021)

- Reduce the volume of waste; or
- Facilitate the processes of treating it when reusing or recycling, or extracting some products from it; or
- Remove organic pollutants, toxic/hazardous metals; or
- Reduce or utilize some of the Waste components; or
- Eliminate the possibility of harm to humans or the environment.



3 ROLES AND RESPONSIBILITIES

The parties involved in the Waste Management include: the competent authority (the Centre), the National Center for Environmental Compliance (NCEC), Design and Construction Companies, Waste Service Providers-Operators (hereby only for treatment facilities) and Investors. The roles and responsibilities are detailed in the next paragraphs.

	Roles and Responsibilities
The Centre	▪ Issuing licence for Waste Incineration in accordance with the controls determined by Law and Regulations; ▪ Monitoring the compliance of Service Providers with the provisions of the Law and the Regulations, the rules and instructions issued thereunder, as well as their licence terms and conditions via the inspectors, who are appointed by a decision of the Minister.
NCEC	▪ Issuing an environmental permit for the construction and operation of a Incineration Plants in accordance with the controls determined by law and Regulations, upon the submission and approval of the Environmental Impact Assessment; ▪ Monitoring the compliance of Service Providers in terms of environmental factors (such as emissions) as per the provisions of the Law and the Regulations, the rules and instructions issued thereunder, as well as their licence terms and conditions via the inspectors, who are appointed by a decision of the Minister.
Design and Construction Companies	Compliance with the provisions of the Law and the Regulations, the rules and instructions issued thereunder, as well as the terms and conditions of the construction and environmental permits, as well as any other pertaining permits.
Service Providers / Operators	▪ Verify the authenticity of the waste transportation manifest details and ensure that they fall within the licence issued for the Waste Incineration Facility competency; ▪ Submit periodic reports to the Centre, as per the controls stipulated by the Regulation; ▪ Maintain an adequate and up to date record of its operations and provide this on a regular basis to the Centre;

	Roles and Responsibilities
	- Provide adequate training to designated staff to ensure the highest level of skills and qualifications; - Ensure proper and safe management of by-products and residues resulting from the Waste Incineration processes, according to the applicable regulations and instructions by the Centre; - Carry out during the operational phase a self-monitoring system[4] of the plant and bear its costs; - Be responsible for the maintenance, supervision, monitoring according to the relevant License and/or other Licenses or Permits required by the Law, the Regulations, and the relevant technical controls the Centre issues; - Report to the Centre notifications within a maximum of 24 hours from the finding of any negative ecological effects revealed by the self-monitoring; - Provide financial guarantees to guarantee the fulfilment of their obligations.
Investors	- Carry out during the operational phase a self-monitoring system[5] of the plant and bear its costs.

[4] Control procedures and monitoring of a plant includes technological self-monitoring and quality of environmental factors self-monitoring

[5] Control procedures and monitoring of a plant includes technological self-monitoring and quality of environmental factors self-monitoring

4 OVERVIEW ON WASTE INCINERATION

Incineration is used as a treatment for a very wide range of wastes. Incineration itself is commonly only one part of a complex waste treatment system that, altogether, provides for the overall management of the broad range of wastes that arise in society.

The first objective of waste incineration is to treat wastes so as to reduce their volume and hazard, whilst capturing (and thus concentrating) or destroying potentially harmful substances that are, or may be, released during incineration. Incineration processes can also provide a means to enable recovery of the energy, mineral and/or chemical content of waste. Energy recovery from municipal and similar waste has become an important second objective of waste incineration ('waste-to-energy', or 'energy-from-waste', concept).

Basically, waste incineration is the oxidation of the combustible materials contained in the waste. Waste is generally a highly heterogeneous material, consisting essentially of organic substances, minerals, metals, and water. During incineration, flue-gases are created that will contain the majority of the available fuel energy as heat.

Auxiliary burners switch on automatically when the temperature of the combustion gases after the last injection of combustion air falls below the temperatures specified in the relevant technical controls issued by the Centre; or used during plant start-up and shut-down operations in order to ensure that those temperatures are maintained at all times during these operations and as long as unburned waste is in the combustion chamber.[6]

The organic fuel substances in the waste will burn when they have reached the necessary ignition temperature and come into contact with oxygen. The actual combustion process takes place in the gas phase in fractions of seconds and simultaneously releases energy where the calorific value of the waste and oxygen supply is sufficient; this can lead to a thermal chain reaction and self-supporting combustion, i.e., there is no need for the addition of other fuels.

The main stages of the incineration process are:

1. Drying and degassing - here, volatile content is evolved (e.g., hydrocarbons and water) at temperatures generally between 100 °C and 300 °C. The drying and degassing processes do not require any oxidising agent and are only dependent on the supplied heat;
2. Pyrolysis and gasification - pyrolysis is the further decomposition of organic substances in the absence of an oxidising agent at approximately 250–700 °C. Gasification of the carbonaceous residues is the reaction of the residues with water vapour and CO_2 at temperatures typically between 500 °C and 1 000 °C, but it can occur at temperatures up to 1600 °C. Thus, solid organic matter is transferred to the gaseous phase. In addition to the temperature, water, steam, and oxygen support this reaction;
3. Oxidation - the combustible gases created in the previous stages are oxidised, depending on the selected incineration method, at flue-gas temperatures generally between 800 °C and 1450 °C.

These individual stages generally overlap, meaning that spatial and temporal separation of these stages during waste incineration may only be possible to a limited extent. Indeed, the processes partly occur in parallel and influence each other. Nevertheless, it is possible, using in-furnace technical measures, to influence these

[6] (The Implementing Regulations of the Waste Management Law, 2021)

processes so as to reduce polluting emissions. Such measures include furnace design, air distribution and control engineering.

In fully oxidative incineration, the main constituents of the flue-gas are water vapour, nitrogen, carbon dioxide and oxygen. Depending on the composition of the material incinerated and on the operating conditions, smaller amounts of CO, HCl, HF, HBr, HI, NO_X, NH_3, SO_2, VOCs, PCDD/F, PCBs, and heavy metal compounds (among others) are formed or remain. Depending on the combustion temperatures during the main stages of incineration, volatile heavy metals, and inorganic compounds (e.g., salts) are totally or partly evaporated.

These substances are transferred from the input waste to both the flue-gas and the fly ash it contains. A mineral residue fly ash (dust) and heavier solid ash (bottom ash) are created. In municipal waste incinerators, bottom ash is approximately 10 vol-% and approximately 20–30 wt-% of the solid waste input. Fly ash quantities are much lower, generally only a few per cent of input. The proportions of solid residue vary greatly according to the waste type and detailed process design.

For effective oxidative combustion, a sufficient oxygen supply is essential. The air ratio number 'n' of the supplied incineration air to the chemically required (or stoichiometric) incineration air usually ranges from 1.2 to 2.5, depending on whether the fuel is gas, liquid or solid, and the furnace system.

Combustion is only one stage of the overall incineration process. Incinerators usually comprise a complex set of interacting technical components which, when considered together, effect an overall treatment of the waste. Each of these components has a slightly different main purpose, as described in Table below.

Table 4-1: Purpose of various components of a waste incinerator

Objective	Incinerator Component
▪ Destruction of organic substances; ▪ Evaporation of water; ▪ Evaporation of volatile heavy metals and inorganic salts; ▪ Production of potentially exploitable slag; ▪ Volume reduction of residues.	Furnace
▪ Recovery of useable energy.	Energy recovery system
▪ Removal and concentration of volatile heavy metals and in organic matter into solid residues, e.g., flue-gas cleaning residues, sludge from wastewater treatment; ▪ Minimising emissions to all media.	Flue-gas cleaning

The concept of a facility dedicated to the management of waste can be either on site of waste to treat one’s own waste or commercial, or off-site facilities that accept waste for treatment and disposal. A waste facility may function with just one technology, or it may combine multiple technologies, particularly if it is a commercial facility serving a number of Waste Generators[7].

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

As far as Waste Incineration is concerned, on-site facilities are in general encountered in large wastewater treatment plants for the thermal treatment of sewage sludge produced, otherwise they are generally off – site, large-scale facilities as they are of higher capex and opex investments and therefore economies of scale are recommended.

In any case a WI facility is not entitled to engage in any activity related to waste unless the activity licence is issued by the Centre.[8]

4.1 Treatment technology overview

The incineration sector has undergone rapid technological development over the last 25 years. Much of this change has been driven by legislation specific to the industry and this has reduced emissions to air and water. Continual process development is ongoing, with the sector now developing techniques, which limit costs, whilst maintaining or improving environmental performance.

The characteristics of the treated material and the effectiveness of a treatment technology can vary greatly depending on the specific properties of the original waste input and on the type of cleaning system applied.[9] The precise design of a Waste Incineration plant will depend on the type of waste that is being treated. The following parameters and their variability are key drivers:

- Waste chemical composition;
- Waste physical composition, e.g., particle size;
- Waste thermal characteristics, e.g., calorific value, moisture levels.

Processes designed for a narrow range of specific inputs can usually be optimised more than those that receive wastes with greater variability. This in turn can allow improvements to be made in process stability and environmental performance and may allow the simplification of downstream operations such as flue-gas cleaning.

As flue-gas cleaning is often a significant contributor to overall incineration costs (i.e., approximately 15 % to 35 % of the total capital investment) this can then lead to reduced treatment costs at the incinerator. The external costs of pre-treatment, or the selective collection of certain wastes, can however add significantly to the overall costs of waste management and to emissions from the entire waste management system. Often, decisions concerning the wider management of waste (i.e., the complete waste arising, collection,

[7] Waste Producer

[8] (The Implementing Regulations of the Waste Management Law, 2021)

[9] (COMMISSION IMPLEMENTING DECISION (EU) 2018/1147. Best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council., 2018)

transportation, treatment, disposal, etc.) take into account a very large number of factors. The selection of the incineration process can form a part of this wider process.

There are lot of processes and technologies applied in the relevant sector. The selection of best suitable technologies for waste incineration approved by the Centre shall consider the characteristics of the waste being treated as well as the desired output of the process.

The basic stages of the incineration process are:

- Pre-treatment, storage, and handling techniques;
- The thermal treatment stage;
- The energy recovery stage;
- Pollution prevention and abatement:
  - Flue gas cleaning and control systems;
  - Wastewater treatment;
  - Solid residue treatment.

For the thermal treatment stage several options exist, including but not limited to:

- Grate incinerators;
- Rotary Kilns;
- Fluidised Beds;
- Pyrolysis Systems; and
- Gasification Systems.

Other thermal treatment techniques are also listed below[10]:

- Incineration chambers for liquid and gaseous wastes;
- Incineration of liquid and gaseous chlorinated wastes with HCl recovery;
- Incineration of chlorinated liquid wastes with chlorine recycling;
- Wastewater incineration; and
- Plasma processes.

Table 4.2 presents the most common technologies in Waste Incineration stage. Further information on the different processes and their outputs can be found under section 6.1.

Table 4-2: Waste Incineration methods, technology summary, and type of waste treated

Treatment Method	Type of Waste Treated	Technology Summary
Grate incinerators	- Mixed Municipal Wastes; - Commercial & Industrial Non-Hazardous Wastes; - Sewage Sludge;	Thermal treatment technology used for non-homogeneous and low calorific waste. Heat is efficiently collected through boiler water pipes constituting the furnace walls. This helps realize highly

[10] These techniques are not discussed in this TG as a result of their non-application.

Treatment Method	Type of Waste Treated	Technology Summary
	- Certain Health care waste (HCW).	efficient power generation via waste incineration.
Rotary kilns	- Almost any waste; regardless of type and composition; - Hazardous Wastes; most hazardous HCW.	Thermal processing furnaces used for processing solid materials at extremely high temperatures in order to cause a chemical reaction or physical change.
Fluidised beds	- Finely divided Wastes (e.g., RDF); - Sewage Sludge.	A combustion technology system in which a sand bed (or similar inert material) is fluidised by air jets, heated to temperatures high enough to support combustion, combustible wastes are then added.
Pyrolysis Systems	- Municipal Wastes; - Sewage Sludge; - Common HCW;	Waste degassing processes in the absence of oxygen, in which pyrolysis gas (often termed syngas), liquid (pyrolysis oil) or solid (char, mainly ash and carbon) are formed.
Gasification Systems	- Municipal Wastes; - Certain Hazardous Wastes; - Dried Sewage Sludge.	Alternative technologies for thermal waste treatment; partial combustion of organic substances to produce gases which can be used as raw material (through certain reforming processes) or as a fuel.

4.2 General Environmental Considerations

The target of incineration is to provide for an overall reduction in the environmental impact that might otherwise arise from the waste. However, in the course of the operation of incineration installations, emissions and consumption arise, whose existence or magnitude is influenced by the installation design and operation. The main environmental issues that arise directly from incineration installations (i.e., it does not include the wider impacts or benefits of incineration) fall into the following main categories:

- Emissions to air and water;
- Residue production;
- Process noise;
- Energy consumption and production;
- Raw material (reagent) consumption;
- Fugitive emissions and odour – mainly from waste storage;
- Reduction of the storage/handling/processing risks of hazardous wastes.

Typical environmental issues arising from waste incineration include:

- Channelled emissions to air (dust, heavy metals, metalloids, acid and other gases, organic compounds, carbon dioxide) arising directly from incineration of waste (stack releases), from handling and storage of waste or from dry reagent handling and from residue handling and treatment. Techniques for the reduction of emissions to air are analysed in Section 6.5.1;
- Discharge to water (metals, inorganic salts (chlorides, sulphates etc), organic compounds, arising from effluents from pollution control devices, final effluent discharges from wastewater treatment, from boiler water and cooling water, from road drainage, from storage and handling areas and from residue handling and treatment. Techniques for the reduction of discharge to water are described in detail in Section 6.5.2;
- Solid residues (bottom ash & slag, fluidised bed ash, boiler ash, sludge, FGC residues) from the incineration itself and FGC. Treatment techniques for solid residues are presented in Section 6.5.3;
- Process noise from equipment (trucks, cranes, exhaust fans, turbogenerators etc.) Techniques for the prevention and control of noise and vibration emissions are analysed in Section 6.5.7;
- Consumption of energy (imported electricity etc.) and raw materials (wastes, support fuels etc.). Techniques to increase energy and material efficiency are defined in Section 6.4 and 6.5.6 respectively.

Outputs. Generally, the outputs from WI installations are:

- Treated wastes for reuse as fill or construction materials;
- Wastes landfilled without further treatment; and
- Energy (electricity and/or heat as steam or hot water).

The above issues are discussed further in chapters 6 – 9 of this guidance document.

5 SITE SPECIFICATIONS AND INFRASTRUCTURE REQUIREMENTS

Article 95 of Section 8 (Chapter 4) of the IR provides general guidelines for site selection of waste facilities including Waste Incineration facilities. Those include:

- The distance between the suggested site and the production, collection, and storage of Waste locations;
- Availability of infrastructure and paths for facilitating the arrival to the location in all seasons, and the impact of the facility on the traffic at that area;
- That the area has suitable capacity for all generated wastes throughout the facility's lifecycle;
- Avoidance of sites on very steep locations, as level grounds are preferrable;
- The dominant direction and speed of the winds, such that the facility must be located in the opposite direction from the wind direction in that area;
- That the site is as far as possible from any masts, electric lines, railways, airports, facilities' pipelines, and highways; and
- Any other controls or requirements the Centre issues.

The Centre may exempt from any of these conditions in accordance with the nature of the project.

As per article 97 of the IR, when siting Waste Incineration facilities the following locations or sensitive areas should be avoided:

- Sites adjacent to planned land for development purposes such as urban, commercial, and agricultural expansion areas;
- Sites located in valleys, reefs, and flood streams, where the treatment and disposal of Waste may expose the water to contamination, as a result of leakage of fluids to the ground;
- Sites with high groundwater attributed, especially in areas where this water is used for agriculture or drinking;
- Sites on historical archaeological or natural areas or environmental reserves; and
- Any other area deemed by the competent authorities as invalid for the establishment of a facility for the treatment and disposal of Waste.

5.1 Site Infrastructure Guidelines for Waste Incineration facilities

The Site Infrastructure Guidelines as far as Waste Incineration facilities are concerned, are set out as follows:

5.1.1 Siting – General Considerations

Waste Incineration facilities should be configured and organized in accordance with the expected uses of the land within them; this form of spatial organization and planning is known as "zoning ".[11]

[11] (United Nations Industrial Development Organization, INTERNATIONAL GUIDELINES FOR INDUSTRIAL PARKS, 2019)

Zoning helps by encouraging on-site economies of scale in utilities infrastructure concentration and utilization, for instance, as regards waste collection and treatment, internal transport networks and other amenities. It also smooths vehicular and pedestrian circulation by enabling clear movement patterns.

Waste Incineration zoning maps are prepared based on such key site parameters as boundary (perimeter) shape, physical site features, area availability, environmental considerations, micro climatic conditions, compatibility issues, surrounding areas, accessibility, transportation issues and visibility.

Existing and adjacent land use are also critical considerations in deciding on nearby and future onsite land uses and zoning.

Zoning within the Waste Incineration Plant can be designed furthermore in such a way as to encourage industrial symbiosis for the utilization of materials, industrial water, and energy by-products.

Energy efficiency optimisation can be attained by stimulating and facilitating ‘energy symbioses’. More specifically, consideration must always be given to utilising not only the electricity from a thermal treatment and/or Waste Incineration plant but also the waste heat. As a result, specific plant should look to be sited close to where its’ electrical and thermal outputs can be used; surrounding industries or nearby communities.

Segregating polluting and non-polluting activity is another sound zoning practice.

In any case, the Waste Incineration Plant must be within the approved plans as industrial zones, and proportional in size to the volume of work and the quantity of production, according to the areas approved in the industrial plans.[12]

5.1.2 Surface Water Drainage

Surface water caused by run off of entrained water from the Waste mass and storm water drainage are collected and managed separately. Contaminated water is transferred to a treatment unit while storm water runoff is disposed on to a natural recipient.

The design of the drainage system must be taken into account pre-development. The drainage systems must be inspected at annual intervals throughout the operational life of the facility to ensure their integrity.

5.1.3 Utilities and Facilities

In order to ensure the health and safety of on-site personnel, and to enable control of operations on site the following utilities and facilities in combination with the appropriate equipment must be provided at all Waste Incineration plants.[13]:

- Water supply:
  - Sufficient drinking and non-potable water, with separate distribution networks;
  - Water pumping station.
- Power supply:
  - Distribution substations at strategic locations, with network of underground cables or

[12] (The Implementing Regulations of the Waste Management Law, 2021)
[13] (United Nations Industrial Development Organization, INTERNATIONAL GUIDELINES FOR INDUSTRIAL PARKS, 2019)

overhead lines.

- Street lighting:
  - Conventional or solar street lighting;
  - Smart energy-efficient lighting.
- Sewerage:
  - Sewage and effluent collection and storage systems;
  - Systems for removal of contaminants from wastewater, and storm run-off through primary treatment of effluents;
  - Treated and recycled water distribution system.
- IT connectivity, telecommunication, and ICT-enabled resident services:
  - High-speed Wi-Fi and internet services;
  - Robust data infrastructure system;
  - Communication system within the physical-chemical treatment plant.
- Safety and security:
  - Health care centre, medical facilities;
  - Emergency response centre/s (including for accidents and first aid, fire, and chemical hazards, security incidents, natural disasters, and crises, etc.);
  - Public safety infrastructure, including lighting and CCTV surveillance systems.

5.1.4 Fencing and Security

A fence must be constructed around the perimeter of the WI plant to reduce onsite trespass, provide a screen for the facility, delineate the property lines, and provide a control for litter blow. Fences must be a minimum of 2 metres tall around the entire perimeter of the site. Appropriate signage to discourage trespassers must be erected at the site entrance.

5.1.5 Waste Rejects Area

An area of the site must be made available to allow for the temporary segregation of suspect, burning or unacceptable Waste loads, which enter the site. This area should be located away from the main areas frequented by personnel. Firefighting equipment must be available in case of burning Waste loads.

This area must be clearly marked with reference to its required purpose to ensure that there is no inadvertent mixing of Waste materials.

A paved surface area of 10 metres by 10 metres minimum must be provided, with its own linked drainage collection system. All drainage from this part of the site must be collected and held in segregation until laboratory testing proves that it is suitable for discharge into the onsite surface drainage system. Where unsuitable, the wash water must be tankered off for offsite treatment at a suitable water treatment facility.

6 DESIGN REQUIREMENTS & BEST SUITABLE TECHNIQUES APPLICABLE FOR WASTE INCINERATION FACILITIES

6.1 Introduction

As mentioned in Section 4.1 in this guidance document the basic stages of the incineration process are:

1. Pre-treatment, storage, and handling techniques;
2. The thermal treatment stage;
3. The energy recovery stage;
4. Pollution prevention and abatement.

Each stage will be designed for the specific type(s) of waste treated at the installation. Information describing these stages is included later in this chapter.

Many installations operate continuously, 24 hours a day, nearly 365 days a year. Control systems and maintenance programs play an important role in securing the availability of the plant. The following figure depicts an example of a MSW incineration plant.

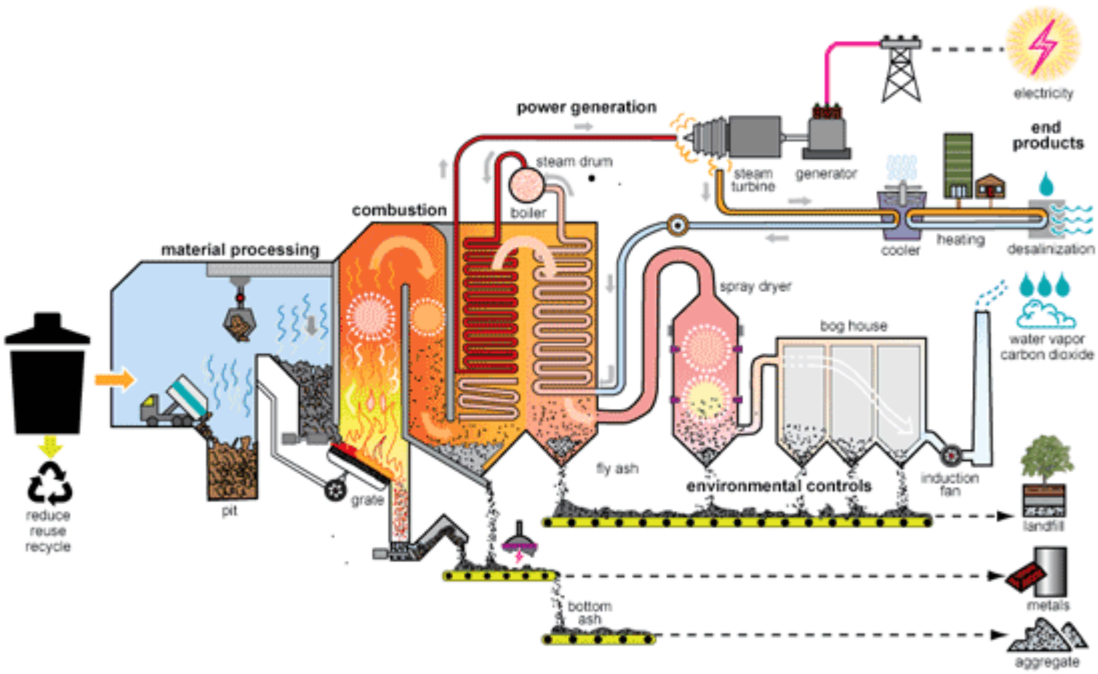


Figure 1: Example of a MSW incineration plant

Following are the best suitable techniques per stage of the incineration process.

6.2 Techniques for pre-treatment storage and handling

The different types of wastes that are incinerated may need different types of pre-treatment, storage and handling operations. This section describes the most relevant of these operations for the following wastes:

- Municipal wastes (residual wastes - not pre-treated);
- Pre-treated municipal wastes (e.g., selected fractions or RDF);
- Non-hazardous industrial wastes and packaging;
- Agricultural waste;
- Hazardous waste;
- Sewage sludge;
- Health care waste[14].

6.2.1 Municipal solid waste and similar (MSW)

6.2.1.1 Collection and pre-treatment outside the MSW incineration plant

The local collection and pre-treatment applied to MSW will strongly influence the nature of the material received at the incineration plant. Recycling schemes may mean that some fractions) [15]have been removed. Therefore, the pre-treatment and other operations carried out at the incinerator should therefore be consistent with the collection system in place.

6.2.1.2 Municipal solid waste pre-treatment within the incineration plant

In-bunker mixing is commonly used to blend MSW. This usually involves using the same waste grab used for hopper loading. Most commonly, the pre-treatment of MSW is limited to the shredding of pressed bales, bulky waste, etc., although sometimes more extensive shredding is carried out.

6.2.1.3 Waste delivery and storage

The waste delivery area is where the delivery trucks, trains or containers arrive in order to unload the waste into the bunker, usually after visual control and weighing. Discharge is carried out through openings between the delivery area and the bunker.

Tilting and sliding beds may be used to facilitate waste transfer to the bunker. The openings can be closed to prevent the escape of odours, act as a firebreak and reduce the risk of vehicle accidents. Enclosure of the delivery area can be effective in reducing odour, noise, and emission problems from the waste.

6.2.2 Hazardous waste

6.2.2.1 Waste acceptance

Due to the very wide variety of wastes encountered, their high potential hazardousness, and elevated uncertainties over the precise knowledge of the waste composition, significant effort is required to assess, characterise, and trace incoming wastes through the entire process. The systems adopted need to provide a clear audit trail that allows the tracing of any incidents to their source. This then enables procedures to be adapted to prevent further incidents. The exact procedures required for waste acceptance and storage depend on the chemical and physical characteristics of the waste.

[14] HWC is mentioned for completeness only. It is analysed in detail in the corresponding TG.

[15] Glass and metals, wastes with a high calorific value (e.g., paper, card, and plastic), organic wastes (e.g., food and garden wastes), bulky wastes, hazardous wastes.

In some cases, a typical incinerator accommodates or is designed to accept and treat both hazardous and non-hazardous wastes (MSW, other non-hazardous waste). A prominent example is both water- cooled grate incinerators and rotary kilns. In this case, flue-gases from the different wastes are treated in common FGC systems.[16]

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 on the appropriate storage and treatment required. Such a declaration may include:

- Data on the waste producer and responsible persons;
- Data on the waste code and other designations for the waste;
- Data on the origin of the waste;
- Analytical data on particular toxic materials;
- General characteristics, including combustion parameters, such as Cl, S, calorific value, water content;
- Other safety/environmental information;
- Legally binding signature; and
- Additional data upon request of the accepting plant.

Some types of waste require additional measures. Homogeneous, production-specific waste can often be adequately described in general terms. Additional measures are usually required for waste of a less well-known composition (e.g., waste from refuse dumps or from the collections of hazardous household waste), including the inspection of each individual waste container.

When the waste composition cannot be described in detail (e.g., small amounts of pesticides or laboratory chemicals), 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. For example, risks may arise from:

- Wastes with phosphides;
- Wastes with isocyanates;
- Wastes with alkaline metals (for example, or other reactive metals);
- Cyanide with acids;
- Wastes forming acid gases during combustion; and
- Wastes with mercury.

Delivered wastes generally undergo specific waste acceptance controls, which may include detailed laboratory analyses depending on the volume and nature of the waste. Visual and analytical investigations of the waste are compared with the data contained in the declaration received from the waste producer. The waste is either accepted and allocated to the appropriate storage area or rejected in the case of significant deviations.

6.2.2.2 Storage

[16] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

The general principles of storage are presented in the TG on Temporary Waste Storage issued by the Centre. This section aims to highlight some issues that are specific to the incineration of hazardous waste within treatment facilities such as Incineration Plants.

A common practice is to ensure, as far as possible, that hazardous wastes are stored in the same containers that are used for transportation, thus avoiding the need for additional handling and transfer. Good communication with the waste producer helps to ensure that waste is stored, transferred, and handled such that risks all along the chain are well managed. It is also important that only well-characterised and compatible[17] wastes are stored in tanks or bunkers.

6.2.2.2.1 Storage of solid hazardous waste

Solid and unpumpable pasty hazardous waste that has not been degassed and does not smell is stored temporarily in bunkers. Storage and mixing areas can be separated in the bunker. This can be achieved through several design segments. Cranes feed both solid and pasty waste products. The bunker must be designed to prevent emissions into the ground.

The bunker and container storage should be enclosed unless there are health and safety reasons for not enclosing them (e.g., danger of explosion and fire). Combustion air for the incinerator is usually taken from the waste storage area to prevent emissions of dust and odours. Waste storage areas should be constantly monitored to ensure the early detection of any fires.

6.2.2.2.2 Storage of pumpable hazardous waste

Larger amounts of fluid and pumpable pasty wastes are temporarily stored in tanks. Sufficient numbers and sizes of tanks must be available to accommodate separate storage of incompatible types of waste (e.g., oxidisers stored separately from flammable materials to prevent fires/explosions, and acids stored separately from sulphides to prevent hydrogen sulphide production).

Tanks, pipelines, valves, and seals must be adapted to the waste characteristics in terms of construction, material selection, and design. They must be sufficiently corrosion-proof and offer the option of cleaning and sampling. Flat-bed tanks are generally only deployed for large loads.

6.2.2.2.3 Storage of containers and tank containers

For safety reasons, hazardous waste is most often accumulated in special containers. These containers are then delivered to the incineration plant. Delivery of bulk liquids is also taken.

The delivered containers may be stored, or the contents transferred. In some cases, according to a risk assessment, the waste may be directly injected via a separate pipeline into the furnace. Heated transfer lines may be used for wastes that are only liquid at higher temperatures.

Storage areas for containers and tank containers are usually located outside, with or without roofs. Drainage from these areas is generally controlled, as contamination may arise.

6.2.2.3 Feeding and pre-treatment

[17] Detailed information on incompatible waste can be found in the Technical Guideline on Temporary Waste Storage

The wide range of chemical and physical properties of some hazardous wastes may cause difficulties in the incineration process. Some degree of waste blending or specific pre-treatment is often carried out to produce a more consistent feed material.

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

- A shredder for bulky solids (e.g., contaminated packages); and
- A dedicated shredder purely for drums.

Other forms of pre-treatment may be carried out depending on the waste composition and the individual characteristics of the incineration plant, for example:

- Neutralisation (for waste acceptance, pH values from 4 to 12 are normal);
- Sludge drainage; and
- Solidification of sludge with binding agents.

6.2.3 Sewage sludge

6.2.3.1 Composition of sewage sludge

The composition of sewage sludge varies according to many factors, including:

- System connections, e.g., industrial inputs can increase heavy metal loads;
- Coastal locations, e.g., for saltwater inclusion;
- Treatments carried out at the treatment works, e.g., crude screening only, anaerobic sludge digestion, aerobic sludge digestion, addition of treatment chemicals;
- Weather/time of year, e.g., rainfall can dilute the sludge.

6.2.3.2 Pre-treatment of sewage sludge

6.2.3.2.1 Physical dewatering

Mechanical drainage before incineration reduces the volume of the sludge mixture and increases the heat value. This allows independent and economical incineration. The success of mechanical drainage depends on the selected machines, the conditioning carried out, and the type and composition of the sludge.

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.

Often the sludge is conditioned before the mechanical drainage to improve its drainage. This is achieved with the help of additives that contain flock-building materials.

6.2.3.2.2 Drying

Often, a substance that has been dried by mechanical drainage is still too wet for auto-thermal incineration. A thermal drying plant can be used to increase the heat value and reduce the volume of the sludge before the incineration furnace.

The drying/dewatering of sewage sludge is carried out in separate or connected drying plants. The following dryer plants are utilised:

- Disk dryer;
- Drum dryer;
- Fluidised bed dryer;
- Belt dryer;
- Thin film dryer/disk dryer;
- Cold air dryer;
- Thin film dryer;
- Centrifugal dryer;
- Solar dryer;
- Combinations of different types.

6.3 Comparison of different processes and techniques for the thermal stage

Combustion, pyrolysis, and gasification are widely used thermal processes for waste [18]conversion to energy that involve thermal breakdown in the form of heat or electricity. These thermal methods are differentiated by process conditions:

- Combustion - full oxidative combustion (by far the most common process);
- Pyrolysis - thermal degradation of organic material in the absence of oxygen;
- Gasification - partial oxidation.

The reaction conditions and products of these thermal treatments are shown in table below[19]:

Table 6-1: Typical reaction conditions and products of combustion, pyrolysis, and gasification processes

	Combustion	Pyrolysis	Gasification
Reaction temperature (ºC)	800-1450	250-700	500-1600
Pressure (bar)	1	1	1-45

[18] municipal wastes (residual wastes - not pretreated); pre-treated municipal wastes (e.g. selected fractions or RDF); non-hazardous industrial wastes and packaging; hazardous wastes; sewage sludges; Health care waste.
[19] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

	Combustion	Pyrolysis	Gasification
Atmosphere	Air	Inert/Nitrogen	Gasification agent: O_2, H_2O
Stoichiometric ratio	>1	0	<1
Products from the process in the gas phase	CO_2, H_2O, O_2, N_2	Syngas(H_2,CO), hydrocarbons, H_2O, N_2	High level of syngas(H_2,CO),CO_2,CH4, H_2O, N_2
Products from the process in the solid phase	Ash, slag	Ash, coke	Slag, ash
Products from the process in the liquid phase		Pyrolysis oil and water	

All these methods have some advantages, limitations, and environmental impact.

Pyrolysis and gasification plants follow a similar basic structure to waste combustion plants but there are some significant differences:

- Reduced generation of pollutants (e.g., dioxin, nitrogen oxides, sulphur oxides, furans);
- Generation of by-products (e.g., syngas) further recovered;
- Product combustion, may be a separate stage and include energy recovery by combustion of the products and subsequent gas/water/solid treatments and management;
- Lack of established technologies in case waste is used as a feedstock;
- Pre-treatment, may be more extensive to provide a narrow profile feedstock and additional equipment is required for handling, treating, and storing the rejected material;
- Loading, greater attention required to sealing;
- Thermal reactor, to replace (or in addition to) the combustion stage;
- Product handling, gaseous and solid products require handling, storage, and possible further treatment.

Table 6.2 shows a comparative analysis of the aforementioned thermal approaches.

Table 6-2:Comparison of different Waste Incineration processes[20]

Waste Incineration Process	Advantages	Limitations
Combustion: A chemical reaction between substances, usually including oxygen and usually accompanied by the generation of heat and light in the form of flame.	• Reduces volume and weight of waste for landfilling (70–80%); • Technology with an established industrial infrastructure; • Converts MSW into combined heat and energy, electricity, and steam.	• Generates huge amounts of greenhouse gases and pollution; • Production of dioxins and other persistent organic pollutants (POP); • Highly ineffective process for waste with a high moisture content; • Extensive infrastructure and equipment required.
Gasification: A thermochemical process that converts biomass into a combustible gas called producer gas (syngas)	• Reducing the waste quantity by 50–90%; • High versatility[21]; • Converts MSW to H_2, CH_4, CO rich[22] synthesis gas and carbon products; • Reduced generation of pollutants (e.g., dioxin & furans) as compared to combustion.	• Tar production; • More suitable for large power plants; • Corrosion of metal pipes during reaction; • Higher operating/maintenance, and pre-treatment l costs as compared to combustion; • High energy consumption; • Extensive infrastructure and equipment required; • Lack of knowledge in the design, manufacture, and operation of gasifiers as well as the hazard and safety issues of gasifiers.
Pyrolysis: The process of thermal conversion of organic matter using a catalyst in the absence of oxygen in which pyrolysis gas (often termed syngas),	• High efficiency, up to 80% energy recovery; • Converts MSW into bio-oil, biochar, and pyrolysis gas; • Limited field requirements;	• Coke formation from liquid products; • Liquid products have a high-water content;

[20] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)
[21] The possibility of managing various types of waste.

[22] High content of H2, CH4, and CO in the synthesis gas can increase its calorific value. waste

Waste Incineration Process	Advantages	Limitations
liquid (pyrolysis oil) or solid (char, mainly ash and carbon) are formed.	• Generates lower amount of pollutants (dioxin, nitrogen oxides and sulphur oxides) as compared to incineration; • High versatility; • No need to do the shredding work; • Emission control strategies are furnished with pyrolysis facility.	• High viscosity of pyrolysis oil may be problematic for its burning and transportation; • Higher pre-treatment, operating and capital costs as compared to gasification and combustion; • Extensive infrastructure and equipment required.

Combustion, pyrolysis, and gasification have many similarities and the products produced can be the same but in a different ratio. When choosing the most suitable mechanism for energy production, the desired final products and end uses are to be taken into account. For example, if the end use is for transportation fuels, power and heat or electricity generation. And whether the desired final product is gas, char, oils or only heat, is to be considered.

A matrix of technologies for Waste Incineration processes is provided in Appendix 1. Most of the Waste Incineration processes are essential unit processes that are widely used in various applications in Waste Incineration.

In particular the matrix in Appendix 1 includes information on a summary of the technology, the output of the process and the related management options, as well as the air emissions and water discharges along with the suitable abatement techniques.

6.4 Techniques to increase energy recovery

Energy inputs to the incineration process may include[23]:

- Waste (mainly);
- Support fuels, (e.g., diesel, natural gas):
  - For start-up and shutdown;
  - To maintain required temperatures with lower calorific value wastes;
  - For flue-gas reheating before treatment or release;
- Imported electricity:
  - When the turbine(s) or all lines are stopped, and for plants without electricity generation.

Energy production, self-consumption and exports may include:

- Heat (as steam or hot water);
- Electricity;

[23] Some of the above energy inputs contribute to steam/heat production where boilers are used and therefore the energy is partially recovered in the process.

- Syngas (pyrolysis and gasification plants that do not burn the syngas on site).

Pyrolysis and gasification processes may export some of the energetic value of the incoming waste with the substances they export, e.g., syngas, chars, oils. In many cases these products are either directly or subsequently burned as fuels to utilise their energy value, although they may also be used for their chemical value as a raw material, after pre-treatment if required.

Most incineration plants in Europe produce and export electricity, heat, or both.

Therefore, the efficient recovery of the energy content of the waste is generally considered to be a key issue for the WI industry. To increase the energy efficiency of the incineration plant, BAT is to use an appropriate combination of the techniques given below.

Technique		Description	Applicability
a	**Drying of sewage sludge**	After mechanical dewatering, sewage sludge is further dried, using for example low-grade heat, before it is fed to the furnace. The extent to which sludge can be dried depends on the furnace feeding system.	Applicable within the constraints associated with the availability of low-grade heat.
b	**Reduction of the flue-gas flow**	The flue-gas flow is reduced through, e.g.: - improving the primary and secondary combustion air distribution; - flue-gas recirculation. A smaller flue-gas flow reduces the energy demand of the plant (e.g., for induced draught fans).	For existing plants, the applicability of flue-gas recirculation may be limited due to technical constraints (e.g., pollutant load in the flue-gas, incineration conditions).
c	**Minimisation of heat losses**	Heat losses are minimised through, e.g.: - Use of integral furnace-boilers, allowing for heat to also be recovered from the furnace sides; - Thermal insulation of furnaces and boilers; - Flue-gas recirculation; - Recovery of heat from the cooling of slags and bottom ashes.	Integral furnace-boilers are not applicable to rotary kilns or to other furnaces dedicated to the high-temperature incineration of hazardous waste.
d	**Optimisation of the boiler design**	The heat transfer in the boiler is improved by optimising, for example, the: - Flue-gas velocity and distribution; - Water/steam circulation; - Convection bundles;	Applicable to new plants and to major retrofits of existing plants.

Technique		Description	Applicability
		▪ On-line and off-line boiler cleaning systems in order to minimise the fouling of the convection bundles.	
e	**Low-temperature flue-gas heat exchangers**	Special corrosion-resistant heat exchangers are used to recover additional energy from the flue-gas at the boiler exit, after an ESP, or after a dry sorbent injection system	Applicable within the constraints of the operating temperature profile of the FGC system. In the case of existing plants, the applicability may be limited by a lack of space.
f	**High steam conditions**	The higher the steam conditions (temperature and pressure), the higher the electricity conversion efficiency allowed by the steam cycle. Working at high steam conditions (e.g., above 45 bar, 400 °C) requires the use of special steel alloys or refractory cladding to protect the boiler sections that are exposed to the highest temperatures.	Applicable to new plants and to major retrofits of existing plants, where the plant is mainly oriented towards the generation of electricity. The applicability may be limited by: ▪ The stickiness of the fly ashes; ▪ The corrosiveness of the flue-gas.
g	**Cogeneration**	Cogeneration of heat and electricity where the heat (mainly from the steam that leaves the turbine) is used for producing hot water/steam to be used in industrial processes/activities or in a district heating/cooling network.	Applicable within the constraints associated with the local heat and power demand and/or availability of networks.
h	**Flue-gas condenser**	A heat exchanger or a scrubber with a heat exchanger, where the water vapour contained in the flue-gas condenses, transferring the latent heat to water at a sufficiently low temperature (e.g., return flow of a district heating network). The flue-gas condenser also provides co-benefits by reducing emissions to air (e.g., of dust and acid gases). The use of heat pumps can increase the amount of energy recovered from flue-gas condensation.	Applicable within the constraints associated with the demand for low-temperature heat, e.g., by the availability of a district heating network with a sufficiently low return temperature.
i	**Dry bottom ash handling**	Dry, hot bottom ash falls from the grate onto a transport system and is cooled down by ambient air. Useful energy is recovered by using the cooling air for combustion	Only applicable to grate furnaces. There may be technical restrictions that prevent retrofitting to existing furnaces.

Also, to increase the resource efficiency of the incineration plant, BAT is to use a heat recovery boiler, in order to recover the energy contained in the flue-gas, producing hot water and/or steam, which may be exported, used internally, and/or used to produce electricity.

6.5 Techniques for the prevention reduction and control of emissions

Waste itself and its management are themselves a significant environmental issue. The thermal treatment of waste may therefore be seen as one of the solutions to the environmental threats posed by poorly managed or unmanaged waste streams.

The target of thermal treatment is to provide for an overall reduction in the environmental impact that might otherwise arise from the waste. However, during the operation of incineration installations, emissions and consumption arise, whose existence or magnitude is influenced by the installation design and operation. This section, therefore, briefly, summarises the main environmental issues that arise directly from incineration installations (i.e., it does not include the wider impacts or benefits of incineration).

Essentially, these direct impacts fall into the following main categories:

- Emissions to air and water;
- Residue production;
- Process noise;
- Energy consumption and production;
- Raw material (reagent) consumption;
- Fugitive emissions and odour – mainly from waste storage;
- Reduction of the storage/handling/processing risks of hazardous wastes.

6.5.1 Techniques for the reduction of emissions to air

Emissions to air have long been the focus of attention for waste incineration plants. Significant advances in technologies for the cleaning of flue-gases in particular have led to major reductions in the emissions to air.

However, the control of emissions to air remains an important issue for the sector. As the entire incineration process is usually under slightly sub atmospheric pressure (because of the common inclusion of an induced draught extraction fan), emissions to air generally take place exclusively from the stack.

A summary of the main emissions to air from stack releases is shown below[24]:

- Dust (particulate matter - various particle sizes);
- Acid and other gases (HCl, HF, HBr, HI, SO_2, NO_x and NH_3);
- Heavy metals (Hg, Cd, Tl, As, Ni and Pb);
- Carbon dioxide (not covered under the IED or this BREF);

[24] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

- Other carbon compounds (CO, VOCs, PCDD/F and PCBs).

Releases to air from other sources may include:

- Odour (from handling and storage of untreated waste);
- Greenhouse gases (from decomposition of stored wastes, e.g., methane, CO_2);
- Dust (from dry reagent handling and waste storage areas).

The forementioned emissions to air from Waste Incineration Plants shall not exceed the emission limit values set by the IR of the Environmental Law (decree M/165) as issued by NCEC.

All of the potential impacts of a WI plant must be identified during conceptual model development and refined during the Authorisation Process (both the authorisation processes carried out by the Centre and NCEC). Detailed measures to mitigate the impacts must be included in the plant design and set out in the Working Plan.

6.5.1.1 Diffuse emissions to air

In order to prevent or reduce diffuse dust emissions to air from the treatment of slags and bottom ashes, BAT is to use an appropriate combination of the techniques given below[25]:

Table 6-3:Techniques to prevent or reduce dust emissions to air from the treatment of slags and bottom ashes

	Abatement Technique	Description	Applicability
a	**Enclose and cover equipment**	Enclose/encapsulate potentially dusty operations (such as grinding, screening) and/or cover conveyors and elevators. Enclosure can also be accomplished by installing all of the equipment in a closed building.	Installing the equipment in a closed building may not be applicable to mobile treatment devices.
b	**Limit height of discharge**	Match the discharge height to the varying height of the heap, automatically if possible (e.g., conveyor belts with adjustable heights).	Generally applicable.
c	**Protect stockpiles against prevailing winds**	Protect bulk storage areas or stockpiles with covers or wind barriers such as screening, walling or vertical greenery, as well as correctly orienting the stockpiles in relation to the prevailing wind.	Generally applicable.

[25] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

Abatement Technique		Description	Applicability
d	**Use water sprays**	Install water spray systems at the main sources of diffuse dust emissions. The humidification of dust particles aids dust agglomeration and settling. Diffuse dust emissions at stockpiles are reduced by ensuring appropriate humidification of the charging and discharging points, or of the stockpiles themselves.	Generally applicable.
e	**Optimise moisture content**	Optimise the moisture content of the slags/bottom ashes to the level required for efficient recovery of metals and mineral materials while minimising the dust release.	Generally applicable.
f	**Operate under sub-atmospheric pressure**	Carry out the treatment of slags and bottom ashes in enclosed equipment or buildings (see technique a) under sub-atmospheric pressure to enable treatment of the extracted air with an abatement technique as channelled emissions.	Only applicable to dry-discharged and other low-moisture bottom ashes.

6.5.1.2 Channelled emissions to air

6.5.1.2.1 Emissions of dust, metals, and metalloids

In order to reduce channelled emissions to air of dust, metals, and metalloids from the incineration of waste, BAT is to use one or a combination of the techniques given below[26]:

Table 6-4: Techniques to reduce emissions to air of dust, metals, and metalloids from the incineration of waste

	Abatement Technique	Description	Applicability
a	**Bag filter**	Bag or fabric filters are constructed from porous woven or felted fabric through which gases are passed to remove particles. The use of a bag filter requires the selection of a fabric suitable for the characteristics of the flue-gas and the maximum operating temperature.	Generally applicable to new plants. Applicable to existing plants within the constraints associated with the operating temperature profile of the FGC system.
b	**Electrostatic precipitator**	Electrostatic precipitators (ESPs) operate such that particles are charged and separated under the influence of an electrical field. Electrostatic precipitators are capable of operating under a wide range of conditions. The abatement efficiency may depend on the number of fields, residence time (size), and upstream particle removal devices. They generally include between two and five fields. Electrostatic precipitators can be of the dry or of the wet type depending on the technique used to collect the dust from the electrodes. Wet ESPs are typically used at the polishing stage to remove residual dust and droplets after wet scrubbing.	Generally applicable.
c	**Dry sorbent injection**	The injection and dispersion of sorbent in the form of a dry powder in the flue-gas stream. Alkaline sorbents (e.g., sodium bicarbonate, hydrated lime) are injected to react with acid gases (HCl, HF and SOX). Activated carbon is injected or co-injected to adsorb in particular PCDD/F and mercury. The resulting solids are removed, most often with a bag filter. The excess reactive agents may be recirculated to decrease their consumption, possibly after	Generally applicable.

[26] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

Abatement Technique		Description	Applicability
		reactivation by maturation or steam injection. Not relevant for the reduction of dust emissions. Adsorption of metals by injection of activated carbon or other reagents in combination with a dry sorbent injection system or a semi-wet absorber that is used to reduce acid gas emissions.	
d	**Wet scrubber**	Use of a liquid, typically water or an aqueous solution/suspension, to capture pollutants from the flue-gas by absorption, in particular acid gases, as well as other soluble compounds and solids. To adsorb mercury and/or PCDD/F, carbon sorbent (as a slurry or as carbon-impregnated plastic packing) can be added to the wet scrubber. Different types of scrubber designs are used, e.g., jet scrubbers, rotation scrubbers, Venturi scrubbers, spray scrubbers and packed tower scrubbers. Wet scrubbing systems are not used to remove the main dust load but installed after other abatement techniques, to further reduce the concentrations of dust, metals, and metalloids in the flue-gas.	There may be applicability restrictions due to low water availability, e.g., in arid areas
e	**Fixed- or moving-bed adsorption**	The flue-gas is passed through a fixed- or a moving-bed filter where an adsorbent (e.g., activated coke, activated lignite or a carbon-impregnated polymer) is used to adsorb pollutants.	The applicability may be limited by the overall pressure drop associated with the FGC system configuration. In the case of existing plants, the applicability may be limited by a lack of space.

Table 6-5: NCEC established limits for channelled emissions to air of dust, metals, and metalloids from the incineration of waste:[27]

	Parameter	Combustion Facilities (constructed or modified after September 1, 2005)	Hazardous and Medical Waste Incineration (For facilities constructed before September 1, 2005)	Hazardous and Medical Waste Incineration (constructed or modified after September 1, 2005)
a	**PM**	43 ng/l (0.1 Ib/MBTU)	34 mg/dscm with correcting divided by 7% of oxygen	34 mg/dscm with correcting divided by 7% of oxygen
b	**Heavy Metals**	▪ Antimoine: 0.001512 ng/J ▪ Arsenic: 0.000378 ng/J ▪ Beryllium: 0.000063 ng/J ▪ Cadmium: 0.000025 ng/J ▪ Chrome: 0.002520 ng/J ▪ Cobalt: 0.003780 ng/J ▪ Lead: 0.001008 ng/J ▪ Manganese: 0.00252 ng/J ▪ Nickel: 0.011340 ng/J ▪ Selenium: 0.002520 ng/J	▪ Antimoine: 300 g/hr ▪ Lead: 90 g/hr ▪ Silver: 3,000 g/hr ▪ Barium: 50,000 gr/hr ▪ Talium: 300 gr/hr ▪ Arsenic: 2.3 g/hr ▪ Cadmium: 5.4 g/hr ▪ Chrome: 0.82 g/hr ▪ Barium: 4 g/hr	-
c	**Tl + Cd**	-	-	0.05 mg/dscm
d	**Sb + Pb + Co + As + Cr + Cu + Mn + Ni + V**	-	-	0.05 mg/dscm

Unless otherwise specified, compliance will be determined by comparing hourly average data corrected for standard temperature, pressure, humidity, and oxygen content as defined by US EPA methods.

[27] (Executive Regulations for Air Quality, For the environmental law issued by the Royal Decree No.(M/165),Ministry of Environment, Water & Agriculture, Dated 19/11/1441 AH, Kingdom of Saudi Arabia)

Table 6-6: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of dust, metals, and metalloids from the incineration of waste:

	Parameter	BAT-AEL (mg/Nm^3)[28 29 30]	Averaging period
a	**Dust**	< 2-5	Daily average
b	**Cd+Tl**	0.005–0.02	Average over the sampling period
c	**Sb+As+Pb+Cr+Co+Cu+Mn+Ni+V**	0.01–0.3	Average over the sampling period
For existing plants dedicated to the incineration of hazardous waste and for which a bag filter is not applicable, the higher end of the BAT-AEL range is 7 mg/Nm^3			

Table 6-7: BAT-associated emission levels (BAT-AELs) for channelled dust emissions to air from the enclosed treatment of slags and bottom ashes with extraction of air

Parameter	BAT-AEL (mg/Nm^3)	Averaging period
Dust	2-5	Average over the sampling period

6.5.1.2.2 Emissions of HCl, HF and SO_2

In order to reduce channelled emissions of HCl, HF and SO_2 to air from the incineration of waste, BAT is to use a combination of the techniques given below[31]:

Table 6-8: Techniques to reduce emissions of HCl, HF and SO_2 to air from the incineration of waste

	Abatement Technique	Description	Applicability
a	**Wet scrubber**	See Section 6.2.1.2.1	There may be applicability restrictions due to low water availability, e.g., in arid areas.
b	**Semi-wet absorber**	Also called semi-dry absorber. An alkaline aqueous solution or suspension (e.g., milk of lime) is added to the flue-gas stream to capture the acid gases. The water evaporates and the reaction products are dry. The resulting solids may be	Generally applicable.

[28] (JRC Reference Report on Monitoring of Emissions to Air and Water from IED installations (ROM REF),JRC IPTS EIPPCB,COM, European Commission, 2018)
[29] (Study of the performances of existing and under development AMSs (Automated Measuring Systems) and SRMs (Standard Reference Methods) for air emissions at the level of and below existing ELVs (Emission Limit Values) and BATAELs (Best Available Techniques A, INERIS, 2017)
[30] (Study on AMS and SRM performances and their impact on the feasibility of lowering ELVs for air emissions in the context of the BREFs and BATs revision and of BATAELs elaboration according to the IED,INERIS, Institut National de l'Environnement Industriel et des Risques,2016)
[31] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

Abatement Technique		Description	Applicability
		recirculated to reduce reagent consumption. This technique includes a range of different designs, including flash-dry processes which consist of injecting water (providing for fast gas cooling) and reagent at the filter inlet.	
c	**Dry sorbent injection**	See Section 6.2.1.2.1	Generally applicable.
d	**Direct desulphurisation**	The addition of magnesium- or calcium-based absorbents to the bed of a fluidised bed furnace. Used for partial abatement of acid gas emissions upstream of other techniques.	Only applicable to fluidised bed furnaces.
e	**Boiler sorbent injection**	The injection of magnesium- or calcium-based absorbents at a high temperature in the boiler post-combustion area, to achieve partial abatement of acid gases. The technique is highly effective for the removal of SO_x and HF and provides additional benefits in terms of flattening emission peaks. Used for partial abatement of acid gas emissions upstream of other techniques.	Generally applicable.

Table 6-9: NCEC established limits for channelled emissions to air of HCl, HF and SO_2 from the incineration of waste[32]

Parameter		Combustion Facilities (constructed or modified after September 1, 2005)	Hazardous and Medical Waste Incineration (For facilities constructed before September 1, 2005)	Hazardous and Medical Waste Incineration (constructed or modified after September 1, 2005)
a	**HCl**	0.00005 ng/J[33]	100 mg/dscm or removal efficiency reaches 99% at least if the emission reaches 1.8 kg/hr	10 mg/dscm
b	**HF**	0.00005 ng/J[34]	5 mg/dscm	1 mg/dscm

[32] (Executive Regulations for Air Quality, For the environmental law issued by the Royal Decree No.(M/165),Ministry of Environment, Water & Agriculture, Dated 19/11/1441 AH, Kingdom of Saudi Arabia)
[33] Fossil-fuel fired team generating unit or furnaces with a heat input capacity more than 250 MBTU/h (73 MW)
[34] Fossil-fuel fired team generating unit or furnaces with a heat input capacity more than 250 MBTU/h (73 MW)

Parameter		Combustion Facilities (constructed or modified after September 1, 2005)	Hazardous and Medical Waste Incineration (For facilities constructed before September 1, 2005)	Hazardous and Medical Waste Incineration (constructed or modified after September 1, 2005)
c	SO_2	215 ng/l (0.5 Ib/MBTU)[35]	500 mg/dscm	50 mg/dscm

Unless otherwise specified, compliance will be determined by comparing hourly average data corrected for standard temperature, pressure, humidity, and oxygen content as defined by US EPA methods.

The SO2 limit should be considered as a moving average of 7 days.

Table 6-10: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of HCl, HF and SO_2 from the incineration of waste

Parameter		BAT-AEL (mg/Nm^3)[36 37 38]		Averaging period
		New plant	Existing plant	
a	HCl	<2-6	<2-8	Daily average
b	HF	<1	<1	Daily average or average over the sampling period
c	SO_2	5-30	5-40	Daily average
The lower end of the BAT-AEL range can be achieved when using a wet scrubber; the higher end of the range may be associated with the use of dry sorbent injection				

6.5.1.2.3 Emissions of NOx, N_2O, CO and NH_3

In order to reduce channelled NO_x emissions to air while limiting the emissions of CO and N_2O from the incineration of waste and the emissions of NH_3 from the use of SNCR and/or SCR, BAT is to use an appropriate combination of the techniques given below[39]:

[35] Small industrial/commercial/institutional steam generating units/furnaces with a heat capacity 100 MBTU/h (29 MW) or less but greater than or equal to 10 MBTU/h (2.9 MW)
[36] (Study on AMS and SRM performances and their impact on the feasibility of lowering ELVs for air emissions in the context of the BREFs and BATs revision and of BATAELs elaboration according to the IED,INERIS, Institut National de l'Environnement Industriel et des Risques,2016)
[37] (Study of the performances of existing and under development AMSs (Automated Measuring Systems) and SRMs (Standard Reference Methods) for air emissions at the level of and below existing ELVs (Emission Limit Values) and BATAELs (Best Available Techniques A, INERIS, 2017)
[38] (JRC Reference Report on Monitoring of Emissions to Air and Water from IED installations (ROM REF),JRC IPTS EIPPCB,COM, European Commission, 2018)
[39] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

Table 6-11:Techniques to reduce NO_x emissions to air from the incineration of waste and NH_3 emissions to air from the use of SNCR and/or SCR

	Abatement Technique	Description	Applicability
a	**Optimisation of the incineration process**	Optimisation of the waste feed rate and composition, of the temperature, and of the flow rates and points of injection of the primary and secondary combustion air to effectively oxidise the organic compounds while reducing the generation of NO_x. Optimisation of the design and operation of the furnace (e.g., flue-gas temperature and turbulence, flue-gas and waste residence time, oxygen level, waste agitation).	Generally applicable.
b	**Flue-gas recirculation**	Recirculation of a part of the flue-gas to the furnace to replace a part of the fresh combustion air, with the dual effect of cooling the temperature and limiting the O2 content for nitrogen oxidation, thus limiting the NOX generation. It implies the supply of flue-gas from the furnace into the flame to reduce the oxygen content and therefore the temperature of the flame.	For existing plants, the applicability may be limited due to technical constraints (e.g., pollutant load in the flue-gas, incineration conditions).
c	**Selective non-catalytic reduction (SNCR)**	Selective reduction of nitrogen oxides to nitrogen with ammonia or urea at high temperatures and without catalyst. The operating temperature window is maintained between 800 °C and 1 000 °C for optimal reaction. The performance of the SNCR system can be increased by controlling the injection of the reagent from multiple lances with the support of a (fast-reacting) acoustic or infrared temperature measurement system so as to ensure that the reagent is injected in the optimum temperature zone at all times.	Generally applicable.
d	**Selective catalytic reduction (SCR)**	Selective reduction of nitrogen oxides with ammonia or urea in the presence of a catalyst. The technique is based on the reduction of NOX to nitrogen in a catalytic bed by reaction with ammonia	In the case of existing plants, the applicability may be limited by a lack of space.

Abatement Technique		Description	Applicability
		at an optimum operating temperature that is typically around 200–450 °C for the high-dust type and 170–250 °C for the tail-end type. In general, ammonia is injected as an aqueous solution; the ammonia source can also be anhydrous ammonia or a urea solution. Several layers of catalyst may be applied. A higher NO_x reduction is achieved with the use of a larger catalyst surface, installed as one or more layer‘. 'In-d’ct' ‘r 's’ip' SCR combines SNCR with downstream SCR which reduces the ammonia slip from SNCR.	
e	**Catalytic filter bags**	Filter bags are either impregnated with a catalyst or the catalyst is directly mixed with organic material in the production of the fibres used for the filter medium. Such filters can be used to reduce PCDD/F emissions as well as, in combination with a source of NH3, to reduce NO_x emissions.	Only applicable to plants fitted with a bag filter.
f	**Optimisation of the SNCR/SCR design and operation**	Optimisation of the reagent to NO_x ratio over the cross-section of the furnace or duct, of the size of the reagent drops and of the temperature window in which the reagent is injected.	Only applicable where SNCR and/or SCR is used for the reduction of NO_x emissions.
g	**Wet scrubber**	See Section 6.2.1.2.1 Where a wet scrubber is used for acid gas abatement, and in particular with SNCR, unreacted ammonia is absorbed by the scrubbing liquor and once stripped, can be recycled as SNCR or SCR reagent.	There may be applicability restrictions due to low water availability, e.g., in arid areas.

Table 6-12: NCEC established limits for channelled NOx and CO emissions to air from the incineration of waste[40]

	Parameter	Combustion Facilities (constructed or modified after September 1, 2005)	Hazardous and Medical Waste Incineration (For facilities constructed before September 1, 2005)	Hazardous and Medical Waste Incineration (constructed or modified after September 1, 2005)
a	NO_x	▪ 43 ng/J (0.1 Ib/MBTU) of the burning oil ▪ 69 ng/J (0.16 Ib/MBTU) of the burning oil	-	▪ 400 mg/m³, capacity less than 6 ton/hr ▪ 200 mg/m³, capacity more than 6 ton/hr
b	CO	-	100 mg/dscm	50 mg/dscm

Unless otherwise specified, compliance will be determined by comparing hourly average data corrected for standard temperature, pressure, humidity, and oxygen content as defined by US EPA methods.

Table 6-13: BAT-associated emission levels (BAT-AELs) for channelled NO_x and CO emissions to air from the incineration of waste and for channelled NH_3 emissions to air from the use of SNCR and/or SCR

	Parameter	BAT-AEL (mg/Nm^3)[41 42 43]		Averaging period
		New plant	Existing plant	
a	NO_X	50-120	50-150	Daily average
b	CO	10-50	10-50	
c	NH_3	2-10	2-10	
The lower end of the BAT-AEL range can be achieved when using SCR. The lower end of the BAT-AEL range may not be achievable when incinerating waste with a high nitrogen content (e.g., residues from the production of organic nitrogen compounds). For existing plants fitted with SNCR without wet abatement techniques, the higher end of the BAT-AEL range is 15 mg/Nm3.				

6.5.1.2.4 Emissions of organic compounds

---

[40] (Executive Regulations for Air Quality, For the environmental law issued by the Royal Decree No.(M/165),Ministry of Environment, Water & Agriculture, Dated 19/11/1441 AH, Kingdom of Saudi Arabia)

[41] (Study on AMS and SRM performances and their impact on the feasibility of lowering ELVs for air emissions in the context of the BREFs and BATs revision and of BATAELs elaboration according to the IED,INERIS, Institut National de l'Environnement Industriel et des Risques,2016)

[42] (Study of the performances of existing and under development AMSs (Automated Measuring Systems) and SRMs (Standard Reference Methods) for air emissions at the level of and below existing ELVs (Emission Limit Values) and BATAELs (Best Available Techniques A, INERIS, 2017)

[43] (JRC Reference Report on Monitoring of Emissions to Air and Water from IED installations (ROM REF),JRC IPTS EIPPCB,COM, European Commission, 2018)

In order to reduce channelled emissions to air of organic compounds including PCDD/F and PCBs from the incineration of waste, BAT is to use techniques (a), (b), (c), (d), and one or a combination of techniques(e) to (i) given below[44]:

Table 6-14: Techniques to reduce emissions to air from organic compounds including PCDD/F and PCBs from the incineration of waste

Abatement Technique		Description	Applicability
a	**Optimisation of the incineration process**	See Section 6.5.1.2.3 Optimisation of incineration parameters to promote the oxidation of organic compounds including PCDD/F and PCBs present in the waste, and to prevent their and their precursors' (re)formation.	Generally applicable.
b	**Control of the waste feed**	Knowledge and control of the combustion characteristics of the waste being fed into the furnace, to ensure optimal and, as far as possible, homogeneous and stable incineration conditions.	Not applicable to clinical waste or to municipal solid waste.
c	**On-line and off-line boiler cleaning**	Efficient cleaning of the boiler bundles to reduce the dust residence time and accumulation in the boiler, thus reducing PCDD/F formation in the boiler. A combination of on-line and off-line boiler cleaning techniques is used.	Generally applicable.
d	**Rapid flue-gas cooling**	Rapid cooling of the flue-gas from temperatures above 400 °C to below 250 °C before dust abatement to prevent the de novo synthesis of PCDD/F. This is achieved by appropriate design of the boiler and/or with the use of a quench system. The latter option limits the amount of energy that can be recovered from the flue-gas and is used in particular in the case of incinerating hazardous wastes with a high halogen content.	Generally applicable.
e	**Dry sorbent injection**	See Section 6.2.1.2.1 Adsorption by injection of activated carbon or other reagents, generally combined with a bag filter where a reaction layer is created in the filter cake and the solids generated are removed.	Generally applicable.
f	**Fixed- or moving-bed adsorption**	See Section 6.2.1.2.1	The applicability may be limited by the overall

[44] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

Abatement Technique		Description	Applicability
			pressure drop associated with the FGC system. In the case of existing plants, the applicability may be limited by a lack of space.
g	**Selective catalytic reduction (SCR)**	See Section 6.2.1.2.3 Where SCR is used for NO_x abatement, the adequate catalyst surface of the SCR system also provides for the partial reduction of the emissions of PCDD/F and PCBs. The technique is generally used in combination with technique (e), (f) or (i).	In the case of existing plants, the applicability may be limited by a lack of space.
h	**Catalytic filter bags**	See Section 6.2.1.2.3	Only applicable to plants fitted with a bag filter.
i	**Carbon sorbent in a wet scrubber**	PCDD/F and PCBs are adsorbed by carbon sorbent added to the wet scrubber, either in the scrubbing liquor or in the form of impregnated packing elements. The technique is used for the removal of PCDD/F in general, and also to prevent and/or reduce the re-emission of PCDD/F accumulated in the scrubber (the so-called memory effect) occurring especially during shutdown and start-up periods	Only applicable to plants fitted with a wet scrubber.

Table 6-15: NCEC established limits for channelled emissions to air of organic compounds from the incineration of waste[45]

Parameter		Combustion Facilities (constructed or modified after September 1, 2005)	Hazardous and Medical Waste Incineration (For facilities constructed before September 1, 2005)	Hazardous and Medical Waste Incineration (constructed or modified after September 1, 2005)	Averaging period
a	**Chlorinated organic matters**			DRE by more than 99.9999% for hazardous primary organic matters	
b	**Organic matters**		DRE by more than 99.99 for POHC	DRE by more than 99.99 for POHC	

[45] (Executive Regulations for Air Quality, For the environmental law issued by the Royal Decree No.(M/165),Ministry of Environment, Water & Agriculture, Dated 19/11/1441 AH, Kingdom of Saudi Arabia)

Parameter		Combustion Facilities (constructed or modified after September 1, 2005)	Hazardous and Medical Waste Incineration (For facilities constructed before September 1, 2005)	Hazardous and Medical Waste Incineration (constructed or modified after September 1, 2005)	Averaging period
c	**Total dioxin and furan**		30 ng TEQ/dscm divided by 7% of oxygen	0.1 ng TEQ/dscm	
d	**PCBs**		1 mg/kg of PCB feeding by a concentrate rate of maximum one hour or DRE by more than 99.999%	1 mg/kg of PCB feeding by a concentrate rate of maximum one hour or DRE by more than 99.999%	

Unless otherwise specified, compliance will be determined by comparing hourly average data corrected for standard temperature, pressure, humidity, and oxygen content as defined by US EPA methods.

Table 6-16: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of TVOC, PCDD/F and dioxin-like PCBs from the incineration of waste

Parameter		Unit	BAT-AEL[46 47 48]		Averaging period
			New plant	Existing plant	
a	**TVOC**	(mg/Nm^3)	<3-10	<3-10	Daily average
b	**PCDD/F**	ng I-TEQ/Nm^3	< 0.01-0.04	<0.01-0.06	Average over the sampling period
			<0.01-0.06	<0.01-0.08	Long-term sampling period
c	**PCDD/F + dioxin-like PCBs**	ng WHO-TEQ/Nm^3	<0.01-0.06	<0.01-0.08	Average over the sampling period
			<0.01-0.08	<0.01-0.1	Long-term sampling period
Either the BAT-AEL for PCDD/F or the BAT-AEL for PCDD/F + dioxin-like PCBs applies. The BAT-AEL does not apply if the emission levels are proven to be sufficiently stable.					

6.5.1.2.5 Emissions of mercury

[46] (Study on AMS and SRM performances and their impact on the feasibility of lowering ELVs for air emissions in the context of the BREFs and BATs revision and of BATAELs elaboration according to the IED,INERIS, Institut National de l'Environnement Industriel et des Risques,2016)
[47] (Study of the performances of existing and under development AMSs (Automated Measuring Systems) and SRMs (Standard Reference Methods) for air emissions at the level of and below existing ELVs (Emission Limit Values) and BATAELs (Best Available Techniques A, INERIS, 2017)
[48] (JRC Reference Report on Monitoring of Emissions to Air and Water from IED installations (ROM REF),JRC IPTS EIPPCB,COM, European Commission, 2018)

In order to reduce channelled mercury emissions to air (including mercury emission peaks) from the incineration of waste, BAT is to use one or a combination of the techniques given below[49]:

Table 6-17: Techniques to reduce mercury emissions to air (including mercury emission peaks) from the incineration of waste

Abatement Technique		Description	Applicability
a	**Wet scrubber (low pH)**	See Section 6.2.1.2.1 The mercury removal rate of the technique can be enhanced by adding reagents and/or adsorbents to the scrubbing liquor, e.g.: ■ Oxidants such as hydrogen peroxide to transform elemental mercury to a water-soluble oxidised form; ■ Sulphur compounds to form stable complexes or salts with mercury; ■ Carbon sorbent to adsorb mercury, including elemental mercury. When designed for a sufficiently high buffer capacity for mercury capture, the technique effectively prevents the occurrence of mercury emission peaks.	There may be applicability restrictions due to low water availability, e.g., in arid areas.
b	**Dry sorbent injection**	See Section 6.2.1.2.1 Adsorption by injection of activated carbon or other reagents, generally combined with a bag filter where a reaction layer is created in the filter cake and the solids generated are removed.	Generally applicable.
c	**Injection of special, highly reactive activated carbon**	Injection of highly reactive activated carbon doped with sulphur or other reagents to enhance the reactivity with mercury. Usually, the injection of this special activated carbon is not continuous but only takes place when a mercury peak is detected. For this purpose, the technique can be used in combination with the continuous monitoring of mercury in the raw flue-gas.	May not be applicable to plants dedicated to the incineration of sewage sludge.
d	**Boiler bromine addition**	Bromide added to the waste or injected into the furnace is converted at high temperatures to elemental bromine, which oxidises elemental mercury to the water-soluble and highly adsorbable $HgBr_2$.	Generally applicable.

[49] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

Abatement Technique		Description	Applicability
		The technique is used in combination with a downstream abatement technique such as a wet scrubber or an activated carbon injection system. Usually, the injection of bromide is not continuous but only takes place when a mercury peak is detected. For this purpose, the technique can be used in combination with the continuous monitoring of mercury in the raw flue-gas.	
e	**Fixed- or moving-bed adsorption**	See Section 6.2.1.2.1 When designed for a sufficiently high adsorption capacity, the technique effectively prevents the occurrence of mercury emission peak	The applicability may be limited by the overall pressure drop associated with the FGC system. In the case of existing plants, the applicability may be limited by a lack of space

Table 6-18: NCEC established limits for channelled mercury emissions to air from the incineration of waste[50]

Parameter	Combustion Facilities (constructed or modified after September 1, 2005)	Hazardous and Medical Waste Incineration (For facilities constructed before September 1, 2005)	Hazardous and Medical Waste Incineration (constructed or modified after September 1, 2005)	Averaging period
Hg	0.000013 ng/J	300 gr/hr	0.05 mg/dscm	

Unless otherwise specified, compliance will be determined by comparing hourly average data corrected for standard temperature, pressure, humidity, and oxygen content as defined by US EPA methods.

Table 6-19: BAT-associated emission levels (BAT-AELs) for channelled mercury emissions to air from the incineration of waste

Parameter	BAT-AEL (µg/Nm^3)		Averaging period
	New plant	**Existing plant**	
Hg	< 5-20	< 5-20	Daily average or average over the sampling period
	1-10	1-10	Long-term sampling period
Either the BAT-AEL for daily average or average over the sampling period or the BAT-AEL for long-term sampling period applies. The BAT-AEL for long-term sampling may apply in the case of plants incinerating waste with a proven low and stable mercury content (e.g., mono-streams of waste of a controlled composition).			

[50] (Executive Regulations for Air Quality, For the environmental law issued by the Royal Decree No.(M/165),Ministry of Environment, Water & Agriculture, Dated 19/11/1441 AH, Kingdom of Saudi Arabia)

Parameter	BAT-AEL (µg/Nm³)		Averaging period
	New plant	Existing plant	
The lower end of the BAT-AEL ranges may be achieved when: • Incinerating wastes with a proven low and stable mercury content (e.g., mono-streams of waste of a controlled composition), or • Using specific techniques to prevent or reduce the occurrence of mercury peak emissions while incinerating non-hazardous waste. The higher end of the BAT-AEL ranges may be associated with the use of dry sorbent injection			

6.5.2 Techniques for the reduction of discharge to water

The incineration process only produces a significant amount of wastewater from wet FGC systems. Other types of flue-gas cleaning systems (dry and semi-dry) do not usually give rise to any effluent. In some cases, the wastewater from wet FGC systems is evaporated and in others it is treated and reused and/or discharged.

The treatment of wastewater from the flue-gas cleaning in waste incineration plants is not fundamentally different from the treatment of wastewater from other industrial processes.

Less information available than for emissions to air is available, reflecting the fact that most WI plants have no wastewater emissions arising from the flue-gas cleaning system.

Normally wastewater from flue-gas cleaning facilities of municipal and hazardous waste incineration plants mainly contains the following substances:

- Total suspended solids (TSS);
- Mercury;
- Other metal and metalloid emissions (arsenic, cadmium, chromium, copper, lead, molybdenum, nickel, thallium, zinc emissions);
- Total organic carbon (TOC);
- Polychlorinated dibenzo-dioxins and furans (PCDD/F);
- Chloride and sulphate content.

Besides the wastewater from the flue-gas cleaning, wastewater can also arise from a number of other sources:

- Bottom ash collection, treatment, and storage;
- Boiler operations;
- Sanitary wastewater;
- Clean rainwater;
- Polluted rainwater;
- Cooling water;
- Condensed wastewater from the partial pre-drying of sewage sludge;

Under the above-mentioned circumstances, wastewater is composed principally of the below substances:

- Metals, including mercury;
- Inorganic salts (chlorides, sulphates, etc.);
- Organic compounds (phenols, PCDD/F).

Discharges of wastewater resulting from the cleaning of waste gases to the aquatic environment shall be in accordance with the IR or TGs established by the National Center for Environmental Compliance (NCEC).

National discharge criteria set by the NCEC, ISO or other international standards are to be used in order to ensure the provision of data of an equivalent scientific quality.

In order to reduce discharge to water from FGC and/or from the storage and treatment of slags and bottom ashes, BAT is to use an appropriate combination of the techniques given below, and to use secondary techniques as close as possible to the source in order to avoid dilution:

Table 6-20: Techniques to reduce discharge to water from FGC and/or from the storage and treatment of slags and bottom ashes[51]

	Typical pollutants targeted	Abatement Technique	Description
		Primary Techniques	
a	**Organic compounds including PCDD/F, ammonia/ammonium**	Optimisation of the incineration process and/or the SNCR/SCR design and operation	See Section 6.5.1.2.3
		Secondary techniques	
Preliminary and primary treatment			
b	**All pollutants**	Equalisation	Balancing of flows and pollutant loads by using tanks or other management techniques.
c	**Acids, alkalis**	Neutralisation	The adjustment of the pH of the wastewater to a neutral value (approximately 7) by the addition of chemicals. Sodium hydroxide ($NaOH$) or calcium hydroxide ($Ca(OH)_2$) is generally used to increase the pH whereas sulphuric acid (H_2SO_4), hydrochloric acid (HCl) or carbon dioxide (CO_2) is used to decrease the pH. The precipitation of some substances may occur during neutralisation.
d	**Gross solids, suspended solids**	Physical separation, e.g., screens, sieves, grit separators, primary settlement tanks	
Physico-chemical treatment			

[51] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

	Typical pollutants targeted	Abatement Technique	Description
e	**Organic compounds including PCDD/F, mercury**	Adsorption on activated carbon	The removal of soluble substances (solutes) from the wastewater by transferring them to the surface of solid, highly porous particles (the adsorbent). Activated carbon is typically used for the adsorption of organic compounds and mercury.
f	**Dissolved metals/metalloids, sulphate**	Precipitation	The conversion of dissolved pollutants into insoluble compounds by adding precipitants. The solid precipitates formed are subsequently separated by sedimentation, flotation, or filtration. Typical chemicals used for metal precipitation are lime, dolomite, sodium hydroxide, sodium carbonate, sodium sulphide and organo-sulphides. Calcium salts (other than lime) are used to precipitate sulphate or fluoride.
g	**Sulphide, sulphite, organic compounds**	Oxidation	The conversion of pollutants by chemical oxidising agents to similar compounds that are less hazardous and/or easier to abate. In the case of wastewater from the use of wet scrubbers, air may be used to oxidise sulphite $(SO_3)^{2-}$ to sulphate $(SO_4)^2$
h	**Dissolved metals/metalloids**	Ion exchange	The retention of ionic pollutants from wastewater and their replacement by more acceptable ions using an ion exchange resin. The pollutants are temporarily retained and afterwards released into a regeneration or backwashing liquid.
i	**Purgeable pollutants (e.g., ammonia/ammonium**	Stripping	The removal of purgeable pollutants (e.g., ammonia) from wastewater by contact with a high flow of a gas current in order to transfer them to the gas phase. The pollutants are subsequently recovered (e.g., by condensation) for further use or disposal. The removal efficiency may be enhanced by increasing the temperature or reducing the pressure.
j	**Ammonia/ammonium, metals/metalloids, sulphate, chloride, organic compounds**	Reverse osmosis	A membrane process in which a pressure difference applied between the compartments separated by the membrane causes water to flow from the more concentrated solution to the less concentrated one.
Final solids removal			
k		Coagulation and flocculation	Coagulation and flocculation are used to separate suspended solids from wastewater and are often carried out in successive steps.

Typical pollutants targeted	Abatement Technique	Description
Suspended solids, particulate-bound metals/metalloids		Coagulation is carried out by adding coagulants (e.g., ferric chloride) with charges opposite to those of the suspended solids. Flocculation is carried out by adding polymers, so that collisions of microfloc particles cause them to bond thereby producing larger flocs. The flocs formed are subsequently separated by sedimentation, air flotation or filtration.
	Sedimentation	The separation of suspended solids by gravitational settling.
	Filtration	The separation of solids from wastewater by passing it through a porous medium. It includes different types of techniques, e.g., sand filtration, microfiltration, and ultrafiltration.
	Flotation	The separation of solid or liquid particles from wastewater by attaching them to fine gas bubbles, usually air. The buoyant particles accumulate at the water surface and are collected with skimmers.

Table 6-21: BAT-AELs for direct emissions to a receiving water body

Parameter		Process	Unit	BAT-AEL[52]
Total suspended solids (TSS)		FGC Bottom ash treatment	mg/l	10-30
Total organic carbon (TOC)		FGC Bottom ash treatment		15-40
Metals and metalloids	As	FGC		0.01–0.05
	Cd	FGC		0.005–0.03
	Cr	FGC		0.01–0.1
	Cu	FGC		0.03–0.15
	Hg	FGC		0.001–0.01
	Ni	FGC		0.03–0.15
	Pb	FGC Bottom ash treatment		0.02–0.06
	Sb	FGC		0.02–0.9
	Tl	FGC		0.005–0.03

[52] (JRC Reference Report on Monitoring of Emissions to Air and Water from IED installations (ROM REF),JRC IPTS EIPPCB,COM, European Commission, 2018)

Parameter		Process	Unit	BAT-AEL[52]
	Zn	FGC		0.01–0.5
Ammonium-nitrogen (NH_4-N)		Bottom ash treatment		10-30
Sulphate (SO_4^{2-})		Bottom ash treatment		400-1000
PCDD/F		FGC	ng I-TEQ/l	0.01–0.05
The averaging periods are defined in the General considerations.				

Table 6-22: BAT-AELs for indirect emissions to a receiving water body

Parameter		Process	Unit	BAT-AEL[53]
Metals and metalloids	As	FGC	mg/l	0.01–0.05
	Cd	FGC		0.005–0.03
	Cr	FGC		0.01–0.1
	Cu	FGC		0.03–0.15
	Hg	FGC		0.001–0.01
	Ni	FGC		0.03–0.15
	Pb	FGC Bottom ash treatment		0.02–0.06
	Sb	FGC		0.02–0.9
	Tl	FGC		0.005–0.03
	Zn	FGC		0.01–0.5
PCDD/F		FGC	ng I-TEQ/l	0.01–0.05
• The averaging periods are defined in the General considerations. • The BAT-AELs may not apply if the downstream wastewater treatment plant is designed and equipped appropriately to abate the pollutants concerned, provided this does not lead to a higher level of pollution in the environment				

NCEC discharge limits to water in accordance with the water body are described in detail in Appendix 3,4 and 5.

6.5.3 Treatment techniques for solid residues

Waste incineration [54]creates various types of solid residues:

- Bottom ash and slag as solid residues removed from the combustion chamber after the waste has been incinerated;

[53] (JRC Reference Report on Monitoring of Emissions to Air and Water from IED installations (ROM REF),JRC IPTS EIPPCB,COM, European Commission, 2018)
[54] Combustion, gasification, pyrolysis

- Fluidised bed ash as solid residue removed from the fluidised bed after the waste has been incinerated;
- Fly ash as the particles from the combustion chamber or formed within the flue-gas stream that are transported in the flue-gas;
- Boiler ash as the part of the fly ash that is removed from the boiler;
- FGC residues as a mixture of the pollutants originally present in the flue-gas and the substances that are used to remove those pollutants;
- Spent catalyst as the used catalyst that has been replaced;
- Sludge as the solid residue removed from the wet scrubber or from the wastewater treatment plant.

The options for recovery and reuse of solid residues depend on:

- The content of organic compounds;
- The total content of heavy metals; the leachability of metals, salts and heavy metals;
- Physical characteristics, e.g., particle size and strength.

In addition, market factors, regulations and policies concerning their use, and specific local environmental issues also impact greatly on the extent to which residues can be recovered. Considerable efforts have been made to improve the environmental quality of residues and to recycle or reuse at least part of specific residue flows. Both in-process and downstream treatment techniques are applied. In-process measures involve changing the incineration parameters to improve burnout or to shift the metal distribution over the various residues. Downstream treatment techniques include: ageing, mechanical treatment, washing, thermal treatment and stabilisation. The various techniques are discussed below.

Either way, the residues must be minimised in their amount and harmfulness and recycled where appropriate. The disposal of the residues which cannot be prevented, reduced, or recycled will be carried out in conformity with the provisions of landfill sites' provisions in the KSA Regulations.[55]

6.5.3.1 Segregation of the bottom ash from flue-gas cleaning residues

The physical and chemical properties of bottom ash mean that it is more suitable for beneficial use than FGC residues. Mixing FGC residues with bottom ash will limit the options for the subsequent use of the bottom ash and therefore should be avoided.

FGC residues have a higher metal content, metal leachability and organic content than bottom ash. Mixing FGC residues with bottom ash will reduce the environmental quality of the bottom ash and so should be avoided.

Segregation of the FGC residue from the bottom ash enables further treatment of the bottom ash (e.g., by dry treatment or by washing out the water-soluble salts, heavy metals in the ash extractor) to yield a material suitable for the intended use.

[55] (The Implementing Regulations of the Waste Management Law, 2021)

Segregation of bottom ash and FGC residues requires the separate collection, storage, and transportation of both residue streams. This involves dedicated storage silos and containers, and specific handling systems for the fine and dusty FGC residue.

A mixed stream of bottom ash and FGC residue cannot be processed into a material suitable for recovery and leaves no other option for the whole residue stream but landfilling] or use in underground applications such as mine backfilling.

6.5.3.2 Bottom ash screening/sieving and crushing

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 roadworks. The treatment operations than can be applied are:

- Manual sorting;
- Granulometric separation by screening/sieving;
- Size reduction by crushing;
- Removal of low-density unburned fractions by air separation.

6.5.3.3 Separation of metals from bottom ash

Both ferrous and non-ferrous metals may be extracted from bottom ash.

Ferrous metal 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. These ferrous metals separation may be performed on the raw ash after it leaves the ash extractor. Efficient ferrous metals separation requires a multi-step treatment with intermediate size reduction and screening.

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. The technique requires the material to be well spread on the moving belt and is generally effective for particle sizes of 4–30 mm, although this range can be extended down to < 1 mm for special applications. The separation is performed after ferrous metal segregation, particle size reduction and screening.

All-metal separators usually detect metal particles by the perturbation they induce in the alternating magnetic field of a detection coil. The metal particles are then separated by one or more air jets located close to the detection coils.

Larger fragments of both ferrous and non-ferrous metals may be removed by manual sorting before further treatment.

6.5.3.4 Bottom ash treatment using ageing

After metal separation, bottom ash from the incineration of non-hazardous waste is stored in the open air or in specific buildings to reduce both the residual reactivity and the leachability of the metals. Stockpiles are wetted and turned regularly to favour the leaching of salts and carbonation.

Carbonation (the reaction between CO_2 and hydroxides in the alkaline bottom ash) is one of the key reactions in the ageing of bottom ash. The purpose of the ageing therefore is to reduce the remaining reactivity and to improve the technical properties. The leaching of bottom ash reduces after ageing, especially the leaching of metals such as Cu, Cr, Pb and Zn.

In practice, an ageing period of 6 to 20 weeks is commonly observed (or prescribed) for treated bottom ash before utilisation as a construction material or in some cases before landfilling. The time necessary for the ageing process varies depending on factors such as stockpile size, ambient temperature, initial moisture content and infiltration of rainwater.

6.5.3.5 Bottom ash treatment using dry treatment systems

Dry bottom ash treatment combines the techniques of metal separation, size reduction and screening, and may be combined with ageing of the treated bottom ash. The product is a dry aggregate with a controlled grain size (e.g., 0–4 mm, 0–10 mm, 4–10 mm), which may be used as a secondary construction material.

The process consists of:

- Crushing of the coarse fraction;
- Sieving;
- Ferrous metal separation;
- Non-ferrous metal separation;
- Ageing.

6.5.3.6 Bottom ash treatment using wet treatment systems

The use of a wet bottom ash treatment system allows the production of a material for recycling with substantially reduced leachability of metals and anions (e.g., salts). The incineration ashes are treated by size reduction, sieving, washing and metal separation. The main feature of the treatment is the wet separation of a 0–2 mm fraction.

6.5.3.7 Techniques to reduce emissions to air from the treatment of incineration slags and bottom ashes

Emissions to air from bottom ash treatment plants are mainly dust and metals coming from bottom ash handling, shredding, sieving, and air separation. There are many techniques so as to prevent, reduce or control the above-mentioned emissions.

The techniques to consider are:

- Humidify the stockpiles and the main sources of diffuse dust emissions:
  - Using techniques that keep the bottom ashes' water content around 20 % reduces the diffuse emissions of dust. This involves maintaining an optimal moisture content, which on the one hand allows the efficient recovery of metals and mineral materials and on the other hand keeps the dust releases low.
- Limit the height of discharge and protect the stockpiles against prevailing winds:

  - Dust releases are also minimised by matching the discharge height to the varying height of the bottom ash heap (e.g., through conveyor belts with adjustable heights), and by protecting bulk storage areas and stockpiles with covers or wind barriers such as screening, walling or vertical greenery.
- Operate in closed building:
  - In order to avoid the release of diffuse emissions into the environment, the storage and treatment of bottom ashes can also be performed in closed buildings.
- Enclose and keep equipment under sub atmospheric pressure:
  - Enclosed equipment such as the shredder, sieve, conveyor belts, wind sifter, air-aeraulic separator working under sub atmospheric pressure is used to prevent emissions to air.
- Treat the extracted air with a bag filter:
  - The extracted air is sent to a bag filter. To reduce the bag filter dust load, in some cases a cyclone is used as a first dedusting step.

6.5.3.8 Wastewater treatment

Wastewater comes mainly from the wet process, washing processes, storage areas, and contaminated rainwater where slags and bottom ashes are stored outside.

Process wastewater contains salts and metals as well as suspended solids and organic substances including PCDD/F.

Techniques to consider for the treatment of wastewater from the IBA treatment plants are:

- Oil separation;
- Neutralisation;
- Sedimentation;
- Chemical precipitation;
- Filtration.

6.5.4 Odour management plan

Design measures must be put in place to minimise the nuisance arising from the Waste Incineration plant in relation to emissions of dust and odour. Therefore, as part of the Working Plan, an Odour Management Plan must be developed and maintained including[56]:

- Control measures to prevent or control odour;
- Demonstration/justification that there will not be an odour problem under normal conditions;
- A description or copy of any conditions or limits put in place by the Competent Agency, which relate to the prevention or minimisation of odour;

[56] (COMMISSION IMPLEMENTING DECISION (EU) 2018/1147. Best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council., 2018)

- Identification of the actions to be taken in the event of abnormal events or conditions which might lead to odour, or potential;
- Odour problems;
- An understanding of the impact in the event of abnormal events or conditions;
- Monitoring undertaken; and
- Communication with local residents if an odour problem arises or is likely to arise.

6.5.5 Management of outputs

At the end of each waste incineration process, the outputs are either subjected to further processing and subsequently disposed of in landfills or constitute by-products for reuse.

As mentioned in Appendix 1 the fly ash derived from combustion and gasification systems is suitable for several uses at a later stage; soil amendment, liming agent, backfilling/filling material etc.

6.5.6 Material efficiency

In order to increase resource efficiency for the treatment of slags and bottom ashes, BAT is to use an appropriate combination of the techniques given below based on a risk assessment depending on the hazardous properties of the slags and bottom ashes:

Technique		Description	Applicability
a	**Screening and sieving**	Oscillating screens, vibrating screens and rotary screens are used for an initial classification of the bottom ashes by size before further treatment.	Generally applicable.
b	**Crushing**	Mechanical treatment operations intended to prepare materials for the recovery of metals or for the subsequent use of those materials, e.g., in road and earthworks construction	Generally applicable.
c	**Aeraulic separation**	Aeraulic separation is used to sort the light, unburnt fractions commingled in the bottom ashes by blowing off light fragments. A vibrating table is used to transport the bottom ashes to a chute, where the material falls through an air stream that blows un-combusted light materials, such as wood, paper, or plastic, onto a removal belt or into a container, so that they can be returned to incineration.	Generally applicable.
d	**Recovery of ferrous and non-ferrous metals**	Different techniques are used, including: ▪ Magnetic separation for ferrous metals; ▪ Eddy current separation for non-ferrous metals; ▪ Induction all-metal separation.	Generally applicable.
e	**Ageing**	The ageing process stabilises the mineral fraction of the bottom ashes by uptake of atmospheric CO_2 (carbonation), draining of excess water and oxidation.	Generally applicable.

Technique		Description	Applicability
		Bottom ashes, after the recovery of metals, are stored in the open air or in covered buildings for several weeks, generally on an impermeable floor allowing for drainage and run-off water to be collected for treatment. The stockpiles may be wetted to optimise the moisture content to favour the leaching of salts and the carbonation process. The wetting of bottom ashes also helps prevent dust emissions.	
f	**Washing**	The washing of bottom ashes enables the production of a material for recycling with minimal leachability of soluble substances (e.g., salts).	Generally applicable.

6.5.7 Techniques for the prevention and control of noise and vibration emissions

The noise aspects of waste incineration are comparable with other industries and with power generation plants. It is common for municipal waste incineration plants to be installed in completely closed buildings. This normally includes reception and unloading of waste, mechanical pre-treatment, flue-gas treatment, treatment of residues, etc. The only activities that are normally located outside the building are the cooling facilities and the long-term storage of bottom ash. Bottom ash treatment may take place in closed buildings or in the open air.[57]

The most important sources of external noise are:

- Trucks for the transport of waste, chemicals, and residues;
- Crane operations in the bunker;
- Mechanical pre-treatment of waste;
- Exhaust fans, extracting flue-gases from the incineration process and resulting in noise from the outlet of the stack;
- Noise related to the cooling system (for evaporation cooling and especially for air cooling);
- Noise related to transport and treatment of bottom ash;
- Noise from the turbo-generator set.

The other activities do not usually produce significant external noise but may contribute to the general external noise produced by the installation.

The degree of noise protection and measures taken are often very specific to the location and risk of impacts.

6.5.7.1 Noise and vibration management plan

[57] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

Such a plan as a part of the environmental management system (EMS) (see Section 10.1) normally does the following[58]:

- Describes the main sources of noise and vibration (including infrequent sources), and the nearest noise-sensitive locations. This description covers the following information for each main source of noise and vibration within the installation:
    - The source and its location on a scaled plan of the site;
    - Whether the noise or vibration is continuous/intermittent, fixed, or mobile;
    - The hours of operation;
    - A description of the noise or vibration, e.g., clatter, whine, hiss, screech, hum, bangs, clicks, thumps, or has tonal elements;
    - Its contribution to the overall site noise emission, e.g., categorised as high, medium, or low unless supporting data are available.
- Also provides the above information for the operation of infrequent sources of noise and vibration (such as infrequently operated/seasonal operations, cleaning/maintenance activities, on-site deliveries/collections/transport or out-of-hours activities, emergency generators or pumps and alarm testing);
- Details the appropriate noise surveys, measurements, investigations (which can involve detailed assessments of sound power levels for individual plant items) or modelling that may be necessary for either new or existing installations taking into consideration the potential for noise problems;
- Describes a protocol for response to identified noise and vibration incidents, e.g., complaints;
- Contains appropriate actions to be undertaken and timelines.

6.5.7.2 Noise and vibration reduction at source and noise abatement

Techniques to reduce noise and vibration emissions include[59]:

- Appropriate location of equipment and buildings: noise levels can be reduced by increasing the distance between the emitter and the receiver, by using buildings as noise screens and by relocating buildings' exits or entrances;
- Inspection and maintenance of equipment;
- Use of low-noise equipment (e.g., compressor with a noise level < 85 dB(A), speed-controlled pumps and fans, direct drive motors);
- Soundproofing of buildings to shelter any noisy operations including:
    - Sound-absorbing walls and ceilings;
    - Sound-isolating doors;
    - Double-glazed windows.
- Use of vibration or acoustic insulation, or vibration isolation;

---

[58] (COMMISSION IMPLEMENTING DECISION (EU) 2018/1147. Best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council., 2018)
[59] (COMMISSION IMPLEMENTING DECISION (EU) 2018/1147. Best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council., 2018)

- Enclosure of noisy equipment;
- Reduction of noise propagation by inserting appropriate obstacles such as protection walls, embankments, and buildings.

6.6 Best suitable techniques to improve economic, energy and environmental performance

Appendix 2 lists the best suitable technologies concerning Economic Performance (Capital Cost, Operating Cost), Energy Performance (Energy consumption, Energy Recovery) and Environmental performance (Water consumption, Emissions to air, Discharge to water, Soil/Residues).

The costs of the construction and operation of incineration-combustion plants (including environmental charges owing to greenhouse gases) are high, and what is more, these costs are constantly growing due to increasingly restrictive environmental regulations. This is in contradistinction to their high energy efficiency rate.

Concerning pyrolysis plants; despite the use of their products60; pyrolysis gas (often termed syngas), liquid (pyrolysis oil) and solid (char, mainly ash and carbon), the overall cost remains higher than for combustion and gasification plants.

Gasification plants have a smaller environmental footprint than pyrolysis and incineration plants.

7 EMERGING TECHNIQUES

An 'emerging technique' is a 'novel technique for an industrial activity that, if commercially developed, could provide either a higher general level of protection of the environment or at least the same level of protection of the environment and higher cost savings than existing best available techniques'.

This chapter contains those techniques that may appear in the near future and that may be applicable to the waste incineration sector.

7.1 Reheating of turbine steam

An option to increase the efficiency of electricity production is the reheating of turbine steam after its first passage through the turbine. For this application, the steam temperature is typically limited to less than 430 °C, but the steam pressure increases.

After the first passage through the high-pressure section of the turbine, the resulting steam is superheated again and subsequently used in the turbine's mid- and low-pressure sections.

Usually, after expanding in the HP turbine, the steam has a lower pressure (typically 10–20 % of the pressure it had on entering) and is reheated with flue-gas in the boiler to the same temperature. The steam is heated with either boiler water or saturated steam.

---

[60] In many cases these products are either directly or subsequently burned as fuels to utilize their energy value, although they may also be used for their chemical value as a raw material, after pre-treatment if required.

This technique being fully proven in large electricity generation plants, the technological risks are considered to be limited. However, there are only a few examples of applications in the waste incineration sector due to economic factors.

7.2 Oil scrubber for the reduction of polyhalogenated aromatics and polyaromatic hydrocarbons (PAHs) in the flue-gases from incineration plants

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 are adsorbed onto dust 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 (and many other organic species) are more lipophilic. A high-boiling partly unsaturated oil or an oil-water emulsion of such oil therefore provides suitable scrubbing media.

The oil/emulsion and absorbed dioxins and furans are exchanged and disposed of as soon as they reach a limit value. The supply quantity is determined so that there is an exchange three to four times a year. This helps prevent excessive ageing of the oil. The contaminated liquor is incinerated in the furnace. To do this, the oil is pumped into a slop wagon (a mobile tank with safety installations) and from there fed directly into a burner in the incineration plant.

This process includes a counter-current scrubber column as its tertiary cleaning stage with a closed oil circuit.

7.3 Flameless pressurised oxycombustion

As a means to reduce emissions to air and produce inert slags, waste is incinerated by flameless combustion in a pressurised atmosphere of oxygen, carbon dioxide and water vapour, at high temperatures.

More specifically, the operating conditions inside the oxidation reactor (residence time: > 2.5 seconds, temperature of 1.250–1.500 °C and pressure of 4–15 absolute bar) enable the complete incineration of the inlet organic compounds (with negligible production of undesirable organic by-products such as PAHs, PCDD/F and PCBs). The high combustion temperature melts the non-combustible materials, forming vitrified slags. This high temperature also represents a condition which thermodynamically and kinetically inhibits sulphur dioxide conversion into sulphur trioxide.

A two-stage wet scrubber is used to clean the flue-gas, followed by a condensation scrubber to recover the flue-gas latent heat. The condensed water is also recovered in the process. Limestone is used in the scrubber's second stage.

7.4 Phosphorus recovery from sewage sludge incineration ashes

Different techniques have been recently developed and piloted to recover the phosphorus contained in the ashes from the mono-incineration of municipal sewage sludge. These processes may also allow the recovery of additional resources contained in the ashes.

Among the process types, wet-chemical processes and thermal processes may be distinguished. While thermal processes are still generally at the piloting phase at the time of writing this document, some wet-chemical processes are approaching the stage of market entry.

Benefits include the reduction of the amount of waste for disposal, recovery of saleable phosphorus products, production of precipitation chemicals that can be recycled to wastewater treatment plants, detoxification of the ashes by separation of heavy metals as chemically stable sulphides.

7.4.1 Wet-chemical processes

The phosphorus content is almost completely dissolved by acidification. This process is unavoidably accompanied by a partial dissolution of the metals contained in the ashes. The species and amount of dissolved metals depends on the composition of the raw input material (Fe- or Al-rich) as well as on the type and amount of the added acid (H_2SO_4 or HCl).

Some processes effectively separate and remove toxic inorganic contaminants (e.g., Pb, Cd, Hg, etc.) in order to increase the quality of the phosphorus-rich recovered product. Additionally, the separation of especially Al and Fe as well may be carried out, as these elements can reduce the quality and plant bioavailability of the recovery product. Cations may be removed from the acidic leachate through different approaches, including sequential precipitation, liquid-liquid extraction, and ion exchange.

Depending on the specific process, phosphorus may be recovered as phosphoric acid or directly as mineral P-fertilisers such as dicalcium phosphate (DCP).

Some processes also rely on the partial direct replacement of ground phosphate rock (up to about 10-20% of the total P-content) by P-rich ashes in the acidulation process applied by the fertilisers industry.

7.4.2 Thermal processes

Nutrients can be recovered from ashes by high temperature treatments. Processes were developed that transfer P into a metallurgical slag by reductive smelting at very high temperature in a shaft furnace or that reduce P to elemental P that is separated via the gas phase in an inductively heated shaft furnace. The general principle is that volatile heavy metals such as Zn, Pb, Cd and Hg are separated from the product via the gas phase and further collected in the flue dust, and heavy metals with high boiling points such as Fe, Cu, Ni and Cr are separated in the form of a liquid alloy.

8 OPERATION AND MAINTENANCE

8.1 Operational techniques to improve environmental performance of Waste Incineration Facilities

For most Waste Incineration facilities, the following order is relevant:

a) Incoming waste reception;

b) Storage of waste and raw materials;

c) Pre-treatment of waste (where required, on site or off site;

d) Loading of waste into the process;

e) Thermal treatment of the waste;

f) Energy recovery (e.g., boiler) and conversion;

g) Flue-gas cleaning (FGC);

h) Flue-gas cleaning residue management;

i) Flue-gas discharge;

j) Emissions monitoring and control;

k) Wastewater control and treatment (e.g., from site drainage, flue-gas cleaning, storage);

l) Ash/bottom ash management and treatment (arising from the combustion stage); and

m) Solid residue discharge/disposal.

Each of these steps requires knowledge and control of the waste as well as specific acceptance and processing management. Knowledge of wastes, before they are accepted, stored, or treated, is a key factor for the management of a treatment facility.

Each stage will be designed for the specific type(s) of waste treated at the installation. Many installations operate continuously, 24 hours a day, nearly 365 days a year. Control systems and maintenance programmes play an important role in securing the availability of the plant.

8.1.1 Quality control of incoming wastes

This section covers those techniques that help the operator to characterise the waste input to be treated. General techniques applied to ensure that the incoming wastes are compatible with the plant characteristics are outlined in the WT BREF and can be referred to for general guidance.[61]

Either way, waste categories rejected and finally not treated by WI Plants are the following[62]:

- Waste transported by an entity that is not appropriately licensed;

[61] (COMMISSION IMPLEMENTING DECISION (EU) 2018/1147. Best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council., 2018)
[62] (The Implementing Regulations of the Waste Management Law, 2021)

- Waste not accompanied by an appropriate Transport Document or manifest;
- Waste received that cannot be appropriately processed by the facility's treatment capabilities.

8.1.1.1 Establishment of plant input limitations and identification of key risks

Every installation has limitations on the characteristics of the wastes that can be fed to the incinerator itself. With knowledge of the incineration process input limitations, it is possible to derive a waste input specification that highlights the maximum and desirable system input rates. It is then possible to identify the key risks, and the procedural controls required to prevent or reduce operation outside these limitations.[63]

Factors that set such boundaries include:

- Design of the waste feed mechanism and the physical suitability of waste received;
- Waste flow rate and heat throughput rating of the furnace;
- Required environmental performance (i.e., pollutant reduction required expressed as a percentage);
- Flue-gas cleaning technology capacity for individual pollutant removal (e.g., limit on flue-gas flow rate, pollutant loading).

Examples of key risks identified can be:

- High mercury input, leading to high raw flue-gas concentrations;
- High iodine or bromine input, leading to high raw flue-gas concentrations;
- High variability in moisture content or CV, leading to combustion irregularities;
- High chlorine loading exceeding FGC capacity;
- High sulphur loading exceeding FGC capacity;
- Rapid change in flue-gas chemistry which affects FGC function;
- Physically large items blocking feed systems, leading to an interruption of regular operation;
- Excessive slagging/fouling of boiler components when certain types of waste are being fed, e.g., high Zn concentration sources (contaminated wood waste) have been reported to cause abnormal slagging in the first boiler pass.

Once the theoretical and actual (i.e. those occurring at plants in operation) risks have been established, the operator can develop a targeted control strategy to reduce those risks, e.g. if experience shows that the HCl emission limit values may be exceeded, then the operator may decide to attempt to control chlorine sources

[63] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

and peak concentrations in the waste fed to the combustion stage and/or to improve the design and operational practice of the acid gas FGC.

8.1.1.2 Communication with waste suppliers[64] to improve incoming waste quality control

Wastes are commonly received from a wide variety of sources over which the operator may have only limited control. Where the operator has identified specific wastes, substances or properties of wastes, or individual sources that can or do cause operational problems, the communication of the operator's concerns to those persons producing and supplying the waste can help to assure quality in the overall chain of waste management. An example is the separate collection of mercury-containing wastes such as batteries or dental amalgam so that the mercury content of the MSW stream is reduced.

The type of techniques used and the degree to which they are employed depend upon the degree of risk and the frequency and nature of any operational difficulties encountered. In general, the greater the variability of the waste types, compositions and sources, the more effort that is required in waste input control.

8.1.1.3 Control of waste feed quality on the incinerator site

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

- Thermal throughput capacity of the incinerator;
- Physical requirements of the feed (particle size);
- Controls used for the incineration process (e.g., using LHV, steam production, O2 content);
- Capacity of the flue-gas treatment system and the derived maximum raw gas input concentrations/rates;
- The emission limit values that need to be met;
- Bottom ash quality requirements.

Wastes can be stored, mixed, or blended (this is restricted by some national legislation) to ensure that the final waste that is fed to the combustor falls within the derived set of quality requirements.

The key substances/properties that will usually require particular procedures to be put in place for their management relate to variations in the concentration and distribution in the waste of the following:

- Mercury, alkali metals and heavy metals;
- Iodine and bromine;
- Chlorine and sulphur;

[64] Service providers

- Variations in heat values / moisture content;
- Critical organic pollutants, e.g., PCBs;
- Physical consistency of the waste, e.g., sewage sludge;
- Mixability of different kinds of waste.

8.1.1.4 Checking, sampling, and testing of incoming wastes

This technique involves the use of a suitable regime for the assessment of incoming waste. The assessments carried out are selected to ensure:

- That the wastes received are within the range suitable for the installation;
- Whether the wastes need special handling/storage/treatment/removal for off-site transfer;
- Whether the wastes are as described by the supplier (for contractual, operational, or legal reasons), or manifest document.

The techniques adopted vary from simple visual assessment to full chemical analysis. The extent of the procedures adopted will depend upon the risk posed by the incoming waste, which in turn will be related to:

- Nature and composition of waste;
- Heterogeneity of the waste;
- Known difficulties with wastes (of a certain type or from a certain source);
- Specific sensitivities of the installation concerned (e.g., certain substances known to cause operational difficulties);
- Whether the waste is of a known or unknown origin;
- Existence or absence of a quality-controlled specification for the waste;
- Whether the waste has been dealt with before and experiences with it.

The main specific techniques applied are listed in Table 8.1

Table 8-1: Techniques applied for the checking and sampling of various waste types

Waste type	Main techniques applied	Comments
Mixed municipal wastes and other non-	▪ Visual inspection in bunker; ▪ Periodic sampling of waste deliveries and analysis of key properties/substances (e.g., calorific value, content of halogens and of metals/metalloids);	Industrial and commercial loads may have elevated risks and require greater attention

Waste type	Main techniques applied	Comments
hazardous waste	■ For municipal solid waste, spot checking of waste deliveries by separate unloading; ■ Weighing the waste as delivered; ■ Radioactive detection.	
Pre-treated municipal wastes and RDF	■ Visual inspection; ■ Periodic sampling and analysis for key properties/substances (e.g., calorific value, content of halogens, POPs, and metals/metalloids).	None
Hazardous wastes other than clinical waste	■ Visual inspection, as far as technically possible; ■ Control and comparison of data on the declaration list with delivered waste; ■ Sampling/analysis of all bulk tankers and trailers; ■ Risk-based checking of packed waste (e.g., in drums, intermediate bulk containers (IBCs) or smaller packaging); ■ Unpacking and checking of packaged loads; ■ Assessment of combustion parameters; ■ Blending tests on liquid wastes prior to storage; ■ Control of flashpoint for wastes in the bunker; ■ Screening of waste input for elemental composition.	Extensive and effective procedures are particularly important for this sector. Plants receiving mono-streams may be able to adopt simplified procedures.
Sewage sludges	■ Weighing of the waste deliveries (or measuring of the flow if the sewage sludge is delivered via pipeline); ■ Visual inspection, as far as technically possible; ■ Periodic sampling and analysis for key properties/substances (e.g., calorific value, water, and mercury content); ■ Checking for hard materials, e.g., stones/metal/wood/plastics, prior to pumping transportation, dewatering, and drying stages; ■ Process control to adapt to sludge variation.	The suitability of the techniques is dependent on the kind of sewage sludge, e.g., raw sludge, digested sludge, oxidised sludge.
Health care waste	■ Control and comparison of data on the declaration list with delivered waste; ■ Screening for radioactivity; ■ Weighing of the waste deliveries; ■ Visual inspection of the packaging integrity.	Infection risk makes sampling inadvisable. Control is required by waste producer.

8.1.1.5 Detectors for radioactive materials

The inclusion of radioactive sources or substances in waste can lead to operational and safety problems. Some wastes are at risk of containing higher levels, particularly those arising from activities that use radioactive materials. Some clinical and industrial wastes may therefore routinely or occasionally contain specific radioactive sources or contamination, although the inclusion of such wastes with municipal waste, and the difficulties of controlling mixed waste collections, can lead to radioactivity in other wastes.

Radioactive materials can often be detected using specific detectors situated at, for example, the entrance to the plant. Tests of waste loads that may have a higher risk of contamination are carried out. Such tests are specifically carried out where loads are accepted on the basis of a maximum level of contamination. Such maximum levels are derived from knowledge of the fate of the isotopes treated, and of the particular process receiving them, and on consideration of the limits set on the contamination levels allowed in releases to land, air, and water.

Plastic scintillation detectors are one type of detector used; these measure photons from gamma-emitting radionuclides and to a lesser extent from beta emitters. Radionuclides are regularly detected in clinical waste, laboratory waste and technically enhanced naturally occurring radioactive material. Also important are the controls put in place to prevent the mixing of radioactive waste with regular waste (sometimes done so as to avoid the high treatment cost associated with radioactive waste).

8.1.2 Waste storage

General techniques applied in waste storage are described in the WT BREF. This section concentrates on the specific techniques that are relevant to waste incineration plants, rather than the more general aspects of storage.

8.1.2.1 Sealed surfaces, controlled drainage, and weatherproofing

The storage of wastes 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 integrity of the impermeable surface is verified periodically.

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 applied.

Table 8-2: Some examples of applied storage techniques for various waste types

Waste type	Storage techniques
All wastes	▪ Odorous materials stored inside with controlled air systems using the discharged air as combustion air (see Section 7.1.2.3); ▪ Designated areas for loading/unloading with controlled drainage; ▪ Clearly marked (e.g., colour-coded) areas for drainage from potential areas of contamination (storage/loading/transportation); ▪ Limitation of storage times according to waste type and risks; ▪ Adequate storage capacity; ▪ Baling or containment of some wastes for temporary storage is possible depending on the waste and location-specific risk factors; ▪ Fire protection measures, e.g., fire-resistant wall between the bunker and the furnace hall;
Solid municipal and other non-hazardous wastes	▪ Sealed floor bunkers or sealed level storage areas; ▪ Covered and walled buildings; ▪ Some bulk items with low pollution potential can be stored without special measures.

Waste type	Storage techniques
Solid pre-treated MSW and RDF	▪ Enclosed hoppers; ▪ Sealed floor bunkers or level storage areas; ▪ Covered and walled buildings; ▪ Wrapped or containerised loads may be suitable for external storage without special measures, depending on the nature of the waste.
Bulk liquid wastes and sludges	▪ Attack-resistant bunded bulk tanks; ▪ Flanges and valves within bunded areas; ▪ Ducting of tank spaces to the incinerator for volatile substances; ▪ Explosion control devices in ducts, etc.; ▪ Tank or bunker storage of sewage sludge.
Drummed liquid wastes and sludges	▪ Storage under cover; ▪ Bunded and resistant surfaces.
Hazardous waste	▪ Segregated storage according to risk assessment; ▪ Special attention to the length of storage times; ▪ Automatic handling and loading devices; ▪ Cleaning facilities for surfaces and containers.
Clinical/Biohazardous wastes	▪ Segregated storage; ▪ Refrigerated or freezer storage for biohazardous wastes; ▪ Special attention to the reduction of storage times; ▪ Automatic handling and loading devices; ▪ Incineration of non-reusable waste containers; ▪ Disinfection facilities for reusable waste containers; ▪ Freezer storage if the storage period exceeds certain time periods, e.g., 48 hours.

8.1.2.2 Sufficient storage capacity

Techniques to consider are a combination of measures to avoid accumulation of waste such as:

- Establishing a maximum waste storage capacity taking into account the characteristics of the wastes, e.g., regarding the risk of fire;
- Regular monitoring of the quantity of waste stored against the maximum storage capacity;
- Establishing a maximum residence time for the wastes that are not mixed during storage.

Storage times can be reduced by:

- Preventing the volumes of wastes stored from becoming too large;
- Controlling and managing deliveries (where possible) by communication with waste suppliers, etc.

8.1.2.3 Extraction of air from storage areas for odour, dust, and diffuse emissions control

Techniques to consider are:

- Extraction of the air from waste storage areas and its use as primary and secondary combustion air;
- Limiting the amount of waste stored when the incinerator is not available;
- Use of an alternative technique to treat the channelled emissions from the storage area when the incinerator is not available.

The incinerator air supply (primary or secondary) can be taken from the waste (or chemical) storage areas. By enclosing the waste storage areas and limiting the size of the entrances to the waste storage areas, the whole waste storage area can be maintained under a slight sub-atmospheric pressure. This reduces the risk of odour releases and ensures that odorous substances are destroyed in the incinerator rather than released.

It is also possible for raw material storage to be ventilated and the air sent to either the combustion chamber or to the flue-gas cleaning equipment, depending on the nature of the air extracted.

The main techniques employed are shown in Table 8.3

Table 8-3: Main techniques for reducing fugitive diffuse emissions to air, odour releases and GHG emissions

Technique	Application
Solid waste in enclosed buildings from which incineration air is drawn	▪ Municipal wastes; ▪ Bulky solid and pasty hazardous wastes; ▪ RDF; ▪ Sewage sludges; ▪ Clinical wastes; ▪ Other odorous wastes.
Ducting tank vent to incineration air feed	▪ Odorous and volatile hazardous wastes, e.g., solvent wastes; ▪ Odorous sludges, e.g., sewage sludge; ▪ Other odorous or volatile wastes.

8.1.2.4 Segregation of waste types for safe processing

Waste acceptance procedures and storage depend on the chemical and physical characteristics of the waste. Appropriate waste assessment is an essential element in the selection of storage and input operations.

This technique is strongly related to the checking, sampling and assessment of incoming wastes outlined in Section 7.1.1.4.

The segregation techniques applied vary according to the type of wastes received at the plant, the ability of the plant to treat those wastes, and the availability of specific alternative treatments or incineration pre-treatment. In some cases, particularly for certain reactive mixtures of hazardous wastes, the segregation is required when the materials are packed at the production site, so that they can be packaged, transported, unloaded, stored, and handled safely. In these cases, segregation at the incineration installation relates to maintaining the separation of these materials so that hazardous mixtures are avoided.

Table 8-4: Some segregation techniques applied for various waste types

Waste type	Segregation techniques
Mixed municipal wastes	▪ Segregation is not routinely applied unless various distinct waste streams are received; ▪ Bulky items requiring pre-treatment can be segregated; ▪ Emergency segregation areas for rejected waste; ▪ For fluidised beds, removal of metals may be required to facilitate shredding and prevent blockage.
Pre-treated municipal wastes and RDF	▪ Segregation not routinely applied; ▪ Emergency segregation areas for rejected waste.
Hazardous wastes	▪ Extensive procedures required to separate chemically incompatible materials; examples include: o Water from phosphides; o Water from isocyanates; o Water from alkaline metals; o Cyanide from acids; o Flammable materials from oxidising agents. ▪ Maintain separation of pre-segregated packed delivered wastes.
Sewage sludges	▪ Wastes generally well mixed before delivery to plant; ▪ Some industrial streams may be delivered separately and require segregation for blending.
Health care waste	▪ Moisture content and CV can vary greatly depending on source; ▪ Segregate different containers to allow suitable storage and controlled feeding.

8.1.2.5 Use of fire detection and control systems

Automatic fire detection and warning systems are used in waste storage areas as well as for bag and fixed-bed coke filters, electrical and control rooms, and other identified areas of risk.

Continuous automatic measurement of temperature is carried out on the surface of wastes stored in the bunkers. Temperature variations can be used to trigger an acoustic alarm.

Complementary visual control by operators can be an effective fire detection measure.

Automatic fire intervention and control systems are applied in some cases, most commonly when storing flammable liquid waste although also in other areas of risk.

Foam and carbon dioxide control systems are used for the storage of flammable liquids. Foam nozzles are commonly used in MSW incineration plants in the waste storage bunker. Water spray systems with monitors, water cannons with the option to use water or foam, and dry powder systems are also used. Nitrogen blanketing may be used in fixed-bed coke filters, bag filters, tank farms, or for the pre-treatment and kiln loading facilities for hazardous wastes.

There are also other safety devices, such as:

- Nozzles above the waste feed hoppers;
- Fire-resistant walls to separate transformers and retention devices under transformers;
- Gas detection above the gas distribution module.

When ammonia is used, its storage requires specific safety measures: NH_3 detection and water spray devices to absorb releases.

The use of nitrogen blanketing requires effective operating procedures and containment to avoid operator exposure. Asphyxiation can occur outside enclosed areas as well as inside.

8.1.3 Pre-treatment of incoming waste, waste transfer and loading

8.1.3.1 Pre-treatment, blending and mixing of wastes

Techniques used for waste pre-treatment and mixing are wide-ranging, and may include:

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

Mixing of waste may serve the purpose of improving feeding and combustion behaviour. The mixing of hazardous waste with other waste or products, prior to incineration, is done to stabilise the waste feed and process conditions, to increase burnout, to improve safe disposal of residues, and to increase the quality of recovered waste fractions. Mixing of hazardous waste can involve risks. Mixing of different waste types may be carried out according to a recipe.

In any case, the mixing of waste prior to incineration should not lead to the dilution of hazardous components which were initially present at a concentration that would not have been acceptable according to the waste incinerator limits.

There are incineration facilities designed to receive and process different hazardous and non-hazardous wastes. For instance, solid waste, liquid waste, gaseous waste, and sludges can all be incinerated in rotary kilns. Solid materials are usually fed through a non-rotating hopper; liquid waste may be injected into the kiln through burner nozzles; pumpable waste and sludges may be injected into the kiln via a water-cooled tube. Moreover, for the incineration of hazardous waste, a combination of rotary kilns and post-combustion chambers has proven successful, as this combination can treat solid, pasty, liquid, and gaseous wastes uniformly.[65]

On the other hand, in grate incinerators, other wastes commonly treated, often as additions with MSW, include commercial and industrial non-hazardous wastes, sewage sludges and certain clinical wastes.

- Addition of sewage sludge to a municipal waste incinerator:

[65] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

If sewage sludge is added to a MSWI, it is often the feeding techniques that represent a significant proportion of the additional investment costs:

- Blown as dust into the furnace dried sewage sludge (~ 90 % dry solids);
- Supplied separately through sprinklers into the incineration chamber, distributed on a grate, and then integrated into the bed material by overturning the waste on the grates drained sewage sludge drained (~ 20–30 % dry solids);
- Added to the municipal waste and the mixture fed into the incineration chamber drained, dried, or partially dried sludge (~ 50–60 % dry solids). [66]

○ Addition of clinical waste to a municipal waste incinerator:

If clinical waste is combusted in the same furnace as the MSW, infectious clinical waste is placed straight into the furnace, without first being mixed with other categories of waste and without direct handling. A separate loading system with airlocks is used. The airlock helps to prevent the uncontrolled entry of combustion air and the possibility of fugitive emissions in the loading area.

The combined incineration of clinical waste with municipal solid waste can be carried out without a separate loading system. For example, automatic loading systems can be used to put the clinical waste directly into the feed hopper with MSW.

National regulations sometimes limit the ratio of clinical waste that may be treated in combined incineration (e.g., in France < 10 % thermal load). Flue-gases from the different wastes are then treated in common FGC systems.

Table 8-5: Summary of the current application of thermal treatment processes applied to different waste types[67]

Technique	Municipal Solid Waste	Other non-hazardous waste	Hazardous waste	Sewage sludge	Clinical Waste
Grate - intermittent/reciprocating	56%	43%	0%	0%	0%
Grate - vibration	0%	0%	11%	0%	0%
Grate - moving	24%	27%	0%	0%	0%
Grate - roller	12%	10%	0%	0%	0%
Grate - water-cooled	22%	48%	17%	0%	0%
Grate plus rotary kiln	0,5%	0%	2%	0%	0%
Rotary kiln	2%	0%	70%	0%	0%

[66] Mixing can occur in the waste bunker through targeted doses by the crane operator, or it can be controlled in a feeding hopper by pumping dewatered sludge into the hopper or into the bunker by spreading systems.
[67] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

Technique	Municipal Solid Waste	Other non-hazardous waste	Hazardous waste	Sewage sludge	Clinical Waste
Static hearth	0%	0%	0%	0%	67%
Static furnace	0%	0%	16%	0%	0%
Fluidised bed - bubbling	2%	13%	0%	90%	0%
Fluidised bed - circulating	3%	8%	0%	10%	0%
Pyrolysis	0%	0%	0%	0%	0%
Gasification	0.5%	0%	0%	0%	33%

Solid heterogeneous wastes (e.g., municipal and packaged hazardous wastes) can benefit from a degree of mixing in the bunker prior to loading into feed mechanisms.

In bunkers, the mixing involves the mixing of wastes using bunker cranes in the storage bunker itself. Crane operators can identify potentially problematic loads (e.g., baled wastes, discrete items that cannot be mixed or will cause loading/feeding problems) and ensure that these are: removed, shredded, or directly blended (as appropriate) with other wastes. The technique is commonly applied at municipal plants and other incinerators where batch loads are delivered for pre-incineration storage in a common bunker. Crane capacity must be designed so that it is sufficient to allow mixing and loading at a suitable rate. Usually there are two cranes, each of them sufficient to cope with the blending and feeding of all the incineration lines.

When other wastes are incinerated together with MSW, they may require specific pre-treatment. Health care waste may be delivered in special packaging, while sewage sludge, when not in a relatively small proportion, may require preliminary partial or total drying, and usually a specific feeding system, e.g., in the feed hopper, in the feed chute, directly in the furnace through a side wall or above the feeder.

The feed equaliser for solid hazardous waste consists of two screw conveyors capable of crushing and feeding solid waste and a feed hopper for receiving various types of waste. Solid bulk waste is fed to the feed hopper with a grab crane through horizontal feed gates. The feed gates are normally closed to prevent gas leakage into the ambient air.

In the bottom of the feed hopper, there are two hydraulically operated feed screws feeding the waste continuously into the feed chute through fire doors. The fire doors prevent backdraught from starting fires in the feed hopper.

The feed hopper is equipped with a level measurement for the upper and lower fill limits of the hopper. At the upper limit this provides a signal to stop the feed into the hopper while the lower limit signal slows down the operation of the screws so that there will always be some waste left in the buffer zone in the hopper to act as a barrier between the screw and the feed hopper.

The feed hopper thus works as a buffer zone preventing:

- Nitrogen from leaking into the kiln; and
- Backdraught from causing fire in the feed hoppers.

Drums can be fed through the front wall of the rotary kiln without a feed hopper.

8.1.3.2 Direct injection of liquid and gaseous wastes

To prevent diffuse emissions and to safely handle these wastes, liquid, pasty and gaseous wastes are fed directly to the furnace via several direct feeding lines. In 2002, almost 8.5 % of the total waste incineration in rotary kilns consisted of liquid waste processed through direct injection lines. Each rotary kiln has 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 the case of sufficiently low viscosity, by emptying the container with pumps. In this way, the liquid waste is fed into the processing line. Depending on the calorific value of the liquid waste, it is injected either into the front of the rotary kiln or into the post-combustion chamber. After processing, the line can be purged with nitrogen, fuel, waste oil or steam.

Multi-purpose and/or dedicated injection lines are used, largely depending on the substances to be incinerated.

8.2 Training

8.2.1 Training requirements

Facilities will only be operated by qualified and trained personnel. Therefore, the Service Provider of Waste Incineration treatment will regularly offer adequate training and education to its staff to ensure they are well-equipped to manage the waste streams safely. Furthermore, the Service Provider will ensure to provide certificate proving the fitness and health of workers on an annual basis.[68]

Training, awareness, and competence of staff are parts of the Environmental Management System (EMS), (See Section 10.1).

In detail, candidates who wish to be professionally certified for proper credentials must have knowledge and be trained in all of the following areas:

- Waste Incineration (WI) facility theory, site infrastructure and basic design concepts including how features protect groundwater, surface water and air quality;
- WI facility site operations such as:
  - Handling of waste including the movement, sorting, and storage of waste;
  - Receiving and transporting waste for onward transfer;
  - Site security.
- Regular maintenance of leachate and gas collection systems, and cleaning and repair of surface water control systems;
- Monitoring and reporting requirements specific to the relevant WI facility including spills and storage requirements;
- Employee health and safety to include hazardous substances, PPE, and clean up requirements;
- Employee training to include developing, implementing, and documenting training programmes for all personnel at the WI facility.

[68] (The Implementing Regulations of the Waste Management Law, 2021)

8.2.2 Emergency training

Prior to commencing work involving handling chemical substances or hazardous wastes, all personnel must be familiar with the relevant hazardous properties and instructed on what to do in case of emergency. Such instruction or training must include, as a minimum, the following:

- How to report a fire, injury, chemical spill, or other emergency;
- First aid/CPR performance;
- The location of emergency equipment, such as safety showers and eyewashes;
- The location of fire extinguishers and spill control equipment;
- The locations of all available exits for evacuation; and
- Names and phone numbers of the designated emergency co-ordinator and an alternate.

Such information must be posted on or by the point of generation and at waste storage areas.

9 HEALTH AND SAFETY CONSIDERATIONS

The design and operation of the Waste Incineration facility must guarantee that all proper measures have been adopted to ensure the safety of all personnel working at the premises, including external service providers and transporters visiting the facility. In order to guarantee the good health of all employees, treatment facilities shall provide a certificate proving the fitness and health of workers on an annual basis. [69]

Electricity, water, sanitation, and communications facilities must be provided at all Waste Incineration facilities to ensure the health and safety of on-site personnel, and to enable control of operations on site (such as dust control, vehicle washing and firefighting).

As a minimum, temporary structures must be located on site providing accommodation to on-site personnel. Such structures must be designed to provide;

- Office space for general site management duties and records storage;
- Sanitation facilities for site staff and visitors;
- Storage space for site equipment and for maintenance purposes;
- First Aid area, fully stocked for minor accidents.

All structures must be located in a suitable area of the site to allow control of day activities whilst also taking account of health and safety aspects.

9.1 Safety devices and measures

This section deals with safety in the sense of preventing accidents that could give rise to pollutant emissions.[70]

Safety-relevant parts of waste incineration plants and, therefore, potential sources of danger include, in particular, areas in which certain substances are present or can be formed in quantities high enough to constitute a safety concern.

These are, in particular:

- 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).

Protective systems used to control risks include:

- Systems for controlling the release of pollutants, such as retention systems for used firefighting water, bunding of tanks for substances constituting a hazard to water;
- Fire protection systems and devices such as firewalls, 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;

[69] (The Implementing Regulations of the Waste Management Law, 2021)
[70] (COMMISSION IMPLEMENTING DECISION EU 2019/2010.Best available techniques (BAT) conclusions for waste incineration, under Directive 2010/75/EU of the European Parliament and of the Council., 2019)

- Systems for protection against sabotage (e.g., building security, access control and surveillance measures);
- Fire dividing walls to separate the transformers and retention devices;
- Fire detection and protection where low-voltage power distribution panels are located;
- Pollutant detection (ammonia, gas, etc.) near corresponding storage, distribution, etc.;
- Systems for protection against environmental hazards (e.g., flooding, strong winds, lightning strikes, and extreme hot and cold weather); and
- Provisions for proper and visible signage.

Other plant components required for operational safety are:

- Machines and equipment designed to ensure input and output of energy (e.g., emergency power generator);
- 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 the disruption of normal operations or restore normal operations. This includes all instrumentation and control systems of a plant. In particular, it includes all instrumentation and control systems for the various process parameters which are essential to secure normal operations, on the one hand, and which, in the event of a disturbance, bring the affected plant components to a safe condition and inform the operating personnel of the disturbance in good time, on the other.

The response of a protective device to a malfunction or an accident may cause a temporary increase in pollutant emissions. The aim of all safety measures must be to keep this time span to a minimum and to restore the safety of the plant.

9.2 Fencing and Security

Fencing is a crucial part of the site and personnel's security, as it prevents trespassing, and properly installation and maintenance are required. Both installation and maintenance properties are described at section 5.1.4.

9.3 Accident Management Plans

An Accident Management Plan must be in place (reviewed at least once every three years, or in an event of an accident) which identifies:

- The likelihood and consequence of accidents; and
- Actions to prevent accidents and mitigate any consequences.

A structured accident management plan includes the following:

- Identifying the hazards to the environment posed by the treatment facilities. Particular areas to consider may include waste types, overfilling of vessels, failure of equipment (e.g. over-pressure of vessels and pipework, blocked drains), failure of containment (e.g. bund and/or overfilling of drainage sumps), failure to contain firefighting water, making the wrong connections in drains or other systems, preventing incompatible substances coming into contact, unwanted reactions and/or runaway reactions, emission of an effluent before adequate checking of its composition has taken place, vandalism/arson, extreme weather conditions, e.g. flooding, very high winds;

- Assessing all risks (hazard multiplied by probability) of accidents and their possible consequences. Having identified the hazards, the process of assessing the risks can be viewed as addressing six basic questions:
  - What is the estimated probability of their occurrence? (Source, frequency);
  - What may be emitted and how much? (Risk evaluation of the event);
  - Where does it go? (Predictions for the emission – what are the pathways and receptors?);
  - What are the consequences? (Consequence assessment – the effects on the receptors);
  - What is the overall risk? (Determination of the overall risk and its significance for the environment);
  - What can be done to prevent or reduce the risk? (Risk management – measures to prevent accidents and/or reduce their environmental consequences).

  In particular, identifying fire risks that may be posed for example by:
  - Arson or vandalism;
  - Self-combustion (e.g., due to chemical oxidation);
  - Plant or equipment failure & other electrical faults;
  - Naked lights & discarded smoking materials;
  - Hot works (e.g., welding or cutting), furnace loading areas, fixed adsorption beds, bag filters, electrical control systems, waste storage/pre-treatment areas, industrial heaters, and hot exhausts;
  - Reactions between incompatible materials;
  - Neighbouring site activities;
  - Sparks from loading buckets;
  - Hot loads deposited at the site.

  The depth and type of assessment will depend on the characteristics of the plant and its location. The main factors taken into account are:
  - The scale and nature of the accident hazard presented by the plant and the activities;
  - The risks to areas of population and the environment (receptors);
  - The nature of the plant and complexity of the activities and the relative difficulty;
  - In deciding on and justifying the adequacy of the risk control techniques.
- Identifying the roles and responsibilities of personnel involved in accident management. Together with this, mitigation actions for each potential risk are identified in the risk assessment register; for example, containment or dispersion, to extinguish fires or to let them burn;
- Establishing communication routes with relevant authorities and emergency services both before and in the event of an accident. Post-accident procedures include an assessment of the harm that may have been caused and remediation actions to be taken;

- Putting in place emergency procedures, including safe shutdown procedures and evacuation procedures;
- Appointing one facility employee as an emergency coordinator to take leadership responsibility for implementing the plan. It is important that the facility offers training to its employees to perform their duties effectively and safely so that staff know how to respond to an emergency (explosion, fire), chemical risks (labelling, carcinogenic substances, toxicity, corrosion, fire), fire extinguishing.

10 MONITORING, RECORDKEEPING AND REPORTING

10.1 Environmental management system (EMS)

In order to improve the overall environmental performance, BAT is to implement and adhere to an Environmental Management System (EMS) that incorporates all of the following features:

- Commitment of the management, including senior management;
- Definition, by the management, of an environmental policy that includes the continuous improvement of the environmental performance of the installation;
- Planning and establishing the necessary procedures, objectives, and targets, in conjunction with financial planning and investment;
- Implementation of procedures paying particular attention to:
  - Structure and responsibility;
  - Recruitment, training, awareness, and competence;
  - Communication;
  - Employee involvement;
  - Documentation;
  - Effective process control;
  - Maintenance programmes;
  - Emergency preparedness and response;
  - Safeguarding compliance with environmental legislation.
- Checking performance and taking corrective action, paying particular attention to:
  - Monitoring and measurement;
  - Corrective and preventive action;
  - Maintenance of records;
  - Independent (where practicable) internal or external auditing in order to determine whether or not EMS conforms to planned arrangements and has been properly implemented and maintained.
- Review, by senior management, of the EMS and its continuing suitability, adequacy, and effectiveness;
- Following the development of cleaner technologies;
- Consideration for the environmental impacts from the eventual decommissioning of the plan at the stage of designing a new plan, and throughout its operating life;
- Application of sectoral benchmarking on a regular basis;
- Waste stream management;
- Residues management plan;
- Accident management plan;
- Odour management plan;
- Noise and vibration management plan.

10.2 Waste input monitoring and recordkeeping

According to the Article CXLVII (147) of the IR, the Service Provider must keep an adequate and up to date record of its operations and provide this on a monthly basis to the Centre, or as per the frequency required by the license. The following data is required as a minimum:

- A description of the characterisation and quantity (in tons) of each Waste transport received and any deviation from the original Transport document. Including the date of receipt, and the date of treatment of this Waste;
- A detailed account of the quality of the treatment process outputs;
- Records of incidents with not-accepted waste;
- The total amount of Waste output at the end of the treatment process and the method and location of its final disposal;
- A detailed account of the process efficiency;
- Copies of all hazardous material safety data forms, where relevant;
- Treatment process air emission concentration measurements;
- Results of wastewater analysis of effluents from the treatment process;
- Any other relevant records specified by the Centre.

All the types and quantities of wastes deposited at the site and waste residues removed from the site must be provided to the Competent Authority at an agreed frequency and in an agreed format and kept in the site office.

To ensure the security of records, in accordance with ISO for the secure maintenance of records and procedures, they must be housed in either locked containers or kept in offices that shall be locked when not attended.

10.3 Monitoring and recordkeeping of identified emissions

BAT is to control-monitor the annual emissions to air (diffuse, channelled) as well as the annual generation of wastewater, with a frequency of at least once per year. Controlling monitoring includes direct measurements, calculation, or recording, e.g., using suitable meters or invoices. The monitoring is broken down at the most appropriate level (e.g., at process or plant/installation level) and considers any significant changes in the plant/installation.

Similarly, the Center prepares and implements a comprehensive program to monitor and control air and water bodies quality throughout the Kingdom. It is prohibited to install and operate monitoring and control networks without obtaining a license from the Center. More specifically, to use the approved monitoring systems, including Continuous Emission Monitoring System (CEMS) and Predictive Emission Monitoring System (PEMS), an application must be submitted. [71]

Then the operational procedures for continuous monitoring systems must be prepared and be submitted to the Center within (90) days of installing the approved monitoring systems.

---

[71] (Executive Regulations for Air Quality, For the environmental law issued by the Royal Decree No.(M/165),Ministry of Environment, Water & Agriculture, Dated 19/11/1441 AH, Kingdom of Saudi Arabia)

Finally, data and reports related to the continuous monitoring of the specified pollutants should periodically be provided to the Center (according to the mechanism and period specified by the Center). However, persons must keep monitoring, control, measurements, and analysis data for no less than (5) years and submit them to the Center whenever requested, and the Center may extend the period for some activities for other (5) other years.[72] [73]In sections 6.5.1 & 6.5.2, several potential emissions to both water and air have been identified as well as the treatment technology along with the BAT and Emissions standards covered in the IR of the Environmental Law (decree M/165), to control and reduce them.

It is crucial that these parameters be monitored primarily in accordance with Law and the Regulations., given in the tables below, in order to prevent either air or water pollution incidents.

Table 10-1: Parameters and minimum monitoring frequency of channelled emissions to air (NCEC)

Substance / Parameter	Waste treatment process	Standard(s)	Minimum monitoring frequency
Opacity (2), PM, SO2(2), NOx (3)	Combustion devices bigger than 73 megawatts of the heat input capacity	NCEC standards	Continuous
CO or hydrocarbon	Industrial boilers and furnaces that are working more than 1000 hours per year	NCEC standards	Continuous
Pouring Carbon Monoxide in the combustion area, waste feed rate, SO2, HCl, PM, O2	Hazardous waste incinerators	NCEC standards	Continuous

Table 10-2: Parameters and minimum monitoring frequency of channelled emissions to air (BAT)

Substance / Parameter	Waste treatment process	Standard(s)	Minimum monitoring frequency
Dust	Bottom ash treatment	EN 13284-1	Once every year
	Incineration of waste	Generic EN standards and EN 13284-2	Continuous
NO_x	Incineration of waste	Generic EN standards	Continuous

[72] (Executive Regulation for Protecting Aquatic Media from Pollution, For the environmental law issued by the Royal Decree No.(M/165),Ministry of Environment, Water & Agriculture, Dated 19/11/1441 AH, Kingdom of Saudi Arabia)

[73] (Implementing Regulation of Environmental Permits for Establishing and Operating Business Activitie , of the Environmental Law issued by the Royal Decree No.(M/165),Ministry of Environment, Water & Agriculture, Dated 19/11/1441 AH, Kingdom of Saudi Arabia)

Substance / Parameter	Waste treatment process	Standard(s)	Minimum monitoring frequency
NH_3	Incineration of waste when SNCR and/or SCR is used	Generic EN standards	Continuous
N_2O	▪ Incineration of waste in fluidised bed furnace; ▪ Incineration of waste when SNCR is operated with urea.	EN 21258 ([74])	Once every year
CO	Incineration of waste	Generic EN standards	Continuous
SO_2	Incineration of waste	Generic EN standards	Continuous
HCl	Incineration of waste	Generic EN standards	Continuous
HF	Incineration of waste	Generic EN standards	Continuous ([75])
Metals and metalloids except mercury (As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Tl, V)	Incineration of waste	EN 14385	Once every six months
Hg	Incineration of waste	Generic EN standards and EN 14884	Continuous ([76])
Total volatile organic carbon, expressed as C (in air) (TVOC)	Incineration of waste	Generic EN standards	Continuous
PBDD/F	Incineration of waste ([77])	No EN standard available	Once every six months
PCDD/F	Incineration of waste	EN 1948-1, EN 1948-2, EN 1948-3	Once every six months for short-term sampling
		No EN standard available for long-term sampling, EN 1948-2, EN 1948-3	Once every month for long-term sampling[78]

[74] If continuous monitoring of N_2O is applied, the generic EN standards for continuous measurements apply.
[75] The continuous measurement of HF may be replaced by periodic measurements with a minimum frequency of once every six months if the HCl emission levels are proven to be sufficiently stable. No EN standard is available for the periodic measurement of HF.
[76] For plants incinerating wastes with a proven low and stable mercury content (e.g. mono-streams of waste of a controlled composition), the continuous monitoring of emissions may be replaced by long-term sampling (no EN standard is available for long-term sampling of Hg or periodic measurements with a minimum frequency of once every six months. In the latter case the relevant standard is EN 13211.
[77] The monitoring only applies to the incineration of waste containing brominated flame retardants or to plants with continuous injection of bromine
[78] The monitoring does not apply if the emission levels are proven to be sufficiently stable.

Substance / Parameter	Waste treatment process	Standard(s)	Minimum monitoring frequency
Dioxin-like PCBs	Incineration of waste	EN 1948-1, EN 1948-2, EN 1948-4	Once every six months for short-term sampling [79]
		No EN standard available for long-term sampling, EN 1948-2, EN 1948-4	Once every month for long-term sampling
Benzo[a]pyrene	Incineration of waste	No EN standard available	Once every year

Table 10-3: Parameters and minimum monitoring frequency of discharge to water from FGC and/or bottom ash treatment

Substance / Parameter	Waste treatment process	Standard(s)	Minimum monitoring frequency
Total organic carbon (TOC)	FGC	EN 1484	Once every month
	Bottom ash treatment		Once every month[80]
Total suspended solids (TSS)	FGC	EN 872	Once every day[81]
	Bottom ash treatment		Once every month
As	FGC	Various EN standards available (e.g., EN ISO 11885, EN ISO 15586 or EN ISO 17294-2)	Once every month
Cd			
Cr			
Cu			
Mo			
Ni			
Pb	FGC		Once every month
	Bottom ash treatment		Once every month
Sb	FGC		Once every month
Tl			
Zn			
Hg		Various EN standards available (e.g., EN ISO 12846 or EN ISO 17852)	
Ammonium-nitrogen (NH_4-N)	Bottom ash treatment	Various EN standards available (e.g., EN ISO 11732, EN ISO 14911)	Once every month
Chloride (Cl^-)		Various EN standards available	

[79] The monitoring does not apply where the emissions of dioxin-like PCBs are proven to be less than 0.01 ng WHO-TEQ/Nm^3.
[80] The monitoring frequency may be at least once every six months if the emissions are proven to be sufficiently stable.
[81] The daily 24-hour flow-proportional composite sampling measurements may be substituted by daily spot sample measurements.

Substance / Parameter	Waste treatment process	Standard(s)	Minimum monitoring frequency
		(e.g., EN ISO 10304-1, EN ISO 15682)	
Sulphate (SO_4^{2-})		EN ISO 10304-1	
PCDD/F	FGC	No EN standard available	Once every month
	Bottom ash treatment		Once every six months

BAT is to monitor emissions according to the frequency set in tables 9-1 and 9-2, and corresponding records to be kept for each parameter monitored, so as to easily follow up the progress made as time passes by.

All monitoring records produced from monitoring procedures must be maintained, secured (see section 10.2) and made available when an inspection from the Centre occurs.

Parameters and minimum monitoring frequency of discharge to water from waste incineration in reference to Emissions standards covered in the IR of the Environmental Law (decree M/165), are presented thoroughly in Appendix 4 and 5.

10.4 Reporting

The designated person should use the data recorded above to monitor the production and/or the management of waste at the Waste Incineration facility on an ongoing basis. The designated person must prepare reports regarding all aspects related to both hazardous and non-hazardous waste such as production, storage, transport, and processing and provide a copy of these to the Centre competent authorities periodically as determined by these authorities.

In addition, the Centre should analyse the data from each facility to compare the amounts of different categories of waste reported and seek reasons or explanations for any significant differences.

APPENDICES

APPENDIX 1 Summary of Treatment Technologies- Waste Incineration Processes

APPENDIX 2 Treatment Technologies- Waste Incineration Processes, Type of Waste Treated, Economic Performance (Capital Cost, Operating Cost), Energy Performance (Energy Consumption, Energy Recovery), and Environmental Performance (Emissions to air, Discharge to Water, Soil/Residues).

APPENDIX 1 Summary of Treatment Technologies- Waste Incineration Processes

Established Treatment technology	Technology summary	Type of Waste Treated	Outputs	Management of Outputs	Type of discharge	Abatement Technology
Combustion **- Grate incinerators**	The most common type of grate mechanism in energy from waste plants, designed to carry the feedstock through the furnace. It is composed of interlocking bars to facilitate movement.	▪ Mixed Municipal wastes; ▪ Commercial/Industrial non-hazardous wastes; ▪ Sewage sludges; ▪ Certain clinical wastes.	- Bottom ash;	Bottom ash treatment (dry treatment systems, wet treatment systems)- Section 6.2.3.5 & 6.2.3.6.	- Diffuse dust emissions to air[1];	▪ Enclosure and equipment (conveyors and elevators) cover; ▪ Water sprays; ▪ Bulk storage areas or stockpiles protection with covers or wind barriers (screening, walling, or vertical greenery).
Combustion **– Rotary kilns**	Thermal processing furnaces used for processing solid materials at extremely high temperatures to cause a chemical reaction or physical change.	▪ Almost any waste; regardless of type and composition; ▪ Hazardous wastes; ▪ Most hazardous clinical waste.	- Boiler ash;	Treated together with the fly or bottom ash.	- Channelled emissions to air of dust, metals, and metalloids[2];	▪ Bag filter; ▪ Electrostatic precipitator; ▪ Dry sorbent injection; ▪ Wet scrubber; ▪ Fixed- or moving-bed adsorption.
			- Slag;	• Disposed of by landfill without further treatment; • Recycled and used in cement industry.	- Channelled emissions to air of HCl, HF and SO_2 (acid gases)[3];	▪ Wet scrubber; ▪ Semi-wet absorber; ▪ Dry sorbent injection; ▪ Direct desulphurisation; ▪ Boiler sorbent injection.
Combustion **– Fluidised beds**	A combustion technology system in which a sand bed (or similar inert material) is fluidised by air jets, heated to temperatures high enough to support combustion, combustible wastes are then added.	▪ Finely divided wastes (e.g., RDF); ▪ Sewage sludge.	- Fly ash;	• Filling material for bound applications in civil construction; • Backfilling of mines; • Recovery of metals (zinc, lead, copper, and cadmium); • Landfilled without further treatment.	- Channelled emissions to air of NOx, N_2O, CO and NH_3[4]; - Channelled emissions to air of organic compounds (PCDD/F and PCBs)[5];	▪ Flue-gas recirculation; ▪ Selective non-catalytic reduction (SNCR); ▪ Selective catalytic reduction (SCR); ▪ Catalytic filter bags; ▪ Wet scrubber; ▪ Optimisation of the incineration process (waste feed rate and composition, temperature, flow rates and points of injection).

[1] from the treatment of slags and bottom ashes
[2] from the incineration of waste
[3] from the incineration of waste
[4] from the incineration of waste and the use of SNCR and/or SCR
[5] from the incineration of waste

Established Treatment technology	Technology summary	Type of Waste Treated	Outputs	Management of Outputs	Type of discharge	Abatement Technology
			- Flue-gases.	Flue gas cleaning (FGC)	- Channelled mercury emissions to air[6];	■ On-line and off-line boiler cleaning; ■ Rapid flue-gas cooling; ■ Dry sorbent injection; ■ Fixed- or moving-bed adsorption; ■ Selective catalytic reduction (SCR); ■ Catalytic filter bags; ■ Carbon sorbent in a wet scrubber.
Pyrolysis	Waste degassing processes in the absence of oxygen, in which pyrolysis gas (often termed syngas), liquid (pyrolysis oil) or solid (char, mainly ash and carbon) are formed.	■ Municipal Solid Waste (household waste); ■ Sewage sludge; ■ Common clinical waste.	- Pyrolysis oil;	Combusted on conventional diesel engines.	- Acids, alkalis[7]; - Gross solids, suspended solids to water[8]; - Organic compounds (PCDD/F, mercury), to water[9];	■ Wet scrubber (low pH); ■ Dry sorbent injection; ■ Injection of special, highly reactive activated carbon; ■ Boiler bromine addition; ■ Fixed- or moving-bed adsorption.
			- Pyrolysis gas;	Combusted in conventional burner or gas engine.		
			- Pyrolysis char;	• Used as raw material, after pre-treatment if required; • Directly or subsequently burned as fuel.		■ Neutralisation.
						■ Physical separation (e.g., screens, sieves, grit separators, primary settlement tanks.
Gasification **– Fluidised bed gasifier**	Fluidized-bed gasifiers suspend feedstock particles in an oxygen-rich gas so the resulting bed within the gasifier acts as a fluid. These gasifiers employ back-mixing, and efficiently mix feed coal particles with coal particles already undergoing gasification. To sustain fluidization, or suspension of coal particles within the gasifier, coal of small particles sizes (<6 mm) is normally used.	■ Municipal Waste; ■ Certain hazardous waste; ■ Dried sewage sludge.	- Syngas;	Combusted in conventional burner or gas engine.	- Dissolved metals/metalloids, sulphate, sulphide, sulphite to water[10]; - Purgeable pollutants (e.g., ammonia/ammonium) to water[11];	■ Adsorption on activated carbon; ■ Reverse osmosis; ■ Oxidation.
Gasification **–Entrained flow gasifier**	In entrained-flow gasifiers, fine feedstock and air or oxygen (known as an		- Bottom Ash;	Used as a fill or construction material after mechanical treatment (screening/sieving and crushing).		■ Ion exchange; ■ Reverse osmosis;

[6] from the incineration of waste
[7] from FGC and/or from the storage and treatment of slags and bottom ashes.
[8] from FGC and/or from the storage and treatment of slags and bottom ashes.
[9] from FGC and/or from the storage and treatment of slags and bottom ashes.
[10] from FGC and/or from the storage and treatment of slags and bottom ashes.
[11] from FGC and/or from the storage and treatment of slags and bottom ashes.

Established Treatment technology	Technology summary	Type of Waste Treated	Outputs	Management of Outputs	Type of discharge	Abatement Technology
	oxidant) and/or steam are fed at the same time into the gasifier.				- Suspended solids, particulate-bound metals/metalloids to water[12].	▪ Oxidation; ▪ Precipitation.
Gasification **– Moving Bed gasifier**	Moving-bed gasifiers are widely used for gasification of biomass due to their lower operating temperature, larger flexibility in feed size, and their ability to handle higher moisture content. There are three types of fixed bed gasifiers: updraft (counter-current), downdraft (co-current), and cross draft gasifier		- Slag;	• Disposed of by landfill without further treatment; • Recycled and used in cement industry.		▪ Stripping; ▪ Reverse osmosis.
			- Fly ash;	• Purifying the raw syngas; • By product for reuse as soil amendment; • Liming agent.		▪ Coagulation and flocculation; ▪ Sedimentation; ▪ Filtration; ▪ Flotation.

[12] from FGC and/or from the storage and treatment of slags and bottom ashes.

APPENDIX 2 Treatment Technologies- Waste Incineration Processes, Type of Waste Treated, Economic Performance (Capital Cost, Operating Cost), Energy Performance (Energy Consumption, Energy Recovery), and Environmental Performance (Emissions to air, Discharge to Water, Soil/Residues)

<table>
<tr><th rowspan="2">Established Treatment technology</th><th rowspan="2">Type of Waste treated</th><th colspan="2">Economic Performance</th><th colspan="2">Energy Performance</th><th colspan="4">Environmental Performance</th></tr>
<tr><th>Capital Cost</th><th>Operating Cost</th><th>Energy Consumption</th><th>Energy Recovery</th><th>Water Consumption</th><th>Emissions to air</th><th>Discharge to Water</th><th>Soil/Residues</th></tr>
<tr><td>Combustion:
– Grate incinerators;
– Rotary kilns;
– Fluidised beds.</td><td rowspan="3">▪ Municipal wastes (residual wastes - not pre-treated);
▪ Pre-treated municipal wastes (e.g., selected fractions or RDF);
▪ Non-hazardous industrial wastes and packaging;
▪ Hazardous wastes;
▪ Sewage sludges;
▪ Clinical wastes.</td><td>High</td><td>High/Medium</td><td>High</td><td>High</td><td>Medium/Low</td><td>High</td><td>Medium</td><td>Medium/Low</td></tr>
<tr><td>Pyrolysis systems</td><td>High</td><td>High</td><td>Low/Medium</td><td>High/Medium</td><td>Medium</td><td>Medium/Low</td><td>Medium/Low</td><td>High</td></tr>
<tr><td>Gasification systems:
– Fluidised bed gasifier;
–Entrained flow gasifier;
– Moving Bed gasifier.</td><td>High/Medium</td><td>High/Medium</td><td>Low/Medium</td><td>High</td><td>Medium</td><td>Medium/Low</td><td>Medium/Low</td><td>Medium</td></tr>
</table>

MWAN مـــوان

المركز الوطني لإدارة النفايات

National Center for Waste Management