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المركز الوطني لإدارة النفايات
National Center for Waste Management

الضوابط والأدلة الفنية
لتصميم وإنشاء وتشغيل منشئات المعالجة الفيزيائية-الكيميائية

Technical Guidelines
Design, Construction and Operation of Physical-Chemical Treatment Facilities

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LIST OF ACRONYMS

AOX	Absorbable Organically Bound Halogens
BAT	Best Available Techniques
BAT-AELs	BAT Associated Emission Levels
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
COD	Amount of oxygen needed for the total chemical oxidation of the organic matter to carbon dioxide.
EMS	Environmental Monitoring System
ESP	Electrostatic Precipitator
FGT	Flue-gas treatment
HEPA	High-Efficiency Particle Air
IR	Implementing Regulations
ISO	International Organization for Standardization
KSA	Kingdom Saudi Arabia
MF	Microfiltration
MSDS	Material Safety Data Sheet
MWAN	National Centre for Waste Management
NCEC	National Centre
PCDD	Polychlorinated Dibenzo-furans
PCDF	Polychlorinated Dibenzo-p-dioxines
PCB	Polychlorinated Biphenyl
PCT	Physico-chemical treatment
PFOA	Perfluorooctanoic Acid
PFOs	Perflurooctanes Ulfonic Acid
POPs	Persistent organic pollutants
PPE	Personal protective equipment
TG	Technical Guideline
TOC	Total Organic Carbon
Total P	Total Phosphorus
TSS	Total Suspended Solids
TVOC	Total volatile organic carbon, expressed as C (in air).
UF	Ultrafiltration

WM	Waste Management
WML	Waste Management Law

DEFINITIONS

Centre	The National Centre for Waste Management.
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.
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
The Minister	Minister of Environment, Water and Agriculture, and Chairman of the Board of Directors of the Centre.
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.
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.
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 Law and Regulations.
Odour Management Plan	An odour management plan is part of the environmental management system (EMS) of the installation (facility) and includes elements to prevent or reduce odorous nuisances.
Regulation	The Implementing Regulation of the Law.
Residues Management Plan	The residue management plan is a set of measures to optimize the production of residues generated by the treatment of waste, to optimize the reuse, regeneration, recycling and/or recovery of the residues and to establish the proper disposal of internal residues or waste.
Sludge Waste	Residual sludge from sewage plants treating domestic or urban wastewaters and from other sewage plants treating waste waters of a composition similar to domestic and urban waste waters; 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.
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	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 physical-chemical treatment of waste based on local KSA economic, environmental, and social context. For the selection of the best option, the following criteria are taken into consideration:

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

This document is intended to provide technical guidance to all stakeholders with respect to physical – chemical treatment activities of waste. Activities 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 addition, the use of products by society leads to residues. In many cases, these types of materials (both secondary products and residues) cannot be reused by other means and may become 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 has to be finally sent for disposal; and
- To transform the waste into a useful material.

This guidance document covers the physical and chemical treatment of waste. Due to the nature of physical and chemical processes, it is mainly applied to the following categories of waste:

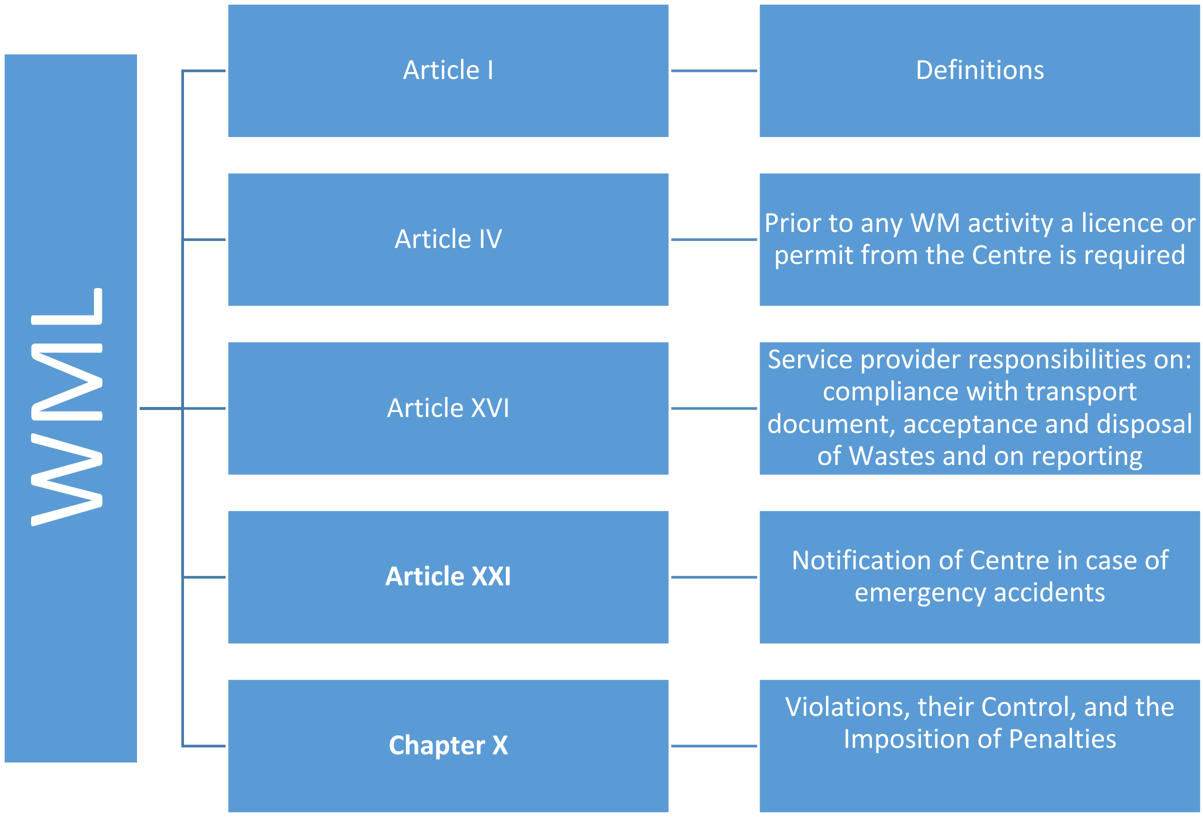
- Solid and/or pasty waste;
- Waste oil;

- Pollution abatement components;
- Flue-gas treatment (FGT) residues;
- Spent solvents;
- Excavated contaminated soil;
- Water-based liquid waste; and
- Waste containing Persistent organic pollutants (POPs) or mercury and of other waste.

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

2 LEGAL REQUIREMENTS

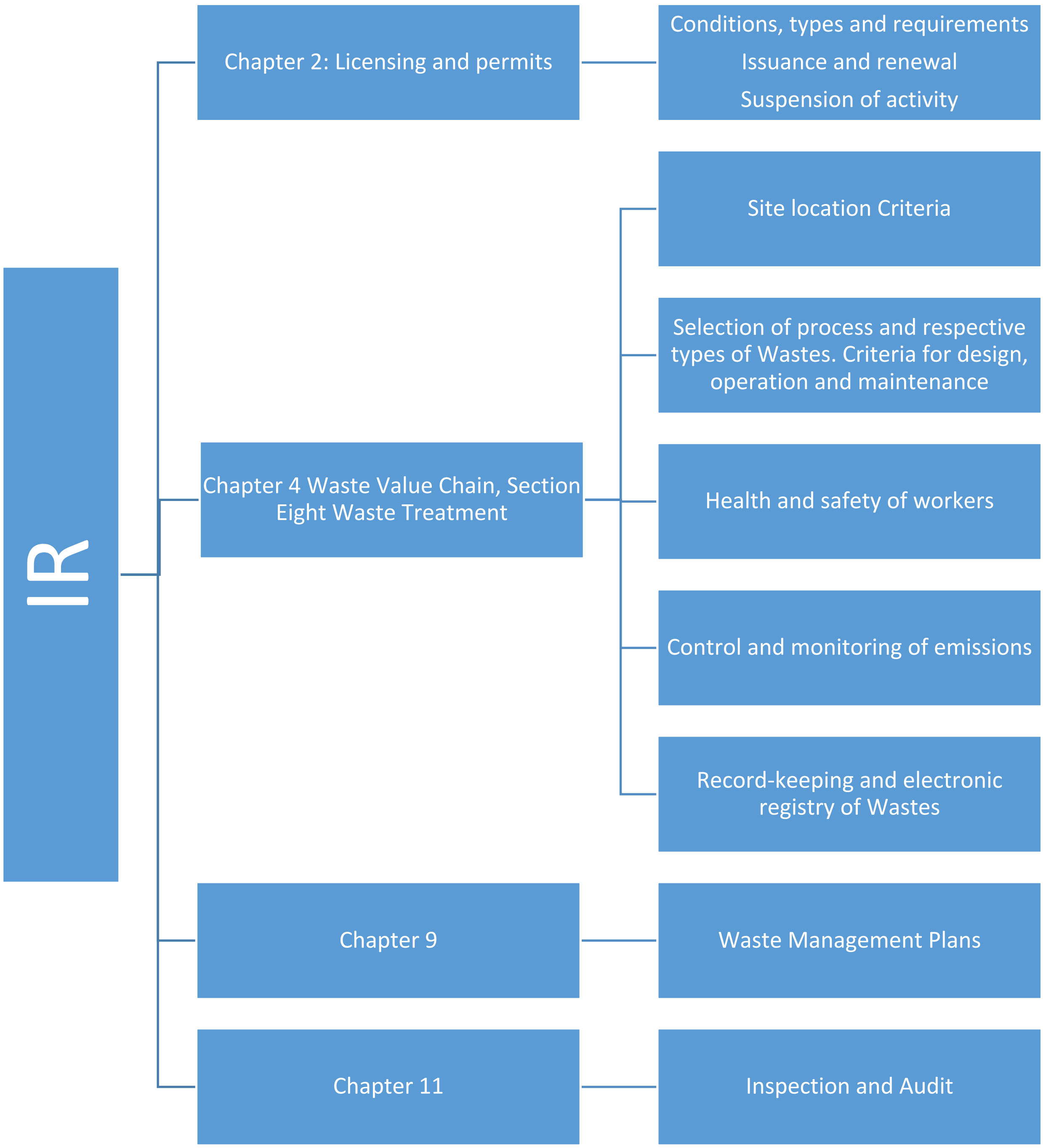
This TG for physical-chemical treatment of waste, complements the information provided by the Waste Management Law (WML) and the corresponding Implementing Regulations (IR) so as to focus on the application of "best available techniques" and "best available practices" based on the local Saudi economic, environmental, and social context. Within this framework, users of this TG, should also consult the WML and the IR, particularly the following provisions[1][2]:



The terms used in this guidance document have the same meanings as in the Waste Management Law. 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 reduce the volume of waste; or
- To facilitate the processes of treating it when reusing or recycling, or extracting some products from it; or
- To remove organic pollutants, toxic/hazardous metals; or
- To reduce or utilize some of the Waste components; or
- To eliminate the possibility of harm to humans or the environment.

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


IR
Chapter 2: Licensing and permits
Conditions, types and requirements
Issuance and renewal
Suspension of activity
Chapter 4 Waste Value Chain, Section Eight Waste Treatment
Site location Criteria
Selection of process and respective types of Wastes. Criteria for design, operation and maintenance
Health and safety of workers
Control and monitoring of emissions
Record-keeping and electronic registry of Wastes
Chapter 9
Waste Management Plans
Chapter 11
Inspection and Audit

3 ROLES AND RESPONSABILITIES

The parties involved in the Waste Management as defined in the WML, include: the competent authority (the Centre), Waste Generators and Waste Service Providers (hereby only for treatment facilities). The roles and responsibilities are detailed in the next paragraphs.

	Roles and Responsibilities
The Centre	▪ Issuing licence for Physical & Chemical Treatment 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.
Waste Producers	▪ Classifying the Waste as per the provisions of the IR based on its hazards and impacts on public health and environment; as well as setting terms and conditions necessary for that; ▪ Ensuring the proper classification of waste; ▪ Transfer waste to licensed treatment facilities via licensed transport Service providers; ▪ Reporting data to the Centre.
Service Providers	▪ Verify the authenticity of the waste manifest details and ensure that they fall within the licence issued for the Physical Chemical Treatment 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 monthly basis to the Centre; ▪ 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 physical & chemical treatment processes of waste, according to the applicable regulations and instructions by the Center.

	Roles and Responsibilities
Operators	▪ Carry out a self-monitoring system of the plant˙technological and quality of environmental factors self-monitoring 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	▪ Commit capital with the expectation of receiving financial returns.

4 OVERVIEW ON PHYSICAL-CHEMICAL TREATMENT

The physical-chemical treatment of waste consists of a process or set of processes intended to adapt the physical and chemical characteristics of the waste in order to produce an innocuous or less hazardous material whenever relevant, while also reducing its volume or segregating the different components so that they are easier to process or dispose.

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

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

There are some differences between a typical commercial off -site facility and an on-site facility typically specializing in the treatment of a particular type of waste. This derives in part from the fact that an off-site facility accepts waste from outside the local community, while an on-site facility handles only that waste generated by what could be a 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.

However, in any case the physical-chemical treatment facility is not entitled to engage in any activity related to waste unless the activity licence is issued by the Centre.[3]

4.1 Treatment technology overview

The physical-chemical treatment of waste refers to reducing its hazardous nature. Physical- chemical treatment also helps to recover valuable by-products from hazardous wastes; thus, it reduces the overall costs of waste disposal. There are lot of processes and technologies applied in the relevant sector.

In principle, all treatment options can be applied to solid and/or pasty Waste. However, the characteristics of the treated material and the effectiveness of a treatment technology can vary greatly depending on the specific properties of the original waste input and on the type of cleaning system applied.[4]

The selection of best suitable technologies for physical-chemical treatment shall consider the characteristics of the waste being treated as well as the desired output of the process. For each purpose several options exist, including but not limited to:

- Chemical Immobilization (stabilization, solidification);
- Solvent Extraction;
- Neutralisation;
- Sedimentation;

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

[4] (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)

- Evaporation; and
- Filtration etc.

Table 4.1 presents the process selection per type of waste in physical-chemical treatment stage. Further information on the different processes and their outputs can be found under section 6.1.2.

Table 4-1: Physico-chemical treatment (PCT) Methods per type of waste:

Type of waste	Treatment Method	Technology Summary
Solid and/or pasty waste	Chemical Immobilization: - Stabilization; - Solidification.	Minimization of the rate of contaminant migration to the environment and/or reduction of the level of toxicity of contaminants, to alter or improve the characteristics of the Waste so that it can be disposed of. Both reduction in the Waste toxicity and mobility as well as improvement in the engineering properties of the stabilized material.
Waste oil	Re-refining	The treatment of Waste oil to reconvert it into a material that can be reused or used as a base oil to produce lubricants.
Pollution abatement components: **Spent activated carbon Ion exchange resins** **Waste catalysts**	Ion exchange	Removal of undesired or hazardous ionic constituents and their replacement by more acceptable ions from an ion exchange resin, where the undesired ions are temporarily retained and afterwards released into a regeneration or backwashing liquid.
FGT residues	Neutralisation	The reaction in which acid and a base react quantitatively with each other.
	Evaporation/drying	One of the main solid-liquid separation techniques. The removal of water by boiling or heating a solution.
	Filtration	The separation of solids from Wastewater effluents passing through a porous medium (membrane).
	Acid extraction	The removal of a significant part of the total amount of heavy metals from the Waste input (Cd Zn Pb, Cu and Hg).
Spent solvents	Distillation - Thin film evaporation; - Short path evaporation; - Single stage flash distillation; - Multi-stage distillation;	The partial evaporation of a liquid phase followed by condensation of the vapour.

Type of waste	Treatment Method	Technology Summary
	- Pressure swing distillation; - Azeotropic distillation; - Extractive distillation.	
	Pervaporation	Separation of mixtures of liquids by partial vaporisation through a non-porous or porous membrane whereby a membrane acts as a selective barrier between a liquid phase and a vapour phase.
	Filtration	The separation of solids from Wastewater effluents passing through a porous medium (membrane).
	Sedimentation/clarification	The separation of suspended particles and floating material by gravitational settling.
	Evaporation/drying: - Thin film evaporation	One of the main solid-liquid separation techniques. The removal of water by boiling or heating a solution.
	Soil washing	An ex-situ process in which contaminated soil is excavated and fed through a water-based washing process.
	Vapour extraction	Removal of volatile organic constituents from contaminated Waste by creating a sufficient subsurface airflow to strip contaminants from the vadose (unsaturated) zone by volatilisation.
	Solvent extraction	Solid separation wherein the contaminant in the hazardous Waste is dissolved by a liquid chemical or supercritical fluid, reducing its concentration in the Waste.
Water-based liquid waste	Evaporation/drying	One of the main solid-liquid separation techniques. The removal of water by boiling or heating a solution.
	Oxidation/reduction	The use of oxidizing agent to oxidize the organic pollutants.
	Filtration	The separation of solids from Wastewater effluents passing through a porous medium (membrane).
	Centrifugation	One of the main solid-liquid separation techniques.
	Sedimentation	The separation of suspended particles and floating material by gravitational settling.
	Precipitation/flocculation	The process of formation of an insoluble solid mass/ The process of formation of solid aggregates from small particles.
	Ion exchange	Removal of undesired or hazardous ionic constituents and their replacement by more acceptable ions from an ion exchange resin, where the undesired ions are

Type of waste	Treatment Method	Technology Summary
		temporarily retained and afterwards released into a regeneration or backwashing liquid.
Waste containing POPs or mercury and of other waste	De-chlorination with metallic alkali	The reaction of metallic alkali with chlorine atoms contained in the chlorinated compounds.
	De-chlorination with potassium and polyethylene glycol (KPEG)	The reaction of potassium hydroxide (KOH) and polyethylene glycol (PEG) with chlorine atoms contained in the chlorinated compounds.
	Hydrogenation of POPs	The reaction of hydrogen with chlorinated organic compounds or non-chlorinated organic contaminants, such as PAHs, at high temperatures.
	Solvated electron process	Free electrons in a solvated electron solution convert contaminants to relatively harmless substances and salts.

4.2 General Environmental Considerations

Waste composition is variable and the potential range of constituents that might be present is significant. Due to such variance in components and composition, various emissions from waste treatment operations should be expected.

Typical environmental issues arising from waste treatment include:

- Emissions to air of particulate matter (for instance simply due to handling operation). Organic compounds are also commonly emitted;
- Discharge of contaminants to water. Typical increase in contaminants include total nitrogen, total organic carbon, total phosphorus, and total suspended solids;
- Output. Generally, the output from WT installations is a treated waste. However, those outputs can be differentiated in two types. One type refers to the treated waste (typically representing the main part of the output) that in some cases can be reused elsewhere. The other type is represented by the waste generated by the treatment process itself;
- Soil and groundwater contamination. In the past, careless handling of wastes has been at the origin of land contamination, as has been the case in almost all industrial sectors. As is the case in many other industries, waste treatment is not currently an activity which leads to land contamination.

According to the process and the type of wastes used, prevention actions have been developed such as retention, impermeabilization, and groundwater monitoring, in order to prevent and control soil and groundwater contamination.

The above issues are discussed further in chapters 6 – 10 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 physical-chemical treatment 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;
- Keeping away from historical sites and reserves;
- 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;
- That the site is distant from valleys, reefs, flood streams, beaches, bodies of water and water sources, such that it does not pollute any water source;
- That the site is not in areas where the groundwater percentage is high, or in sabkhas;
- 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 distant from currently used lands or the lands that are planned for development purposes, such as urbanized, commercial, agricultural, or industrial areas;
- In case of choosing a location for a landfill, the suitable and fulfilling soil must be existent to cover the waste, taking into consideration that the soil has low permeability and coherence;
- That the site is as far as possible from any masts, electric lines, railways, airports, facilities' pipelines, and highways;
- 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, it is forbidden to build a PCT facility on the following sites and areas:

- 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 very steep locations;
- Sites on historical archaeological or natural areas or environmental reserves;
- Areas adjacent to airports and subject to the classification of the General Authority of Civil Aviation; 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 physical-chemical treatment facilities

The Site Infrastructure Guidelines as far as physical-chemical treatment facilities are concerned, are set out as follows:

5.1.1 Siting – General Considerations

Physical-chemical treatment 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 ".[5]

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.

Physical – Chemical Plants 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 Physical-Chemical Treatment 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' and cooperation amongst residents. Surplus energy (e.g., heat, steam, hot water, etc.) from a plant can be transferred to other companies, either within the Physical-Chemical Treatment Plant or in nearby communities.

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

In any case, the Physical-Chemical Treatment 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.[6]

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.

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

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

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 physical-chemical plants.[7]:

- 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 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.

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

5.1.4 Fencing and Security

A fence must be constructed around the perimeter of the physical-chemical treatment 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.

6 DESIGN REQUIREMENTS & BEST SUITABLE TECHNIQUES APPLICABLE FOR PHYSICAL – CHEMICAL TREATMENT FACILITIES

6.1 Overview & performance of physical chemical processes

The main goal in physical-chemical waste treatment is to render waste stable / inert and non-hazardous to the environment and health and safety so it may be safely reused as by-products or disposed.

A matrix of technologies for physical and/or chemical treatment (PCT) processes is provided in Appendix 1. Most of the physical chemical processes are established, and they are very essential unit processes that are widely used in various applications in physical-chemical treatment. The matrix lists the technologies per type of Waste, as in many cases the PCT process is directly related to the type of waste and cannot by reviewed separately. The matrix also 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.

A more detailed matrix is provided in Appendix 3 and includes additional information on alternative technologies, risks and benefits, energy, and water consumption, as well as the techniques to be considered for improving performance. These techniques are further analysed in section 6.5.

6.2 Techniques for the prevention and control of emissions

As mentioned in 4.2, waste composition is variable and the potential range of components that might be present is wide. However, in all cases many waste treatment technologies deal with the following environmental issues:

- Emissions to air of particulate matter (for instance simply due to handling operation). Organic compounds are also commonly emitted;
- Contaminated effluent discharge to water. Most waste installations declare an emission of total nitrogen, total organic carbon, total phosphorus, and total suspended solids;
- Outputs to be properly managed in order to prevent pollution of soil.

The forementioned emissions to air and the limited potential for discharges to water by leachate from Physical-Chemical Plants shall not exceed the emission limit values set out in the KSA legislation.

All of the potential impacts of a physical-chemical treatment 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.

6.2.1 Channelled emissions to air

Channelled emissions relate to those emissions that result from the collection of gas from a vessel or area and that are passed on, either via abatement or directly, to a stack or vent. The next tables present:

- The process selection per type of waste in physico-chemical treatment stage (Table 6-1);
- Parameters and frequency for reduction and controlling emissions to air (Table 6-2); and
- Techniques used in the waste treatment sector to prevent, reduce, or control the emissions to air (Table 6-3).

Table 6-1: Physico- chemical treatment (PCT) Methods and type of respective discharge

Process Technology	Type of discharge
Chemical Immobilization – Stabilization – Solidification	Emissions of dust, volatile organic compounds (VOCs) and NH3 to air.
Ion exchange	Emissions of HCl, HF, dust, and volatile organic compounds (VOCs) to air.
Re-refining	Emissions of volatile organic compounds (VOCs) to air.
Neutralisation	Emissions of dust to air.
Oxidation/reduction	Emissions of VOCs, acid gases, ammonia, xylene, dust, NOx, SOx, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol to air.
Filtration	Emissions of dust, volatile organic compounds (VOCs) and NH3 to air.
Distillation –Thin film evaporation –Short path evaporation –Single stage flash distillation –Multi-stage distillation –Pressure swing distillation –Azeotropic distillation –Extractive distillation	Emissions of volatile organic compounds (VOCs) to air.
Precipitation/flocculation	Emissions of volatile organic compounds (VOCs), NH3, and acid gases to air.
Sedimentation	Emissions of VOCs, acid gases, ammonia, xylene, dust, NOx, Sox, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol to air.
Acid extraction	Emissions of dust to air.
Soil washing	Emissions of dust, TOC, Hg, Pb, Cr, Ni to air.
Solvent extraction	NI
Centrifugation	Emissions of VOCs, acid gases, ammonia, xylene, dust, NOx, SOx, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol to air.
Vapour extraction	Emissions of untreated volatile organics from the extraction process, NOX, dust, CO, and acid gases to air.
Pervaporation	Emissions of volatile organic compounds (VOCs) to air.
Dechlorination with metallic alkali	Mercury emissions to air.

Process Technology	Type of discharge
Dechlorination with potassium and polyethylene glycol (KPEG)	Dust emissions to air.
Hydrogenation of POPs	
Solvated electron process	
Evaporation/drying	Emissions of dust, VOCs, acid gases, ammonia, xylene, dust, NOx, SOx, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol to air.

Table 6-2: Parameters and frequency for reducing and controlling emissions to air

Substance / Parameter	Standard	Waste treatment process	Range (mg/Nm3 except for odour)	Available Abatement Techniques
Dust	EN 13284-1	Physico-chemical treatment of solid and/or pasty waste	0.5–18	Cyclone
				Wet scrubbing
				Electrostatic precipitator (ESP)
				Fabric filter
				HEPA filter
Hydrogen Chloride (HCl)	EN 1911	Treatment of water-based liquid waste	0.0005–11.3	Thermal Oxidation
Dioxin-like PCBs	EN 1948-1, -2, and -4	Decontamination of equipment containing PCBs	NA	Thermal oxidation
Ammonia (NH_3)	No EN standard available	Physico-chemical treatment of solid and/or pasty waste	0.1–31	Biofilter
		Treatment of water-based liquid waste	0.00005–20	
(Volatile organic compounds) TVOC	EN 12619	Physico-chemical treatment of solid and/or pasty waste	6–34	Adsorption
		Decontamination of equipment containing PCBs		Condensation and cryogenic condensation
		Physico-chemical treatment of waste with calorific value	3.3–117.1	Biofilter
		Treatment of water-based liquid waste	1.9–38	Thermal oxidation
		Re-refining of waste oil		Wet scrubbing
		Regeneration of spent solvents		
		Water washing of excavated		

Substance / Parameter	Standard	Waste treatment process	Range (mg/Nm3 except for odour)	Available Abatement Techniques
		contaminated soil		

Table 6-3: Techniques used in the waste treatment sector to prevent, reduce or control the emissions to air

Air emissions control technology	Description
Adsorption	Adsorption is a heterogeneous reaction in which gas molecules are retained on a solid or liquid surface that prefers specific compounds to others and thus removes them from effluent streams. When the surface has adsorbed as much as it can, the adsorbent is replaced, or the adsorbed content is desorbed as part of the regeneration of the adsorbent. When desorbed, the contaminants are usually at a higher concentration and can either be recovered or disposed of. The most common adsorbent is granular activated carbon.
Biofilter	The waste gas stream is passed through a bed of organic material (such as peat, heather, compost, root, tree bark, softwood, and different combinations) or some inert material (such as clay, activated carbon, and polyurethane), where it is biologically oxidised by naturally occurring microorganisms into carbon dioxide, water, inorganic salts, and biomass. A biofilter is designed considering the type(s) of waste input. An appropriate bed material, e.g., in terms of water retention capacity, bulk density, porosity, structural integrity, is selected. Also important are an appropriate height and surface area of the filter bed. The biofilter is connected to a suitable ventilation and air circulation system in order to ensure a uniform air distribution through the bed and a sufficient residence time of the waste gas inside the bed.
Condensation & cryogenic condensation	Condensation is a technique that eliminates solvent vapours from a waste gas stream by reducing its temperature below its dew point. For cryogenic condensation, the operating temperature can be down to -120 °C, but in practice it is often between -40 °C and -80 °C in the condensation device. Cryogenic condensation can cope with all VOCs and volatile inorganic pollutants, irrespective of their individual vapour pressures. The low temperatures applied allow for very high condensation efficiencies which make it well-suited as a final VOC emission control technique.
Cyclone	Cyclone filters are used to remove heavier particulates, which 'fall out' as the waste gases are forced into a rotating motion before they leave the separator. Cyclones are used to control particulate material, primarily PM10.
Electrostatic precipitator (ESP)	Electrostatic precipitators operate such that particles are charged and separated under the influence of an electrical field. Electrostatic precipitators are capable of operating under a wide range of conditions. In a dry ESP, the collected material is mechanically removed (e.g., by shaking, vibration, compressed air), while in a wet ESP it is flushed with a suitable liquid, usually water.

Air emissions control technology	Description
Fabric filter	Fabric filters, often referred to as bag filters, are constructed from porous woven or felted fabric through which gases are passed to remove particles. The use of a fabric filter requires the selection of a fabric suitable for the characteristics of the waste gas and the maximum operating temperature.
HEPA filter	HEPA filters (high-efficiency particle air filters) are absolute filters. The filter medium consists of paper or matted glass fibre with a high packing density. The waste gas stream is passed through the filter medium, where particulate matter is collected.
Thermal oxidation	The oxidation of combustible gases and odorants in a waste gas stream by heating the mixture of contaminants with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water.
Wet scrubbing	The removal of gaseous or particulate pollutants from a gas stream via mass transfer to a liquid solvent, often water or an aqueous solution. It may involve a chemical reaction (e.g., in an acid or alkaline scrubber). In some cases, the compounds may be recovered from the solvent.

6.2.2 Odour management plan

Design measures must be put in place to minimise the nuisance arising from the physical-chemical treatment 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[8]:

- 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;
- 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.

[8] (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)

6.2.3 Fugitive emissions to air

6.2.3.1 Leak detection and repair programme

There is a structured approach to reduce fugitive emissions of organic compounds by detection and subsequent repair or replacement of leaking components. Sniffing and optical gas imaging methods are available for the identification of leaks.

Sniffing method: The first step is the detection using hand-held organic compound analysers measuring the concentration adjacent to the equipment (e.g., using flame ionisation or photo- ionisation). The second step consists of enclosing the component in an impermeable bag to carry out a direct measurement at the source of the emission. This second step is sometimes replaced by mathematical correlation curves derived from statistical results obtained from a large number of previous measurements made on similar components.

Optical gas imaging methods: Optical imaging uses small lightweight hand-held cameras which enable the visualisation of gas leaks in real time, so that they appear as 'smoke' on a video recorder together with the normal image of the component concerned, to easily and rapidly locate significant organic compound leaks. Active systems produce an image with a back-scattered infrared laser light reflected on the component and its surroundings. Passive systems are based on the natural infrared radiation of the equipment and its surroundings.

6.2.3.2 Prevention or reduction of diffuse emissions to air

The following techniques are to be followed:

- Minimisation of the number of potential emission sources;
- Selection of high-integrity equipment and corrosion prevention;
- Minimise the residence time of (potentially) odorous waste in collection, storage, and handling systems;
- Use chemicals to destroy or to reduce the formation of odorous compounds;
- Cover or enclose facilities for storing, handling, collecting, and treating odorous waste (including wastewater and sludge) and collect the odorous waste gas for further treatment;
- End-of-pipe treatment.

According to this structured approach diffuse emissions of organic compounds to air are to be detected at least once per year using one or a combination of the techniques given below.

Table 6-4: Techniques controlling -monitoring diffuse emissions to air and the respective treatment technologies to which they apply.

Technique		Description	Treatment technologies
a	**Measurement**	Sniffing methods, optical gas imaging, solar occultation flux or differential absorption	Chemical Immobilization; Re-refining; Fluidification; Emulsification; Distillation;
b	**Emissions factors**	Calculation of emissions based on emissions factors, periodically validated (e.g., once every two years) by measurements	

Technique		Description	Treatment technologies
c	**Mass balance**	Calculation of diffuse emissions using a mass balance considering the solvent input, channelled emissions to air, emissions to water, the solvent in the process output, and process (e.g., distillation) residues.	▪ Pervaporation; ▪ Centrifugation; ▪ Sedimentation; ▪ Evaporation/drying; ▪ Filtration; ▪ Ion exchange; ▪ Acid extraction; ▪ Neutralisation; ▪ Soil washing; ▪ Vapour extraction; ▪ Precipitation/flocculation Dechlorination; ▪ Hydrogenation of POPs; ▪ Solvated electron process.

BAT is to periodically monitor odour emissions which can be controlled-monitored using:

- Standards methods like EN standards (e.g., dynamic olfactometry according to EN 13725 in order to determine the odour concentration or EN 16841-1 or -2 in order to determine the odour exposure);
- When applying alternative methods for which no national standards are available (e.g., estimation of odour impact), ISO or other international standards that ensure the provision of data of an equivalent scientific quality.

The applicability is restricted to cases where an odour nuisance at sensitive receptors in expected and/or has been substantiated.

6.2.4 Discharge to water

Liquid waste emissions must be controlled. National discharge criteria set by the National Center for the Environmental Compliance (NCEC), ISO or other international standards are to be used in order to ensure the provision of data of an equivalent scientific quality.

The following tables present the liquid waste pollutants expected per treatment process and the best suitable technologies for their abatement.

Table 6-5: Physico- chemical treatment (PCT) methods, main parameters in liquid waste produced and techniques for reducing and controlling discharge to water

Waste treatment process	Substance / Parameter	Standard	Available Abatement Techniques
▪ Sedimentation; ▪ Evaporation/drying; ▪ Oxidation/reduction; ▪ Filtration; ▪ Ion exchange.	**Absorbable organically bound halogens (AOX)**	EN ISO 9562	▪ Air stripping; ▪ Neutralisation; ▪ Chemical reduction; ▪ Chemical oxidation; ▪ Filtration; ▪ Ion exchange; ▪ Neutralisation; ▪ Press filtering; ▪ Sand filtration; ▪ Active sludge systems -SBR Flocculation; ▪ Active sludge system –SBR Adsorption; ▪ Emulsion breaking Press filtering.
▪ Centrifugation; ▪ Sedimentation; ▪ Evaporation/drying; ▪ Oxidation/reduction.	**Benzene, toluene, ethylbenzene, xylene (BTEX)**	EN ISO 15680	▪ Activated Carbon Adsorption; ▪ Biofilter; ▪ Bag/Fabric filter; ▪ Wet scrubbing; ▪ Thermal Oxidation; ▪ Condensation or Cryogenic condensation; ▪ Recirculation of process off-gases in a steam boiler;
▪ Precipitation/flocculation; ▪ Sedimentation; ▪ Evaporation/drying; ▪ Oxidation/reduction; ▪ Filtration; ▪ Ion exchange.	**Chemical oxygen demand (COD)**	No EN standard available	▪ Neutralisation; ▪ Chemical oxidation; ▪ Filtration; ▪ Ion exchange; ▪ Neutralisation; ▪ Press filtering; ▪ Sand filtration; ▪ Air stripping; ▪ Chemical reduction; ▪ Active sludge systems -SBR Flocculation; ▪ Active sludge system –SBR Adsorption;

Waste treatment process	Substance / Parameter	Standard	Available Abatement Techniques
			▪ Emulsion breaking Press filtering.
▪ Sedimentation; ▪ Evaporation/drying; ▪ Oxidation/reduction; ▪ Filtration; ▪ Ion exchange.	**Hydrocarbon oil index (HOI)**	EN ISO 9377-2	▪ Active sludge systems -SBR Flocculation; ▪ Air stripping; ▪ Ion exchange; ▪ Neutralisation; ▪ Filtration; ▪ Chemical reduction; ▪ Chemical oxidation; ▪ Press filtering; ▪ Active sludge system –SBR Adsorption; ▪ Emulsion breaking Press filtering; ▪ Sand filtration.
▪ Sedimentation; ▪ Evaporation/drying; ▪ Oxidation/reduction; ▪ Filtration; ▪ Ion exchange.	**Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), Zinc (Zn)**	Various EN standards available (e.g., EN ISO 11885, EN ISO 17294-1, EN ISO 15586)	▪ Ion exchange; ▪ Neutralisation; ▪ Press filtering; ▪ Sand filtration; ▪ Air stripping; ▪ Neutralisation; ▪ Chemical reduction; ▪ Chemical oxidation; ▪ Filtration; ▪ Active sludge systems -SBR Flocculation; ▪ Active sludge system –SBR Adsorption; ▪ Emulsion breaking Press filtering;

Waste treatment process	Substance / Parameter	Standard	Available Abatement Techniques
▪ Sedimentation; ▪ Evaporation/drying; ▪ Oxidation/reduction; ▪ Filtration; ▪ Ion exchange.	**Hexavalent chromium (Cr(VI))**	Various EN standards available (E.g. EN ISO 10304-3, EN ISO 23913)	▪ Press filtering; ▪ Air stripping; ▪ Neutralisation; ▪ Chemical reduction; ▪ Chemical oxidation; ▪ Filtration; ▪ Ion exchange; ▪ Neutralisation; ▪ Sand filtration; ▪ Active sludge systems -SBR Flocculation; ▪ Active sludge system –SBR Adsorption; ▪ Emulsion breaking Press filtering.
Dechlorination with metallic alkali	**Mercury (Hg)**	Various EN standards available (e.g., EN ISO 17852, EN ISO 12846)	▪ Bag/fabric filter; ▪ Activated carbon adsorption; ▪ Cyclones; ▪ Sulphur impregnated activated carbon; ▪ High-efficiency particle air (HEPA) filter;
All waste treatments	**PFOA**	No EN standard available	NI
	PFOS		
▪ Chemical Immobilization; ▪ Precipitation/flocculation.	**Total nitrogen (Total N)**	EN 12260, EN ISO 11905-1	▪ Acid scrubber system; ▪ Activated carbon adsorption; ▪ Alkaline oxidative scrubber system.

Waste treatment process	Substance / Parameter	Standard	Available Abatement Techniques
▪ Chemical Immobilization; ▪ Re-refining; ▪ Distillation; ▪ Pervaporation; ▪ Centrifugation; ▪ Sedimentation; ▪ Evaporation/drying; ▪ Filtration; ▪ Ion exchange; ▪ Soil washing; ▪ Vapour extraction.	**Total organic carbon (TOC)**	EN 1484	▪ Thermal Oxidation; ▪ Adsorption; ▪ Biofilter; ▪ Bag/Fabric filter; ▪ Wet scrubbing; ▪ Cryogenic condensation; ▪ Recirculation of process off-gases in a steam boiler; ▪ Cyclone; ▪ Electrostatic precipitator.
▪ Precipitation/flocculation; ▪ Sedimentation; ▪ Evaporation/drying; ▪ Oxidation/reduction; ▪ Filtration; ▪ Ion exchange.	**Total phosphorus (Total P)**	Various EN standards available (i.e., EN ISO 15681-1 and -2, EN ISO 6878, EN ISO 11885)	▪ Biofiltering; ▪ Wet scrubbing; ▪ Acid scrubber system; ▪ Activated carbon adsorption; ▪ Alkaline oxidative scrubber system.
▪ Re-refining; ▪ Distillation; ▪ Pervaporation; ▪ Centrifugation; ▪ Chemical Immobilization; ▪ Sedimentation; ▪ Evaporation/drying; ▪ Filtration; ▪ Soil washing; ▪ Vapour extraction.	**Total suspended solids (TSS)**	EN 872	▪ Bag/fabric filter; ▪ Filtration; ▪ High-efficiency particle air (HEPA) filter; ▪ Press filtering; ▪ Sand filtration.

Table 6-6: Techniques used in the waste treatment sector to prevent, reduce or control the emissions to water

Type of discharge	Abatement Technology	Description
Biodegradable organic compounds	**Activated sludge process**	The biological oxidation of dissolved organic pollutants with oxygen using the metabolism of microorganisms. In the presence of dissolved oxygen (injected as air or pure oxygen), the organic components are transformed into carbon dioxide, water or other metabolites and biomass (i.e., the activated sludge). The microorganisms are maintained in suspension in the wastewater and the whole mixture is mechanically aerated. The activated sludge mixture is sent to a separation facility from where the sludge is recycled to the aeration tank.
Adsorbable dissolved non-biodegradable or inhibitory pollutants, e.g., hydrocarbons, mercury, AOX	**Adsorption**	Separation method in which compounds (i.e., pollutants) in a fluid (i.e. waste water) are retained on a solid surface (typically activated carbon).
Oxidisable dissolved non-biodegradable or inhibitory pollutants, e.g., nitrite, cyanide	**Chemical oxidation**	Organic compounds are oxidised to less harmful and more easily biodegradable compounds. Techniques include wet oxidation or oxidation with ozone or hydrogen peroxide, optionally supported by catalysts or UV radiation. Chemical oxidation is also used to degrade organic compounds causing odour, taste, and colour and for disinfection purposes.
Reducible dissolved non-biodegradable or inhibitory pollutants, e.g. hexavalent chromium (Cr(VI))	**Chemical reduction**	Chemical reduction is the conversion of pollutants by chemical reducing agents into similar but less harmful or hazardous compounds.
Suspended solids and particulate-bound metals	**Coagulation & flocculation**	Coagulation and flocculation are used to separate suspended solids from wastewater and are often carried out in successive steps. Coagulation is carried out by adding coagulants with charges opposite to those of the suspended solids. Flocculation is carried out by adding polymers, so that collisions of microfloc particles cause them to bond to produce larger flocs. The flocs formed are subsequently separated by sedimentation, air flotation or filtration.

Type of discharge	Abatement Technology	Description
Dissolved nonbiodegradable or inhibitory pollutants that can be distilled, e.g., some solvents	**Distillation/rectification**	Distillation is a technique to separate compounds with different boiling points by partial evaporation and recondensation. Wastewater distillation is the removal of low-boiling contaminants from wastewater by transferring them into the vapour phase. Distillation is carried out in columns, equipped with plates, or packing material, and a downstream condenser.
All pollutants	**Equalisation**	Balancing of flows and pollutant loads by using tanks or other management techniques.
Soluble pollutants	**Evaporation**	The use of distillation (see above) to concentrate aqueous solutions of high boiling substances for further use, processing, or disposal (e.g., wastewater incineration) by transferring water to the vapour phase. It is typically carried out in multistage units with increasing vacuum, to reduce the energy demand. The water vapours are condensed, to be reused or discharged as wastewater.
Suspended solids and particulate-bound metals	**Filtration**	The separation of solids from wastewater by passing them through a porous medium, 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.
Ionic dissolved nonbiodegradable or inhibitory pollutants, e.g., metals	**Ion exchange**	The retention of undesired or hazardous ionic constituents of 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.
Biodegradable organic compounds	**Membrane bioreactor**	A combination of activated sludge treatment and membrane filtration. Two variants are used: a) an external recirculation loop between the activated sludge tank and the membrane module; and b) immersion of the membrane module in the aerated activated sludge tank, where the effluent is filtered through a hollow fibre membrane, the biomass remaining in the tank.
Suspended solids and particulate-bound metals	**Membrane filtration**	Microfiltration (MF) and ultrafiltration (UF) are membrane filtration processes that retain and concentrate, on one side of the membrane, pollutants such as suspended particles and colloidal particles contained in waste waters.

Type of discharge	Abatement Technology	Description
Acids, alkalis	**Neutralisation**	The adjustment of the pH of wastewater to a neutral level (approximately 7) by the addition of chemicals. Sodium hydroxide (NaOH) or calcium hydroxide (Ca(OH)2) may be used to increase the pH, whereas sulphuric acid (H2SO4), hydrochloric acid (HCl) or carbon dioxide (CO2) may be used to decrease the pH. The precipitation of some pollutants may occur during neutralisation.
Total nitrogen, ammonia	**Nitrification/ denitrification**	A two-step process that is typically incorporated into biological wastewater treatment plants. The first step is aerobic nitrification where microorganisms oxidise ammonium (NH4 +) to the intermediate nitrite (NO2 -), which is then further oxidised to nitrate (NO3 -). In the subsequent anoxic denitrification step, microorganisms chemically reduce nitrate to nitrogen gas.
Oil/grease	**Oil-water separation**	The separation of oil and water and subsequent oil removal by gravity separation of free oil, using separation equipment or emulsion breaking (using emulsion breaking chemicals such as metal salts, mineral acids, adsorbents, and organic polymers).
Suspended solids and particulate-bound metals	**Sedimentation**	The separation of suspended particles by gravitational settling.
Precipitable dissolved non-biodegradable or inhibitory pollutants, e.g. metals, phosphorus	**Precipitation**	The conversion of dissolved pollutants into insoluble compounds by adding precipitants. The solid precipitates formed are subsequently separated by sedimentation, air flotation or filtration.
Purgeable pollutants, e.g. hydrogen sulphide (H2S), ammonia (NH3), some adsorbable organically bound halogens (AOX),	**Stripping**	The removal of purgeable pollutants from the aqueous phase by a gaseous phase (e.g., steam, nitrogen or air) that is passed through the liquid. They 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.

6.2.5 Management of outputs

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

As mentioned in Table 6.1 the Outputs of **Solid and/or pasty Waste, Waste with calorific value, excavated contaminated soil, Water-based liquid waste,** and **Waste containing POPs or mercury, or other waste** require special treatment in order to be usable or to be transferred to a landfill site.

6.2.6 Material and energy efficiency

BAT is to control-monitor also the annual consumption of water, energy, and raw materials as well as the annual generation of residues and 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.

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

6.3.1 Noise and vibration management plan

Such a plan as a part of the environmental management system (EMS) (see Section 9.1) normally does the following:

- 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.

6.3.2 Noise and vibration reduction at source and noise abatement

Techniques to reduce noise and vibration emissions include:

- Appropriate location of equipment and buildings: noise levels can be reduced by increasing the distance between the emitter and the receiver, 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;
- Enclosure of noisy equipment;
- Reduction of noise propagation by inserting appropriate obstacles such as protection walls, embankments, and buildings.

6.4 Techniques for the prevention and reduction of soil and water contamination

These techniques relate to water spills and other fugitive emissions into soil and groundwater:

- Impermeable surface and secondary containment;
- Adequate drainage infrastructure;
- Design and maintenance provisions to allow detection and repair of leaks;
- Buffer storage for contaminated surges.

Some specific techniques include the following:

- Having in place containment measures to prevent wastes from escaping. All bunds, humps, vessels, tanks, pipes, containers are sound, and maintained and checked as required.
- Providing and then maintaining the surfaces of operational areas, including applying measures to prevent or quickly clear away leaks and spillages, and ensuring maintenance of drainage systems and other subsurface structures.
- Depending on the risks posed by the waste in terms of soil and/or water contamination, making the surface of the whole waste treatment areas (e.g., waste reception, handling, storage, treatment, and dispatch areas) impermeable to the liquids concerned. This impermeable surface and internal site drainage systems lead to storage tanks or to interceptors that can collect rainwater and any spillages. Interceptors with an overflow to the sewer usually need automatic monitoring systems, such as a pH check, which can shut down the overflow.
- Collecting rainwater falling on the storage and processing areas along with tanker wash water, occasional spillages, drum wash water, etc. Rainwater is returned to the processing plant or collected for further treatment if it is found to be contaminated.
- Ensuring that the drainage infrastructure is capable of collecting and discharging all runoff water in case of heavy rains.
- Having in place a regular inspection and maintenance programme of underground equipment.
- Depending on the risks posed by the liquids in terms of soil and/or water contamination, ensuring that the areas where liquids are transferred are bunded and that the bund is resistant to stored materials. The bund is designed so that in the event of an accident the liquid can be contained until security measures are in place. The bund has sufficient capacity to cope with any spillage and firefighting water and is used to ensure containment of wastes and raw materials.
- Systems already applied for the prevention of fugitive emissions are generally relevant to drainage systems too.

- Inspecting pavements, drainage, and bunds daily. Particular attention is paid to signs of damage, deterioration, and leakage. Records are kept detailing any action taken. Damages and deterioration are repaired as soon as practicable. If the containment capacity or the capability of the bund, sump or pavement is compromised the waste is immediately removed until the repair is completed.

6.5 Best suitable techniques to improve environmental performance per physical – chemical type of treatment

Appendix 1 lists the best suitable technologies per type of Waste, Energy consumption and Environmental performance (Water consumption, Emissions to air, Discharge to water, Soil Residues).

6.5.1 Physico-chemical treatment of solid and/or pasty waste

6.5.1.1 Overall environmental performance

In order to ensure the smooth operation of the installation and compliance with all necessary procedures and legislation waste input properties must be controlled. The controlling of the waste input properties may include the following measurements:

- Measurement of the waste input organic content (TOC). (A TOC concentration < 6 % is commonly adopted.) The potential effect of a high organic content in the waste input includes:
    - Disturbance of the chemical reactions during the period of curing (pozzolanic and/or hydraulic reaction);
    - In the long term, biodegradation of organic compounds which involves destruction of the concrete-like bulk waste and disturbance of the physico-chemical equilibrium of the intra-porous liquid phase of the concrete-like waste with a potential release of heavy metals and salts.
- Measurement of the waste input mercury content. Mercury remains available in the waste and can involve contamination in the long term. Even if the mercury is in a sulphide form, the co-disposal with concrete-like waste will destroy sulphide mercury because of the alkaline pH.
- Measurement of the waste input salt content. Certain salts cannot be immobilised, e.g., chlorine salts, or can be immobilised to the level of the solubility product. For this type of salt, the compliance test for leaching of granular waste materials typically alters the physical form of the solidified material and therefore will overestimate the leaching of salts.
- Regular test for hydrogen (H2) generation when FGT residues containing carbonate are mixed with water. Physico-chemical conditions when fly ashes or FGT residues are mixed with water involve hydrolysis, e.g., of aluminium, which generates hydrogen emissions. This reaction is catalysed in the presence of carbonate (which is the case, for example, for FGT residues generated by dry flue-gas cleaning using sodium bicarbonate). This leads to a risk of explosion in closed or confined areas where the limit of explosivity can be easily reached.

6.5.1.2 Emissions to air

In order to reduce emissions of dust, organic compounds and NH_3 to air, BAT is to use one or a combination of the techniques given below.

Table 6-7: Techniques to reduce emissions of dust, organic compounds and NH3 to air

Waste Treatment Technology	Technique	Description
▪ Chemical Immobilization; ▪ Re-refining; ▪ Fluidification; ▪ Emulsification; ▪ Distillation; ▪ Pervaporation; ▪ Centrifugation; ▪ Sedimentation; ▪ Evaporation/drying; ▪ Filtration; ▪ Soil washing; ▪ Vapour extraction; ▪ Precipitation/flocculation; ▪ Ion exchange; ▪ Neutralisation; ▪ Acid extraction.	Absorption	Adsorption is a heterogeneous reaction in which gas molecules are retained on a solid or liquid surface that prefers specific compounds to others and thus removes them from effluent streams. When the surface has adsorbed as much as it can, the adsorbent is replaced, or the adsorbed content is desorbed as part of the regeneration of the adsorbent. When desorbed, the contaminants are usually at a higher concentration and can either be recovered or disposed of. The most common adsorbent is granular activated carbon.
▪ Chemical Immobilization; ▪ Precipitation/flocculation.	Biofilter	The waste gas stream is passed through a bed of organic material (such aspeat, heather, compost, root, tree bark, softwood and different combinations) or some inert material (such as clay, activated carbon, and polyurethane), where it is biologically oxidised by naturally occurring microorganisms into carbon dioxide, water, inorganic salts and biomass. A biofilter is designed considering the type(s) of waste input. An appropriate bed material, e.g. in terms of water retention capacity, bulk density, porosity, structural integrity, is selected. Also important are an appropriate height and surface area of the filter bed. The biofilter is connected to a suitable ventilation and air circulation system in order to ensure a uniform air distribution through the bed and a sufficient residence time of the waste gas inside the bed.
▪ Chemical Immobilization; ▪ Fluidification; ▪ Emulsification; ▪ Soil washing; ▪ Ion exchange; ▪ Neutralisation; ▪ Acid extraction; ▪ Filtration; ▪ Evaporation/drying.	Fabric filter	Fabric filters, often referred to as bag filters, are constructed from porous woven or felted fabric through which gases are passed to remove particles. The use of a fabric filter requires the selection of a fabric suitable for the characteristics of the waste gas and the maximum operating temperature

Waste Treatment Technology	Technique	Description
▪ Chemical Immobilization; ▪ Re-refining; ▪ Fluidification; ▪ Emulsification; ▪ Distillation; ▪ Pervaporation; ▪ Centrifugation; ▪ Sedimentation; ▪ Evaporation/drying; ▪ Filtration; ▪ Ion exchange; ▪ Soil washing; ▪ Precipitation/flocculation.	Wet scrubbing	The removal of gaseous or particulate pollutants from a gas stream via mass transfer to a liquid solvent, often water or an aqueous solution. It may involve a chemical reaction (e.g., in an acid or alkaline scrubber). In some cases, the compounds may be recovered from the solvent.

The use of enclosed equipment or buildings may be restricted by safety considerations such as the risk of explosion or oxygen depletion. The use of enclosed equipment or buildings may also be constrained by the volume of waste.

Table 6-8: Associated emission level for channelled emissions of dust to air from physico-chemical treatment of solid and/or pasty waste

Parameter	**Unit**	**BAT-AEL (Average over the sampling period)**
Dust	mg/Nm³	2-5

6.5.2 Re-refining of waste oil

6.5.2.1 Overall environmental performance

In order to improve the overall environmental performance, BAT is to control-monitor the waste input as part of the waste pre-acceptance and acceptance procedures. Monitoring of the waste input in terms of content of chlorinated compounds (e.g., chlorinated solvent or PCBs)

In order to reduce the quantity of the waste sent for disposal, BAT is to apply technique of containment, collection, and treatment of diffuse emission and to use one or both of the techniques given below:

Table 6-9: Techniques to reduce the quantity of waste

Technique		Description
a	Material recovery	Using the organic residues from vacuum distillation, solvent extraction, thin film evaporators, etc. in asphalt products etc.
b	Energy recovery	Using the organic residues from vacuum distillation, solvent extraction, thin film evaporators, etc. to recover energy.

6.5.2.2 Emissions to air

In order to reduce emissions of organic compounds to air, BAT is to apply the technique of containment, collection and treatment of diffuse emission as described in 6.2 and to use one or a combination of the techniques given below:

Table 6-10: Techniques to reduce emissions of organic compounds:

Technique			Description
a	**Absorption**		See section 6.3.1
b	**Thermal oxidation**		The oxidation of combustible gases and odorants in a waste gas stream by heating the mixture of contaminants with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water.
c	**Wet scrubbing**		See section 6.3.1

Table 6-11: BAT-AEL for emissions of organic compounds to air from the re-refining of waste oil

Parameter	Unit	BAT-AEL (Average over the sampling period)
TVOC	mg/Nm³	5-30
The BAT-AEL does not apply when the emission load is below 2 kg/h at the emission point provided that no CMR substances are identified as relevant in the waste gas stream.		

6.5.3 Physico-chemical treatment of waste with calorific value

6.5.3.1 Emissions to air

In order to reduce emissions of organic compounds to air, BAT is to use one or a combination of the techniques given in Section 6.2.1 including Cryogenic condensation technique.

Cryogenic condensation can cope with all VOCs and volatile inorganic pollutants, irrespective of their individual vapour pressures. The low temperatures applied allow for very high condensation efficiencies which make it well-suited as a final VOC emission control technique.

6.5.4 Regeneration of spent solvents

6.5.4.1 Overall environment performance

In order to improve the overall environmental performance of the regeneration of spent solvents, BAT is to use one or both of the techniques given below:

Table 6-12: Techniques to improve the overall environmental performance

	Technique	Description	Applicability
a	**Material recovery**	Solvents are recovered from the distillation residues by evaporation.	Applicability may be restricted when the energy demand is excessive with

	Technique	Description	Applicability
			regards to the quantity of solvent recovered.
b	**Thermal oxidation**	The residues from distillation are used to recover energy.	Generally applicable.

6.5.4.2 Emissions to air

In order to reduce emissions of organic compounds to air, BAT is to apply the technique of containment, collection and treatment of diffuse emission as described in 6.2.1 and to use one or a combination of the techniques given below:

Table 6-13: Techniques to reduce emissions of organic compounds to air

Technique		Description	Applicability
a	**Recirculation of process off-gases stream boiler**	The process off-gases from the condensers are sent to the stream boiler supplying the plant.	May not be applicable to the treatment of halogenated solvent wastes, in order to avoid generating and emitting PCBs and/or PCDD/F.
b	**Absorption**	See section 6.3.1	There may be limitations to the applicability of the technique due to safety reasons (e.g., activated carbon beds tend to self-ignite when loaded with ketones)
c	**Thermal oxidation**	See section 6.2.1	May not be applicable to the treatment of halogenated solvent wastes, in order to avoid generating and emitting PCBs and/or PCDD/F.
d	**Condensation or cryogenic condensation**	Condensation is a technique that eliminates solvent vapours from a waste gas stream by reducing its temperature below its dew point. For cryogenic condensation, the operating temperature can be down to -120 °C, but in practice it is often between -40 °C and -80 °C in the condensation device. Cryogenic condensation can cope with all VOCs and volatile inorganic pollutants, irrespective of their individual vapour pressures. The low temperatures applied allow for very high condensation efficiencies which make it well-suited as a final VOC emission control technique.	Generally applicable
e	**Wet scrubbing**	See section 6.3.1	Generally applicable

Table 6-14: BAT-AEL for emissions of organic compounds to air from the regeneration of spent solvents

Parameter	Unit	BAT-AEL (Average over the sampling period)
TVOC	mg/Nm³	5-30
The BAT-AEL does not apply when the emission load is below 2 kg/h at the emission point provided that no CMR substances are identified as relevant in the waste gas stream.		

6.5.5 Water washing of excavated contaminated soil

6.5.5.1 Emissions to air

In order to reduce emissions of dust and organic compounds to air from the storage, handling and washing steps, BAT is to apply the technique of containment, collection and treatment of diffuse emission as described in 6.3.1 and to use one or a combination of the techniques given below:

Table 6-15: Techniques to reduce emissions of dust and organic compounds to air from the storage

Technique		Description	Applicability
a	**Absorption**	See section 6.3.1	There may be limitations to the applicability of the technique due to safety reasons (e.g., activated carbon beds tend to self-ignite when loaded with ketones)
b	**Fabric filter**	See section 6.3.1	
c	**Wet scrubbing**	See section 6.3.1	Generally applicable

6.5.6 Decontamination of equipment containing PCBs

6.5.6.1 Overall environmental performance

In order to improve the overall environmental performance and to reduce channelled emissions of PCBs and organic compounds to air, BAT is to use all of the techniques given below:

Table 6-16: Techniques to improve the overall environmental performance and to reduce channelled emissions of PCBs and organic compounds to air

Technique		Description
a	Coating of the storage and treatment areas	This includes techniques such as resin coating applied to the concrete floor of the whole storage and treatment area.
b	Implementation of staff access rules to prevent dispersion of contamination	This includes techniques such as: • Access points to storage and treatment areas are locked; • Special qualification is required to access the area where the contaminated equipment is stored and handled; • Separate 'clean' and 'dirty' cloakrooms to put on/remove individual protective outfit.
c	Optimised equipment cleaning and drainage	This includes techniques such as:

	Technique	Description
		• External surfaces of the contaminated equipment are cleaned with anionic detergent; • Emptying of the equipment with a pump or under vacuum instead of gravity emptying; • Procedures are defined and used for filling, emptying and (dis)connecting the vacuum vessel; • A long period of drainage (at least 12 hours) is ensured to avoid any dripping of contaminated liquid during further treatment operations, after the • Separation of the core from the casing of an electrical transformer.
d	Control and monitoring of emissions to air	This includes techniques such as: • The air of the decontamination area is collected and treated with activated carbon filters; • The exhaust of the vacuum pump mentioned in technique c. above is connected to an end-of-pipe abatement system (e.g. a high-temperature incinerator, thermal oxidation or adsorption on activated carbon); • The channelled emissions are monitored; • The potential atmospheric deposition of PCBs is monitored (e.g., through physico-chemical measurements or biomonitoring).
e	Disposal of waste treatment residues	This includes techniques such as: • Porous, contaminated parts of the electrical transformer (wood and paper) are sent to high temperature incineration; • PCBs in the oils are destroyed (e.g., dechlorination, hydrogenation, solvated electron processes, high temperature incineration).
f	Recovery of solvent when solvent washing is used	Organic solvent is collected and distilled to be reused in the process.

6.5.7 Treatment of water-based liquid waste

6.5.7.1 Overall environmental performance

In order to improve the overall environmental performance, BAT is to control-monitor the waste input as part of the waste pre-acceptance and acceptance procedures, in terms of:

- Bio-eliminability (e.g., BOD, BOD to COD ratio, Zahn-Wellens test, biological inhibition potential (e.g., inhibition of activated sludge));
- feasibility of emulsion breaking, e.g., by means of laboratory-scale tests.

6.5.7.2 Emissions to air

In order to reduce emissions of HCl, NH_3 and organic compounds to air, BAT is to apply the technique of containment, collection and treatment of diffuse emission as described in 6.2.1 and to use one or a combination of the techniques given below.

Table 6-17: Techniques to reduce emissions of HCl, NH3 and organic compounds to air

Technique		Description	Applicability
a	Absorption	See section 6.3.1	There may be limitations to the applicability of the technique due to safety reasons (e.g., activated carbon beds tend to self-ignite when loaded with ketones).
b	Biofilter	See section 6.3.1	
c	Thermal oxidation	See section 6.2.1	
d	Wet scrubbing	See section 6.3.1	Generally applicable.

Table 6-18: BAT-AEL for channelled emissions of HCl and TVOC to air from the treatment of water-based liquid waste

Parameter	Unit	BAT-AEL (Average over the sampling period)
HCl	mg/Nm³	1-5
TVOC		3-20

7 OPERATION AND MAINTENANCE

7.1 Operational techniques to improve performance of Physico-Chemical Treatment Facilities

For most physico-chemical treatment facilities, the following order is relevant: a) pre-acceptance, b) acceptance, c) storage, d) treatment, and e) storage of residues and emissions. 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.

Waste pre-acceptance	• to ensure the technical (and legal) suitability of the waste treatment operation for a particular waste.
Waste acceptance	• to confirm the characteristics of the waste, as identified in the preacceptance stage.
Waste sampling	• to select the waste samples which will undergo characterisation, analyses or tests.
Waste tracking system and waste inventory	• to hold all the information generated during pre-acceptance, acceptance, storage, treatment and/or removal off site
Output quality management for the waste treatment	• ensure that the output of the waste treatment is in line with the expectations
Waste compatibility assessment	• set of checks and tests to detect any unwanted and potentially dangerous chemical reactions between wastes (polymerisation, gas evolution, exothermic reaction, decomposition, crystallisation, precipitation, etc.) during mixing, blending or other treatment operations

In the following paragraphs the best available techniques and technologies applied for each step are discussed.

7.1.1 Waste pre-acceptance

The waste pre-acceptance procedure ensures the technical (and legal) suitability of the waste treatment operation for a particular waste and the best relevant techniques are as follows[9]:

- Manifest (hard copy or electronic) on the Waste Generator, origin of waste, quantity and composition and confirmation that no radioactive, military and any other non-compatible contamination is included;
- A representative sample of the waste should be collected and analysed if:
  - The chemical composition or variability of the waste is unclear from the information supplied by the customer, or there are doubts about whether the sample analysed is representative of the waste; and
  - The facility accepts this waste category.
- A representative sample may not be required where the waste is asbestos or a pure product chemical or aerosol or laboratory smalls in containers or contaminated clothing, packaging, or rags etc.;

[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)

- A technical assessment is made of the suitability of the waste for treatment or storage to ensure permit conditions can be met;
- The personnel dealing with the pre-acceptance procedure have the necessary professional skills, training and/or experience;
- Material flow analysis for the components in the waste will help identify the flow(s) and fate(s) of the components in the waste;
- Records of pre-acceptance are kept for at least 3 years following receipt of the waste in a computerised process control system;
- The information required at pre-acceptance is reassessed if:
    - The waste changes;
    - The process giving rise to the waste changes;
    - The waste as received is found not to conform to the pre-acceptance information;
    - In any case, on an annual basis.
- Odour criteria are applied to reject biodegradable wastes that release mercaptans or other VOCs, low molecular weight amines, acrylates, or other similarly highly odorous materials that are only suitable for acceptance under special handling requirements.

7.1.2 Waste acceptance

The waste acceptance procedure provides details of the following steps which are undertaken by operators when the waste arrives at the facility. It also takes into consideration the objectives of the treatment (which includes the specification intended for the output).

1. Acceptance principles:
    - Other than in an emergency, the operator only receives onto the site prebooked wastes that have been adequately pre-accepted;
    - All wastes are checked and verified against pre-acceptance information and transfer documentation before being received on site;
    - Waste is only received and accepted under the supervision of a suitably qualified person;
    - All transfer documentation is manifested;
    - The operator ensures that the facility has the necessary capacity to receive the waste for all storage areas (quarantine, reception, general and bulk) and treatment processes;
    - The waste is checked to determine that it is not a radioactive waste.
2. Sampling:
   Other than some wastes such as:
    - Pure waste chemicals;
    - Expired chemicals;
    - Material with proper Material Safety Data Sheet (MSDS);
    - Asbestos;
    - Contaminated clothing, packaging, or rags;
    - 'Articles';
    - Laboratory smalls;

- Solid non-hazardous waste (except for mirror entries when the waste composition is unknown);
- Contaminated wood and roofing material;
- Green wastes and food wastes;

All wastes, bulk or containerized (including from every container), are representatively sampled and undergo verification and compliance testing. Reliance solely on the written information supplied is not sufficient.

Sampling takes place on site under the supervision of the site's qualified staff. Where the driver arrives at the site with a sample taken elsewhere, there is a full risk assessment to check that the sample is representative, reliable and was only taken for specific health or safety purposes (for example, air- or water-reactive wastes).

A record of the sampling regime, process and justification is maintained in the computerised waste process control system.

Acceptance samples are retained on site for an appropriate amount of time (e.g., 2 days) after the waste has been treated or removed from the facility including all residues from its treatment.

3. Inspection and analysis

   The tests required for verification purposes at acceptance (for example, metal content, total petroleum hydrocarbons, colour, pH, and odour) are listed in the computerized waste process control system. If visual inspection is not feasible (e.g., for occupational safety reasons), the compliance of the waste input is checked by analytical equipment (e.g., viscometry, infrared, chromatography, mass spectrometry), laboratories and adequate human resources. Analysis of waste is carried out by a laboratory with suitably recognized test methods. Where the waste received is hazardous, the laboratory is on site or routinely available at another site.

4. Reception:

   - It is ensured that all containers are adequately labelled and in sound condition;
   - Following visual inspection, waste containers are offloaded into a dedicated reception area to await sampling and verification;
   - Any containers in the reception area are sampled and verified as compliant as soon as possible (e.g., within one working day of receipt) and transferred to the relevant general storage area on site, or quarantine for a maximum of five working days if appropriate. Wastes are not deposited within a reception area without adequate space;
   - For some limited and specific cases (for example detection of radioactivity), the quarantine storage could be longer;
   - The residual waste quarantine, reception, general and bulk storage capacity of the installation is kept up to date in a computerised waste process control system;
   - Bulk loads (liquid or solid) can only be offloaded once they have been fully verified as Compliant;
   - Separate spaces are foreseen in the reception area for the separation of extraneous materials or oversized pieces;

- The designated sampling point(s) or reception area need to be in close proximity to the laboratory/checking facility and need to be visible;
- The reception area is equipped with a suitably sealed drainage system to prevent contaminated run-off, and a separate collection system for spills which is separated from rainwater collection drains;
- The offloading, sampling point/reception and quarantine areas have an impervious surface with self-contained drainage, to prevent any spillage entering the storage systems or escaping off site;
- Absorbents need to be made available to deal with any spills.

7.1.2.1 Allowed – Rejected Waste

An indicative and not exclusive list of waste categories treated by physico-chemical treatments are listed below[10]:

- Fly ash and flue-gas treatment residues;
- Industrial sludge; sludge from chemical industry may contain sulphates and organic salts;
- Mineral residues from chemical processing;
- High arsenic content residues from the chemical, metallurgical or ore industries;
- Contaminated dredge material;
- Contaminated soil;
- Flammable and highly flammable wastes (e.g., low-flashpoint solvents);
- Wastes containing volatile substances;
- Oxidising agents;
- 0dorous Wastes;
- Waste containing highly soluble organic Waste and with a high COD content;
- Waste containing molybdenum;
- Waste containing soluble inorganic salts;
- Solid cyanides;
- Chelating agents;
- Water-reactive Wastes.

On the other hand, waste categories rejected and finally not treated by physico-chemical treatments are the following[11]:

- Waste transported by an entity that is not appropriately licensed;
- Waste not accompanied by an appropriate Transport Document or manifest;

[10] (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)
[11] (The Implementing Regulations of the Waste Management Law, 2021)

- Waste received that cannot be appropriately processed by the facility's treatment capabilities.

7.1.3 Waste sampling

The sampling procedure is used as part of the pre-acceptance and acceptance steps to select the waste samples which will undergo characterisation, analyses, or tests. Both onsite and offsite laboratory is utilised, and this is recommended for all types of facilities. A sampling procedure is designed based on the following principles[12]:

- A risk approach based on the type of waste (e.g., hazardous, or non-hazardous); knowledge of the customer (e.g., waste producer); the impact of potential mixing or blending; and the possibilities for subsequent treatment.
- The relevant physico-chemical parameters are checked (e.g., by viscometry, infrared, chromatography, and mass spectrometry as appropriate).
- Sampling procedures are customised for bulk liquid, bulk solids, large and small containers/vessels (the number of samples increases with the number of containers/vessels and the variability of the waste), laboratory smalls;
- The procedure contains details of the sampling of wastes in drums within designated storage, e.g., the timescale after receipt;
- The following information is determined and recorded:
    - The sampling regime for each load, together with a record of the justification for the selection of each option;
    - A suitable location for the sampling points;
    - The capacity of the sampled vessel;
    - The number of samples and degree of consolidation;
    - The operating conditions at the time of sampling.
- In the case of cold ambient temperatures, a temporary storage may be needed in order to allow sampling after defrosting;
- A laboratory to analyse all the samples in a timely manner at the required speed. Particularly for hazardous wastes, this often means that the laboratory (with suitable equipment) needs to be on site.

7.1.4 Waste tracking and waste inventory

A waste tracking system for the site holds all the information generated during pre-acceptance, acceptance, storage, treatment and/or removal off site. The waste tracking system must account for the following information:

- Total quantity of waste present on site at any one time, in appropriate units;
- Breakdown of waste quantities being stored pending on-site treatment, classified by treatment route;
- Breakdown of waste quantities on site for storage only, i.e., awaiting onward transfer;
- Breakdown of waste quantities by hazard classification;
- Where the waste is located on site relative to a site plan;

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[12] (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)

- The quantity on site compared to the total permitted;
- The time the waste has been on site compared to the permitted time limit.

Records are made in the computerised waste process control system and kept up to date on an ongoing basis to reflect deliveries, on-site treatment, and despatches. The tracking system operates as a waste inventory/stock control system and includes as a minimum[13]:

- Date of arrival on site;
- Producer details;
- Previous holder;
- A unique reference number;
- Pre-acceptance and acceptance analysis results;
- Package type and size;
- Intended treatment route;
- Accurate records of the nature and quantity of waste held on site, including all identified hazards;
- Where the waste is physically located in relation to a site plan;
- Where the waste is in the designated waste treatment route (for batch treatment);
- Accurate records of decisions regarding pre-acceptance, acceptance, storage, treatment or
- Rejection of waste streams;
- Recipient of the output.

As a way of keeping an up-to-date waste inventory, the waste tracking system also aims at avoiding an accumulation of waste, which may in turn lead to the deterioration or deformation of the containers. It also helps in identifying any ageing waste on site and in ensuring that any accumulations of liquids in bunds, sumps, etc. are dealt with promptly.

In principle, all received / treated wastes are to be tracked and kept on record as per the IR. The waste tracking system is risk-based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety, and environmental impact as well as the knowledge of the previous waste holder(s).

7.1.5 Output quality management for the waste treatment

The set-up and implementation of an output quality management system, so as to ensure that the output of the waste treatment is in line with the expectations, using for example existing Standards methods like EN standards (e.g., dynamic olfactometry according to EN 13725 in order to determine the odour concentration or EN 16841-1 or -2 in order to determine the odour exposure).

This management system allows verification that the characteristics of the waste output are in line with the expectations, which may be product specifications, contaminant removal efficiency rate, etc.

[13] (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)

The management system also helps monitor and optimise the performance of the waste treatment and, for this purpose, it may include a material flow analysis of relevant components throughout the waste treatment.

Material flow analysis for some contaminants in the waste will help identify the flow(s) and fate(s) of these contaminants. This analysis can be helpful in choosing the most appropriate forms of treatment for the waste either directly at the site or at any subsequent treatment site. It considers the contaminant quantity in the waste input, in the different waste treatment outputs and in the waste treatment emissions. The aim of the material flow analysis and the subsequent knowledge of the fate of the contaminants is to ensure that those contaminants are correctly treated and either destroyed or removed.

The use of a material flow analysis is risk-based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety, and environmental impact as well as the knowledge of the previous waste holder(s).

7.1.6 Waste compatibility assessment

Waste compatibility assessment is a set of checks and tests to detect any unwanted and potentially dangerous chemical reactions between wastes (polymerisation, gas evolution, exothermic reaction, decomposition, crystallisation, precipitation, etc.) during mixing, blending or other treatment operations[14].

Compatibility assessment can be done at pre-acceptance, acceptance and before any step in the waste treatment process.

The compatibility assessment is adapted to each waste storage and treatment operation. For example, it can consist of specific procedures for solid wastes, for long reaction times, for waste in small packages, etc.

In order to prevent any adverse or unexpected reactions and releases before transfer involving the following activities, testing takes place prior to the transfer:

- Tanker discharge to bulk storage;
- Tank-to-tank transfer;
- Transfer from container to bulk tank;
- Bulking into drums or IBCs;
- Bulking of solid waste into drums or skips.

A list of unacceptable waste is established based on the facility's permit and on whether the waste poses specific risks to the installation or process such as:

- Risk of explosion (e.g., presence of ammunition, mixing processes that could lead to explosion); corrosion to the installation (e.g., strong acids);
- Risk of uncontrolled reactions (e.g., presence of peroxides or strong oxidants, or polymerising components such as certain isocyanates);
- Risk of the evolution of gases (e.g., presence of cyanides, sulphides, dissolved gas).

The above list is very specific for the treatment operation and final treatment and requires the waste operators to establish it on a case-by-case basis for their specific operation.

[14] (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)

The type of compatibility test varies according to the type of waste and the waste treatment operation (for example unloading, grouping, homogenisation).

The main principle is to mix a first waste sample with a sample of a second waste with which it will be mixed. The compatibility test is done in a laboratory and is performed under the same adiabatic conditions as the full-scale mixing. The test considers the following elements:

- Temperature increase, exothermic reaction;
- Physical aspect/behaviour of the mixing (e.g., several phases or not, emulsions);
- Potential precipitation, crystallisation, polymerisation, and other chemical reactions;
- Gas emission.

The time of the test varies, for example from 15 minutes to 24 hours, according to the type of waste.

In order to better characterize the reactivity of the waste, additional tests could be needed such as oxidant and reduction tests, pH determination, release test. The rejection criteria of the compatibility tests may be unique or combined and are defined according to the type of waste and waste treatment process, and can be temperature modifications (for example, an increase of 3 °C upon mixing indicates incompatible wastes), mixing aspects (if polymerisation occurs the wastes are not compatible for mixing), etc.

Any evolved gases and causes of odour are identified. If any adverse reaction is observed, an alternative discharge or disposal route is found.

The compatibility tests are risk-based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety, and environmental impact as well as the knowledge of the previous waste holder(s).

7.2 Training

7.2.1 Training requirements

Facilities will only be operated by qualified and trained personnel. Therefore, the Service Provider of physical-chemical treatment of waste 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.[15]

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

i. Physico-Chemical Treatment (PCT) facility theory, site infrastructure and basic design concepts including how features protect groundwater, surface water and air quality.
ii. PCT 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.
iii. Regular maintenance of leachate and gas collection systems, and cleaning and repair of surface water control systems;

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

iv. Monitoring and reporting requirements specific to the relevant PCT facility including spills and storage requirements;
v. Employee health and safety to include hazardous substances, PPE, and clean up requirements;
vi. Employee training to include developing, implementing, and documenting training programmes for all personnel at the PCT facility.

7.2.2 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:

i. How to report a fire, injury, chemical spill, or other emergency;
ii. The location of emergency equipment, such as safety showers and eyewashes;
iii. The location of fire extinguishers and spill control equipment;
iv. The locations of all available exits for evacuation; and
v. 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.

8 HEALTH AND SAFETY CONSIDERATIONS

The design and operation of the physico-chemical waste treatment 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. [16]

Electricity, water, sanitation, and communications facilities must be provided at all physico-chemical treatment 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.

8.1 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.

8.2 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;

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

- 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), 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, clear guidance is available on how each accident scenario needs to be managed; for example, containment or dispersion, to extinguish fires or to let them burn;
- Establishing communication routes with relevant authorities and emergency services both before and in the event of an accident. Post-accident procedures 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.

9 MONITORING, RECORDKEEPING AND REPORTING

9.1 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,

9.2 Waste input monitoring and recordkeeping

According to the Article CXLVII (147) on 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. 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.

9.3 Monitoring and recordkeeping of identified emissions

In sections 6.2 & 6.3, several potential emissions to both water and air have been identified as well as the emitting source in each treatment technology along with the BAT to control and reduce them. It is crucial that these parameters be monitored in a frequently basis, given in the tables below, in order to prevent either air or water pollution incidents.

Table 9-1: Parameters and minimum monitoring frequency of emissions to air

Substance / Parameter	Waste treatment process	Minimum monitoring frequency
Dust	Physico-chemical treatment of solid and/or pasty waste	Once every six months
Hydrogen Chloride (HCl)	Treatment of water-based liquid waste	Once every six months
Dioxin-like PCBs	Treatment of water-based liquid waste	Once every three months
Ammonia (NH_3)	Physico-chemical treatment of solid and/or pasty waste	Once every six months

Substance / Parameter	Waste treatment process	Minimum monitoring frequency
	Treatment of water-based liquid waste	
(Volatile organic compounds) TVOC	Physico-chemical treatment of solid and/or pasty waste	Once every six months
	Decontamination of equipment containing PCBs	
	Physico-chemical treatment of waste with calorific value	
	Treatment of water-based liquid waste	
	Re-refining of waste oil	
	Regeneration of spent solvents	
	Water washing of excavated contaminated soil	

Table 9-2: Parameters and minimum monitoring frequency of emissions to water

Substance / Parameter	Waste treatment process	Minimum monitoring frequency
Absorbable organically bound halogens (AOX)	Treatment of water-based liquid waste	Once every day
Benzene, toluene, ethylbenzene, xylene (BTEX)	Treatment of water-based liquid waste	Once every month
Chemical oxygen demand (COD)	Treatment of water-based liquid waste	Once every day
Hydrocarbon oil index (HOI)	Physico-chemical treatment of waste with calorific value	Once every month
	Re-refining of waste oil	Once every day
Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), Zinc (Zn)	Physico-chemical treatment of waste with calorific value	Once every month
	Physico-chemical treatment of solid and/or pasty waste	
	Contaminated soil	
Hexavalent chromium (Cr(VI))	Treatment of water-based liquid waste	Once every day
Mercury (Hg)	Physico-chemical treatment of waste with calorific value	Once every month
	Physico-chemical treatment of solid and/or pasty waste	
	Treatment of water-based liquid waste	Once every day
PFOA	All waste treatments	Once every six months
PFOS		
Phenol index	Physico-chemical treatment of waste with calorific value	Once every month
	Treatment of water-based liquid waste	Once every day
	Re-refining of waste oil	
Total nitrogen (Total N)	Treatment of water-based liquid waste	Once every day

Substance / Parameter	Waste treatment process	Minimum monitoring frequency
Total organic carbon (TOC)	All waste treatments except treatment of water-based liquid waste	Once every month
	Treatment of water-based liquid waste	Once every day
Total phosphorus (Total P)	Treatment of water-based liquid waste	Once every day
	Treatment of waste oil	
Total suspended solids (TSS)	All waste treatments except treatment of water-based liquid waste	Once every month
	Treatment of water-based liquid waste	Once every day

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 9.1.2) and made available when an inspection from the Centre occurs.

9.4 Reporting

The designated person should use the data recorded above to monitor the production and/or the management of waste at the chemical-physical treatment 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- Physical/Chemical Treatment Processes

APPENDIX 2 Treatment Technologies- Physical/Chemical Treatment Processes per type of Waste, Energy Consumption, and Environmental Performance (Emissions to air, Discharge to Water, Soil/Residues)

APPENDIX 3 List of Treatment Technologies- Physical/Chemical Treatment Processes per type of Waste, the respective outputs, and their most suitable management options, as well as the type of discharge and their abatement technology

APPENDIX 1 Summary of Treatment Technologies- Physical/Chemical Treatment Processes

Established Treatment technology	Technology summary	Type of Waste treated	Type of technology	Outputs	Management of Outputs	Type of discharge	Abatement Technology
Chemical Immobilization -Stabilization	Stabilisation changes the chemical state of the constituent of the waste input. With complete stabilisation, a hazardous waste can be transformed into a non-hazardous waste by means of specific chemical reactions that either destroy organic hazardous contents, or convert inorganic hazardous substances into non-hazardous compounds	Solid and/or pasty Waste	Chemical	Stabilized material	Landfill	Emissions of dust, volatile organic compounds (VOCs) and NH_3 to air.	a.Adsorption b. Biofilter c. Bag/Fabric filter d. Wet scrubbing
Chemical Immobilization – Solidification	Solidification changes the physical properties of the waste input by using additives. Partial stabilisation or solidification processes do not change the hazardous nature of wastes, and the classification of waste with regards to pollutant parameters is therefore not modified			Solidified material	Landfill or as backfilling material in mines		
Ion exchange`	Removal of undesired or hazardous ionic constituents and their replacement by more acceptable ions from an ion exchange resin, where the undesired ions are temporarily retained and afterwards released into a regeneration or backwashing liquid.	Pollution abatement components	Chemical	Regenerated activated carbon Regenerated resins Regenerated catalysts	By product for reuse	Emissions of HCl, HF, dust and volatile organic compounds (VOCs) to air.	a. Cyclone b. Electrostatic precipitator (ESP) c. Bag/fabric filter d. Wet scrubbing e. Adsorption f. Condensation g. Thermal oxidation
		Water-based liquid Waste		Water / Spent solvent / Solid residue / Concentrate	Disposal usually by Immobilisation or incineration.	Emissions of Total hydrocarbons (THC), Hydrocarbon oil index (HOI), Free cyanide (CN), Adsorbable organically bound halogens (AOX) and metals to water	a. Air stripping b.Neutralisation c. Chemical reduction d. Chemical oxidation e. Filtration f. Ion exchange g. Neutralisation h. Press filtering i. Sand filtration j. Active sludge systems -SBR Flocculation k. Active sludge system –SBR Adsorption l. Emulsion breaking Press filtering
Re-refining	The treatment of Waste oil to reconvert it into a material that can be reused or used as a base oil to produce lubricants.	Waste oil	Physical & Chemical	Lubricant base oil	By product for reuse	Emissions of volatile organic compounds (VOCs) to air	a. Activated Carbon Adsorption b. Wet scrubbing c. Thermal Oxidation

Established Treatment technology	Technology summary	Type of Waste treated	Type of technology	Outputs	Management of Outputs	Type of discharge	Abatement Technology
Neutralisation	The reaction in which acid and a base react quantitatively with each other.	FGT residues	Chemical	Recovery of Raw Material (Residual Sodium Chemicals)	By product for reuse	Emissions of dust to air	a. Bag/fabric filter b. Activated carbon adsorption
Oxidation/reduction	The use of oxidizing agent to oxidize the organic pollutants.	Water-based liquid Waste	Chemical	Water / Spent solvent / Solid residue / Concentrate	Disposal usually by Immobilisation or incineration.	Emissions of Total hydrocarbons (THC), Hydrocarbon oil index (HOI), Free cyanide (CN), Adsorbable organically bound halogens (AOX) and metals to water. Emissions of VOCs, acid gases, ammonia, xylene, dust, NOx, SOx, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol	a. Air stripping b.Neutralisation c. Chemical reduction d. Chemical oxidation e. Filtration f. Ion exchange g. Neutralisation h. Press filtering i. Sand filtration j. Active sludge systems -SBR Flocculation k. Active sludge system –SBR Adsorption l. Emulsion breaking Press filtering
Filtration	The separation of solids from Wastewater effluents passing through a porous medium (membrane).	FGT residues	Physical	Recovery of Raw Material (Residual Sodium Chemicals)	By product for reuse	Emissions of dust to air	a. Bag/fabric filter b. Activated carbon adsorption
		Spent solvents		Recovered solvent	By product for reuse	Emissions of volatile organic compounds (VOCs) to air	a. Recirculation of process off-gases in a steam boiler b. Adsorption c. Thermal oxidation d. Condensation or cryogenic condensation e. Wet scrubbing
		Water-based liquid Waste		Water / Spent solvent / Solid residue / Concentrate	Pressed and sent to further treatment /Pressed and mixed with other sludges (generally organic) on site/Mixed with residues from waste gas cleaning to give a solid product (with an exothermic reaction) *	Emissions of Total hydrocarbons (THC), Hydrocarbon oil index (HOI), Free cyanide (CN), Adsorbable organically bound halogens (AOX) and metals to water Emissions of dust, volatile organic compounds (VOCs) and NH3 to air.	a. Air stripping b.Neutralisation c. Chemical reduction d. Chemical oxidation e. Filtration f. Ion exchange g. Neutralisation h. Press filtering i. Sand filtration j. Active sludge systems -SBR Flocculation k. Active sludge system –SBR Adsorption l. Emulsion breaking Press filtering

Established Treatment technology	Technology summary	Type of Waste treated	Type of technology	Outputs	Management of Outputs	Type of discharge	Abatement Technology
Distillation **–**Thin film evaporation –Short path evaporation –Single stage flash distillation –Multi-stage distillation –Pressure swing distillation –Azeotropic distillation –Extractive distillation	The partial evaporation of a liquid phase followed by condensation of the vapour.	Spent solvents	Physical	Recovered solvent	By product for reuse	Emissions of volatile organic compounds (VOCs) to air. Water from steam and cooling systems to be recycled and managed separately. Wastewater from ceaning tanks, distillation etc has low pollutant loads.	a.Recirculation of process off-gases in a steam boiler b. Adsorption c. Thermal oxidation d. Condensation or cryogenic condensation e. Wet scrubbing
Precipitation/flocculation	The process of formation of an insoluble solid mass/ The process of formation of solid aggregates from small particles.	Water-based liquid waste	Physical &Chemical	Sludge	Pressed and sent to further treatment /Pressed and mixed with other sludges (generally organic) on site/Mixed with residues from waste gas cleaning to give a solid product (with an exothermic reaction) *	Emissions of volatile organic compounds (VOCs), NH3, and acid gases to air. Contaminated water (nitrus oxide, metals, ammonia, organic chemicals, oil content, sulphates, sulphites, sulphides)	a.Biofiltering b.Wet scrubbing c.Acid scrubber system d.Activated carbon adsorption e.Alkaline oxidative scrubber system
Sedimentation	The separation of suspended particles and floating material by gravitational settling.	Spent solvents	Physical	Recovered solvent	By product for reuse	Emissions of volatile organic compounds (VOCs) to air. Water from steam and cooling systems to be recycled and managed separately, Wastewater from ceaning tanks, distillation etc has low pollutant loads	a.Recirculation of process off-gases in a steam boiler b. Adsorption c. Thermal oxidation d. Condensation or cryogenic condensation e. Wet scrubbing
		Water-based liquid Waste		Filter cake	Pressed and mixed with other sludges (generally organic) on site or mixed with residues from waste gas cleaning to give a solid product (with an exothermic reaction)	Emissions of Total hydrocarbons (THC), Hydrocarbon oil index (HOI), Free cyanide (CN), Adsorbable organically bound halogens (AOX) and metals to water Emissions of VOCs, acid gases,ammonia, xylene, dust, NOx, Sox, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol to air	a. Air stripping b.Neutralisation c. Chemical reduction d. Chemical oxidation e. Filtration f. Ion exchange g. Neutralisation h. Press filtering i. Sand filtration j. Active sludge systems -SBR Flocculation k. Active sludge system –SBR Adsorption

Established Treatment technology	Technology summary	Type of Waste treated	Type of technology	Outputs	Management of Outputs	Type of discharge	Abatement Technology
							l. Emulsion breaking Press filtering
Acid extraction	The removal of a significant part of the total amount of heavy metals from the Waste input (Cd Zn Pb, Cu and Hg); the leachability of the material is reduced by a factor 10^2–10^3.	FGT residues	Chemical	Fly ashes without heavy metals and salts	Disposal in landfills	Emissions of dust to air	a.Bag/fabric filter b.Activated carbon adsorption
Soil washing	An ex situ process in which contaminated soil is excavated and fed through a water-based washing process. It operates on the principle that contaminants are associated with certain size fractions of soil particles and that these contaminants can be dissolved or suspended in an aqueous solution or removed by separating out clay and silt particles from the bulk soil.	Excavated contaminated soil	Physical	Recycled materials	Construction Industry	Emissions of dust, TOC, Hg, Pb, Cr, Ni to air.	a.Wet scrubbing b.Bag/fabric filter c.Adsorption
Solvent extraction	Solid separation wherein the contaminant in the hazardous Waste is dissolved by a liquid chemical or supercritical fluid, reducing its concentration in the Waste. The extracted solution containing the contaminant is usually collected for recycling, further treatment, or destroyed.	Excavated contaminated soil	Physical	Solid waste with a reduced pollutant load concentration- Concentrated contaminants	Concentrated contaminants are designated for further treatment, recycling or reuse before disposal/ Soil will need dewatering, treatment for residual organic compounds, additional separation, stabilisation.	NI	NI
Centrifugation	One of the main solid-liquid separation techniques.	Water-based liquid waste	Physical	Sludge/ Solid residue	Pressed and mixed with other sludges (generally organic) on site or mixed with residues from waste gas cleaning to give a solid product (with an exothermic reaction)	Emissions of VOCs, acid gases, ammonia, xylene, dust, NOx, SOx, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol Contaminated water (nitrus oxide, metals, ammonia, organic chemicals, oil content, sulphates, sulphites, sulphides)	a.Recirculation of process off-gases in a steam boiler b.Adsorption c. Thermal oxidation d. Condensation or cryogenic condensation e. Wet scrubbing
Vapour extraction	Removal of volatile organic constituents from contaminated Waste by creating a sufficient subsurface airflow to strip contaminants from the vadose (unsaturated) zone by volatilisation.	Excavated contaminated soil	Physical	Treated solids with possible contamination	Further treatment may be required	Emissions of untreated volatile organics from the extraction process, NOX, dust, CO, and acid gases to air	a.Direct combustion b.Catalytic oxidation c.Carbon adsorption
Pervaporation	Separation of mixtures of liquids by partial vaporisation through a non-porous or porous membrane whereby a	Spent solvents	Physical	Recovered solvent	By product for reuse	Emissions of volatile organic compounds (VOCs) to air.	a. Recirculation of process off-gases in a steam boiler. b. Adsorption

Established Treatment technology	Technology summary	Type of Waste treated	Type of technology	Outputs	Management of Outputs	Type of discharge	Abatement Technology
	membrane acts as a selective barrier between a liquid phase and a vapour phase					Water from steam and cooling systems to be recycled and managed separately Wastewater from ceaning tanks, distillation etc has low pollutant loads.	c Thermal oxidation d. Condensation or cryogenic condensation e. Wet scrubbing
Dechlorination with metallic alkali	The reaction of metallic alkali with chlorine atoms contained in the chlorinated compounds.	Waste containing POPs or mercury or other waste	Chemical	Organic compounds(oil) /Recovery of Raw Material (salt)	Reused after a regeneration treatment/by product for reuse	Mercury emissions to air	a.Bag/fabric filter b.Activated carbon adsorption c.Cyclones d.Sulphur impregnated activated carbon e.High-efficiency particle air (HEPA) filter
Dechlorination with potassium and polyethylene glycol (KPEG)	The reaction of potassium hydroxide (KOH) and polyethylene glycol (PEG) with chlorine atoms contained in the chlorinated compounds.			Mineral oil/ sludge	Reused after a regeneration treatment/*	Dust emissions to air	
Hydrogenation of POPs	The reaction of hydrogen with chlorinated organic compounds or non-chlorinated organic contaminants, such as PAHs, at high temperatures			Primarily Methane and hydrogen chloride for PCBs / Methane and minor amounts of light hydrocarbons for PAHs			
Solvated electron process	Free electrons in a solvated electron solution convert contaminants to relatively harmless substances and salts		Physical & Chemical	Decontaminated soils	Enriched in nitrogen from the trace amounts of residual ammonia before returning to the site.		
Evaporation/drying	One of the main solid-liquid separation techniques. The removal of water by boiling or heating a solution	Spent solvents	Physical	Recovered solvent	By product for reuse	Emissions of volatile organic compounds (VOCs) to air. Water from steam and cooling systems to be recycled and managed separately. Wastewater from ceaning tanks, distillation etc has low pollutant loads	a.Recirculation of process off-gases in a steam boiler b.Adsorption c.Thermal oxidation d. Condensation or cryogenic condensation e. Wet scrubbing
		FGT residues		Recovery of Raw Material (Residual Sodium Chemicals)	By product for reuse	Emissions of dust to air	a.Bag/fabric filter b.Activated carbon adsorption
		Water-based liquid Waste		Filter cake/ Solid residue	Pressed and mixed with other sludges (generally organic) on site or mixed with residues from waste	Emissions of Total hydrocarbons (THC), Hydrocarbon oil index (HOI), Free cyanide (CN), Adsorbable	a. Air stripping b.Neutralisation c. Chemical reduction d. Chemical oxidation e. Filtration

Established Treatment technology	Technology summary	Type of Waste treated	Type of technology	Outputs	Management of Outputs	Type of discharge	Abatement Technology
					gas cleaning to give a solid product (with an exothermic reaction)	organically bound halogens (AOX) and metals to water. Emissions of VOCs, acid gases, ammonia, xylene, dust, NOx, SOx, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol to air.	f. Ion exchange g. Neutralisation h. Press filtering i. Sand filtration j. Active sludge systems -SBR Flocculation k. Active sludge system –SBR Adsorption l. Emulsion breaking Press filtering

APPENDIX 2 Treatment Technologies- Physical/Chemical Treatment Processes per type of Waste, Energy Consumption, and Environmental Performance (Emissions to air, Discharge to Water, Soil/Residues)

Established Treatment technology	Type of Waste treated	Energy Consumption	Environmental Performance			
			Water Consumption	Emissions to air	Discharge to Water	Soil/Residues
Chemical Immobilization Stabilization	Solid and/or pasty Waste	Low	Low /Zero	Low	Zero	Zero
Chemical Immobilization Solidification		Low	Zero	Low	Zero	Zero
Ion exchange	Pollution abatement components	High	High	Low/Medium	Low/Medium	Medium/High
	Water-based liquid Waste	Medium	Zero	Low/Zero	Medium	Low/Medium
Re-refining	Waste oil	High	High	LMedium	Low	Low
Neutralisation	FGT residues	Medium	Low/Zero	Low	Low/Medium	Low
Oxidation/reduction	Water-based liquid Waste	Medium/High	Zero	Low	Low/Medium	Medium/Low
Filtration	Spent solvents	High	Medium	Low/Medium	Low	Low
	Water-based liquid Waste	Medium	Zero	Low/Zero	Low/Medium	Medium
Distillation	Spent solvents	High	Medium	Medium	Low	Medium/Low
Precipitation/flocculation	Water-based liquid waste	Low/Medium	Zero	Low/Medium	Low	Low

Established Treatment technology	Type of Waste treated	Energy Consumption	Environmental Performance			
			Water Consumption	Emissions to air	Discharge to Water	Soil/Residues
Sedimentation	Spent solvents	High	Medium	Low/Medium	Low	Low
	Water-based liquid waste	Medium	Zero	Low	Low/Medium	High
Acid extraction	FGT residues	Medium	Medium	Medium	Low/Medium	High
Soil washing	Excavated contaminated soil	Low/Zero	Medium	Low	Low/Medium	High
Solvent extraction	Excavated contaminated soil	Zero	Zero	Zero	Medium/High	High
Centrifugation	Water- based liquid waste Spent Solvents	Medium	Low/Zero	Medium	Low/Medium	Medium/High
Vapour extraction	Excavated contaminated soil	Zero	Zero	Low/Zero	Zero	High
Pervaporation	Spent solvents	High	Medium	Low/Medium	Low	Medium/Low
Dechlorination with metallic alkali	Waste containing POPs or mercury	Low	Low/Zero	Low	Low/Zero	Low
Dechlorination with potassium and polyethylene glycol (KPEG)		Low	Low/Zero	Low	Low/Zero	Low
Hydrogenation of POPs		Medium	Low	Low	Low/Zero	Low
Solvated electron process		High	Low	Low	Low/Zero	High
Evaporation/drying	FGT residues	Medium/High	Low/Zero	Low/Medium	Low/Zero	Low
	Spent solvents	High	Medium	Low/Medium	Low	Low
	Water-based liquid waste	Low/Medium	Zero	Low/Medium	Low/Medium	Low

APPENDIX 3 List of Treatment Technologies- Physical/Chemical Treatment Processes per type of Waste, the respective outputs, and their most suitable management options, as well as the type of discharge and their abatement technology

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be appplied
Stabilization	Chemical	Solid and/or pasty Waste	Stabilisation changes the chemical state of the constituent of the waste input. With complete stabilisation, a hazardous waste can be transformed into a non-hazardous waste by means of specific chemical reactions that either destroy organic hazardous contents, or convert inorganic hazardous substances into non-hazardous compounds	Phosphate stabilisation	Stabilised material	Landfill	Substantial leaching is possible after landfilling, particularly in the case of some heavy metals due to increased solubility	Simple operation, low consumption of water, no WW is generated	30 kWh/t	6L/t		VOCs, dust, NH3	No wastewater is generated	No	Monitoring of the waste input Techniques for the prevention or reduction of emissions to air
Solidification	Chemical	Solid and/or pasty Waste	Solidification changes the physical properties of the waste input by using additives. Partial stabilisation or solidification processes do not change the hazardous nature of wastes, and the classification of waste with regards to pollutant parameters is therefore not modified	Cement solidification	Solidified material	Landfill or as backfilling material in mines	The leaching of soluble salts is not hampered and this can eventually result in the physical disintegration of the solidified product, thus allowing further leaching. In this case, the entry of air may result in some carbonation, partially rectifying the increase in porosity and loss of strength. The process leads to an increase in weight and a minor change in the volume of the waste.	Simple operation, widely used, comparable with standard practices in cement industry	30kWh/t	NQ		VOCs, dust	No wastewater is generated	No	Monitoring of the waste input Techniques for the prevention or reduction of emissions to air
Physical-chemical treatment before backfilling	Physical - Chemical	Solid and/or pasty Waste	Physico-chemical treatment of waste prior to backfilling consists of adapting the structural and physical characteristics of the waste input (mainly fly ashes) in accordance with local	Compaction using gravity or vibration	A material with adequate structural and physical characteristics for backfilling	backfilling material in mines			30kWh/t		VOCs, dust, odors	VOCs, dust	No wastewater is generated	No	Monitoring of the waste input Techniques for the prevention or reduction of emissions to air

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be applied
			conditions for long-term storage in the mine.												
Laundering for reuse of waste oils	Physical - Chemical	clean waste oils (transformer oils, industrial lubricants)	The processes start with pretreatment and cleaning, which involve the removal of impurities, defects and any leftover products from the waste oil's former use. Reuse treatment usually involves only these two steps, but some substances may be added to the cleaned waste oil subsequently, to attain the specifications of a virgin product.	Adsorption Heating Filtration Vacuum dewatering	clean industrial lubricant	returned to users	high use of energy	re-use of materials	500-2000kWh/t	8000l/t	Products of incomplete combustion + VOCs	Odours can be generated during storage, e.g. odour problems can arise by leaving hatches open at the top of each settlement tank and oil storage tank, or in open vibrating sieves	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc	sludges (metals, oil)	Selection of waste oils to be re-refined Reduction of water usage and emissions to water in waste oil rerefining plants . Reduction of waste generated by waste oil re-refining installations Reduction of VOC emissions from waste oil re-refining plants
Reclamation for reuse of waste oils	Physical - Chemical	clean waste (industrial) oils			clean industrial lubricant	returned to users		re-use of materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		
Mild processes for reuse of waste oils	Physical - Chemical	all types of waste oils	Mild reprocessing is cleaning the waste oils to improve the physical properties so that they can be used as a fuel by a wider variety of end users.	settling with heating, chemical demineralisation, centrifugation membrane filtration	Waste fuel blend with fuel oil (replacement of fuel oil)	Cement kilns, Roadstone plants, Large marine engines, Pulverised power plants							Idem above		
Mild processes + distillation for reuse of vegetable waste oils	Physical - Chemical	vegetable waste oils	filtration, removal of water, distillation		biodiesel	fuel							Idem above		

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Severe reprocessing (PCT) for reuse of waste oils: pre-treatment (Settling, centrifugation, distillation) cleaning (distillation, solvent extraction and addition of acids) fractionation (distillation) finishing (alkali treatment, bleaching earth, clay polishing, hydrotreatment, solvent cleaning)	Physical - Chemical	engine waste oils, clean waste oils	The re-refining process involves additional steps of fractionation and finishing, which use similar techniques and unit operations to refineries and chemical (e.g. olefins) processing.	acid clay + distillation	lubricant base oil	industry	results in polluted clay as a waste product, yield = 50%	re-use of materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		
Severe PCT reprocessing for reuse of waste oils	Physical - Chemical	engine waste oils, clean waste oils		distillation and chemical treatment and/or solvent extraction	good quality base oils		yield 65-70%	Some processes of this type do not generate residues because they transform the residues into products. Re-use of materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		
Severe PCT reprocessing for reuse of waste oils	Physical - Chemical	engine waste oils, clean waste oils		Propane deasphalting and hydrofinishing	bitumen		yiled = 75-80%, maybe expensive, significant amount of residues to be disposed of	yields many marketable materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be applied
Severe PCT reprocessing for reuse of waste oils	Physical - Chemical	engine waste oils, clean waste oils		Distillation and alkali treatment	Base oils and asphaltic residue			re-use of materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		
Severe PCT reprocessing for reuse of waste oils	Physical - Chemical	engine waste oils, clean waste oils		Thin film evaporators (TFE) and different finishing processes	medium quality base oil	used as diesel extender	yiled depends on finishing: 50-91%	re-use of materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		
Severe PCT reprocessing for reuse of waste oils	Physical - Chemical	engine waste oils, clean waste oils		Thermal deasphalting process (TDA)/ Hydrofinishing	- base oil - gas oil - asphalt		Yield = 75%	re-use of materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		
Severe PCT reprocessing for reuse of waste oils	Physical - Chemical	engine waste oils, clean waste oils		Direct contact hydrogenation process (DCH)	- base oil - desulphurised diesel - naptha - heavy fuel oil		Yield>70%	re-use of materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		
Severe PCT reprocessing for reuse of waste oils	Physical - Chemical	engine waste oils, clean waste oils		Caustic soda and bleaching earth treatment	good quality base oils			re-use of materials			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates, NH3, phenols, metals etc		
Severe PCT reprocessing for reuse of waste oils	Physical - Chemical	engine waste oils, clean waste oils		Integration in the base oil production of a refinery	good quality base oils			re-use of energy			Products of incomplete combustion + VOCs	odors	Re-refining and other preparations for reuse of waste oils result in ww with organic load, sulphates,		

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be appplied
													NH_3, phenols, metals etc		
Thermal cracking for reuse of waste oils	Physical	all types of waste oils	The strategy of thermal cracking is to crack large viscous molecules into more valuable shorter molecules ranging from demetallised heavy fuel oil to re-refined light industrial lube oil, including gas oil products as well as other materials for other uses. The process operates at very high temperatures (thus evaporating all the water present). After removal of the water, much of the heavy metal content is removed as sludge or via an acid treatment prior to the cracking step.	Super oil cracking (SOC) processes Great Northern Processing (GNP) processes	distillate gas oil products	product			60kWh/t	<100L/t	Products of incomplete combustion + VOCs	odors	grey water from cleaning only		Reduction of VOC emissions to air when preparing waste fuel from liquid and semi-liquid wast
Gasification for reuse of waste	Physical	mixed wastes		gasification	synthetic gas	product			60kWh/t	<100L/t	Products of incomplete combustion + VOCs	odors	grey water from cleaning only		
Recovery of waste solvents	Physical	waste solvents	The process includes distillation (batch, continuous or by use of steam, etc.) where high recovery rates are readily achieved. It is ultimately the incoming waste solvent and the desired recovered solvent output purity characteristics that dictate the technology to be deployed for reuse, but more simple techniques including filtration, centrifuging or stripping may suffice for certain reuses.	Distillation (Thin film evaporation, Short path evaporation, Single stage flash distillation, Multi-stage distillation, Pressure swing distillation, Azeotropic distillation, Extractive distillation)	recovered solvent				800kWh/t	200L/t	VOCs	VOCs	water from steam and cooling systems to be recycled and managed separately, wastewater from ceaning tanks, distillation etc has low pollutant loads	distillation residues	Recovery of raw material or energy from distillation residues Monitoring of diffuse and fugitive VOC emissions to air Collection and abatement of VOC emissions to air Reduction of waste water generation and of water usage from vacuum generation

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be applied
Recovery of waste solvents	Physical - Chemical	waste solvents		More complex separations. Where simple distillation is insufficient to extract the desired solvent from the waste stream, solvent extraction techniques (usually using a solvent of the opposite polarity) are then the most important liquid-liquid separation processes used.	recovered solvent				800kWh/t	200L/t	VOCs	VOCs	water from steam and cooling systems to be recycled and managed separately, wastewater from ceaning tanks, distillation etc has low pollutant loads	distillation residues	
Recovery of waste solvents	Physical	waste solvents		Pervaporation	recovered solvent				800kWh/t	200L/t	VOCs	VOCs	water from steam and cooling systems to be recycled and managed separately, wastewater from ceaning tanks, distillation etc has low pollutant loads	distillation residues	
Recovery of waste solvents	Physical	waste solvents		liquid - solid separation (centrifuging, filtration, sedimentation, evaporation, drying)	recovered solvent				800kWh/t	200L/t	VOCs	VOCs	water from steam and cooling systems to be recycled and managed separately, wastewater from ceaning tanks, distillation etc has low pollutant loads	distillation residues	
Regeneration of spent activated carbon	Physical	Extruded or granular spent activated carbon	Regeneration is normally carried out thermally and is typically composed of the following operations: 1. Receipt, handling and dewatering, 2. Thermal regeneration. Steam, chemical and	Multiple hearth furnaces, Directly fired rotary kilns, Indirectly heated kilns,			alternatives are to imrove yield in general inversely proportion to the quantity of flue gases produced				dust, CO/CO2, NOx, SOx, organic compounds or partial oxidation products	dust, CO/CO2, NOx, SOx, organic compounds or partial oxidation products	wastewater is generated by dewatering step, by coolers and by scrubber	sludge from wastewater treatment	Heat recovery and waste gas treatment

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be applied
			biological regeneration are also to be used in situ but not as stand alone methods.	Infrared furnaces											
Regeneration of ion exchange resins	Physical - Chemical	spent resin		Steam/hot water/chemical regeneration	regenerated resin										
Regeneration of waste catalysts	Physical	waste catalysts	Ex situ thermal regeneration is performed in specially designed equipment as well as in standard equipment		Regenerated catalysts						SO2, NOX, VOCs, dioxins, metals		suspended solids, oil, TOC, metals	oil, metals, dust	Heat recovery and waste gas treatment
Recycling of Residual Sodium Chemicals from solid Flue Gas Treatment residues	Physical	Residual Sodium Chemicals	The process aims to recycle the water-soluble fraction of sodium-based FGT residues to produce purified brine by dissolution of the salts and purification of the resulting brine, by separation of insoluble matter, and by adding specific additives and chemical treatments. The purified brine resulting from the recycling process is a REACH registered product.	RSC is transferred in storage silos and filtered. Purification of clear raw brine in three sequential steps: i. filtration on sand filter; ii. organic matter removal on active carbon column; iii. in-depth heavy metal removal on two ion exchange resin	The soluble part of FGT residues which is reused in the chemical industry, replacing the use of fresh materials				110kW/t	2200L/t	dust		water is recycled	The landfilled solid part of FGT residues	

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be appplied
Recovery of salts from liquid FGT residues by solution/evaporation	Physical	scrubber fluid	When solid wastes are produced, the recovery potential can be considered. The recovery, for example, of salts (NaCl, CaCl2, HCl and gypsum) may be a possibility. These products could be obtained by evaporation or recrystallisation of the salt from the flue-gas cleaning system waste water, either locally or at a centralised evaporation plant.		A marketable liquid containing mainly sodium and calcium chloride.										
Washing of FGT residues and their use as a raw material for production of construction products	Physical	FGT residues	The washing process treats waste powders such as FGT residues in order to make them suitable for use in the manufacture of construction product	FGT residues are slurried using water and the slurry is pumped through a membrane filter press. The solids are held within the filter press and undergo additional washing and drying steps before the process is complete. The liquid filtrate from the process is held within a storage tank and can be recycled into the process as slurry water until such a point that it becomes saturated	Calcium hydroxide and gypsum										

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Acid extraction		FGT residues	To extract heavy metals and salts from fly ashes, using acid.	Acid extraction process w/th possible thermal treatment	heavy metals									Solid residue is free of heavy metals and cal be landfilled or returned to combustion.	
Thermal desorption	physical separation	Excavated contaminated soil	In the thermal desorption process, volatile and semi-volatile contaminants are removed from soils, sediments, slurries, and filter cakes. Typical operating temperatures are between 175 °C and 370 °C, but temperatures from 90 °C to 650 °C may be employed.	thermal desorbers (Rotary dryer, Asphalt plant, Thermal screw, Conveyor furnace)	Treated solids	recovered, landfilled or treated further		fuel savings, small volumes of off-gases to be treated	200 - 400 kWh/t	90 - 180 lt/t	VOCs, dust, SOx, NOx, CO, HCl, HF, TVOC, Cd+Tl, Hg, metals, PCDD/PCDF	VOCs, dust, SOx, NOx, CO, HCl, HF, TVOC, Cd+Tl, Hg, metals, PCDD/PCDF	No wastewater is generated		Monitoring of the waste input Techniques for the prevention or reduction of emissions to air
Vapour extraction	physical separation	Excavated contaminated soil	Vapour extraction removes volatile organic constituents from contaminated waste by creating a sufficient subsurface airflow to strip contaminants from the vadose (unsaturated) zone by volatilisation. As the contaminant vapours are removed, they may be vented directly to the air or controlled in a number of ways	Vapour extraction	treated solids with possible contamination	further treatment may be required	Effectiveness depends on the ability of air to flow through the soil. Complete removal of contaminants may not be possible with this technique alone. Moreover, this technique is not applicable for saturated soils or for soils with low air permeability	Large volumes of excavated soil can be treated in a cost-effective manner.			untreated volatile organics from the extraction process, NOX, dust, CO, and acid gases		No wastewater is generated		Monitoring of the waste input Techniques for the prevention or reduction of emissions to air
Soil washing	physical separation	Excavated contaminated soil	Soil washing is an ex situ process in which contaminated soil is excavated and fed through a water-based washing process. It operates on the principle that contaminants are associated with certain size fractions of soil particles and that these contaminants can be dissolved or suspended in an aqueous solution or removed by separating out clay and silt particles from the bulk soil.	· dissolving or suspending contaminants in the wash solution · concentrating contaminants into a smaller volume of soil through particle size separation, gravity separation,	Recycled materials	Construction Industry		cost-effective technique	8 - 18 kWh/t	63 - 110 lt/t	Dust, TOC, Hg, Pb, Cr, Ni	Dust, TOC, Hg, Pb, Cr, Ni	wastewater	contaminated solids	Monitoring of the waste input Techniques for the prevention or reduction of emissions to wastewater

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be applied
				and attrition scrubbing											
Solvent extraction	physical separation	Excavated contaminated soil	It is a separation process that does not destroy the contaminants. It works as the contaminants will have a greater solubility in the solvent than in the soil.	Solvent extraction	Concentrated contaminants	Analysed and subsequently designated for further treatment, recycling or reuse before disposal							wastewater	contaminated solids	Monitoring of the waste input Techniques for the prevention or reduction of emissions to wastewater
PCT Technologies which apply physico-chemical reactions for material conversion (e.g. oxidation, reduction) and for material separation (e.g. filtration, sedimentation, ion exchange)	physico-chemical	Water-based liquid waste	During the treatment of water-based liquid waste, water is separated and processed for discharge to sewerage systems or water bodies. This processed water becomes subject to various pieces of water legislation as soon as it is discharged	Combination of the following: · sieving; · storage/ accumulation; · neutralisation; · sedimentation; · precipitation/ flocculation; · ion exchange; · oxidation/reduction; · sorption · evaporation/ distillation; · membrane filtration; · stripping; · extraction; · filtration/draining; · acid splitting of emulsions -	· sludge; · filter cake; · solid residue;	· pressed and sent to further treatment, · pressed and mixed with other sludges (generally organic) on site or mixed with residues from waste gas cleaning to give a solid product (with an exothermic reaction)		maximum amount of recyclable materials can be separated so that a minimum amount of auxiliary materials is used.	10 - 210 kWh/t	contaminated water	VOCs, acid gases,ammonia, xylene, dust, NOx, SOx, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol	VOCs, acid gases,ammonia, xylene, dust, NOx, SOx, CO, HCl, HF, HCN, H2S, Odour, Cd+Tl, Hg, metals, benzol	contaminated water (nitrus oxide, metals, ammonia, organic chemicals, oil content, sulphates, sulphites, sulphides)	· sludge; · filter cake; · solid residue;	Monitoring of the waste input, Techniques for the prevention or reduction of emissions to air, Techniques for the prevention or reduction of emissions to wastewater

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be appplied
				emulsion breaking; · organic splitting of emulsions - emulsion breaking; · centrifugation;											
					· waste oil; · waste fuel; · spent solvent; · water; · concentrate	· recycled/ disposal · futrher treatment									
Decontamination of waste or equipment polluted with persistent organic pollutants (POPs)	Physical	Waste which contains POPs and is intended to be reused or recovered at a level complying with requirements for its further use or disposal in an	Decontamination is intended to remove POPs from equipment or substances. These pollutants are undesirable because they present an important risk to health and/or the environment in the reuse, recycling or disposal of the equipment or substances in an environmentally sound way.	crushing; sorting, sieving; vacuum cleaning; distillation; thermal processes	A treated waste intended to be reused or recovered at a level complying with requirements for its further use or disposal in an environmentally sound way		If either the product gas or the ambient air used as combustion air for the boiler or similar units contains hydrogen chloride or other chlorinated species, dioxins may be generated during their combustion. In order to meet the fundamental technical criteria for POP destruction, both the product gas and combustion air must be treated to remove such chlorine donors			no usage	VOCs			waste generated by the treatment process itself	Optimisation of the environmental performance of PCB decontamination Capture and control of VOC emissions from solvent washing

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be appplied
		environmentally sound way					and so prevent dioxin formation.								
Destruction of POPs	Physical - Chemical			Alkali metal reduction Incineration Base catalysed decomposition Catalytic hydrodechlorination Cement kiln coincineration Gas phase chemical Plasma arc Plasma melting decomposition method Supercritical and subcritical water oxidation Thermal and metallurgical production of metals						no usage					
Innovative processes	Physical - Chemical		Removal of harmful components (e.g. brominated flame retardants – BFRs) and recycling of polymers from waste plastic materials by selective extraction: a) the dissolving of the waste plastic material in solvents; b) the addition of the precipitant to form a gelatinous precipitation product (polymers) with BFRs and other contaminants (e.g. softeners, additives) remaining in the solvent; c) the gelatinous polymer fraction is separated from		Usable polymer recyclate, BFR-rich concentrate, and, if present, a metals-rich insoluble fraction					no usage					

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be applied
			the solvent fraction which contains contaminants, further dried and prepared for remelting into products.												
Treatment of mercury-containing waste	Treatment of mercury-containing waste	The feed is sludge containing mercury from the oil and gas production industry, batteries, catalysts, activated carbon filters, thermometers, waste from the dental sector, fluorescent tubes, flat panel displays, blasting grit and soil	Decontamination processes differ depending on the type of waste. All processes aim at separating the mercury from one/several other fraction(s). This can be done mechanically, chemically or thermally. The safe management of these processes involves the avoidance of mercury emission in order to protect health and the environment. In some cases, mercury can also be recovered for allowed uses.	1. Removal of Hg from waste (eg breakin gof thermometers, centrifuging sludge, shredding of flat panels with Hg lamps etc), 2. separation anf concentration of Hg by evaporation and condensation, treatment of off gases with dusta filters anf carbon filters, return of dust and contaminated carbon to the process	Separated mercury recycled for authorised uses				180 kW/t	no usage	dust			mercury-containing residues	Reduction of mercury and dust emissions to air

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be appplied
Thermochemical conversion technology	Physical - Chemical	waste asbestos	Pyrolysis or oxidation of the organic compounds takes place in the rotary hearth. The pyrolysis and/or oxidation products are directed via an induced draft to a thermal oxidation unit that destroys any residual organic contamination that might be present in the off-gas. From the thermal oxidiser, the off-gases are cooled and scrubbed of any particulates and acid components that might be present. The presence of demineralising agents accelerates molecular diffusion in inorganic waste during heating, which destroys inorganic compounds such as asbestos and causes a simultaneous oxidation and molecular bonding of metals and radionuclides within the waste media. This results in the immobilisation of metals and radionuclides. The process also results in significant reduction of the waste volume.					reduction of volume, immobilization of metals and radionucleotides							
Treatment of SF6-containing waste	physical	SF6-containing waste	All processes aim at separating the gaseous SF6 and solid decomposition products from one/several other fraction(s). The safe management of these processes involves the avoidance of SF6 emissions. The decontamination process has two main steps: · SF6 recovery process by pressure compensation chamber; · removal of solid decomposition products from the enclosure by washing machine		· used SF6 gas (a hazardous waste), · decontaminated electric equipment; · used washing solutions	· the SF6 gas is suitable after purification for reuse in gas compartments, which consequently reduces the usage of new gas; · the used washing solutions after					used SF6 gas	used SF6 gas	used washing solutions		Monitoring of the waste input, Techniques for the prevention or reduction of emissions to air

PCT Technology	Treatment Type	Waste	Summary	Process alternatives	Output	Management Method	Risks (Cons)	Advantages (Pros)	Energy	Water	Air emissions	Air emissions - Fugitive	Water discharge	Soil/ Residues	BAT to be appplied
						filtration and disposal of separated solids, can potentially be reused									
Treatment of healthcare waste	physical	healthcare waste	Sterilisation of healthcare waste prior to incineration by thermal treatment or by ozonation.	steam sterilization; chemical sterilization; UV sterilization	residues	incineration for destruction and/or energy recovery					odours	odours		sterilized solid residues for disposal	Monitoring of the waste input, Techniques for the prevention or reduction of emissions to air
Regeneration of spent acids	physical	sulphuric acid	Thermal decomposition of spent sulphuric acid to give SO_2, achieved in a furnace at temperatures of around 1000 °C or reconcentration of weak/spent sulphuric acid, with or without the separation of the potential impurities	NI	regenerated sulphuric acid	reuse					Sulphur oxides, NOx	Sulphur oxides, NOx			Monitoring of the waste input, Techniques for the prevention or reduction of emissions to air
		hydrochloric acid	HCl is generally produced in the gaseous phase and directly reused in a chemical process. It can also be dissolved in water and used as a raw material for the production of other chemicals, such as a water treatment product in electrolysis or as a neutralisation agent.	NI	regenerated hydrochloric acid	reuse					Halogens: HCl and HF, NOx	Halogens: HCl and HF, NOx	Halogens: HCl and HF		Monitoring of the waste input, Techniques for the prevention or reduction of emissions to air

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