Safe Hazardous Waste Management Systems

A State-of-the-Art Guide for Decision Makers

Update 2002
SAFE HAZARDOUS WASTE MANAGEMENT SYSTEMS
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Update 2002
ISWA Working Group on Hazardous Waste

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**Appendix 1** Disposal proof and transport document in Ireland  
**Appendix 2** Various collection systems  
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1 Introduction

During the last half of the 20th Century, the need for comprehensive systems to manage increasing amounts of hazardous wastes has become apparent worldwide. Individually or in cooperation with one another, many countries have launched such systems, and although these national systems may differ from one another they all consist of similar working components.

In this report these common technical features, used to support safe and effective hazardous waste management systems, are discussed. Transportation, collection, acceptance, treatment and disposal methods are highlighted individually. Safety issues and public concerns surrounding hazardous waste management are also discussed.

In publishing this report, the ISWA Working Group on Hazardous Wastes (WGHW) offers advice to ISWA member countries and to others on how to structure the technical components of hazardous waste management systems. Depending on national circumstances, interested parties can use the report and its guidelines to meet their own unique needs in the area of hazardous waste management.

Most national hazardous waste management systems are mandated by specific legislation. Certainly, if systems are to be effective, well-written and thorough legislation must be implemented in support of all phases of national hazardous waste management.

When a legislative model is needed to initiate national hazardous waste management laws and policies, it is recommended that countries with comparable economic and industrial conditions be referenced. Two major components are necessary for all systems: strong enforcement and adequate treatment capability. The effectiveness of hazardous waste laws strongly relies on the enforcement powers granted to regulatory authorities. Also, legislation must take into account the availability of hazardous waste treatment and disposal facilities. To avoid the mismanagement of hazardous wastes that occurs when laws and disposal capacity are lacking, temporary facilities operating under interim guidelines need to be considered.

In establishing a reliable hazardous waste management system, the ten elements listed below are essential:

1) Appropriate, well-written legislation addressing the supporting components of a hazardous waste management system must exist.

2) The separate responsibilities of waste generators, government officials, and treatment companies must be clearly specified.

3) Sufficient control and supervision of principal participants involved in the system, especially the generators, transporters, collectors, and operators of treatments and disposal facilities, must be in place.

4) Clean manufacturing and recycling technologies must be promoted and utilised.

5) Adequate collection capacity for hazardous wastes must be available.

6) Adequate treatment and disposal capacity must be in place.
7) Regional (International) solutions for small countries, and statewide solutions for larger countries, should be set up.

8) Adequate information must be made available to waste generators and the public concerning safe hazardous waste management practices.

9) Introduction of good and sustainable waste management practices in the operational area, giving priority to waste minimisation and waste recycling, should be promoted.

10) Appropriate, well-written legislation on dangerous chemicals classification, labelling and safety data sheets to give information to users of chemicals so they can evaluate the hazard of the waste produced.

2 Legal and regulatory elements of a hazardous waste management system.

2.1 Introduction

An effective hazardous waste management system consists of safe methods to collect, transport, accept, treat and dispose of hazardous wastes. These methods are developed over a period of time to protect the well being of society and the environment. It is important to remember that separately and collectively these elements constitute legitimate business operations. Hazardous waste management activities, therefore, must be conducted with a sense of responsibility towards the business community as well as toward society and the environment.

Unfortunately, managing hazardous wastes requires more government oversight then most other business endeavours. This is due, in part, to the cumulative effects of neglect that have characterised past hazardous waste management practices. Up until the latter part of this century, industrial waste generators, waste management companies, and governments, all failed to recognise the need to manage hazardous wastes adequately. Today, such mistakes have turned out to be quite costly, both economically and socially. Payment on these debts, the increasing costs of hazardous waste management, and the need for a high level of safety in waste management practice, mandate that governments assume the role of regulator.

Good knowledge of the characteristics of all chemicals that are used or produced helps to evaluate whether wastes produced are hazardous or not. Therefore, there must be a good system for obtaining the information relating to the chemical’s risk. Ideally appropriate legislation on dangerous chemicals, which consists of classification and labelling of chemicals including a safety data sheet system. This kind of system is used in most industrial countries. When dangerous goods (mainly chemicals) are transported similar information must be with the carrier of dangerous goods according to ADR and International Maritime Organisation (IMO) regulations.

It is important to recognise all the pieces in the hazardous waste puzzle. Society and the environment are the beneficiaries of good hazardous waste management. The waste generator is the customer with a product that needs to be serviced, while the waste management company is the service provider. On behalf of society and the environment, legislators and government officials also are involved in overseeing and ensuring that the business of hazardous waste management is conducted safely.
To reduce the costs of waste management services, waste generators may wish to develop their own waste management capabilities on-site, at the industrial facilities where hazardous wastes are produced. When properly performed, on-site waste management practices are preferred because they reduce certain environmental risks inherent in transport when contracting with outside private waste management companies.

In recognising that hazardous waste management is, in fact, a business, it is important to consider how market conditions and accounting and economic principles apply. First and foremost, in initiating a hazardous waste management system it is important to acquire thorough knowledge of the types and quantities of hazardous wastes that are generated. During this phase of developing a hazardous waste management system, it is important for government officials to establish good working relationships with the industrial waste generators, as well as with the organisations and private companies that provide special expertise in hazardous waste management.

With information on the quantity and quality of hazardous waste generated, nationally or regionally, it is possible to plan more efficient collection, transportation, and treatment and disposal requirements. With a good understanding of hazardous wastes, it is also possible to identify opportunities for hazardous waste avoidance, and for recycling wastes into usable and saleable processes and products.

2.2 Defining Hazardous Wastes

It has been difficult for waste management professionals to agree upon a precise international definition of what constitutes hazardous waste. Countries differ both in the definitional method employed, and in the scope of what is defined as hazardous waste. In view of the variety and quantity of chemical substances available today for use in industrial manufacturing processes, this difficulty in defining hazardous wastes is understandable, but still in need of being addressed.

As a rule, chemical and oil by-products that serve no useful purpose, and which pose a threat to the environment and human health when improperly disposed of, are most often deemed hazardous. These types of by-products are typically generated by industrial manufacturing processes. At the same time, consumer products contain many hazardous constituents, which upon disposal may be released into the environment and cause harm. The user of chemicals and consumer products obtains information from labels and safety data sheets about the potential kinds of dangerous substances used chemicals and products contain. If this information is available, it is easy to evaluate the hazard of the waste.

Of the hundreds of hazardous waste substances present in our surroundings, some examples include: used motor oils, spilled petroleum, paint residues, used solvents, acids, alkalis, PCB’s, cyanide, pesticides, and heavy metals. Obviously, the term “hazardous waste” can cover a wide range of substances, from relatively harmless oil and paint residues to extremely toxic products and waste streams containing PCB’s, cyanide, and other highly toxic chemicals. In the Basel Convention and EC Directives there are lists of waste that are deemed to be hazardous.
It is important to note that all the different types of wastes included under the collective term “hazardous waste” cannot be treated in the same manner. While most organic wastes can be incinerated, most inorganic wastes cannot, but they can be solidified. Therefore, the chemical composition of waste products, their physical condition, the availability of a treatment process, all need to be considered prior to treating a waste. Hazardous wastes should only be handled and treated by companies with special capabilities, and then only after special permits have been obtained from governmental authorities.

2.3 Quantifying Hazardous Waste Volumes

Many countries, even those with comprehensive hazardous waste management systems, still lack good data on the volumes of hazardous wastes generated and on pre-existing wastes requiring treatment. This data gap may be due to variations in defining hazardous wastes. It is more likely, however, that the gap can be traced to a need for improved administrative and waste-tracking procedures within the hazardous waste management system.

In recognition of this need, some countries have established inspectorates and other such agencies to assess and verify the amount of hazardous waste generated nationally or regionally. One result has been to gain more concise estimates on the production of hazardous wastes. By gaining a better idea of waste volumes produced, countries improve their ability to encompass more wastes within a system and properly manage it.
Table. 1: Generation of hazardous waste in Austria

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste from food processing</td>
<td>t/a</td>
<td>1,600</td>
<td>1,600</td>
<td>20</td>
</tr>
<tr>
<td>Waste from producing vegetable and animal fats</td>
<td>t/a</td>
<td>47,775</td>
<td>50,541</td>
<td>49,135</td>
</tr>
<tr>
<td>Farming waste from animals and butchery</td>
<td>t/a</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Timber waste</td>
<td>t/a</td>
<td>1,470</td>
<td>9,371</td>
<td>3,072</td>
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<tr>
<td>Waste from pulp, paper and paperboard</td>
<td>t/a</td>
<td>3,875</td>
<td>1,265</td>
<td>180</td>
</tr>
<tr>
<td>Waste of mineral origin</td>
<td>t/a</td>
<td>310,942</td>
<td>359,708</td>
<td>357,029</td>
</tr>
<tr>
<td>Metal waste</td>
<td>t/a</td>
<td>24,765</td>
<td>269,236</td>
<td>79,671</td>
</tr>
<tr>
<td>Other waste of mineral origin and waste from finishing products</td>
<td>t/a</td>
<td>850</td>
<td>850</td>
<td>2</td>
</tr>
<tr>
<td>Oxides, hydroxides and saline waste</td>
<td>t/a</td>
<td>19,651</td>
<td>25,509</td>
<td>19,331</td>
</tr>
<tr>
<td>Waste from acids, alkaline solutions and concentrates</td>
<td>t/a</td>
<td>12,701</td>
<td>19,626</td>
<td>23,108</td>
</tr>
<tr>
<td>Waste from pesticides, pharmaceuticals and disinfectants</td>
<td>t/a</td>
<td>2,115</td>
<td>2,230</td>
<td>1,880</td>
</tr>
<tr>
<td>Waste from refined petroleum- and coal-products</td>
<td>t/a</td>
<td>131,559</td>
<td>169,263</td>
<td>168,829</td>
</tr>
<tr>
<td>Waste from organic solvents, paints, varnishes, adhesives and resins</td>
<td>t/a</td>
<td>46,701</td>
<td>55,431</td>
<td>40,002</td>
</tr>
<tr>
<td>Rubber and plastic waste</td>
<td>t/a</td>
<td>4,610</td>
<td>4,811</td>
<td>6,146</td>
</tr>
<tr>
<td>Textile waste (manufacturing of natural and synthetic products)</td>
<td>t/a</td>
<td>750</td>
<td>801</td>
<td>412</td>
</tr>
<tr>
<td>Other waste from chemical transformation and synthetic products</td>
<td>t/a</td>
<td>4,814</td>
<td>4,962</td>
<td>3,639</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>t/a</td>
<td>1,200</td>
<td>1,200</td>
<td>600</td>
</tr>
<tr>
<td>Liquid waste from waste treatment facilities</td>
<td>t/a</td>
<td>0</td>
<td>500</td>
<td>1,000</td>
</tr>
<tr>
<td>Hospital waste</td>
<td>t/a</td>
<td>2,200</td>
<td>2,500</td>
<td>3,101</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>617,579</td>
<td>979,407</td>
<td>757,160</td>
</tr>
</tbody>
</table>

A good understanding of both the volume and quality of hazardous wastes produced, therefore, is vital to integrating a service into a fully developed hazardous waste management system. Such knowledge enables managers to construct efficient and effective methods for collection, transporting, accepting, treating and disposing of hazardous wastes, if a serviceable support structure is to be developed.

It is significant to note the direct relationship between the level of service a (national) waste system provides and the amount of hazardous waste handled within that system. The higher the level of service, the greater the amount of waste that is adequately controlled.

Unfortunately, local and regional estimates produced by certain countries indicate that world-wide significant quantities of hazardous waste are channelled outside the intended waste disposal stream. At the same time, there is a lack of good data as to where or how these wastes are disposed of. Part of this problem is due to a lack of data on the quality and quantity of waste a nation produces. The remaining portion of
the problem can be attributed to poor control over the movement of hazardous wastes.

2.4 Tracking Hazardous Wastes

The second step in developing a hazardous waste management system is to secure control over the movement of the wastes. To accomplish this, many countries, in one form or another, have developed waste tracking systems. The system begins with a Waste Declaration Form, which is prepared by the waste generator upon the generation of a waste load. This form generally contains relevant information about the waste generator, the facility responsible for generating the waste, as well as the information on the content and quantity of the waste (see Appendix 1 "Disposal proof and transport document in Ireland ").

All parties who, at various points will handle the waste should make several copies of the form available for use. These include waste collectors, transporters, and operators of treatment, storage and disposal facilities. A copy also should be transmitted to designated government authorities. Information from the waste declaration form likewise should be entered into a central computer system for reference, in order to facilitate the use and retrieval of the information.

Despite its administrative complexity, the benefits of a waste tracking system make it well worthwhile. It enables a country to maintain a record of the waste generated and handled within its hazardous waste management system. This information can be used to ensure that wastes have arrived at their designated points of treatment / disposal and arrival within a reasonable period of time.

For transboundary movements of waste the Basel Convention Secretariat has created a tracking formula which contains all the information needed to control even the movements inside a country.

2.5 Treatment Resources and Waste Minimisation Practices

Once wastes have been defined, quantified, and a tracking system installed, it is necessary to consider the availability of treatment resources. Although great efforts are made in some regions to create and increase the resources necessary to manage hazardous wastes, there is general agreement that the best way to solve problems associated with hazardous waste production is to minimise its production. Within the past decade, as administrative and technological costs and other factors for treating hazardous wastes have increased, a parallel trend has developed. In those regions where effective and expensive hazardous waste management systems are in place, producers do consider how to produce less waste.

In eliminating or reducing the production of hazardous wastes, the manufacturing process is altered. The easiest way to reduce waste production is to improve basic housekeeping practices at the manufacturing facility, keeping in mind that complex process changes, material substitutions, and internal recycling techniques, may be required at certain facilities if this is to be accomplished. If it is not possible to eliminate, reduce or recycle a hazardous waste, it may be possible to recover useful characteristics of the waste such as energy.

Society and its regulatory agencies are placing increased pressure on industry to develop Clean Technologies in order to minimise waste production. Waste reduction and recycling practices are always preferred over treatment, with the land disposal of
wastes reserved primarily for reduced or treated residues. At the same time, clean technologies will not eliminate in the foreseeable future the need to treat and dispose of hazardous wastes. No matter how sophisticated methods of waste minimisation or recycling technologies become it is virtually impossible to eliminate the production of all hazardous wastes.

Once waste minimisation or recycling options have been exhausted, the waste manager today can turn to a variety of hazardous waste treatment technologies capable of achieving high levels of environmental soundness. Based on available thermal, chemical, and biological engineering practices, it is possible to treat hazardous wastes and significantly reduce their volumes, toxicity’s, and potential for ground and underground migration.

In reviewing the hazardous waste systems developed in various countries, states and/or municipalities, it can be observed that most available technology is not being fully utilised. The key to resolving this problem is legislation. It is extremely important that relevant legislation includes standards that set acceptable limits on the pollutants that may be released from all hazardous waste treatment facilities. Such pollutants may be released in the form of flue gas emissions, water effluents, soil contaminants and recycled products or by-products. By setting a limit on emission, effluent, and contamination levels in products and/or reused by-products, the design and level of treatment at facilities can be influenced.
Table 2: Air emission limit values (Directive 2000/76/EC on the incineration of waste)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Air emission limit values</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Daily average values</td>
<td></td>
</tr>
<tr>
<td>Total dust</td>
<td>10 mg/m_</td>
</tr>
<tr>
<td>Gaseous and vaporous organic substances, expressed as total organic carbon</td>
<td>10 mg/m_</td>
</tr>
<tr>
<td>Hydrogen chloride (HCl)</td>
<td>10 mg/m_</td>
</tr>
<tr>
<td>Hydrogen fluoride (HF)</td>
<td>1 mg/m_</td>
</tr>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>50 mg/m_</td>
</tr>
<tr>
<td>Nitrogen monoxide (NO) and nitrogen dioxide (NO₂), expressed as nitrogen</td>
<td>200 mg/m_ (*)</td>
</tr>
<tr>
<td>dioxide for existing incineration plants with a nominal capacity exceeding</td>
<td></td>
</tr>
<tr>
<td>6 tonnes per hour or new incineration plants</td>
<td></td>
</tr>
<tr>
<td>Nitrogen monoxide (NO) and nitrogen dioxide (NO₂), expressed as nitrogen</td>
<td>400 mg/m_ (*)</td>
</tr>
<tr>
<td>dioxide for existing incineration plants with a nominal capacity of 6</td>
<td></td>
</tr>
<tr>
<td>tonnes per hour or less</td>
<td></td>
</tr>
<tr>
<td>(b) Half-hourly average values (not listed)</td>
<td></td>
</tr>
<tr>
<td>(c) Average values (sample period min. 30 min, max. 8 h)</td>
<td></td>
</tr>
<tr>
<td>Cadmium and its compounds, expressed as cadmium (Cd)</td>
<td>total 0.05 mg/m_</td>
</tr>
<tr>
<td>Thallium and its compounds, expressed as thallium (Tl)</td>
<td>(total 0.1 mg/m_ (**))</td>
</tr>
<tr>
<td>Mercury and its compounds, expressed as mercury (Hg)</td>
<td>0.05 mg/m_</td>
</tr>
<tr>
<td>Antimony and its compounds, expressed as antimony (Sb)</td>
<td>total 0.05 mg/m_</td>
</tr>
<tr>
<td>Arsenic and its compounds, expressed as arsenic (As)</td>
<td>(total 1 mg/m_ (**))</td>
</tr>
<tr>
<td>Lead and its compounds, expressed as lead (Pb)</td>
<td></td>
</tr>
<tr>
<td>Chromium and its compounds, expressed as chromium (Cr)</td>
<td></td>
</tr>
<tr>
<td>Cobalt and its compounds, expressed as cobalt (Co)</td>
<td></td>
</tr>
<tr>
<td>Copper and its compounds, expressed as copper (Cu)</td>
<td></td>
</tr>
<tr>
<td>Manganese and its compounds, expressed as manganese (Mn)</td>
<td></td>
</tr>
<tr>
<td>Nickel and its compounds, expressed as nickel (Ni)</td>
<td></td>
</tr>
<tr>
<td>Vanadium and its compounds, expressed as vanadium (V)</td>
<td></td>
</tr>
<tr>
<td>(d) Average value (sample period min. 6 h, max. 8 h)</td>
<td>0.1 ng/m_</td>
</tr>
<tr>
<td>(c) Daily average value</td>
<td></td>
</tr>
<tr>
<td>Carbon monoxide (CO) in the combustion gases</td>
<td>50 mg/m_</td>
</tr>
</tbody>
</table>

(*) Until 1 January 2007 and without prejudice to relevant (Community) legislation the emission value for NOₓ does not apply to plants only incinerating hazardous waste.

(**) Until 1 January 2007 average values for existing plants for which the permit to operate has been granted before 31 December 1996, and which incinerate hazardous waste only.

Emission efficiencies for specialised incinerators that burn hazardous wastes achieve 99.999 percent and even 99.9999 percent (input-output ratio). This may be linked to the efficiency standard of 99.999 percent that has been legislatively imposed on incinerators in some industrial countries. In the same way, low concentration levels of heavy metals in wastewater have been achieved. As well as emission efficiencies for incineration in many countries there are emission limit values for unburned organic material and for dioxins and for heavy metals, dust, hydrogen chloride, hydrogen fluoride, sulphur dioxide and nitrogen oxides. For example in EC Directive for incineration of hazardous wastes there are emission limit values for total organic
carbon (TOC) 10 mg/Nm$^3$ and for dioxins and furans 0.1 ng/Nm$^3$ which also indicate incinerator efficiency.

With the demand for increased stringency on emission standards, hazardous waste treatment technologies for incinerators have greatly improved. Regardless, there usually remains a residual product containing the inorganic contaminants. i.e., heavy metals like cadmium and mercury that requires landfilling. Such residual products must be less hazardous to the environment than the original waste, which have undergone some form of treatment prior to, or in conjunction with, landfilling.

2.6 Economic Issues

It is generally agreed that increased spending is required today in order to strengthen measures to protect the environment. This agreement persists despite the various ideologies that underlie some proposed solutions to current environmental problems. The need for more funding is evident in all areas of environmental management, but is especially evident in hazardous waste management, especially in developing countries. Indeed, many of the environmental problems facing the world can be traced directly to this neglect.

The chief economic reality underlying hazardous waste management operations is that treatment/disposal costs have to be born by someone at some point in the process, most logically by the generator of the hazardous waste. It is also deemed desirable to have special accounting procedure so that each type of waste stream can identify and bear its own costs. Identifying the costs of separate collection, transport, treatment, and disposal activities in a waste stream may encourage waste generators to practise more care in the handling of raw manufacturing materials and to seek benefits in waste minimisation and recycling practices.

Despite this general economic principle, a certain amount of government funding may be necessary to develop a hazardous waste management system especially during its initial stages. There may be a need for incentives like state grants, tax reductions and in some cases investment subsidies to establish certain treatment plants. In addition, government support may be necessary to facilitate the availability of information.

2.7 Social and Political Issues

Responsibility for hazardous waste management, whether in a country or a regional group of countries, resides in the populace that benefits from it. In today’s increasingly global world, it can be said that the industrial population in its entirety holds this responsibility. This is because all members, through their direct or indirect use of industrial and consumer products, contribute to the generation of hazardous wastes. Certainly, as the world’s population has increased and industrial manufacturing practices have advanced, the output of hazardous wastes has increased.

Many societies acknowledge their responsibilities toward the environment. These societies may not understand, however, that this responsibility entails active participation in learning about the technical requirements for constructing a hazardous waste management system. Nevertheless, an increasing number of societies are
communicating their desire for new and improved laws to protect the environment and human health.

As representatives of society, legislators and government officials must act to ensure that the planning and control needed to manage hazardous wastes and to protect the environment are consistent with society's demands. There are, at the same time, benefits to be gained from leaving the planning and control processes open to market forces. Thus, for a variety of environmental, economic and political reasons, it is important to find the right balance between control by society and control by market forces.

An issue that demands special attention in this context is the fear and opposition of the general public towards seemingly all activities involving hazardous wastes. This fear expresses itself in what has become known as the NIMBY (Not In My Back Yard) syndrome. Underlying the NIMBY syndrome is an understandable public attitude: "Environmental protection? Yes! Facilities and procedures that will handle hazardous wastes to ensure environmental protection? All right. But not in this municipality, not in this region, not anywhere near me."

This attitude creates great difficulties and may even paralyse the process of permitting and constructing facilities necessary to meet society's environmental expectations. The process is not eased by the fact that the NIMBY syndrome is on the rise in virtually every country throughout the world. Thus, in the midst of this fear, a way must be found to work with society so that necessary decisions are made in accordance with normal political and democratic processes. This will involve increasing communications with the public at several levels.

The first level of communication must assure the public that civil servants and scientific and industry experts truly are committed to constructing an environmentally safe, sound, and reliable hazardous waste management system. Several features, then, must be built into the system to ensure that it will operate safely and reliably. Communications must be further enhanced among industry, the public and government. Open and matter-of-fact information about the costs, benefits, and risks, must be made available. The public should be given the opportunity to express its fears and concerns, and those fears and concerns should be addressed in the permitting and construction requirements imposed on hazardous waste facilities.

These communications should translate into a significantly new approach by public servants and private individuals skilled in waste management practices. Hopefully, it will also result in a more enlightened general public. Such an approach is necessary, if a general increase in public confidence is to be gained. The public's confidence is necessary if government officials and private companies truly wish to plan and construct an optimally safe and economically sound system, especially in terms of transportation routes and facility locations.

These concerns are very well known. A lack of interest in protecting the environment is not an obstacle in achieving this goal. The stumbling block is often the absence of a desire to accept responsibility for creating resources to protect the environment. The public distrust is so great that many officials feel defeated before they begin. Making these difficult decisions requires an increased commitment both to reaching our environmental goals and to communicating those goals openly. The following points, clearly established and articulated, can go a long way toward increasing public trust and clarifying needs for the regulated community:
1) Responsibilities of industrial waste generators, communities, government authorities, and other involved parties, must be clearly defined and enforced.

2) Information on use of chemicals and the overall structure and detailed standards supporting a hazardous waste system must be made available from central regulatory authorities. Advice and instructions on how to comply with the structure and standards should also be made available.

3) A waste declaration and tracking system (preferably computerised) to help ensure that waste quantities are documented, safely transported, treated and disposed of, should be imposed.

4) A communication network between specialised companies and organisations that possess technical, economic, and human resources helpful in implementing collection, transportation, treatment and disposal procedures for hazardous wastes, must be established.

5) Requirements for the construction and operation of regional stations that will receive and reload wastes must be developed.

6) Requirements for the construction and operation of plants that will pre-treat hazardous waste must be developed.

7) Requirements for the construction and operation of central and regional waste recovery and treatment plants, together with mid-term and long-term storage facilities must be developed.

8) Requirements for the construction and operation of regional landfilling depots for wastes and treated waste residues must be developed.

9) Planned import and export controls on hazardous wastes that will facilitate collaboration and optimise treatment specialisation among countries must be developed.

10) Information on the monitoring of activities for the whole of a hazardous waste system, at central, regional and local levels, must be made available.

11) Qualified training activities within the various governmental branches that oversee hazardous waste activities must be made available.

12) Research and development activities that foster co-operative ventures between government and industry, with the goal of minimising wastes and creating self-contained industrial processes to encourage increased recovery and improved final treatment need to be promoted.
3 Collection and Transportation

3.1 Introduction

Within the network of a hazardous waste management system, collection and transportation procedures ensure the safe delivery of waste from the producer to appropriate recycling, treatment and disposal facilities.

A balance between costs and safety factors must be considered in devising collection and transport systems. Experiences from different countries show that such balances are possible. Experiences also show that if cost factors outweigh safety consideration, an unacceptable level of risk is assumed. Such a risk threatens the integrity of the waste management system, the environment, and society’s confidence in the system as well.

As with all other elements in a hazardous waste management system, effective transportation and collection procedures begin with good legislation. Legislation to regulate the collection and transportation of hazardous waste may be developed as a separate code, or written in the framework of national or regional transportation laws.

3.2 Collection

The hazardous waste management chain starts with collection and in this early phase of waste management the need for professional knowledge in hazardous waste handling is already apparent. The producer of waste obtains information to classify hazardous waste from the information of chemicals used. Utilised chemicals also include information for transportation, such information can in most cases be used to classify the transportation risk of the waste produced. The collection process includes judging waste declarations, classifying the waste, determining the means of transport and further handling, and giving advice to the waste producer. To fulfil these procedures successfully a constructive and service-minded contact with the waste producer is essential.

Small and medium-sized industries often have limited knowledge of chemistry and hazardous waste handling procedures. Thus, advisory and consulting activities are important parts of collection procedures. This can include advice on how to fill out declaration forms, what packing to use, how to label containers and how to complete the correct transport documents (see Appendix 1).

In cases where hazardous wastes are dangerous goods as well, which often is the case, there almost always is additional legislation to consider. Regarding land transports, most European countries have adopted so-called ADR rules, which is used as a reference in this report. The ADR rules place the responsibility for packing procedures, as well as correct labelling, mainly on the sender of the goods. The transporter has to ensure that the documents are in compliance regarding the quantity of goods, the labelling and the packaging.
It follows from the above that the collection phase requires skilled chemists, well acquainted with all environmental legislation and with that related to hazardous waste in particular. Furthermore, insight into transportation regulations (ADR rules in applicable countries) and thorough experience in hazardous waste management are necessary. In many hazardous waste management companies, therefore, specially qualified members of the staff are engaged in this first link of the hazardous waste management chain.

3.3 Transportation

Apart from road transport, hazardous wastes are also transported by ship and railway. For dangerous goods, International Maritime Dangerous Goods (IMDG) and RID regulations (Regulations concerning the International Carriage of Dangerous Goods by Rail) respectively apply. Since road transports are predominant, the following remarks are confined to these.

Hazardous wastes appear in different forms: solid, semi-solid, liquid, and numerous possible combinations. They may be dangerous or relatively harmless. Their most common characteristic is that they rarely resemble a pure product.

Since regulations are written mainly to apply to pure products they create a number of difficulties when applied to hazardous waste transport. Liquid hazardous wastes, especially, are often mixtures of different substances that consequently lead to classification problems. However, if the producer of hazardous waste knows the ADR-rules and chemical classification systems used in industrial countries, it should not be too difficult to classify wastes which are normally mixtures.

Another example is a load of several different chemical wastes, for instance those from a laboratory. ADR rules require a complete transport document and a transportation card for each of the single chemicals. This can result in an
unreasonable amount of paper work with questionable improvement in transport safety.

From the fact that hazardous wastes can appear in so many different forms, it follows that a variety of transportation techniques must be available. Liquid wastes, for example, may be transported in closed containers, in barrels, in suction trucks or tanker. Also, since hazardous wastes may be corrosive, inflammable, or reactive, there are varying needs for tank materials and vehicle construction. ADR rules are elaborate in their requirements regarding vehicles carrying dangerous goods. Each vehicle has to be approved for specific classes of wastes, according to the ADR classification.

Suction trucks are a convenient means for collecting liquid hazardous wastes, they can easily be collected whether the waste producer stores them in tanks, barrels, or other kinds of vessels. The collector has to have its disposal trucks equipped with acid-resisting steel tanks, as well as trucks approved for highly inflammable liquids.

Solid wastes may be transported by specially equipped trucks, in containers, or in capped drums (see Appendix 2: "Various collection systems"). The means of transportation is often determined by treatment plant requirements. This is also true for the choice of transport regarding semi-solid and liquid wastes.

3.4 Intermediate storage

Intermediate storage, sometimes an important part of the hazardous waste management chain, has a specific connection with transportation. A transportation organisation without access to its own treatment facilities may benefit from having some kind of intermediate storage capability available.

Figure. 3: Intermediate storage of small containers
Reloading and repackaging the hazardous wastes may be economically essential in order to obtain optimal transport volumes. In collecting small amounts of motor oil from a number of workshops, for instance, it is much more efficient to have a storage tank from which larger tankers or railway tankers can deliver the oils to the treatment plant.

Other methods of sorting and pouring wastes together into larger batches, by knowledgeable chemists (of course), can be performed at these storage facilities with positive economic and other benefits.

3.5 Integration Benefits

A related area of activity for hazardous waste companies is clean up after accidents or spillage involving oils or chemicals. The equipment, experienced staff and other resources needed are much the same as for collection and transportation of hazardous wastes.

This section has described an essential aspect of hazardous waste management. It consists of collection, including the important co-operation with the waste producer, and transportation, either directly to a treatment plant or to an intermediate storage area. The final link of the chain is the treatment plant.

The crucial asset available for firms and agencies operating in this field is specific knowledge of hazardous waste handling and its related chemistry. The structure of this knowledge is much the same in other areas of hazardous waste management. Indeed, the problems connected with collection, transportation and treatment of hazardous wastes have much in common.

A conclusion to be drawn is that a number of factors favour the integrated management of wastes, or the management of as many links of the hazardous waste chain as possible within one organisation.
In regulating safe and effective hazardous waste collection and transportation procedures, a list of important criteria to be considered is given in Table 3.

### Table 3 Collection and transport criteria

<table>
<thead>
<tr>
<th>*The identification of local and regional transport stations to be used for the reception, temporary storage, and reloading of hazardous wastes. This study can be used to attain the best possible logistical flow of hazardous wastes in terms of technique, economy, and environmental impact.</th>
<th>*The availability of equipment and laboratory resources for use at special waste reception stations that provide pre-treatment services.</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Communication with national or regional planning authorities to assist in designing safe and efficient transportation routes for the flow of hazardous wastes.</td>
<td>*The establishment of a waste tracking system, preferably computerised, which will leave a trail of information on the quantity, quality and whereabouts of a hazardous waste load. A waste declaration form should be made available for use not only by the waste producer, but also by waste transporters, recycling, treatment and disposal companies, and appropriate government authorities.</td>
</tr>
<tr>
<td>*Communication with specialist organisations that employ qualified chemists proficient in hazardous waste treatment and disposal techniques. Such organisations can assist in facilitating co-operation between waste producers and planning authorities in developing safe and efficient transportation routes.</td>
<td>*Qualified on-going training opportunities for workers involved in collecting and transporting hazardous waste should be made available.</td>
</tr>
<tr>
<td>*The availability of equipment, such as vehicles, containers, and pumps, specially designed for the collection and transport of hazardous waste. Such equipment must comply with rigorous safety standards.</td>
<td>*Finally, an important future task for collecting and transporting hazardous waste is an expanded, selective collection for recyclable wastes.</td>
</tr>
</tbody>
</table>

## 4 Successful Hazardous Waste Management

### 4.1 Introduction

There are two essential types of hazardous waste treatment facilities: chemical processing (CP) facilities and incinerators. While the design of these facilities varies significantly depending on the types of wastes they are permitted to accept and treat, certain operating procedures and practices should be maintained at all hazardous waste facilities.

At a minimum, these include the following administrative functions: acceptance, analysis and storage, and basic safety practices. In this discussion a brief review of these procedures is provided below when CP facilities and incinerators are discussed individually.
4.2 Administration

All hazardous waste facilities must maintain an efficient administrative department. This department should be able to assist plant personnel and be knowledgeable about government regulations and related facility operational requirements. As most of these facilities will be private or only quasi-public, administrative personnel specialising in legal matters should develop and maintain strong contacts with governing authorities as well as the industrial community of waste producers.

With a good knowledge of government regulations and the types of wastes generated by its industrial customers, administrators at hazardous waste plants can ensure that wastes received are actually wastes the plants are permitted to accept and treat. Plant administrators should also be capable of recommending alternate treatments, or possibly waste minimisation and recovery technologies for a particular waste load, when appropriate.

It is likewise recommended that hazardous waste plants operate a public affairs office. The public affairs office should function to inform nearby communities of the plant’s problems and successes.

4.3 Acceptance, Analysis and Storage Procedures

In addition to retaining educated and qualified administrators, there are certain technical tasks that all hazardous waste facilities should be capable of performing. These technical tasks involve accepting, analysing and storing hazardous wastes. Such functions require support from qualified administrators, technicians and chemical engineers and a good laboratory with the proper equipment.

Figure. 5: Laboratory for waste analysis
4.3.1 Accepting Hazardous Wastes

In addition to technical and engineering needs, commercial needs must be considered if the operation of the facility is to be successful. After all, the plant is selling a service. A plant can have fixed or varying prices, depending on the treatment available and the relationship between the industrial waste producer and the waste management company.

The waste producer, or customer, initiates the procedures by filling out a form that includes information on the chemical composition, aggregation, form of delivery, and hazardous quality of the waste load. Examples of these forms may be obtained from existing hazardous waste facilities operating in ISWA member countries (see Appendix 1).

With the information obtained from these forms, the waste management company will quote a price to the producer, according to various acceptance criteria and rules. Every waste stream must be viewed as a unit product, with prices established accordingly. All relevant data must be stored separately for each waste stream to maintain the cost integrity of the waste management system, and this information made available for review to all departments and agencies concerned with the waste.

Once a waste management company and waste producer have reached an agreement, the waste load is collected and transported from the producer’s site to the treatment facility.

4.3.2 Analytical Procedures and Laboratory Requirements

Ample space for vehicles delivering hazardous waste must be available at the waste facility. The space should allow vehicles to park with room for the taking of a waste sample. When wastes arrive in drums they, too, have to be tested by the laboratory staff, and then forwarded to a drum storage area prior to treatment. Weighing devices must also be accessible.

After a sample is taken it is sent to the laboratory, which should be located on-site at the treatment facility. At a minimum, the laboratory should contain the equipment in Table 4.

<table>
<thead>
<tr>
<th>Table 4: Laboratory equipment</th>
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</thead>
<tbody>
<tr>
<td>Apparatus for AOX determination</td>
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<tr>
<td>Apparatus for CSB determination</td>
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<tr>
<td>Apparatus for oil determination</td>
</tr>
<tr>
<td>Atomic absorption Spectrophotometer</td>
</tr>
<tr>
<td>Calorimeter</td>
</tr>
<tr>
<td>Conductimeter</td>
</tr>
<tr>
<td>Flash test apparatus</td>
</tr>
<tr>
<td>Photometer</td>
</tr>
<tr>
<td>Gas chromatograph with mass spectograph and ECD (electron captive detector)</td>
</tr>
<tr>
<td>• Ray Spectrophotometer (Required of laboratories supporting incinerators)</td>
</tr>
</tbody>
</table>
A commercial analysis of the waste then is executed. In the event that the waste is to be incinerated, an analysis for incineration also is performed.

The purpose of the commercial analysis is to confirm that the waste matches the description given on the accompanying waste declaration form. This test must be performed to ensure that the waste has not been improperly mixed with, or substituted for, other wastes. When PCB, benzene, toluene and heavy metals are present in a waste stream, special tests are conducted to determine their concentration levels.

For hazard analysis the product information supplied by the customer is strongly relied on as a starting point. This information is also essential in order to minimise exposure to the wastes by laboratory technicians, engineers and other employees working at the waste facility.

Once the contents of a waste have been analysed and verified, this information must be reviewed to ensure its compatibility with the conditions proposed for treatment. To facilitate this, a computer program to input the chemical analysis of a waste and other information contained on the waste declaration form is proposed. Such a computer program can be used to gain information about the impact that residues may have on other plant operations. For example, components such as waste water or solid residues must be analysed before making decisions on final disposal into a sewer system or landfill. At incinerators, flue gas monitoring should be included.

While it is essential that all hazardous waste facilities are equipped with basic laboratory tools, additional waste handling instruments and pollution control equipment must also be made available. The technology employed at, and wastes received by a hazardous waste facility, will dictate the design of such equipment. This is discussed in more detail in the following sections on CP and incineration facilities.

When analyses have been completed, the laboratory staff must also decide which waste components can be mixed and where and how the delivered wastes are to be stored before treatment. For safety reasons, flash point and reactivity tests are performed on wastes that are mixed with other wastes prior to storage.

4.3.3 Storage Facilities for Hazardous Wastes

In principle, hazardous waste is stored, ready for treatment, soon after its arrival at the facility. In reality, it may be necessary to perform some level of pre-treatment. These pre-treatment and storage techniques vary slightly from one hazardous waste plant to the next. All plants, however, are equipped with a tank yard for fluid wastes, sludge tanks and bunkers for solid waste and a separate storage area for hazardous wastes delivered in drums.
In general, the investment in storage is dictated by market conditions. Are customers willing to bear the extra costs of building a storage facility? Large storage investments can double the costs of the treatment facility, if large storage capacity is required. Therefore, market demand must be considered in determining storage capacity, the size of a facility, and its throughput.

After the laboratory has completed an analysis, the waste product will be pumped into a storage tank adequate to contain it. The number and size of storage tanks will depend on the plant’s treatment capacity. Procedures should be in place to ensure that the incoming waste will not react with residues of wastes previously stored in the designated tank.

Since waste products always contain some solid material, it is recommended that all tanks are equipped with a collection container and screening apparatus. If the presence of solid materials is so high that it builds up and obstructs the screens within a short time, waste products should be discharged into an open basin. In a properly designed open basin, it is possible to separate liquid and solid materials without difficulty. In general, liquids and sludges can be pumped, and solid materials can be stored in bunkers.

In any case, pumping solid wastes and liquid wastes into the same tank should be avoided. When pumped together, sedimentation will occur making it difficult to empty the tanks later, and it also will result in limitations on the usable volume of the tanks. An open basin can be quite useful because it can be used to discharge solids that remain in suction trucks.

Storage pits should be enclosed in a building with a sliding front door large enough to allow trucks to drive through to the storage pits’s edge. The building itself must be connected to the plant’s exhaust air-cleaning system. The tanks must also be connected to the gas cleaning system, so that the air that escapes during waste exchanges is cleaned before being discharged into the atmosphere. Moreover, a two-way valve must be installed so that air can also refill the tank when it is emptied.

Separated solid materials usually have a syrup-like consistency and must be treated with solidifying additives, such as fly ash, before they can be disposed of in a
landfill. If the solid materials contain high organic content, they too must be treated as a hazardous waste. Freed of solid matter, the liquid waste is pumped into the tanks. Waste products with the same or similar treatment requirements can be collected into a single tank and be treated together.

Emulsions always form individual phases within the tanks, so some tanks should be equipped with a stirrer to ensure a steady and homogeneous quality to the wastes. This system helps to facilitate treatment later. Storage tanks are usually made of steel, but sometimes plastics or composites are used. For certain wastes, such as lye and acids, tank materials resistant to the characteristics of these wastes must be chosen.

To avoid contaminating soil and/or groundwater in the event of tank leaks or spillage, tanks must also be bunded. These bunds are normally made of concrete. Technical specifications on the dimensions of these bunds must be followed. The ground surface beneath the bunds must also be covered with materials resistant to chemicals found in waste products. It is also necessary to install a groundwater monitoring system around the perimeter of a hazardous waste facility, in the event of an accidental discharge.

Pipes, armatures and pumps that convey wastes should also be made of chemically resistant materials. In addition, it is recommended that these materials be selected so as to require as little maintenance as possible. This can help to keep down the costs. In areas where temperatures fall below zero in winter, a heating system should be installed to avoid pipe damage and breakage.

4.4 Safety and Reliability

For purposes of this report, the preventive measures and maintenance tasks required to ensure that a hazardous waste treatment facility is safely and reliably operated, are simply too numerous for all to be explained in depth. At the same time, legal instructions and regulations vary among nations. Therefore, the highlights of good safety practice will be considered.

Stringent regulations on safety and reliability practices must be written by legislators, and followed by owners and operators of hazardous waste treatment facilities. The objectives of these regulations are: to ensure the protection of worker health and safety, to protect against dangers during plant breakdowns, to protect against fires and gas emissions and to set requirements for the flame trap.

Because many safety and reliability procedures depend on the skills and experience of workers employed by the facility, worker-training programs on safety and reliability procedures must be continuously available. Workers should also be trained in emergency procedures. The focus of such programs should be on establishing and executing acceptance and discharge procedures, control of entrances, control of operational processes, maintaining operation diaries, and regular equipment maintenance.

By means of permanent examination, institutions like the “Technischer Überwachungsverein” in Germany may be solicited for assistance in developing safety and maintenance procedures. In the USA, organisations such as the American Institute of Chemical Engineers (AICE) and Chemical Manufacturers Association (CMA), also provide safety and reliability guidelines. Drawing on the expertise of such organisations may help to ensure optimal safety and reliability. These procedures must, however, meet appropriate government regulations.
To fulfil all responsibilities, the owner or operator of these facilities should develop an integrated operation manual covering all plant activities. At minimum, this manual should describe: normal operations, start-up procedures and operation, shut-down procedures and operation, emergency shut-down procedures, field inspections during operation, and minimum maintenance requirements.

These manuals should contain all relevant documents, technical and legal, necessary for the plant to operate. Specific safety and reliability procedures to be followed at CP and incineration plants are included respectively in Chapter 5, sections 5.1 and 5.2.

5 Successful Treatment Practices

5.1 Chemical-Physical Treatment Facilities

5.1.1 Introduction

The purpose of chemical-physical (CP) hazardous waste treatment facilities is to convert the chemical and physical qualities of hazardous wastes into forms that poses significantly reduced threats to human health or the environment. Both organic and inorganic waste streams, either solid or liquid, may be treated at a CP facility, depending on its capability specified in its permit.

The technical design of a CP treatment is primarily determined by the characteristics of the waste to be treated. Individually or combined, the objectives of CP treatment are: to utilise or recycle chemicals in the wastes, to alter or to reduce the hazardous potential of the wastes, to affect the waste stream so that when disposed of, it will have no adverse effect on the environment. Recommended treatments for specific waste types are listed in Appendix 3.

These objectives can be achieved through a number of different physical and chemical processing technologies, identified in Table 5.

Table 5: Conceptual requirements of a chemical/physical hazardous waste plant

<table>
<thead>
<tr>
<th>Physical Technologies</th>
<th>Chemical Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation / De-watering</td>
<td>Chemical separation of emulsions</td>
</tr>
<tr>
<td>Conditioning</td>
<td>Neutralisation</td>
</tr>
<tr>
<td>Centrifugation / Flotation</td>
<td>Precipitation / Flocculation</td>
</tr>
<tr>
<td>Drying / Evaporation</td>
<td>Oxidation</td>
</tr>
<tr>
<td>Evapo-incineration</td>
<td>Reduction</td>
</tr>
<tr>
<td>Thermal separation of Emulsions</td>
<td></td>
</tr>
<tr>
<td>Distillation</td>
<td></td>
</tr>
<tr>
<td>Ultra-filtration</td>
<td></td>
</tr>
<tr>
<td>Reverse-osmosis / Stripping</td>
<td></td>
</tr>
</tbody>
</table>

In constructing a CP treatment facility, national, regional, and local laws and regulations, all have to be met. While this discussion references these legal requirements, it primarily focuses on the structure and organisation of the industrial processes that occur at CP treatment facilities. These points are critical to the efficiency and performance of the plant.
The conceptual needs of CP plants are listed in Table 5. The table identifies the most important areas in a CP plant, and provides individual working sequences. The areas and sequences identified include the following:

- The laboratory
- Receiving and discharge stations
- Tank storage facilities
- Treatment facilities for liquid organic and inorganic wastes
- Storage and disposal facilities for reaction products, waste waters, and filter cakes
- The cleaning and exhaust air system
- Intermediate storage areas for wastes to be incinerated
- Safety features and equipment

5.1.2 Treatment of Aqueous Organic Wastes

Aqueous organic wastes are received primarily as mixtures containing water and several different types of polluted oils. It should be noted that emulsions present in organic wastes might also be polluted with solvents. Therefore, a good laboratory check should be made to ensure that emulsions polluted with solvents are collected and diverted for separate treatment.

Figure 7: Receiving station of chemical-physical hazardous waste treatment facility, Mönchengladbach, Germany
CP waste facilities that specialise in treating organic wastes usually apply various techniques to separate and treat emulsions. Some of the commonly applied separation techniques include flotation, centrifugation, thermal splitting of emulsions, chemical splitting of emulsions, and membrane techniques.

Once water and oils have been separated, the consolidated oily wastes are likely to require further treatment, as may the wastewater, depending on the degree of contamination.

Thermal techniques are reported to have produced some of the most impressive separation results. When surplus energy is available, thermal separation techniques are commonly used. Because most facilities need to conserve energy, however, there has been a lot of work to improve the effectiveness of other available techniques, both when applied alone or in combination with one another.

It should be noted too, that membrane techniques have proven to be successful when applied at one-site treatment facilities located in large industrial parks. This is because very specific information on the composition of the wastes is usually more comprehensively available at these facilities. Such knowledge can rarely be provided at plants open to general use.

Automated process controls, containers, and pump systems, among other kinds of equipment, are also needed to perform the processes involved in chemically treating wastes. The process is composed of three basic steps, which take place individually, yet continuously, in three containers placed one after the other. The three basic steps involve continuously pumping the waste from container 1 to container 2 to container 3. Three specifically prescribed reactions take place in each of the containers.

As the containers in which the chemical reactions take place are exposed to heavy corrosion, materials with a correspondingly high resistance to corrosion have to be chosen. Containers with an internal coating of plastics reinforced with fibreglass or other strengtheners have proven to be reliable.
To avoid any emissions that may endanger the environment or working areas, the containers are connected with the facility’s exhaust air cleaning system. Into container 1, a pre-determined amount of acid is pumped continuously, along with the waste from its storage tank. With the aid of a pH electrode the flow and proportions of the acid and the waste emulsions are regulated and mixed according to a pre-defined prescription. It is also recommended that a stirrer be used to help ensure a good intermixture of the waste and acid.

The acid selected will depend upon contaminants present in the organic waste. In the event, however, that a waste acid is available and safe enough to be disposed of, for example, from a pickling line, then it is recommended for use in this process. Such an acid also provides a sufficient quantity of iron, which eliminates the need to supply iron separately.

The second container is equipped with a mechanical oil separator, ensuring that the oil can be skimmed off.

Lime milk is added to the third container, which is also equipped with stirrers, in order to neutralise the medium and to precipitate the heavy metals as hydroxides. The hydroxide sludge is pumped, first, into a working container, and then into a chamber filter press where liquids and solid materials are separated. Products of this treatment are wastewater and filter cakes, which after further treatment respectively are disposed of into a sewer system and shipped to a landfill for final disposal.

The separated oil is collected in a tank, and then either burned or conveyed to a distillation plant for recovery. Emulsions are often contaminated with solvents and this can be determined by laboratory tests, and should be collected and treated separately. In some cases the only environmentally safe treatment is incineration.

5.1.3 Treatment of Aqueous Inorganic Wastes

Depending upon the components, different processes are involved in chemically treating inorganic wastes. Although processes used to treat inorganic wastes may be chemically based, they are significantly different from the chemical processes used to treat organic wastes.
Toxic anions, such as cyanide, nitrite or chromate, are often present in inorganic wastes and are transformed through the addition of oxidation/reduction chemicals. Additional dosages of chemical additives are regulated with automatic process controls.

Generally, sodium perchloride (NaOCl) is used as an oxidising agent. Wastes, polluted with cyanide or nitrite often are treated in this way. On the other hand, wastes contaminated with chromates are reduced to chromium (III) compounds by adding iron (II) chlorides (FeCl₂).

The above reactions take place only within certain pH levels, which means that the waste media may have to be acidified or made alkaline. Pre-treatment becomes necessary when the filtration qualities of the hydroxide sludge resulting from the detoxification must be improved. This occurs when NaOH is used for neutralisation.

As in the case of organic wastes, the containers, pumps and pipes of detoxification facilities used for inorganic wastes must be made of chemically resistant materials. Stirrers should be used to obtain a good mixture of the wastes and chemical additives. Also, the containers used must be placed in a collecting basin and connected with exhaust air cleaning facilities.

Inorganic wastes can be treated by the mechanical means of pressing. In order to achieve a good filterability, a certain quantity of lime milk is usually added. In a model plant, such wastes can be pumped directly into the third container, where the dosage of the lime milk is controlled by a pH electrode.

In addition to the above, precipitation of heavy metals with the aid of lime milk may also be used. Higher degrees of purity are achieved with this technique. For most operations precipitation with lime milk is preferred, as heavy metal sulfides from sodium perchlorate can present management problems at the disposal plant. Other problems likewise can occur. The formation of hydrogen sulfide, which is annoying because of its smell, can be produced by anaerobic decomposition processes. Also,
if the wastes contain complex forming substances that prevent precipitation, difficulties with performance of precipitation can occur and will require remediation.

5.1.4 Treatment of Waste Residues

After neutralisation, a sludge is produced that requires further treatment prior to disposal. To continue treatment, this sludge is pumped to a chamber filter press.

Figure. 10: Chamber filter press

The chamber filter press may be powered with either piston diaphragm pumps or electric screw pumps. To ensure optimum efficiency, the presses should be well maintained and their filter cloths cleaned regularly. Good press maintenance practices will also help to achieve significant reductions in the water content of the sludge.

As the sludge runs through the presses, pressed sludge or “filter-cakes” fall into containers placed below the presses. By means of this process, the water content of the sludge can be reduced by 60 percent, or possibly even 70 percent. Some presses, however, may not achieve such high reduction rates.

Both the filtrate water and filter cakes that are produced must be analysed. Undoubtedly the filter cakes will retain certain levels of organic components, such as oils, greases and hydrocarbons like benzene, xylene, and phenol, which are likely to be absorbed from the hydroxide-flocule during precipitation in the neutralisation process. The levels of these organics should be considered in determining what facilities can accept and dispose of the filter cakes.

As the process continues, the filtrate water, produced during pressing, flows into an intermediate tank and is pumped from there into the tanks of a wastewater tank depot by means of a centrifugal pump. Before discharging the wastewater into a sewage system, levels of pollutants must be measured to ensure that they do not
exceed limits affixed to the operating license of the CP plant. If the limits are exceeded, the waste water must be treated again until they meet or fall below the limits.

If stringent limits on waste water discharges are to be obtained, additional cleaning processes such as stripping or carbon absorption are likely to be required.

In addition to treating the liquid and solid waste residues generated at CP facilities, it is necessary to treat polluted air emissions before they escape into the atmosphere. As has been pointed out, emission sources such as tanks and basins must be enclosed or covered and connected to the facility’s main exhaust air cleaning system. Polluted air then will be cleaned at the facility equipped with the correct technology. This is necessary to protect the environment, employees and neighbouring communities.

A basic two-step “washing” procedure for air emissions is recommended. This includes the application of an alkaline medium, such as NaOH, followed by an acid medium, such as H₂SO₄.

If organic discharges still exceed national emission limits, another cleaning method or an additional step of treatment must be employed. Such treatments can include: thermal afterburning, catalytic incineration, and absorption by activated carbon. The level of pollution, flow of volume and potential for the CP plant to recover and use energy, will determine which method is chosen.

Currently, the efficiency of biological cleaning techniques are under study. A problem common to biological treatment, however, is the wide range of impurities in the air emission. Hydrocarbon content, for example, can vary from 50 – 300 ppm/Nm³, and render the procedure difficult.

5.1.5 Intermediate Storage for Waste to be Incinerated

To provide waste generators with comprehensive treatment, operators of CP facilities may include tank storage for wastes that require further treatment in the form of incineration. Combustible wastes should be categorised by flash points. Generally only two categories need to be established. The first category applies to substances with a flash point less than 21°C. The second category to substances with flash points greater than or equal to 21°C but less than or equal to 55°C.
Storage for both categories of wastes must be equipped with special fittings. Some examples of fittings include: fireproofing filters for pipes, a lightning protector, explosion-proof engines, and fire-fighting equipment.

Separate discharging stations for tanks storing combustible wastes should also be set up. Screening facilities that separate the solid materials from the liquid before the tanks are filled are a necessary part of every station. Liquid wastes should not be mixed prior to treatment, except in cases where laboratory tests have demonstrated there is no risk.

Since most waste products with flash points equal to 21°C have very strong scents, the gas/air mixtures removed during the filling or emptying processes have to be fed back into the tank or the filling car by a second pipe system. This process requires that operating procedures regarding lightning protection, flame trap, and fire protection, be followed closely. Managing extremely flammable substances demands extreme caution and security. Laws and regulations must be written and followed that meet these caution and security needs.

5.2 Thermal Treatment Facilities

5.2.1 Introduction

In the incineration of hazardous wastes, the goals are to reduce volume, to destroy as many toxic constituents as possible and to recover the energy potential in hazardous wastes.

Specialised incinerators are designed according to the types of wastes they burn. Several different designs are available today. The most commonly used incinerators are classified according to grid: rotary kilns, fluidised bed reactors, plasma arc incinerators, electrical incinerators, chamber incinerators, and incinerators for fluids.

Of these designs only rotary kiln incinerators are capable of treating a broad range of wastes. In this discussion on incinerators, rotary kiln units, because of their diverse capabilities, will be discussed in detail.
Other incinerator designs are more focussed or have been developed for selected waste streams. Improved pre-treatment technologies allow diversification of the capabilities of these incinerators.

Steps already outlined provide the basic acceptance, analysis, laboratory, pre-treatment and storage procedures, followed at incinerator plants. In this section, the need to restrict emissions, safety and reliability procedures, treatment guarantees and other issues as they specifically pertain to incinerators, are discussed.

It should be noted here that incineration involves another analytical step. The analysis for incineration is normally element analysis, whereby a menu is composed with information obtained from the element analysis. The aim of the menu is to feed the incinerator with enough high and low calorific wastes, as well as enough contaminated waste such as heavy metals or halogens, to achieve optimum results. The goal is to prevent overloading the incinerator, while simultaneously tapping into its maximum capacity by reworking and mixing the contents of different waste streams.

5.2.2 Rotary Kiln Incineration

An outline of an incineration plant equipped with a rotary kiln unit, and illustrating the flow of wastes through the plant, is provided in figure 12.

Figure 12 Rotary kiln

Rotary kiln incinerators normally have the capacity to treat 25,000 to 50,000 tons of hazardous waste per year. A well-designed incinerator has an overall destruction efficiency of more than 99.999 per cent under normal operating conditions.
It is usual for several hundred different types of wastes to be treated at a rotary kiln incinerator. These wastes are reworked and fed by means of an automated menu system. Adequate process controls must be installed, including automatic shutdown when the operating conditions exceed or fail to meet specifications.

Waste can be brought into the rotary kiln by means of lances (liquids and sludges), grabs (solids), or a barrel supply system (packed waste).

The combustion temperature in the kiln is about 1200°C. In the after burner the temperature is 1000°C or higher. The temperature should be raised during incineration to at least 1200°C for wastes containing chlorinated aromatic compounds, such as PCBs.

The residence time of the flue gas is about eight seconds: two seconds in the kiln and six seconds in the afterburner. This is divided into three seconds before secondary air and three seconds after secondary air. The residence time of the slag is half an hour or more. As can be seen in the diagram, the kiln produces slag that is removed by means of a wet deslagging system.

The discharge of the afterburner leads to a waste heat boiler. The boiler is divided into two sections: a radiating section and a convection section. Both sections produce steam. This steam can be used to generate electricity, or for direct heating purposes.

Part of the particulate matter present in the flue gases is deposited in the boiler. Removal of these ashes takes place by means of boiler hoppers.

Flue gases are primarily treated toward the end of the process through the use of a wet scrubber. In this scrubber, several pollutants, such as HCl, HF, SO₂ and heavy metals, are significantly reduced. Next, the fluids discharged from the scrubber must be cleaned. This cleaning is accomplished by a series of neutralisation, flocculation and sedimentation processes.

The sludge is sent to a sedimentation tank, where a filterpress to dewater it is applied. In many countries, this process is no longer considered sufficient to reduce pollutant levels adequate enough to meet treatment standards. Additional processes frequently imposed include: ultra filtration, reverse osmosis, activated carbon filter or ion exchange. Another alternative is to evaporate the discharge waste and apply additional heat to further treat the sludge residues.

Flue gases also demand additional cleaning requirements. A dry system, using a reactor and bag filter, may be applied. Systems that incorporate the evaporation of lime slurry, a reactor, and bag filter, also may be used. The emissions from these systems may be higher for gaseous heavy metals and acid components.

The slag produced, fly ash, dewatered sludges, and other treated residues are transported to a landfill that is specially equipped to handle and dispose of these wastes safely, following suitable pre-treatment.

Although the quantities of these treated residues vary depending on the capacity of the incinerator, incinerators with a 50,000 ton capacity typically generate approximately 10,000 tons of slag, 1000 tons of fly ash, and 150 tons of dewatered sludge per year.
5.2.3 Incinerator Emissions

Incinerator emissions that escape into the atmosphere, especially those containing dioxins and benzofurans, have caused a great deal of public concern about their impacts on the environment and human health. Consequently, the effects of incinerator emissions are debated and under close examination in political, public and scientific circles. Efforts are under way to further reduce the pollutants found in incinerator emissions.

The types and levels of pollutants present in emissions are directly related to the incinerator’s system design and hardware. For example, a one-stage wet scrubber or two-stage wet scrubber may be installed, resulting in different levels of pollutants in emissions. Different pollutant levels are also achieved, depending on whether a wet and dry electrostatic precipitation unit is used. For wet, dry or semi-dry systems the environmental impacts on air, water and soil resources will vary significantly.

The choice of a gas-cleaning system often depends on national, regional or local regulations. As has been stated, emission and other pollution standards, as put forward under the law, have a significant impact on the design of all hazardous waste treatment facilities, including incinerators.

Pollution standards, which can be measured by the destruction efficiencies achieved in an incinerator, are calculated by comparing the total amount of a component in all process outlets with the amount in the incinerated wastes. Furthermore, a comparison must be made of the pollutant content in process outlets during the combustion of wastes, based on whether they contain or do not contain chlorinated aromatic compounds. This is especially true of dioxins and benzofurans.

In most member states of the EU the emission limit of 0.1 ng TEQ/Nm³ for dioxins and benzofurans has been introduced. The expression in TEQ means that the total amount of dioxins and benzofurans are calculated back to a theoretical amount (toxicity equivalents) of 2, 3, 7, 8 TCDD.

For newly constructed incinerators it is important to aim for optimal destruction efficiencies. Meantime, the level of 0.1 ng/TEQ/Nm³ can be achieved with some commercially available gas cleaning systems. Either deep cooling or installation of an activated carbon filter process is necessary. Without this extra equipment the concentration of dioxins and benzofurans is dependent on design and operation conditions, and typically is about 1.0 ng TEQ/Nm³ under optimal conditions. It is known that the emissions of dioxins can be ten to 100 times more than 1.0 ng TEQ/Nm³, when combinations of design, menu, temperature, residence time and oxygen content are not operating optimally.

In designing, constructing and operating an incinerator, certain goals must be in place to meet specific destruction efficiencies and pollution standards. These efficiencies and standards also are used in executing a guaranteed measurement program, which should be made available to customers, and government authorities, and to provide guidance for staff working at the incinerator site.

5.2.4 Guaranteed Measurement Programs

The purpose of a guaranteed measurement program is to supply information about the efficiency of the incinerator, especially as it relates to flue gas cleaning and wastewater purification systems. Other guaranteed figures traditionally supplied include:
• Thermal capacity of incinerator unit.
• Waste heat boiler flue gas exit temperature.
• Pressure and temperature of produced steam.
• Flue gas composition at outlet of stack (These values are attained assuming standards for untreated flue gas conditions).
• Liquid effluent composition after purification of scrubber wastewater.
• Solids content of sludge from the gas cleaning system.
• Maximum noise level.
• Destruction efficiency for halogenated organic compounds.
• Performance as determined by an uninterrupted test period.
• Operating hours per year.
• Usage of spare parts in the first one or two years of operation.

To meet the responsibilities and terms included in a guaranteed measurement program the following supports need to be in place:

• Professional and qualified engineering personnel to deliver a correct and up-to-date design and manufacturing for the incineration system.
• All supplies to be up to the latest accepted techniques and technology, and in accordance with relevant standards and specifications.
• Good workmanship for manufacturing, installation and erection.
• Good quality for all supplies and use of only new and best quality materials.
• Execution of design, engineering, purchasing, procurement and expediting with inspection in time and according the planning of all deliveries.

Another important aspect in guaranteeing the performance of an incinerator, is in the waste declaration test. This step involves verifying the contents of the waste shipment delivered for thermal treatment, and the information supplied on its accompanying waste declaration form.

In various testing periods under well-defined conditions, the compositions of incinerated wastes, slag, fly ashes, flue gases, discharge waters, sludge and effluent are determined. The conditions during the testing periods differ from one another either in degree of charge, in the level of combustion temperature, or in the composition of the incinerated wastes.

On behalf of the guaranteed measurements, the composition of the various process outlets such as for flue gases and effluents are compared with the guaranteed terms and permit conditions. Another important aspect of the guaranteed measurements is the testing of the destruction efficiency for chlorinated aromatic compounds. This is necessary when wastes with high contents of PCBs, chlorobenzenes or chlorophenols are incinerated.

5.2.5 Special Safety and Reliability Requirement for Incinerators

Hazardous waste treatment must be undertaken under stringent regulations. In fact, the same safety standards are applicable as those for the chemical industry. This means that the infrastructure must be present for protection against fire, gas emissions, and explosions, and for training employees in calamity procedures.

In modern incinerator designs several safety precautions are built in. Examples are:
• Automatic shutdown procedures for the whole plant when important parameters are outside the setpoints.
• Automatic shutdown of feeding systems when incineration conditions are not optimal.
• Automatic start of oil burners when temperatures fall below a fixed temperature.
• Back up systems for electricity and instrument air.
• Nitrogen blanketing of storage tanks.
• Venting of storage tanks to the incinerator.

5.2.6 Co-combustion

5.2.6.1 The co-combustion process

A number of industrial processes may use wastes containing energy, minerals or both. Co-processing in heat and powers plants, cement kiln, glass kiln, steel plants, achieve an appropriate solution for certain types of waste.

Cement kiln waste co-combustion is the main co-processing development in all the world.

Cement is an artificial rock, primarily consisting of calcium silicates, calcium aluminates and calcium ferroaluminates. It is prepared from a basic component called clinker. Additions of others components such as slag and fly ash can be made during the final grinding process to give cement certain particular properties.

The basic components of the clinker are natural materials that are extracted from quarries. Limestone provides the calcium carbonate which will decompose into lime, while clay provides silica, alumina and iron oxide. These natural rocks also contain trace elements, such as sulphur, chlorine and miscellaneous metals.

There are three different types of burning processes: wet, half-dry and dry. In all three cases, the different phases of the transformation of the raw feed into clinker are the same:

550°C : complete drying and dehydration of the clay,

550°C to 900°C :
calcination of CaCO₃ into lime(CaO) and carbon dioxide (CO₂)

900°C to 1450°C :
reaction of the lime with silica, alumina and iron oxide; formation of calcium aluminate, ferro-aluminate and silicates.

In all three processes, the burner (flame temperature 2000°C) is located in the lower part of the kiln. The rotation of the kiln chamber, together with its slope, generates a slow flow of the load toward the flame. At the same time, there is a counterflow, upward, of the hot combustion gases.

The differences between the three processes, wet, half-dry and dry, are only relevant to the physical aspects of the process; the water content of the materials going into the system is the result of an evolution in process technology from the wet process towards dry process, in order to reduce energy consumption. Since the 1970s, most installations have been re-engineered so that they use the dry process.
In cement kilns, the raw materials temperature reaches 1450 °C and the combustion gases stay above 1200 °C for 5 to 6 seconds. The flame temperature is about 2000 °C.

Figure. 13

**DRY PROCESS + CALCINER**

**INJECTION POINTS**

1 : Main burner
2 : Calciner
3 : Kiln inlet
4 : Raw mill (strictly mineral waste)

To dust collector

To raw mill

100 % mineral waste

Raw mill

ID fan

100 % mineral waste

200°C Rotary kiln

1100°C

Liquids Solids in lumps Waste tires

Liquids Fine solid waste Rough solids

Tertiary air

5.2.6.2 Emissions

As a result of the very large quantity of lime present in the clinker process, the cement kiln is a huge scrubber in itself. The traces of sulfur and chlorine that are found in the fossil fuel and in the waste are neutralized due to the excess of lime.

Clinker production facilities can include efficient dust collection systems (electrostatic precipitator or bag filter) that collects fugitive dust. Furthermore, the use of well defined waste-derived fuels in the kiln has no significant effect on the characteristics of this dust.

Due to the specific temperature profile in the cement kiln and preheater systems, the formation of dioxins are not likely to occur on a significant scale.

The European Directive has set up a limit for dioxins and furans emissions of 0.1 ng/Nm³ TEQ. This can be achieved by proper operation.

The majority of metallic elements in the cement comes from raw materials and only a few from the treatment of waste. During the process of cement kiln incineration, they are fixed by the clinker into stable chemical combination. Silicates are formed that are directly integrated into the clinker chemical structure.
5.2.6.3 Storage and injection facilities

Some liquid wastes are delivered directly from the producers to the cement plants. Most of the time, though, the liquid wastes are delivered to the plant through a pre-treatment platform where they are transferred from small conditionings to storage tanks (grouping). The storage tanks are equipped with agitators in order to transform the wastes from various origins into a waste derived fuel conform to general specifications.

Some platforms transform sludge and solid wastes into an homogeneous pumpable product which can be handled by the same type of storage / injection installations than the installations for strictly liquid wastes. A liquid waste storage installation can include 2 or 3 different storage and injection circuits. A typical liquid installation includes:

- One unloading system for bulk tank trucks
- One or several storage tanks with agitators
- One dosing and injection circuit

The installations are engineered according to the state of the art technologies for environment protection and fire protection.

Solid wastes are normally delivered through a pre-treatment platform where they are transformed in a solid waste derived fuel with convenient characteristics for a proper handling and efficient and stable energy supply to the kiln. Solids or liquids entering the cement plant are controlled before unloading to ensure that their quality responds to the environmental regulations and to physico-chemical characteristics specific to the cement process or to a particular plant.

Installations for solid wastes can be of different types according to the unloading storage and reclaim facilities. In all cases, the circuit includes a dosing system, a transfer conveyor to the vicinity of the injection point and the final injection system, generally a pneumatic system or a double valve gravity system for coarser waste (crushed tyres for example).

The future development of new pre-treatment processes will lead to the development of other types of installations adapted to the new types of waste derived fuel prepared.

In modern kilns, waste can be injected at different points of the installation depending on their quality and their size.

Possible injection points are the following:

- At the main burner were the conditions of the incineration are the best for liquid wastes and small size solid wastes. The necessity to have at this point a high temperature for the flame (2000 °C) and the material (1450 °C) leads to inject at this point wastes with a very short inflammation time. Wastewaters can be injected at this point because the water has a cooling effect on the flame, which reduces the formation of thermal NOx.

- At the kiln inlet (upper part of the kiln) were solid wastes in large lumps are generally introduced (whole or crushed tyres).

- At the Lepol grate in semi-dry process kilns.
- In the riser duct at the inlet of the kiln (liquids).
- In the calciner were solid waste of medium size can be injected.

In long kilns, wet or dry process, wastes (liquids or fine solids) can be injected at the main burner. Solid wastes can be introduced in the middle of the kiln through a special opening (mid kiln system).

In conclusion, several injection points are available, depending on the particular type of waste.

Strictly mineral waste with no organic component can be introduced during the raw feed preparation (quarry crusher, pre blending, raw mill).

5.3 Safe Landfill Management Facilities

5.3.1 Introduction

This section on landfill management focuses on specific design elements and closure procedures. These elements and procedures help to ensure that operations at a landfill are safely performed. All landfill operations should be performed with a goal toward preventing the dispersion of toxic and other hazardous constituents in the waste into the environment.

Important items of consideration when designing a landfill include:

- Characteristics of the wastes that will be disposed of in the landfill.
- Geographical and hydrological characteristics of the landfill site.
- Lining systems.
- Drainage networks and monitoring systems for leachate and runoff.
- Post-closure monitoring systems.
5.3.2 Waste Characteristics

The following characteristics may be used in distinguishing hazardous wastes: physical state (liquid or solid) of the waste, flammability, reactive nature and toxicity of the waste. When accepting waste for disposal in a landfill, the waste should have been treated to some extent so as to reduce its threat to the environment and human health. As a general rule, landfills should be used only for the disposal of treated hazardous waste residuals. The wastes in Table 6 should be landfilled only after the designated appropriate treatments.

Table 6 Landfill acceptance criteria

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid</td>
<td>Only after solidification</td>
</tr>
<tr>
<td>Flammable</td>
<td>Only after being made non-flammable through proper treatment</td>
</tr>
<tr>
<td>Reactive</td>
<td>Only after being made non-reactive through proper treatment</td>
</tr>
<tr>
<td>Toxic</td>
<td>Only after toxicity has been reduced to an environmentally compatible level</td>
</tr>
</tbody>
</table>

In many European countries organic hazardous waste must always be incinerated. Many European countries dispose of only inorganic waste to landfills even then, only after treatment.

5.3.3 Siting Characteristics

In selecting a site for the construction of a hazardous waste landfill, several geographical and hydrological factors will have a significant bearing on the level of environmental protection provided by the landfill. Geographical and hydrological factors of a site will also influence the design of the landfill, including the type of liner system, drainage network, and groundwater monitors installed.

In addition, the degree of urbanisation and its proximity to a landfill site should be considered. When an urban centre is near, extra effort must be taken to reduce any social disturbances the landfill may impose. Such disturbances include impacts on the landscape and sewage systems, noise levels, odour levels, and traffic patterns. Also great care must be taken in developing an emergency procedure plan in the event of a gas leak or other accident.

5.3.3.1 Hydrological Characteristics

All potable water supply points, and distances between these points, in the area surrounding a landfill should be identified. The landfill must be located far enough away from these sources so that in the event of an accident and contamination, there will be enough time to provide warning and alternative drinking water supplies to communities that rely on the contaminated water aquifer.

The surface hydrology of an area should also be considered, so as to avoid areas prone to flooding or susceptible to erosion. In considering flooding, 100 years return rate is recommended as a minimum.
In studying the hydrology of an area, seasonal variations in water table depth, and the table’s maximum historical height, must be determined. The depth of a landfill bottom must be placed some meters above the maximum water table increase.

5.3.3.2 Geographical Characteristics

The most important geographical factor involved in choosing a landfill site is the stability of the area. The morphology of a location also must be carefully considered.

Depending on geographical and morphological factors, three different types of landfills are generally constructed: superficial, depression, and slope. In addition, underground structures located in lithologically stable areas are sometimes used for the disposal of highly toxic stable wastes.

Figure 15: Hazardous waste landfill Klintholm, Denmark
Superficial landfills may be constructed when the water table is near the ground surface. If the soil is soft clay, or otherwise cohesive, the foundation of the landfill must be built so as to ensure its stability. If the foundation is not stable, and wastes are rapidly accumulated, a rotational slip may occur.

Gullies or abandoned quarries are natural locations for the construction of a depressed landfill. It may be necessary, however, to reinforce excavation walls so as to prevent landslides.

In choosing to construct a slope landfill, the stability of the slope, the surface foundation, and the mass of the waste itself must be considered. Particularly for slope landfills, it should be noted that the primary cause of a landslide is related to the seepage of water. When positioned close to the slope, a landfill may alter the natural flow of nearby surface waters. It is therefore important that intensity, average amounts of rainfall, and the capacity of natural drainage networks, all based upon a ten year cycle, be considered.

Underground storage structures such as caverns, salt formations or deep wells, likewise must be located in lithologically stable areas. Their use must be carefully evaluated for their economic benefit, as well as for their long-term stability.

5.3.4 Liner Systems

After a landfill site has been selected, a system to line the landfill must be chosen. Increasingly, double and sometimes even triple liner systems are being selected.

The liner system is key to achieving the goal of landfill management to insulate and prevent toxic and other hazardous compounds from being released beyond the confines of the landfill into the environment.
An interpretative logical scheme of the physical phenomenon of pollution is provided by Darcy’s Law: \( Q = K i s \). In this scheme: \( Q \) equals the flow passing through a porous medium, \( K \) equals the permeability coefficient, \( i \) equals the hydraulic gradient, and \( s \) equals the surface controlled by the flow.

To avoid the release of polluted compounds, it is necessary to minimise \( Q \), as well as to reduce the other elements of Darcy’s Law.

To minimise the permeability coefficient the two elements composing the coefficient itself must be minimised. These two elements are the soil underlying the landfill structure, and the liner system imposed between the wastes and the soil. A reduction in the hydraulic gradient can be obtained by reducing the hydraulic head through the drainage system, increasing the thickness of the liner so as to reduce its permeability.

The surface expansion of a landfill can be reduced by increasing its depth and modifying its geometric shape correspondingly. The liner system is of critical importance in landfill design because as Darcy’s Law demonstrates, it directly impacts the landfill’s permeability (\( K \)), the hydraulic gradient (\( i \)), and the flow of contaminants from the landfill into the environment (\( Q \)).

Basic conditions in choosing a liner for a landfill structure are:

- The efficiency of the liner material should be such that it maintains its permeability (\( K \)) even in the event of a chemical leakage.
- The liner material should be resistant to damages resulting from accidents throughout the life of the landfill, including its construction phase, normal operations, and closure.
- The availability of acceptable materials.

There are several materials commercially available, both synthetic and natural, for use as landfill liner. The materials include a variety of high performance polymers, or geomembranes. To these can be added: bituminous structures, cement, bentonite, and other clay substances. This section on lining systems is concluded with some discussion on each of these materials. In all cases it should be noted that the regardless of whether a liner is composed of synthetic or natural materials, the possibility of its destruction from the seepage of waste contaminants must be investigated prior to installation.
5.3.4.1 Geomembranes

The use of geomembrane liners, consisting of synthetic polymers and rubbers, is on the increase. Their popularity is due to their wide availability, flexibility and other performance qualities. Some of the most widely used polymer and rubber materials for liners include:

- Butyl Rubber (BR)
- Chlorinated Polyethylene (CPE)
- Chlorosulfonate Polyethylene (CSPE)
- Ethylene Propylene Diene Monomer EPDM)
- Polychloroprene (PC)
- Polyethylene Low Density and High Density (LDPE and HDPE)
- Polyvinylchloride (PVC)

The performance of geomembrane liners can be determined by several characteristics:

- The first of these is thickness. The linear relationship between the thickness of a geomembrane liner and its resistance to tears and punctures should be evaluated.

- The second is water resistance. A geomembrane liner should be assessed for its stability, ozone resistance, thermal shrinkage, and resistance to worst case high and low temperatures.

- The third is resistance to biological attack. Organic plasticizers are often used in the manufacture of geomembrane liners. As these plasticizers are susceptible to microbial attacks, the liner’s ability to resist microbes should be determined.

- The fourth is chemical resistance. In addition to plasticizers, other additives may be used in the manufacture of geomembrane liners. The compatibility of these
additives with the chemical compounds present in hazardous wastes must be determined.

The installation of a geomembrane liner requires special handling procedures. For example, a consistently flat wall plate must be prepared. Also, it should be remembered that geomembrane liners are especially prone to damage and must be handled with special care throughout the installation.

Special consideration must also be given to the seaming process used to install a geomembrane liner. As they are laid into the floor of a landfill structure, large sections of geomembrane liners must be seamed together. The process involves a high level of precision, as well as the use of chemical adhesives and sealants. In addition to ensuring precision along the seam lines, the chemical content of the adhesives and sealants should not react negatively with the hazardous wastes to be deposited in the landfill.

There are several advantages to using a geomembrane liner. These include: low permeability, flexibility in layout, improved efficiency for the leachate collection system, fast and wide availability, and overall good chemical resistance.

The disadvantages in using a geomembrane liner include: they are easily damaged during both the construction and day-to-day management operations of a landfill, alone they do not provide a long-term protection, and in the case of a tear there can be considerable leakage.

5.3.4.2 Low Permeability Soils

Clay soils with low permeability have long been a mainstay among the materials used to line landfills. The most suitable clays are cohesive and possess a fine granularity that can reach permeability values on the border of $1 \times 10^{-6}$ up to $1 \times 10^{-8}$ m/sec. Such clays can exist naturally at the landfill, or may be shipped in for use as a liner over naturally occurring high permeability soils.

Laboratory tests are necessary to assure that the permeability values, installation modalities, and thickness of clay are sufficient for use as a landfill liner.

The advantages of low-permeable clay soils, are their resistance to damages caused by management activities, good durability, a tendency to self-seal, good resistance to leakage, and their abundance. The disadvantages of low permeable clay soils include construction difficulties, and their non-homogenous nature, which can reduce their efficiency.

5.3.4.3 Bituminous Soils

When mixed with granular materials, bitumen may be used as a landfill liner. It is necessary to study and test the granulometric curve of the mixture to ensure that a material with low impermeability has been obtained.

The advantages of bituminous soils are: their low permeability ($10^{-8}$ to $10^{-10}$ m/s), good flexibility, and resistance to damages from construction site activity. The disadvantages of bituminous soils are: installation difficulties, particularly among slopes; leakage from unstable components of bitumen; difficulty in providing a foundation with an adequate density; difficulty in assuring chemical resistance, and leakage from the joints of bituminous liners.
5.3.4.4 Lining with Soil Cement

As with bitumen, cement may be used when mixed with fine granular materials. It is also necessary to study and test the granulometric curve of the mixture to ensure that a material with low impermeability has been obtained. In a laboratory, it is possible to reach permeability values for cement mixtures as low as those of bituminous materials ($10^{-8}$ to $10^{-9}$ m/s).

The advantages of cement linings include: its availability, its ease of instalment, and its resistance to damage and leakage. The disadvantages of cement materials are: cracking due to the differential settlement, sensitivity to thermal variations, the joint leakage, and construction difficulties along slopes.

5.3.4.5 Bentonite

Bentonite can be used alone or mixed with sand. When used alone, bentonite requires special support, such as geotextiles or cardboard backings. A bentonite/sand mixture can produce impermeability values equivalent to those of bituminous materials or cement mixtures. Laboratory tests are necessary to ensure values.

The advantages of a sand/bentonite mixture are: its resistance to damage during landfill construction and operation, self-sealing capabilities, and its resistance to leakage. The disadvantages are: its special mixing requirements and installation difficulties along slopes.

5.3.4.6 Double Liner System

Double liner systems are increasingly being used to improve the level of protection provided by a landfill. In fact, it is generally agreed that double liner systems should be installed at all hazardous waste landfills.

Typically, the two liners are constructed of different materials, each of which brings its distinct advantages to the system, while compensating for the disadvantages of the other. Moreover, when two liners are installed and properly monitored, they can be used as an alarm system to alert workers in the event of a leak or failure in the other liner.

Placed above a second lining, the first lining usually consists of a geomembrane material. The second lining is usually one of the soil mixtures described or it may be a second geomembrane. A draining layer separates the two linings. Other barriers, natural or manmade, should be installed to minimise the possibility of environmental dispersion over time.

5.3.5 Leachate and Runoff Management

After liner systems, the drainage network, which is used to collect leachate and rain water runoff, is the second most important component in safe landfill management. Leachate is the liquid material that can drain from the landfill cell where the waste is deposited. A system for collecting leachate must be built into the landfill. Likewise, a treatment system for any leachate collected must be devised.
5.3.6 Closure system

The closure system of a completed landfill usually exhibits the following elements:

- Vegetative cover
- A top substrate (with surface drainage)
- A sealing system
- Gas and leachate drainage
- A levelling layer

The correct design of the surface covering requires the detailed formulation of the tasks to be performed by each element of the closure system. The vegetative cover has three distinct tasks: protection of the covering soil from erosion, maximisation of the evapotranspiration rate, and landscape quality maintenance.

The top substrate protects the sealing system from damage and frost, acting at the same time as root space for the surface vegetation. A drainage system is, in most cases, inserted between the top substrate and the sealing system in order to discharge the seepage water not absorbed by the plant roots.

The primary task of the sealing system is to prevent penetration of seepage water into the body of the landfill, while at the same time preventing the escape of gases. Under the sealing system, gas collection and leachate systems are required in order to collect and remove gas and leachate produced by the landfill. The levelling layer has the function of compensating for irregularities of the waste surface.
When a landfill is designed to store significantly different waste streams with wide ranging characteristics, wastes are stored in distinct and separate sections of the landfill structure, called cells. A drainage network dedicated to each of these cells must also be constructed.

Normally, during the management phase, if the wastes are not loaded simultaneously into the whole area, two different networks are installed: one for leachate and the other for rainfall. When the liner system is constructed with two (or more) liners, it is necessary to install additional drainage networks between the liners.

Each network is connected separately to a leachate-collecting basin. A granular layer of soil or other material underlies the basin. By connecting the network to the leachate collection basin, it can be used to check the efficiency of the liners. The bottom of the basin and leachate collection system must have an adequate slope to prevent leaks.

In cases where there are gas emissions from the sanitary landfills, pipelines to collect gases must also be installed, as well as the necessary treatment apparatus.

5.3.7 Monitoring

Great effort must go towards minimising the environmental risks of a hazardous waste landfill, and the success of these efforts must be evaluated by a monitoring system. The efficacy of a monitoring system lies in its ability to warn about a failure in the liner, drainage network, leachate collection system, or gas monitoring systems, before any harm has been done to the environment or human health.

Temporal diagrams and the use of numerical models facilitate the processing of information on a landfill’s design and may help in the prediction of landfill behaviour. These tools should be used in developing a monitoring system for a landfill.

Monitoring systems should be employed in all phases of landfill operations. Tests can be conducted with lisimeters placed under the landfill surface. Underground waters can be protected by means of monitoring wells with piezometers placed around the landfill in accordance with water flow potentials. In order to compare changes over a period of time, the measurements obtained from monitoring networks must be stored and periodically analysed.

5.3.8 Quality Control Plans

Past experiences sadly demonstrate that hazardous waste landfills operating without basic quality control or long-term post-closure plans are likely to cause enormous environmental damage. Plans, therefore, must be developed and used.

5.3.9 Post-Closure Requirements

The pollution potential of a landfill continues for a long time after closure (30-100 years). The leachate collection and removal system and the closure system must function continuously. In 2 to 5 years after the final cover, leachate production falls to zero, if the closure works properly. The expected leachate value must be estimated in advance.

Consequently, a control plan must include provisions for management activities after the landfill has closed. Likewise, quality assurance controls are very important in defining the area where potential leaks are likely to occur. Such post-closure
provisions include continuous monitoring, development of a response action plan, and emergency procedures.

Basic elements of a quality control plan, which should be established for the sake of accountability, include:

- A good definition of responsibilities for the people involved in the planning, authorisation and construction of the landfill.
- The qualifications of the workers operating the landfill.
- Work inspection modalities.
- Sampling modalities for construction materials.
- Documentation demonstrating that the construction works have been carried out under quality control.
- The preservation of all the information on the quality control of the construction works.
- The documentation of management activities and types of wastes stored.
Appendix 1

WASTE MANAGEMENT (MOVEMENT OF HAZARDOUS WASTE) REGULATIONS, 1998

Form C.I.

Consignment Note for consignments of hazardous waste transported within the State
(NOT to be used for transhipment into or out of the State)

B 0116441

PART A (to be completed by the consigner)

1. Name and address of consignor: ABC Chemicals Limited, Dublin City, Rep. of Ireland

2. Name and chemical composition of waste: Mixed Solvent Waste – Acetone and Hexane

3. European Waste Catalogue/Hazardous Waste List Description(s) and Code(s): 070704*

4. Origin of waste (name and address of producer, if different from 1.): As above

5. Process(es) that waste originates from: Manufacture of chemical products

6. Quantity (indicate kg or litres): 24,000 litres approx.

7. Size, type and number of containers: 27,000l x 8 x 1

8. Physical characteristics: 5

9. Components which are hazardous (giving concentrations in each case): 75% Acetone, 25% Hexane

10. Hazardous properties and special handling instruction (if any): Highly Flammable – See TRIPS CARD

11. Name and address of consignee: MinChem Environmental Services Limited, Tolka Quay Road, Dublin Port

12. I, the consignor, certify that the information given in Part A above is complete and correct to the best of my knowledge.

Signed: John Jones

Date: 01/02/03

Name (block letters): John Jones

Position held by person signing: Environmental Officer

on behalf of: ABC Chemicals Limited

PART B (to be completed by the carrier)

13. I, the carrier,* certify that I collected the waste described in Part A in vehicle (reg. no.) 02022456... at (time) 3pm... on (date) 01/02/03 and that I have been informed of the hazardous nature of the waste, as set out in that Part.

Signed: Mark Smith

Name (Block Letters): Mark Smith

Signature of consignor as witness: John Jones

on behalf of: Waste Haulage Limited

PART C (to be completed by the consignee)

14. Name and address of consignee: MinChem Environmental Services Limited, Tolka Quay Road, Dublin Port

15. Waste licence number (if applicable): 36-1

Waste permit number (if applicable): N/A

Certificate of registration (if applicable): N/A

16. The waste described in Part A was delivered to me by (carrier) Waste Haulage Limited in vehicle (reg.no.) 02022456... at (time) 12pm... on (date) 01/02/03... on behalf of (consignor) ABC Chemicals Limited

17. (a) The consignment was accepted: Yes

(b) The consignment was rejected: N/A

18. If the consignment of waste was rejected, state the reason(s): N/A

19. If the consignment of waste was accepted, state the recovery/disposal activity(ies) to which it will be subject and provide code number and description of the technology involved:

DIO Incineration on land

20. I, the consignee, certify that the information given in Part C above is complete and correct to the best of my knowledge.

Signed: Mary Murphy

Date: 01/02/03

Name (block letters): Mary Murphy

Position held by person signing: Site Operations Administrator

on behalf of: MinChem Environmental Services Limited

Footnotes 1 to 11 see relevant definitions and lists in the "Instructions for completion of Consignment notes for Hazardous Waste".

CARRIER’S COPY - to be given to the carrier of the waste, after completion of PART C by the consignee, and retained by the carrier.
## Appendix 2

<table>
<thead>
<tr>
<th>Use accessories/special equipment</th>
<th>technical data</th>
</tr>
</thead>
</table>
| **lidless container for skip-handler**
5, 7 and 10 cbm | Demolition waste, construction and demolition waste, garden and park waste, mixed waste for recycling, wood, metal scrap, paper and cardboard |
| **container for skip-handler with lid**
5, 7 and 10 cbm | Demolition waste, construction and demolition waste, garden and park waste, mixed waste for recycling, wood, metal scrap, paper and cardboard with lockable lid possible |
| **Roll-off-flat bed container**
6, 8 and 12 cbm | Demolition waste, construction and demolition waste, garden and park waste, glass, wood, metal scrap |
| **Roll-off-container**
16, 20, 24, 30 and 36 cbm | Construction and demolition waste, discarded electrical and electronic equipment, garden and park waste, mixed waste for recycling, wood, metal scrap, paper and cardboard |

### 5 cbm Container
- Volume: 5 cbm · altitude: 1.300 mm
- width: 1.900 mm · depth: 3.200 mm
- altitude sill: 600 mm

### 7 cbm Container
- Volume: 7 cbm · altitude: 1.420 mm
- width: 1.600 mm · depth: 3.666 mm
- altitude sill: 400 mm

### 10 cbm Container
- Volume: 10 cbm · altitude: 1.820 mm
- width: 1.600 mm · depth: 4.145 mm
- altitude sill: 1.240 mm

### 6 cbm flat bed container
- Volume: 6 cbm · altitude: 500 mm
- width: 2.300 mm · depth: 5.250 mm

### 8 cbm flat bed-container
- Volume: 8 cbm · altitude: 500 mm
- width: 2.300 mm · depth: 7.000 mm

### 12 cbm flat bed-container
- Volume: 12 cbm · altitude: 750 mm
- width: 2.300 mm · depth: 7.000 mm

### 16 cbm container
- Volume: 16 cbm · altitude: 1.000 mm
- width: 2.300 mm · depth: 7.000 mm

### 20 cbm container
- Volume: 20 cbm · altitude: 1.350 mm
- width: 2.300 mm · depth: 7.000 mm

### 30 cbm container
- Volume: 30 cbm · altitude: 2.000 mm
- width: 2.300 mm · depth: 6.500 mm

### 36 cbm container
- Volume: 36 cbm · altitude: 2.250 mm
- width: 2.300 mm · depth: 7.000 mm
<table>
<thead>
<tr>
<th><strong>Use accessories/special equipment</strong></th>
<th><strong>technical data</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canister / Can</strong>&lt;br&gt;10, 25, 30 and 60 litre</td>
<td><strong>Canister 10 litre</strong>&lt;br&gt;Volume: 10 litre - altitude: 318 mm width: 194 mm - depth: 231 mm</td>
</tr>
<tr>
<td></td>
<td><strong>Canister 25 litre</strong>&lt;br&gt;Volume: 25 litre - altitude: 350 mm width: 280 mm - depth: 375 mm</td>
</tr>
<tr>
<td></td>
<td><strong>Canister 30 litre</strong>&lt;br&gt;Volume: 30 litre - altitude: 388 mm width: 285 mm - depth: 375 mm</td>
</tr>
<tr>
<td></td>
<td><strong>Canister 60 litre</strong>&lt;br&gt;Volume: 60 litre - altitude: 630 mm width: 334 mm - depth: 398 mm</td>
</tr>
<tr>
<td></td>
<td><strong>Barrel with locking ring lid</strong>&lt;br&gt;30, 60 and 120 litre</td>
</tr>
<tr>
<td></td>
<td><strong>Barrel with locking ring lid 60 litre</strong>&lt;br&gt;Volume: 60 litre - altitude: 628 mm</td>
</tr>
<tr>
<td></td>
<td><strong>Barrel with locking ring lid 120 litre</strong>&lt;br&gt;Volume: 120 litre - altitude: 800 mm</td>
</tr>
<tr>
<td><strong>Barrel with bunghole, metal/plastic</strong>&lt;br&gt;30 and 60 litre</td>
<td><strong>Barrel with bunghole 30 litre</strong>&lt;br&gt;Volume: 30 litre - altitude: 570 mm diameter: 280 mm - weight: 3,3 kg</td>
</tr>
<tr>
<td></td>
<td><strong>Barrel with bunghole 60 litre</strong>&lt;br&gt;Volume: 60 litre - altitude: 690 mm diameter: 350 mm - weight: 5,2 kg</td>
</tr>
<tr>
<td><strong>Barrel with bunghole metal (blue)</strong>&lt;br&gt;Barrel with locking ring lid metal (yellow)&lt;br&gt;200 litre</td>
<td><strong>Barrel with bunghole (blue)</strong>&lt;br&gt;for neutral liquids, for example brake fluids and cooling-water, oil, solvent&lt;br&gt;Barrel with locking ring lid (yellow), for pasty and solid waste, for example operating materials with oil, PER</td>
</tr>
<tr>
<td></td>
<td><strong>Volume: 200 litre</strong>&lt;br&gt;altitude: 890 mm diameter: 600 mm weight: 20 kg</td>
</tr>
<tr>
<td>Use accessories/special equipment</td>
<td>technical data</td>
</tr>
<tr>
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</tr>
<tr>
<td><strong>Tank for liquid hazardous waste</strong>&lt;br&gt; 250, 450, 540 and 1.000 litre</td>
<td><strong>ASB 250</strong>&lt;br&gt;Volume: 250 litre - altitude: 890 mm width: 715 mm - depth: 715 mm</td>
</tr>
<tr>
<td><strong>Burnable liquids at flashpoint &lt; 21°C, also for storage</strong></td>
<td><strong>ASB 450</strong>&lt;br&gt;Volume: 450 litre - altitude: 820 mm width: 1.200 mm - depth: 1.000 mm</td>
</tr>
<tr>
<td><strong>ASK 540</strong>&lt;br&gt;for acids and bases, for example fixer and developer solutions</td>
<td><strong>ASK 540</strong>&lt;br&gt;Volume: 540 mm - altitude: 1.245 mm width: 1.200 mm - depth: 1.000 mm</td>
</tr>
<tr>
<td><strong>ASF 1.000</strong>&lt;br&gt;for neutral liquids, for example brake fluids and cooling-water, solvent, oil</td>
<td><strong>ASF 1.000</strong>&lt;br&gt;Volume: 1.000 mm - altitude: 1.340 mm width: 1.200 mm - depth: 1.000 mm</td>
</tr>
<tr>
<td><strong>Container for solid and pasty hazardous waste</strong>&lt;br&gt; 445 and 800 litre</td>
<td><strong>ASP 445</strong>&lt;br&gt;Volume: 445 litre - altitude: 830 mm width: 1.000 mm - depth: 1.200 mm</td>
</tr>
<tr>
<td><strong>Solid and pasty hazardous waste, for example lubricating oils, oil filters, not wrapped and in barrels</strong></td>
<td><strong>ASP 800</strong>&lt;br&gt;Volume: 800 litre - altitude: 1.235 mm width: 1.000 mm - depth: 1.200 mm</td>
</tr>
<tr>
<td><strong>Container for accumulators</strong>&lt;br&gt; 600 litre</td>
<td><strong>ASP 600</strong>&lt;br&gt;Volume: 600 litre - altitude: 1.055 mm width: 1.000 mm - depth: 1.200 mm</td>
</tr>
<tr>
<td><strong>Accumulators (containing acid)</strong></td>
<td><strong>SAT-Box</strong>&lt;br&gt;Capacity: zirka 800 fluorescent tubes altitude: 1.030 mm width: 770 mm depth: 2.070 mm</td>
</tr>
<tr>
<td><strong>Special box for fluorescent tubes</strong></td>
<td><strong>fluorescent tubes</strong></td>
</tr>
<tr>
<td>Use accessories/special equipment</td>
<td>technical data</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------</td>
</tr>
</tbody>
</table>
| **Bin for hospital-specific waste**  
30 and 50 litre                      | Volume: 30 litre · altitude: 380 mm  
width: 335 mm · depth: 380 mm       |
|                                   | Volume: 60 litre · altitude: 380 mm  
width: 380 mm · depth: 480 mm       |
| **Vehicle for collecting hazardous waste** | Vehicle equipment  
ASP-, ASF-Container, Barrel with locking ring lid  
(qualified team workers and technical equipment according to TRGS 520) |
| **Vacuum Tanker**  
Emptying of tank and separator      | Volume: 1 cbm  
Demolition waste, construction and demolition waste, plastic film/waste packaging, styrofoam |
| **Big Bags**                       | Volume: 26,000 litre, Testing pressure: 4,0 bar, total weight: 32,000 kg, Gardner-Denver-Wittig-Pump, sucking-capacity: 1,180 m³/h |
Appendix 3

Recommended Treatments

Recent developments in some countries indicate that the instructions and regulations will be set up to ensure certain safe treatment methods for different types of wastes.

The following lists provide proposals and recommendations for these various hazardous waste treatments. Generally, the recommendation is to recover as much as possible, and to pretreat and treat with the maximum use of valuable components. For instance, the energy component in thermal treatment can be used to produce electricity. Final disposal must be minimised and used only for nonreactive inorganics. In the lists that follow, the recommended types of treatments are described utilising the following numbers:

1) Chemical/physical treatment (including recovery and solidification)
2) Domestic waste incineration (small amounts of hazardous waste (HW))
3) Special HW incineration (1000-1200°C)
4) HW landfilling
5) HW landfilling one type of waste only (mono)
6) HW storage in mines or caves under special stringent conditions
7) Co-incineration

Sometimes more than one type of treatment is possible. If so, this is indicated. Types of waste are categorised into groups A-I. Codisposal with household waste, lagooning, sea incineration, and dumping into the sea, are not recommended. These lists will need to be adjusted and extended from time to time.
<table>
<thead>
<tr>
<th>Type of waste</th>
<th>Generation</th>
<th>Type of Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Wastes of plant and animal origin</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensate from tobacco fume</td>
<td>tobacco research</td>
<td>3</td>
</tr>
<tr>
<td>Washing water from food tanks</td>
<td>tank cleaning</td>
<td>1/3</td>
</tr>
<tr>
<td>Grease residue</td>
<td>wire production</td>
<td>3/7</td>
</tr>
<tr>
<td>Acid fat residue</td>
<td>food and soap production</td>
<td>3/7</td>
</tr>
<tr>
<td>Animal Excrements, infectious</td>
<td>test animal institutes</td>
<td>3</td>
</tr>
<tr>
<td>Sludge from tanning</td>
<td>tannery</td>
<td>1</td>
</tr>
<tr>
<td>Oily sawdust</td>
<td>from oil accident emergency</td>
<td>2/3/7</td>
</tr>
<tr>
<td>Contaminated wood packagings</td>
<td>various trade branches (non-halogenated)</td>
<td>2/3</td>
</tr>
<tr>
<td>Contaminated paper packagings</td>
<td>various trade branches (non-halogenated)</td>
<td>2/3</td>
</tr>
<tr>
<td>Contaminated filter papers</td>
<td>filtration, air and gas cleaning, chemical industry</td>
<td>2/3</td>
</tr>
<tr>
<td>Type of waste</td>
<td>Generation</td>
<td>Type of Treatment</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>B. Wastes of mineral origin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broken furnaces</td>
<td>metal production, casting</td>
<td>4/5</td>
</tr>
<tr>
<td>Slag from nonferrous metal melting</td>
<td>nonferrous metal production, casting</td>
<td>4/5</td>
</tr>
<tr>
<td>Dross from lead</td>
<td>lead casting, printing</td>
<td>1 + 4</td>
</tr>
<tr>
<td>Dross from Al or Mg</td>
<td>Al and Mg production, casting, melting</td>
<td>1 + 6</td>
</tr>
<tr>
<td>Salt slag with Al or Mg</td>
<td>melting of Al and Mg</td>
<td>1 + 6</td>
</tr>
<tr>
<td>Zinc slag</td>
<td>zinc production</td>
<td>4</td>
</tr>
<tr>
<td>Ashes with lead</td>
<td>lead production</td>
<td>1 + 4</td>
</tr>
<tr>
<td>Slag from electric furnace</td>
<td>metal production</td>
<td>5</td>
</tr>
<tr>
<td>Fly ash</td>
<td>municipal or sewage sludge incinerator</td>
<td>1 + 4/5</td>
</tr>
<tr>
<td>Fly ash</td>
<td>hazardous waste incinerator</td>
<td>1 + 4/5</td>
</tr>
<tr>
<td>Solid flue gas cleaning product</td>
<td>municipal incinerator</td>
<td>4/6</td>
</tr>
<tr>
<td>Solid flue gas cleaning product</td>
<td>hazardous waste incinerator</td>
<td>6</td>
</tr>
<tr>
<td>Oil contaminated soil</td>
<td>from oil accident emergency</td>
<td>1/3/4</td>
</tr>
<tr>
<td>Moulding sand</td>
<td>foundry</td>
<td>5</td>
</tr>
<tr>
<td>Asbestos dust</td>
<td>asbestos shops</td>
<td>1/4</td>
</tr>
<tr>
<td>Sandblasting dust</td>
<td>sandblasting units</td>
<td>4/5</td>
</tr>
<tr>
<td>Type of waste</td>
<td>Generation</td>
<td>Type of Treatment</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td><strong>B. Wastes of mineral origin</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicic acid residue</td>
<td>ceramic and chemical industry</td>
<td>3/4</td>
</tr>
<tr>
<td>Gypsum sludge</td>
<td>neutralization, flue gas cleaning</td>
<td>1 + 5*</td>
</tr>
<tr>
<td>Calciumphosphate sludge</td>
<td>chemical industry</td>
<td>1 + 5*</td>
</tr>
<tr>
<td>Cyanidic sludge</td>
<td>heat treating shops</td>
<td>1 + 6*</td>
</tr>
<tr>
<td>Sludge from precipitation and diluting processes</td>
<td>chemical and metal industries</td>
<td>1 + 4*</td>
</tr>
<tr>
<td>Lead residue</td>
<td>lead production, casting, printing, electronic industry</td>
<td>1 + 4</td>
</tr>
<tr>
<td>Residue with beryllium</td>
<td>beryllium processing</td>
<td>6</td>
</tr>
<tr>
<td>Used batteries with mercury</td>
<td>production, trade, user</td>
<td>6</td>
</tr>
</tbody>
</table>

* = dewatering or drying
<table>
<thead>
<tr>
<th>Type of waste</th>
<th>Generation</th>
<th>Type of Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Oxides, hydroxides, and salts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyanidic sludge</td>
<td>galvanic shops</td>
<td>1 + 4/5</td>
</tr>
<tr>
<td>Galvanic sludge with Cr IV, Cr III, Cu, Zn, Cd, Ni, Co, or other metals</td>
<td>galvanic shops</td>
<td>1 + 4/5</td>
</tr>
<tr>
<td>Salts from slaughtering and from tanning</td>
<td>slaughtering, tannery</td>
<td>6</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>trade, user</td>
<td>6</td>
</tr>
<tr>
<td>Ammonium chloride</td>
<td>chemical industry</td>
<td>6</td>
</tr>
<tr>
<td>Arsenic calcium</td>
<td>nonferrous metal production</td>
<td>6</td>
</tr>
<tr>
<td>Sodiumbromide</td>
<td>photochemical industry</td>
<td>6</td>
</tr>
<tr>
<td>Salts with cyanids, nitrites and nitrates</td>
<td>chemical industry, heat, treating shops</td>
<td>6</td>
</tr>
<tr>
<td>Salt rubble</td>
<td>mining</td>
<td>6</td>
</tr>
<tr>
<td>Arsenics</td>
<td>chemical and ceramic industries</td>
<td>6</td>
</tr>
<tr>
<td>Type of waste</td>
<td>Generation</td>
<td>Type of Treatment</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td><strong>D. Acids, caustics and concentrates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids from batteries</td>
<td>cars, scrap industry</td>
<td>1</td>
</tr>
<tr>
<td>Mixed inorganic acids</td>
<td>plating, galvanics, laboratories</td>
<td>1</td>
</tr>
<tr>
<td>Organic acids with halogens</td>
<td>chemical and pharmaceutical industry plating, galvanics</td>
<td>3</td>
</tr>
<tr>
<td>Caustics, mixed caustics</td>
<td>chemical industry</td>
<td>1</td>
</tr>
<tr>
<td>Diluted ammonium</td>
<td>copy shops</td>
<td>1</td>
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<tr>
<td>Caustic hypochlorite</td>
<td>pulp industry, textile industry, bleaching</td>
<td>1</td>
</tr>
<tr>
<td>Fixation solvents</td>
<td>photochemical shops, laboratories, printing</td>
<td>1/3</td>
</tr>
<tr>
<td>Caustic sulfite</td>
<td>pulp industry</td>
<td>3</td>
</tr>
<tr>
<td>Cyanidic concentrates</td>
<td>plating</td>
<td>1</td>
</tr>
<tr>
<td>Developing liquids</td>
<td>photochemical shops, printing</td>
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</tr>
<tr>
<td>Type of waste</td>
<td>Generation</td>
<td>Type of Treatment</td>
</tr>
<tr>
<td>-----------------------------------</td>
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<td>E. Hazardous Chemicals</td>
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<tr>
<td>Unused herbicides and pesticides</td>
<td>chemical industry, trade, user</td>
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<td>Residue from herbicide and pesticide production</td>
<td>chemical industry</td>
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<td>Cosmetic residues</td>
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<td>Disinfectants</td>
<td>chemical industry, hospital, farming</td>
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<td>Type of waste</td>
<td>Generation</td>
<td>Type of Treatment</td>
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<tr>
<td><strong>F. Waste from mineral oils and synthetic oil</strong></td>
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<tr>
<td>Oil preparing</td>
<td>textile and chemical filter industry</td>
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<td>Waste oil</td>
<td>gasoline stations</td>
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<td>Contaminated gasoline</td>
<td>tank storage</td>
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<td>Oil with PCB</td>
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<td>Contaminated diesel oil</td>
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<td>PCB contaminated waste</td>
<td>transformer / condensator production</td>
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<td>Fat from mineral oil</td>
<td>chemical industry</td>
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<td>Metal soaps</td>
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<td>Oil emulsions</td>
<td>metal works</td>
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<td>Synthetic grease and cooling</td>
<td>metal works</td>
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<td>Bitumen emulsion</td>
<td>chemical industry, construction material</td>
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<td>Sludge from oil and gasoline skimming</td>
<td>service stations, car maintenance shops</td>
<td>1 + 3/7</td>
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<td>Sludge from tank cleaning</td>
<td>tank and barrel cleaning, ships</td>
<td>1 + 3/7</td>
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<td>Oily sludge from grinding</td>
<td>metal polishing</td>
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<td>Acid tar from oil refining</td>
<td>waste oil and grease oil refining</td>
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<td>Type of waste</td>
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<td>F. <strong>Waste from mineral oils and synthetic oil</strong></td>
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<td>Oily acids</td>
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<td>Oily water</td>
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<td>Sludge with phenols</td>
<td>gas works, chemical industry</td>
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<td>Solid naphtalins</td>
<td>gas works, chemical industry</td>
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<td>Solid phenols</td>
<td>gas works, chemical industry</td>
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<td>Tar</td>
<td>gas works, chemical industry</td>
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<td>Sludge with cyanids</td>
<td>gas works</td>
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<td>Type of waste</td>
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<td><strong>G. Waste solvents, paintings, adhesives</strong></td>
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<tr>
<td>Chloroform</td>
<td>chemical industry</td>
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<td>Chlorobenzene</td>
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<td>Fluorochlorohydro-carbons</td>
<td>chemical industry</td>
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<td>Trichloroethylene</td>
<td>chemical industry, textile, dry cleaning</td>
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<td>Mixed solvents with halogens</td>
<td>petrochemical industry</td>
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<td>Solvents mixed with water</td>
<td>chemical industry, dry cleaning</td>
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<td>Acetone</td>
<td>chemical industry, painting production</td>
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<td>Benzene</td>
<td>surface cleaning, metal industry</td>
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<td>Gasoline</td>
<td>surface cleaning, metal industry, gas works</td>
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<td>Solvents for paintings</td>
<td>painting production, surface cleaning, textile industry, plastic works</td>
<td>1/3/7</td>
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<td>Sludge with solvents</td>
<td>chemical and metal industries, surface cleaning</td>
<td>1 + 3/7</td>
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<td>Sludge from painting</td>
<td>painting shops</td>
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<tr>
<td>Fluid lacquer residue</td>
<td>painting shops</td>
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<td>Organic pigments</td>
<td>lacquer production</td>
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<td>G. Waste solvents, paintings, adhesives</td>
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<tr>
<td>Inorganic pigments</td>
<td>lacquer production</td>
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<td>Resin residue</td>
<td>plastic production, lacquer production</td>
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<td>Adhesives</td>
<td>adhesive production</td>
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<td>Contaminated plastic packaging</td>
<td>trade, industry</td>
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<td>Latex sludge</td>
<td>textile industry</td>
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<td>Sludge from rubber with solvents</td>
<td>tyre and rubber industry</td>
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<td><strong>H. Chemicals</strong></td>
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<td>Chemicals from laboratories</td>
<td>chemical industry, laboratories schools, universities</td>
<td>1/3/4/6 depending on quality</td>
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<td>Fluid surfactants</td>
<td>production of washing agents, chemical industry</td>
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<td>Solid surfactants</td>
<td>production of washing agents, chemical industry</td>
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<td>Inorganic distilling residue</td>
<td>redistilling, chemical industry</td>
<td>4/5/6</td>
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<td>Organic distilling residue</td>
<td>redistilling, chemical industry</td>
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<td>PCB's</td>
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<td>Organic peroxides</td>
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<td>Inorganic peroxides</td>
<td>chemical industry, laboratory</td>
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<td>Captured gas</td>
<td>chemical industry, laboratory</td>
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<td>Scrap from electrolytic cells</td>
<td>chemical industry</td>
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<td>Industrial sewage sludge</td>
<td>industrial waste, water cleaning</td>
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<td>Generation</td>
<td>Type of Treatment</td>
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<td><strong>I. Waste from hospitals</strong></td>
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<tr>
<td>Dry infectious waste</td>
<td>hospitals with blood bank, department for infectious disease, microbiology, other medical area</td>
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<tr>
<td>Pathological waste</td>
<td>pathology, other medical area</td>
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</table>
In this report, the ISWA Working Group on Hazardous Wastes sets up guidance on how to structure the technical components of hazardous waste management systems. When setting up a management system ten elements are essential:

1. Appropriate, well-written legislation addressing the supporting components of a hazardous waste management system must exist.
2. The separate responsibilities of waste generators, government officials, and treatment companies must be clearly specified.
3. Sufficient control and supervision of principal participants involved in the system, especially the generators, transporters, collectors, and operators of treatments and disposal facilities, must be in place.
4. Clean manufacturing and recycling technologies must be promoted and utilised.
5. Adequate collection capacity for hazardous wastes must be available.
6. Adequate treatment and disposal capacity must be in place.
7. Regional (International) solutions for small countries, and statewide solutions for larger countries, should be set up.
8. Adequate information must be made available to waste generators and the public concerning safe hazardous waste management practices.
9. Introduction of good and sustainable waste management practices in the operational area, giving priority to waste minimisation and waste recycling, should be promoted.

Chapter 2 is stressing the importance of having a legal and regulatory framework, which means to quantify the hazardous waste volumes, to track hazardous wastes, develop instruments for prevention, economic issues, social issues and political issues.

Chapter 3 deals with the collection and the transportation issues, such as storage and safety rules and guidelines.

Chapter 4 is outlining the way to develop a successful hazardous waste management. It describes the procedures to be taken from the waste enters the plant and to its final treatment.

Chapter 5 is dealing with physical and chemical technologies it contains information on experiences with the various technologies and is also offering a guide to the best solutions.

The Working Group on Hazardous Wastes have previous published a guide for developing countries. This is guide however for all decision makers that needs an overview of the state of the art of handling of hazardous waste.

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