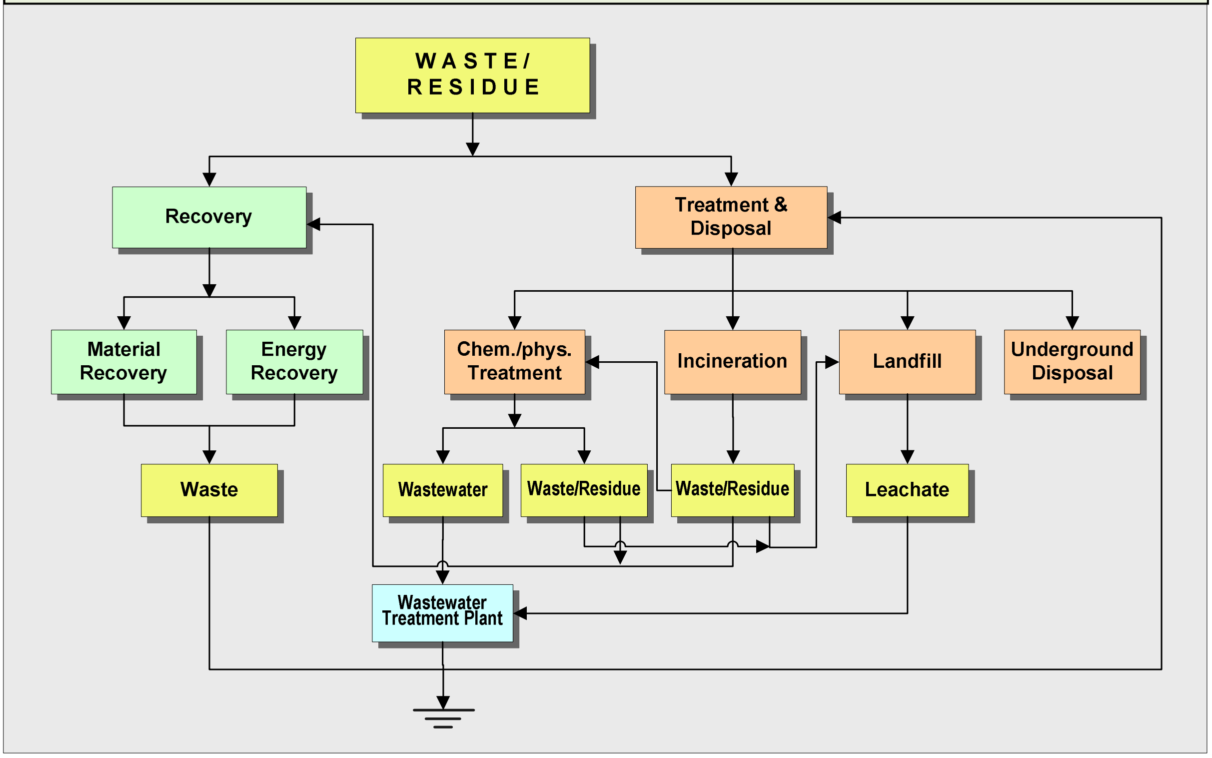


- **Module 4**
- ***Allocation of hazardous waste to treatment and disposal facilities***
- ***Generalities about Chemical Physical Biological Treatment (CPT) facilities***

giz CHS Convention Project Chemical Safety

On behalf of Federal Ministry for Economic Cooperation and Development

- Allocation of Hazardous Waste to Recovery and Disposal Options

According to the chemical and physical properties of the waste, the environmentally most friendly waste management option should be chosen according to the waste five-step hierarchy as set out by EU legislation (Waste Framework Directive 2008/98/EC).

5 step waste hierarchy

Life-cycle thinking is an additional new aspect to be considered in order to apply the waste management option with the minimum negative effect on the environment.

Waste management is an area where local conditions often influence the choice of policy options.

Typical questions that can arise in local or regional settings include:

- Is it better to recycle waste or to recover energy from it?

  What are the trade-offs for particular waste streams?

- Is it better to replace appliances with new, more energy efficient models or keep using the old ones and avoid generating waste?

- Are the greenhouse gas emissions created when collecting waste justified by the expected benefits?

The following figure shows the systematic approach of EU waste management, including examples of operations critical to classify.

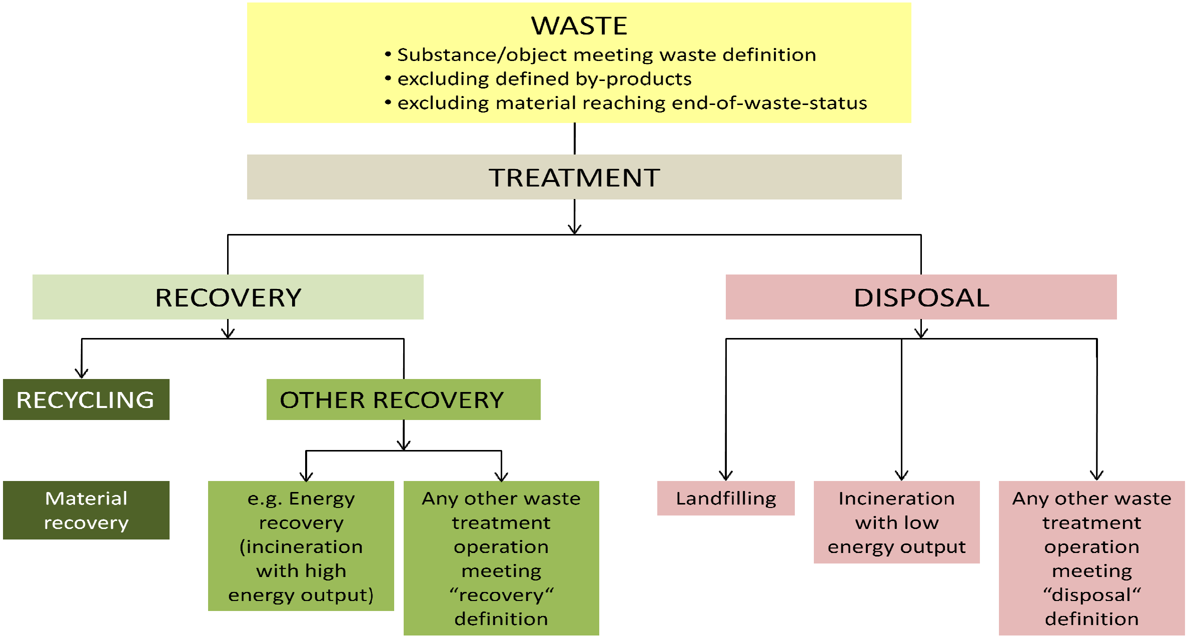


Fig. 46: Recovery and Disposal options for (hazardous) waste according to EU five-step waste hierarchy

European waste policy aims to reduce the negative environmental impacts of waste generation and management, and to contribute to an overall reduction of the environmental impact of the use of resources. The evaluation of environmental impacts of different waste management options can be a complex task because:

- Benefits and burdens can occur at different stages of the life cycle (e.g. waste prevention in the production stage or recycling of used products)
- Benefits and burdens can occur in different geographic regions and over a long time scale (e.g. emissions from landfills)
- Benefits and burdens can occur in very different forms (e.g. in the form of credit for recovered energy)
- Benefits and burdens can be difficult to identify, quantify and compare

It is therefore important to define information and data, in consultation with key stakeholders and supporting guidance documents. This information can then be used to make Life Cycle Thinking easy to use in waste management decision-making from local to European level, with an agreed approach and methodology.

Further for identifying the adequate treatment option wastes may require testing of their chemical and physical properties. In the European Union, waste types that recovery and disposal facilities are permitted to accept, have to be laid down in their operational licenses. (see details in modules 5, 6 and 7 and supplement to module 4). This is to ensure that accepted wastes correspond to the treatment method and to the pollution control devices of those facilities.

7.1. Allocation Criteria

According to the waste management hierarchy, waste prevention (including reuse) and waste recovery are the preferred options in comparison to disposal. Recovery can be differentiated into recycling (material recovery), energy recovery and other waste treatment options. Recycling makes use of the material value embedded in waste whereas energy recovery utilizes the calorific value. When selecting between material- and energy recovery for a given waste type (provided both options are possible), priority should be given to the option that has less negative environmental impacts.

In the supplement to module 4 a more detailed allocation to the different EWL codes is presented.

7.1.1. Recycling

Recycling is a form of recovery. Under the WFD, the definition of 'recycling' is *"any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations"*. Thus, specific waste management activities that are classed as recycling under the WFD include (but are not limited to) material recycling such as. plastic products or components into plastic feedstock materials; glass into glass cullet; glass for building aggregate; paper into recycled paper; paper into tissue products; etc.

Recycling means that a waste changed into a product again by means of recovery procedures. It differs from other recovery operations, which result merely in a change in the nature or composition of the waste. Recycling is different to other forms of recovery in that it results in the substance in question ceasing to be waste when it is transformed.

It follows from the WFD recycling definition, that only the reprocessing of waste into products, materials or substances can be accepted as recycling.

7.1.2. Other recovery - Energy recovery/use as a fuel

The principal purpose of energy recovery is to make use of the energy value embedded in the waste. Liquid, slurry and solid wastes with sufficient calorific value such as spent lube oil, solvents, tank bottom sludge, solid and semi-solid grease, wax, organic distillation residues, waste wood and saw dust, waste paper & plastic packaging material, etc. can be used as a substitute- or alternative fuel for all industrial processes that require thermal energy input. During the combustion process organic pollutants contained in the material are degraded by oxidation. Alternative fuels made from waste may replace a certain portion of the regular fuel used (co-incineration).

According to current German regulation energy recovery from waste is permissible when the calorific value is $\geq$11,000 kJ/kg (prior to blending with other materials) while the combustion efficiency of the combustion furnace in which energy recovery takes place must not be less than 75%[108].

7.1.3. Other recovery - back filling

Backfilling can be understood as the use of materials to refill excavated areas (such as underground mines, gravel pits) for the purpose of slope reclamation or safety or as filling in landscaping or on landfill. In Germany material used for back filling has to comply with contamination limits which are related to, but stricter than limits applied as acceptance criteria for landfill.

7.1.4. Chemical/physical and biological treatment (CPT)

CPT is of high relevance for the treatment of liquid and slurry hazardous wastes. CPT of waste includes the following types of plants:

For hazardous waste:

- Chemical physical treatment plants for liquid and semisolid hazardous waste
- Biological treatment plants for contaminated soils

To enable mass transfer in a chemical/physical treatment plant, waste must be pumpable. In general, waste that neither meets the strength- nor the eluate criteria of Table 22 needs chemical/physical treatment, or, in other terms, stabilization in addition to solidification. Particularly inorganic liquid and slurry hazardous wastes require chemical/physical treatment. The solids resulting from the treatment are filter cakes that can be disposed on landfill sites.

Also liquid and slurry aqueous wastes with an emulsified or separate organic phase require chemical/physical treatment. A typical example is cutting oil emulsions with an oil content of < 10%. Another prominent waste type generated in huge quantities across many sectors is content of oil interceptors. The organic phase isolated by the treatment can be utilized for energy recovery or has to be incinerated. See more details on CPT in chapter 9.

[108] Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal (KrW-/AbfG), Article 6; Germany 1994 http://www.gesetze-im-internet.de/krw-_abfg/BJNR270510994.html (Please note that a recent review proposal does not contain these provisions anymore)

Bioremediation[109] is defined as use of biological processes to degrade, break down, transform, and/or essentially remove contaminants or impairments of quality from soil and water. Bioremediation is a natural process which relies on bacteria, fungi, and plants to alter contaminants as these organisms carry out their normal life functions. Metabolic processes of these organisms are capable of using chemical contaminants as an energy source, rendering the contaminants harmless or less toxic products in most cases.

7.1.5. Landfill disposal

Important assignment criteria for landfill disposal are low organic content and sufficient strength (in other words the threshold value for ignition loss is $\leq$ 10%, and threshold value for vane shear strength is $\geq$ 25 kN/m^2, according to German regulation). A threshold value for ignition loss of $\leq$ 10% is very rigid as enforced in Germany for hazardous waste landfill disposal. Enforcement may require allocation of waste types hitherto disposed on landfill sites to thermal pre-treatment by incineration. Implementation of this regime needs therefore a transition period of sufficient length in order to provide time for stakeholders to adjust. A staged implementation is recommended with more lenient values enforced at the beginning.

Wastes that meet all the criteria of Table 22 (in chapter 11) can be directly disposed on a landfill site. (see module 7)

7.1.5.1. Solidification

Wastes that meet all the threshold values of Table 22 except the strength criteria require solidification with appropriate agents such as lime, fly ash or cement. Afterwards it can be disposed in a landfill.

7.1.6. Incineration

Solid or slurry waste with an organic content too high for landfill disposal is a case for incineration (ignition loss $\geq$ 10%, according to German regulation). Also liquid organic wastes that cannot be used as alternative fuels due to high contamination levels require incineration. Liquid aqueous waste with high dissolved organic content may be incinerated unless appropriate waste water treatment or chemical/physical treatment is feasible. (see module 6)

7.1.7. Underground disposal (High-safety above-ground disposal)

Solid waste with water soluble content $\geq$ 10 %, or special solid waste containing cyanide, mercury and arsenic should be disposed in an underground disposal site. In case such a facility is not available, the barrier function of dedicated cells in an above-ground landfill site

109 http://waterquality.montana.edu/docs/methane/Donlan.shtml

has to be enforced accordingly e.g. by cement concrete structures and additional lining. Water access to such cells must be excluded under all circumstances. Waste should also be packed and sealed in drums. These cells require permanent supervision.

7.2. Regulating Hazardous Waste Acceptance in the Licenses of the Facilities

According to EU legislation HW shall be only send to recovery and disposal facility licensed for HW in order to protect the environment and human health.

7.2.1. Application of Positive and Negative Lists for Facility Licensing

7.2.1.1. Negative lists

Negative lists designate waste types that operators of hazardous waste recovery or disposal facilities shall not accept. On landfill sites waste that is liquid, explosive, corrosive, oxidizing, flammable or infectious must not be accepted. (In the EU this is regulated in specific legislation on landfill of waste Directive 1999/31/EC) For underground disposal facilities negative acceptance criteria are given in Table 25 in chapter 12.

At centralized hazardous waste incinerators waste that is radioactive, explosive or infectious must not be accepted (acceptance of infectious waste is only permitted if special devices such as sluices are installed in the bunker area for avoiding spread of germs).

Negative lists can be also more specific and designate specific waste types that are not permitted for acceptance. For example EU waste legislation sets out that used tires must not be accepted for landfill disposal.

7.2.1.2. Positive lists

Positive lists should designate waste types that can be accepted at a facility. Therefore, they should be more restrictive than negative lists. Positive lists are usually based on a national or international hazardous waste catalogue. On European scale positive lists are stipulated in the Waste Acceptance Criteria Decision (2003/33/EC) for inert waste. Individual positive lists can be included in facility permits.

An example of a positive list is shown in table 16 that presents an excerpt of a site specific ‘waste acceptance catalogue’ of a German HW facility consisting of a chemical/physical treatment plant and a HW incinerator. The catalogue lists selected waste codes acceptable at this facility according to its permit. In addition, the treatment type is specified.

Waste acceptance lists/catalogues are an important management tool of competent authorities for waste stream control. Acceptance catalogues are also helpful for waste producers during pre-screening of adequate recovery or disposal facilities that can treat the wastes they are generating. After having found an operator that can treat his waste, both parties may conclude a disposal contract and prepare the ‘record of proper waste management’ (see chapter 6).

Positive lists may be also very specific and designate single waste streams of individual waste producers. This is useful for example in case of permits for trial operation before a permanent license is granted (e.g. co-processing).

Some links for positive and negative lists from Germany are given below[110].

Table 14: Excerpt of a positive list (waste acceptance catalogue) of a HW disposal facility (chemical/physical treatment (first raw:CPT) and HW incineration (second raw:HWI), x = permitted for acceptance)

CPT	HWI	EWL Code	Waste Categories, Waste Names
...	...	...	....
		11 01	**Wastes from chemical surface treatment and coating of metals and other materials (for example galvanic processes, zinc coating processes, pickling processes, etching, phosphating, alkaline degreasing, anodising)**
x		11 01 05*	pickling acids
x		11 01 06*	acids not otherwise specified
x		11 01 07*	pickling bases
x		11 01 08*	phosphatising sludges
x		11 01 09*	sludges and filter cakes containing dangerous substances
x		11 01 10	sludges and filter cakes other than those mentioned in 11 01 09
x		11 01 11*	aqueous rinsing liquids containing dangerous substances
x		11 01 12	aqueous rinsing liquids other than those mentioned in 11 01 11
x	x	11 01 13*	degreasing wastes containing dangerous substances
x	x	11 01 14	degreasing wastes other than those mentioned in 11 01 13
...	...	...	...
		12 01	**wastes from shaping and physical and mechanical surface treatment of metals and plastics**
	x	12 01 06*	mineral-based machining oils containing halogens (except emulsions and solutions)
	x	12 01 07*	mineral-based machining oils free of halogens (except emulsions and solutions)
x		12 01 08*	machining emulsions and solutions containing halogens

[110] Some examples of **Positive lists:**
http://www.dbv-velbert.de/resources/Positivliste+IS+Stand+30+11+05.pdf
http://www.koepu.de/index.php?act=Annahmekatalog&group=puls&lang=en
http://www.avg-hamburg.de/fileadmin/user_upload/downloads/avg_catalog_eak_01.pdf
http://www.zimn.de/annahmekatalog.htm
http://www.luechow-dannenberg.de/Portaldata/2/Resources/kld_dateien/landkreis/landkreis_dokumente/Abfallentsorgungssatzung_2007_Anhang1.pdf
Negative lists:
http://www.luechow-dannenberg.de/Portaldata/2/Resources/kld_dateien/landkreis/landkreis_dokumente/Abfallentsorgungssatzung_2007_Anlagen2-3.pdf
http://www.ks-entsorgung.com/de/downloads/annahmekriterien.html

CPT	HWI	EWL Code	Waste Categories, Waste Names
x		12 01 09*	machining emulsions and solutions free of halogens
x	x	12 01 10*	synthetic machining oils
x	x	12 01 12*	spent waxes and fats
...	...	...	...

7.2.2. Prescription of Specific Limit Values for Waste Acceptance

There are several reasons for imposing limit values for waste acceptance at hazardous waste recovery and disposal facilities:

- Protection of the environment (= environmentally viable allocation of waste streams to disposal options)
- Protection of occupational health and safety
- Quality requirements of the product
- Requirements related to the process

Limit values for the last two issues are determined in most cases by operators or are defined by product quality standards unless regulated otherwise.

7.2.2.1. Limit Values Related to Environmental Protection

In addition to negative and positive lists specific limit values for pollutants contained in waste should be used as acceptance criteria.

An example for a limit list for landfill disposal is shown in Table 22. Most of the limit values focus on groundwater protection. Wastes that do not comply with these criteria need either chemical/physical treatment, stabilization, solidification or have to be foreseen for other disposal options such as incineration or underground disposal.

Limit values for chemical/physical treatment refer usually to the secondary wastes/residues generated by the treatment. Chemical/physical treatability is tested by performing the envisaged treatment at a lab scale on a sample of the respective waste. When the resulting filter cake meets the criteria for landfill disposal and the resulting aqueous phase meets the wastewater discharge standards, the waste is considered treatable.

Thermal treatment plants are usually obliged by license conditions to control input of pollutants that may cause air pollution. This is in order to enable adequate feed of waste into the rotary kiln and to avoid emissions and the overload of the Air Pollution control (APC) system. Concentration of the following parameters should be checked:

- nitrogen,
- sulphur,
- halogens,
- halogenated organics,
- arsenic,
- antimony,
- heavy metals
- mercury,
- cadmium
- thallium.

Heavy metals in general should be measured and in particular volatile heavy metals of which mercury, cadmium and thallium are already listed above.

According to EU legislation on waste incineration, waste that contains ≥ 1% w/w halogenated organics has to be incinerated in high temperature incineration above 1100 ℃ (Article 6 of Directive 2000/76/EC).

Designated limit values for hazardous waste co-processing in cement kilns should be also set. Switzerland has notified a positive list of alternative fuels and raw materials that are permitted to be used for cement kiln co-processing (this list is based on the Swiss waste catalogue http://www.bafu.admin.ch/suchen/index.html?lang=de&keywords=Abfallverzeichnis&search_mode=OR&from_day=&from_month=&from_year=&to_day=&to_month=&to_year=&site_mode=intern&nsb_mode=yes#volltextsuche). The list specifies additionally limit values for relevant pollutants.[111]

For limit values of underground disposal, refer to Table 25

"Dangerous substances in waste treatment were highlighted by the European Agency for Safety and Health at Work in 2009 as emerging risks. High levels of dust and over 100 volatile organic compounds (VOCs) were found. Electrical and electronic equipment and end-of-life vehicles are increasingly being recycled and contain lead, cadmium, mercury and polychlorinated biphenyls (PCBs). While it is not possible to completely eliminate the chemical risks inherent in waste management, the most efficient prevention measure is to reduce the generation of dust, aerosols and VOCs. Technical collective measures and hygiene plans also contribute greatly to reducing workers' exposure. Prevention should be adapted to the type of waste and treatment activities concerned".[112]

[111] Swiss Agency for the Environment, Forests and Landscape: "Guidelines Disposal of Wastes in Cement plants", Appendix I, 1998

[112] European Agency for Safety and Health at Work (http://osha.europa.eu)

Additionally the Waste Framework Directive 2008/98/EC of 19 November 2008 **lays down the principles of waste management.** This document emphasizes that the protection of the environment and human health against harmful effects caused by the collection, transport, treatment, storage and tipping (final disposal) of waste should be the overall objective of any waste management activity.

7.2.2.2. Limit Values Related to Protection of Occupational Health and Safety

Competent authorities may impose limit values on pollutants contained in waste also in order to ensure protection of occupational health and safety in hazardous waste treatment facilities. For example, when measures for fire protection in the bunker area or in the tank battery of an incinerator are insufficient, there may be flashpoint limitations for wastes to be accepted.

When batch reactors of chemical/physical treatment plants are not encapsulated and equipped with suction fans and off gas treatment, toxic gases such as nitrous oxides or ammonia may be released to the workplace atmosphere from reactions like acid cleavage of emulsions or precipitation of heavy metals. As a proactive measure for protecting workers health, competent authorities may impose concentration limits on respective pollutants contained in the waste.

Of course, application of such threshold limitations makes only sense in regions where sufficient alternative facilities are available. This approach, using limits for achieving better occupational health and safety conditions, has been used e.g. in the German State North-Rhine Westphalia where the hazardous waste management infrastructure is largely organized by private operators who would experience such limitations as economical loss unless they upgrade their installations.

7.2.3. Licensing and Ensuring Compliance with License Conditions

As discussed above competent national authorities usually specify waste types that hazardous waste recovery and disposal facilities are licensed to accept by means of negative and positive lists as well as by suitable limit- or control values. These acceptance criteria should be part of the facilities' operational licenses.

Furthermore, conditions that oblige operators to establish and to record compliance with the national acceptance criteria via self-monitoring should be laid down in the license. Operators should have to document all types and quantities of wastes accepted. It should be mandatory to document compliance with the national acceptance criteria. From each consignment accepted a sample should be taken as a reference. This sample should be kept for a period of time determined by the competent authority considering the HW class/type of waste (see also section 11.3.4., “on-site verification”).

Competent authorities should realize random visits to the operators located in their administrational area and check the operator’s documentation.

7.3. Chemical Analysis of Hazardous Waste

Sampling and testing for basic characterization and compliance testing shall be carried out by independent and qualified persons and institutions. Laboratories shall have proven experience in waste testing and analysis and an efficient quality assurance system.

Analysis methods should namely be able to detect heavy metals, salts, and organic pollutants. Tests used for chemical analysis of hazardous waste shall follow standardized methods, whenever possible in order to assure sufficient reliability of results.

In the European Union such standards are established for a number of wastes and substances.

As long as a CEN standard is not available as formal EN, Member States will use either national standards or procedures or the draft CEN standard, when it has reached the prEN stage.

Available CEN standards can be found at: http://esearch.cen.eu/ (ICS code 13.030.-)

7.3.1. Sampling

The objective of waste sampling is the extraction of a subset representative for the entire batch of the waste material from where the sample is taken. Waste sampling should follow specific indications as under certain circumstances it is not as easy as that to take a representative sample. For example it can be a challenge to sample waste if the waste material is solid and inhomogeneous regarding the distribution of components, particularly in combination with a high variation in particle size.

Moreover sampling should consider whether samples are taken from drums, containers, tanker trucks or waste piles.

Liquid wastes are usually homogeneous and do not pose a problem with regard to sampling. Slurries or wastes with several phases have to be temporarily homogenized by stirring before a sample is taken.

In order to ensure representative sampling from heterogeneous solid waste materials, several single samples have to be taken and united to composite samples for subsequent analysis. Number and volume of single and composite samples is subject to the quantity and volume of the waste batch to be sampled, to the expected extent of heterogeneity, to the particle size of the material.

For proper waste sampling the following points should be taken into consideration:

- Objective of the sampling
- Origin of the respective waste
- Expected types of pollutants
- Extent of heterogeneity
- Parameters to be determined

For on- site sampling, a sampling plan has to be elaborated that should consider issues such as:

- Local conditions (samples to be taken from drums, piles, moving waste streams etc.)
- Quantity/volume of the waste batch to be sampled
- Heterogeneity of the waste batch
- Lumpiness or particle size of the waste material (solid waste)
- Sampling procedure
- Determination of the minimum number of single and composite samples to be taken
- Determination of the minimum volume of single samples to be taken

Each waste batch should be sampled individually. Sampling of waste should be conducted only by qualified persons and if possible by an independent laboratory. For more detailed information about sampling special literature may be referred to.[113, 114, 115]

7.3.2. Objective and Methods of Testing

A basic characterization of the waste should include information of the following parameters:

- consistency and composition
- hazardous properties, for example as listed in Annex III to Waste Framework Directive 2008/98/EC

[113] Laenderarbeitsgemeinschaft Abfall: "LAGA PN 98. Richtlinien für das Vorgehen bei physikalischen, chemischen und biologischen Untersuchungen im Zusammenhang mit der Verwertung/Beseitigung von Abfaellen"; Mainz, Germany; 2004 (German version only) http://www.google.de/url?q=http://www.laga-online.de/servlet/is/23874/M32_LAGA_PN98.pdf%3Fcommand%3DdownloadContent%26filename%3DM32_LAGA_PN98.pdf&sa=U&ei=rKKOT7GCLMjChAfigKniCg&ved=0CBQQFjAA&usg=AFQjCNFnpVzjZcwrEtl3WzivoiCvyrPZhg

[114] US Environmental Protection Agency: "RCRA Waste Sampling Draft Technical Guidance. Planning, Implementation, and Assessment" Washington, 2002

[115] European Commission: "Reference Document on Best Available Techniques for the Waste Treatment Industries" Chapter 4.1.1.4 "Sampling"; Sevilla, Spain,2005

- presence or absence of R-phrases/hazard statements according to Regulation (EC) No 1272/2008 (CLP)
- appearance, color
- odor
- combustion properties under normal condition
- eluate behavior
- reactions with water and other substances

One objective of a chemical analysis is to make sure that the hazardous waste is generally appropriate for the particular treatment option. The analysis should be carried out on a representative sample with standardized methods. Often a waste producer has a production process which is not changed in its process (using same machines, same chronological order etc.) and the same input materials are used (raw materials, materials used during the production process). Therefore, the results of the chemical analysis and the basic characterization can be valid for a longer period of time (also years) and as long as the production process and input materials are not changed. However, a compliance check of the delivered waste should be made frequently (e.g. with rapid tests) in order to ensure that no divergences exist and that the same waste as declared is delivered.

Rapid tests can consist e.g. of quick leaching test on 20 to 100 g (or 20 to 100 mg) of each waste delivered for landfills. A detailed analysis of the waste is essential to chose the best treatment option. Therefore additional chemical analysis, e.g. the determination of the gross calorific value are useful to be carried out to clarify if the HW can be incinerated according to its material composition..

In the case of recycling the relevant parameters for chemical analysis depend mainly on the product that should be obtained. For example in case of metal recycling the metal concentration is essential for the analysis,

In the case of chemical-physical treatment, the chemical analysis depends mainly on the particular activities of the plant. For the treatment of oil-polluted wastewater, for example, an aqueous phase and an oil-rich sludge are generated by addition of chemical substances. Therefore, the cleavage property has to be tested. Also the chemical precipitation of heavy metals has to be tested and this information is of importance for the precipitation. An additional simple test with nickel salt for the existence/concentration of complex-forming agents is also very useful.

Limit values for chemical/physical treatment refer to the secondary wastes/residues generated by the treatment. Chemical/physical treatability is tested by performing the envisaged treatment on a sample of the waste at a laboratory. When the resulting filter cake *meets the criteria for landfill disposal and the resulting aqueous phase meets the wastewater discharge standards, the waste is considered treatable.*

In the case of incineration, the following parameters are checked continuously or at the start of operation/after changes in operational procedures:

- dust
- total carbon
- chlorine, fluoride and sulphur, NO_x
- mercury
- heavy metals (at start of operation/after changes)
- polychlorinated dibenzo-p-dioxins and dibenzofurans (at start of operation/after changes)

In the case of co-processing for cement production also the amount of salts (mainly chloride) and of some volatile metals like mercury or cadmium and/or chromium (to avoid high hexavalent chromium-concentration in the cement) are tested.

In the case of a ground-level hazardous waste landfill, the following parameters are of relevance according to the Landfill Directive (Directive 1999/31/EC) (the list of parameters for Germany set out in Table 22 is slightly different, since EU Member States are allowed to add additional parameters than stipulated in the Landfill Directive):

[1] Total organic carbon (TOC) or loss of ignition (LOI)

[2] Acid neutralization capacity (ANC)

Batch leaching test at L/S = 2 or L/S = 10 or percolation leaching test

[3] pH, electric conductivity, arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr total), copper (Cu), mercury (Hg), molybdenum (Mo), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), zinc (Zn), fluoride, chlorine and sulphate or total amount of dissolved substances (TDS), dissolved organic carbon (DOC).

Other parameters such as polycyclic aromatic hydrocarbons (PAH) in solid matter, or cyanide in the leachate, can be of interest to the surveillance authority or the landfill operating company.

For a chemical analysis of the parameters, for the sampling procedure and the performance of leachate tests (see Fig. 47 and Fig. 48), EU standards are available and outlined in the corresponding Directives (for example: CEN (2002): EN 12457/1-4 Characterization of waste

-Leaching - Compliance test for leaching of granular waste materials and sludges- Parts 1-4 CEN[116]

Fig. 47 Examples for preparation of the eluate (overhead room shaker; gentle overhead movement for waste analysis)

Fig. 48: Percolation test; water is pumped upstream through waste material (black) in a column, and collected and analyzed at a certain L/S-ratio (e.g. 0.1 or 2.0)[117]

The extent and number of analytical tests that are performed on a batch of hazardous waste depends on the intended treatment and disposal route. Incineration or thermal treatment require percentage assay of inorganic elements such as cadmium, mercury, thallium and

[116] Can be retrieved from http://www.cen.eu/cenorm/homepage.htm

[117] A L/S-ratio (L/S; Liquid to Solid) of 2 means that 2 parts of water and 1 part of waste (dry) are leached and a L/S-ratio of 10 means that 10 parts of water and 1 part of waste (dry) are leached , for example 100 g of dry waste with 1000 g of distilled water

sulphur, as well as of chlorine and highly toxic organic compounds such as dioxins. For above ground hazardous waste landfill, a leachate test and assay of parameters such as total organic carbon and dissolved organic carbon are essential. If physical-chemical treatment is intended, the requirements for the chemical analysis depend on the activities of the treatment facility.

Regarding possible disposal routes for hazardous waste, reuse and recycling processes are considered first. Possible ways to eliminate hazardous substances contained in the waste are chemical oxidation, reduction or stabilization. Stabilization of hazardous waste can sometimes be performed using another waste, e.g. coal fly ashes.

Other relevant information is available from different institutions:

- E-waste is provided e.g. by the Indo-German-Swiss e-waste Initiative[118]
- Used oil is given in the Basel Convention Technical Guidelines on Used Oil Re-Refining or Other Re-Reuses of Previously Used Oils[119].
- Basel Convention technical guidelines at: **http://archive.basel.int/meetings/sbc/workdoc/techdocs.html** provide useful information on available techniqueshow to choose recovery or treatment options for some specific hazardous waste.

  Best waste treatment options for each waste code in line with the EWL as recommended by the Ministry for the Environment and Transport Baden-Wuerttemberg[120] as modified by Vida 2010. The table can be used as a first orientation step. (see supplement 1)

7.4. Recovery and Disposal Codes

The Basel convention defines 15 D-Codes for disposal operations and 13 R-Codes for recovery operations that are not only applied for allocating waste streams during trans-boundary shipment of hazardous waste but also serve as a reference in many national waste legislations and international agreements. On the other side the EU Directive 2008/98/EC enumerates thirteen possible recovery operations. Each of these options can be identified with an R code for recovery Also this Directive assigns specific identification codes (D-codes) for fifteen different disposal operations:

Recovery operations Recovery operations according to Directive 2008/98/EC, Annex II

[118] For Information on the project refer to http://www.asemindia.com/indo_german.html
[119] UNEP/SBC, 1995 http://www.google.de/url?q=http://archive.basel.int/meetings/sbc/workdoc/old%2520docs/tech-r9.pdf&sa=U&ei=lECpT6zYFomFhQfbguDRCg&ved=0CBQQFjAA&usg=AFQjCNF25-4WOeIZgkYklaoYA8wjglyk5w
[120] Ministry for the Environment and Transport Baden-Wuerttemberg, 2003

R 1 Use principally as a fuel or other means to generate energy (*)[121]

R 2 Solvent reclamation/regeneration

R 3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes) (**)

R 4 Recycling/reclamation of metals and metal compounds

R 5 Recycling/reclamation of other inorganic materials (***)

R 6 Regeneration of acids or bases

R 7 Recovery of components used for pollution abatement

R 8 Recovery of components from catalysts

R 9 Oil re-refining or other reuses of oil

R 10 Land treatment resulting in benefit to agriculture or ecological improvement

R 11 Use of waste obtained from any of the operations numbered R 1 to R 10

R 12 Exchange of waste for submission to any of the operations numbered R 1 to R 11 (****)

R 13 Storage of waste pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where the waste is produced) (*****)

<u>Disposal operations</u>

If a particular waste cannot be recycled or recovered, the respective waste needs to be referred to a facility for further treatment or final disposal. To assign hazardous wastes to specific treatment procedures criteria need to be applied. The objective is to render the hazardous waste non-hazardous, or to dispose it of, or encapsulate it in a manner such as to prevent harm to the environment and human health.

Disposal operations and codes according to Directive 2008/98/EC, Annex I

D 1 Deposit into or on to land (e.g. landfill, etc.)

---

[121] (*) This includes incineration facilities dedicated to the processing of municipal solid waste only where their energy efficiency is equal to or above: — 0,60 for installations in operation and permitted in accordance with applicable Community legislation before 1 January 2009, — 0,65 for installations permitted after 31 December 2008, using the following formula: Energy efficiency = (Ep - (Ef + Ei))/(0,97 × (Ew + Ef))
In which: Ep means annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by 2,6 and heat produced for commercial use multiplied by 1,1 (GJ/year)
Ef means annual energy input to the system from fuels contributing to the production of steam (GJ/year)
Ew means annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year) Ei means annual energy imported excluding Ew and Ef (GJ/year) 0,97 is a factor accounting for energy losses due to bottom ash and radiation. This formula shall be applied in accordance with the reference document on Best Available Techniques for waste incineration.
(**) This includes gasification and pyrolisis using the components as chemicals.
(***) This includes soil cleaning resulting in recovery of the soil and recycling of inorganic construction materials.
(****) If there is no other R code appropriate, this can include preliminary operations prior to recovery including pre-processing such as,
inter alia, dismantling, sorting, crushing, compacting, pelletizing, drying, shredding, conditioning, repackaging, separating, blending
or mixing prior to submission to any of the operations numbered R1 to R11.
(*****) Temporary storage means preliminary storage according to point (10) of Article 3.

D 2 Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)

D 3 Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)

D 4 Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.)

D 5 Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)

D 6 Release into a water body except seas/oceans

D 7 Release to seas/oceans including sea-bed insertion

D 8 Biological treatment which results in final compounds or mixtures, which are discarded by means of any of the operations, numbered D 1 to D 12

D 9 Physico-chemical treatment which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)

D 10 Incineration on land

D 11 Incineration at sea (*)[122]

D 12 Permanent storage (e.g. emplacement of containers in a mine, etc.)

D 13 Blending or mixing prior to submission to any of the operations numbered D 1 to D 12 (**)

D 14 Repackaging prior to submission to any of the operations numbered D 1 to D 13

D 15 Storage pending any of the operations numbered D 1 to D 14 (excluding temporary storage, pending collection, on the site where the waste is produced) (***)

[122] (*) This operation is prohibited by EU legislation and international conventions.
(**) If there is no other D code appropriate, this can include preliminary operations prior to disposal including pre-processing such as, inter alia, sorting, crushing, compacting, pelletising, drying, shredding, conditioning or separating prior to submission to any of the operations numbered D1 to D12.

(***) Temporary storage means preliminary storage according to point (10) of Article 3.

- Generalities about Chemical / Physical Biological Treatment of HW for Disposal

8.1. General Chemical / Physical Biological Treatment of HW for Disposal

Physico-chemical treatments apply to waste waters, waste solids and sludges. Physico-chemical treatment applies more than 133 techniques for waste treatment, prevention and management. Techniques applied for waste waters and sludges comprise neutralization, precipitation, oxidation/reduction, flocculation and evaporation, filtration, sieving, dewatering, decanting and centrifuging.

For solid granular wastes the most important technique is solidification/immobilization (mechanical) or stabilization (chemical).

The procedures serve the specific application of physico-chemical reactions for material conversion (e.g. neutralization, oxidation, reduction) and for material separation (e.g. filtration, sedimentation, distillation, ion exchange).

By quantity 'Chemical-Physical Treatment' (CPT) is mostly used for pre-treatment of inorganic and organic liquid aqueous wastes. Pre-treatment refers to treatment prior to recovery or final disposal. Wastes that undergo CPT may be also slurry or pasty in nature, however in order to enable the material flow in a CPT plant, the materials must be *pumpable (including e.g. dusts, ashes)*. Wastes to be treated are from various industrial and commercial production processes, and from maintenance, repair and cleaning activities.

Supplement 2: Basel Convention Y list code and allocation to physico-chemical treatment methods

or

Basel Convention technical guidelines at: http://archive.basel.int/meetings/sbc/workdoc/techdocs.html

See also Supplement 1: allocating EWL waste codes to recovery and disposal options

By consulting also the DEFRA Guideline you will be guided on how to implement the waste hierarchy principle. More information at:

http://www.google.de/url?q=http://www.defra.gov.uk/publications/files/pb13687-hazardous-waste-hierarchy-111202.pdf&sa=U&ei=2CKMT5uNM4qFhQe4kdHsCQ&ved=0CBkQFjAC&usg=AFQjCNF8Zn6VWw52FAHDYZKbQlC_Q9xR1g

Characteristic waste types are:

- o Inorganic wastes
  - – Various liquids and slurries containing pollutants such as heavy metals, Cr(VI), cyanide, nitrite, complexing agents, ammonia and others e.g. from metal processing- and finishing industries
  - – Acids (e.g. from pickling) and alkaline solutions
- o Organic wastes
  - – Spent cooling oil emulsions
  - – All types of oil/water mixtures
  - – All types of oil/water/solid slurries such as contents of settling chambers, oil/water separators etc.
  - – Paint sludge and latex residues

Inorganic hazards wastes are treated in basins equipped with dosage devices for the addition of reducing or oxidizing chemicals or addition of alkaline solutions for the precipitation of toxic heavy metals, and with devices for the removal of the precipitated heavy metal hydroxides. Inorganic hazardous substances like cyanide can be chemically oxidized by agents such as sodium-hypochlorite or hydrogen peroxide. Hazardous hexavalent chromium can be reduced by reducing agents (e.g. sodium bisulfite, ferrous sulfate) and precipitated subsequently.

For the treatment of organic hazard waste such as oil-contaminated waste waters, emulsions – basins with mechanical equipment for oil separation and dosage, devices for the addition of demulsifying chemicals must be installed. For emulsions containing hydrocarbons, a cleavage of the emulsion by addition of acids is the most favored treatment option. Chemical oxidation is also possible for some organic substances.

Physico-chemical treatment plants are designed and equipped in order to ensure that the maximum amount of recyclable materials can be separated so that a minimum amount of auxiliary materials is used.

According to the BREF document on waste treatment, the purposes of physico-chemical treatment plants are to:

- – enable delivery of environmental protection goals, in particular, water quality management. In such plants, materials which may be hazardous to water are either treated, withheld and/or converted to a non-hazardous form;

– enable the correct disposal of large quantities of (generally) aqueous liquid waste and waste requiring special controls

– separate oil or organic fraction to be used as fuel.

Physico-chemical treatment plants are configured on a case-by-case basis depending on requirements and/or application. Each physico-chemical treatment plant has a specific individual technological and operational concept; this is geared to the waste to be treated. For this reason, there is no 'standard' physico-chemical treatment plant. Although all plants have inspection and process laboratories and tend to have a neutralization function, the range of pretreatment processes, sludge handling methods and the combination of input waste streams makes each a unique operation.

Installations for the physico-chemical treatment of waste waters

This sector is represented by a large range of processes categorized as 'chemical treatments'. These range from blending systems with no actual chemical interactions to complex plants with a range of treatment options, some custom designed for specific waste streams. An example of a physico-chemical treatment facility of waste waters typically contains the following unit processes: cyanide destruction, chromium reduction, two-stage metal precipitation, pH adjustment (e.g. neutralization), solid filtration, biological treatment, carbon adsorption, sludge dewatering, coagulation/flocculation and some others.

Physico-chemical treatments of waste solids and waste sludges

The main goal in the physico-chemical treatments of waste solids and waste sludges is to minimize the long-term release by leaching out the primarily heavy metals and low biodegradable compounds. The available treatment options act to prolong the leaching time period by releasing, for example, heavy metals at lower and more environmentally acceptable concentrations for an extended period of time. Typical physico chemical treatments of waste solids and waste sludges are extraction and separation , thermal treatment, mechanical separation, conditioning , immobilization (this treatment covers solidification and stabilization), dewatering, drying, thermal desorption, vapor extraction from excavated soil, solvent extraction from solid waste (e.g. excavated soil), excavation and removal of excavated soil and soil washing.

Unit level operations applied in CPT can be differentiated with respect to their impact on the pollutants into those that degrade or convert pollutants into less hazardous substances and those that separate or concentrate pollutants. The most prominent unit level operations and their respective effects are shown in Table 15.

Table 15: Unit level operations for chemical-physical treatment and their effect on pollutants

Unit operation	Effect on pollutants	
	Degradation, conversion	Separation, concentration
Neutralization (chem.)	x	
Oxidation (chem.)	x	
Reduction (chem.)	x	
Precipitation (chem.)	x	X
Acid cleavage of emulsions (chem.)		X
Flocculation (phys.)		X
Sedimentation (phys.)		X
Filtration (phys.)		X
Centrifugation (phys.)		X
Adsorption (phys.)		X
Stripping (phys.)		X
Distillation (phys.)		X
Membrane processes (phys.)		X

Output from chemical-physical treatment

As a result of CPT, there are three output streams:

- o Separated organic materials, in most cases mineral oil that is sent to other facilities for use as a secondary fuel or, if it does not meet the required specifications, to an incinerator.
- o Solid dewatered residues, in most cases filter cakes containing immobilized heavy metals in sparingly soluble compounds as well as other fixed pollutants. These materials have to be disposed on hazardous waste landfill sites.
- o Wastewater that meets industrial discharge standards and can be discharged to a domestic wastewater treatment plant for final treatment

Process design

Operation of a CPT plant makes only sense in combination with recovery facilities (material recycling or energy recovery) or/and disposal facilities (incineration, landfill).

CPT is carried out by a batch operation. The treatment line for the inorganic waste stream is strictly separated from the organic treatment line. Experiences from Germany and other European countries have shown that separated treatment lines for organically and inorganically contaminated liquid hazardous wastes are necessary for an effective treatment. Only in the last stage of the treatment – the mechanical dewatering of the sludge arising from the treatment – the streams can be combined (see Fig 49)

The treatment line for the organic hazard waste stream includes the following main elements:

- Delivery stations for the receipt of all types of oil water mixtures and emulsions
- Heated tank for storage and separation of oil – emulsions
- Reactor for phase separation of emulsions
- Settling tank
- Storage tank for separated oil phase

The line for the inorganic hazard waste stream includes the following main elements:

- Delivery stations for the receipt of waste acids, metal concentrates, alkaline lyes and chromate
- Separate storage tanks for the different inorganic wastes
- Reactor for neutralization, chromate reduction and heavy metal precipitation

For the solidification of the sludge mechanical dewatering by chamber filter presses is recommended. Compared to the alternative solidification with additives the chamber filter press leads to volume and quantity reduction of the resulting waste.

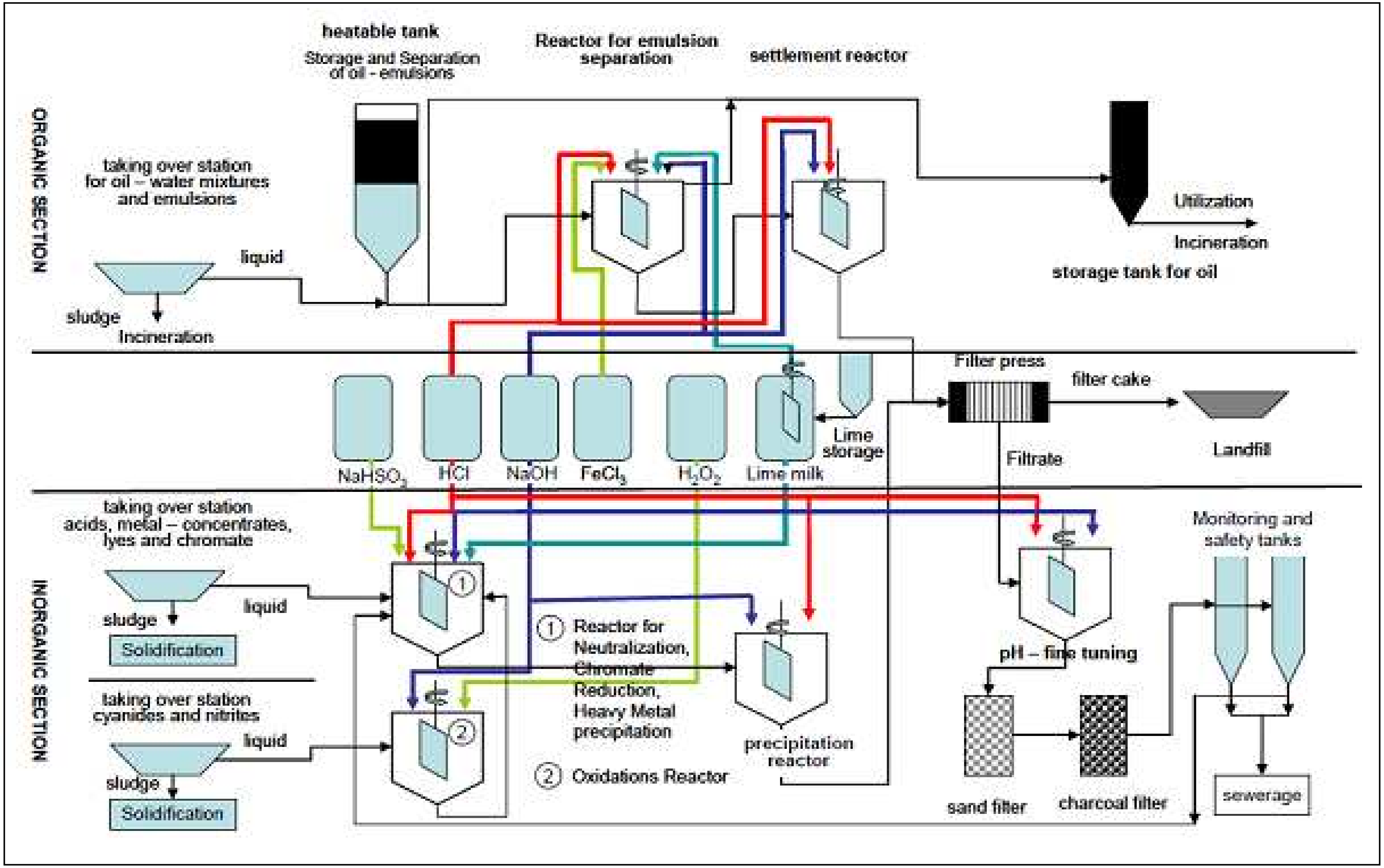
- Heated tank for storage and separation of oil – emulsions
- Reactor for phase separation of emulsions
- Settling tank
- Storage tank for separated oil phase

The line for the inorganic waste stream includes the following main elements:

- Delivery stations for the receipt of waste acids, metal concentrates, alkaline lyes and chromate
- Separate storage tanks for the different inorganic wastes
- Reactor for neutralization, chromate reduction and heavy metal precipitation

For the solidification of the sludge mechanical dewatering by chamber filter presses is recommended. Compared to the alternative solidification with additives, the chamber filter press leads to volume and quantity reduction of the resulting waste.

Fig. 49: Process scheme of a chemical-physical treatment plant with two treatment sections (organic and inorganic)



Source: E. Schultes, HIM GmbH

Occupational health and safety requirements

Chemical/physical treatment (CPT) is a method of final disposal that is often underestimated in its complexity. In the course of a CPT, reactive or even highly reactive alloys / mixtures are often handled. This kind of reactivity can potentially lead to hazardous incidents. For instance, neutralisations, i.e. reactions between acids and leachates, are frequently not carried out with pure substances. When, for example, the residue of a strong mineral acid (e.g. from a pickling / etching process) is to be neutralised, this can be done by adding some type of lye like sodium hydroxide. The use of a pure substance, however, would be relatively costly. These costs can be reduced if another waste substance consisting of an alkaline solution (i.e. lye) also has to be neutralised. In this case, neutralisation could be reached by mixing the two types of chemical waste in the correct mixing ratio. This method cannot be criticised on economic nor on ecological grounds – on the contrary, it is in fact ecologically sound as well as economical.

If, however, additional components of the solution lead to side-effects in the form of chemical reactions apart from the intended neutralisation, this can be critical for the facility. One potential side-effect that could be generated is a redox reaction. If the pickling solution were to contain divalent iron salts and the lye on the other hand nitrates, this could lead to the creation of nitrous gases in the defined pH-range. This redox reaction constitutes only one of many potential scenarios for chemical reactions that might lead to an incident in the facility.

This is the reason why it is problematic to mix wastes / residues the composition of which is not sufficiently clear or clarified. Consequently, it is essential to obtain information on the provenance and composition of the chemicals prior to the mixing of the waste substances. In that context, there should also be at least one employee in the enterprise with a basic knowledge of chemistry (at least on the level required for this purpose). In the case of new types of waste of unknown origin, conducting a chemical analysis is highly advisable.

Furthermore, a “tube test” (“beaker glass test”) should be carried out routinely for bigger quantities of distinct chemicals prior to their intermixture, even if the waste type and origin are known. The term “tube test” denotes a test in which small quantities of the two waste substances in question are combined and mixed in a beaker in a laboratory under practical conditions in order to detect and identify any potential chemical reactions that might lead to incidents beforehand.

The design and operation of the facility must comply with occupational health and safety requirements:

- The complete installation including storage areas has to be sealed to prevent sub soil contamination
- Gaseous emissions have to be collected and treated in suitable gas cleaning installations

- All tanks and reactors have to be equipped with leakage monitoring systems
- The health and safety equipment has to fulfill the requirements of comparable installations of the chemical industry

Ancillary Equipment

Essential for the operation of a CPT plant is the following ancillary equipment:

- o **Laboratory:** The delivered waste has to be checked by quick tests if it complies with the criteria of the basic characterization analysis, the treatment methods have to be developed and the quality of the discharged materials (waste water, filter cake, oil) have to be monitored.
- o **Intermediate storage:** It is recommended to operate tank farms for organic materials like oil – water – mixtures or oil – emulsions and for oil after treatment. For acids, lyes and heavy metal containing wastes a storage area for containers or drums should be planned.

In order to ensure that only waste water, complying with national discharge standards, is discharged to the sewerage system, two or three compensation tanks with sufficient capacity should be installed. In these tanks the waste water is collected and analyzed prior to discharge.

The final design of a CPT plant depends strongly on the quantities and qualities of the waste to be treated. Especially the ratio between organic and inorganic waste or special waste types like hydrofluoric acids have a great influence on the final specification.

8.2. Scale of CPT plants – Economy of scale

In contrast to incinerators, chemical-physical treatment plants are relatively independent from the scale, with respect to technical as well as economical aspects.

Table 16 presents various financial parameters for CPT plants of different capacities ranging from 10,000 to 30,000 t/a. Calculations refer to CPT plants with two treatment lines (inorganic–organic) and were made during a hazardous waste infrastructure planning project in the Chinese Province Zhejiang as part of the “Environmental Enterprise Consultancy Zhejiang” Program (GTZ). As the table shows, the investment required for CPT plants is much less than for incinerators, and the specific costs per ton of waste to be incinerated drop only to a minor extent with increasing capacity of the facilities.

The input materials for CPT are usually waste types that are liquid, pasty or slurry in nature, meaning waste with a considerable water content. From an economical point of view it is therefore sensible to separate the water content of such waste close to the point of generation and prior to transport thus reducing the overall amount of the materials that have to be transported to the final treatment and disposal destinations (recovery facilities, incinerators, landfills).

Keeping in mind that the investment for CPT plants is relatively low, it is obvious that CPT plants are usually implemented on a much lower level of centralization than expensive incinerators or landfill sites. CPT plants are ideally suited to cater to the industries of a city or of an industrial park. CPT plants may moreover serve as collection points for other waste types to assemble them to transport units for further transfer to other centralized facilities such as incinerators and landfill sites.

Details of calculations of specific costs CPT in China

Table 16: “Economy of Scale” effect for chemical-pysical treatment plants of different capacities (based on estimated local costs, China, 2007. 1RMB ≈ 0.1€)[123]

Capacity	**10,000**	**20,000** (2 shifts)	**15,000**	**30,000** (2 shifts)	**tons/a**
Investment CPT	**20**	**20**	**25**	**25**	**Mio. RMB**
Annual costs Amortization Interest	 1.33 0.8	 1.33 0.8	 1.67 1	 1.67 1	 Mio. RMB/a Mio. RMB/a
Capital costs per year	**2.13**	**2.13**	**2.67**	**2.67**	**Mio. RMB/a**
Maintenance Personnel	1.50% 0.3 0.45	3.00% 0.6 0.61	1.50% 0.375 0.49	3.00% 0.75 0.73	(% of invest.) Mio. RMB/a Mio. RMB/a
Fixed operating costs	**0.75**	**1.21**	**0.87**	**1.48**	**Mio RMB/a**
Total annual fixed costs	**2.88**	**3.35**	**3.53**	**4.15**	**Mio. RMB/a**
Specific costs per ton Capital costs per ton	 213	 107	 178	 89	 RMB/ton
Fixed operating costs per ton	75	61	58	49	RMB/ton
Total fixed costs per ton	**288**	**167**	**236**	**138**	**RMB/ton**
Variable operating costs per ton	527.35	527.35	527.35	527.35	RMB/ton
Total var. & fixed op. costs	**602**	**588**	**585**	**577**	**RMB/ton**
Total costs per ton:	**815**	**695**	**763**	**666**	**RMB/ton**

[123] Decker, K. H.; Hasel, B.; Krüger C.; Mertins, L.; Vida, J.: “Hazardous Waste Management Infrastructure Plan for Zhejiang Province“, ERM GmbH, Neu-Isenburg, Hangzhou, 2007

- **Cost assessment from the Sino – German cooperation project in Zhejiang, China for a CPT plant**

The following 3 tables present a detailed cost assessment for a chemical physical treatment plant with an operation period of minimum 20 years with one or two shift operation and treatment of 10.000 -30.000 tones waste per year. The data is from China, 2007. (1RMB = 0.1€)

The cost assessment consists of:

1. Staff costs as part of the fixed operating cost of CPT
2. Total and Specific Capital and Operating Costs of CPTs with different Capacities
3. Consumption per ton as part of the operating Costs of CPT

Explanation of the different cost types

Cost Type	Explanation
Annual costs	
Capital costs per year	Amortization + interest rate
Fixed operating costs per year	Maintenance and staff costs
Specific costs per ton of waste	
Capital costs per ton	Amortization + interest rate
Fixed operating costs per ton	Maintenance and staff costs
Variable operating costs per ton	- as calculated -
Total operating costs per ton	Variable and fixed operating costs
Transport costs per ton	Flat rates for transport assuming transport in a 20 t truck
Total costs per ton	Sum of capital costs, fixed operating and variable operating costs (if indicated also transport costs)

CPT staff cost

Capacity	No of Staff for 10' t/y	20' t/y	15' t/y	30' t/y	Salary / month (RMB/m)	Salary / year (RMB/y)	Annual Staff Cost per given Capacity (RMB/y) 10' t/y	20' t/y	15' t/y	30' t/y
Employees	1 shift	2 shifts	1 shift	2 shifts			(t/y/1shift)	(t/y/2shift)	(t/y/1shift)	(t/y/2shift)
Head	1	1	1	1	3500	45,500	45,500	45,500	45,500	45,500
Secretary	1	1	1	1	1800	23,400	23,400	23,400	23,400	23,400
Department heads (Engineers)	2	2	2	2	2400	31,200	62,400	62,400	62,400	62,400
Shift leader	1	2	1	2	2000	26,000	26,000	52,000	26,000	52,000
Plant worker	6	10	8	14	1800	23,400	140,400	234,000	187,200	327,600
Workshop	2	3	2	3	1800	23,400	46,800	70,200	46,800	70,200
Laboratory	3	4	3	4	2000	26,000	78,000	104,000	78,000	104,000
Dispatcher	1	1	1	2	1800	23,400	23,400	23,400	23,400	46,800
IB total RMB/t							**445,900** **45**	**614,900** **31**	**492,700** **33**	**731,900** **24**

Total and Specific Capital and Operating Costs of CPTs with different Capacities

Capacity	10,000	20,000 (2 shifts)	15,000	30,000 (2 shifts)	tons/year
Investment CPT	**20**	**20**	**25**	**25**	**Mio. RMB**
Annual costs Amortisation Interest	1.33 0.8	1.33 0.8	1.671	1.671	Mio. RMB/a
Capital costs per year	**2.13**	**2.13**	**2.67**	**2.67**	**Mio. RMB/a**
Maintenance Personnel	1.50% 0.3 0.45	3.00% 0.6 0.61	1.50% 0.375 0.49	3.00% 0.75 0.73	(% of invest.) Mio. RMB/a Mio. RMB/a
Fixed operating costs	**0.75**	**1.21**	**0.87**	**1.48**	**Mio RMB/a**
Total annual fixed costs	**2.88**	**3.35**	**3.53**	**4.15**	**Mio. RMB/a**
Specific costs per ton Capital costs per ton	213	107	178	89	RMB/ton
Fixed operating costs per ton	75	61	58	49	RMB/ton
Total fixed costs per ton	**288**	**167**	**236**	**138**	**RMB/ton**
Variable operating costs per ton:	527.35	527.35	527.35	527.35	RMB/ton
Total variable and fixed operating costs	**602**	**588**	**585**	**577**	**RMB/ton**
Total costs per ton	**815**	**695**	**763**	**666**	**RMB/ton**

Consumption per ton as part of the operating Costs of CPT

Cost item	Per ton of waste		Price/ unit [RMB]	Specific costs [RMB/t]	
Lime	0.05	tons	350	17.50	RMB/t
Electricity	200	kWh	0.25	50.00	RMB/t
Activated Carbon	0.0005	tons	200	0.10	RMB/t
Industrial water	0.1	m^3	2.5	0.25	RMB/t
Caustic soda	0.03	tons	3200	96.00	RMB/t
Iron-salts	0.01	tons	250	2.50	RMB/t
Acids	0.01	tons	100	1.00	RMB/t
Production per ton:					
Residues for Landfill	0.2	tons	800	160.00	RMB/t
Residues for incineration	0.1	tons	1800	180.00	RMB/t
Other costs:				20.00	RMB/t
Variable operating costs				**527.35**	**RMB/t**

E. Schultes, HIM GmbH

Fig. 50: Chemical / Physical Treatment Plant of HIM GmbH at Kassel, Germany (Total capacity = 31,000 t/a; thereof 25,000 t/a capacity for oil emulsion treatment)

8.3. Clarification of terms: Stabilization – Solidification – Chemical-physical treatment

"Stabilization" and "solidification" are two terms frequently mentioned in the context of pre-treating hazardous waste. Whereas "chemical-physical treatment" designates pre-treatment prior to all management options such as recovery, incineration or, land filling. "Stabilization" and "solidification" usually refer exclusively to pre-treatment prior to land filling.

EU Decision 2000/532/EC defines: *"Stabilization processes change the dangerousness of the constituents in the waste and thus transform hazardous waste into non-hazardous waste. Solidification processes only change the physical state of the waste (e.g. liquid into solid) by using additives without changing the chemical properties of the waste."*

Solidification as exclusive treatment is therefore not sustainable; in order to render hazardous waste non-hazardous it must always be encompassed by stabilization. Stabilization and solidification are mainly applied to inorganic waste. Hazardous substances like heavy metals cannot be destroyed chemically. They have to be immobilized into insoluble forms so that they cannot be leached out. Common stabilization processes often work with fixation in cement phases.

Stabilization processes include also the chemical unit operations listed in Table 15. The effectiveness of stabilization may be checked by eluate tests.

Solidification uses binders such as cement, lime/limestone or pozzolana based systems. In contrast to chemical/physical treatment where stabilized products are only solidified by dewatering, solidification with the use of additives is accompanied by an increase in mass and volume and, accordingly, causes additional operating costs and landfill space consumption.

Stabilized hazardous wastes have their own identification code in the European waste list (EWL). They are referred to as “stabilized/solidified wastes” and coded with 19 03. Stabilized/solidified hazardous waste is e.g. used as construction material on domestic waste landfills in Germany.

The concept of solidification and stabilization originates from Anglo-Saxon countries. In USA “stabilization” and “solidification” are also applied to *organic* hazardous waste and are mainly used for the rehabilitation of polluted soils. US EPA has its own definition of these terms.[124] [125]

Fig. 51: Different types of residues from physico-chemical treatment containing dangerous substances, disposed on an above-ground hazardous waste landfill

[124] US Environmental Protection Agency: “Solidification/Stabilization Resource Guide”, P. 7, Washington DC. 1999
[125] US Environmental Protection Agency: “A Citizen’s Guide to Solidification/Stabilization”, Washington DC, 2001

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Friedrich-Ebert-Allee 40
53113 Bonn, Germany
Phone: +49 228 44 60-0
Fax: +49 228 44 60-17 66

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
Phone: +49 61 96 79-0
Fax: +49 61 96 79-11 15

Email: info@giz.de
Internet: www.giz.de

Convention Project Chemical Safety
Responsible: Dr. Frank Fecher

Authors: Jochen Vida, Adi Heindl, Ulrike Potzel, Peter Schagerl, Franziska Frölich, Ferdinand Zotz, Anke Joas, Uwe Lahl and Alberto Camacho

Contact person at the Federal Ministry for
Economic Cooperation and Development (BMZ):
Heiko Warnken

Bonn, May 2012

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was formed on 1 January 2011. It has brought together under one roof the capacities and long-standing experience of three organisations: the Deutscher Entwicklungsdienst (DED) gGmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German technical cooperation) and Inwent – Capacity Building International, Germany. For further information go to www.giz.de.