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N° 17

Landfill of Hazardous Industrial Wastes

A Training Manual

With the cooperation of

THE INTERNATIONAL SOLID WASTE & PUBLIC CLEANSING ASSOCIATION (ISWA)

UNEP

Landfill of Hazardous Industrial Wastes

A Training Manual

Technical Report No 17

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This is the 17th publications in a Technical Report Series that regroups the Guidelines, Overviews, Technical Reviews, and Workshop Proceedings previously published by UNEP IE/PAC. The regrouping into a single series will ensure a greater cohesion among future publications, and allows a single document to include the various elements of IE/PAC work that had earlier been presented separately.

As before, the Technical Report Series aims to meet the needs of a wide range of government officials, industry managers, and environmental protection associations, by providing information on the issues and methods of environmental management relevant to various industrial sectors.

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PREFACE

ABOUT THIS MANUAL

1 The best way of learning is by doing. This manual allows the user to explore the complex aspects of hazardous waste landfill by working on practical exercises.

The exercises are based on a case study specifically developed for the manual. The case study is in the form of a national report such as might be prepared for any country around the world.

The entire set of exercises forms a simulation study to solve the industrial landfill problems of a fictitious country, *Udanax*. The problems are drawn from the collective experience in several regions of the world. Of course, other problems not listed in the manual can also be encountered in many places.

The format of this manual follows that of an earlier training initiative on hazardous waste management policies and strategies. This involved a number of training workshops around the world, and the publication of a training manual to allow others to organise similar programmes themselves. An outline of this manual is shown in *Annex VI*.

2 Like the earlier "Policies" manual, this manual has its origins in the practical exercises used during the training workshops organised by UNEP IE/PAC.

Formal lectures presented the factual information needed for the casework tasks, country reports explored the particular circumstances in developing countries, and field visits demonstrated the practical aspects of what had up to then been theory.

The deliberate ambiguity in some exercises, and in background data, allows considerable freedom of discussion. It also requires careful guidance from expert session leaders.

Accordingly, some parts of this manual will not be appropriate for individual study.

Nevertheless the individual will find many parts of the manual rewarding and challenging.

3 As presently structured the manual serves best as a resource book for the professional trainer. Exercises can be selected, adapted and grouped into a package for either short or long courses on hazardous waste management. In its entirety the manual would suit a curriculum extending over several semesters.

4 Many exercises require technical information as input. Some of this is given in the tables and figures of the manual itself. In a few cases the references will need to be consulted.

As far a possible the manual has been designed to stand by itself, although previous technical training is of course necessary to understand the behaviour of wastes, the functioning of treatment plants, engineering aspects of landfills etc.

There are no "right" answers to the exercises. The purpose of the manual is to provide insight into the methodology and constraints of hazardous waste landfill, not to turn out a numerical answer according to pre-determined rules.

Accordingly it serves best as a component in a more comprehensive training curriculum. This is the way it is being used by UNEP itself.

5 The present version of the manual has been compiled from diverse inputs. Proper waste management is still a subjective art requiring experience, insight, and adaptability.

Although the technical content has been reviewed by hazardous waste experts, the manual is far from perfect—additional material could be added, the validity of the exercises will be sometimes disputed, the layout could be improved.

No doubt some errors and ambiguities remain in the text. Rather than spend more time on a lengthy review process we have decided to publish it as it is, with an apology in advance for any difficulties the user may find.

Comments, corrections and suggestions received by IE/PAC may find their way into future revised versions.

ABOUT UNEP IE/PAC

UNEP's Industry and Environment Programme Activity Centre (IE/PAC) in Paris was established in 1975 to bring industry, governments and non-government organisations together to work towards environmentally sound forms of industrial development.

IE/PAC seeks to:

- encourage the incorporation of environmental criteria in industrial development,
- formulate and facilitate the implementation of procedures to protect the environment,
- promote the use of safe, low- and non-waste technologies (ie. cleaner production),
- stimulate the exchange of information on environmentally sound industrial development.

One of the priority work areas for IE/PAC is the *Cleaner Production Programme*. Cleaner production is a broad concept that considers and minimises environmental impact from all parts of the product cycle, from conception and design of the product, to economical use of raw materials and energy, through to choice of low-waste manufacturing technologies and its careful operation.

Even with maximum application of these principles, there is often still a need for responsible residue management. Accordingly, IE/PAC has developed parallel activities on information exchange and training in hazardous waste management, including the facilitation of training workshops in all regions of the world. Technical information is produced in support of these workshops.

In pursuing these activities, IE/PAC works closely with other UNEP units, and with other international organisations.

ABOUT UNEP/EETU

EETU is concerned with all aspects of environmental education. EETU promotes the incorporation of environmental subjects into education programmes around the world, as well as fostering more specialised environmental training for professionals.

EETU has played a key role in the preparation of this manual.

ABOUT ISWA

The International Solid Waste and Public Cleansing Association (ISWA) is a worldwide association of professionals concerned with the proper management and disposal of waste.

Within ISWA, the Working Group on Hazardous Waste (WGHW) is concerned with promoting the rational management of hazardous waste. This is carried out through the preparation of special publications and the holding of conferences and seminars. The Working Group has established a Developing Country Programme which works closely with UNEP IE/PAC on matters of training, documentation, and information exchange.

HAZARDOUS WASTE AND THE BASEL CONVENTION

A major recent event in the area of hazardous waste was the coming into force in 1992 of the *Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal.* This Convention seeks to improve the national management of hazardous waste as well as of any transboundary movements that may occur. By outlining a training programme for the national authorities this manual can assist in the implementation of the Convention by signatory countries.

The implementation of the Convention is facilitated and monitored by the Secretariat of the Convention, located in Geneva, Switzerland.

The Secretariat has contributed to this and previous manuals by way of technical advice, and information. The Guidelines in *Annex III* were produced by a technical working group convened by the Secretariat.

Further development of training initiatives and technical guidance on hazardous waste management is available from the Secretariat as well as from IE/PAC.

For further information about the Basel Convention and the activities of the secretariat write to:

Secretariat of the Basel Convention
Palais des Nations
1211 Geneva
Switzerland

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UNEP and ISWA owe a special thanks to Dr.G.Tharun of the CDG–SEAPO (Bangkok) whose ideas on groupwork training were an important early source of inspiration in structuring the IE/PAC training manuals.

A number of the exercises and some of the material are drawn from an ISWA workshop held in Honolulu in September 1989, under the leadership of John Skinner, the then Chairman of ISWA's Working Group on Hazardous Waste.

SETTING THE SCENE

This manual deals with the problems of a fictitious country, ***Udanax***.

Consciousness of hazardous waste and pollution has been growing steadily in Udanax.

However there is still little reliable documentation, and opinion is divided over how serious the issues really are. There have been some attempts by authorities to control pollution, but they have not been systematic, and results have not been satisfactory in all instances.

A recent survey carried out by the National Environmental Bureau reveals that eighty percent of the total hazardous wastes is produced in Udanax City, the country's capital. Industrial activities in Udanax City occur principally in two industrial estates situated in the northern and southern parts of the city. Practically all aqueous toxic wastes are discharged into the municipal sewers or into nearby surface drainage systems. Solid wastes are either dumped in the municipal dumpsite or stored on the producers' premises.

The pollution due to hazardous wastes has already had an impact on the local economy and environment. Groundwater aquifers in both industrial estates are polluted, and the Ministry of Health has recommended not to use these sources for drinking water. There is surface water and coastal pollution in some parts of the city due to municipal dumpsites.

Concerned about the degree of hazard posed by hazardous industrial wastes, Udanax City Council has recently reviewed the current status of hazardous waste management, and proposed a set of technical and administrative measures to rectify the present situation.

Although other measures are also proposed, the Council considers that a part of the current waste stream needs to be disposed of in a landfill site.

Following the review, a Task Force was created to carry out a detailed investigation on landfill disposal options, and prepare technical and administrative guidelines for hazardous waste landfilling. This work is proceeding in several stages:

i) identification of hazardous waste to be landfilled
ii) site selection and EIA
iii) engineering aspects of landfill
iv) operation and management of landfills
v) administrative procedures for landfills
vi) eventual landfill closure and site rehabilitation

As a new landfill site is still some years off, the Task Force is also considering what intermediate temporary measures can be taken to reduce the risk from industrial wastes at existing dumpsites.

In order to better review the situation in Udanax, the Task Force commissioned the National Research Institute to prepare a country report of important background information. The Task Force will ultimately publish its final conclusions for public review.

This manual will simulate the work of the Task Force and its expert working groups.

PART I

Background Materials and References

WORKING DEFINITIONS IN HAZARDOUS WASTE MANAGEMENT AND LANDFILL DISPOSAL USED IN THIS MANUAL

Absorptive capacity: The maximum amount of liquid taken up and retained by unit weight of solid in a landfill before leachate is produced.

Audit: A systematic check of relevant aspects of an operation. Audits may include energy, wastes, or a full environmental audit of all matters that influence environmental performance.

Attenuate and disperse: Landfills which allow the migration of leachate and where conversion of the polluting species within the leachate takes place mainly in the strata beneath or around the site.

Biological treatment: A method of wastewater treatment in which bacterial or biochemical action is intensified to stabilise and oxidise the unstable organic matter.

Capping: The covering of a landfill with low permeability material to minimise the infiltration of rainfall, to control gas migration and to provide a base for the site's restoration.

Chemical fixation: A process whereby waste is bonded chemically to a stable inert matrix.

Chemical treatment: Any water or wastewater treatment process involving the addition of chemicals to obtain a desired result such as precipitation, coagulation, flocculation, sludge conditioning, disinfection or odour control.

Cleaner production: A concept of industrial production which minimises all environmental impacts through careful management of resources use, of product design and use, systematic waste avoidance and management of residuals, safe working practices, and industrial safety.

Cleaner technologies: Production processes or equipment with a low rate of waste production. Treatment or recycling plants are not classed as clean technologies.

Co-disposal: The disposal of limited amount of certain hazardous wastes (solid and liquid) with household and similar waste in such a way that the final deposit has an environmental impact no worse than that resulting from the disposal of household waste alone.

Containment site: Landfill site where the rate of release of leachate into the environment is extremely low. Polluting components in waste are retained within such landfills to allow biodegradation and attenuating process to occur.

Corrosive: Ability to damage or destroy organic tissues or other materials by chemical action.

Cover: Material used to cover wastes deposited in landfills. *Intermediate* cover is used to cover each lift or layer at the end of the working day. *Final* cover is the layer, or layers of materials placed on the surface of the landfill prior to its restoration.

Disposal: The discharge of deposit of waste into the environment, or the complete destruction of waste without residue.

Disposal facility: A plant or structure used for the destruction, removal and disposal of waste materials. Recycling plants are sometimes included under this definition.

Dump: An uncontrolled disposal site where no attention is given to safety or environmental factors.

Effluent: Any liquid waste discharged through pipelines from industrial or municipal sources

Environment: The physical factors of the surroundings of human beings including the land, water, atmosphere, climate, sound, odours, tastes; the biological factors of animals and plants and the social factor of aesthetics, and the relationship among them.

Flammable liquids: Liquids with a flash-point below 61°C when determined by the methods designated by the Institute of Petroleum, England.

Hazardous: Harmful or dangerous.

Hazardous waste: Any waste containing significant quantities of a substance which may present danger:

(i) to the life or health of living organisms when released into the environment.

(ii) to the safety of humans or equipment in disposal plants if incorrectly handled.

Hazardous properties include toxic, carcinogenic, mutagenic or teratogenic characteristics, as well as flammability, chemical reactivity or other biologically damaging properties (including radioactivity).

Incineration: Combustion or controlled burning of volatile organic matter in sludge and solid waste which reduces the volume of the material while producing heat, dry inorganic ash, and gaseous emission.

Inert waste: Waste for which the environmental impact of deposit is not greater than that of topsoil.

Landfill: A controlled site for disposal of wastes on land, run in accordance with safety and environmental requirements laid down by a regulatory authority.

Leachate: Liquid which has percolated through or drained from waste material and which contains soluble components of the waste.

Management: Effective control of activities involving waste materials. Cradle-to-grave management involves the supervision of all phases in the life cycle of a waste material.

Manifest: A certificate or trip-ticket, usually comprising multiple copies, which accompanies a load of transported waste so as to verify that it has reached its intended destination.

Minimisation: Actions to avoid, reduce or in other ways diminish the volume or the hazards of waste at their source. Recycling is, strictly speaking, not a minimisation technique, but is often included in such programmes for practical reasons.

Monitoring: A continuous or regular periodic check to determine the environmental impact of waste facilities or to ensure compliance with site licence conditions.

Mono-disposal: A landfill operation where only one type of waste is deposited.

Multi-disposal: A landfill operation where number of types of wastes are deposited together but without deliberate aim of reacting them together.

Municipal wastes: The combined residential and commercial wastes generated in a given municipal area. The collection and disposal of these wastes are usually the responsibility of the local government.

Off-site: Away from the site of production of waste.

On-site: On or adjacent to the site of production of waste.

Pre-treatment: Initial treatment of waste materials to make them safe to handle, or precondition them for subsequent processing or disposal.

Recycling: The retrieval of materials or products either for re-use in their original form or for reprocessing into products of similar composition.

Recovery: The removal of recyclable materials from the waste stream.

Risk: The probability of injury or loss, or of a hazardous event occurring (some definitions include consideration of the magnitude of the event).

Segregation: The physical separation of different consignments or parts of a consignment of waste.

Stabilisation: A general and non-specific term describing a chemical transformation to a more stable, or a less soluble, form.

Toxic substance: Any substance producing a harmful effect on living organisms by physical contact, ingestion or inhalation.

Treatment: A change in the composition or concentration of a waste substances so as to make it less hazardous or to make it acceptable at disposal facilities. Sometimes treatment can result in complete elimination of waste components. It is then also a disposal technique.

Waste: Any matter prescribed to be waste under legislation, any material listed as waste in appropriate schedules, and in general, any surplus or reject material that is no longer useful and which is to be disposed of.

INTRODUCTION TO LANDFILL OF HAZARDOUS INDUSTRIAL WASTE

Control of Hazardous Waste

1. Hazardous waste is now as an important environmental and health issue, but it was not always so. Until recently, many industrial wastes were carelessly dumped without regard to the consequences. In fact, this situation is still common in many places, and workers and the local population around dumpsites continue to be at significant risk.

2. A real assessment of the impact of hazardous waste is difficult to carry out, but we know from personal observation and local information that the environment is suffering, that workers' health is deteriorating, that groundwater is being contaminated, that land resources are being damaged. Both present and future populations are victims of this situation.

3. Many solutions have been proposed to improve the management of hazardous waste. It is now accepted that the best approach is to produce less waste by adopting cleaner production methods in industry, and by minimising wastes wherever possible. If wastes are nevertheless produced, they can often be recycled or reclaimed.

4. Only when the above possibilities have been exhausted should treatment and disposal be considered. Proven, safe methods of disposal need to be selected. Further research may also produce new or cheaper methods of disposal in future.

5. The various components of a hazardous waste strategy are described in a separate manual on *Policies and Strategies for Hazardous Waste Management* (see Ref. 1, p.35). This note will introduce the role of landfill within such a strategy.

The Role of Landfill

6. Even with effective waste reduction programmes and an integrated system of treatment facilities, there will remain some wastes for which landfill (under controlled conditions) is the only feasible disposal option. Safe landfill will always be an important part of a waste management strategy. Where comprehensive facilities do not yet exist, the role of controlled landfill will be proportionally greater as an interim method. The role of landfill will diminish as a complete strategy is gradually put into place and implemented.

7. If we have to use landfill, we must learn how to do it well. We must be clear about the circumstances and the wastes for which landfill is really necessary, when to carry out pre-treatment, and when to recommend other methods of disposal.

8. When we use landfill we must carry it out safely, and in the right place. As buried wastes remain in place for a long time, we must know what to do with a site after it is closed.

9. Landfill will often be used as a temporary disposal measure while other waste management measures are being implemented. The objectives and priorities of temporary landfill operations are somewhat different to those recommended for permanent installations. A high level of safety and performance must of course be maintained, but some changes to administrative requirements and legal constraints may be necessary.

10. Whatever the circumstances, we should always consider how landfill plays its part in a larger hazardous waste programme, and not as an isolated operation run for short-term expediency. Such a clear view is necessary by both the regulatory authorities and the site management.

Management Elements for Hazardous Waste Landfill

11. The correct identification of industrial waste is an important first step in a landfill disposal plan. Identification requires knowledge of the source of the waste and its chemical composition, including any trace constituents in supposedly 'non-hazardous' wastes. Identification can be based on chemical analysis of incoming wastes. Past experience shows that the same industrial process around the world usually produces similar waste types. Identification of process origin thus already gives much of the information for early management decisions.

12. A practical waste classification system is at the heart of the identification procedure. The classification system should be in accordance with established criteria of chemical characteristics of waste, its process origins, and its hazard properties. These criteria are elaborated in various national and international reference documents. The *Basel Convention*, for example, lists the waste characteristics and properties that have now been accepted by much of the international community.

13. Few sites are naturally fully suitable for the disposal of industrial wastes. However, site development techniques have improved in recent years so that it is now possible to build facilities that give good environmental performance for many wastes, especially if they are adequately pre-treated (liquid wastes, incidentally, are no longer regarded as suitable for landfill). The engineering techniques will depend on local considerations of geology, of the type of waste, climate, and level of ongoing operation. Features include artificial membranes, the use of special waste cells, impermeable capping, and leachate collection drains. Site licences may make such engineered safeguards mandatory.

14. The environmental impact of a landfill site depends on the interaction of the wastes deposited with the physical and operational site features. Once these features have been selected "in principle", it is possible to carry out an environmental impact assessment for the site. The assessment may suggest further modifications to the engineering or to the waste pre-treatment in order to give a higher level of security. Site assessments may use checklists of possible impacts, modelling or other predictive methods, and risk assessment to see if the impact is acceptable. Formal studies constitute an *Environmental Impact Assessment* (EIA). The assessment document is called an *Environmental Impact Statement* (EIS). The decision to proceed with a landfill project will also take account of economic, social and political factors.

15. Competent, safe operation is one of the features that distinguishes a landfill facility from a dumpsite.

    Careful operation can make up for some deficiencies in siting or design. Conversely, careless site management can turn even the best designed facility into an environmental disaster.

16. As landfills usually accept wastes from a multitude of sources, operational procedures must be inherently cautious. The greatest possible safeguards against waste smuggling must be taken, loads must be regularly checked, and precautions taken to avoid accidents. Technical staff must be trained to handle exceptional circumstances as well as the day-to-day running of a landfill. Operations must be regularly monitored to give the manager information about the performance of the site. Public relations is also becoming more important in site management.

17. The correct choice of site, design, and operation is unlikely to occur if it is not demanded by law. Regulations may take the form of general standards for landfill siting and management, or as site-specific licences. Frequently both are applied together. Regulations need to be enforced, and this relies on inspection and monitoring. An administration is thus necessary to oversee and control landfills. Public involvement in regulatory affairs is now more and more necessary in all countries. Often, there is widespread mistrust of the operators and of the regulatory agencies. An open-door policy and a high level of transparency in operations can help to overcome some of this mistrust.

18. Wastes buried in a landfill will remain there after the site operator departs. Public access after closure and re-development of the site will be key concerns of the community when new landfill proposals are announced. It is necessary to address these issues from the outset, and take measures to guarantee long-term safety. Ongoing monitoring of the site is one aspect of such long-term care. Financial liability and possible retrospective site action at some future time must also be assured. Legal responsibilities of the operator and the waste generators must be defined at the outset.

19. For many communities the rehabilitation of dumpsites which already exist is also important. Here, decisions of site location, design, and operation were made long ago, and management options now concern upgrading rather than approval. Upgrading is not easy. Technical choices may be limited, finance scarce, and competent operators not available. Public opposition may already be high. The upgrading of old sites is now a major challenge to many authorities. Each case must be dealt with separately, using the technical criteria for new sites to guide the practical rehabilitation techniques that have been developed.

20. Even for new sites, compromises may be necessary in many countries. A small scale of operation does not always permit a high technology design. Natural features are often not favourable, and finance for industrial infrastructure such as pre-treatment facilities is scarce. Again, the current technical wisdom has to be adapted in the light of circumstances so as to establish the best operation that is feasible.

21. For many countries, co-disposal of industrial waste with urban refuse is one of the compromises that will probably have to be made,

at least in the medium term. This is especially true for small countries that lack large industries which could financially support a purpose-built landfill. In these cases, the adaptation of engineering and operating procedures to serve the dual industrial/municipal disposal role will be particularly exacting if public and environmental health is to be maintained. Nevertheless, the principles developed for advanced industrial sites will also find application in these circumstances.

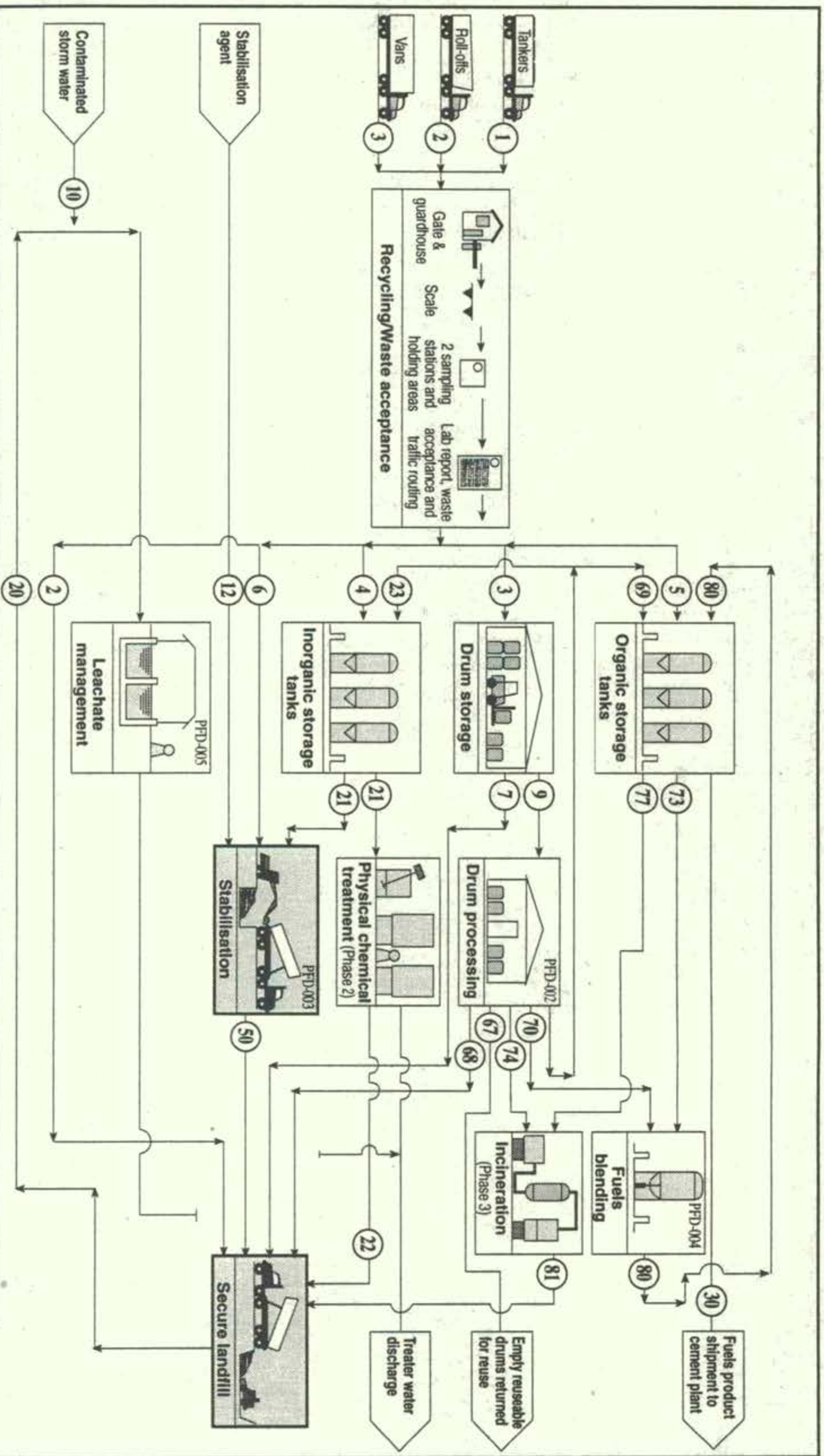
22. A landfill site is often the first industrial waste disposal facility to be established. The site should then be managed to serve also as a bridge to developing other facilities. An existing landfill can assist in estimating waste types and quantities, helps to train local staff to and handle industrial wastes, and serves as a political and social initiation to the realities of waste management. The site may accommodate temporary or experimental treatment plants for special waste. Any such dual role must be built into the operating procedures, and approved by the regulatory authorities.

Summary

23. Despite other important initiatives in hazardous waste minimisation and treatment, safe landfill disposal remains a necessary part of a management strategy. Accurate identification and pre-treatment of wastes is a prerequisite to safe operation. Landfills need to rely on both natural and engineered safeguards, and be operated in accordance with regulatory requirements. New landfill projects should be subject to rigorous environmental assessment. Reclamation after closure is an important consideration in planning and operating of a new site.

24. In some circumstances, standard site development and operating procedures must be adapted to the needs of communities that have no means to carry out a large project. Co-disposal is one example of a generally non-recommended technique that will nevertheless be used in practice. The rehabilitation of existing dumpsites also presents particular challenges, as neither the site nor the operation are usually ideal.

Figure 1: Example of the role of landfill in an industrial waste disposal procedure



Stream Number	1	2	3	4	5	6	7	9	10	12	20	21	22
Stream Name Description	Bulk tanker shipments	Bulk solid shipments	Drum shipments	Inorganic liquid waste	Organic bulk liquid	Inorganic sludge waste	Solid drums to landfill	Drummed waste	Contaminated storm water	Stabilisation agent	Landfill leachate	Inorganic liquid waste	Residue to landfill

Stream Number	23	30	50	67	68	69	70	73	74	77	80	81
Stream Name Description	Inorganic liquids	Fuels product shipment	Stabilised waste to landfill	Reuseable empty drums	Stabilised drums to landfill	Organic liquid	Sludge waste fuel	Recoverable organic liquids	Organic solids	Unrecoverable organic liquids	Blended fuel product	Ash

Source: Waste Management, Indonesia

WORKING TABLE FOR CALCULATION OF WASTE LOADS[1] FROM INDUSTRIAL PLANT

Industry & Process	Waste Quantity (kg/tonne of production or output)	Nature of Waste
Vegetable oil refining	4.7	Purification muds soaked in oil
Pulp mills	50.0	Cellulose, lignins, reducing sugars, etc.
Phosphoric acid	4 750.0	Gypsum when removed from the effluents
Pesticides	200.0	Containers, bags, 1.5% active toxic material, etc.
Latex paints	5.8	Paint sludge[2], waste solvents etc.
Pharmaceutical chemicals	800.0	Waste solvents
Rubber tyres	55.0	Rubber waste, fillers, etc.
Metallurgic coke oven	5.5	Condensate and sludge[2] with Cr, Cu, Pb, Zn; oil
Blast furnace	348.0 16.2 24.4	Slag (Cr, Cu, Mn, Ni, Pb, Zn) Dust (Cr, Cu, Mn, Ni, Pb, Zn) Sludge[2] (Cr, Cu, Mn, Ni, Pb, Zn)
Steel foundries	361.0 780.0 36.4	Slag, dust, refractories Sand Sludge[2]
Primary tin smelting	915.0	Slag (Sn, Pb, As, Zn, Sb)
Cu electroplating	9.0	Cu in the effluent treatment sludge[2]
Ni electroplating	4.0	Ni in the effluent treatment sludge[2]
Cr electroplating	250.0	Cr in the effluent treatment sludge[2]
Zn electroplating	220.0	Zn in the effluent treatment sludge[2]

Source: *Rapid Assessment of Sources of Air, Water, and Land Pollution*, WHO, 1982.

WORKING TABLES FOR CALCULATION OF URBAN WASTE AND SEWAGE SLUDGE

Table 1: Municipal solid waste factors for different regions of the world[3]

Area	Municipal wastes
Lowest income areas in South East Asia	0.4 kg per person per day
Typical cities in Asia, North Africa, and South America	0.7 kg per person per day
Typical cities in industrialised nations	1.1 kg per person per day
Typical cities in wealthy regions (USA and Gulf countries)	2.5 kg per person per day

Source: *Rapid Assessment of Sources of Air, Water and Land Pollution*, WHO, 1982.

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[1] Values for other industrial processes not listed here may be found in the source reference for this table, or elsewhere.

[2] Note that many sludges have high liquid content. Some sludges should therefore be handled as liquids.

[3] Based on fieldwork, unpublished data.

Table 2: Composition and density of municipal wastes in different countries[4]

Waste type (%)	Britain	India	Mexico	Tunisia	Ecuador
Vegetable putrescible	28.0	75.2	55.0	80.8	65.5
Paper	37.0	1.5	15.0	9.6	17.9
Metals	9.0	0.1	6.0	2.1	1.4
Glass	9.0	0.2	4.0	1.1	1.7
Textiles	3.0	3.1	6.0	2.9	3.1
Plastic and rubber	3.0	0.9	4.0	1.2	2.7
Miscellaneous combustible	1.0	0.2	2.0	0.5	3.0
Misc. incombustible	1.0	6.9	6.0	0.1	0.9
Inert below 10 mm	9.0	12.0	0.0	1.8	3.8 (30 mm)
Density, kg/m^3	150.0	570.0		321.0	292.0

Source: *Rapid Assessment of Sources of Air, Water, and Land Pollution*, WHO, 1982.

Table 3: Quantities of wastewater sludges[5, 6]

Treatment Process	Quantity of sludge			
	Wet		Dry	
	kg/m^3 of sewage	m^3/1000 persons/day	kg/1000m^3 of sewage	kg/1000 persons/day
Primary sedimentation				
• Undigested	3.0	0.6	150	30
• Digested in separate tanks	1.5	0.3	90	16
• Digested and dewatered on sand beds	0.2	0.1	90	16
Trickling filters	0.8	0.2	57	12
Chemical precipitation	5.3	1.1	396	79
• Dewatered on sand beds	1.4	0.3	396	79
Primary sedimentation and activated sludge				
• Undigested	7.0	1.4	280	56
• Digested in separate tanks	2.0	0.4	168	33
• Digested and dewatered on sand beds	0.4	0.1	168	33
Activated sludge				
• Wet sludge	19.5	3.9	270	17
Septic tank sludge, digested	-	0.2	97	20
Imhoff tank sludge, digested	-	0.1	83	17

Table 4: Water treatment sludges—lime-soda softening

Sediment per 1000 m^3 of water treated = 0.2 t (dry weight) or 2000 litres (sludge).

Source: *Water Treatment Plant Design*, New York, N.Y., 1969.

[4] Flintoff, F. Personal communication.

[5] Based on a sewage flow of 200 litres/person/day or 0.06kg/person/day of suspended solids in sewage.

[6] Adapted from Metcalf & Eddy, Inc. Waste Water Engineering, New York, N.Y., McGraw Hill, 1972.

Table 5: National Industrial Hazardous Waste Coefficients

In many situations, it is not feasible to calculate wastes from each factory in order to obtain a regional or national total.

In such cases, it is possible to use a set of waste generation coefficients based on national employment or other criteria. The table below gives a set of coefficients developed in Canada in 1982. Note that the resulting waste loads may be liquid or solid, and hence do not necessarily indicate what would go to landfill. They do however permit a rapid overview of national waste generation, and so give a better focus to subsequent surveys. The only input data required is national employment statistics in various industry sectors.

The use of this and other rapid assessment tools is explained in more detail in the UNEP IE/PAC publication *"Hazardous Waste Policies and Strategies: A Training Manual"* Technical Report Series N° 10, 1991

Coefficients used to estimate Waste Generation[7]

tonnes of waste / 1 000 production employees / year

Item \ Industry Sector (ISIC)	FOOD, BEVERAGES, TOBACCO 31	TEXTILES, CLOTHING, FOOTWEAR 32	WOOD, WOOD PRODUCTS 33	PAPER PRODUCTS, PRINTING 34	CHEMICALS, PETROLEUM, COAL 35	NON-METALLIC PRODUCTS 36	BASIC METAL PRODUCTS 37	FABRICATED METAL PRODUCTS 38(a)	TRANSPORT EQUIPMENT 38(b)	OTHER MACHINERY, ETC. 38(c)	MISCELLANEOUS MANUFACTURING 39
Plating/metal treatment	0.2	0.2	0.3	0.3	0.3	0.2	0.1	40.0	10.0	10.0	20.0
Acids	0.3	1.0	0.1	1.0	50.2	5.1	401.7	50.0	99.9	100.0	50.0
Alkalis	100.0	1.4	3.0	6.0	200.6	50.2	100.4	50.0	10.0	20.0	30.0
Inorganic wastes	2.0	3.4	4.0	10.0	40.1	80.3	40.2	8.0	6.0	8.0	6.0
Reactive waste	0.0	0.0	0.0	4.0	8.0	0.0	2.0	2.0	2.0	0.0	2.0
Paints, resins etc.	0.0	8.6	20.0	20.0	20.1	10.0	0.0	20.0	10.0	20.0	100.1
Organic solvents	2.0	2.3	2.0	5.0	7.0	0.1	1.0	5.0	3.0	1.0	6.0
Putrescible wastes	200.0	5.0	1.0	5.0	10.0	0.0	0.0	0.0	1.0	5.0	10.0
Textile wastes	0.0	69.2	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	15.0
Oils/oily wastes	10.0	38.2	10.0	10.0	80.2	10.0	60.2	30.0	59.9	30.0	30.0
Contaminated containers	2.0	1.3	2.0	2.0	20.1	1.0	2.0	3.0	2.0	10.0	10.0
Inert wastes	10.0	17.3	20.0	50.1	200.6	401.8	200.9	40.0	30.0	40.0	30.0
Organic chemicals	0.2	0.1	0.1	0.2	2.0	0.0	0.0	0.0	0.0	0.1	0.2
Pesticides	0.0	0.0	0.1	0.1	10.0	0.0	0.7	0.1	0.2	1.0	0.1

[7] These coefficients were developed for a hazardous waste strategy in Victoria, Australia, in 1985. They are based on a survey of industries carried out in Canada in 1982. The situation in other countries *this* year will differ to a greater or lesser extent from this.

EXAMPLES OF LANDFILL SITES ACCEPTING SPECIAL INDUSTRIAL WASTE

1. C_2 Landfill Site, Rotterdam, The Netherlands

Objective

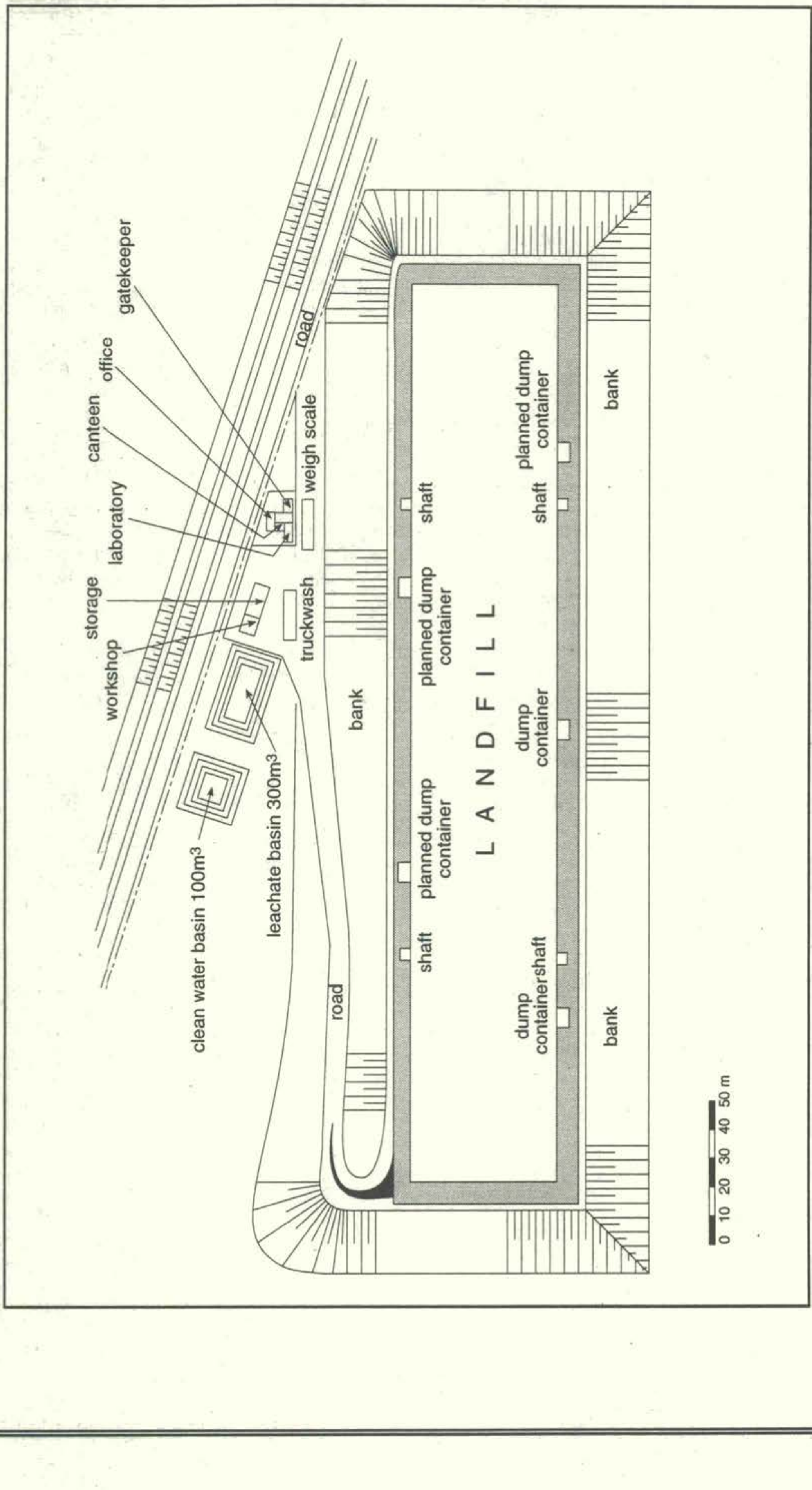
Controlled permanent storage of non-treatable chemical residues.

Main design and construction features

Landfill type	Containment, special waste only, engineered site.
Amount of waste deposited	30,000–50,000 tonnes/year.
Wastes accepted include	*Metal sludge:* originates mainly from the treatment of wastewater from electroplating and engraving plants. It contains various heavy metals and other components. *Leather tanning sludge:* originates from treatment of wastewater from leather tanning plants. Chrome is the main contaminant. *Gas scrubber sludge:* originates from incineration of chemical waste and it contains various heavy metals.
Total volume of the landfill	210,000 m^3 of concrete tank.
Location	Sited at Massvlakte. It is a large scale industrial and port area with coal and oil terminals, harbours and canals. This site was created by hydraulic sand filling of a part of the Haringvliet estuary.
Liner system	Synthetic liner to protect the walls. Below the drainage system is a layer of cast asphalt and a layer of mastic asphalt.
Leachate collection	Drainage system is placed at the bottom of the landfill structure. The leachate is collected through this drainage network and transported to the treatment plant.
Site closure & rehabilitation	The landfill is covered with two layers of HDPE[8] liner, with a clay liner in between. A dune is created at this site by covering the landfill site with a sand bed.
Major environmental impacts	*During construction:* minor lowering of the groundwater; noise due to pile driving but mainly restricted to a zone of maximum 1 km from the site. *During filling:* no odour problem, as putrescible waste is not accepted at this site; dust nuisance from fly ash.

[8] High density polyethylene

Figure 2: C_2 Landfill site lay-out, Rotterdam



2. Treatment and Disposal Centre, Kettleman Hills, California, USA

Objective

Treatment and controlled storage of hazardous wastes.

Main design and construction features

Landfill type

Engineered and constructed for secure containment of solid hazardous wastes.

Wastes accepted

Residues taken to the site include all solid, semi-solid, and liquid hazardous and extremely hazardous, restricted and non-restricted wastes, excluding Class A explosives, radioactive materials, biological agents, and certain air and water reactives.

Treatment methods

Preparation of solvent derived fuels; chemical fixation; cyanide treatment; drum decantation; PCB transformer services; solar evaporation.

Location

Kettleman Hills (Central California) approximately 200 miles south-east from the San Francisco Bay Area.

Liner system

Following excavation, a neutron probe is placed in the vadose zone for moisture detection. Above the monitoring system, a 1m layer of compacted clay is installed as the secondary containment liner. Over the clay, a synthetic liner is installed (60 mil HDPE Geomembrane). Above the secondary clay and synthetic liners, a leachate collection and removal system is constructed. The system involves several separate layers including natural gravel and synthetic materials.

The protective layers are then repeated, including a primary clay liner, primary synthetic liner, and primary leachate collection and removal system. A 60cm layer of soil protects the liner from damage by heavy equipment.

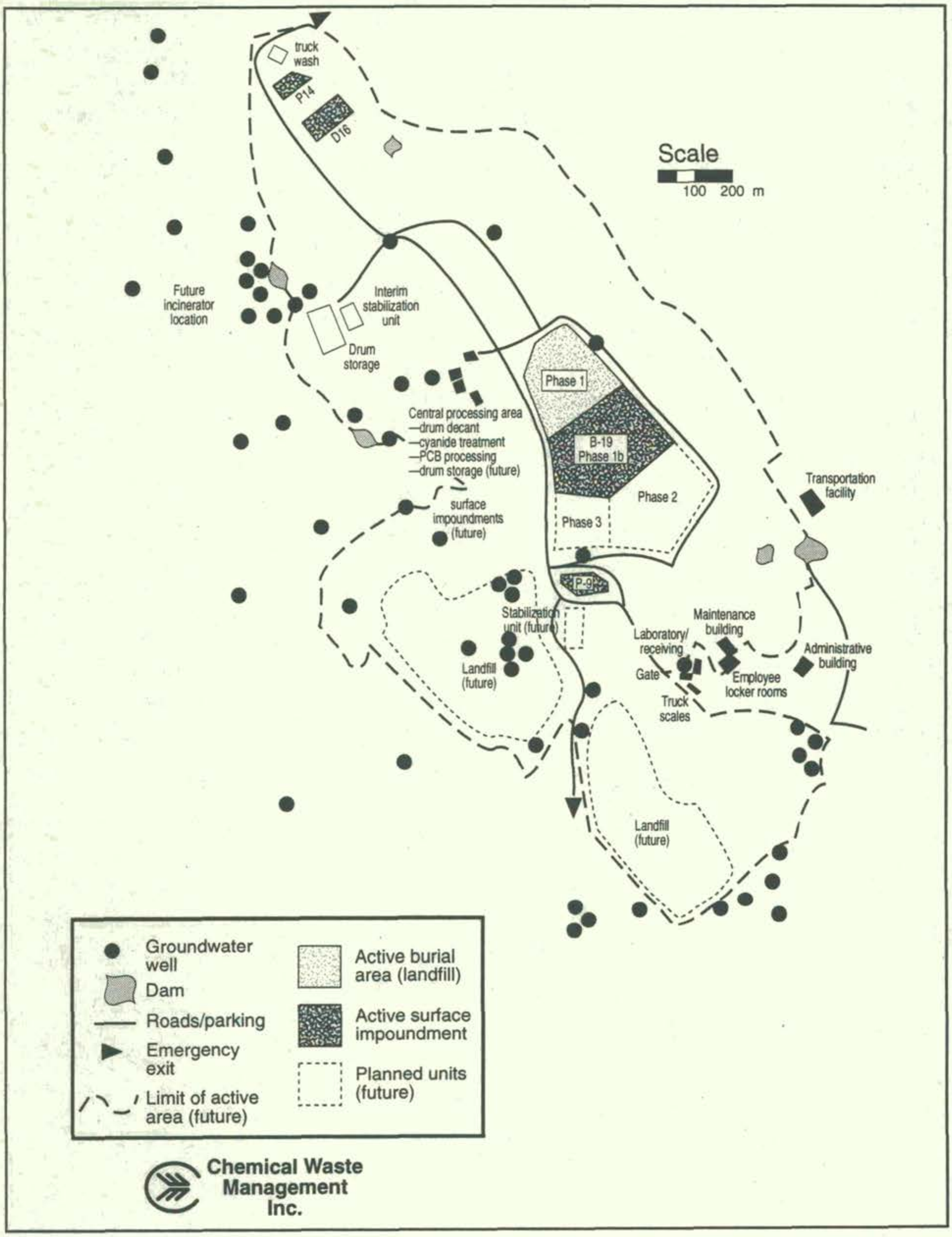
Site closure and rehabilitation

When the landfill reaches its maximum designed capacity, a protective cover is constructed. This cover includes compacted clay and polyethylene liners and a geonet layer for drainage. Natural vegetation is replanted to minimise erosion, and the surface sloped to promote drainage of rainwater away from the landfill.

Monitoring

A total of 32 wells have been installed to monitor the groundwater. In addition, the site has five permanent air monitoring stations. The stations collect samples 24 hours, seven days per week. Meteorological data are collected from three stations.

Figure 3: Kettleman Hills Hazardous Waste Management Facility



3. Cibinong Hazardous Waste Site, Indonesia

Objective

Controlled disposal of stabilised industrial waste. A wide variety of inorganic wastes will be accepted in drums or in bulk at the reception area for testing and pre-treatment and stabilisation prior to deposit in lined disposal cells.

The landfill is the first phase of an integrated waste management site (treatment, storage, disposal). Included in the first phase is a cement kiln fuel blending operation.

The site has been designed and built for the Indonesian government by a large western contractor. The agreement stipulates emission and effluent standards and operating procedures.

Main design and construction features

Landfill type	Containment in specially designed, lined cells.
Amount of waste deposited	Estimated at 28 000 t/a Only inorganic waste suitable for chemical stabilisation (or already stable) will be accepted. Final material to be filled must meet a leachate test similar to that used in the USA. Stabilised material is placed in the landfill in the wet state and allowed to harden.
Total life of site	Estimated at 10 years
Location	Cibinong, Indonesia. Hilly site in rural area. High rainfall.
Liner system	HDPE base liner, leachate collection and treatment, surface liner, surface runoff control.
Site rehabilitation	Clay cover, HDPE or clay cap, surface drainage system, final cover and revegetation, proposed after-use as wildlife refuge.
Major environmental impacts	None expected as no putrescible or soluble waste will be accepted. All environmental issues were addressed in a pre-construction EIA

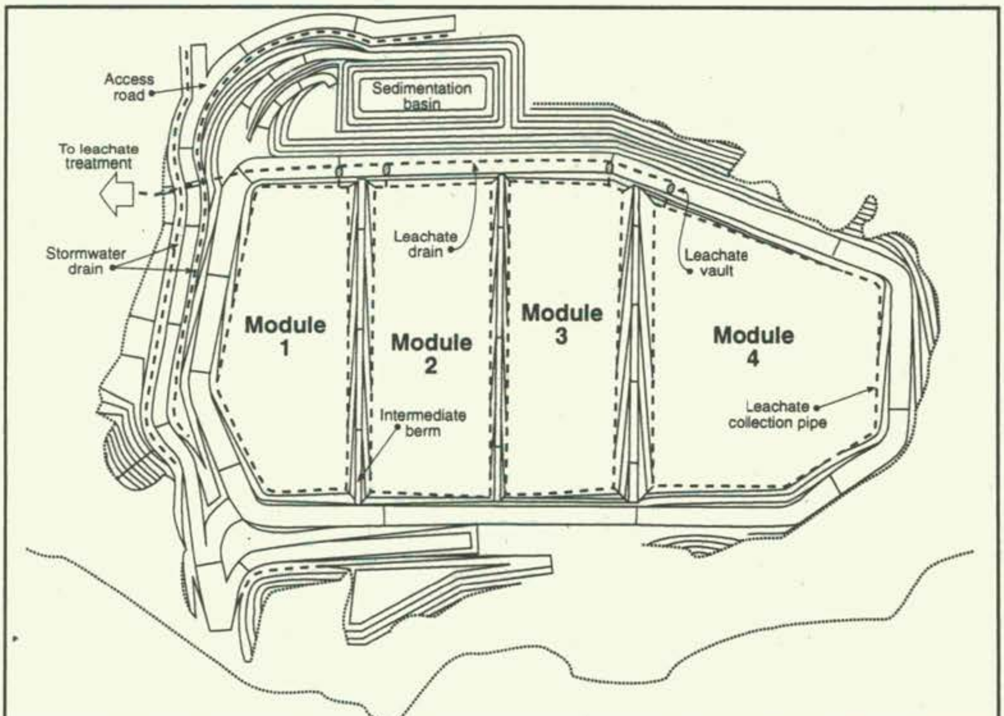


Figure 4: Cibinong hazardous waste site

4. Hazardous Waste Landfill Site, Trzesieka, Poland

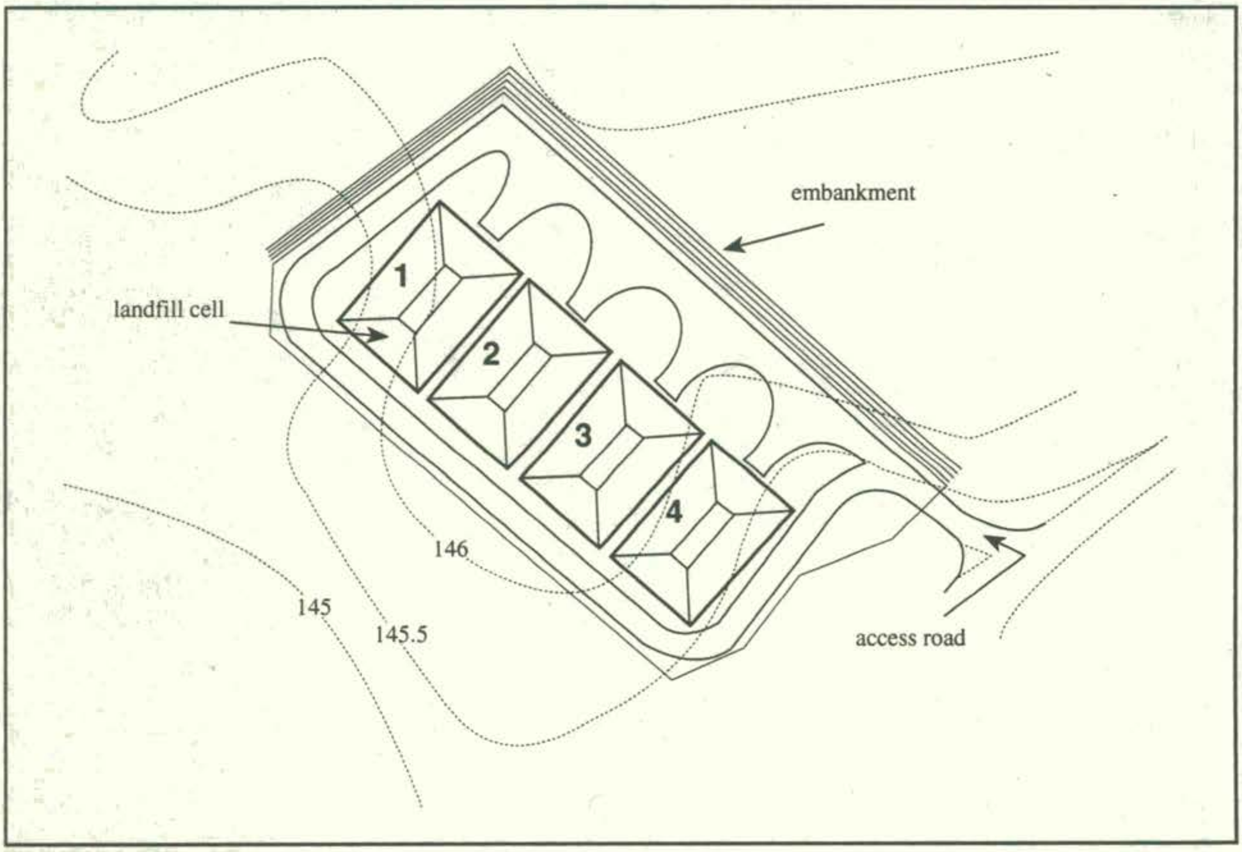
Objective

Landfill disposal of hazardous waste from galvanising plant in Trzesieka.

Main design and construction features

Landfill type	Hazardous waste landfill (constructed in May 1991), waste disposal in separate isolated cells. *Total disposal area:* 2 000 m^2. Hazardous waste consists of different chemical residues including heavy metals.
Projected operation time	10 years.
Location	The village of Trzesieka near the city of Szczecin.
Liner system	2,5 mm HDPE liner.
Site closure and recultivation	Closure cap (HDPE liner), plus 50 cm of cover material and topsoil (for vegetative growth).

Figure 5: Hazardous waste site in Poland



5. Hazardous Waste Disposal Site, Aszod, Hungary

Objective

Secure landfill disposal of industrial waste from all over Hungary.

Main design and construction features

Landfill type	The landfill comprises two zones, the first for Class I wastes, the second for less toxic Class II wastes. *Class I* wastes are accepted in either drums or larger containers made to fit the above-ground, pyramid-shaped entombments. *Class II* wastes are disposed to cells dug into the ground, prepared with clay, then fitted with HDPE liner. Cells operate under a moving roof to keep rainwater from infiltrating.
Amount deposited	1989: 5200 m^3; 1990: 6100 m^3; 1991: 5060 m^3. The disposal site accepts wastes defined as hazardous waste Class I and Class II under the Hungarian regulations, includes: poisons, acid sludges, alkaline sludges, galvanic sludges, incinerator ash and paint sludges, plastic refuse, plaster sludges, sludges containing metals or phosphate, asbestos, contaminated soil. The landfill cannot accept: combustible, explosive, radioactive, biodegradable and liquid hazardous wastes.
Location	On an old military shooting-range in a valley between hills near city of Aszod.
Liner system	Though the site has a deep natural clay base, a 2mm thick HDPE lining is used.
Leachate collection	Can be collected from part of the area. When generated—none so far—leachate will be treated in an engineered structure on the disposal site.
Duration of operation:	Up to 25 years.
Major environmental impact	None.

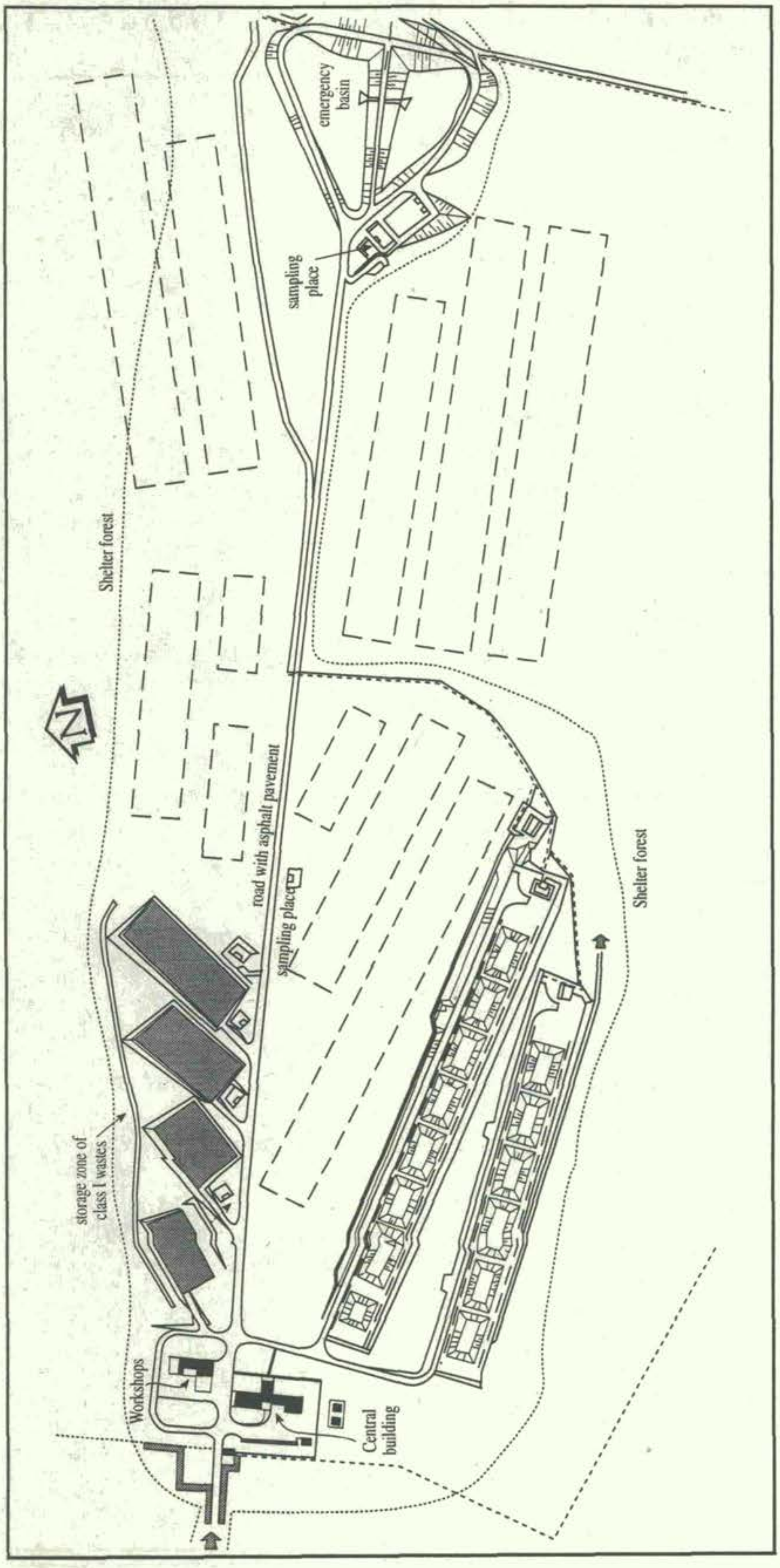


Figure 6:
Hazardous waste disposal site at Aszod, Hungary

6. Sakai Section Reclamation Site, Osaka Industrial Waste Management Public Corp., Japan

Objective

Disposal of non-hazardous industrial waste from Osaka prefecture.

Main design and construction features

Landfill type
Controlled deposit. The site is constructed in the sea.

Amount deposited
1989—

Non-hazardous industrial wastes: 2,966,000 tonnes/year
Sludge from water supply and sewerage: 111,000 tonnes/year
Cement solidified hazardous wastes: 1,000 tonnes/year
Solidified organic sludge: 2,000 tonnes/year

Hazardous wastes are solidified with cement at the Osaka industrial waste intermediate treatment centre. The centre is located in the disposal site, and solidified wastes are filled. Organic sludges are also solidified with a coagulant.

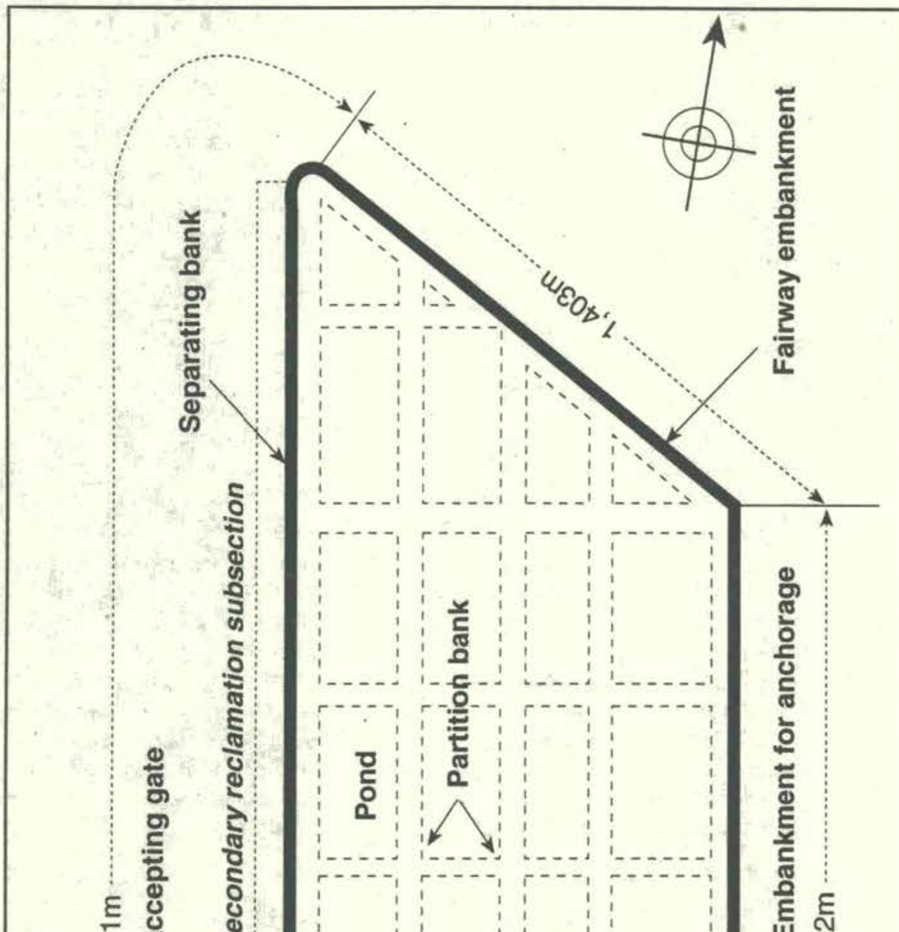
Location
In the area of Sakai Port, in Osaka bay.

Liner system
There is no liner system. Wastes are dumped on the layer of clay soil at the base of the reclaimed area. The wastes are isolated by the clay soil so they are never in direct contact with sea water.

Leachate collection
The wastes remain isolated by the clay so leachate does not generate.

Site closure and rehabilitation:
Not yet decided. Part of the site is provisionally used for a park.

Major environmental impact
The qualities of the sea water around the site and pond water are tested periodically, there is no impact from the landfill site. The major change is that of reclamation of the sea.



Since the land reclamation waste disposal operation began in 1974, a total of eighty hectares of land has been reclaimed.

Figure 7:
Plan of reclamation for Sakai Section Reclamation Site, Japan

7. Hazardous Waste Treatment and Landfill Facility, Swan Hills, Canada

Objective

Safe disposal of all classes of hazardous wastes (with the exception of explosive, radioactive and biomedical wastes) from within the Province of Alberta. All treated and stabilised wastes from the plant's incineration, physical/chemical and stabilisation units go into the landfill cells.

Main design and construction features

Landfill type Artificial complete containment.

Liner system The cells are classified as Class I landfill cells which require two liners of which at least one is a synthetic liner, a leachate collection and removal system, a leak detection system between the two liners, a surface run-off control system and a groundwater monitoring system.

The cells are excavated in the thick layer of natural clay beneath the site and incorporates an abrasion resistant geotextile liner, an HDPE liner and another abrasion resistant geotextile liner. Above the HDPE liner is the leachate collection system consisting of a sump and piping allowing for the extraction of any liquids that may accumulate. A leachate monitoring system below the HDPE liner is used to check for leaks even though no liquids are placed in the cell. Each cell is enclosed in a moveable building to keep out rain and snow, and minimise dust when in use. When full, a HDPE cap is heat-welded to the HDPE liner and the cell is covered with clay and soil and revegetated. The size of the average cell is 50m long, 22.5m wide and 5.4m deep.

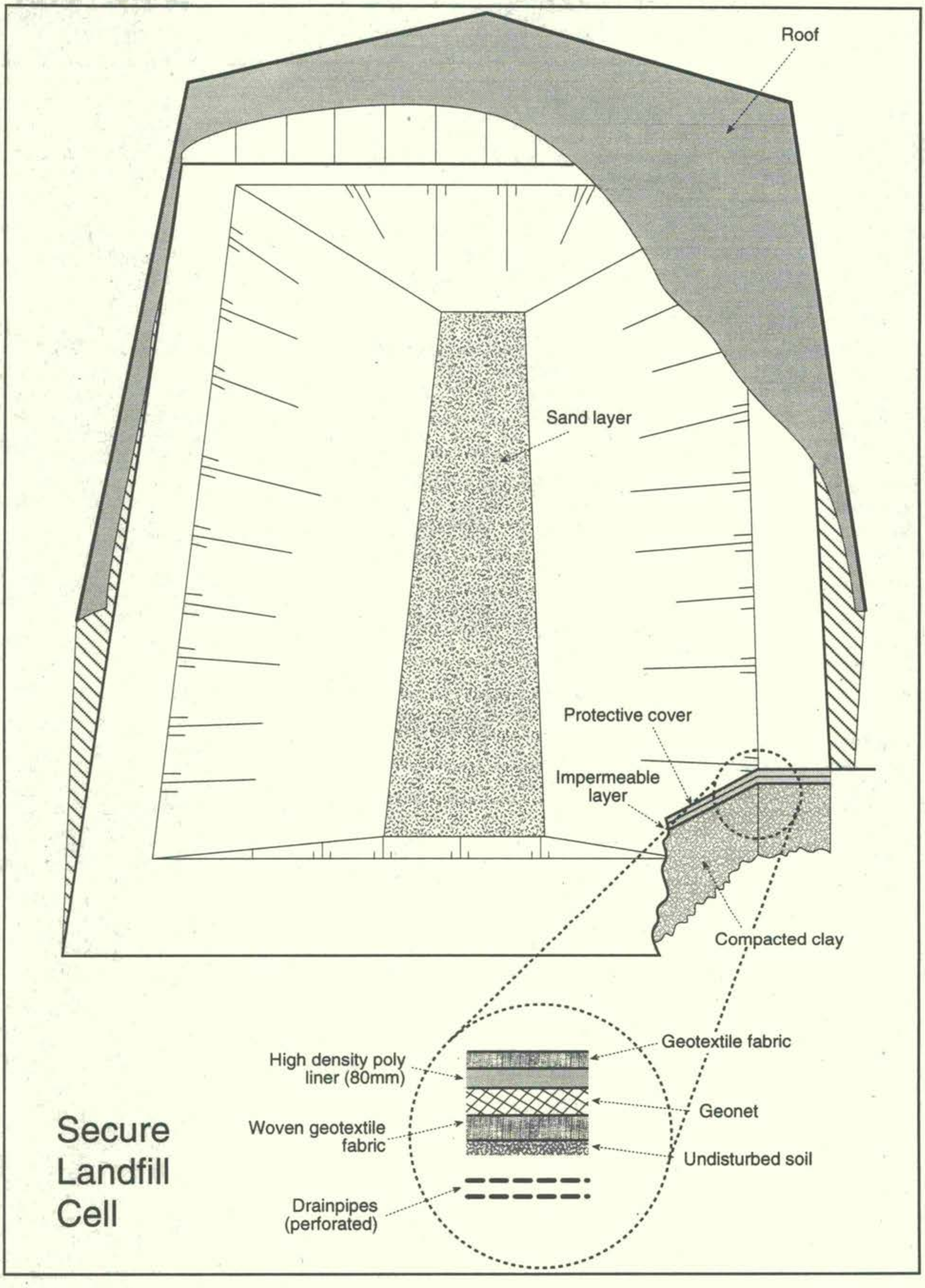
Amount deposited Approximately 15,000 m^3.

Location Central Alberta, 12km north east of the town of Swan Hills.

Site closure and rehabilitation Closure plan established and responsibility of the Government of Alberta

Major environment impact None identified.

Figure 8: Hazardous waste treatment and landfill facility, Swan Hills, Canada



EXAMPLES OF SANITARY LANDFILLS RECEIVING INDUSTRIAL WASTE

1. Maghtab, Malta

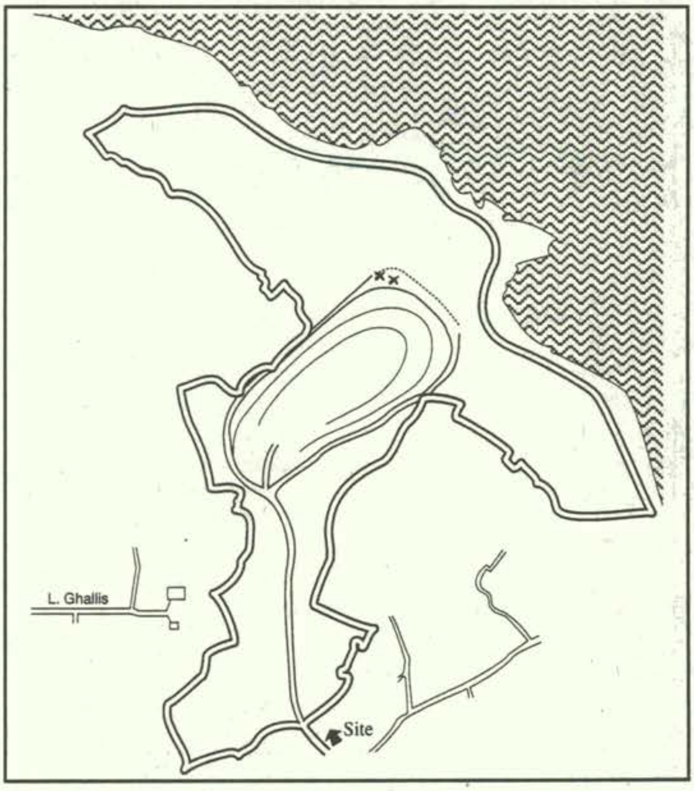
Objective

The Maghtab site is one of the two landfills on the main island of Malta, and is the only one to accept industrial waste which is disposed of with community and commercial rubbish. Management of the site is under control of the Ministry of Environment. The site was opened in 1977 as part of a land reclamation project.

Design and construction features

Landfill type	Sanitary landfill. The site accepts around 1000 tonnes/week of industrial wastes such as wood carton, textiles and metals, although some materials such as metals are unofficially collected and recycled prior to dumping. Limited quantities of sludges from electroplating, expired medicines, residues from detergent manufacture, tarry residues and solidified wastes are accepted. Hospital and abattoir wastes are also accepted. Conversely, pulverised fuel ash from the power station is not accepted.
Location	Coastal site, remote from the city.
Site features	Open area, maximum 70ha available, no special preparation other than roads and embankments.
Leachate collection	None.
Amounts deposited	Municipal: 42 000 t/a; industrial/commercial: 43 000 t/a; debris; 63 000 t/a.
Maintenance	Two bulldozers
Major environmental impact	Smoke from burning, windborne dust, rodents.

Figure 9:
Solid waste disposal site at Maghtab, Malta



2. General Industrial Waste Landfill Ponce, Puerto Rico

Objective

Landfill disposal of community waste from the municipality of Ponce; also non-hazardous industrial waste from elsewhere in Puerto Rico.

Main design and construction features

Landfill type Containment, co-disposal. Special waste is deposited in separate isolated cells.

Amount deposited 1992—municipal: 50 000 m^3; special industrial: 40 000 m^3.

Some wastes requiring special handling are accepted, and the site accepts some non-hazardous industrial liquids for solidification before they are landfilled. All special wastes are deposited in separate cells away from the main fill area. Special wastes defined as non-hazardous under the US regulations include asbestos, contaminated soil, empty containers, incinerator ash, waste oil, off-spec pharmaceutical products, rejected manufacture items, non-hazardous tank bottoms, grease trap wastewaters, and similar other materials.

Location At site of earlier municipal dumpsite in a valley between steep hills near city of Ponce.

Liner system None required as only dry waste is deposited, and site has a deep natural clay base.

Leachate collection From special fill area only. When generated (none so far in 1990), leachate will be evaporated in a plastic-lined pit.

Site closure and rehabilitation Not yet decided by municipality.

Major environmental impact Dust from vehicles and filling, windblown litter from general waste, litter along access road. Ultimately a change in landform by filling in the valley.

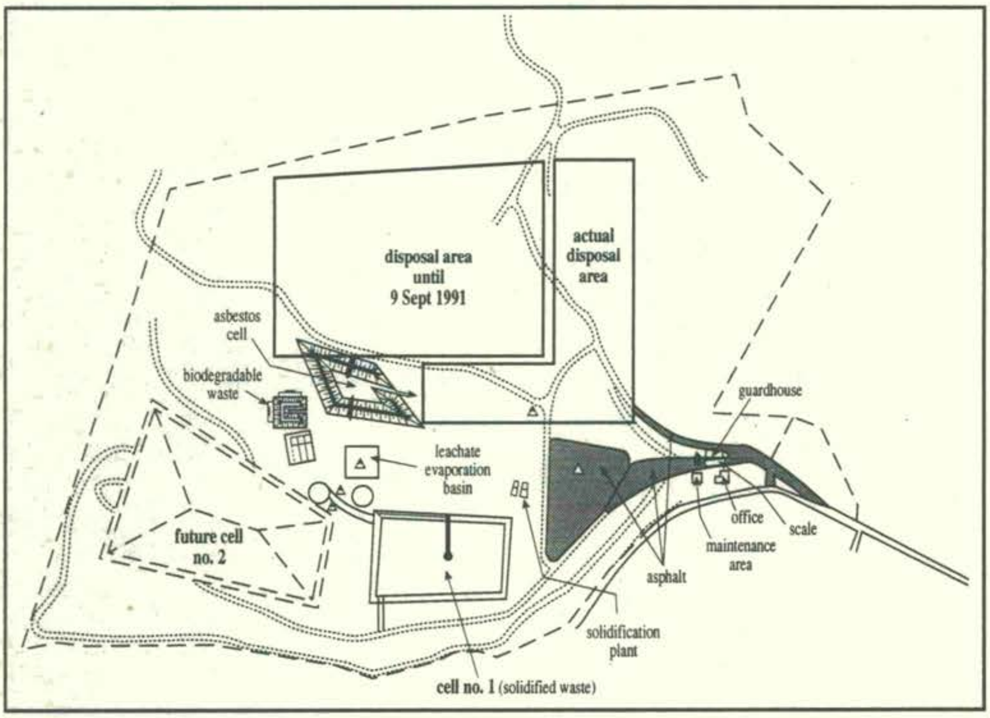


Figure 10: General industrial waste landfill at Ponce, Puerto Rico

3. Margolis Sanitary Landfill Johannesburg, Republic of South Africa[9]

Objective

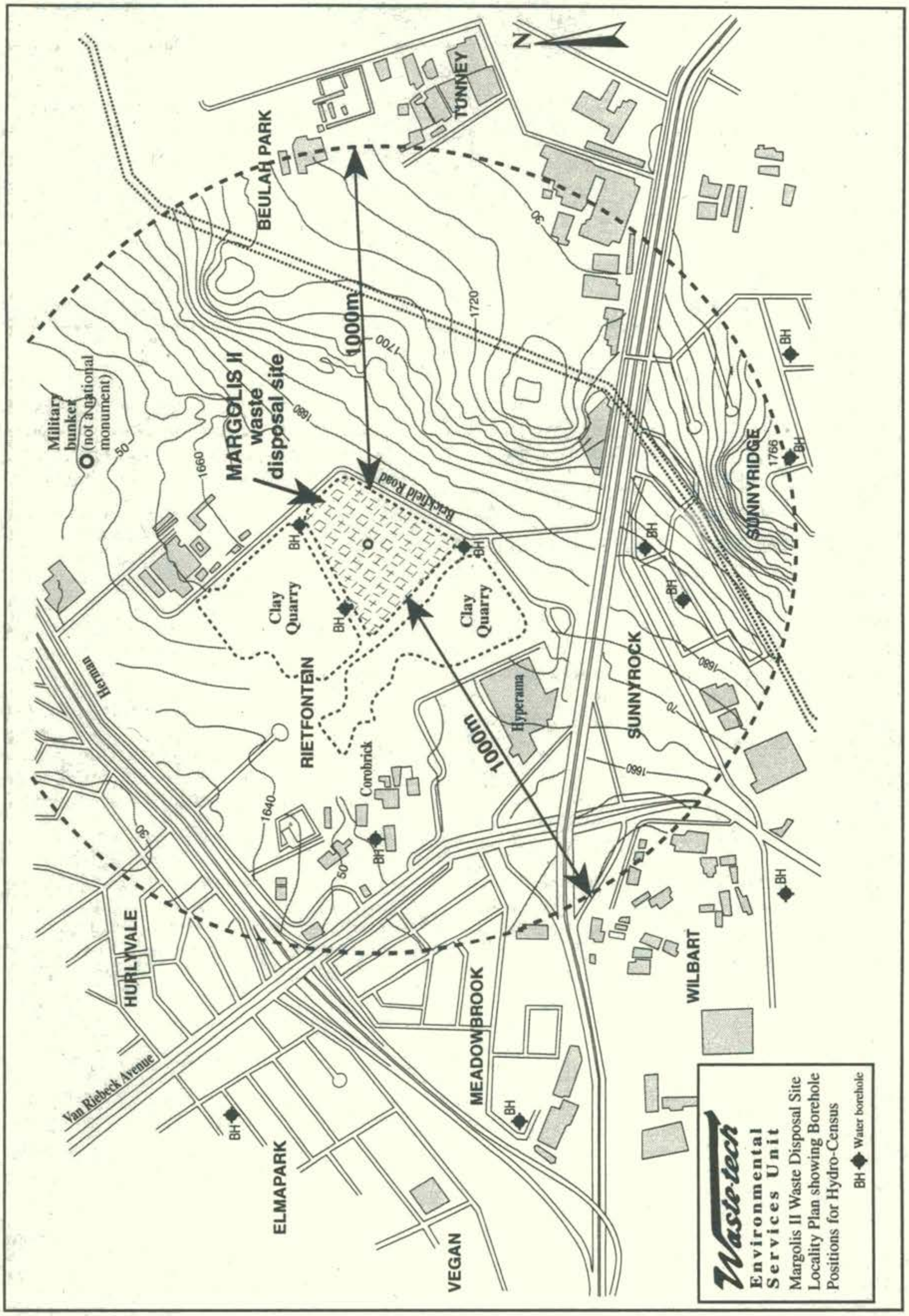
High standard disposal of domestic and industrial waste in a managed co-disposal operation. Incineration of hospital waste, and physical-chemical pre-treatment of liquid waste also takes place on the site.

Main design and construction features

Landfill type	Containment in a clay quarry, engineered site accepting a wide range of solid and liquid waste. Incineration of medical waste, pre-treatment of liquids, co-disposal in trenches in the waste, some separate disposal of special wastes and encapsulated materials.
Amount of waste accepted	Data not available.
Location	Disused clay quarry on industrial land adjacent to residential areas (1km) in an outer suburb of Johannesburg.
Containment system	By natural clay of the site. Some hazardous wastes are encapsulated in concrete before deposit.
Leachate	Background monitoring of aquifer occurs. Contaminated surface water is contained in a dam, treated and released to sewer.
Waste control procedures	Strict control over incoming waste (notification, testing, manifest). Not accepted are explosives, radioactive wastes, compressed gases, acidic or highly alkaline wastes, cyanides, sulphides, flammable wastes, reactive wastes. Special pre-treatment or in-situ treatment occurs for specified wastes, some wastes are encapsulated for special burial according to written procedure.
Site closure	Closure and rehabilitation as soon as final contours are reached. 1m minimum of cover, planted.
Major environmental impacts	Information not available.

[9] A more complete description of the operation of this site is included in *Annex IV*.

Figure 11: Margolis sanitary landfill at Johannesburg



HAZARDOUS WASTE LANDFILL COUNTRY REPORT

This report can be prepared as a first stage to identify the situation concerning industrial waste disposal in a country, with emphasis on landfill problems.

The Country Report Udanax in *Part II* shows how such a report can look when it is completed. Report length should not exceed eight pages. Tables may be attached.

Report Format

1. *National Profile:* population and growth rate, geographical and climatic conditions, resources, economic base, administration and government, technical services, environment (one page max.).
2. *Industry Profile:* types of existing industries, their location, output, employment.
3. *List of environmental problems being experienced due to hazardous waste dumping or disposal:* e.g. pollution, adverse health impact, unsafe landfilling, illegal dumping, unsafe transport, unsatisfactory storage, soil contamination, etc.
4. *Main types and quantities of hazardous wastes in the country*, including both industrial and other sources of waste. Mention explicitly any wastes imported or exported.
5. *Extent of current treatment, recycling or disposal facili-ties:* e.g., oil recovery plants, solvents recovery, incineration, storage sites, treatment plants, land disposal, and any similar installations.
6. *Present landfill practice:* number of landfills and dumpsites used for waste disposal or co-disposal, problems related to construction, operation and maintenance of landfills, technical description of existing landfill(s), types of landfilled wastes, site selection procedures, monitoring of landfill leachate and gas, monitoring of incoming wastes. Mention any sites used specifically for industrial wastes, including those on company premises. Mention any dumping at sea.
7. *Extent of infrastructures and services already available:* e.g., specialised chemical transport, emergency clean-up service, waste exchange service, experienced consultants, hydraulic and geological investigators, training institutes, laboratories, professional associations, research groups. List any companies running landfill services.
8. *Current of policies, laws and regulations to reduce and control pollution, solid waste disposal, and hazardous chemicals:* e.g., water standards, sewer standards, health laws, landfill regulations, waste transport, chemicals controls, facility permits, EIA.
9. *Which organisations have responsibility for*: landfill operation and control, pollution, solid waste, hazardous wastes, toxic chemicals, industry permits, export/import of wastes and chemicals, pesticides, environmental monitoring, industrial training, clean technologies, dissemination of information.

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CONVERSION FACTORS

	From	To	Conversion Factor
Length	millimetre (mm)	inch (in)	0.0394
	centimetre (cm)	inch (in)	0.3937
	metre (m)	foot (ft)	3.2808
	kilometre (km)	mile	0.6214
	inch (in)	millimetre (mm)	2.54
	foot (ft)	metre (m)	0.3048
	mile	kilometre (km)	1.6093
Area	square centimetre (cm^2)	square inch (in^2)	0.1550
	square metre (m^2)	square foot (ft^2)	10.7639
	hectare (ha)	acre	2.471
	1000 m^2	acre	0.2471
	square kilometre (km2)	square mile	0.3861
	square inch (in^2)	square centimetre (cm^2)	6.4516
	square foot (ft^2)	square metre (m^2)	0.0929
	acre	hectare (ha)	0.405
	acre	square metre (m^2)	4046.8
	square mile	square kilometre (km^2)	2.5900
Volume	litre	cubic foot (ft^3)	0.03531
	cubic centimetre (cm^3)	cubic inch (in^3)	0.06102
	cubic metre (m^3)	cubic foot (ft^3)	35.31
	cubic foot (ft^3)	litre (l)	28.317
	cubic foot (ft^3)	cubic metre (m^3)	0.0283
Liquid capacity	litre (l)	quart (US)	1.0567
	litre (l)	gallon (US) (US gal)	0.2642
	litre (l)	quart (UK)	0.8799
	litre (l)	gallon (UK) (UK gal)	0.2200
	quart (US)	litre (l)	0.9464
	gallon (US) (US gal)	litre (l)	3.7854
	quart (UK)	litre (l)	1.1365
	gallon (UK gal)[10]	litre (l)	4.5461
	barrel	litre (l)	158.984
	barrel	gallon (UK)	34.9726
	barrel	gallon (US)	42.00
Weight	gram (g)	grain	15.4323
	kilogram (kg)	pound (lb)	2.2046
	metric ton (1000 kg)	ton (US) (2000 lb)	1.1023
	grain	gram (g)	0.0648
	pound (lb)	kilogram (kg)	0.4536
	ton (US)	kilogram (kg)	907.2

Source: *Rapid Assessment of Sources of Air, Water, and Land Pollution*, WHO, 1982.

[10] Known also as 'imperial' gallon (imp.gal.).

Part II

Country Report
Udanax

Report prepared in 1990 by The National Research Institute, Udanax

1. NATIONAL PROFILE: UDANAX

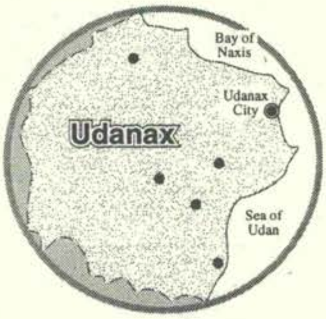
Geographical

Area	700 000 km^2; 1 100 km of coastline.
Climate	Temperate to hot.
Temperature	Minimum 14°C; maximum 30°C.
Rainfall	Average 650 mm/year in coastal areas; average 780 mm/year in inland areas.
Harbours	Four.
Population	20 million, six cities with population above 200 000. 8% of the population belongs to poor minority groups; 50% of the population lives in coastal areas.
Capital	Udanax City with population of 2.3 million.

The terrain of Udanax is generally flat, with scattered hills (200m to 800m high) in central region. There are 15 rivers with a length over 150km. The longest river is 365km in length, which flows through Udanax City before reaching the sea. This river serves as a main inland waterway system.

From the meteorological point of view, seasons in this country may be divided into three groups—

1. *Winter season from October to January*. This is the mildest period of the year
2. *Summer or pre-monsoon season*, in February to May. April is the hottest month of the year.
3. *Rainy or monsoon season* from June to September, with peak rainfall usually occurring in August.



The coastal region experiences relatively high temperature and low rainfall in comparison to the central region. The highest temperature (41°C) of the country was recorded at Udanax City in 13 May, 1959. The lowest temperature ever recorded in Udanax was 2°C at the central region on 11 January 1960.

Udanax is not situated in an earthquake zone. However a small earthquake was recorded in the central hilly area on 12 April, 1958. Frequent landslides are observed in this region, specially during the rainy season.

Resources and Urban Services

Minerals and energy	Moderate minerals; substantial oil, gas, coal.
Agricultural land	Moderate.
Water supply:	Limited surface and groundwater.
Transport	Good network.
Sewerage	Udanax City 50% sewered, primary treatment only.

Economics and Industry

(see Section 2 for details)

Energy resource based, heavy industry, some light manufacturing, and service industries are represented. Extensive trade and commerce with foreign countries.

Agriculture is reasonably extensive, with many export crops based on irrigated production of fruit, vegetables and livestock. Tourism is a growing industry, especially in coastal areas. Fisheries are an important export industry. Most fishermen belong to the largest of the ethnic minority groups.

Administration

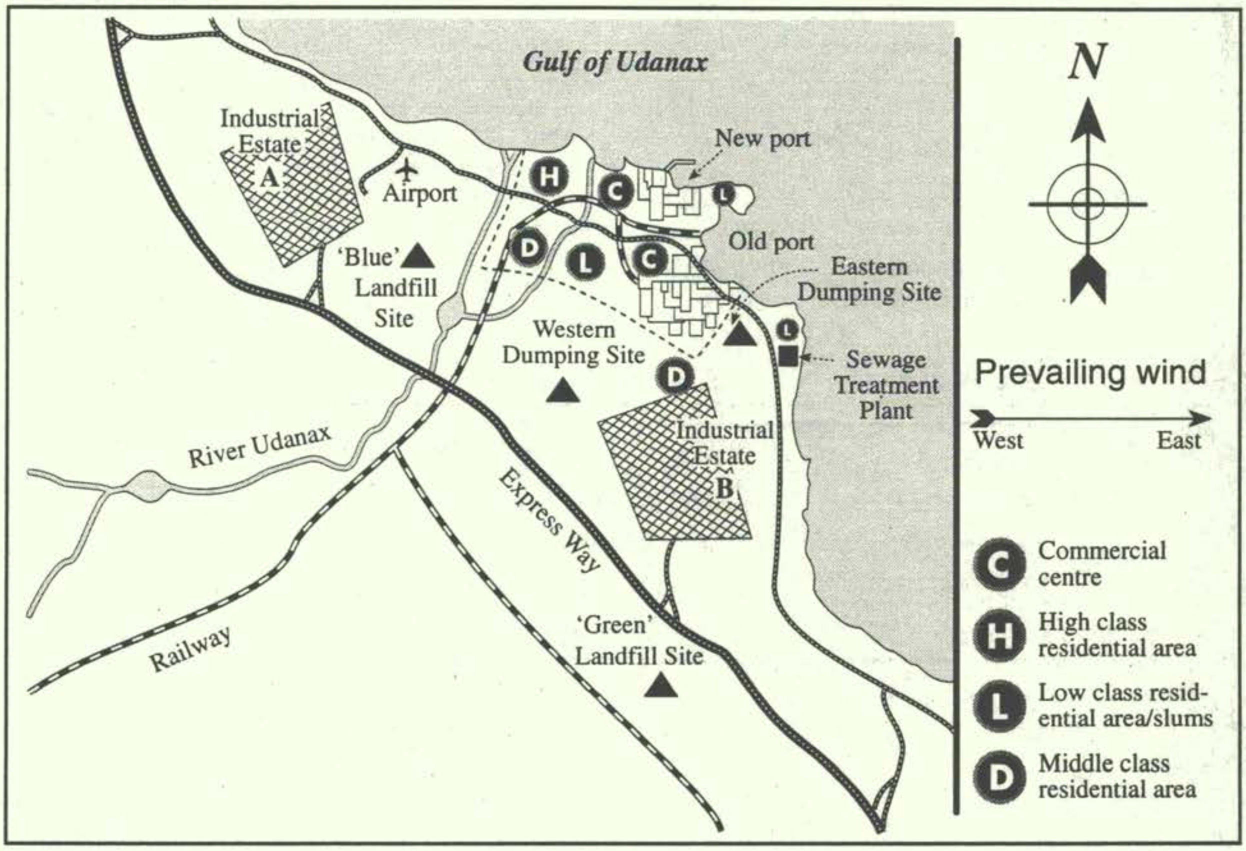
Government	Constitutional monarchy with a Prime Minister and parliament; four provinces with governors and parliaments; 65 local government authorities.
Administration	National ministries of development, industry, health, resources and energy, transport, fisheries and navigation, agriculture. The Prime Minister's Department carries out the necessary coordination between ministries, including environmental affairs. Provincial ministries of planning, land, factories, roads. Local departments of sanitation and water supply, waste disposal.

Technical Services

Researchers in the three universities are interested in environmental pollution. Engineering departments occasionally help industries with pollution control problems. Several engineering consultants have offices in the country. They have been mostly involved in plant design and operation.

There is a local Chamber of Commerce, but it is dominated by finance interests. The chemical and petroleum sector has its own trade association (UCPA).

Figure 1: Udanax City Metropolitan Area Map



2. INDUSTRY PROFILE

The majority of manufacturing activity is concentrated in two industrial estates situated near the Udanax City. Mining and petroleum activity, including refining is located primarily in the interior of the country. Agriculture is mostly near the coastal strip, and along the main river valleys where irrigation water is available. Employment according to industrial sector and its structure is shown in *Table 2*. Data were supplied by the Ministry of Industry, and Ministry of Employment.

These tables are for Udanax as a whole.

Table 1: Employment by sector

	% of labour force
Agriculture	46
Industry	17
Services	37
Total	**100**

Table 2: Structure of employment

	% of total
Agriculture & fishing	46.0
Petroleum, mining & quarrying	1.7
Manufacturing	7.3
Construction	2.9
Commerce	8.2
Transport	3.6
Electricity, gas, water	0.3
Government, community, social & personal services	30.0
Total	**100.0**

Industry data specific to Udanax City and its associated industrial estates is found in *Tables 5* and *6*.

Table 3a: Structure of manufacturing industries

	Total average employment ('000)
Food & beverages	80
Textiles & clothing	110
Leather products	6
Paper & paper products	10
Printing & publishing	50
Industrial chemicals & plastics	30
Petroleum refining	8
Cement	2
Aluminium	2
Iron & steel	12
Non-ferrous metal	1
Fabricated metal products	20
Electrical machinery & apparatus	4
Transport equipment	20
Miscellaneous products	6
Total	**361**

Table 3b: Udanax industrial output[1]

Iron ore (10^3 t)	2,750.0
Lime phosphates (10^3 t)	1,124.0
Zinc (10^3 t)	7.6
Phosphate fertiliser	300 t/day P_2O_5
Aluminium smelter	50 000 t/y
Sulphuric acid plant	500 t/day
Iron and steel plant	1 300 000 t/y
Chlorine plant	300 t/day
Battery production plant uses	4 000 t/y of acid
Textile production (three plants)	26m m. of material
Leather production (eight companies)	3m hides/y
Pulp & paper (two plants)	125 000 t/y

[1] Figures as available but probably not complete.

3. INFORMATION ABOUT ENVIRONMENT AND HAZARDOUS WASTE IN UDANAX

Some ad-hoc information on waste-related problems has been collected:

- Residents near existing dumpsites complain about odour and noise problems.
- Two explosions of toxic chemical containers were recorded in 1990 at the local dumpsite; one explosion caused injury to two site workers.
- Aquifers below both industrial estates, up to a depth of 60m, are polluted by toxic chemicals.
- The local Green Party is actively campaigning against the operation of the eastern dumpsite.
- There has been a sharp decline in land values near the existing dumpsite.
- Fish kills in the river due to toxic discharge occur periodically. Local fishermen report that water clarity in estuaries and lagoons has decreased over the past ten years.
- The owner of 200 tonnes of chemical waste located in an abandoned warehouse in the harbour area cannot be traced.
- A chemical warehouse fire left large quantities of contaminated debris for disposal. These were dumped in the local municipal dumpsite near the beach (July 1985).
- Waste oil is often dumped on unused ground outside the city. Waste oil from small local fishing boats is accumulating on the wharves.
- Only one hospital is known to be equipped with an incineration unit to treat its wastes; in most cases, the wastes from the other hospitals are dumped with the domestic waste.
- Swimming pool chemicals dumped at the local landfill in 1989 caused a serious fire, releasing clouds of chlorine gas. Twenty-three persons were hospitalised.
- Some chemical companies, have been stockpiling chlorinated hydrocarbons, cyanide salts, and arsenic wastes, as there are no local disposal facilities.
- Agricultural inspectors report surplus pesticides being stored under unsatisfactory conditions. One report referred to the death of 16 farm animals due to contaminated water supply; one warehouse has 12 tonnes of off-specification DDT.
- Scavenger communities belonging to an ethnic minority make a living by recovering materials from the local dumps. They are known from health surveys to be frequent carriers of communicable disease, and suffer more illness generally, but they have resisted official attempts to remove them from the sites which are their only means of livelihood. The dumpsites are known to receive industrial and medical waste.

4. HAZARDOUS WASTE GENERATION IN UDANAX: CITY METROPOLITAN AREA

The National Environmental Bureau estimates that 80 per cent of the total hazardous wastes are produced in the Udanax City Metropolitan Area. The Bureau carried out a survey in UCMA to identify the hazardous wastes sources and their quantities.

During the survey of Industrial Estate A and Udanax City, a technical group visited each of the waste producers with the objective of identifying the waste type and quantifying the waste load. However in most situations, due to poor record keeping practice, it was difficult to estimate the waste quantities. In such cases, the waste quantity was measured for a short period and then extrapolated. The results of this survey are summarised in *Table 5*.

Due to lack of time and financial constraints, a more simplified type of survey was carried out in Industrial Estate B. Here, a simple questionnaire was mailed to all waste producers, requesting details of:

- type of manufacturing or process
- total production output per year
- total quantity of waste (liquid and solid) generated
- present waste disposal practice

The information obtained through this survey is summarised in *Table 6*.

Table 5: Measured hazardous waste in Industrial Estate 'A' and Udanax City

Process/Source	Waste type	Quantity (m^3/year)[2]	Current practice[3]
Industrial Estate A			
Chemicals manufacture	Acids, chemicals	53	Drain
Metal finishing	Metals	44 628	Drain
Detergents	Alkalis	2323	Drain
Fertiliser	Heavy metals, alkalis	165	Drain
Foundry	Dust/Slag	503	Dump
Resin manufacture	Formaldehyde	438	Drain
Electronics	Oil & solvents	404	Sold
Foundry/metal works	Hydrocarbon	115	Sold
Packaging/printing	Solvent sludges	27	Dump
Vehicle assembly	Sludge (paint)	12	Stored
Battery manufacture	Sludge with heavy metals	60	Dump
Leather tanning	Treatment sludge	892	Dump
Pesticides	Filter materials, surplus stock	111	Dump
Textiles	Sludge	236	Dump
Chlorine production	Sludge(contains mercury)	122	Dump
Vehicle assembly	Non-halogenated spent solvent	224	Dump
Electroplating	Cyanide wastes	28	Stored
Plastics & rubber	PVC waste	48	Dump
Beverage industry	Organic waste	13 000	Drain
Wood products	Chemical sludges	125	Drain
Pulp & paper	Toxic sludge	180	Unknown
Refineries	Hydrocarbons	180	Export
Foundry	PCB (once only)	(1380)	Export
Refineries	Caustic sludge	120	Dump
Packaging & print	Resin & glue	60	Dump
Glass making	Lead sludge	72	Dump
Manufacture of explosive	TNT & explosives	20	Stored
Fish canning	Treatment sludge	15 000	Dump
	Total	**79 146**	
Pesticides	Containers (estimate)	1600	Stored
Printing	Containers (estimate)	200	Dump
Detergent & soap	Containers	3150	Stored
	Total	**4950**	
Udanax City			
Excavation (old gas works)	Contaminated soil (tar) *(once only)*	(1000)	Dump
Auto work shop	Oil & sludges, solvents	6225	Sold
Shipyard	Hydrocarbon oils	983	Sold
Hospital	Pathological waste	472	Dump
Construction sites	Asbestos	190	Dump
Laboratories	Mixed chemicals	253	Drain
Harbour	Sludges	328	Dump
Printing	Photographic wastes	434	Drain
Power plant	Ash & PCB	700	Dump
Storeyard	Pesticides/DDT	50	Dump
WW treatment plant	Sludge	800	Dump
	Total	**10 483**	

[2] Quantities in cubic meters per year, containers in pieces per year

[3] ***Drain:*** discharged to a drain or surface water body; ***Dump:*** disposed at a offsite or on-site dumping ground; ***Export:*** export out of Udanax for treatment & disposal; ***Sold:*** sold to another party offsite for other use; ***Stored:*** stored on site, awaiting a disposal option; ***Unknown:*** present disposal option is unknown.

Table 6: Result [4] of questionnaire survey of hazardous waste in Industrial Estate B

Plant/Process	**Industrial production output** (10^3 tonnes/year)	**Quantity of waste** [5] (solid and liquid)
Vegetable oil refining	50	
Phosphoric acid	90	
Latex paints	230	
Tanning	3m hides/y	
Battery production	(uses 4000 t/y)	
Sulphuric acid	120	
Textile	26m m/y	
Pharmaceutical	40	
Rubber tyres	100	
Paper & pulp	125	
Steel foundries	50	
Electroplating Cu	20	
Electroplating Cr	8	
Pesticides	35	

[4] Not all industries in the Estate responded to the survey.

[5] None of the respondents supplied information on quantities and disposal method.

5. CURRENT STATE OF HAZARDOUS WASTE DISPOSAL

General

It is known from the industrial survey that a number of companies treat their own wastewaters and air emissions, but this is not universal.

Many treatment systems are known to be ineffective, or badly operated.

Most residues and chemical wastes are dumped on factory land or taken away to local dumping grounds.

No records are kept.

Two industrial waste recyclers in *Industrial Estate B* are active in reclaiming profitable waste streams such as oils and solvents respectively. Total capacity is around $400m^3$ p.a. solvents, and $1000m^3$ p.a. of oil. Around $4000m^3$ of waste oil is also burnt as supplementary fuel in two industrial boilers.

Refineries burn waste oil and sludge as fuel on-site. One company collects and reclaims batteries. Asbestos waste from building sites is dumped together with other building debris.

Existing municipal dumping sites in Udanax City

At present there are two dumping sites within the Udanax City Metropolitan Area, namely:

Eastern dumping site
(850,000 cubic meters)

This site is located on the eastern part of the city, approximately 2km from the coast. The site structure consists of fine sands to gravel, with a thin deposit of low permeable clay layer.

It is operated by a private company and it accepts only domestic wastes. As a general practice, industrial and toxic wastes are not dumped in this site.

Some of the major problems of this site are—

- high groundwater table
- bacteriological contamination of groundwater aquifers
- pollution of nearby coastal area
- frequent complaints from the nearby residents about odour and noise pollution
- scavenging
- residential areas within 150 m of the site
- no security fencing, amenity blocks, or proper roads.

Western dumping site
(2,500,000 cubic meters)

This site is located to the south-west of the city. It is operated by a local municipal authority. Both domestic and toxic industrial wastes are dumped in this site. Even though this site is situated in a clay pit, due to lack of initial lining, all the nearby groundwater aquifers are already contaminated with trace metals.

For the past three years, the National Environmental Bureau has monitored the groundwater quality in this site, and the results are presented in *Table 7.*

As this site is located further away from the residential area, the site operators receive fewer complaints from the public.

Some of the problems of this dumpsite are:

- groundwater pollution (but relatively low groundwater table)
- operational problems due to hazardous wastes (explosions, fires, poor handling of wastes, etc.)
- odour problem
- excessive scavenging
- consumption of raw garbage by domestic animals (goats, cows, etc.)
- no security fencing, amenity blocks, or proper access roads.

Recently the Udanax City Council has formed an ad-hoc committee to identify appropriate disposal options for the hazardous wastes produced in *Industrial Estates A* and *B*, and in Udanax City. After reviewing all possible options, the committee concluded in its report to the mayor, that:

> *"Taking into consideration the availability of the trained professionals and their technical know-how, and economical aspects, the most immediate hazardous waste disposal option for the Udanax City Metropolitan Area is through construction of a landfill disposal site, with pre-treatment units".*

The committee also proposed a set of policy elements for hazardous waste control, namely:

1. Waste reduction is the first priority for all industrial waste streams.
2. The waste producer has to bear the cost of waste treatment and disposal.
3. Liquid wastes will not be accepted for landfill (even in drums).
4. All liquid waste has to be solidified either by the waste producers or at the landfill site prior to landfill.
5. All toxic waste needs to be appropriately pre-treated prior to disposal at the landfill site.
6. Landfill sites should be operated by a private contractor, and the control and surveillance should be under the authority of the Municipalities, pending the creation of an eventual national environmental agency.
7. On-site landfill of industrial wastes at factories is not advocated.
8. All new toxic wastes should be subject to comprehensive hazard evaluation, by the National Environmental Bureau prior to landfilling.
9. The local public should be involved in all decision making stages of landfill site selection, design, operation, and rehabilitation.

Following the ad-hoc committee's recommendation, a regional committee—consisting of local engineering consultancies, Udanax City administrators and environmental authorities—was established to recommend a plan for a landfill disposal facility.

This committee has identified two potential sites and their characteristics are shown in *Table 8*. The location of these sites is indicated in *Figure 1*.

Table 7: Groundwater quality in the Western dumping site

Parameter	WHO [6]	1988	1989	1990
Colour	5	7	10	11
pH	7-8.5	8	8.4	8.9
Turbidity (units)	5	11	13	15
Total solids (mg/l)	500	400	450	570
Total Iron (mg/l)	0.1	0.11	0.14	0.11
Copper (mg/l)	0.05	0.01	0.03	0.05
Zinc (mg/l)	5.0	4.4	5.5	5.9
Calcium (mg/l)	75	80	77	88
Sulphate (mg/l)	200	125	155	160
Chloride (mg/l)	200	250	290	330
Arsenic (mg/l)	0.05	0.04	0.07	0.09
Cadmium (mg/l)	0.01	0.002	0.015	0.019
Cyanide (mg/l)	0.05	0.035	0.049	0.066
Lead (mg/l)	0.1	0.08	0.09	0.12
Mercury (mg/l)	0.001	0.002	0.002	0.003

[6] WHO 1971 Highest Desirable Level for Drinking Water.

Table 8: Characteristics of the proposed new landfill sites

	Blue site	Green site
Soil properties		
Moderately coarse sandy soil	—	0-5m
Medium silty clay	0-18m	5-11m
Fine silty clay	18-40m	11-40m
Erosion potential (surface)	Average	Minimum
Hydrology		
Floodplain area	yes	no
Wetlands	no	no
Distance from nearest water supply source	4km	10km
Groundwater table	5m	55m
Groundwater quality		
Total dissolved solids (mg/l)	7400	1000
Chloride (mg/l)	2000	200
Nitrates (mg/l)	40	80
pH	8	7.8
Topography		
Nature of the site	flat	uneven
Present land use	wooded area	cotton growing
Drainage	poor	good
Present air quality	average	good
Present odour problems	none	none
Infrastructure		
Distance from Industrial Estate A	5km	35km
Distance from Industrial Estate B	29km	8km
Distance from Udanax City centre	14km	28km
Distance from nearest expressway	6km	2km
Distance from nearest railway line	5km	5km
Distance from the coast	5km	10km
Nearest residential area	5km	18km
Construction of power supply lines	500m	1.5km
Construction of water supply lines	700m	8km
Construction of sewer lines	700m	8km
Meteorological		
Rainfall (mm/year)	650	680
Average temperature (°C)	24	27
Prevailing wind direction	west to east	

Figure 1 indicates the location of the Industrial Estates with respects to the landfill sites.

6. INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

Oil companies and some chemical companies have bulk chemical transport vehicles and trained drivers, but most chemical products and wastes are transported in drums in conventional trucks. Labelling and identification of hazards is generally poor.

Emergency service teams exist at the major petrochemical complexes. An oil spill response team has been created in the major ports that handle tankers.

Engineering consultants are reasonably well represented in Udanax but have little experience in designing waste treatment plants. Apart from the National Environmental Research Centre, four chemical laboratories in the universities, and the health and agriculture ministries, there are no public facilities for sophisticated chemical analysis. Company laboratories sometimes carry out waste analysis for outside bodies during emergencies.

The Civil Engineering Department of the National University of Udanax has a special curriculum on environmental and geotechnical engineering. This department offers both undergraduate and postgraduate level courses, and trains around 50 environmental and geotechnical engineers per year. The environmental engineering section carries out fundamental research in fields such as: pollution control, solid and hazardous waste disposal, water pollution, water and wastewater treatment. The geotechnical section is involved in conducting field surveys on the western dump site for its upgrading.

Neither the Institution of Engineers nor the Chamber of Commerce has an environmental committee.

7. ADMINISTRATIVE RESPONSIBILITIES IN ENVIRONMENT AND WASTE DISPOSAL

a) General Environment

Water pollution regulations are administered by four inspectors in the Ministry of Resources and Energy (Water Supply Department). The main emphasis has been on quality of drinking water supplies. Specific monitoring and enforcement is carried out by regional office staff in the provinces with the assistance of National Environmental Research Centre.

The Ministry of Agriculture is responsible for pesticides and groundwater affairs. It has delegated day-to-day responsibility to provincial administrations. The main purpose of the Groundwater Act is to provide a mechanism for collecting pumping fees. The Ministry has the power to approve or ban pesticides.

Occupational health regulations do not yet include chemical exposure limits.

Environmental impact assessments are evaluated by the Ministry of Planning when it examines major projects. One officer handles these assessments and advises the Minister accordingly.

An Environmental Bureau of four persons within the Prime Minister's Department is responsible for coordinating environmental programmes, acting as international focal points, and advising the Prime Minister. The Bureau has no formal links with other ministries.

b) Waste Disposal

The waste disposal regulations are administered by the municipalities. In most places, municipal employees collect and transport city garbage to the dumping grounds.

Industry employs cartage contractors for this task, or uses its own vehicles.

Table 9: Summary of current pollution and waste laws

Water Pollution Regulations (1981) under the Water Resources Act (1978)

- offence to pollute
- can set standards for effluents
- can order action to clean-up

Environment Assessment Act (1985)

- EIA required for all large industrial projects $ 2 m+
- EIA report format is prescribed

Waste Disposal Regulations under Public Health Act (1958)

- wastes must be placed in designated locations
- deposit to be kept free of disease, vermin, fires
- only approved operators may run a waste disposal operation
- must be safe at all times
- municipalities have duty to ensure collection of waste

PART III

Casework Sessions

A NOTE FOR SESSION LEADERS

The notes provided in this manual are centred around a series of tasks that need to be completed in order to satisfactorily plan for, construct and operate industrial landfills that accept hazardous waste. The needs of regulatory authorities are also addressed.

The notes for each session specify the tasks to be carried out, and give some further information that will assist in completing them.

However, the information is not necessarily complete, nor need the examples be always followed. Often guidance by session leaders will be necessary to interpret and adapt the practical exercises.

Many of the exercises are open-ended.

A time limit should be set for the exercises chosen. Not all the exercises may be able to be done in the time available.

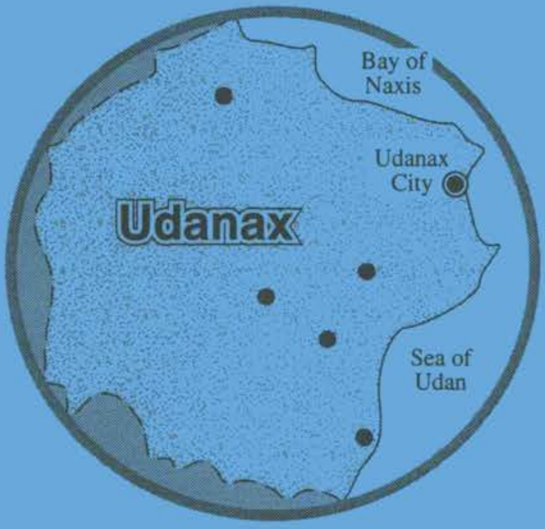
The notes are intended to stimulate, but not substitute for group work.

Local experience of participants may be valuable in guiding the discussion.

Casework Notes *for* SESSION 1

PART III

UNEP



Identification of Hazardous Wastes and Disposal Options

CONTENTS

1.1 INTRODUCTION

The options for disposal of wastes depend very much on the chemical and physical characteristics of the waste, as well as on the quantities involved.

Accordingly the correct identification of industrial waste is an important first step in any waste disposal plan.

Identification must be sufficiently comprehensive to decide—

- whether it can be accepted into a site
- if it needs pre-treatment or stabilisation before disposal
- what are the hazards to workers
- how it should be handled and disposed of.

Identification must also—

- indicate any special monitoring parameters
- allow listing in the reporting documents of the site.

Identification must always be in accordance with established criteria based on the chemical characteristics of the waste, its process origins, and its hazard properties. These criteria are elaborated in a variety of national and international reference documents. The Basel Convention, for example, shows the waste characteristics and properties that have now been accepted by most of the international community.

The relevant tables from the Basel Convention can be found in the references. Some other characteristics and criteria useful in decisions on landfill are shown on the following pages.

A full identification of wastes requires exhaustive chemical analysis, including search for trace constituents in supposedly non-hazardous wastes.

Past experience, however, has shown that industrial processes around the world usually produce similar waste types, and an identification according to process origin already gives most of the information we need to make management decisions.

The quantities of waste generated may also influence decisions on disposal. Treatment and disposal options for small quantities are often different to those for large volumes of waste. The total volume of waste has to be estimated in order to calculate landfill capacity.

The exercises in this session will aim to identify the industrial waste stream in Udanax, and estimate how much of this is hazardous.

Subsequently the best disposal options can be selected, including the amount that needs to be disposed of to landfill. Waste quantities were already identified in the Udanax country report. In this Session, *Section 1.2* on *Background Information* gives some tables that will help in identifying hazards and disposal options, but other criteria can also be used.

For the purposes of this workshop, only the information in the Udanax country report is used. This gives a first overview of the wastes; however, in real situations, a certain amount of further survey and analysis may be needed in order to improve the accuracy of the evaluation.

1.2 BACKGROUND INFORMATION

Table 1.1: Properties and disposal of common industrial wastes

Reprinted from: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*; 3 vols, World Bank/WHO/UNEP, 1989.

Recommendations are those for general situations. Practical choices will be influenced by appropriate pre-treatment and/or availability of suitable facilities. Disposal to sewers, watercourses and landfill is subject to acceptance criteria of relevant authorities.

Key

Property		Recommended Disposal	
S	= toxic, carcinogenic	r	= recovery, recycle
F	= flammable	pc	= physical/chemical treatment
R	= corrosive, highly reactive	s	= solidification
P	= putrescible	l	= landfill (normal) (licensed)
Od	= odorous	l*	= landfill (impervious) (licensed)
		b	= biological treatment
		i	= incineration
		d	= water/sewer discharge subject to agreement or licence

Waste Type	Code	Property					Recommended Disposal items in ( ) refer to treatment residue							
		S	F	R	P	Od	r	pc	s	l	l*	b	i	d
Abbatoirs residues	061				✓	✓				✓		✓	✓	(✓)
Acids and solutions *(inorganic)*														
Alkylation acid	029	✓		✓			✓	✓			(✓)			(✓)
Boric	029	✓					✓	✓			(✓)			(✓)
Chromic	023	✓		✓			✓	✓			(✓)			(✓)
Fluosilic	029	✓		✓			✓	✓			(✓)			(✓)
Fluoboric	029	✓		✓			✓	✓			(✓)			
Hydrochloric	021	✓		✓			✓	✓			(✓)			
Hydrofluoric	023	✓		✓			✓	✓			(✓)			
Nitric	022	✓		✓			✓	✓			(✓)			
Perchloric	029	✓		✓			✓	✓			(✓)			
Phosphoric	022	✓		✓			✓	✓			(✓)			
Pickling acids	029	✓		✓			✓	✓			(✓)			
Sulphurous	029	✓		✓			✓	✓			(✓)			
Sulphuric	021	✓		✓			✓	✓			(✓)			
Acids, organic														
Acetic	029	✓	✓	✓		✓	✓	✓			(✓)			(✓)
Butyric	029		✓			✓	✓	✓			(✓)	✓	✓	(✓)
Formic	029	✓	✓	✓		✓	✓	✓			(✓)		✓	(✓)
Lactic	029					✓	✓	✓			(✓)	✓		(✓)
Oxalic	029	✓		✓			✓	✓			(✓)			(✓)
Sulphonic acids	029	✓		✓			✓	✓			(✓)			(✓)
Trichloacetic	029	✓		✓			✓	✓			(✓)			(✓)
Alkaline materials														
Ammoniacal solutions	031	✓		✓		✓	✓	✓			(✓)			(✓)
Caustic soda or Sodium hydroxide	031	✓		✓			✓	✓			(✓)			(✓)
Lime slurries	032			✓		✓	✓	✓		✓				
Lime neutralised metal sludge	033	✓							✓		✓			
Soda ash or Sodium carbonate	031			✓			✓	✓			(✓)			(✓)

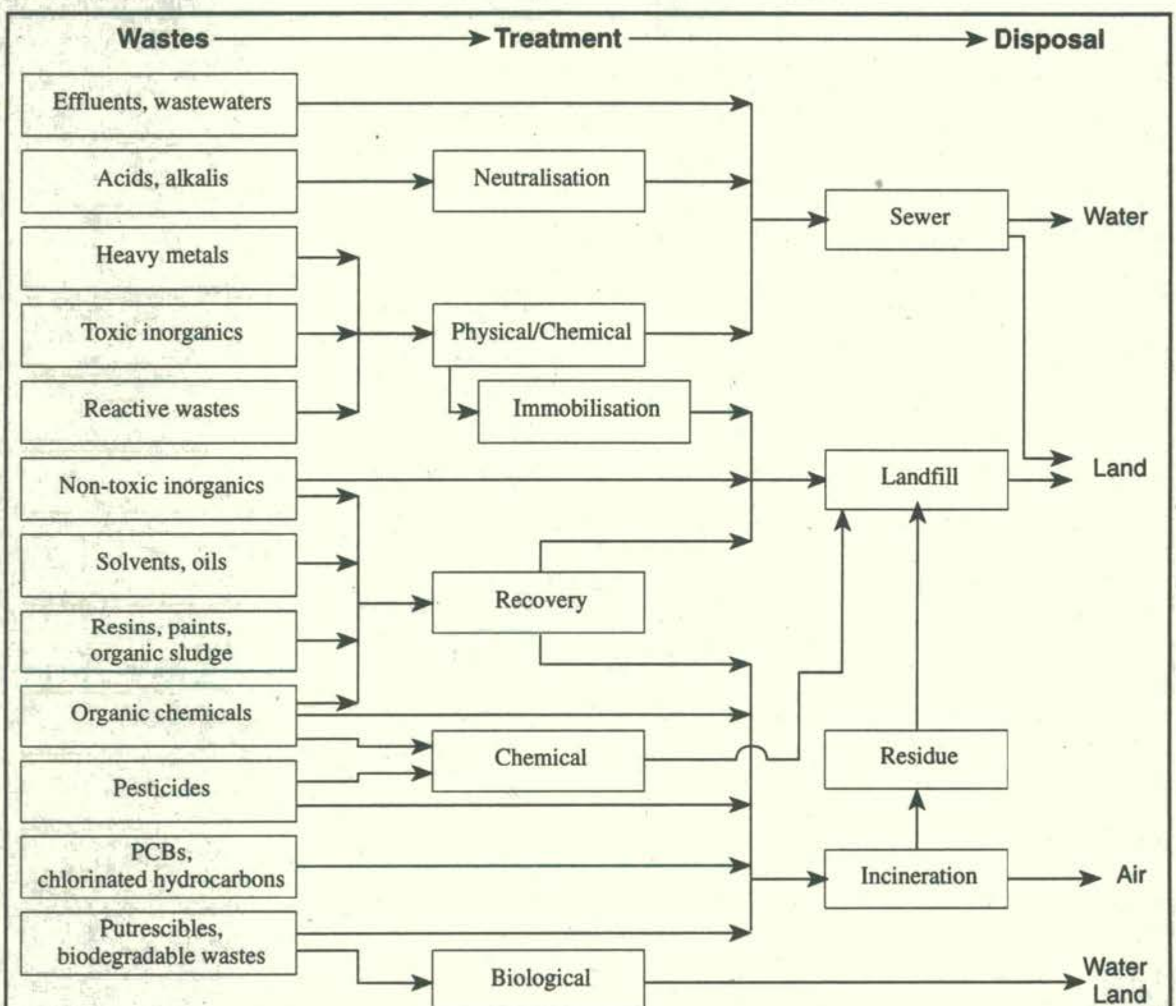
Waste Type	Code	Property					Recommended Disposal items in ( ) refer to treatment residue							
		S	F	R	P	Od	r	pc	s	l	l*	b	i	d
Sodium phosphate or polyphosphates	031	✓		✓			✓	✓		(✓)			(✓)	
Sodium silicate	031	✓		✓			✓	4			(✓)			(✓)
Sodium sulphode	045	✓				✓	✓	✓			(✓)			(✓)
Sodium peroxide	051	✓		✓			✓	✓			(✓)			(✓)
Alkaline cleaners	031	✓		✓			✓	✓			(✓)			(✓)
Alkali metals	055	✓	✓	✓			✓	✓			(✓)			(✓)
Animal residues	061				✓	✓	✓			✓		✓	✓	
Antimony compounds	045	✓					✓	✓	(✓)		(✓)			
Arsenic compounds	045	✓					✓	✓	(✓)		(✓)			
Asbestos wastes	181	✓							✓	✓				
Bags—*previously contained hazardous materials*	121	✓							✓		✓		✓	
Barium salts	045	✓					✓	✓	✓		(✓)			
Bleaching powders and solutions	051	✓		✓		✓	✓	✓			✓			
Boron (compounds of)	045	✓					✓	✓			✓			
Cadmium (compounds of)	045	✓					✓	✓	(✓)		(✓)			
Cannery wastes	062				✓	✓				✓		✓		
Cattle dips and residues	049	✓			✓	✓		✓	✓	(✓)	(✓)			
Carbonised liquors *wood or coal*	159					✓		✓					✓	
Chlorinated hydrocarbons														
Chloroform	074	✓				✓	✓						✓	
Carbon tetrachloride	074	✓				✓	✓						✓	
Ethylene dichloride	074	✓				✓	✓						✓	
Perchlorethylene	074	✓				✓	✓						✓	
Trichloroethane	074	✓				✓	✓						✓	
Trichloroethylene	074	✓				✓	✓						✓	
Chromium compounds	045	✓					✓	✓	✓		(✓)			
Copper compounds	045	✓					✓	✓	✓		(✓)			
Cyanides														
Plating residues	013	✓					✓	✓			(✓)			(✓)
Heat treatment residues	014	✓					✓	✓			(✓)			(✓)
Metal complexes	015	✓					✓	✓			(✓)			(✓)
Organo cyanides	159	✓	✓	✓			✓	✓			(✓)			
Detergents	155	✓					✓	✓			✓			(✓)
Disinfectants	159						✓	✓			(✓)			(✓)
Drugs—*see Pharmaceuticals and residues*														
Dyestuffs	061/9	✓									✓		✓	
Explosives	053	✓	✓	✓				✓						
Fats, grease	104				✓	✓	✓			✓		✓	✓	
Fish residues	081				✓	✓				✓		✓	✓	
Fluorides and compounds containing fluorine	042	✓					✓	✓	✓		✓			
Fruit residues	082				✓	✓				✓		✓		(✓)
Fungicides—see *Pesticides*														
Grease trap residues														
domestic	083				✓	✓				✓		✓		
commercial	084				✓	✓					✓	✓		

Waste Type	**Code**	**Property**					**Recommended Disposal** items in ( ) refer to treatment residue							
		S	F	R	P	Od	r	pc	s	l	l*	b	i	d
Hydrocarbons														
Lubricating oil	101		✓				✓						✓	
Light oil	101		✓				✓						✓	
Solvents (low flashpoint)	072		✓				✓						✓	
Insecticides and contaminated containers—see *Pesticides*														
Isocyanates	159	✓	✓	✓			✓	✓			(✓)			(✓)
Lead compounds	045	✓					✓	✓	(✓)		(✓)			
Lime slurries	032			✓			✓	✓		✓				
Lime neutralised metal sludges	033	✓							✓		✓			
Manganese compounds	047	✓					✓	✓	(✓)		(✓)			
Mercaptans	153	✓	✓			✓		✓					✓	
Mercury and compounds	045	✓					✓	✓	(✓)		(✓)			
Methacrylates	153	✓	✓			✓	✓	✓					✓	
Motor fuel additives and residues	071	✓	✓								✓		✓	
Nickel compounds	045	✓					✓	✓	✓		(✓)			
Nitrates	051	✓		✓			✓	✓			(✓)			(✓)
Oils														
Cutting oils	101		✓				✓				✓		✓	
Cutting emulsions	103					✓		✓			✓		(✓)	(✓)
Hydrocarbon	101		✓				✓				✓		✓	
Lubricating	101		✓				✓				✓		✓	
Organo-Nitrates	159	✓	✓	✓			✓	✓						
Oxidising agents														
Chlorates	051	✓		✓			✓	✓			(✓)			(✓)
Chromates	051	✓					✓	✓			(✓)			(✓)
Nitrates	051	✓		✓			✓	✓			(✓)			(✓)
Permanganates	051	✓		✓			✓	✓			(✓)			(✓)
Peroxides	051	✓		✓			✓	✓			(✓)			(✓)
Paint thinners (low flashpoint)	072		✓				✓						✓	
Pesticides	161/ 9						✓	✓	(✓)		(✓)		✓	
Peroxides	061	✓		✓			✓	✓			(✓)			(✓)
Pharmaceuticals and residues	154	✓						✓	✓	(✓)	✓		✓	
Phenol and phenolic compounds	152	✓				✓							✓	
Phosphorous residues	054	✓	✓	✓		✓		✓	✓		(✓)		✓	
Pickling acids/solutions	029	✓		✓			✓	✓			(✓)			(✓)
Poisons—*any material which would be labelled under Schedules 1-7 of the Poison Act*	045	✓							✓		✓			✓
Polychlorinated Biphenyls (PCBs)	156	✓						✓					✓	
Radioactive materials—*controlled under other Acts*	171/ 2	✓						✓	(✓)		(✓)			
Scallop shells	081				✓	✓				✓				
Selenium compounds	045	✓					✓	✓	✓		(✓)			
Sheep dips and residues	049	✓						✓	✓	(✓)	(✓)			
Solvents, low flashpoint	072		✓				✓						✓	
Sulphides	045	✓				✓	✓	✓			(✓)			(✓)
Sulphites	045	✓				✓	✓	✓			(✓)			(✓)
Surfactants	155	✓					✓				✓		✓	
Tetraethyl lead residues	151	✓	✓						✓		(✓)		✓	

Waste Type	Code	Property					Recommended Disposal items in ( ) refer to treatment residue							
		S	F	R	P	Od	r	pc	s	l	l*	b	i	d
Timber preservatives	049	✓						✓	(✓)		(✓)			
Thallium compounds	045	✓					✓	✓	(✓)		(✓)			
Triple Interceptor Trap residues (TIT)	103					✓		✓		✓				✓
Turpentine residues	071	✓	✓				✓						✓	
Vanadium compounds	045	✓					✓		✓		(✓)			
Vegetable wastes	082				✓	✓	✓			✓		✓		
Waxes—animal and plant	182		✓			✓	✓			✓			✓	
Weedicides—see *Pesticides*														
White spirits	072		✓				✓						✓	
Zinc compounds	045	✓					✓	✓			✓			

Based on: Draft Industrial Waste Strategy for Victoria, EPA of Victoria—Australia, 1985.

Figure 1.1: Recommended treatment and disposal of industrial wastes



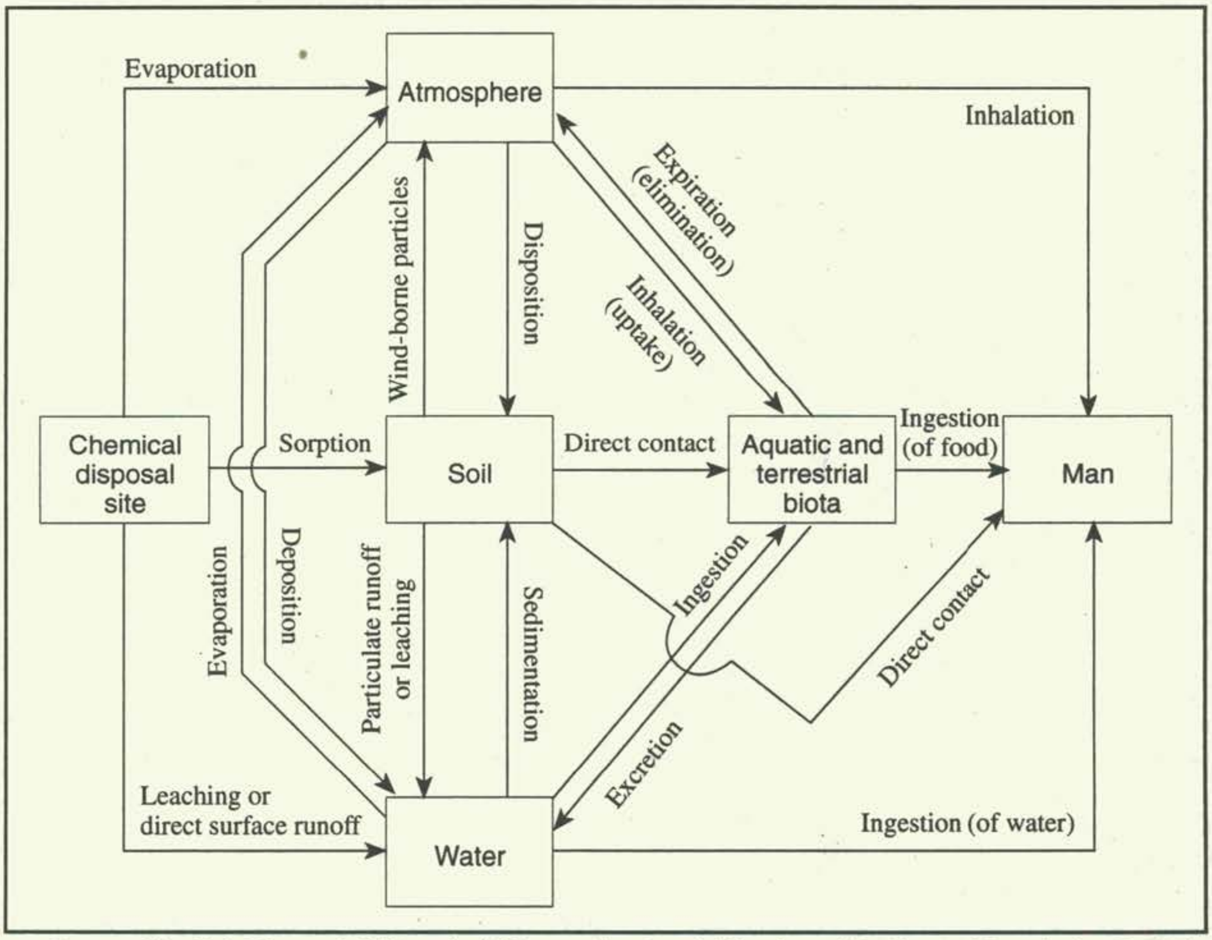
Based on: Draft Industrial Waste Strategy for Victoria, EPA of Victoria—Australia, 1985.

Table 1.2: Potential risks of landfills

Source	Pathway	Receptors	Risks
Liner failure; leachate leakage	Hydrogeological	Groundwater; potable water supply; the public; rivers and associated flora and fauna	Pollution of groundwater; loss of a potable supply; public health risk; damage or loss of flora and fauna
Leachate discharge	Sewer	Sewage treatment works	Effects upon biological process
Contaminated surface water	Run-off	Soils, flora and fauna, watercourses, the public (via ingestion of water)	Water pollution; public health risk; damage or loss of fauna
Gas migration	Geological: soils, landfill cap, to air	Buildings and people, flora	Explosion and fire, death or serious injury, asphyxiation; damage and loss of flora
Dust	Air	People and flora	Health risk
Odour	Air	People	Loss of amenity and nuisance
Exposed wastes	Direct contact	People	Health risk

Source: J. Petts, Loughborough University, 1993.

Figure 1.2: Potential human and animal/plant exposure pathways of hazardous substances from a disposal site



Source: *The Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989.

Table 1.3: Waste treatment/disposal technologies checklist

General Division	Subdivision		
Recycling	• Gravity Separation • Solvent Extraction	• Filtration • Chemical Regeneration	• Distillation
Physical chemical	• Neutralisation	• Precipitation/Separation	• Detoxification(chemical)
Biological	• Aerobic Reactor	• Anaerobic Reactor	• Soil Culture
Incineration	• High temperature	• Medium temperature	• Co-incineration
Immobilisation	• Chemical fixation • Solidification	• Encapsulation	• Stabilisation
Landfill	• Secure landfill	• Normal landfill	• Co-disposal
Offshore	• Ocean incineration	• Ocean dumping	• Export

Table 1.4: List of potentially incompatible wastes [1]

1	Oxidising mineral acids	1											
2	Caustics	H	2										
3	Aromatic hydrocarbons	H,F		3									
4	Halogenated organics	H,F, GT	H, GF		4								
5	Metals	GF, H,F			H,F	5							
6	Toxic metals	S	S				6						
7	Sat aliphatic hydrocarbons	H,F						7					
8	Phenols and cresols	H,F							8				
9	Strong oxidising agents		H	H,F		H,F		H		9			
10	Strong reducing agents	H,F, GT			H, GT				GF, H	H,F, E	10		
11	Water and mixtures containing water	H			H,E		S				GF, GT	11	
12	Water reactive substances	← Extremely reactive: do not mix with any chemical or waste material →											12

E Explosive
F Fire
GF Flammable gas
GT Toxic gas
H Heat generation
S Solubilisation of toxins

Source: *Safe Disposal of Hazardous Waste: The Special Needs and Problems of Developing Countries* World Bank/WHO/UNEP, 1989.

[1] Before treatment

Table 1.5: Compatibility of selected waste categories with different waste solidification/stabilisation techniques

Waste Component	Cement-based	Lime-based	Thermoplastic encapsulation	Thermosetting micro-encapsulation	Macro-encapsulation
Organics					
Organic solvents and oils	May impede setting, may escape as vapour	May impede setting, may escape as vapour	Organics may vaporise on heating	May retard set of polymers	Must first be absorbed on solid matrix
Solid organics (e.g. plastics, resins)	Good: often increases durability	Good: often increases durability	Possible use as binding agent	May retard set of polymers	Compatible: many encapsulation materials are plastics
Inorganics					
Acid wastes	Cement will neutralise acids	Compatible	Can be neutralised before incorporation	Compatible	Can be neutralised before incorporation
Oxidisers	Compatible	Compatible	May cause matrix breakdown or fire	May cause matrix breakdown	May cause deterioration of encapsulating materials
Sulphates	May retard setting and cause spalling unless special cement is used	Compatible	May dehydrate and rehydrate causing splitting	Compatible	Compatible
Halides	Easily leached from cement, may retard setting	May retard set, most are easily leached	May dehydrate	Compatible	Compatible
Heavy metals	Compatible	Compatible	Compatible	Acid pH solubilises metal hydroxides	Compatible

Source: US EPA, 1981, Report N° SW-873 (PB-81-181-505)

1.3 EXERCISES

Preliminary Exercise

What environmental problems from landfills or dumpsites have been already observed in Udanax?

EXERCISE 1.1 Landfill hazards

Refer to *Part II*, *Table 5*[2]. Review quickly the types of industrial and other hazardous waste currently going to the dumpsites in Udanax. What problems is each of these likely to give **during a landfill operation**?

What long-term problems could each of these wastes give rise to **in a completed landfill**?

[2] For ease of reference, this Table has been reproduced on the next page as *Table 1.6/*

Table 1.6: Measured hazardous waste in Industrial Estate 'A' and Udanax City

Process/Source	Waste type	Quantity (m^3/year)[3]	Current practice[4]	Landfill option
Industrial Estate A				
Chemicals manufacture	Acids, chemicals	53	Drain	
Metal finishing	Metals	44 628	Drain	
Detergents	Alkalis	2323	Drain	
Fertiliser	Heavy metals, alkalis	165	Drain	
Foundry	Dust/Slag	503	Dump	
Resin manufacture	Formaldehyde	438	Drain	
Electronics	Oil & solvents	404	Sold	
Foundry/metal works	Hydrocarbon	115	Sold	
Packaging/printing	Solvent sludges	27	Dump	
Vehicle assembly	Sludge (paint)	12	Stored	
Battery manufacture	Sludge with heavy metals	60	Dump	
Leather tanning	Treatment sludge	892	Dump	
Pesticides	Filter materials, surplus stock	111	Dump	
Textiles	Sludge	236	Dump	
Chlorine production	Sludge(contains mercury)	122	Dump	
Vehicle assembly	Non-halogenated spent solvent	224	Dump	
Electroplating	Cyanide wastes	28	Stored	
Plastics & rubber	PVC waste	48	Dump	
Beverage industry	Organic waste	13 000	Drain	
Wood products	Chemical sludges	125	Drain	
Pulp & paper	Toxic sludge	180	Unknown	
Refineries	Hydrocarbons	180	Export	
Foundry	PCB (once only)	(1380)	Export	
Refineries	Caustic sludge	120	Dump	
Packaging & print	Resin & glue	60	Dump	
Glass making	Lead sludge	72	Dump	
Manufacture of explosive	TNT & explosives	20	Stored	
Fish canning	Treatment sludge	15 000	Dump	
	Total	**79 146**		
Pesticides	Containers (estimate)	1600	Stored	
Printing	Containers (estimate)	200	Dump	
Detergent & soap	Containers	3150	Stored	
	Total	**4950**		
Udanax City				
Excavation (old gas works)	Contaminated soil (tar) *(once only)*	(1000)	Dump	
Auto work shop	Oil & sludges, solvents	6225	Sold	
Shipyard	Hydrocarbon oils	983	Sold	
Hospital	Pathological waste	472	Dump	
Construction sites	Asbestos	190	Dump	
Laboratories	Mixed chemicals	253	Drain	
Harbour	Sludges	328	Dump	
Printing	Photographic wastes	434	Drain	
Power plant	Ash & PCB	700	Dump	
Storeyard	Pesticides/DDT	50	Dump	
WW treatment plant	Sludge	800	Dump	
	Total	**10 483**		

[3] Quantities in cubic meters per year, containers in pieces per year

[4] ***Drain:*** discharged to a drain or surface waterbody; ***Dump:*** disposed at a offsite or on-site dumping ground; ***Export:*** export out of Udanax for treatment & disposal; ***Sold:*** sold to another party offsite for other use; ***Stored:*** stored on site, awaiting a disposal option; ***Unknown:*** present disposal option is unknown.

EXERCISE 1.2 Identification of types of wastes that could be disposed in a landfill site

You are carrying out a feasibility study for the future company that will manage the new ***Green Site*** (see *Part II* for details if you need to). You are preparing schedules for wastes the site can accept, as per waste groups below.

For the purpose of this exercise you have identified industrial wastes in Udanax with respect to the landfill options that a landfill manager has to face, as follows:

1. **Wastes that will definitely need to be landfilled as no other options are practicable:**

   e.g., Asbestos—based on the technical and economical considerations, secure landfill is the best option.

2. **Wastes that could be safely landfilled without prior treatment:**

   e.g., Biodegradable wastes—technically, biodegradable wastes can be landfilled; however, there often exist better options.

3. **Wastes which could be landfilled if they were pre-treated prior to landfill:**

   e.g., Liquid wastes; heavy metal salts. Pre-treatment options should include detoxification, precipitation, chemical and solidification, as appropriate.

4. **Wastes that should not be landfilled*:**

   e.g., Explosives, compressed toxic gases, liquid PCBs should not be landfilled for technical reasons. This group also includes wastes that should not be landfilled for policy reasons (in Udanax) e.g.. motor oils or surplus pesticides that can be reused.

(Can you think of other landfill options from the point of view of the operator?)

Table 1.6 is similar to *Table 5* from *Part II* of this Manual; however, a fifth column has been added. Indicate in this column which landfill option above is appropriate for each waste, i.e. number *1, 2, 3,* or *4*. If time is short, consider only those wastes from the city of Udanax that are currently being dumped. If more time is available, consider also wastes currently going to drains, exported, stored etc. (Remember that in the case of effluents it is the treatment sludges, not the effluent, that would be considered for landfill.)

Now, list some hazardous wastes from non-industrial sources such as small shops, agriculture, transport, households etc. Again indicate which landfill option above applies.

*Supplementary Exercise

For wastes in *Group 4* above, what alternative options should be applied? (ref. for example to Tables in Section 1.2)

EXERCISE 1.3 Quantities of hazardous waste for landfill

From *Table 1.6*, calculate as far as you can the total quantity of wastes in each category below.

Notes for the exercise

(i) Volumes in "current practice" in Table 1.6 do not necessarily represent the exact amount likely to go to a controlled landfill if it were available. Why not?

(ii) For non-industrial sources of hazardous waste, below, you will have to use intuition to guess the quantities you feel are likely.

	Waste type	Quantity (give units)
1	**Wastes that will definitely need to be landfilled**	
	• Industrial Estate A	
	• Udanax City	
	• Non-industrial sources (hazardous waste)	
2	**Wastes that could be landfilled without prior treatment**	
	• Industrial Estate A	
	• Udanax City	
	• Non-industrial sources (hazardous waste)	
3	**Wastes which should be pre-treated prior to landfill**	
	• Industrial Estate A	
	• Udanax City	
	• Non-industrial sources (hazardous waste)	
4	**Wastes that should not be landfilled**	
	• Industrial Estate A	
	• Udanax City	
	• Non-industrial sources (hazardous waste)	

EXERCISE 1.4 Calculation of wastes to be landfilled from Industrial Estate B

Table 6 in *Part II* of this Manual gave some information about waste produced from **Industrial Estate B**; however, the information was incomplete.

First, in the table below, try to provide as much of the missing information as possible using working tables for the calculation of waste loads shown in *Part II*.

Next, try to work out how much of the waste could in principle go to landfill disposal (categories *1*, *2* and *3* in Exercise 1).

(This Exercise clearly demonstrates how difficult it is to obtain a good answer if the initial information is not good.)

Complete as well as you can the Table below, and work out the total volume of industrial waste from Industrial Estate B that needs to be landfilled.

Plant/Process [5]	**Industrial Production Output** (10^3 tonnes/year)	**Quantity of Waste** (solid & liquid)	**For Landfill** (categories 1, 2 & 3)
Vegetable oil refining	50		
Phosphoric acid	90		
Latex paints	230		
Tanning	3m hides/y		
Battery production	(uses 4000 t/y)		
Sulphuric acid	120		
Textile	26m m/y		
Pharmaceutical	40		
Rubber tyres	100		
Paper & pulp	125		
Steel foundries	50		
Electroplating Cu	20		
Electroplating Cr	8		
Pesticides	35		

[5] Not all industries in the Estate responded to the survey.

EXERCISE 1.5 National waste generation

Note: This exercise is relevant if it is likely that a future secure landfill site will accept wastes from outside the immediate area of Udanax City. In this case an estimation of national waste generation will be necessary.

For further details of such estimation refer to the UNEP document *Hazardous Waste Policies and Strategies: A Training Manual.*

Exercises

(a) Using the waste coefficients in *Table 5* in the Background Section, together with the national employment figures in Table 3a of the Country Report, calculate the total quantity of plating/metal treatment waste that will be generated throughout Udanax.

(b) Compare this with the amount of electroplating waste expected from Industrial Estates A and B.

(c) What can you conclude from the comparison?

EXERCISE 1.6 Comparison of industrial and other waste quantities

Here you will calculate the total quantity of urban waste and sewage sludge generated in Udanax City, and compare this with the total amount of industrial waste generated in the City and in the two Industrial Estates.

The Country Report (Part II of this Manual) gives enough information for you to be able to use the working tables in Part I to calculate:

(i) urban waste quantities

(ii) sewage sludge (assume this is landfilled)

(you will have to make some assumptions in several places)

You should compare the total with the maximum amount of hazardous waste that might be landfilled (Exercises 3 and 4).

EXERCISE 1.7 Accuracy of calculation

How useful do you think the results of your calculations are, keeping in mind the purpose for which you are doing them?

How can you improve the accuracy?

1.4 SESSION REPORT

In the space below, prepare a summary of your conclusions on the identification of hazardous waste in Udanax, and the role that landfill will need to play in the management of this waste.

This summary will be included in the final Task Force report to the mayor of Udanax.

Work Group ______________________________

Session ______________ Subject ______________

Main results and conclusions

Work Group Members ______________________________

____

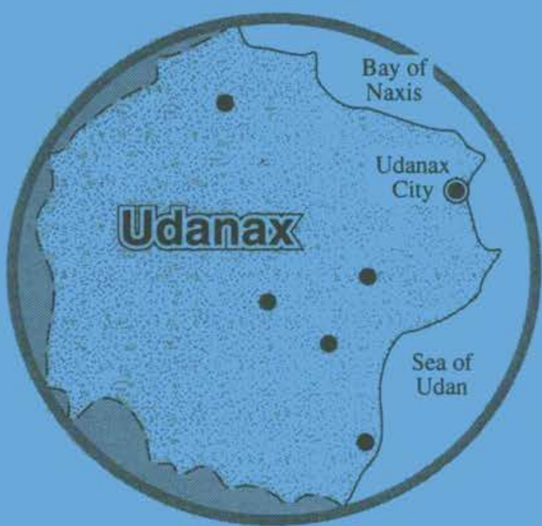
____

Return completed sheet to workshop co-ordinator for incorporation in the workshop report.

Casework Notes *for* SESSION 2

PART III

UNEP



Siting of Landfills: site selection and EIA

CONTENTS

2.1 INTRODUCTION

The suitability of a particular site for disposal of waste depends on many factors. These include—

- the quality and quantity of waste
- natural features of the site
- engineered safeguards
- operational procedures that will be adopted.

The assessment of a site must take all of the above into account, and try to predict the likely human and environmental consequences. If the impact is too high, then the site should not be used.

Siting criteria can often be presented as a series of map overlays which, when put together, clearly identify areas that meet all (or most) criteria.

Site assessment procedures vary according to the circumstances, but typically involve the following—

- checklists of possible impacts, to ensure that nothing is forgotten
- modelling or other predictive methods to evaluate likely impacts
- risk assessment to see if the impacts are acceptable

Formal studies on the above lines may take the form of Environmental Impact Studies (EIS), or equivalent. Such studies determine the likely impact. A decision to proceed also takes account of economic, social and political factors.

Landfill sites are often regarded with disfavour by local communities. This is partly because in the past, landfill sites have been badly chosen and operated, and partly because of the social stigma that now surrounds "wastes". The choice of future landfill sites must therefore be carefully explained.

Worldwide experience has been that a public dialogue must commence very early in a project, not as a communiqué when all decisions have been made.

2.2 BACKGROUND INFORMATION

Table 2.1: Landfill site selection criteria

Physical site	Should be large enough to accommodate waste for life of production facility.
Proximity	Locate as close as possible to production facility to minimise handling and reduce transport cost. Locate away from water supply (suggested minimum 1 km) and property line (suggested minimum 250 m).
Access	Should be all-weather, have adequate width and load capacity, with minimum traffic congestion. Easy access to major highways and railway transport.
Topography	Should minimise earth-moving, take advantage of natural conditions. Avoid natural depression and valleys where water contamination is likely unless good control of surface water can be assured (suggested site slope of less than 5%).
Geology	Avoid areas with earthquakes, slides, faults, underlying mines, sinkholes and solution cavities.
Hydrology	Areas with low rainfall and high evapotranspiration and not affected by tidal water movements and seasonal high water table.
Soils	Should have a natural clay base, or clay available for liner, and final cover material available; stable soil/rock structure. Avoid sites with thin soil above groundwater, highly permeable soil above shallow groundwater and soils with extreme erosion potential.
Drainage	Areas with good surface drainage and easy control of runoff.
Surface water	Protection of the site against floods. Avoid wetlands or other areas with high water tables.
Groundwater	No contact with groundwater. Base of fill must be above high groundwater table. Avoid sites above sole-source aquifers and areas of groundwater recharge.
Temperature	Not within area of recurring temperature inversions.
Air/wind direction	Areas where prevailing wind will carry-away any dust, emissions and odour from populated areas or ecologically sensitive areas.
Terrestrial and aquatic ecology	Avoid unique habitat areas (important to propagation of rare and endangered species) and wetlands. Avoid national parks, forests, flora and fauna reserves, and coastal areas.
Public health	Areas where construction and operation will not adversely affect public health.
Aesthetic	Sites where minimum visual impact is created due to construction and operation; sites should be designed considering surrounding landscape.
Noise	Truck traffic and equipment operation noise will not create nuisance.
Land use	Avoid populated areas and areas of conflicting land use such as parks, scenic areas, labour intensive industrial sectors, recreational reserves, camp sites, sporting reserves, intensive agricultural area, areas zoned for future urban development, etc.
Cultural resources	Avoid areas of unique archaeological, historical and paleontological interest.
Power and water	Areas with easy access to adequate power and water supply.
Sewer	Site near interceptor sewer or wastewater treatment plants.

Source: Compiled from various reference documents cited in *Part I.*

Table 2.2: Rating chart for screening of hazardous waste disposal sites

SCREENING/SELECTION CRITERIA	RELATIVE VALUE: 6 Ideal — 5 Excellent — 4 Above average — 3 Average — 2 Below average — 1 Marginal — 0 Unacceptable	Actual value	= Relative value	X Weight of criterion	= Weighted value
Office Review					
Precipitation *(inches/year)*	< 5 — 6, 7, 8, 9, 10, 15 — > 18			10	
Nearest surface water or stream *(miles)*	> 20 — 15, 10, 5, 4, 3, 2 — < 1			5	
Nearest use (discharge point) *(miles)*	> 20 — < 1			5	
Seismic activity *(miles)*	> 15 — 10, 5 — < 2			2	
Preliminary Field Reconnaissance					
Slope *(percent)* *	1.5, 2, 3, 4, 5, 10 — > 15 1.5, 1.2, 1.0, 0.9, 0.8, 0.7, 0.6 — < 0.5			4	
Geomorphic stability *(qualitative)*	Stable — Unstable			4	
Flooding potential *(qualitative)*	Low — High			4	
Wind erosion potential *(qualitative)*	Low — High			2	
Depth to water table *(feet)*	> 1000 — 700, 500, 400, 300, 200, 100, 80, 70, 60 — < 50			5	
Depth (distance) to fractured bedrock *(feet)*	> 1000 — 500, 400, 300, 200, 100 — < 50			5	
Type of burial media *(qualitative)*	Very fine sands & silts — Gravel Very fine sands & silts — Clay			4	
Subsidence *(feet)*	0 — < 5			3	
Optimum wind direction *(qualitative)*	Good — Bad			2	
Intermediate Field Reconnaissance					
Distance to known fault *(feet)*	> 5000 — 4000, 3000, 2000 — < 1500			3	
Burial media and underlying strata: Sorption capacity *(me/100gm)*	> 50 — 40, 30, 20, 10, 5 — < 2			4	
Burial media and underlying strata: Thickness *(feet)*	> 500 — 400, 300, 200, 100 — < 50			4	
Burial media and underlying strata: Engineering properties *(qualitative)*	Good — Bad			4	
Burial media and underlying strata: Permeability *(gal/day/ft²)*	0.1 — 0.2, 0.3, 0.4, 0.5, 1.0, 2, 3, 4, 5 — > 10 0.1 — 0.5, 0.2, 0.001, 0.005, 0.002 — > 0.001			4	
Burial media and underlying strata: Effective porosity *(percent)*	Intermediate — High Intermediate — Low			4	
Burial media and underlying strata: Structure *(qualitative)*	Simple — Complex			4	
A ratio of pan evaporation to precipitation minus runoff	> 84 — 80, 70, 60, 50 — < 40			5	
Hydrogeologic complexity *(qualitative)*	Simple — Complex			5	
Suitability for control of water table *(qualitative)*	Easy — Difficult			2	
Monitorability *(qualitative)*	Easy — Difficult			3	
Remediability *(qualitative)*	Easy — Difficult			3	
Hydraulic gradient *(feet/mile)*	< 10 — 20, 30, 40, 50, 70 — > 100			4	
	6 — 5 — 4 — 3 — 2 — 1 — 0			Total	

* If the slope is less than one percent and the site does not lie in the defined floodway of a stream course or lake and all other criteria have relative values above average, disregard chart values for *'slope'* and substitute an arbitrary value of *'6'*. In all other cases, use chart values.

Source: US EPA 600/2 - 85/018, 1985

Table 2.3: Landfill design elements for evaluation

1. Project outline

a. **Project description/outline proposals**
- area, depth, volume
- conceptual design.

b. **Design principles/site characteristics**
- dilute and disperse/containment/accumulate
- minimal leachate generation
- minimal environmental impact
- restoration of mineral workings or derelict land
- preserve, protect and enhance the natural environment of the site and its surroundings.

c. **Justification of scheme**
- waste sources, quantity, type, location
- area local plans (minerals, waste disposal)
- country structure plan
- local need
- site volume and life: *input rates; yearly, daily peak*.

d. **Community liaison/involvement**
- informal consultations.

e. **Inspections/visits**
- regulatory
- independent.

f. **Future legislation**
- incorporated in design
- phasing to permit later modifications.

2. Landfill operators details and resources

a. **Company and management structure of the landfill operator**
b. **Proposed staffing levels and experience**
c. **Technical and management support**
d. **Management systems, quality assurance**
e. **Previous company experience**
f. **Training policy**
g. **Health and safety policy and actions**
h. **Environmental policy and action**
i. **Consultants brief/scope (if used for part or whole of proposal document)**

3. Site characteristics

a. **National Grid reference**

b. **Past and existing land uses (official and unofficial)**
- mineral workings and reserves; contaminated land; material assets, e.g. roads and buildings; vegetation, woodland, crops, amenity use.

c. **Position in relation to other developments (existing or planned)**
- housing; industrial; agricultural; airports; local communities; land ownership.

d. **Surface and groundwater quality and quantity**
- seasonal fluctuations; base flow data; licensed and unlicensed waster abstractions; hydrology (ditches, streams, rivers, land drainage, floods).

e. **Land zoning designations**
- green belt; special landscape area; area of outstanding natural beauty; site of special scientific interest; agricultural land classification; rights of way;

f. **Topographic details**
- land survey; photographs; maps.

g. **Utilities**
- gas; electricity; telephone; water; sewerage.

h. **Geotechnical investigation**
- boreholes and trial pit logs; test results; soil tests.

i. **Background monitoring**
- water, surface, ground; air, dust; noise; traffic.

j. **Climate**
- prevailing wind direction; rainfall quantity, distribution; evaporation; variations.

k. **Transport infrastructure and usage**
- road, accident statistics; railway; river, canals.

l. **Geology**
- regional/local; solid/drift; subgrade stability/risk of subsidence.

m. **Hydrogeology**
- water sources; aquifers; water tables; flow rates and direction.

n. **Ecology**
- habitats; species; value.

o. **Landscape**
- form; value.

p. **Cultural heritage**
- archaeology; local cultures; value.

4. Environmental impact, mitigating measures and opportunities

The documentation should address the possible effects of the proposed landfill on any of the items identified during the site investigation and assessment. It should also identify the effects of landfilling operations and measures to be taken to reduce the possibility of an adverse environmental impact.

In addition to site specific items, the probable minimum to be covered will be—

a. **Traffic**
- numbers; types; access routes; highway cleaning; enforcement.

b. **Mud on roads**
- wheel cleaning; highway cleaning; enforcement.

c. **Litter**
- windblown; dropped on approach roads; litter pickers; litter nets (fixed or mobile); dumping outside the fence; illegal access to site; covered vehicles.

d. **Noise**
- existing levels; increase; screening.

e. **Odours and gaseous emissions**
- *from fresh waste:* daily cover, exposed area
- *from landfill gas:* control system, liner and cap
- *from leachate:* control system, liner and cap.

f. **Pests**
- *birds:* scaring, exposed area
- *rodents:* pest control officer, exposed area
- *flies:* pesticide, exposed area
- operational practices, waste type
- daily cover.

g. **Visual intrusion**
- long and short distance views; screening bunds, tree planting; phasing; long- and short-term.

h. Liquid emissions and discharges

- *surface water:* effect on local system
- *treated leachate:* control system
- *accidental:* control system and barriers; migration.

i. Surface and groundwater

- effects on quantity, quality, hydrographs, water tables, long term and seasonal fluctuations.

j. Fires

- precautions; emergency procedure.

k. Dust and debris

- daily cover; spraying of roads.

l. Temporary or permanent loss or damage to:

- existing land use; adjacent land use; landscape; transport infrastructure; geological formations; ecology; cultural heritage; public access/rights of way.

m. Hours of operation

- weekly working; weekends; lighting/noise/vehicle movements; holidays; emergency opening.

n. Benefits of proposed landfill

- new land use; reclamation of derelict land; conservation potential.

The above must consider the effects before, during and after landfilling.

5. Detailed design

a. Design criteria

b. Liquid control

- *surface water:* run off; ditches; cap requirements
- *groundwater:* dewatering; control.
- *leachate:* water balance calculations; formation rate, quantity, quality; critical level; collection, drains; abstraction passive/active; treatment; disposal; monitoring; migration, attenuation; liner requirements.

c. Gas control

- formation, rate, quantity, quality; abstraction; treatment; utilisation; diffusion/migration; condensate; liner and cap requirements.

d. Liner requirements

- material, sources, quantities; specifications; testing; quality control; method statements.

e. Hazard and risk management/assessments

- site specific requirements; components of system.

f. General and specific environmental monitoring

- amenity items; operations; quantitative; inspections; audits; frequency and schedule; gas, leachate and water; settlement; system for action and follow-up.

g. Waste body stability

- during filling; after completion.

h. Restoration

- aims; planned use; vegetation; construction; settlement; capping; soils; drainage; aftercare.

i. Site infrastructure

- offices, welfare/canteen: *building details/regulations*
- weighbridge
- roads: *car park; truck park; skip/bin park; broken-down vehicles*
- workshops/garages
- stores: *inflammable/fuel; waste; parts*
- laboratory facilities
- security fencing, gates, cameras, keyholders
- notice boards, signs
- mains services or alternatives

- wheel/vehicle cleaning
- landscaping of reception area.

6. Site operations

a. **Waste handling**
- *standard procedures:* plant; compaction method
- *difficult and special wastes:* drum; handling, disposal and recycling; clinical waste; asbestos; animal waste; slurries and sludges; malodorous wastes; liquid waste; other difficult waste.

b. **Traffic control**
- signs; supervision; routing of vehicles; lighting; roads, deposit area; face control; cover; sources, application.

c. **Inputs**
- administration; records, documentation, site diary. Monitoring; sampling, schedule. Non-conforming waste.

d. **Other operations**
- treatment plants; quarrying; recycling (facilities, screening, stockpiles); transfer (slave vehicles).

e. **Health and safety**
- high visibility clothing; protective equipment; electricity; excavation of waste—drilling; emergency plans (fire, spillages, non-conforming waste); trespassers.

f. **Working/operational plan**
- preparation; update; adherence to design and procedure for approval of deviations; fill sequence; lagoons, trenches, bunds; poor, inclement, winter weather (fog, rain, wind); dewatering; secure burial; cell construction; quantity control.

7. Possible consultees

- Local councils and authorities
- Health and safety ministry: e.g. mines and quarries inspectorate, factory inspectorate
- Ministry of environment
- Fire service
- Police
- Port authorities
- Railways
- Electricity/gas supply companies
- Society for the protection of nature
- Local pressure groups
- Local landowners
- Ministry of agricultural/fisheries/food
- Rivers authority
- Civil aviation authority
- Meteorological office
- Forestry department
- Water and sewerage companies
- Landowners association
- Local amenity societies
- National environmental groups
- National farmers union
- Department of environment
- Resident associations

Source: Shanks Mc Ewan, UK.

Table 2.4: Different stages of landfill site selection

1. Developing site selection criteria	6. Final technical evaluation and ranking of sites.
2. Identifying candidate sites best meeting these criteria.	7. Public involvement.
3. Initial review and evaluation of candidate sites.	8. Site selection.
4. Selection of sites for final evaluation.	9. Public hearing.
5. Evaluation of regional awareness.	10. Review.

Source: *The Solid Waste Handbook: A Practical Guide*, W.D. Robinson, 1986.

Table 2.5: Some possible impacts on ecology and human health

- **On ecology**

Construction period (land clearing)
- loss of ecosystem integrity
- erosion of soil
- alteration of nutrient cycle
- disturbance due to noise and vibration
- water quality deterioration
- dust/air pollution.

Landfilling period
- uptake of contaminated water by plants
- food chain (consumption of contaminated food/prey)
- bioaccumulation
- water, air and noise pollution
- introduction of species foreign to the area.

Post-closure period
- uptake of contaminated water by plants
- food chain (consumption of contaminated food/prey)
- bioaccumulation
- water, air and noise pollution
- establishment of foreign species.

Vulnerable components
- local species of fauna/flora
- endangered species
- fish and wildlife nursery areas
- spawning grounds
- ecologically sensitive areas such as mangroves.

- **On human health**

Construction period
- noise, dust/air pollution
- water pollution.

Landfilling and post closure period (release of hazardous substances)
- exposure pathways (inhalation, ingestion, skin contact, water consumption)
- exposure duration and magnitude.

Vulnerable components
- workers
- children
- elderly.

Figure 2.1: EIA scoping matrix

KEY

- ☐ Significant impact
- ☐ Low impact
- ☐ Negligible impact
- ☐ Unknown impact

	EFFECTS ON	Human, flora & fauna								Land use					Land			Water				Air					
	ACTIVITIES	Rocks	Noise	Emissions	Visibility	Appearance & landscape	Population change	Flora	Fauna	Recreation	Archaeology	Footpaths	Minerals	Agriculture	Surrounding land	Geological	Physical effects	Chemical emissions	Pollutants	Drainage	Hydrographic	Climate	Offensive odours	Particulate matter	Chemical emissions	Associated development	Traffic
Development stage	SITE FACILITIES																										
Development stage	ACCESS CONSTRUCTION																										
Development stage	SITE CLEARANCE																										
Development stage	SOIL STRIPPING																										
Development stage	DIVERSION OF SERVICES																										
Development stage	DIVERSION OF WATERCOURSES																										
Development stage	SCREENING																										
Development stage	LINER INSTALLATION																										
Development stage	EARTH MOVING																										
Development stage																											
Development stage																											
Operational stage	TRAFFIC MOVEMENTS																										
Operational stage	MINERAL EXCAVATION																										
Operational stage	MINERAL PROCESSING																										
Operational stage	WASTE UNLOADING																										
Operational stage	WASTE COMPACTING																										
Operational stage	DAILY COVER SPREADING																										
Operational stage	LEACHATE																										
Operational stage	GAS																										
Operational stage	LITTER																										
Operational stage	VERMIN																										
Operational stage	CAPPING																										
Operational stage	SOIL REPLACEMENT																										
Operational stage	REVEGETATION																										
Operational stage	TREE PLANTING																										
Final stage	LEACHATE																										
Final stage	GAS																										
Final stage	AFTERCARE																										
Final stage	MONITORING																										

Please note that the impact may have a positive effect, a negative effect, or a combined effect.

Source: Shanks McEwan, UK.

Table 2.6: Content of a typical environmental impact statement for a landfill

1. The proposed action

a. Purpose and justification
b. Project description
c. Primary impact area
d. Relationship with laws, policies and plans.

2. Existing conditions

a. Natural environment
b. Man-made environment

3. Environmental impacts

a. Topographic, geologic and soils
b. Water quality and drainage
c. Ecological community
d. Land use, zoning and socio-economic functions
e. Aesthetic
f. Health
g. Air quality
h. Noise

4. Unavoidable adverse impacts

a. Disruption of agricultural lands
b. Increased traffic
c. Modification of surface water drainage patterns

5. Alternatives to the proposed actions

a. No action
b. Alternative to the project
c. Alternative within the project

6. Relationship between local short term environmental uses and the maintenance and enhancement of long-term productivity

7. Irreversible and irretrievable resource commitments with the proposed action

Source: *The Solid Waste Handbook: A Practical Guide*, W.D. Robinson, 1986.

Table 2.7: Public relations and public participation

Objectives of a public participation programme

- Promoting full public understanding of the need for a landfill and the principles of its operation
- Keeping the public well-informed on the status of various planning, design and operation activities
- Soliciting from concerned citizens their relevant options and perceptions involving landfill development
- Promote consciousness of the public of their role as waste generators

Advantages of a public participation programme

- An increased likelihood of public approval for the final plans
- A method of providing useful information to decision makers, especially where values or factors that are not easily quantified are concerned
- Assurance that all issues are fully and carefully considered
- A safety valve in providing a forum whereby suppressed feelings can be aired
- Increased accountability by decision makers
- An effective mechanism to force decision-makers to be responsive to issues beyond those of the immediate project
- An effective mechanism to encourage public reflection on their role as waste producers

Disadvantages of a public participation programme:

- A potential for confusion of the issues since many new perspectives may be introduced
- A possibility that erroneous information will be disseminated from unknowledgeable participants
- An added cost to the project due to public involvement
- Possible delays in the project due to public involvement
- A possibility that the effort will not involve the appropriate people or the citizen, will not develop an interest in the project until it is too late for changes to be initiated
- Public resistance to landfilling may still be high despite the best efforts of public participation programme

Table 2.8: Potential participants of a public participation programme [1]

• Local elected officials	• State elected officials
• State and local government agencies	• Federal agencies
• State and local public works personnel	• Conservation/environmental groups
• Business and industrial groups	• Service clubs and civic organisations
• Property owners and users of the proposed sites and neighbouring areas	
• Media including newspaper, radio, television etc.	• Farm organisations
• Educational institutions	• Professional groups and organisations
• Various urban groups, economic opportunity groups	• Political groups and associations
• Labour unions	• Others

Source: *Landfill Disposal of Hazardous Wastes and Sludges*, Pollution Technology Review No. 62 Marshall Sittig, 1979.

Table 2.9: Public participation techniques

• Public hearing	• Public meeting
• Liaison committee meetings	• Mailings
• Contact persons	• Newspaper articles
• News releases	• Audio-visual presentation
• Newspaper advertisements	• Posters, brochures, displays
• Workshops	• Radio talk shows
• Tours/fields trips	• Ombudsman
• Task force	• Telephone line

Source: *Landfill Disposal of Hazardous Wastes and Sludges*, Pollution Technology Review No. 62 Marshall Sittig, 1979.

Table 2.10: Community concerns in landfill siting

• Predevelopment land use and subsequent environmental impacts	
• Zoning problems/conflicting land uses	• Groundwater pollution and leachate
• Gas migration	• Vectors
• Noise	• Odour
• Aesthetics including site visibility	• Safety and health
• Traffic	• Spillage
• Sedimentation and erosion	• Final land use

Source: US EPA

[1] See also *Table 2.2, Part 7.*

Figure 2.2: Suggested timing of public participation activities for sample landfill development

PUBLIC PARTICIPATION PROGRAMME	DECISION STAGE																
	Initial planning			Site selection							Design			Construction		Operation	
Activities and mechanisms	MONTH																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Public hearings		(x)										(x)					
Public meetings		(x)				(x)			(x)			(x)			(x)		
Advisory Committee meetings		(x)		x		(x)		x	(x)		x	(x)			(x)		
Mailing list development and mailing	→	→	→	→	→	→	→	→	→	→	→	→	→				
Availability of contact people	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
Newspaper articles	x	x	x		x			x									
New releases		x			x			x									
Audio-visual presentations		x				x			x			x			x		
Newspaper advertisements			x				x			x			x				
Posters, brochures, dipslays	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
Workshops			x					x									
Radio talk-shows							x			x							
Tours/field trips								x			x				x		x
Ombudsman	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
Task force											→	→	→	→			
Telephone line	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→

(x) ⋮ (x) *Joint meeting*

Source: US EPA Process Design Manual *Municipal Sludge Landfills*, 1978

2.3 EXERCISES

EXERCISE 2.1 Environmental Impact Assessment

Two candidate sites have been proposed for construction of a new landfill facility in order to dispose the waste produced in Udanax City Metropolitan Area.

The site characteristics are presented in the *Country Report, Table 8.*

For each of these two sites, rate the possible impacts on a scale of 1 to 3, where—

1: not important

2: important

3: very important

Item	Blue site	Green site
Surface water pollution	☐	☐
Groundwater pollution	☐	☐
Coastal pollution	☐	☐
Noise pollution		
• construction stage	☐	☐
• operation stage	☐	☐
Air pollution		
• odour	☐	☐
• windborne contaminated particles	☐	☐
• volatilisation of wastes/emission of gases	☐	☐
• aesthetic	☐	☐
Land transportation of wastes	☐	☐
Pollution due to construction of additional infrastructures	☐	☐
Effects on surrounding plants and animals	☐	☐
Property values	☐	☐
Proximity to residential area or sensitive sites	☐	☐

Which of these two sites do you prefer for an industrial waste landfill?

Why?

Supplementary Exercise

Explain why you cannot just add up the individual ratings for each site to obtain a total score.

EXERCISE 2.2 Public participation

(a) Assume that an *Environmental Impact Statement* (EIS) along the lines shown in *Table 2.5* has been prepared for one of the sites considered in *Exercise 2.1*. How would you use this EIS in a public relations programme designed to overcome public opposition in Udanax?

(b) What other activities would you include in your public relations programme?

(c) From the country report, who are the key individuals and groups to contact in Udanax?

EXERCISE 2.3 Public information

You are preparing an information package to support the proposal to establish a new landfill on the Blue Site (or the Green Site)—

(a) Prepare a list of points that is designed to convince the public and the politicians that a new site is necessary, that other options are not practicable, or may be less satisfactory.

(b) Prepare a list of points that is designed to convince the community that they will not be adversely affected by the new site. (Some of these points will involve decisions on design, operation etc. of the future site).

(c) Prepare a one-page briefing note to the Mayor of Udanax city on the above; *or* prepare a one-page Press Release for local newspapers.

2.4 SESSION REPORT

In the space below, prepare a summary of your conclusions on the process of site selection in Udanax.

This summary will be included in the final Task Force report to the mayor of Udanax.

Work Group ____________________

Session ____________________ Subject ____________________

Main results and conclusions

Work Group Members ____________________

____

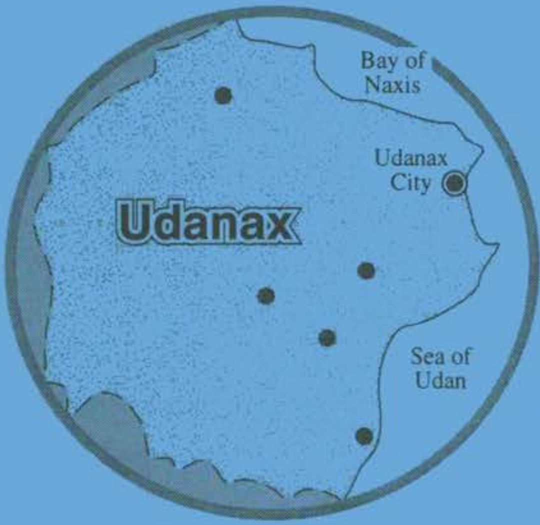
____

Return completed sheet to workshop co-ordinator for incorporation in the workshop report.

Casework Notes *for* SESSION 3

PART III

UNEP



Engineering Aspects of Landfill

CONTENTS

3.1 INTRODUCTION

Good design of facilities is a key component in ecologically sound landfill disposal (other components are siting, waste pre-treatment, and safe operation). The engineering aspects of landfills must take the natural site features into account, as well as the construction of artificial barriers to leachate movement, cell construction, site capping and so on.

Landfill design has developed considerably in recent years. The main emphasis has been to introduce greater safeguards against escape of contaminants from the site. The key issue in this respect is to minimise leachate generation and escape by paying close attention to surface water management, as well as avoiding the entry of liquid waste to the site.

However, it is likely that some liquids will penetrate the site, and so barriers to leachate escape must be provided. This is done using natural soil or artificial membrane liners to limit leachate movement.

Other engineering aspects include gas collection (where biodegradable wastes are involved), proper site stability, and diversion of surface drainage. In some landfills, special measures are taken to deal with wastes—such as asbestos, encapsulated wastes, for example.

However sophisticated in itself, landfill site engineering has to pay regard to the way the site will be operated, and also to long-term security after closure. Accordingly, site design must allow for easy operation and systematic monitoring.

Actual design is a lengthy task. The exercises in this session give an insight into several aspects of landfill engineering, such as the selection of the best method and leachate control. In real situations, a number of special wastes are often confronted, and an exercise on this is also included.

3.2 BACKGROUND INFORMATION

Table 3.1: Landfill engineering disciplines

Chemical engineering	Electrical engineering	Meteorology
Chemistry	Environmental engineering	Microbiology
Civil engineering	Geotechnics	Reclamation
Climatology	Horticulture	Soil mechanics
Cost and benefit analyses	Hydrology	Transportation economics
Ecology	Landscaping	Water engineering

Source: *Disposal and Recovery of Municipal Solid Waste*, Ed. M.E.Hemstock. Butterworths, 1983.

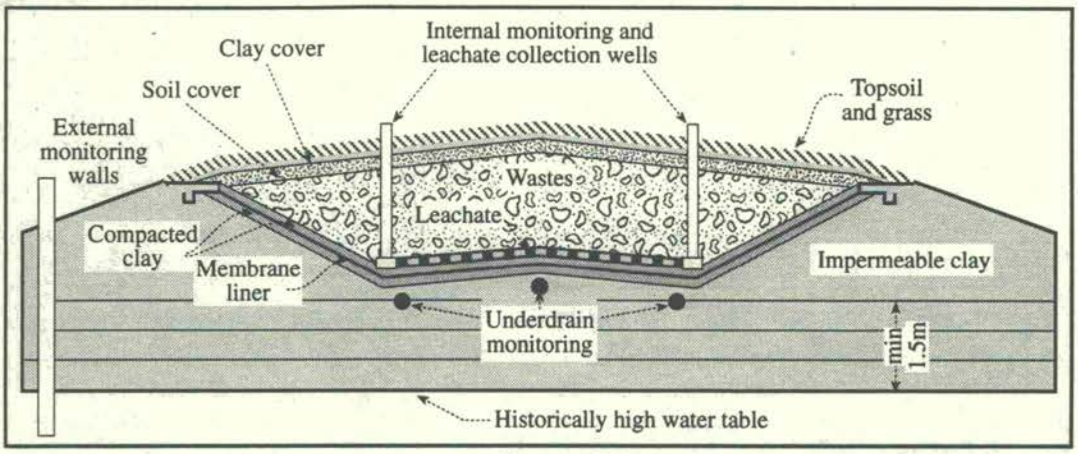
Table 3.2: Landfill types and methods

Landfill concepts
1. ***Attenuate and disperse*** sites where leachate and waste is allowed to escape into the environment at a controlled rate. Pollution is reduced by degradation and attenuation within the landfills and by dilution of the leachate plume in the aquifer.
2. ***Containment*** sites are aimed at isolating wastes and leachate from the surrounding environment for a considerable time.
3. ***Archival*** sites are specifically engineered to contain wastes indefinitely, but also to permit later identification and retrieval.
Methods of landfill
1. ***Co-disposal:*** when hazardous wastes are deposited with or into household or similar wastes with the objective of taking advantage of the attenuation process occurring in such wastes. Wastes must be critically assessed prior to being introduced to ensure that they are compatible with household waste. There are several ways of arranging co-disposal operations, such as trench disposal, or mixing directly with waste deposited on the face.
2. ***Monodisposal:*** where wastes having the same general physical and chemical form, often by lagooning in the case of sludge. Once deposited, the wastes do not necessarily remain in the same physical form—for example, lagooned sludges are generally allowed to dewater, but usually would remain in the same chemical form. Highly polluting wastes would not normally be disposed of in this manner.
3. ***Multi-disposal:*** where the practice of disposing chemically different wastes in the same sites with the aim of reducing the polluting potential of the individual wastes.

Table 3.3: Landfill lining

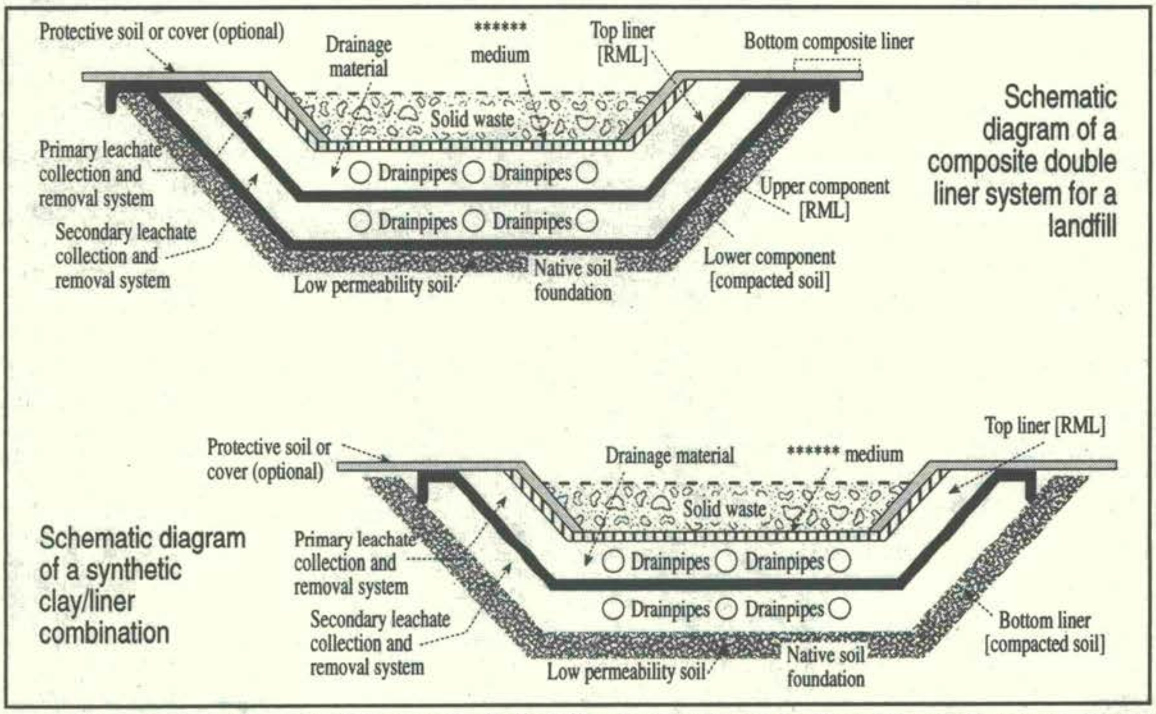
Selecting a liner depends on—
• degree of protection desired against leachate escape • effectiveness: liner types and waste types
• cost: both acquisition and installation • installation time • durability
Potential disadvantages of the liner
• the expected life of liners has not been established. Liners have been used at landfills over a relatively short period (less than 10 years), whereas effectiveness must be assured for many decades
• effects of various waste types on liners over time are not well understood
• difficulty of assuring the quality of the installation
• waste disposal operations can tear the liner, causing leachate seepage
• changes in hydraulic conductivity of the underlying or surrounding soil cause the groundwater to rise, which exerts upward pressure on the liner
• once the liner is in place and waste is deposited, liner failure cannot be easily detected or readily repaired

Figure 3.1: Schematic cross-section of a landfill



Source: *Environmental Science and Engineering*, Prentice Hall

Figure 3.2: Composite liner systems



Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989.

Figure 3.3: Leachate monitoring borehole

Figure 3.3a *Basement layer system (Germany)*

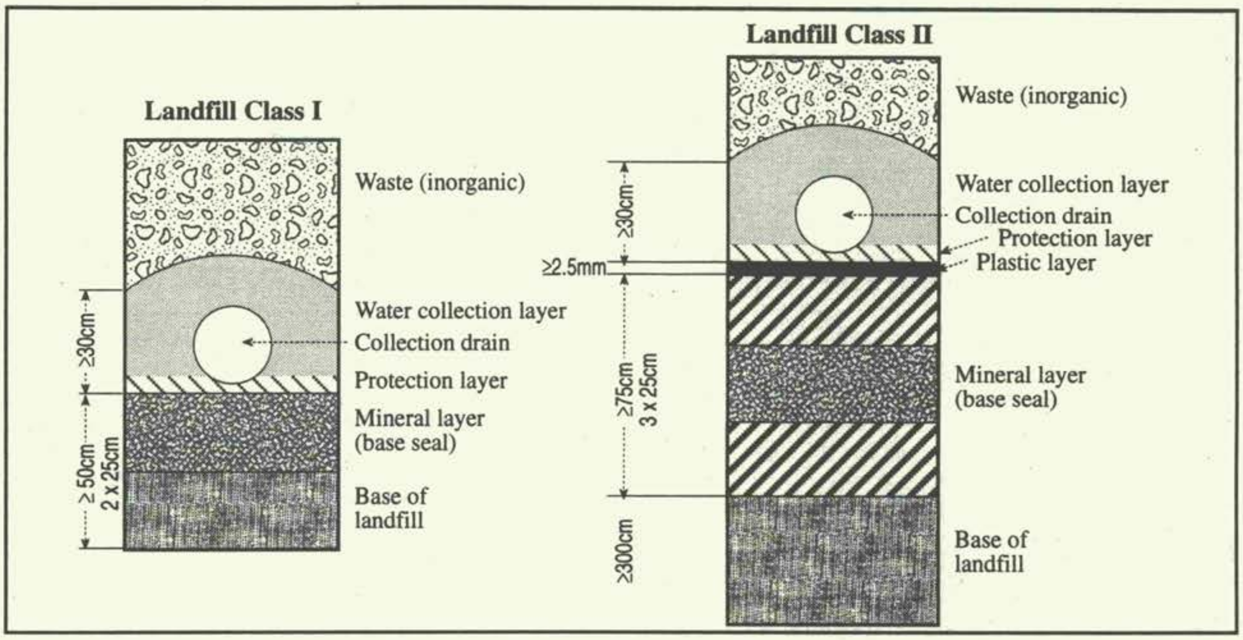


Figure 3.3b *Landfill cross section—base liner (Cibinong, Indonesia)*

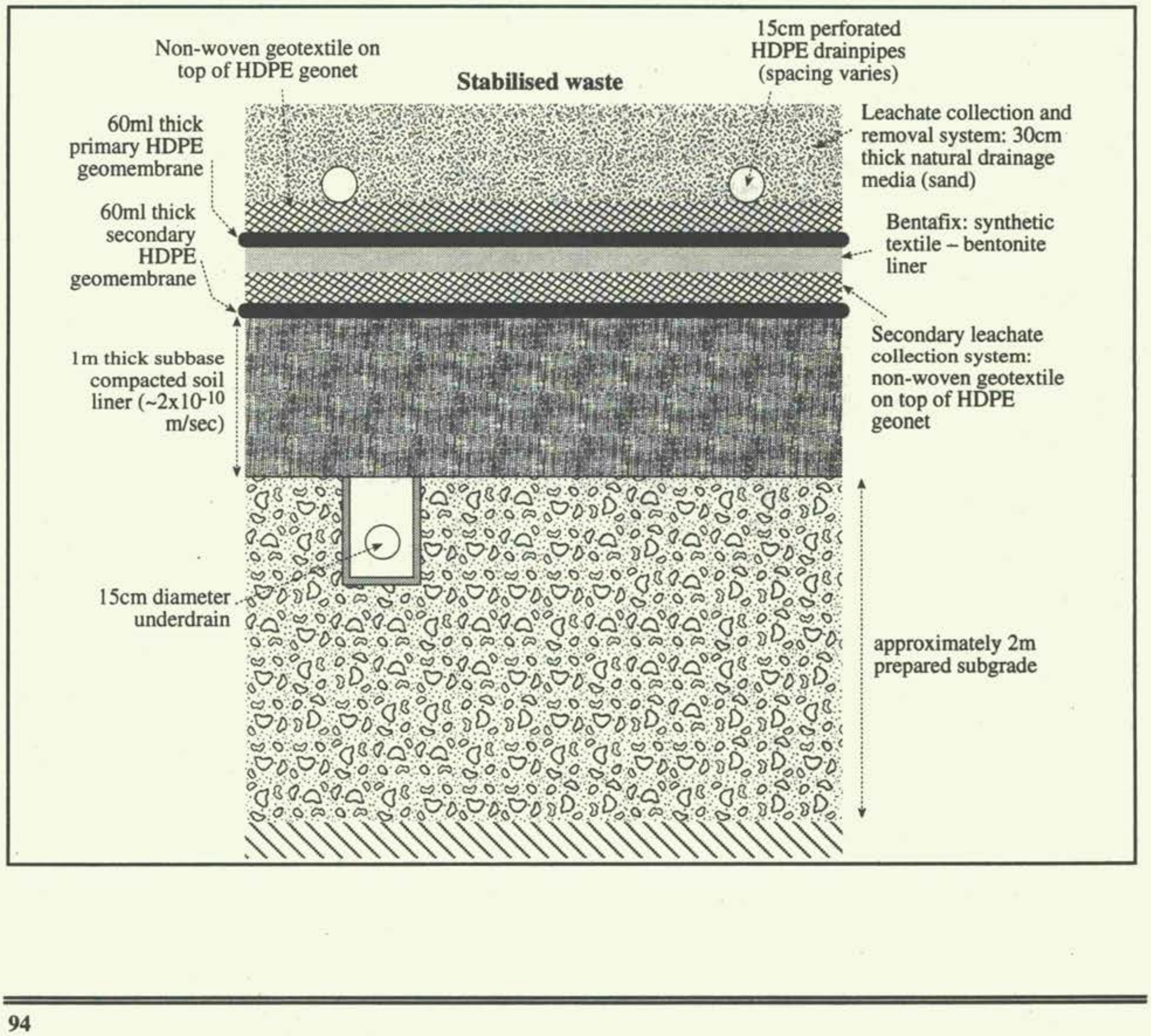


Table 3.4: Characteristics, advantages, and disadvantages of different synthetic liners

Liner material	Characteristics	Range of costs [1]	Advantages	Disadvantages
Chlorosulfonated polyethylene	Family of polymers prepared by reacting polyethylene with chlorine and sulphur dioxide	M	Good resistance to ozone, heat, acids and alkalis, easy to seam	Tensile strength increases on ageing: good tensile when supported; poor resistance to oil
Linear low density polyethylene; very low density polyethylene	Blown or sheet extruded	M to H (based on thickness)	Good resistance to oils and chemicals, resistant to weathering; available in 40–120mm thickness	
Polypropylene	Calendered, blown or sheet extruded	M to H (based on thickness)	Easy to seam in the field, available in 40–120mm thickness	
Ethylene interpolymer alloy	Calendered (reinforced)	M to H	Good chemical resistance, available in 30–80mm, good UV control	
Neoprene	Synthetic rubber based on chloroprene	H	Resistant to oils, weathering, ozone and ultraviolet radiation, to puncture, abrasion and mechanical damage	Difficult to seam or repair
Polyvinyl chloride	Produced in roll form in various widths and thicknesses; polymerisation of vinyl chloride monomer	L	Good resistance to inorganics, good tensile, elongation, puncture, and abrasion resistant properties, wide range of physical properties, easy to seam	Attacked by many organics, including hydrocarbons, solvents and oils; not recommended for exposure to weathering and ultraviolet light conditions
Thermoplastic elastomers	Relatively new class of polymeric materials ranging from highly polar to non-polar	M	Excellent oil, fuel and water resistance with high tensile strength and excellent resistance to weathering and ozone	None reported
High density polyethylene	Blow or sheet extended PE	M to H (based on thickness)	Good resistance to oils and chemicals; resistant to weathering; available in 20–150mm thicknesses, resistance to high temperature	Thicker sheets require more field seams; subject to stress cracking; subject to puncture at lower thicknesses; poor tear propagation.

All ratings are based on proprietary compounded materials designed for that specific application.

Source: US Environmental Protection Agency Handbook *Remedial Action at Waste Disposal Sites*, EPA 625/6–85-006, Cincinnati, Ohio; Office of Research and Development [1985]

[1] Range of costs: L = \$1.4/yd^2, M = \$4.8/y^2, H = \$8.12/yd^2 (installed costs).

Table 3.5: Values of porosity and hydraulic conductivity

		Hydraulic Conductivity	
Soil type	**Porosity %**	**Description**	**K (m/sec)** [2]
Gravel	25-40	High permeability	Over $1x10^{-3}$
Sand to fine sand	25-50	Medium permeability	$1x10^{-3}$ to $1x10^{-5}$
Silty sand to dirty sand	30-50	Low permeability	$1x10^{-5}$ to $1x10^{-7}$
Silt	35-50	Very low permeability	$1x10^{-7}$ to $1x10^{-9}$
Clay	40-70	Practically impervious	less than $1x10^{-9}$

Source: **For porosity values**, Freeze, R.A., and Cherry, J.A., *Groundwater*, Englewood Cliffs, N.J.: Prentice Hall, 1979, pp. 36-37. **For hydraulic conductivity values**, Theil, P. 'Subsurface Disposal of Storm Water' in *Modern Sewer Design*, Canadian Edition, ed. Committee of Sheet Steel Producers, Washington, D.C.: American Iron and Steel Institute, 1980, pp. 175-193. From: *Environmental Science and Engineering*, J.G. Henry and G.W. Heinke, Prentice Hall International Editions.

Significance of soil permeability values

Permeability value (K_s)	**Equivalent movement of liquid and associated contaminants**	
(m/sec)	(m/year)	(feet/year)
$1x10^{-3}$	31500	100 000
$1x10^{-5}$	315.0	1000
$1x10^{-7}$	3.2	10
$1x10^{-9}$	0.03	0.1

The above is only indicative as actual flow rates will depend on the hydraulic gradient and other factors. Contaminants may not move at the same rate as the water, due to attenuation or solute potential.

Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989.

[2] Conversions: m/sec x 0.0197 = feet/min; m/sec x 28.80 = feet/day; m/sec x 212 = qpd/ft^2

Table 3.6: Landfill leachate

Factors which affect movement of leachate in a landfill site	
• geohydrologic conditions	• disposal methods and operating conditions
• climatic conditions	• types of waste
• engineering design	• age of site
Estimation of leachate seepage velocity	
Darcy's Law: Q = KA*(dh/dL)	
Where: Q *is the seepage discharge flow rate*	A *is a cross-section area of the bed*
K *is the coefficient of permeability*	dh/dL *is the hydraulic gradient*
Estimation of amount of leachate produced	
$$L_0 = L - E - aW$$	
Where: L_0	*is the free leachate retained at the site (m^3/annum)*
L	*is the total liquid input (precipitation + liquid waste + surface and groundwater inflow + liquid content of waste) in m^3/annum*
E	*is the evapotranspiration losses in m^3/annum*
a	*is the absorptive capacity of the waste in m^3/tonne*
W	*is the weight of the waste deposited in tonnes/annum*
Leachate treatment methods	
• recirculation through landfill	• on-site treatment: chemical/physical treatment
• spray irrigation	• biological treatment
• evaporation in collection pond	• evaporation of leachate in collection pond
• discharged to municipal wastewater collection system	

Table 3.7: Composition of some leachates from landfills
(all results in mg/l except pH value)

	Household waste	**Pitsea** [UK] *Industrial* 43%	**Rainham** [3] [UK] *Industrial/ Household*	**Granmo** [NORWAY] *Industrial* 66%	**Cedar Hill** [USA] *Industrial/ Household*
pH value	5.8–7.5	8.0–8.5	6.9–8.0	6.8	5.4
COD	100–62 400	850–1350		470	38 800
BOD	2–38 000	80–250		320	24 500
TOC	20–19 000	200–650	77–10 000	100	
Volatile acids (C1–C6)	ND–3700	20	600–10 000	10	7100
Ammoniacal–N	5–1000	200–600	90–1700	120	
Organic–N	ND–770	5–20		62	
Nitrate–N	0.5–5			0.04	
Nitrate–N	0.2–2	0.10–10	8.0		
o-Phosphate	0.02–3	0.20		0.6 (total)	11.3 (total)
Chloride	100–3000	3400	400–1300	680	
Sulphate	60–460	340	150–1100	30	
Sodium (Na)	40–2800	2185	2000	462	
Potassium (K)	20–2050	888	50–125	200	
Magnesium (Mg)	10–480	214		66	
Calcium (Ca)	1.0–165	88		188	
Chromium (Cr)	0.05–1.0	0.05	0.5	0.02	1.05
Manganese (Mn)	0.3–250	0.5			
Iron (Fe)	0.1–2050	10	0.6–1000	70	810
Nickel (Ni)	0.05–1.70	0.04	0.5	0.1	1.20
Copper (Cu)	0.01–1.15	0.09	0.5	0.09	1.30
Zinc (Zn)	0.05–130	0.16	1.0–10	0.06	155
Cadmium (Cd)	0.005–0.01	0.02		0.0005	0.03
Lead (Pb)	0.05–0.60	0.10	0.5	0.004	1.40
Monohydric phenols		0.01	ND–2.0		
Total cyanide		0.01	0.09–0.52		
Organochloride pesticides		0.01			
Organophosphorous pesticides		0.05			
PCBs		0.05			

Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries,* World Bank/WHO/UNEP, 1989.

[3] Samples obtained from boreholes within the fill.

Table 3.8: Landfill design factors

1.	**Design objectives**
	A. Safe and permanent treatment and disposal of hazardous and toxic wastes
	a All wastes will be required to be assessed for their suitability for landfill. Wastes should be rendered inert prior to placement in the landfill to the extent practicable.
	b A successful treatment facility will— • *recover useful materials from waste* • *reduce quantities to be landfilled* • *prepare waste for disposal (render contaminants as insoluble as practicable).*
	B. Provide an economic balance between public and environmental well-being and impacts on the nation's industrial sector
2.	**Factors influencing design**
	A. Public acceptance and support
	B. Permitting and regulatory compliance (compromise between various government agencies and municipalities)
	C. Site access and topography
	D. Availability of suitable land
	E. Availability of technology, equipment and spare parts
	F. Geotechnical aspects of the site
	G. Climate and availability of climatological data
	H. Design of contaminant control mechanisms and monitoring systems
	I. After-use of the site.
3.	**Administrative and processing facility design**
	A. Transportation
	a Impacts on connection to the regional transit system (roads, highways, railroads)
	b Internal facility circulation— • *minimise cross traffic* • *one way traffic is preferred*
	c Wheel cleaning and vehicle wash facilities.
	B. Administration area
	a Administrative building for— • *operations engineering* • *record keeping and accounting* • *security headquarters*
	b Weighbridge and reception point (with sanitary facilities, utilities etc.)— • *Entrance and exit scale to avoid traffic conflicts*
	c Loading inspection area
	d Parking lot for personnel and visitors
	e Pullout area for incoming vehicles applying for permits at the administrative building.
	C. Waste receiving area
	a Loading docks for drums and bulk waste
	b Storage and segregation area for drums and bulk wastes
	c Transfer area for roll-offs and trailers
	d Hot pad, holding quarantine area for non-conforming, leaking or unidentified loads.
	D. Process treatment
	a Physical/chemical treatment (including for leachate): these process treatments prepare waste for landfill. They oxidise cyanide wastes, reduce hexavalent chromium, precipitate and remove heavy metals and remove organic contaminants and suspended solids
	b Solidification and stabilisation: utilises cementitious reactions to incorporate the waste material in a solid matrix with greatly reduced susceptibility to leaching.

E. Infrastructure and support facilities

- *a* Maintenance (workshops etc.)
- *b* Emergency equipment (fire, spillage)
- *c* Monitoring (weather station, laboratory facilities for waste analysis).

4. Excavation and disposal area design

A. Hydrogeological information

- *a* Soil (depth, texture, structure, porosity, permeability, moisture, ease of excavation, stability, pH and cation exchange capacity)
- *b* Bedrock (depth, type, presence of fractures, location of surface outcrops)
- *c* Groundwater (average depth, seasonal fluctuations, hydraulic gradient and direction of flow, rate of flow, quality, uses)
- *d* Proximity of surface waters
- *e* Seismicity of the region.

B. Design of landfilling area

- *a* Select landfilling method
- *b* Knowing projected waste stream quantities and types of waste expected, determine capacity for 30 to 40 year design life
- *c* Specify design dimensions (trench or cell width, depth, length, spacing, number, and interim cover and final cover thickness)
- *d* Specify operational features (use of cover soil, method of cover application, need for imported soil, equipment requirements, personnel requirements)
- *e* Specify final landforms (contours, slopes).

C. Disposal area layout

- *a* Optimise land use and facilitate operations
- *b* Provide security fencing and buffer zones, escape routes
- *c* Follow government regulations, observe property set-backs.

D. Liner design

- *a* Consult manufacturers and installers of flexible membrane liners
- *b* Evaluate compatibility of liner materials with expected leachate.

E. Leachate collection system

- *a* Sumps and monitoring wells
- *b* Manholes and risers
- *c* Leachate treatment.

F. Drainage design

- *a* Run-on-runoff control systems
- *b* On-site runoff may or may not need treatment.

G. Closure plan

- *a* Impermeable cap design
- *b* Gas generation control
- *c* Long term ground water monitoring
- *d* Restoration and after-care.

H. Construction and disposal sequence

I. Quality assurance plan

J. Construction specifications, cost estimate and operations plan.

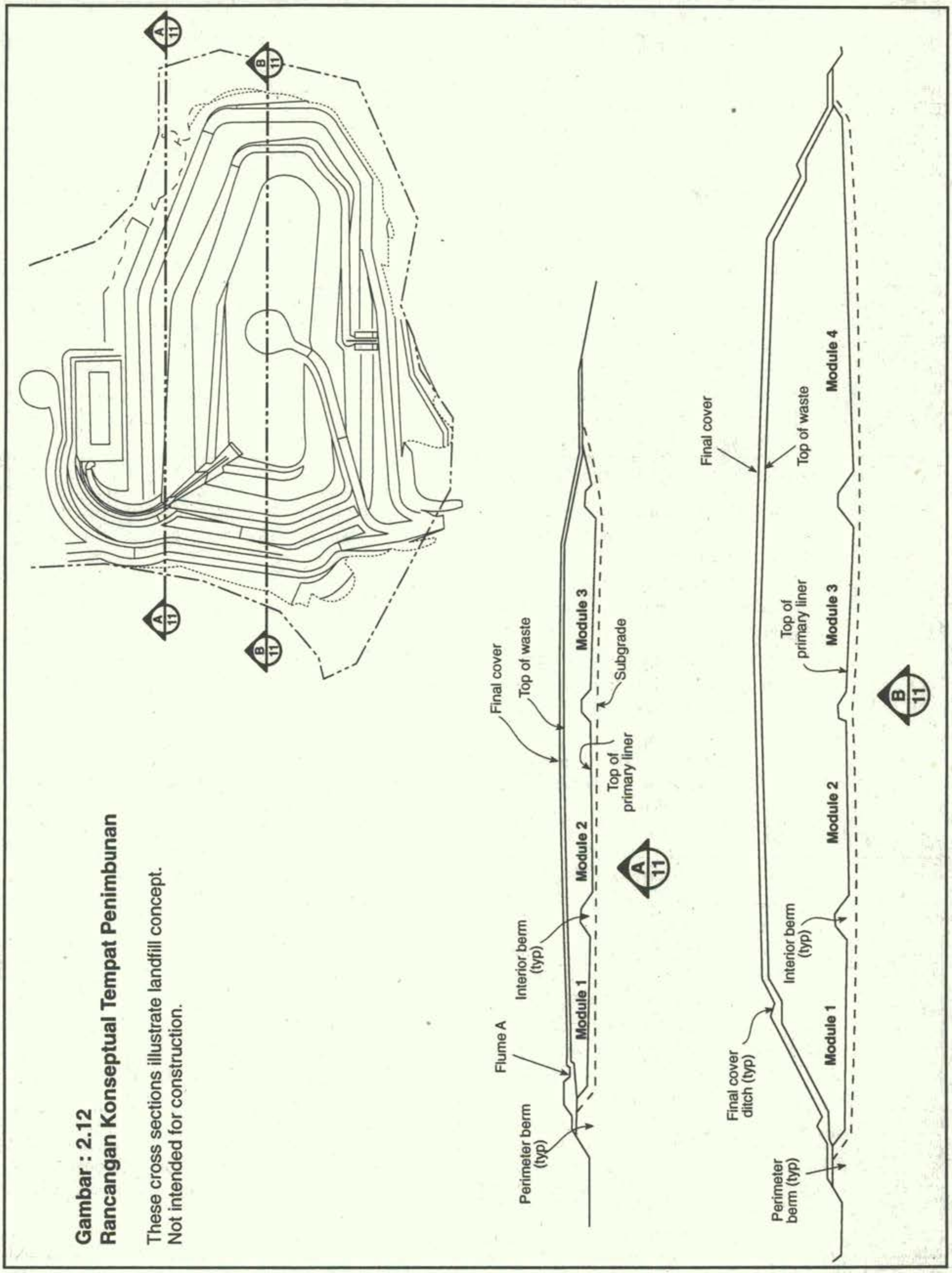
Source: Udanax Environmental Consultancy, Udanax City.

Table 3.9: Landfill design criteria

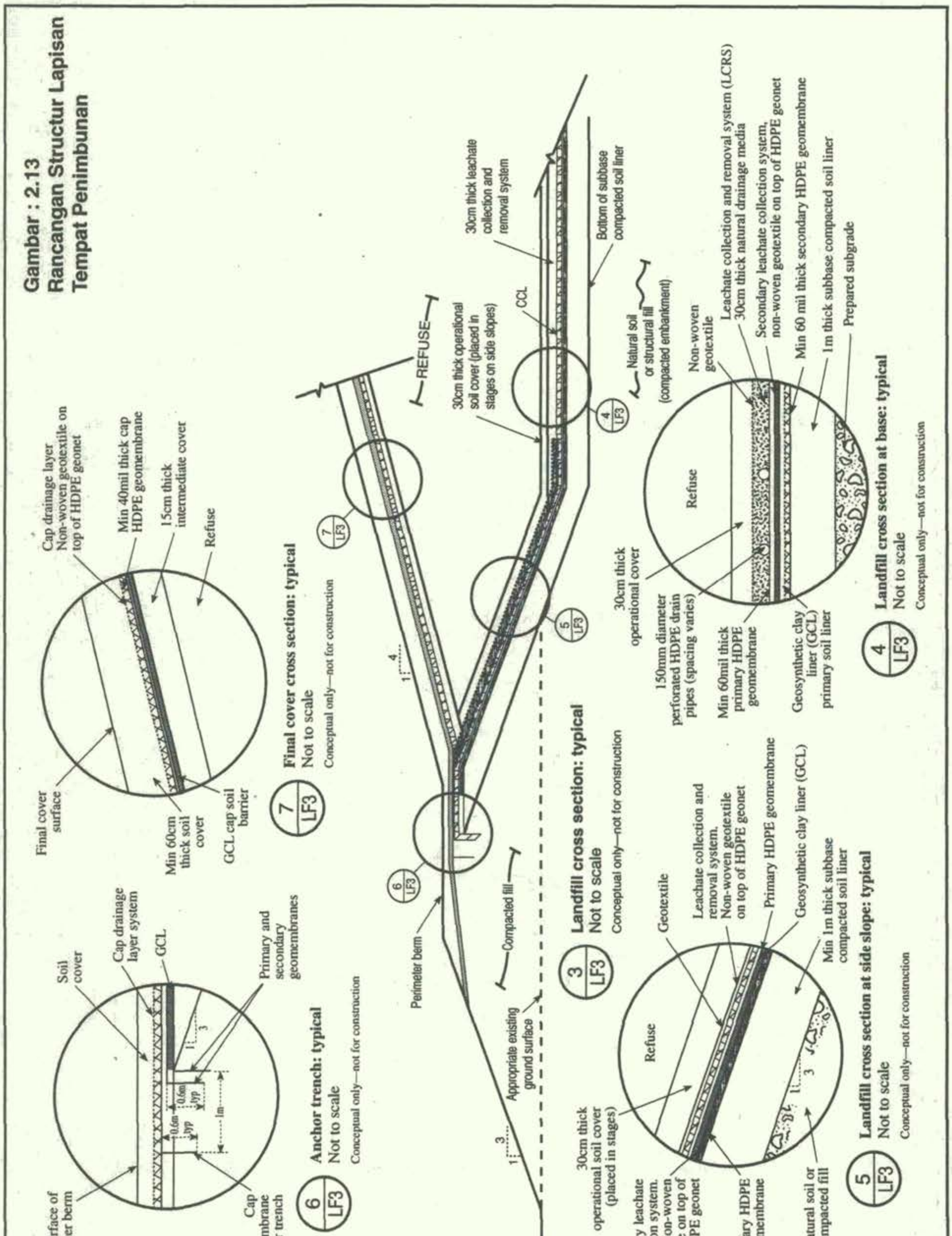
1.	**General constraints**
	a 15 m minimum from edge of landfill to property line *b* Base of liner foundation must be 2.4 m above water table.
2.	**Recommended slopes**
	a Final cover— • *minimum 2%; recommended 5%; maximum 33%* *b* Interim and perimeter berms • *1% to 5%* *c* Base • *2% desirable; 0.5% minimum.*
3.	**Landfill liners**
	Permeability <= 1 x 10^{-7} cm/s *a* Clay liners • *minimum amount of clay 25-28 % by weight; compacted to 95 % maximum density* *b* Flexible membrane liners • *synthetic polymer liners; resistance to chemical attack.*
4.	**Leachate and gas collection system**
	The leachate collection and removal system consists of a network of drains to collect and remove any accumulation of leachate that might develop in the bottom of the landfill, and it prevents migration of leachate to the subsurface. *a* Collection drain layer • *layer permeability not less than 10^{-3} m/sec; minimum thickness 30 cm; minimum slope 3%* *b* Drain Pipe • *size & hydraulic capacity: large enough to carry-off the collected leachate* • *spacing (recommend by U.S. EPA)* *size : 15 cm diameter perforated or slotted; spacing: 5 to 60 m apart* *c* Gas Collection • *active or passive system using vertical/horizontal wells or venting trenches.* *Unless the landfill is to receive mainly inert wastes an active (i.e. pumped) a gas collection system is needed.*
5.	**Final cover**
	Settlement allowance: need to surcharge contours by 10-25% depending on wastes landfilled. *a* Geometry of the design • *avoid ponding* • *adequate drainage without inducing unacceptable erosion* • *adequate landscape integration* *b* Arrangement (US EPA Regulation) • *vegetated top layer with minimum thickness 60 cm* • *middle drainage layer with minimum thickness of 30 cm and permeability of 10^{-3} m/sec* • *low permeability bottom layer (10^{-9} m/sec) with two-component system: i] membrane liner; ii] underlain by at least 60 cm of compacted clay*
6.	**Run-on/Run-off systems**
	This system consists of combination of dikes, berms, ditches and sumps to intercept run-off from off-site areas and divert it away from the landfill. The system is also designed to collect, store and if necessary treat any precipitation falling directly on the landfill. Design criteria: 24 hour 25 year storm event.

Source: Udanax Environmental Consultancy, Udanax City.

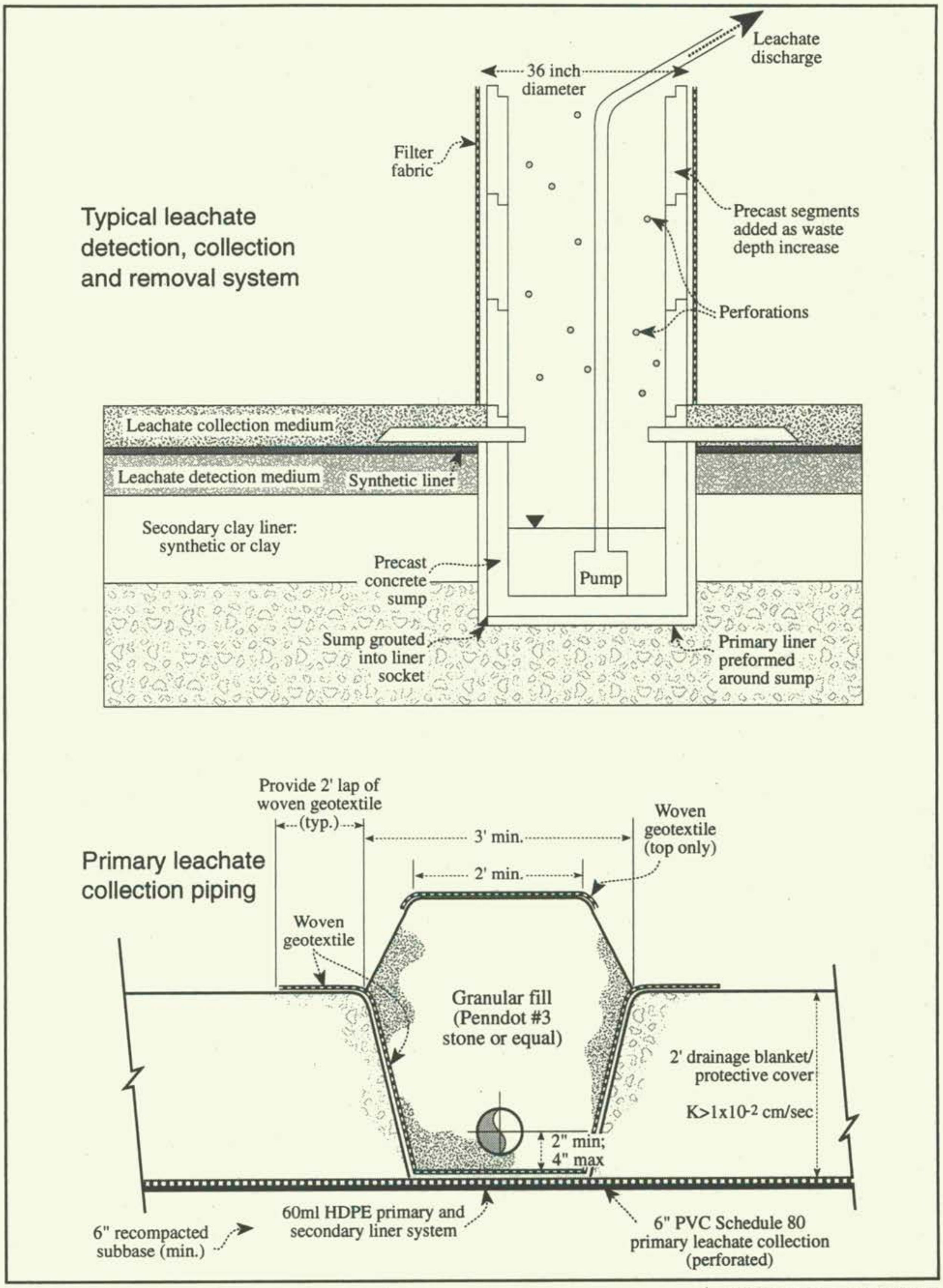
Figure 3.5: Example of design of hazardous waste landfill *(Indonesia)*



Source: EMDI, Indonesia



Gambar : 2.13
Rancangan Structur Lapisan Tempat Penimbunan



Source: Dames and Moore

Table 3.10: Indicative site development costs

Assumptions
1. **Site investigation proves the site suitable for waste disposal**
2. **Access to the site by rail is achieved**
3. **Overhead power lines cannot be relocated**
4. **Streams on site can be diverted** (if not, site volume may be reduced slightly)
5. **Filling rate of 300,000 m^3/a is achieved**
6. **Site volume = 7 million m^3**
7. **Area suitable for landfill = 434,000 m^2 (average fill depth = 16m)**
8. **Site life = 23 years**

1. Planning and site licence

Site investigation $80,000

Preparation of EIA and application $220,000

Application fee $13,000

Appeal costs $400,000

Licence application $14,000

Topographic survey $12,000

2. Rail transfer facility

The facility will need to be built level with the existing rail track, around 6m above the surrounding land.

This is a very rough estimate and will require considerable work to be accurately assessed.
Fill, track, points, ballast, signals and access ramps and mobile crane. $4,000,000

3. Access

Required for employees and plant.

Upgrade existing farm track 400 x 5m^2 at \$20/m^2 .... $40,000

New road to reception area (350x5) + 100m^2 of passing bays at \$40/m^2 .... $74,000

4. Reception area

Hardstanding 2,500m^2 at \$ 20/m^2 .... $50,000

Office $14,000

Canteen $14,000

Electricity $100,000

Water $30,000

Telecom .... $nil

Sewage (septic tank) $4,000

Fuel Tank $9,000

Workshop $14,000

5. Preparation of base

1m of "soil" to be stripped and stockpiled from the initial area to be prepared. Thereafter stockpiling will not be needed. Soil stripped from a new area will be used directly to restore a filled area.

Total area = 434,000 m^3. Annually 434,000/23 will be needed—i.e. 18,900 m^2/a

Prior to site opening two years landfilling space will be prepared.

Soil strip and stockpile = 2 x 18,900m^3 at \$2.80/m^3 .... $106,000
Rework 1m depth of clay = 2 x 18,900m^3 at \$3.60 .... $136,000

Thereafter annually:

Soil will be stripped and used for restoration (years 1 to 21): see *Restoration* section.
Rework 1m depth of clay = 18,900m^3 at \$3.60 .... $68,000

Additionally, annually allow for movement of 10,000m^3 for bunding etc at \$3.20 .... $34,000

6. Leachate drainage

Using perforated pipe surrounded by shredded tyres. Runs to be spaced at 20m centres.

Tyres shred 2.5m^3/m run — Section = $25.00/m
Back haul at, say, $6.00/m^3 = $15/m — Geotextile at $6.00/m
Slotted aquapipe 125mm at $74/3m

Base of site .... Cost/linear m = $41.00

1m of pipe services 20m^2 of floor
Cost per m^2 of floor = $41.00/20 = $2.05
Annually require 18,900m^2 of floor to be covered

Therefore annual cost is $38,800/a

Leachate chimneys: allow a further $12,000/a

Provision of an artificial membrane if required

HDPE geotextile at $4.00/m^2
2.5mm HDPE membrane at $12.00/m^2 .... $27.20/m^2
HDPE geotextile at $4.00/m^2
Sand blinding at $7.20/m^2

This gives an annual cost of $38.40 x 18,900 .... $726,000/a

7. Leachate generation and treatment [4]

Year cost	Area	15% of effective rainfall *(m/yr)*	Volume of leachate *(m^3)*	Capital cost *($)*	Treatment running
1	18,900	0.055	1,040	60,000	20,800
2	37,800	0.055	2,079		41,580
3	56,700	0.055	3,118		62,360
4	75,600	0.055	4,160		83,200
5	94,500	0.055	5,200		104,000
6	113,400	0.055	6,240		124,800
7	132,300	0.055	7,280	60,000	145,600
8	151,200	0.055	8,320		166,400
9	170,100	0.055	9,360		187,200
10	189,000	0.055	10,400		208,000
11	207,900	0.055	11,440		228,800
12	226,800	0.055	12,480		249,600
13	245,700	0.055	13,520		270,400
14	264,600	0.055	14,560	60,000	291,200
15	283,500	0.055	15,600		312,000
16	302,400	0.055	16,640		332,800
17	321,300	0.055	17,680		353,600
18	340,200	0.055	18,720		374,400
19	359,100	0.055	19,760		395,200
20	378,000	0.055	20,800		416,000
21	396,000	0.055	21,840	60,000	436,800
22	415,000	0.055	22,880		457,600
23	434,700	0.055	23,920		478,400
24	434,700	0.055	23,920		478,400
25	434,700	0.055	23,920		478,400

Continues 20+ years

[4] Based on an activated sludge system, treating 7,300m^3/a at $60,000 per plant. Cost of treatment = $20/m^3.

8. Landfill gas control

Based on estimated costs of:

Capital = \$0.30/m^3 of waste imported; Running cost = \$0.050/m^3 in situ;
Volume placed annually = 300,000m^3

Year	Volume of waste		Capital	Running
	Input/yr	Cumulative input	$	$
1	300,000	300,000	90,000	15,000
2	300,000	600,000	90,000	30,000
3	300,000	900,000	90,000	45,000
4	300,000	1,200,000	90,000	60,000
5	300,000	1,500,000	90,000	75,000
6	300,000	1,800,000	90,000	90,000
7	300,000	2,100,000	90,000	105,000
8	300,000	2,400,000	90,000	120,000
9	300,000	2,700,000	90,000	135,000
10	300,000	3,000,000	90,000	150,000
11	300,000	3,300,000	90,000	165,000
12	300,000	3,600,000	90,000	180,000
13	300,000	3,900,000	90,000	195,000
14	300,000	4,200,000	90,000	210,000
15	300,000	4,500,000	90,000	225,000
16	300,000	4,800,000	90,000	240,000
17	300,000	5,100,000	90,000	255,000
18	300,000	5,400,000	90,000	270,000
19	300,000	5,700,000	90,000	285,000
20	300,000	6,000,000	90,000	300,000
21	300,000	6,300,000	90,000	311,000
22	300,000	6,600,000	90,000	330,000
23	300,000	6,900,000	90,000	345,000
24	NIL	6,900,000	NIL	345,000
25	NIL	6,900,000	NIL	345,000

9. Surface water pick up drains

2,800m of ditching at \$12/m \$33,600

10. Capping and restoration

Engineering cap: to be placed each year following filling

Area to be capped annually = 18,900 m^2

Using on-site material 18,900m^3 at \$3.60/m^2 .... \$68,000/a

Alternative cost if VLDPE is used

Geotextiles and VLDPE = \$12.20/m^2 .... \$241,560

Replacement of soil (agricultural cap)

18,900 m^3 at \$2.80/m^3 .... \$52,920/a

11. Fencing

Given that the site is isolated security fencing may not be needed except for a compound around the reception area—say, 300m at $30/m $9,000

(Should it be needed around the entire site, the cost would be 2,800m at $30/m) $84,000

12. Monitoring

Groundwater monitoring boreholes: 6 at $8,000 each $48,000

Gas probes: say, 30 at $200 each $6,000

Environmental monitoring: annually $60,000/a

13. Consultants

VTU surveys, levelling etc $12,000/a

Supervision of earthworks by geotechnical engineer $8,000/a

Materials testing $6,000/a

14. Site roads

Initially one main site road 800m x 8m at $50/m^2 .... $320,000

Maintenance $30,000/a

Annually site road construction: allow a contingency of $40,000

Source: Shanks McEwen, UK.

3.3 EXERCISES

EXERCISE 3.1 Selection of a landfill method

In *Session 1*, you attempted to calculate the amount of hazardous waste in the Udanax City region that would need to be landfilled (Category 1, 2 and 3 wastes)

Use the results of *Session 1* as a basis for the exercise below.

(Alternatively, go back to *Table 5* in *Part II*, and use the raw data presented there. However, this Table shows what is presently happening—not what you intend to happen in future).

Based on the list of wastes to be landfilled in Udanax City Metropolitan Area:

(a) Discuss whether to select co-disposal or mono-disposal methods for these wastes.

(In your discussion, take into account the volumes, the chemical characteristics after pre-treatment, the long-term effects in the landfill, etc.)

(b) Select an appropriate landfill design for hazardous industrial waste in Udanax, and give the reasons for your selection. Provide a sketch of your proposal.

(c) In order to obtain a landfill construction permit, you have been asked by the Udanax City Council to prepare a engineering report for the selected landfill method. Indicate what are the items you will incorporate in this report, and prepare a detailed table of contents.

(d) The Udanax ***Save the Mother Earth*** movement campaigns against disposal of hazardous wastes by landfill method. It claims that no landfill site can be ever totally safe and it is practically impossible to prevent groundwater pollution. As a landfill design engineer, what arguments will you use to justify your project?

EXERCISE 3.2 Burial of special wastes: *Interim Options for some Category 4 wastes*

Some of the *Category 4* wastes which have been identified in Udanax and which are normally considered unsuitable for landfill are shown below:

- pesticide residues (inorganic: mercury, copper fungicides)
- PCB equipment (from which PCBs have been drained).
- surplus laboratory chemicals.

Currently there is no possibility for treatment or for shipping back to the suppliers, and—although it is not the best long-term option,—a special landfill operation is currently being contemplated on a once-off basis, under supervised conditions.

Although you are not completely in agreement with this decision, you have been asked to advise on how to make this operation as environmentally sound as possible.

Recommend arrangements for pre-treatment procedures, and the location and design of a special disposal area.

EXERCISE 3.3 Leachate production

(a) Predict the amount of leachate that will be produced in the proposed *Blue Site*. Assume a first stage of operation of one hectare (100mx100m). The amount waste disposed at this site will be limited to 100,000 tonnes/year. Assume annual rainfall of 650mm and evapotranspiration of 350mm, and an absorptive capacity of the wastes of 0.025m^3/tonne.

(b) Determine the thickness of a clay liner that must be placed in the bottom of this site if the flow rate of seepage is to be limited to 0.05 gal/day/unit area. Assume that the water table is located at the bottom of the landfill and the leachate level in the landfill above the clay liner is to be maintained at two feet by pumping. The K value of the clay liner that is available is 0.02 gal/day/ft^2.

(c) The leachate composition from a co-disposal site situated at Granmo, Norway, was shown in *Table 3.7*. Assuming that this will be typical of the leachate from the future Blue Site, propose a treatment method for this leachate.

3.4 SESSION REPORT

In the space below, prepare a summary of your conclusions on the design and construction of a landfill site in Udanax.

This summary will be included in the final Task Force report to the mayor of Udanax.

Work Group ______________________________

Session ______________ Subject ______________

Main results and conclusions

Work Group Members ______________________________

____

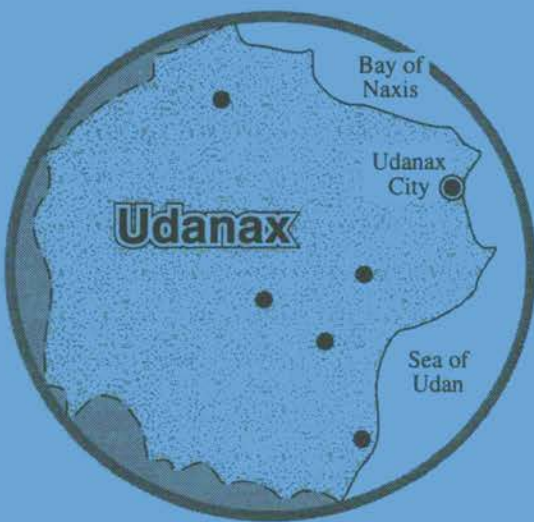
____

Return completed sheet to workshop co-ordinator for incorporation in the workshop report.

Casework Notes *for* SESSION 4

PART III

UNEP



Operation and Management of Landfills

CONTENTS

4.1 INTRODUCTION

Competent, safe operation is what distinguishes a landfill facility from a dumpsite.

Careful operation can make up for some deficiencies in siting or design. Conversely, careless site management can turn even the best designed facility into an environmental disaster.

Operational objectives include on-site safety as well as wider ecological impact.

As landfill sites accept a range of wastes from a multitude of operators, operational procedures must be inherently cautious. The greatest possible safeguards against waste "smuggling" must be taken, loads must be regularly checked, and precautions must be taken to avoid accidents.

All operations should be monitored so as to give the manager adequate information about the performance of the site.

The importance of record-keeping is frequently underestimated. Only if good information is kept on hand can the manager intervene when problems occur.

Record-keeping is often a condition of operating licences, which are becoming increasingly demanding as time goes on.

The exercises in this session include some common operational considerations which are relevant to all sites.

4.2 BACKGROUND INFORMATION

Table 4.1: Operational activities related to a landfill

Prior to landfill		
• reception of wastes • sampling and analysis • segregation of wastes	• preparation of waste for landfill (pre-treatment) • temporary storage	• identification of special and incompatible wastes • record keeping
During landfill		
• traffic movement (roads, safety) • landfilling method— *(i) trench operation* *(ii) area fill operation* *(iv) codisposal operation* • excavation	• filling • compaction • daily cover • intermediate cover • final cover • vermin control	• leachate control • monitoring • record keeping • nuisance mitigation (litter, odour, vermin, dust) • surface water management
Post landfill		
• site access (security) • restoration • leachate control	• runoff control • monitoring • record keeping	• aftercare • gas control

Source: Compiled from various reference documents cited in *Section Part I.*

Table 4.2: Hazard identification

Major types of hazards one might encounter in hazardous waste landfill operation—
• *Chemical exposure:* airborne and skin exposure to dusts, gases, vapours or liquids, reactive compounds
• *Fire and explosion:* from liquids, gases and reactive wastes
• *Oxygen deficiency:* oxygen displacement by gases and vapours in enclosed spaces or low lying areas
• *Ionisation radiation:* from hospital and industrial wastes
• *Biological hazards:* from hospital and sanitation wastes, food and fibre processing, wildlife, parasites
• *Physical safety hazards:* machinery operation, restriction of movement or vision due to protective clothing, uneven terrain, steep grades, sharp objects
• *Electrical hazards:* from transformers, power, lightning
• *Noise:* from compressors, machinery
• *Temperature:* heat stress and cold exposure

Table 4.3: Common landfill problems

Leachate: pollutants escape to contaminate surface or groundwater
Fires: due to self-ignition or mixing of incompatible substances; rupture of drums containing oxidising substances
Dust: from wastes, or from dry soil surfaces
Odours: from wastes, or from wastes decomposing
Handling hazards: due to hazardous wastes being accepted. Also a problem if scavengers have access to the site
Vermin: rats, birds, flies and other vectors breeding, living or feeding on any food wastes brought onto sites and spreading disease and nuisance to off-site areas
Litter and windblown rubbish: often a problem on access roads as well as the site itself
Visible intrusion
Noise
Runoff of dirty or polluted water
Uneven settling or consolidation due to soluble or putrescible wastes, or containers rupturing under pressure

Table 4.4: Contents of a typical site working plan

1. Introduction

- 1.1 The Site
- 1.2 Waste Inputs
- 1.3 Plant and Staff

2. Site Assessment

- 2.1 Geology
- 2.2 Hydrogeology
  - 2.2.1 Description and Permeability
  - 2.2.2 Piezometric Head
  - 2.2.3 Groundwater Quality and Monitoring
- 2.3 Hydrology

3. Infrastructure

- 3.1 Site Entrance
- 3.2 Site Security
- 3.3 Site Access
- 3.4 Site Amenities and Office
  - 3.4.1 Site Office
  - 3.4.2 Canteen
- 3.5 Parking
- 3.6 Workshop and Stores
- 3.7 Fuel Storage
- 3.8 Lighting
- 3.9 Signs and Directions
  - 3.9.1 Directions
  - 3.9.2 Safety and Warning
- 3.10 Wheel Cleaning
- 3.11 Rail Terminal and Crane Gantry
- 3.12 Fencing
- 3.13 Inventory of Plant and Equipment
- 3.14 Site Services
  - 3.14.1 Telephone
  - 3.14.2 Electricity
  - 3.14.3 Water
  - 3.14.4 Sewage
  - 3.14.5 Services Inspection
- 3.15 Communications
- 3.16 Staff Training Policy
  - 3.16.1 Introduction
  - 3.16.2 Technically Competent Persons

4. Operational Methods

- 4.1 Introduction
- 4.2 Reception and Monitoring of Waste
  - 4.2.1 Input Monitoring
  - 4.2.2 Background Monitoring
  - 4.2.3 Monitoring and Non-Conforming Wastes
- 4.3 Access Roads
- 4.4 Traffic Movement
- 4.5 Cell Construction
- 4.6 Discharge of Waste from Vehicles
  - 4.6.1 Train Face
  - 4.6.2 Road-borne Waste Vehicles
- 4.7 Emplacement of Waste
- 4.8 Cover
- 4.9 Disposal of Asbestos Wastes
- 4.10 Difficult and Special Wastes
  - 4.10.1 Difficult Wastes
  - 4.10.2 Special Wastes
- 4.11 Secure Burial
- 4.12 Disposal of Liquid Waste
- 4.13 Final Refuse Level
- 4.14 Avoidance of Environmental Nuisance
  - 4.14.1 Smell
  - 4.14.2 Mud of Roads
  - 4.14.3 Traffic Queuing
  - 4.14.4 Noise
  - 4.14.5 Windborne Litter
  - 4.14.6 Rodents and Insects
  - 4.14.7 Birds
  - 4.14.8 Dust
  - 4.14.9 Visual Intrusion

5. Engineering Methods

- 5.1 Introduction
- 5.2 Cell Design
- 5.3 Pit Base and Side Seal Specifications
  - 5.3.1 Introduction
  - 5.3.2 Side Seals
  - 5.3.3 Base Seals
- 5.4 Engineering Caps
  - 5.4.1 Design Criteria
  - 5.4.2 Methods of Construction and Testing of Engineering Caps
- 5.5 Summary of Available Materials
  - 5.5.1 Pit
  - 5.5.2 Other Pits

6. Leachate and Water Management

- 6.1 Introduction
- 6.2 Water Management
  - 6.2.1 Containment of Ground Water
  - 6.2.2 Monitoring of Ground Water
  - 6.2.3 Control of Surface Water

6.3 Leachate Collection
- 6.3.1 Permissible Exposed Surface Area of Waste
- 6.3.2 Active Leachate Abstraction
- 6.3.3 Passive Leachate Collection
- 6.3.4 Monitoring of Leachate Levels

6.4 Leachate Treatment
- 6.4.1 Primary Treatment
- 6.4.2 Secondary Treatment
- 6.4.3 Final Treatment and Discharge
- 6.4.4 Monitoring of Leachate Treatment
- 6.4.5 Future Leachate Treatment Plans

7. Landfill Gas Management

7.1 Landfill Gas Extraction
- 7.1.2 Monitoring of Landfill Gas

7.2 Landfill Gas Utilisation

7.3 Future Landfill Gas Collection

7.4 Security, Safety & Monitoring of Gas Compounds

8. Safety

8.1 Health and Safety Policy

8.2 Safety Procedures

8.3 Safety representative

8.4 Health Screening

9. Landfill Restoration and Aftercare

9.1 Introduction

9.2 Restoration
- 9.2.1 Placement of the Agricultural Cap
- 9.2.2 Soil Improvement

9.3 Aftercare

10. Environmental Monitoring and Inspection

10.1 Introduction

10.2 Internal Monitoring and Inspection

10.3 Overview Inspection

10.4 Forward Planning Meeting

10.5 Operations Meetings

10.6 Quantitative Monitoring
- 10.6.1 Introduction
- 10.6.2 Gas Migration
- 10.6.3 Gas Quality and Quantity
- 10.6.4 Leachate Levels and Quality
- 10.6.5 Surface Water Quality and Quantity
- 10.6.6 Groundwater Levels and Quality
- 10.6.7 Stability
- 10.6.8 Settlement

10.7 Monitoring of Gas Compounds

10.8 Wildlife and Habitat Surveys

10.9 Aftercare Monitoring

10.10 Safety Inspections

10.11 Q.A. Compliance Audits

11. Operational Plan

11.1 Current Phase of Operations (Pit 1)
- 11.1.1 Introduction
- 11.1.2 Filling Sequence
- 11.1.3 Access
- 11.1.4 Engineering Capping
- 11.1.5 Agricultural Capping
- 11.1.6 Control of Surface Water
- 11.1.7 Leachate Collection and Treatment
- 11.1.8 Gas Control
- 11.1.9 Current Engineering Works
- 11.1.10 Future Engineering Works

11.2 Phasing of Operations in Subsequent Pits
- 11.2.1 Introduction
- 11.2.2 Cell Sizes and Engineering
- 11.2.3 Description of Filling Sequence
- 11.2.4 Access
- 11.2.5 Capping
- 11.2.6 Surface Water Control
- 11.2.7 Leachate Control and Treatment
- 11.2.8 Gas Control and Utilisation

Source: Shanks McEwen, UK.

Table 4.5: Emergencies at landfill operation

• Worker related

- — accidents
- — chemical exposure
- — protective equipment failure

• Waste related

- — fire
- — explosion
- — leak
- — release of vapour cloud
- — reaction
- — container failure

Table 4.6: A summary of landfill site monitoring

• Objectives

- — establishing baseline data
- — detecting contamination
- — satisfying regulatory constraints
- — securing data for use in litigation
- — conducting research projects
- — improved understanding of landfill processes

• Monitoring activities

- — limit of exposure of toxic substances on operating personnel
- — monitoring leachate (level and quality) and gas (quality, migration and pressure)
- — measurement of hydrogeological parameters: surface and groundwater quality, groundwater flow, acidity, etc.
- — meteorological observation
- — morphology: extent and nature of soil erosion processes
- — ground stability: changes of on seismic nature, erosion processes, changes due to settlement and to operation of the landfills, verification by inspection of geophysical data, loads and failure of lining, etc.

• Location of monitoring points

- — minimum one upgradient well (leachate)
- — minimum three downgradient wells (leachate)
- — gas migration probes (perimeter, 100m spacing)

• Sample collection technique

- — bail
- — air lift
- — vacuum
- — centrifugal pump

• Frequency of sample collection

Depends on:

- — goal and level of monitoring programme
- — specific characters of the site (soil/climate estimated rate of travel of pollutants in a given hydrogeological condition)
- — history of variability

• Parameters to be analysed

Depend on:

- — monitoring goals and levels
- — funding
- — waste composition
- — use of nearby groundwater and surface water sources
- — regulatory requirements

Source: Udanax Engineering Consultants, Udanax.

Table 4.7: Site monitoring plans

Table 4.7a: *Overall monitoring scheme*

		Monitor for	Minimum frequency	By	Record	Primary review
1	Urgent and amenity items					
	Public roads	Cleanness	Daily & as indicated by conditions	Foreman (etc)	Site log	District Manager
	Site entrance	Cleanness; tidiness	Daily	Foreman	Site log	District Manager
	Main access road	Cleanness	Daily	Foreman	Site log	District Manager
	Wheelwash	Effectiveness	Daily	Foreman	Site log	District Manager
	Waste as tipped	Conformity	Daily	Foreman	Site log	District Manager & technically competent person
	Working areas	To procedures & work instructions	Daily	Foreman	Site log	District Manager
	Discharges	–	Each	Foreman/Engineer	Site log	District Manager
	Complaints	Cause	Each	Responsible person/Engineer (etc)	Complaints book	Complaints procedure
2	Site inspections					
	[a] Amenity: whole site & environs	As in [a] plus smells, wind blown, refuse, odour control, measures	Weekly & as indicated by conditions	District Manager/ Engineer or Landfill Manager	Site log	Area Manager
	[b] Operations: working areas	To procedures & work instructions; to licence; safety	Weekly	District Manager/ Engineer	Site log	Area Manager
	Workshops	Tidiness; safety	Monthly	District Manager/ Engineer	Site log	Area Manager
	[c] Safety: whole site	Safety	3-monthly; yearly	Safety Manager & Risk Advisers	Action List; Report	Managing Director
3	Quantitative monitoring	*(see Table 4.7b)*				
4	Overview inspection					
	Whole site & environs	To Licence; to discharge; consents; to Procedures & work instructions; safety; amenity; operations; water; management; gas etc.; VDA reports; other records	As required	Overview inspector	Report	Technical Director
5	Forward landfill planning					
	Meeting	All aspects	Monthly	Planning group	Action list/ minutes/report	Technical Director
	Formal visit	All aspects	Six-monthly	Planning group	Action list/ minutes/report	Technical Director
	Other team visits	Any item	as indicated by conditions	Planning group	Action list/ minutes/report	Technical Director
6	Gas survey	*(see also Table 4.8b)*				
	Site & environs (incl. buildings)	Gas migration	Yearly	Landfill Gas Manager	Report	Technical Director
7	Aftercare	All aspects	Yearly	Overview Inspector (Aftercare)	Report	Technical Director
8	Habitat survey	Any ecosystem	As required	Ecologist	Report	Technical Director
		Fresh water; biotic index	Yearly	Ecologist	Report	Technical Director
9	Audit					
	Internal audit	All reports etc.	As required		As required	Technical Director, Managing Director or Director of Planning & Environment
	Annual review/audit	All aspects	Yearly	Consultant	Audit reports	Director of Planning & Environment & Managing Director

Source: Shanks & McEwan, UK.

Table 4.7b: *Quantitative environmental monitoring scheme*

Environmental

		Domain	Parameter	Frequency	By	Comment
1		Surface water				
	a	Outside working area	quality, volume	Half-yearly	Environmental Monitoring Team	
	b	Within working area	quality, volume	Quarterly+	Environmental Monitoring Team	
	c	Treatment system (part)	quality, volume	Monthly+	Environmental Monitoring Team	
	d	Recycling settling wheelwash	quality, volume	Quarterly	Environmental Monitoring Team	
2		Discharges				
	a	Consented discharge				
		i] treatment system batch	quality, flow	E + Weekly	Site Engineer	
		ii] treatment system cont.	quality, flow	Monthly + as indicated by conditions	Site Engineer (+Environmental Monitoring Team)	
		iii] wheelwash	quality	Quarterly +	Environmental Monitoring Team	
	b	Receiving watercourse				
		i] upstream	quality	Quarterly + as indicated by conditions	Environmental Monitoring Team	
		ii] downstream	quality	As indicated by conditions	Environmental Monitoring Team	
	c	Run-off from cap etc.	quality, route	As indicated by conditions	Site Engineer (+Environmental Monitoring Team)	
	d	Watercourse downstream [1]	quality	Quarterly + as indicated by conditions	Environmental Monitoring Team	
3		Refuse water (leachate)				
	a	Within fill				
		i] selected gas wells	level, quality	Quarterly	Environmental Monitoring Team	
		ii] standpipes	level, (quality)	Quarterly + as indicated by conditions	Environmental Monitoring Team	
	b	Lagooned				
		i] static	volume, quality	Weekly	Site Engineer	consider route
		ii] for treatment	volume, quality	Weekly	Site Engineer}	{needs frequent
		iii] for reabsorption	volume, (quality)	Monthly +	Site Engineer}	{review
	c	Uncontrolled	flow, route, quality	Weekly +	Site Engineer	control
4		Groundwater				
	a	Piezometers	head, quality	Monthly	Environmental Monitoring Team	
	b	On-site standpipes	head, (quality)	Quarterly	Environmental Monitoring Team	
	c	Perimeter standpipes	head, quality	Quarterly +	Environmental Monitoring Team	
	d	Off-site: aquifers	quality, head	Half-yearly	Environmental Monitoring Team	plus hydrologist
5		Gas migration				
	a	Migration probes	CH_4, CO_2 + other gases	Monthly	Environmental Monitoring Team	
	b	Perimeter standpipes	CH_4, CO_2 + other gases	Quarterly +	Environmental Monitoring Team	

Notes: extracted gas quality is monitored under the gas control system.

Volumetric

		Parameter	Source	Frequency	By
6		Volume input			
	a	Input tonnages	from tipping summary	Monthly	District Manager or responsible person
	b	Volume estimation	from input tonnages	Monthly	responsible person
7		Void take-up (VIU)	by volumetric survey	Half-yearly	Surveyor
8		Settlement	by survey	Half-yearly	Surveyor

Source: Shanks & McEwan, UK, 1990.

[1] Adjacent watercourse position to pick up any potential pollution.

Table 4.8a: Landfill site supervision

Normal Inspection	
Objective	**Frequent check on normal operation**
Points to consider	• visit each site at least once a day • always observe at first hand what is going on • check if the prescribed procedures are being adopted • observe and be informed of actual or potential problems; take necessary action • during the visit wear appropriate safety footwear and clothing • make some visits at irregular times • let your presence (authority) be seen
Extended Inspection	
Objective	**Less frequent, but thorough check on all facilities**
Points to consider	• weekly or fortnightly visit as circumstances demand • allow sufficient time to carry out the inspection properly • prepare in advance a check list • take action on any thing below standard • keep copies of check list for reference and ensure previous shortcomings have been corrected • maintain a proper record of all visits • try to find solution for problems which often re-occur

Source: *Basic Landfill Management*, Institute of Waste Management publication N° 11, J.D.A. Chivers, June, 1982.

Table 4.8b: Emergency response plan

Personnel	• identification • training	• responsibility • communication
Site	• maps • evacuations routes • engineered control	• security and control • decontamination stations
Medical/First Aid	**Equipment**	**Emergency response support**
Emergency procedures	and	**Reporting**

Table 4.9: Site inspection frequency

Type of facility	Number of inspections per month
Landfills/transfer station taking non-biodegradable wastes	2
Household & commercial waste landfills/transfer station	4
Industrial waste transfer station	4
Industrial waste landfill	4
Industry waste landfill (factory curtilage)	1
Multi-disposal landfill site taking non-special waste	4
Co-disposal landfill site taking difficult and special waste	8
Treatment plant	4
Household waste and merchant incinerators	4
In-house storage facilities	0.25
Household waste amenity sites	4
Scrapyards	1

These are minimum recommended figures, and the frequency of inspection should increase when the facility is not (or is in danger of not) operating to the required standards.

Source: Her Majesty's Inspectorate of Pollution, Waste Management Paper N° 4, *The Licensing of Waste Facilities*, London, 1976.

Table 4.10: Environmental controls

	Environmental problems								
	Spillage	Siltation and erosion	Mud	Dust	Vectors	Odours	Noise	Aesthetics	Safety
Safety programme									✗
Maintain washrooms for personnel	✗		✗	✗	✗	✗		✗	✗
Training of new personnel	✗	✗	✗	✗	✗	✗	✗	✗	✗
Maintain road markings and trench barriers	✗	✗	✗					✗	✗
Maintain fencing					✗		✗	✗	✗
Apply insecticide		✗	✗	✗		✗	✗	✗	
Maintain buffer areas and grass	✗	✗	✗	✗	✗	✗	✗	✗	✗
Proper equipment maintenance			✗	✗			✗		✗
Spray water/oil/liquid/asphalt			✗	✗		✗			
Truck wash pad (to clean trucks)		✗	✗	✗				✗	
Maintain grass waterways, diversion ditches, rip-rap		✗						✗	
Final grading of disturbed areas		✗	✗	✗				✗	✗
Chemical masking agent						✗			
Workers supplied with aerators				✗		✗			✗
Cover solid waste daily					✗	✗		✗	✗
Water diverted away from site		✗	✗						

Source: US EPA—*Solid Waste Landfill Design and Operation Practices*, 1981

Table 4.11: Personnel requirement for an industrial waste landfill operation and their responsibilities

Redland Purle Safety Manual	SAFETY DATA	SD 3-87
		Sheet 8 of 15
		Issue 1
		Date June 1991
Subject Standard Operating Procedure (SOP) for Industrial Waste at Pitsea		

Appendix A

Site personnel involved in the operation of this S.O.P. are as shown below with a description of their areas of responsibility, function and duties.

1 Industrial Waste Manager

Responsible to the Site Manager for industrial waste operations on the site. He is responsible for—

[a] The allocation of land to the various disposal areas.

[b] The administration of the Pitsea Disposal Application Procedure (Form F), also checking the WS classification of material and that the disposal method and area are appropriate.

[c] Monitoring the disposal area.

[d] Ensuring that the emergency procedures are effective.

[e] The condition and availability of all equipment in his functional area.

[f] The control of emergency incidents.

[g] Assisting in the training of his staff in their duties.

2 Site Chemist

Responsible to the Industrial Waste Manager, providing technical assistance for industrial waste operations on the site. He is also responsible for—

[a] Assisting the I.W.M with 1.[a], [b], [e], [f] and [g] above.

[b] Sampling and on-site testing of waste.

[c] Technical supervision of waste deposits where necessary.

[d] Inspecting all drums prior to deposit, venting and emptying them where necessary.

3 Industrial Waste Supervisor

Responsible to the Industrial Waste Manager for the operation of the Industrial Waste Reception Areas, the Common Reception sumps, oversite pumping, together with contract and direction of operatives and plant within the waste disposal function. He is also responsible for—

[a] Upkeep and execution of works in established disposal area.

[b] Daily and short term planning within the IW function.

[c] Ensuring plant and equipment under his control is maintained in good condition.

[d] Maintenance of efficient documentation and records.

[e] Direction of disposal vehicle drivers.

4 Site Reception Clerk

Responsible to the Industrial Waste Manager for the checking and recording facilities at the gatehouse.

[a] Checks documentation of vehicles as they arrive at the gatehouse.

[b] Records the loads and times of arrival of these vehicles.

[c] Authorises the vehicles to proceed to the IWRA.

[d] Sample checks that vehicle is displaying Tremcard and Hazchem information as per Form F.

5 Communications Clerk

Responsible to Industrial Waste Manager for checking and recording facilities at the Communications Office at Waste Reception Area, and maintaining radio contact with the relevant marshal. He—

[a] Checks documentation of vehicles as they arrive at the IWRA.

[b] Records the time of arrival and departure of these vehicles.

[c] Ensures that the driver has the correct safety equipment and liaises with the Site Chemist or Industrial Waste Supervisor to ensure any special facilities are available where required by Form F.

[d] Logs the movement of these vehicles, where necessary using radio contact.

6 Industrial Waste Reception Area Marshal *(Area 1)*

Responsible to the Industrial Waste Supervisor for traffic and discharge control in the above area. He—

[a] Receives vehicles into his area.

[b] Stops the discharge of any load in the event of an unexpected or vigorous reaction.

[c] Is competent to handle the emergency equipment.

[d] Is responsible for all safety equipment in his area and the daily rechecking of the Site Ambulance.

[e] Makes daily inspection of oversite pipeline from IWRA to Common Reception excavations.

[f] Maintains equipment and good housekeeping within the area.

7 Separate Excavation Area Marshal *(Areas 5B, 5C, 6 and 7)*

Responsible to the Industrial Waste Supervisor for traffic and discharge control. He in particular—

[a] Accompanies or receives vehicles into his area.

[b] Checks documentation and directs vehicles to excavations reserved for the load category.

[c] Supervises the unloading of the vehicles.

[d] Initials the driver's copy of the Form F on completion of discharge.

[e] Stops the discharge of any load in the event of an unexpected or vigorous reaction.

[f] Maintains radio contact with the Industrial Waste Supervisor or CC.

[g] Is competent to handle the emergency equipment.

[h] Checks the excavations are not over-filled.

[i] Ensures that backfilling operations are carried out.

[j] Is responsible for all emergency and safety equipment in his area.

8 Non-Compatible Liquid Waste Disposal Area Marshal *(Areas 2 and 3)*

Responsible to the Industrial Waste Supervisor for traffic and discharge control in the above areas. He—

[a] Accompanies or receives the vehicle into his area.

[b] Checks documentation and directs the vehicle load to the appropriate area excavation.

[c] Supervises the unloading of the vehicles.

[d] Initials the driver's copy of the Form F on completion of the discharge.

[e] Is competent to handle the emergency equipment.

9 Notifiable Dry Industrial Waste Area Marshal *(Area 4)*

Responsible to the Industrial Waste Supervisor for traffic and discharge control in the above area. He—

[a] Receives the vehicle into his area.

[b] Supervises the unloading of the vehicle.

[c] Operates the bulldozer on the disposal face.

[d] Ensures that deposited materials are covered in accordance with Site Licence requirements.

[e] Receives, supervises and directs vehicles containing domestic refuse, roadborne trade waste and inert cover material.

[f] Is responsible for and is competent to handle the emergency equipment in his area.

Source: *Control, Inspection and Surveillance of Landfill Waste Disposal Sites,* one day Seminar, Kensington, UK, May, 1982.

Note on Hazardous Waste Landfilling Procedures

In addition to controlling the wastes coming in to the site, correct procedures must be used in actually placing the waste in its intended location.

Only compatible wastes are placed together (see *Table 1-4*, for example). The various locations for placement of wastes must be clearly defined for the operator.

Waste is deposited in a grid system, in defined layers.

Cell sizes for wastes depend on the nature of the waste and its packaging. Bulk waste can be spread in layers up to 1m thick before covering. In mono-landfills the layers may be much thicker.

Encapsulated wastes are placed in their containers, and subsequently inert material is filled in the spaces between containers. Special lifting machinery may be needed.

4.3 EXERCISES

EXERCISE 4.1 Landfill operational methods

Opposite are some Udanax wastes chosen at random from *Table 5, Udanax Country Report*.

Indicate which wastes should *not* be landfilled in their current form.

What operational procedures could be used to safely landfill these wastes, and what pretreatment should be used prior to landfill?

(i) dust/slag from foundries
(ii) solvent sludges (semi-solid in drums)
(iii) lime sludges containing heavy metals
(iv) soil contaminated with refinery tars
(v) asbestos from buildings
(vi) pesticide containers

EXERCISE 4.2 Checking/monitoring incoming wastes

(a) *At the Western dumpsite:* recommend measures that can be introduced quickly and cheaply by the city authority to identify the quantity and the types of hazardous wastes currently coming to the site. Who should undertake this?

(b) A future new industrial landfill site: recommend measures for comprehensive checking and monitoring of incoming hazardous wastes. How many personnel and what equipment is needed?

EXERCISE 4.3 Operation of a site

(a) As the general manager of the disposal company (you are located in another town, 200 km away), how will you assure yourself that your staff are operating the site properly?

(b) As a responsible waste generator in Udanax who wants to avoid adverse publicity or later repercussions from the authorities, how do you assure yourself that the landfill site you are now using is (or is not) [i] properly managed, [ii] not likely to result in pollution?

EXERCISE 4.4 Landfilling prohibited wastes

(a) A transporter has knowingly brought in prohibited waste into your licensed landfill facility. What will you do? Explain.

(b) The Udanax City authorities approach you to accept 2000m^3 of contaminated soil and debris from a recent chemical warehouse fire in the harbour area. At the time over 60 different chemicals were stored there. No comprehensive analysis for residues is currently possible in exiting laboratories in Udanax. Will you accept this waste for landfilling?

If *yes*, what precautions will you have to take?

If *no*, what should the city authorities do with the soil and debris?

EXERCISE 4.5 Site operation information programme

Prepare a list of points a landfill operator should include in an information bulletin for his clients who bring potentially hazardous waste onto the site for disposal.

(a) To transporter

For example—

1. All vehicles must be clearly identified with a hazard warning label, as appropriate.
2. All vehicles must be in a sound, safe condition.
3. Documentation describing the waste load must be carried in the vehicle.
4. Now continue …

(b) To waste producer

For example—

1. The hazardous nature of the waste must be identified to the driver and to the landfill operator.
2. Landfill operator must be informed a minimum of 24 hours in advance about disposal of wastes.
3. Now continue …

EXERCISE 4.6 Upgrading an old dumpsite

Assume that the *Western Dumpsite* in Udanax City will be upgraded as an interim measure to allow disposal of some hazardous wastes.

In such circumstances, discuss the new operational activities to be carried out in the dumpsite.

Some of the operational activities are listed here—

- fencing the dumpsite
- controlled access to the dumpsite
- lining one section of the dumpsite to accept hazardous wastes

Indicate other possible operational activities below.

EXERCISE 4.7 Site fees

Propose a set of fees to be charged by the management for disposal of industrial waste at the upgraded Western dumpsite. Explain your proposal.

4.4 SESSION REPORT

In the space below, prepare a summary of your conclusions on the operational procedures to be adopted in Udanax. This summary will be included in the final Task Force report to the mayor of Udanax.

Work Group ______________________________

Session ______________ Subject ______________

Main results and conclusions

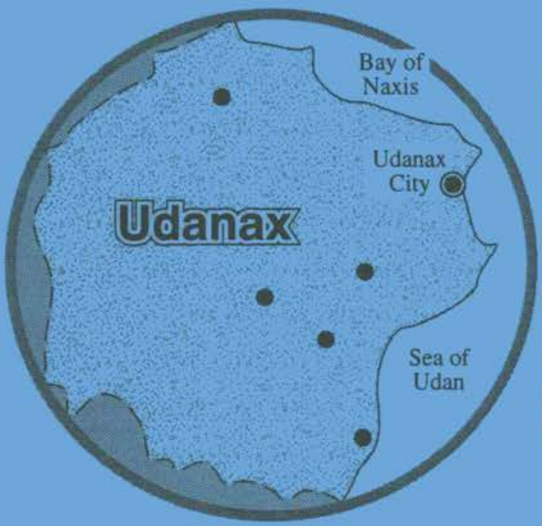
Work Group Members ______________________________

Return completed sheet to workshop co-ordinator for incorporation in the workshop report.

Casework Notes *for* SESSION 5

PART III

UNEP



Regulatory Procedures for Landfill Operation

CONTENTS

5.1 INTRODUCTION

It is unlikely that the correct choice of site, good engineering design, and careful operation would always occur if they were not demanded by regulation.

Regulations may take the form of general standards for landfill siting and management, or as site licences. In many countries both methods apply simultaneously.

Regulations are ineffective unless they are adequately enforced. Enforcement relies on monitoring.

In the end, a comprehensive administrative capability is needed to exercise the necessary control over all aspects of landfill operations.

The question of public involvement in regulatory affairs has become more important in recent years.

Public acceptance of landfills is generally low, and there is widespread mistrust of operators and of control agencies.

Regulatory and enforcement activities, as well as the operator, now need to have a high level of transparency if they are to retain public confidence.

The exercises here simulate a number of the regulatory considerations commonly faced by administrators and operators.

5.2 BACKGROUND INFORMATION

Table 5.1: Option menu for hazardous waste legislation

Purpose and scope		
• Public health	• Raise funds	• Pollution prevention
• Empower a corporation	• Workplace safety	• Co-ordinate agencies
• Control operations		• Establish liabilities
Type		
• Framework law (enabling legislation)	• Subordinate regulations	
• Subordinate law	• Schedules	
• Primary laws on hazardous waste	• Complementary laws on hazardous waste	
• Waste provisions in other laws		
Application		
• Waste handling	• Waste information	• Chemical use
• Definitions	• Waste generation	• Assessments/studies
• Storage	• Research	• Transport
• Measurements	• Treatment/recycling	• Training
• Disposal	• Dumping	• Clean-up
Instruments		
• Notification	• Standards	• Certification
• Guidelines/codes/policies	• Labelling	• Monitoring
• Orders to act/not to act	• Release of information	• Bans
• Assistance measures	• Licensing/permitting	• Fiscal measures
Fiscal measures		
• Fees and charges	• Compensations	• Fines
• Tax concessions	• Subsidies	• Levies
Powers		
• Obligations	• Giving directions/orders	• Responsibilities
• Right of refusal	• Offences	• Right to know
• Authorisations/delegations		• Right to secrecy
Enforcement		
• Which agencies	• Extent of proof	
• Possible conflict of interest (self-licensing of agencies)		

Note: This list is not exhaustive

Table 5.2: Support services for hazardous waste management

Codes of practice; standards; guidelines

- site design, equipment design
- site operation
- waste handling
- waste sampling and analysis

Technical services and research

- laboratory facilities to provide information on waste composition and environmental contamination
- environmental investigation of site problems
- plant feasibility assessment, design and construction
- emergency response and accident clean-up
- site rehabilitation
- research into improved recycling and treatment methods

Training

- personnel involved in handling and transporting of wastes, and operating facilities
- surveillance and enforcement staff
- emergency response crews
- waste managers, supervisors, senior government staff, consultants
- future professional engineers and scientists

Extension and advisory services

- advice on waste treatment and disposal methods
- interpretation of environmental monitoring information
- access to technical literature and information network
- public education and information

Management services

- co-ordination of the waste exchange services
- conduct of a periodic census of waste quantities
- initiation and co-ordination of collection and storage of miscellaneous wastes
- facilitation of interstate or international arrangement for waste treatment
- facilitation of co-operative disposal and other arrangements

Monitoring

- ambient environmental monitoring around waste disposal facilities and elsewhere (groundwater, surface water etc.)
- waste composition and quantities
- waste transport operations
- waste treated and disposed of
- potential for recycling, waste reduction and reclamation

Source: Compiled from various reference documents cited in *Part I*.

Table 5.3: Disposal and treatment cost estimation

Hazardous waste management costs consist of—

- avoidance cost
- abatement cost
- damage cost
- compensation cost
- transaction cost

Economic incentives—

- government grants
- subsidies
- tax reduction
- incentives for waste reduction/avoidance
- deposit refund programme
- incentives for waste recovery and reuse (oils, batteries etc.)
- low permit fees for recycling facilities

Figure 5.1: Example of a transport certificate [1]

ENVIRONMENT PROTECTION AUTHORITY

CERTIFICATE FOR THE TRANSPORT AND DISPOSAL OF WASTES

PLEASE COMPLETE IN BLOCK LETTERS

Part 'A' – to be completed by Waste Producer

Name of Producer

Postcode

Telephone No

Waste Code No

Quantity

Units – cross component square

m³ / l / kg

Waste Type
(place 'x' in appropriate squares)

solid / liquid sludge / inert / poisonous (toxic) / flammable / corrosive / odorous / highly reactive / infectious

Intended Disposal Route

Recycling / Incineration / Land / Immobilisation / Phys/Chem Treatment / Others

Description of Waste including identification of hazardous components

Further Comments:

Nominated Disposal Site
(please name selected site)

Refer to E.P.A. for list of current facilities

Signature of Waste Producer

Signature of Driver

Part 'B' – to be completed by Transporter

Name of Transporter

Transport Permit No

Vehicle Reg. No.

Loading Date 19

Part 'C' – to be completed by Disposal/Treatment Site Attendant

Name of Disposal/Treatment Site

Site Licence No 19

Deposit Date 19

Signature of Site Attendant

Source: Australian Environment Protection Authority, Draft Industrial Waste Strategy for Victoria, Melbourne, 1985.

[1] Such a certificate is commonly used in the form of multiple copies, as shown in *Figure 5.2.*

Figure 5.2: Transport control

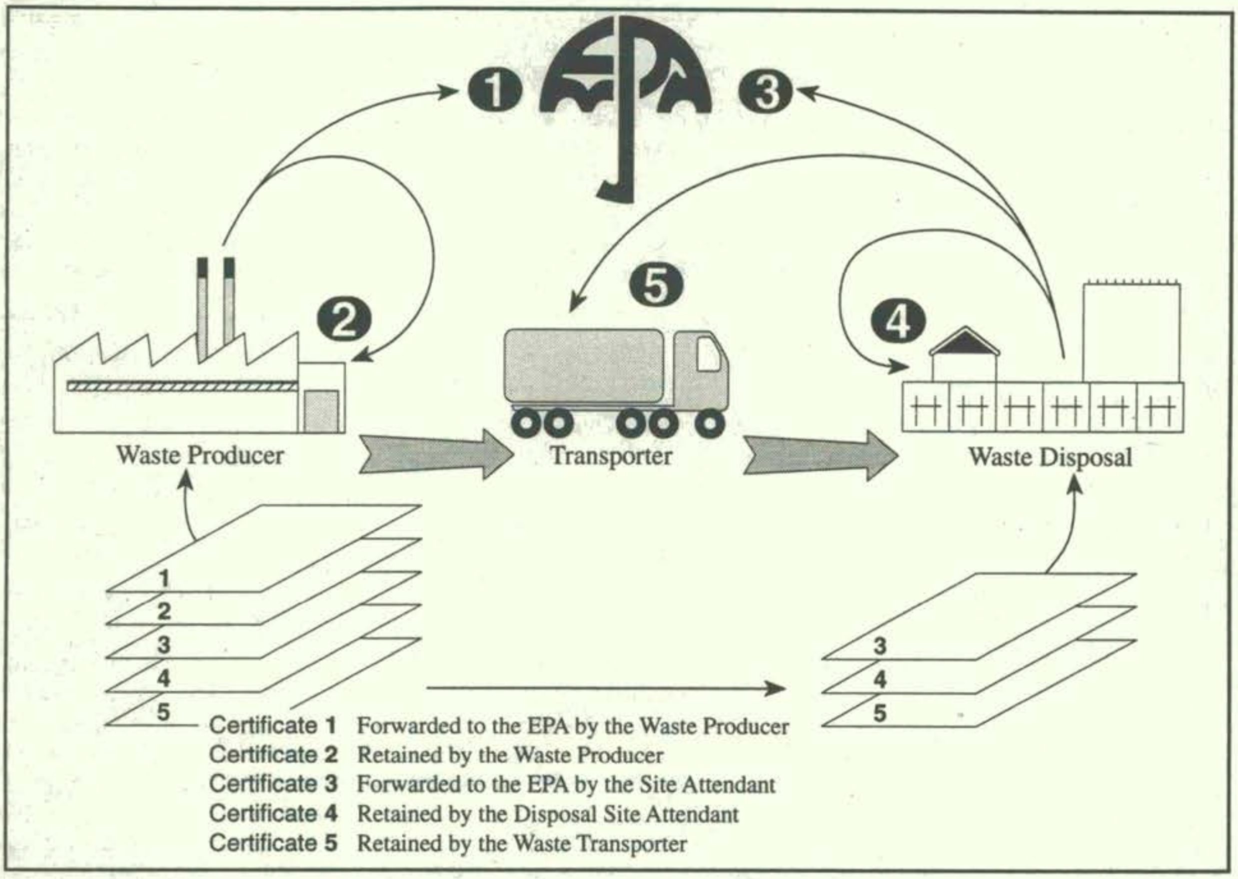


Table 5.4: Licensing elements for ha`zardous waste landfill sites

The site
- geological requirements
- planning constraints
- zoning for subsequent use

The waste
- permitted and prohibited wastes
- waste transport certificate

Plant design
- suitability of the plant for its purpose
- correct design parameters
- design evaluation (performance, hazard)

Operation
- licensee to be a "fit and proper" person
- care and responsible operation
- operators to be duly qualified
- details of operation
- on-site technical expertise
- personnel training
- who is responsible in case of non-compliance?

Reporting and monitoring
- person designated responsible for submitting reports
- ambient environmental monitoring and reporting
- sampling and recording of waste
- reporting of site operation and accidents
- annual report of operation
- recycling potential of accepted wastes

Site rehabilitation

Financial bond or liability insurance

Progressive rehabilitation

Perpetual care details; ongoing monitoring

Cancellation of licence

Adapted from: Australian Environmental Protection Authority, Draft Industrial Waste Strategy for Victoria, Melbourne, 1985.

Table 5.5: Example of landfill licence conditions

The following example licence conditions show how some of the operational criteria and standards discussed in the text may be translated into reasonable conditions. The figures in [ ] refer to site specific conditions.

It cannot be stressed too strongly that these example conditions are provided for the purposes of illustration only. It cannot be assumed that any of them would apply to an existing, or proposed, waste facility. They are written in such a way that they require appropriate modification before incorporation into a licence.

B.10 Example Licence Condition for site entrance to waste treatment facility taking some 5,000 TPA of liquid industrial wastes

The layout of the site entrance shall be as set out in Drawing No [ ] of the Working Plan. In constructing the site entrance, the following standards shall be met:

a) The road leading from the highway to the site entrance shall not be less than [ ] wide and surfaced with [ ]. Potholes which develop shall be filled with [ ] and resurfaced. The condition of the road will be inspected daily by the site foreman.

b) No water shall be allowed to pond on the surface of the road and accordingly drains of not less than [ ] diameter and with inlets at [ ] metre intervals shall be constructed on either side of the road. Each inlet shall be screened to prevent ingress of leaves or other solid debris. The inlets shall be inspected daily and kept free of debris.

c) The gates at the site entrance shall be [ ] metres high and surmounted by a device designed to prevent unauthorised entry. The gates shall be constructed of mesh steel with a maximum mesh gap of [ ]. Gates will be securely locked during periods when the site is not in operation. All damage to the gates which impairs their effectiveness will be repaired as soon as practicable and if this cannot be accomplished by the end of the working day the operator shall provide security personnel to guard the entrance whilst the site is closed.

B.2 Example Licence Condition on maintenance of a site road at a landfill site taking household and similar wastes

1. The road from the site entrance to the reception office, as defined in Drawing No [ ] of this licence, shall be kept in good repair such that any crack or pothole shall be repaired within [ ] working days. A repair shall consist of the crack or pothole being filled with appropriately sized hardcore and compacted. The surface of the repair shall be finished flush to the surface of the road with [ ].
2. The site road shall be kept free of mud or other debris, at least to the extent necessary to prevent fouling of the public highway and shall be swept by mechanical sweeper as required. All drains and inlets shall be kept free from mud and inspected [ ].

B.3 Example Licence Condition for the inspection of special wastes at a treatment plant

1. All vehicles containing wastes listed in condition [ ] of this licence shall proceed directly to the parking area adjacent to the control room marked [*A*] on Drawing No [ ].
2. Special wastes must be accompanied by an analysis or description of relevant parameters prepared by the producer and the site chemist shall certify, by countersigning the document, that the wastes conform to those permitted by this licence to be deposited. Accordingly confirmatory analyses of [*pH, acidity and flash point*] will be undertaken for these wastes.
3. Vehicles carrying wastes shall be permitted to proceed from the parking area to the disposal area only when the site chemist has confirmed as above that the wastes conform to those permitted by this licence.
4. Copies of all signed documents shall be kept in chronological order and made available at all reasonable times for inspection by any authorised officer of the WDA.

B.4 Example Licence Condition specifying manning and equipment levels at a transfer station taking mixed waste of more than 25,000 PTA

1. The site shall be manned at all times by at least [ ] operatives when it is open for the reception of wastes. One operative shall man the waste reception office and be responsible for record keeping.
2. The site shall be equipped with at least [*one mechanical shovel*] to move wastes deposited on the floor to the appropriate storage area. The operative supervising vehicle movements shall be responsible for ensuring that wastes deposited on the floor conform to the requirements of this licence. Wastes found not to conform shall be dealt with strictly in accordance with condition [ ] of this licence.
3. In the event of a breakdown of the mechanical shovel and no replacement being available within [ ] hours the facility shall cease accepting wastes. The date and time of any breakdowns shall be recorded above the signature of the site manager. These records shall be kept on site and made available to any authorised officer of the WDA.

B.5 Example Licence Condition regulating the input of household waste into a multi-disposal landfill

1. No waste shall be accepted until a stockpile of suitable cover material (earth, clean builders rubble and construction debris; sand and similar non-reactive wastes) of at least [ ] m^3 has been formed. Thereafter no wastes shall be accepted on site if this stockpile of cover at the beginning of the working day has fallen to less than [ ] m^3.
2. The maximum quantities of household waste accepted during the working day shall not exceed [ ] loads. For the purposes of this condition all vehicles discharging wastes of whatever size shall count towards this total.
3. A record, as specified in condition [ ], shall be kept of all vehicles entering the site. These records will be kept at the site office [*Block A in Drawing A*] and shall be made available for inspection during working hours to any authorised officer of the WDA.

B.6 Example Licence Condition regulating waste types and amounts entering a co-disposal landfill which can accept difficult and special wastes

1. The following wastes may be deposited (subject to 2–6 below):
   a) Household and commercial wastes as defined in Section 30 of the Control of Pollution Act, 1974 and in Schedules 1 and 4 of the Collection and Disposal of Waste Regulations 1988;
   b) Industrial wastes as defined in Section 30 of the Control of Pollution Act, 1974 and in Schedule 3 of the Collection and Disposal of Wastes Regulations 1988.
2. No difficult or special waste, other than those listed below, shall be accepted:
   a) The following materials whose physical properties require special care in handling

      [....]
      [....]
      [....]
   b) Waste containing up to [ ] by weight total non-alkyl mercury or [ ] by weight alkyl mercury up to a maximum of [ ] per day and [ ] per calendar month of mercury;
   c) Waste contaminated with cyanide not exceeding [ ] cyanide up to a maximum of [ ] per day and [ ] tonne per calendar month of cyanide;
   d) Arsenic, antimony and selenium contaminated wastes where the maximum concentration of each element does not exceed [ ] by weight. The total quantity of elemental arsenic, antimony and selenium deposited shall not exceed [ ] per day and [ ] per calendar month. The total quantity of non-elemental arsenic, selenium and antimony deposited shall not exceed [ ] per day, and [ ] per calendar month.
3. The maximum quantities of waste types specified in 2(b), (c) and (d) above which may be deposited at the site shall not exceed [ ] tonnes per month ([ ] tonnes per day) as measured by a weighbridge.
4. The site may only accept wastes in categories 3(b), (c) and (d) above provided that in the previous three calendar months the amount of wastes specified in 1 above exceeded [ ] tonnes.

5. All consignments of waste types specified in 3(b), (c) and (d) above shall be accompanied by a description of relevant parameters, which must be certified before the waste is deposited (see condition [ ]).

6. All difficult and special wastes shall be accompanied by a relevant description of appropriate parameters, which must be checked before the waste is deposited (see condition [ ]). They shall also be accompanied by a weighbridge ticket or be weighed before acceptance on site (see condition [ ]).

B.7 Example Condition covering the installation of a clay liner at a landfill site where the lining is to be completed fully before wastes are deposited

1. The base and sides of the site shall be lined with a minimum of [ ] metre of clay as specified in Drawing [*A*] and the working plan.

2. Representative samples of the material used in the liner shall be tested in an approved soils laboratory to ensure it is capable of being compacted to achieve a permeability of not more than [ ]. Samples shall be taken at [ ] intervals on a regular grid.

3. The method of soil testing shall be in accordance with the following schedule:

   The density/moisture content relationship of the material shall be determined in accordance with B.S. 1377 Tests 12 and 13. The appropriate size of hammer shall be selected to reflect the actual compaction equipment it is proposed to use on site. Where there is any uncertainty regarding the type of plant both tests are to be carried out.

4. The permeability of the re-compacted sample shall be measured for each moisture content increment of the compaction test. This will involve at least [ ] permeability values being obtained from each sample. When testing the re-compacted clay the permeability shall be measured directly by the falling head method, using the B.S. compaction mould.

5. The natural moisture content and Atterberg Limits (Liquid Limit and Plastic Limit) of each sample shall be measured in accordance with B.S. 1377: Tests 1, 2 and 3 respectively. The Particle Size Distribution, and in particular the clay contents, shall be determined by B.S. 1377 Test 7.

6. Where in-situ material is to be used to contain leachate or to form part of the seal it shall be tested to establish that it has a permeability of not more than [ ]. In the case of soils, permeability measurements shall be carried out either in the field using variable head or constant head tests in accordance with B.S. 5930, Section 21.4, or in the laboratory by the falling head method. The thickness of the in-situ material shall be measured to establish:

   1) If sufficient material is present to meet the requirements, or,
   2) The additional thickness of material required.

7. The minimum thickness of clay liners shall be [ ] metres. The minimum thickness of final caps shall be [ ] metres. The thickness shall be measured normal to the surface of the seal at the point of test. The material shall be placed in a series of thin layers and repeatedly tracked using the agreed compaction equipment. The maximum thickness of each layer will be [ ] and the minimum number of passes will be [ ].

8. The following unsuitable materials will be excluded from the liner:

   1) Materials from swamps, marshes and bogs,
   2) Peat, log stumps and perishable material,
   3) Material susceptible to spontaneous combustion,
   4) Material in a frozen condition,
   5) Industrial, commercial or household waste,
   6) Rocks, concrete or boulders having a volume greater than 0.05 cubic metres.

B.8 Example Licence Condition regulating the deposit of special wastes at a multi- or co-disposal landfill

1. The location of all special wastes shall be recorded on a drawing of the site in accord with the requirements of the Control of Pollution (Special Waste) Regulations 1980.

2. The location of all deposits of special wastes shall be identified by reference to site posts located at [ ] metre intervals around the perimeter of the site and located on a [ ] scale plan of the site. This drawing shall be divided into [ ] metre squares and the location of each deposit shall be marked on the drawing as falling into one of these squares.
3. The site shall be surveyed every [ ] months and a new plan at [ ] scale prepared to take account of changes due to infilling. This drawing shall also be divided into [ ] metre squares.
4. A copy of the superseded drawing shall be retained at the site office and a copy forwarded to the WDA within [ ] working days of the new drawing being prepared.

B.9 Example Condition regulating input of a liquid waste into a treatment plant

1. The total amount of wastes on-site shall not exceed the storage capacity of the site which is [ ] million litres in tanks A to C and [ ] million litres in drum stores R through to Z as specified in Drawing A.
2. All liquid wastes entering the site shall be accompanied by a description of relevant parameters provided by the waste producer. No waste shall be accepted for treatment unless an appropriately qualified person has certified that the description of the wastes conform to that previously approved for receipt.
3. All wastes not conforming to the specification set out in Condition [ ] shall, if possible, be held on the vehicle at Area P as shown in Drawing A of the working plan. The maximum time a non-permitted waste may be stored on site shall not exceed [ ] days and the WDA shall be informed within one hour of all cases where non-permitted wastes have to be stored or turned away. In the latter case information on the vehicle registration number, driver's name, producer's name and destination of waste shall be given.
4. A record of the description of the relevant parameters of all wastes received for treatment shall be maintained at the site office and made available on demand to any authorised officer of the WDA.

B.10 Example Condition covering storage of wastes at a transfer station

The following wastes shall be stored at the locations specified below as shown in Drawing A.

Construction and demolition rubble, road chippings and hardcore	Bay A
Asbestos	Lockable skip of [ ] metres capacity located in Bay B
Decontaminated empty containers of less than 50 litres capacity	Up to a maximum of [ ] in Bay C
Commercial waste	Bay D

Before any wastes are deposited in Bays A and D a line [ ] metres above ground level shall be painted on the sides and walls of the bay. Wastes shall not be stored above that line and the front face of the wastes shall be laid at such an angle that there is no likelihood of the wastes flowing out beyond the bay.

Source: Her Majesty's Inspectorate of Pollution, Waste Management Paper No. 4, *The Licensing of Waste Facilities*, London, 1976, amended 1988.

Table 5.6: Typical data collection check list for issuing licence

1.0 Name of the site ....

2.0 Site No ....

3.0 Grid Ref ....

4.0 Planning application numbers and appropriate date for—

4.1 Extraction ....
4.2 Disposal ....
4.3 Any other purpose ....

5.0 Site description

5.1 Area for extraction—
- 5.1.1 Permitted ....
- 5.1.2 Worked ....
- 5.1.3 Reserves ....
- 5.1.4 Restored ....
- 5.1.5 Estimated rate of extraction ....

5.2 Area for disposal—
- 5.2.1 Permitted ....
- 5.2.2 Reserved ....
- 5.2.3 Restored ....
- 5.2.4 Face height (meters): Max. depth of hole ....
- 5.2.5 Volume available if extraction still taking place (m^3) ....
- 5.2.6 Volume available after extraction is completed (m^3) ....

5.3 Is surface water present?
- 5.3.1 Indicate: pool/lagoon/puddle/brook/adit other ....

5.4 Is mineshaft(s) present? ....
5.5 Geology of quarry floor/substrate ....
5.6 Requirement for retention of top soil .... yes ☐ no ☐
5.7 Requirement for retention of sub-soil .... yes ☐ no ☐
5.8 Relevant restoration conditions—

		Existing	*Proposed*
5.8.1	None		
5.8.2	Restore to an even contour	☐	☐
5.8.3	Backfilling with suitable waste, grade and top soil	☐	☐
5.8.4	Restore to as near to original conditions as possible	☐	☐
5.8.5	Any others	☐	☐

6.0 Land use

6.1 *Present use:* derelict/suitably rehabilitate itinerants/fly tipping/others (specify): ....
6.2 *Possible future use, after tipping:* indicate recreation/agriculture/woodland/caravan site/ industrial/others (specify): ....

7.0 Any problem with operational needs of site .... yes ☐ no ☐ negotiable ☐

7.1 Is there any services traversing the site overhead or underground? ....

8.0 Visual amenities

8.1 Distance to nearest dwelling .... (m)
8.2 Distance to nearest main road .... (m)
8.3 Distance to nearest railway line .... (m)
8.4 Distance to nearest canal .... (m)
8.5 Distance from the main river .... (m)
8.6 Distance to nearest groundwater source .... (m)

8.7 Distance to nearest surface water source .... (m)
8.8 Distance to airport .... (m)
8.9 Distance from nearest school .... (m)
8.10 Distance from nearest hospital .... (m)
8.11 Distance from nearest water reservoir .... (m)

9.0 Accessibility for heavy vehicles

9.1 Existing .... Good ☐ Adequate ☐ Poor ☐
9.2 Is there a load restriction on the access road? .... Yes ☐ No ☐
If Yes specify:
9.3 Work required to create adequate access .... Minor ☐ Major ☐
9.4 Distance to suitable road (m) ....
9.5 Effect of heavy goods vehicles on locality .... Little ☐ Minor ☐ Major and objectionable ☐

10.0 Time scale

10.1 Estimated availability period of site .... Many years ☐ Immediate ☐
10.2 Estimated length of time facility should continue .... years

11.0 List of work necessary before/during operations to make this a safe and acceptable site (in brief) ....

12.0 Site suitable for

12.1 Domestic refuse .... Yes ☐ No ☐
12.2 Pulverised domestic refuse .... Yes ☐ No ☐
12.3 High density domestic refuse .... Yes ☐ No ☐
12.4 Incineration ash from domestic refuse .... Yes ☐ No ☐
12.5 Demolition waste .... Yes ☐ No ☐
12.6 Commercial waste .... Yes ☐ No ☐
12.7 Less toxic industrial wastes (give details) .... Yes ☐ No ☐
12.8 Particularly toxic wastes (give details) .... Yes ☐ No ☐
12.9 Inert waste .... Yes ☐ No ☐
12.10 Farm waste .... Yes ☐ No ☐
12.11 Sewage sludge from non-industrial area .... Yes ☐ No ☐
12.12 Sewage sludge from industrial area .... Yes ☐ No ☐
12.13 Liquid waste (give details) .... Yes ☐ No ☐
12.14 Others .... Yes ☐ No ☐
Specify if dusty or odorous waste could be allowed ....

13.0 Water pollution

13.1 Is this site (with respect to the waste applied for)—
.... Very safe ☐ Safe ☐ Can be made safe ☐ Unusable ☐
13.2 For the materials specified above in *Section 12*, is the site—
.... Very safe ☐ Safe ☐ Suitable ☐

14.0 Would you like to impose a noise limit at the noise sensitive area? .... Yes ☐ No ☐

14.1 If Yes, give limit ....

15.0 Would dust level control be required? .... Yes ☐ No ☐

15.1 Give parameter and specify place ....

16.0 Is subterranean disposal acceptable for the waste(s) applied for? .... Yes ☐ No ☐

17.0 Any conflicting condition/interest involved such as no tree felling, etc. .... Yes ☐ No ☐

18.0 Any other comments ....
....

Source: *Control Inspection Surveillance of Landfill Waste Disposal Sites*; One day seminar report, Kensington, 14 May, 1982, UK.

Table 5.7: Parameters for hazardous waste laboratory analysis [2]

Physical factors			
• appearance/physical nature	• odour	• colour	• temperature
• viscosity - mobility	• water content	• settleable matter	
Physico-chemical and biological factors			
• pH	• COD	• BOD	• calorific value
• flash point/flammability	• ash content	• chloride	• nitrogen
• phosphorous	• pathogenic organisms	• sulphide	• organic carbon
Potentially important chemical components			
• acidity	• alkalinity	• heavy metal content	• phenols
• oil & grease	• cyanide	• chromium/chromate	• boron
• mercury	• arsenic	• coal tar	• halogens
• chlorinated and other biocides	• PCBs	• polyaromatic hydrocarbons	

Table 5.8: Monitoring to be carried out at landfills taking biodegradable wastes

Leachate, surface and groundwater	
Monthly	Levels in monitoring wells and volumes discharged; pH; Chloride
Bi-annually	COD; BOD; Total organic carbon; Conductivity
Landfill gas	
Weekly	Methane/carbon dioxide concentration at vents and boreholes
Monthly	Gas pressure and barometric pressure
Others	
Weekly	Vegetation die-back and vermin presence
Annually	Void utilisation; Settlement

Source: Her Majesty's Inspectorate of Pollution, Waste Management Paper No. 4, *The Licensing of Waste Facilities*, London, 1976, revised 1988.

Table 5.9: Basic landfill site laboratory equipment

	Equipment	Parameter
1.	Sampling devices for liquid/sludge wastes	
2.	pH papers or pH meter	pH
3.	Titration equipment	acid/alkali strength
4.	Adsorbent paper and matches	flammability
5.	Glassware	appearance
6.	Droppler bottles of selected reagents	reactivity
7.	Bellows and a selection of gas detection tubes	volatility and gas type
8.	Filtration equipment	
9.	Hydrometer	specific gravity

Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989.

[2] Actual parameters will depend on the site, and especially on the types of wastes accepted at the site.

5.3 EXERCISES

EXERCISE 5.1 Landfill licensing

(a) A new operator takes over the management of the Western Dumpsite, and you are reviewing the permit. What permit conditions or other requirements would you place on the contractor to ensure better management of the site?

(b) How would you enforce these conditions with the present staff available?

(c) What conditions would you place on the operation of a new landfill site (Blue or Green)? (Consider design, operation, waste acceptance, and closure issues as minimum).

(d) You are granting a contract to a local transport company to collect waste from Industrial Estate A. What conditions will you place on the contract?

(e) How do you intend to see that the conditions are complied with?

(f) What will you do if the contractor does not comply with the conditions?

EXERCISE 5.2 Checking/monitoring incoming wastes

(a) *At the Western dumpsite:* recommend measures that can be introduced quickly and cheaply by the city authority to identify the quantity and the types of hazardous wastes currently coming to the site. Who should undertake this?

(b) A future new industrial landfill site: recommend measures for comprehensive checking and monitoring of incoming hazardous wastes. How many personnel and equipment is needed?

EXERCISE 5.3: Treatment and disposal fees and economic incentives

(a) As the soon to be appointed Director of Udanax City Hazardous Waste Management Programme, you have been asked to propose a system of government charges to be imposed on landfilled wastes. Explain which method of fees calculation you will adopt:

Option 1:	Single price for all wastes based on a weight or volume basis
Option 2:	Incorporate a "degree of hazard" approach, i.e., fees based on a graduated scale in terms of hazard
Option 3:	A combination of above two methods
Option 4:	Based on cost recovery of government inspection and monitoring
Option 5:	Based on the policy of discouraging landfilling certain of wastes
Option 6:	Other

List advantages and disadvantages of the method you have chosen.

(b) What fees will you charge small generators of chemical waste (shops, schools, workshops, farms, etc)?

(c) Assume that the future Udanax City landfill site will be owned by the government but will be operated by a private company. In such a situation what type of economic incentives or disincentives the government should adopt with respect to:

(i) Waste generators

(ii) The landfill operator

(iii) Reduce public opposition over the landfill site

EXERCISE 5.4 Reporting requirements

(a) Regular monitoring and sampling of incoming wastes in a landfill site in an important task. Nevertheless, the type of analysis carried out at landfills depends on the nature and quantity of incoming waste. For the proposed landfill site in Udanax, from *Tables 5.7* and *5.8*, list ten common tests you will carry out for all incoming wastes.

Indicate what information you will request from the waste producer.

(b) In addition to the above mentioned regular record keeping of all incoming wastes, list the activities the site operator has to report to the Udanax City council:

For example—

1. Quantity and type of wastes landfilled
2. Planned changes to the site facility layout
3. ....
4. ....
5. ....
6. ....
7. ....
8. ....

EXERCISE 5.5 Interim waste disposal programme

The construction of new landfill facility in Udanax will take at least 12 months. During this period, a list of interim administrative procedures have been proposed to improve the existing hazardous waste disposal practice. From the list below, select five important ones and rank them in order of priority:

- Continue the present practice of unsafe dumping
- Upgrade one of the existing dumpsites on a temporary basis
- Store hazardous wastes in a safe site for future landfill
- Solidification of hazardous wastes with cement or lime before dumping
- Special burial at a secure site elsewhere
- Co-incineration of organic wastes in a cement-kiln situated 250km from Udanax City
- Collect for destruction at an overseas facility
- Dumping on the existing land adjacent to factories in the industrial estates
- Greater sharing existing private facilities
- Impose stringent waste control standards
- Promote waste segregation, recovery and recycle policies
- Ocean disposal
- Deepwell injection in a site 300 km from Udanax City
- Segregation of wastes at the sources and dispose relatively toxic wastes in the upgraded landfill site

Indicate any additional measures you would like to propose to the above list.

Imagine as an interim measure that one of the existing dumpsites in Udanax City will be upgraded to accept certain toxic wastes. Indicate the administrative procedures and/or activities you have to plan.

For example:

- Setting-up interim standards for waste dumping
- Regular site inspection and monitoring
- ....
- ....

EXERCISE 5.6 Regulatory needs

Examine the current regulations in Udanax that apply to industrial waste landfill. In the light of a) current disposal problems, and b) the need for new facilities, recommend legislative changes and additions so as to better control the situation.

5.4 SESSION REPORT

In the space below, prepare a summary of your conclusions on the administrative and regulatory measures needed in Udanax to control future industrial landfilling operations.

This summary will be included in the final Task Force report to the mayor of Udanax.

Work Group ______________________________

Session ______________ Subject ______________

Main results and conclusions

Work Group Members ______________________________

____

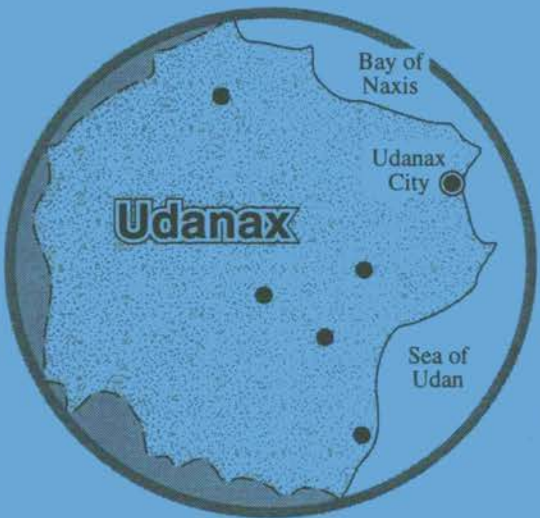
____

Return completed sheet to workshop co-ordinator for incorporation in the workshop report.

Casework Notes *for* SESSION 6

PART III

UNEP



Landfill Closure and Site Rehabilitation

CONTENTS

6.1 INTRODUCTION

In most cases, the wastes buried in a landfill site will remain there far longer than the company that is operating the site. It is therefore necessary to think about long-term security of a site, and the measures that will achieve this.

Compared to the base liner of a landfill, the surface liner or "cap" has several diverse functions.

It has to—

- prevent wastes from being removed by human or natural forces
- prevent surface water from reaching the waste
- retain any gas that may be generated

and also

- support a final plant cover on the site.

The single most important element to achieve all this is to build a low-permeability clay layer over the wastes as soon as the filling phase is completed.

The later use of the landfill site has to be decided before operations commence, as this will influence the types of wastes accepted, the design of the landfill and the method of site closure.

Ongoing monitoring long after the site is closed will be a cost burden long after the income-generating phase of the site. Money has to be set aside for this, as well as for possible interventions to clean up any unsatisfactory part of the site, if this is found to be a problem. For example, clay and other materials to repair any damage to the cap should be stored on the site.

An operator should be designated with responsibility for ongoing inspections and repair work. Post-closure conditions, because of their cost, have to be built into the initial site approval.

6.2 BACKGROUND INFORMATION

Table 6.1: Closure of a landfill site

Objective
• Final land use should be an immediate and future benefit to the local community
Administrative issues
• Integrating final site use plan into the preliminary site design
• Arrangement of operating fees for final site development and maintenance
• Liability and responsibility for post closure site monitoring and maintenance
• Possibility of selling the land
• Record keeping (location of specific waste types, quantities, monitoring etc.)
• Funds for aftercare

Source: Udanax Environmental Consultancy, Udanax City.

Table 6.2: Components of a hazardous waste landfill closure plan

Upon closure the following should occur—
• Decontaminate and decommission any hazardous waste treatment and storage facilities
• Provide a final appropriate cover for the landfill
• Control pollutant migration from the landfill via surface water
• Maintain the existing groundwater monitoring network for the required period of post-closure maintenance
• Continue to divert run-on from the landfill
• Prevent soil and wind erosion
• Control surface water infiltration and ponding at the closed site
• Maintain any gas leachate collection, removal and treatment system
• Maintain the integrity of the final cover and any liners
• Restrict access to the landfill as appropriate for the post closure area

Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989.

Table 6.3: Procedures for landfill site closure

- No waste should be left exposed. Trenches and lifts should be sufficiently covered. If trenches and lifts are unstable, they should be well marked with barricades.
- Although the rate of settling varies, maximum settlement will occur within the first year of landfilling. Accordingly, sufficient time should be allowed for area to settle. As necessary, the area should be regraded taking into account settlement. After maximum settlement has occurred, the area should be regraded to ensure proper drainage. Depressions and cracks should be filled using on-site or borrowed soil. Bulldozers and/or graders are normally used for spreading and grading the soil.
- 0.3 to 0.9 m of final cover may be applied. This cover may consist of topsoil which was stripped and stock piled prior to commencing the landfilling operation.
- Final slope generally range from 2 to 5%. Factors that influence the final grade are: climate, vegetation and soil characteristics. In relatively dry climate with suitable vegetative cover, slopes may safely exceed 5%. In areas with high rainfalls, it is necessary to use extensive erosion and drainage control for slopes above 5%.
- Check sediment and erosion control and modify according to any change in grade.
- Disassemble temporary structures and receiving areas not required for final site use.
- Hydroseed denuded area with the appropriate mixture of grasses. Climate and final site use are a major factor in determining the type of grass and vegetation selected.
- Outline a timetable to ensure that the following features are inspected at regular intervals:
  - —settlement, cover soil integrity and need for grading
  - —sedimentation and erosion control facilities
  - —leachate and gas control
  - —vandalism prevention measures
  - —buffers and vegetation
  - —fencing
  - —integrity of final site use facility
  - —monitoring

Source: 'Landfill Disposal of Hazardous Wastes and Sludges', *Pollution Technology Review* N° 62, Marshall Sittig, 1979.

Table 6.4: General landfill rehabilitation options

1.	**Agriculture**	arable land, grazing, exercise pasture
2.	**Forestation**	woodland, tree screens, nature reserves
3.	**Amenity**	open space, buffer zones, industries, airport runways
4.	**Recreation**	parks, playing fields, sports complexes, tracks and golf courses
5.	**Habitation**	caravan sites, gardens, play areas
6.	**Industry**	storage areas, parking, fabrication areas

Table 6.5: Design considerations for the final cover

- Low permeability clay layer
- Run-off control of surface water
- Gas control
- Later use
- Remove treatment facilities no longer needed.
- If damage occurs repair the top layer.
- Revegetation of the top layer
- Control of leachate
- Final slope
- Prevent erosion, avoid ponding of surface water.
- Storage or easy borrowing of clay and soil.

Table 6.6: Control of landfill after closure

- Erosion control
- Observation of settlement and possible deformations
- Groundwater monitoring:
  —At least one upgradient well and at least three downgradient wells
  —Measurement of groundwater level and groundwater quality
  —Parameters that can be measured easily: pH, electrical conductivity
  —At certain time intervals: also chemical analysis
- Leachate and gas control
- Meteorological data
- Observation of vegetation and vermin, odours
- Continue recording into the future

Figure 6.1: Some requirements for the final cover of a hazardous waste landfill *(Class II, Germany)*

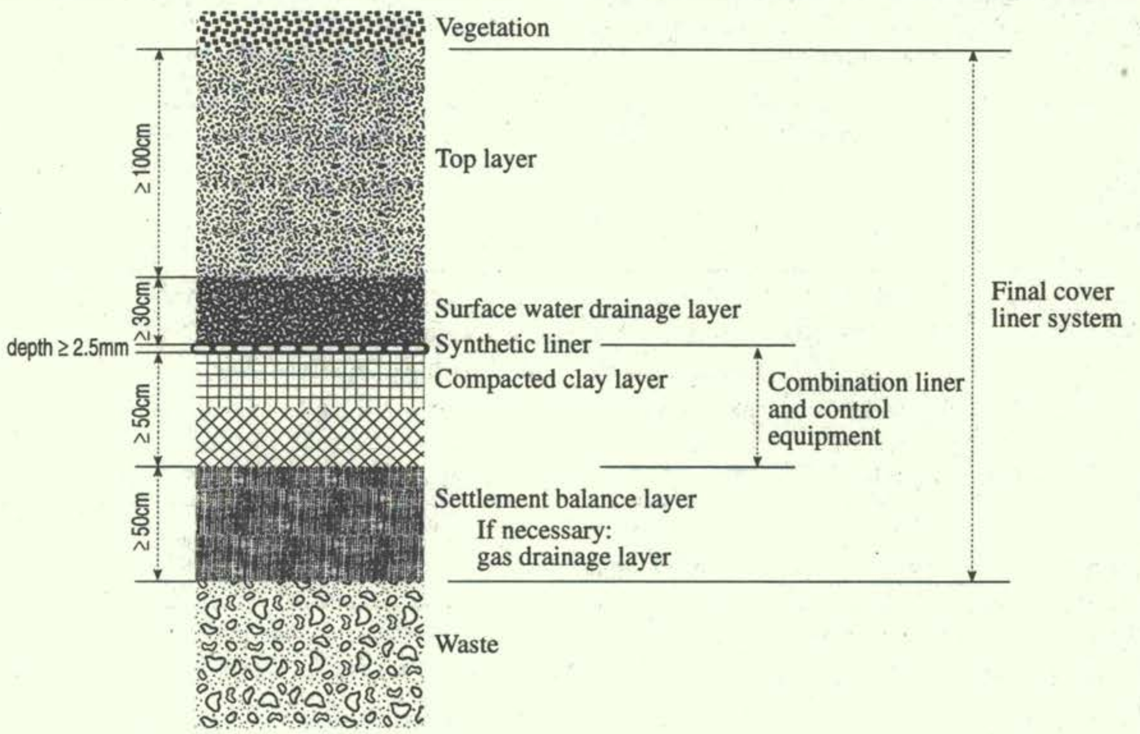


Table 6.7: Closure and post-closure care checklist

I	**Purpose**
	1 Closure i] Eliminate threat to human health and environment. ii] Reduce maintenance of closed landfill. iii] Rehabilitate landfill area. iv] Final landfill as a benefit to the community. **2 Post-closure care (USA is 30 years)** i] Maintain integrity of landfill. ii] Maintain integrity of monitoring systems. iii] Protect against threat to human health and environment.
II	**Closure Plan**
	1 Final site use plan integrated to preliminary design i] Closure plan should be prepared for permit process. ii] Closure plan maintained in files at facility. iii] Closure plan amended within 60 days of any change. **2 Closure plan includes:** i] Time and manner facility will be closed. ii] Description of closure requirements. iii] Record of waste types, locations, quantities. iv] Description of cap cover and monitoring systems. v] Steps to decontaminate and decommission equipment. vi] Estimate closure costs. vii] Arrange for operating fees for final site maintenance. **3 Procedure for closure** i] No waste left exposed. ii] Time allowed for settlement of landfill. iii] Approximately 0.3 to 0.9 metres of final cover. iv] Final slopes 2–5%. v] Sediment and erosion control plan. vi] Remove temporary structures. vii] Seeding of denuded area. viii] Periodic inspections. **4 Inspections** i] Settlement and cap cover conditions. ii] Buffer zone and fences. iii] Sedimentation and erosion. iv] Vegetation conditions. v] Leachate and gas control. vi] Integrity of final landfill. vii] Vandalism prevention measures. viii] Monitoring programme integrity. *continued ...*

III Post-Closure Care (30 years)

1 **Description of monitoring systems.**

2 **Description of maintenance and inspection activities.**

3 **Name, address and telephone number of contact person.**

4 **Updating of post-closure plan.**

5 **Maintain monitoring system operations.**

6 **Diverting run-off from landfill.**

7 **Soil and wind erosion control.**

8 **Water infiltration control.**

9 **Restricting access to facility.**

10 **Estimating post-closure costs.**

11 **Arranging operating fees for maintenance.**

12 **Conduct post-closure survey.**

IV Financial Assistance

1 **Financial obligations**

- i] Written estimate of cost to close facility.
- ii] Monitor facility annually.
- iii] Adjustment for inflation.
- iv] Revise whenever a change in plans increases costs.

2 **Establishing financial assurance**

- i] Closure and post-closure trust fund.
- ii] Surety bond guaranteeing payment into closure and post-closure care together with a standby trust fund.
- iii] Surety bond guaranteeing performance of closure and post-closure care together with standby trust fund.
- iv] Closure and post-closure letter of credit together with standby trust fund.
- v] Closure and post-closure insurance.
- vi] Passing a financial test based on detailed reckoning and professional certifications of value of the assets and liabilities.

3 **Final release**

- i] Certification of closure and post-closure by owner.
- ii] Approval of final release by government.

Source: P. Gelabert, 1991.

6.3 EXERCISES

EXERCISE 6.1 Landfill site closure

The existing Western Dumpsite will be closed in three years time. The site has been used in the past for industrial as well as municipal waste (see *Country Report*).

(a) Prepare quickly a plan for operating the site for the next three years so as to prepare it for closure.

Hint: The plan could, for example, identify wastes that will still be accepted (or not accepted), pre-treatment of some wastes (on the site or at the generator's premises), places where certain wastes may be dumped, wastes to be segregated, security measures at the site, records to be kept, types of cover for wastes, interim regulations, who should operate the site, fees for permits (if any) and wastes, operating budget and who should pay for the operation, and so on. Final site restoration and cover, and land after-use also need to be considered.

(b) How do you recommend the site be rehabilitated? How will this be paid for?

EXERCISE 6.2 Rehabilitation options

(a) List some possible rehabilitation options for the Western dumpsite after it closes, and rank them in order of feasibility.

(b) What future land-use can be foreseen for the site of the new Blue Landfill Site, following its eventual closure in 15 years time?

(c) During a meeting of the planning committee of Udanax City, one of the committee members recommended that the Western dumpsite should be rehabilitated by construction of low-cost housing. The Prime Minister has been told that the project is safe. Will you accept this recommendation? If not, list some reasons that will convince the Prime Minister to abandon the project. If you agree, what precautions will you propose to make the site safe?

Exercise 6.3 Monitoring

In view of the uncontrolled use of the site in the past, what monitoring requirements would you make after closure? For how long would these continue? Who would pay for this?

6.4 SESSION REPORT

In the space below, prepare a summary of your conclusions on the issue of site closure of both existing and new landfill sites in Udanax.

This summary will be included in the final Task Force report to the mayor of Udanax.

Work Group ______________________________

Session ______________ Subject ______________

Main results and conclusions

Work Group Members ______________________________

Return completed sheet to workshop co-ordinator for incorporation in the workshop report.

ANNEXES

CONTENTS

ANNEX I

Example of a Workshop based on this Manual

United Nations Environment Programme

UNEP

- **Industry and Environment Programme Activity Centre (IE/PAC)**
- **Regional Office for West Asia (ROWA)**
- **Environmental Education and Training Unit (EETU)**

Regional Workshop on

LANDFILL *of* HAZARDOUS INDUSTRIAL WASTE

Amman, Jordan

22–25 June 1992

FINAL REPORT

Held with the cooperation of—

- **World Health Organisation (WHO)**
- **International Solid Waste & Public Cleansing Association (ISWA)**

Hosted by—

- **The Government of Jordan**

CONTENTS

PREFACE

The need to provide training opportunities and information on hazardous waste management to developing countries has been recognised by the international community for some time. Many countries face environmental degradation and health risks from locally produced wastes. Countries must also know how to handle the possibility that wastes will be brought in from abroad by unscrupulous operators, or as part of the operation of international transport vessels.

The importance of training and technical assistance is acknowledged in several international guidelines (e.g. *Cairo Guidelines and the Principles for the Environmentally Sound Management of Hazardous Wastes*) and conventions (e.g. *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*).

In response to this need, UNEP IE/PAC has pursued a programme of workshops which is run in all regions of the world. These are designed to raise the level of awareness and skills of national administrators in order to facilitate the establishment of effective management measures.

The UNEP programme of workshops deal in sequence with—

- policy options and strategies for management
- landfill of industrial wastes
- treatment, storage, and transport
- waste minimisation and cleaner production.

These workshops are financially supported by national and international organisations, and extensive assistance is given by various institutes and individuals in their respective regions. The workshop described here is the second in this series for West Asia, the first regional workshop on *Policies and Strategies* having taken place in Bahrain in 1989.

ACKNOWLEDGEMENTS

UNEP, WHO and ISWA would like to thank the following individuals and organisations who provided assistance with the workshop—

Resource persons

- Environmental Resources Ltd. (UK): *Mr Simon Blackley*
- Environment Protection Agency (USA): *Dr James Smith*
- Municipality of Dubai (UAE): *Mr Jon Ward*
- Forschungs & Entwicklungszentrum Sondermull (Germany): *Dr Beate Gade*.

Professor Kriton Curi, from the Bogozici University in Istanbul, also represented the Turkish National Committee on Solid Wastes.

The Interim Secretariat of the Basel Convention provided documents on the Convention.

UNDP offices in various countries in West Asia assisted with the travel arrangements of participants. The UNDP office in Amman provided administrative support on per diem, and receipt of technical documents.

The workshop manual was originally prepared by Dr. C. Visvanathan under contract to UNEP IE/PAC. Mr A. Ryan, Shanks McEwen (UK) provided further reference material and critical review.

The workshop was sponsored by the Government of Germany and the Government of Finland.

The Ministry of Municipal, Rural Affairs and Environment, Hashemite Kingdom of Jordan hosted the workshop and assisted with local arrangements.

1 INTRODUCTION TO THE WORKSHOP

The present workshop was the second in a series of four to be organised by UNEP for West Asia. The present theme of *Landfill of Hazardous Industrial Waste* is important for many countries in addressing wastes currently being produced by local generators. While waste avoidance is clearly the preferred management option, current patterns of waste generation mean that landfill and other disposal methods will need to be used in the short and medium term. It is important that these disposal methods be managed in the safest possible way.

The workshop programme has been developed by UNEP IE/PAC as a result of previous experience in developing countries. The workshop uses practical problem-solving sessions rather than formal lectures. Participants are expected to analyse their own national situations as well as working on model case studies. The work plan emphasises groupwork sessions rather than individual study, so as to give participants the opportunity of sharing their national experiences. By working as a team, participants pool their resources and skill, much like other waste management task forces around the world. Background information, case studies and groupwork exercises were contained in a manual developed specifically for the workshop.

The forty participants from ten countries came from a broad range of backgrounds. Many had some experience and responsibility for landfill and for the management of industrial and hazardous waste in their own countries. Accordingly, the sharing of regional experiences was an important outcome of the workshop.

Two countries from outside West Asia participated in this workshop—Egypt and Mozambique.

Technical experts were drawn from regional and outside organisations so as to balance the need for local knowledge with the general desire to also learn of experiences elsewhere. All resource persons were familiar with landfill issues.

Time being limited to four days, not every important topic could be included in the programme. The technical documentation distributed to participants will, however, allow further study of supplementary issues in their home countries. Through organisations affil-iated with ISWA, it may also be possible for partici-pants to undertake follow-up training at installations and administrations in industrialised countries.

Post-workshop evaluation of participants and resource persons confirmed that the objectives of skills development and improved insight into landfill and other hazardous waste problems had been largely achieved. Participants greatly appreciated the hands-on approach to problem-solving, and the availability of a practical resource book (the workshop manual). Nevertheless, a great deal of further training and follow-up is needed if these results are to be consolidated.

2 OBJECTIVES AND WORKSHOP METHODOLOGY

The purpose of the workshop was to improve the abilities of countries to manage the safe landfill of hazardous waste, whether locally generated or imported.

The workshop contributes to the implementation of international agreements such as the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*. The important management elements were outlined in the *Cairo Guidelines and Principles for the Environmentally Sound Management of Hazardous Waste*, published by UNEP in 1987.

The workshop ***programme*** focused on key elements in the safe landfill of industrial wastes—

- techniques for assessing hazardous waste quantities and their disposal options
- engineering of industrial landfills
- operation and management of landfills
- regulatory and administrative aspects
- site selection and environmental assessment
- landfill closure and site rehabilitation.

The workshop ***methodology*** used a combination of activities, such as—

- technical presentations on key issues in landfill
- study of examples of hazardous waste landfill
- groupwork exercises on practical landfill problems
- report-back sessions on groupwork exercises
- panel sessions on common landfill problems
- short country reports by participants
- a final synthesis session.

Important ***technical information***, the model case study, and groupwork exercises were included in a manual distributed to participants before the workshop. The manual included pre-workshop exercises to make participants familiar with the manual and the programme. The manual can also be used as a reference document after the workshop.

Problem-solving exercises were carried out by groups of participants, under the guidance of a chairman chosen from within the group. The group acted as an autonomous unit, assisted by resource persons to provide guidance on technical matters. Speakers for the report-back sessions were also chosen by the group.

Follow-up activities after the workshop will include regular mailing of technical information, important updates on hazardous wastes, and facilitation (on request) of further in-depth training.

3 WORKSHOP CONTENTS

The detailed workshop programme is shown in *Appendix A*.

3.1 Opening session

The workshop was formally opened by HE Dr Abdul Razak Tobaishat, Minister of Municipal, Rural Affairs and Environment, Jordan. The chairman of the opening session was Dr Mohammed Ben Hani, Deputy Minister.

Also present was Dr Salih Al-Shara'a, Director, Department of Environment. UNEP was represented by Dr Fritz Balkau, Senior Prog-ramme Officer, IE/PAC, and Dr Fouad Kanbour, Senior Environmental Affairs Officer, ROWA.

3.2 Summary of the technical presentations

The technical presentations summarised below introduced the major subject areas covered by the workshop. The presentations were generally short (twenty minutes), and outlined the main issues and ideas on the subject. For technical detail, the participants were referred to references and to tables annexed to the presentations.

Identification of hazardous wastes and disposal options *(Fritz Balkau, IE/PAC)*

The identification of wastes generated by industry and their hazardous properties is an important preliminary step to determining disposal options. The chemical nature of industrial wastes can be elucidated by laboratory analysis. Waste quantities, if not already surveyed, can be found indirectly using a variety of assessment techniques. Once the waste has been quantified, disposal options can be selected. Landfill is the last priority for disposal, but nevertheless remains indispensable for many wastes. Waste avoidance or recycling is preferable if at all practicable.

Siting of landfills and EIA *(Jim Smith, US EPA)*

The siting process incorporates two separate, but equally important, elements—a technical and economic screening based on engineering and ecological criteria, and a public approval process abased on legal and social acceptability. The screening and selection process thus requires input from many sources, as well as good judgement in weighing various alternatives.

Engineering aspects of industrial landfills *(Simon Blackley, ERL)*

Landfill engineering has advanced rapidly in recent years. Water control is the single most important consideration of landfill engineering. Lining to prevent leachate escape and surface sealing to prevent ingress of runoff and rainfall are among the features which achieve this. Calculation procedures have become commonly available to help engineers produce designs that achieve a high level of environmental safety.

Operation and management of industrial landfills *(Simon /Jim Smith)*

Good operation is as necessary as good design. Operational procedures must exercise effective control over incoming wastes, accepting only those wastes which are permitted by local licence or regulation. Safe handling of wastes is a subsequent step that depends on trained staff and comprehensive written procedure in a site operation manual.

Administrative procedures for landfill operation *(Jon Ward, Dubai)*

The choice of site, proper engineering, and good operation will only occur if it is required by regulation. Both general standards and specific site licences are relevant for landfills.

Such controls are only effective in the context of more comprehensive laws on hazardous waste. An effective enforcement procedure is required, and ongoing monitoring must be carried out to confirm compliance.

Landfill closure and site rehabilitation *(Beate Gade, FES, Germany)*

In most cases, the wastes buried in a landfill site will remain far longer than the company that is operating the site. It is necessary to think about long-term security of a site, and the measures that will achieve this.

Design of the final cover is vital. It has to prevent gas emissions, loss of waste by natural agents or people (or animals), and to prevent entry of rainfall. Most covers are multiple layers of materials, placed under stringent conditions of design and supervision.

Ongoing monitoring after the site is closed occurs after the income-generating phase of the site. Money has to be set aside for this, as well as for possible interventions to clean up unsatisfactory parts of the site, if this is found to be a problem.

Such costly post-closure conditions have to be built into the initial site approval.

The full text of the technical presentations above is available on request from UNEP IE/PAC, UNEP/ROWA, or through WHO/EMRO/CEHA.

3.3 Case study and groupwork exercises

The case study used for practical purposes is elaborated in the workshop manual *(see 3.4 below)* which was distributed to participants before the workshop. This case study consisted of a country report for a fictitious nation, Udanax. This contained information on environmental problems experienced as a result of hazardous waste dumping, the existing environmental control systems in the country, and data on the landfill situation concerning industrial and other wastes.

Groupwork exercises required participants to analyse the information in the country report, and to recommend actions on landfill and hazardous waste management. The work of the groups stimulated the activities of expert task forces such as have actually been set up in a number of countries. Resource persons were available to guide the groupwork; however, the essential tasks had to be done by the participants themselves, pooling their knowledge and searching for other information in the workshop manual.

At the end of every working session, a one-page session report was prepared by each group. A member of the respective group gave a ten-minute oral presentation, in plenary session, of the outcome of the work. Other participants and resource persons were able to compare the work of all the groups. The session reports are available from IE/PAC.

3.4 Workshop manual

The manual prepared for this workshop contained all the information needed by participants in order to study the landfill problem, and to carry out the working exercises. In addition, the manual is designed to serve as a practical handbook when participants return to their normal jobs.

In order to make participants familiar with the manual before the workshop, a series of pre-workshop exercises was sent out to be completed before coming to Jordan. These exercises are simple, but do require familiarity with the structure and contents of the manual.

The groupwork exercises selected from the manual were—

Session 1: **Identification of hazardous wastes and disposal options**

- *Exercise 1:* identification of types of waste that could be disposed of in a landfill site
- *Exercise 4:* landfill hazards

Session 2: **Engineering aspects of landfills**

- *Exercise 1:* selection of a landfill method
- *Exercise 3:* estimation of leachate production

Session 3: **Operation and management of industrial landfills**

- *Exercise 4:* landfilling of difficult wastes
- *Exercise 6:* upgrading an old dumpsite

Session 4: **Siting of landfills and EIA**

- *Exercise 1:* Environmental Impact Assessment
- *Exercise 2:* public participation

Session 5: **Administrative procedures for landfill operation**

- *Exercise 2, Session 3:* monitoring incoming wastes

Session 6: **Landfill closure and site rehabilitation**

- *Exercise 1:* landfill site closure

Participants were encouraged to carry out other relevant exercises in their own time.

3.5 Country reports

Country reports were prepared by participants prior to the workshop in accordance with the attached proforma *(Appendix C)*. Most participants gave an oral summary in plenary session. An overview of the results of the country reports is shown below. The full country reports are available from UNEP IE/PAC, UNEP/ROWA, or WHO/CEHA.

Overview of country reports on hazardous wastes management

Amman, 22–25 June 1992

Major industrial wastes	Environmental problems exc. Industrial Wastes	Responsible Agency for Hazardous Waste Management	Waste Surveys done?	Waste Transport Disposal			Contaminated Sites	Regulations/Standards		
				Specialised disposal facilities	Industrial waste recycling	Refuse dumps receiving quantities?		Waste Classification	Hazardous Waste Disposal	Export Import
Bahrain										
Oil refining Aluminium smelter Power and Desalt. Ammonia/methanol Dry Dock (shipping) land and water	Land	Ministry of Health and Agencies (Public Health Act of 1978)	Yes	No	No Yes No No No		No	No	No	Yes, PCBs
Egypt										
Iron and Steel Organic chemicals Fertilisers Foodstuffs Sugar Petroleum	Water	Various Agencies (Ministries of Health, Environment, Industry) (Law #48 in 1981 Law #380 in 1982)		No info.	No info.	No info.	No info.	No info.	No info.	No info.
Iraq										
Paper products Glass & ceramics Petroleum Petrochemicals Fertilisers Foodstuffs Textile Power plants Plastics Sulphur refining	Water Land Air	High Council of Env. Protect. and Env. Protect. Centre and other agencies	Yes	Yes	Yes: e.g. plastics, paper	N/A	Yes (some sites)	No Env.	Yes Sanitary Landfill –Regulations 1980 Env. Protection and Improve. Ac 76, 1986 – Signed Basel Convention	No
Jordan										
Chemicals Metal finishing Foodstuffs Petroleum ref. Fertilisers Cement Phosphate Potash	Water Land Air	Dept. of Env. Ministry of Health Water Auth. of Jordan and others	Yes	Yes	Yes (limited)	No info.	Yes (some)	No	Standards no.2, 1971; 202, 1981; no.18, 1988; March 1989 Signed Basel Convention	No
				Chloralkali plant in Znyga area caused water and soil mercury pollution in 1981; industries stockpile wastes in their yards.						

ctd ...

Overview of country reports on hazardous wastes management (continued)

Major industrial wastes	Environmental problems exc. Industrial Wastes	Responsible Agency for Hazardous Waste Management	Waste Surveys done?	Waste Transport Disposal			Contaminated Sites	Regulations/Standards		
				Specialised disposal facilities	Industrial waste recycling	Refuse dumps receiving quantities?		Waste Classification	Hazardous Waste Disposal	Export Import
Mozambique										
Asbestos Pesticides Waste-oils Chemicals Hospitals Dusts	Water Land Air	Nat'l. Env. Commission Ministry of Health City Councils	No	No	No	No info.	No info.	No	No	No
Oman										
Oil refining Mining Lead (batteries) Second process Heavy metals	Water Land	Ministry of Municipalities and Environment; individual municipalities; Minister of State (Royal Decrees 10/82, 8/84, 5/86)	Yes	No	No	No info.	Yes	No	Draft Regs. by Ministry of Municipalities and Environment	Yes (exp ort)
				Hazardous waste is co-disposed with other wastes; individual hospitals have incinerators.						
Qatar										
Syria										
Pesticides Oil refinery Waste oils Hospitals Chemicals Asbestos Lead (batteries) Textile Fertilisers Phospho-gypsum Foodstuffs	Water Land Air	Central Commission for Environment Protection	No info.	No info.	No info.	No info.	No info.	No info.	–1975 signed Barcelona Convention. –Basel Convention guidelines followed; signing under consideration.	No info.
UAE (Dubai)										
Oil refinery Asbestos Aluminium Dry dock (shipping) PCBs Waste oils Chemicals Lead (batteries)	Water Land	Ministry of Health (Env. Protect. and Safety Section); Municipalities	Yes	Yes *Isbal Ali site for co-disposal*	Yes	Yes	No info.	Yes	–Local Order no.61, 1991	Yes (import)

ctd ...

Overview of country reports on hazardous wastes management (continued)

Major industrial wastes	Environmental problems exc. Industrial Wastes	Responsible Agency for Hazardous Waste Management	Waste Surveys done?	Waste Transport Disposal: Specialised disposal facilities	Waste Transport Disposal: Industrial waste recycling	Waste Transport Disposal: Refuse dumps receiving quantities?	Contaminated Sites	Regulations/Standards: Waste Classification	Regulations/Standards: Hazardous Waste Disposal	Regulations/Standards: Export Import
Yemen										
Waste oils Lead (batteries) Paint Hospitals Textiles Tanneries Foodstuffs	Land Water	Env. Protection Council	No	No	No	No info.	No info.	No	No	No
				Pathological waste from hospitals incinerated; industries asked to pre-treat.						

Summary

Major industrial wastes	Environmental problems exc. Industrial Wastes	Responsible Agency for Hazardous Waste Management	Waste Surveys done?	Waste Transport Disposal: Specialised disposal facilities	Waste Transport Disposal: Industrial waste recycling	Waste Transport Disposal: Refuse dumps receiving quantities?	Contaminated Sites	Regulations/Standards: Waste Classification	Regulations/Standards: Hazardous Waste Disposal	Regulations/Standards: Export Import
See below	Land (8)	(9)	Y (5)	Y (3)	Y (3)	Y (2)	Y (3)	Y (2)	Y (5)	Y (2)
	Water (8)		N (2)	N (4)	N (4)	N (0)	N (1)	N (2)	N (3)	N (4)
	Air (4)		N/I (2)	N/I (2)	N/I (2)	N/I (1)	N/I (5)	N/I (5)	N/I (1)	N/I (3)

Y = yes; N = no; N/I = no information available

Major industrial wastes

- Oil refining / petroleum (6)
- Fertilisers / foodstuffs / hospitals / lead (batteries) (4)
- Power and desalination / textile / chemicals / asbestos / waste oils (3)
- Aluminium smelter / dry dock (shipping) / organic chemicals / pesticides (2)
- Ammonia / methanol / iron and steel / paper products / petrochemicals / plastics / sulphur refining / metal finishing / cement / phosphates / potash / mining / secondary processing / heavy metals / phospho-gypsum / PCBs / paint / tanneries / dusts (1)

3.6 Expert panels

Several short panel sessions were conducted where landfill experts responded to questions from country participants on specific waste problems. The panel members indicated their personal preference for managing the nominated wastes, and under which conditions they would be prepared to accept them into a landfill (if at all).

Problems included 20,000 tonnes of waste oil (Oman); corroded gas cylinders that are still pressurised (Jordan); pesticide residues (Egypt, Mozambique); slaughterhouse wastes (Bahrain); electroplating sludge (Jordan); phosphogypsum wastes (Syria); oil sludges (Dubai); and asbestos wastes (Jordan).

3.7 Synthesis session on landfill of hazardous wastes

This session summarised the immediate actions that can be taken to implement better landfill practices, and better hazardous waste management in the countries at the workshop. Resource persons presented some simple, practical propositions, and prompted interaction from the participants so as to explore the implications.

The subjects covered included—

- what to do about present landfill/dumpsites to allow improved disposal of industrial wastes *(S. Blackley)*
- how to improve information about hazardous wastes, and use some simple but useful administrative measures that can easily be put into place *(J. Ward)*
- how to start planning for a more satisfactory landfill for industrial wastes *(K. Curi)*
- upstream waste control to encourage reduction/recycling/exchange, and to improve the level of pre-treatment; simple waste-specific measures *(B. Gade)*.

It is also useful to note the key issues from the technical sessions of the workshop—

- *Waste identification:* a key to successful management control. It is necessary to monitor the environment as well as sources.
- *Engineering:* effective control (elimination, if possible) of surface and accepted water is an important point, as well as containment of hazardous wastes within the landfill.
- *Operation:* goes hand in hand with engineering. Good operation is essential if environmental goals are to be met. Control over incoming wastes is the single most important factor.
- *Siting and EIA:* the optimum site must be geologically satisfactory, but the social and political factors must also be addressed from the outset.
- *Regulation and permitting:* key aspects to make sure that technical standards are met.
- *Site closure:* long-term care and responsibility, including monitoring, is a key aspect. These issues have to be built into the site from the outset, not added later.

3.8 Presentations by ISWA and CEHA

Professor Kriton Curi outlined the activities of the International Solid Waste and Public Cleansing Association (ISWA), especially as it related to the working groups on hazardous waste and on landfill respectively. By becoming members of ISWA, individuals and organisations can more easily remain in touch with events around the world.

Dr Ali Khan described the objectives and activities of the WHO Centre for Environmental Health Activities (CEHA). The Centre was established in 1983 and provides information and training to countries in the region on issues related to environmental health. Hazardous waste is one of the issues on which CEHA has acted.

3.9 Synthesis session on hazardous waste management

Fritz Balkau (UNEP IE/PAC) gave a final overview of waste management principles, focusing particularly on techniques of waste assessment, and of waste avoidance.

As many countries are starting with an unregulated dumping site, they need to focus on short-term improvements as well as long-term waste management strategies. Short-term actions must commence with the monitoring and reporting of wastes received and any problems caused by unregulated disposal. Some control must be exercised at dumping sites while simultaneous attempts are made to upgrade the site. A useful basic technology that can be used immediately to improve handling and disposal in the field in any country is solidification and chemical fixation. Very soon after—or even better, simultaneously—there must be an attempt to go back to the source of the wastes to see if some reductions cannot be made there. For many wastes where there is no good disposal option, only source reduction is a viable management action, especially in small countries.

In general, waste avoidance and reduction (i.e. cleaner production) must be addressed seriously as the only sensible long-term approach to wastes. UNEP IE/PAC and other organisations are able to advise countries on how to implement cleaner production programmes.

3.10 Regional overview of hazardous waste

A comparative overview of the country reports was prepared by Jim Smith (EPA) and Ali Khan (CEHA), and presented by Jim Smith. Details are covered under *Country Reports* above.

The importance of learning from the experiences of other countries in the region also became obvious during the workshop.

The lack of systematic, quantified information on hazardous waste from the region needs to be addressed more seriously. There is often no mechanism by which relevant national information can be collected.

3.11 Workshop closure

The chairmen of the working groups gave their appreciation of the outcome of the workshop as discussed in the final meeting of their respective groups. The key points are summarised in *Section 5.1* of this Annex.

The closing session was chaired by Dr Fouad Kanbour (UNEP/ROWA). The workshop was closed by Dr Mohammed Beni Hani (Deputy Minister of Municipal, Rural Affairs and Environment), after final conclusions and farewells given by Dr Hassan El Baroudi (WHO/CEHA) and Mr F Balkau (UNEP IE/PAC).

4 WORKSHOP CONCLUSIONS AND SUMMARY

The results of the working group sessions were already discussed in the synthesis in *Section 3* of this Annex. Despite some administrative problems arising during the workshop, the programme ran smoothly. The groupwork format based on practical problem-solving gave participants a good feel for the types of decisions that would have to be made in real situations in their countries. The workshop evaluation questionnaire (see *Section 5* below) indicated that the workshop had been a useful learning experience. The suggestions for improvements in future workshops are sound; however, some of the solutions (e.g. timely nomination by governments to allow distribution of documents before the meeting) are beyond UNEP's control.

It was apparent that the relative lack of experience with industrial residues was, for many participants, a major handicap in successfully understanding the complex decision making that hazardous waste management inevitably involves. Further training can help somewhat; however, there is no real alternative to practical experience in the field.

The definitions of some technical terms needs to be appreciated by decision makers, as—for example—co-disposal, multiple-disposal, and mono-disposal.

Both these problems suggest that there is a great need for further training on basic hazardous waste management in the region. Further training was, in fact, requested by a number of participants. This could be through further workshops in the UNEP series, or by intensive work experience in actual facilities and administrations abroad. ISWA and UNEP are able to assist in identifying appropriate venues for such training on request.

The country reports by participants showed that, with few exceptions, there is little real control of industrial wastes in the region. Even basic information on hazardous wastes generation is missing.

On the other hand, there are many simple management measures that can be taken to improve current landfill practices, many of which are still little more than open dumping. These simple measures would greatly improve safety in industrial waste disposal while more permanent facilities are planned.

A copy of the certificate of participation is shown in *Appendix D*.

5 EVALUATION

Evaluation was based in part on oral presentations by the chairmen of the working groups in the final session, and partly on a written evaluation by participants after the workshop. A separate evaluation session was held by the resource persons.

5.1 Workshop review by participants [1]

In addition to completing an evaluation questionnaire, working groups prepared their own assessment of the workshop for presentation in the closing session. Relevant comments were—

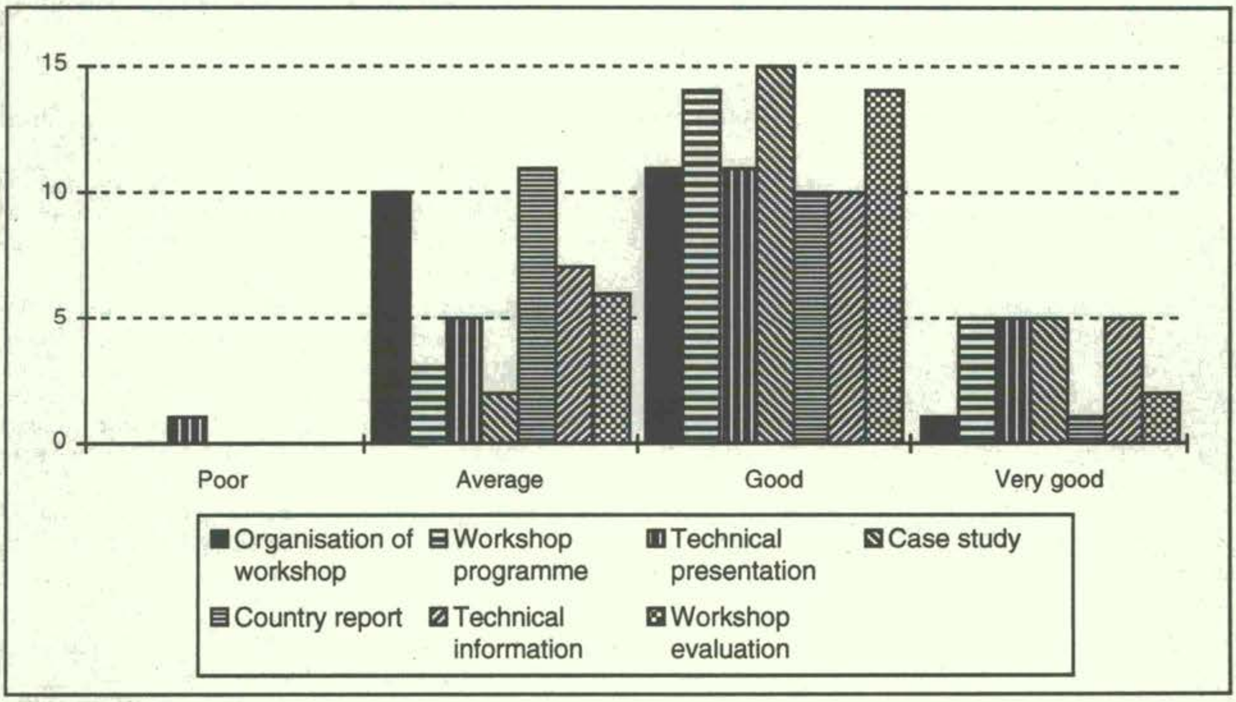
- Good knowledge and insights on landfill and waste management were obtained, with constructive ideas on how to improve landfill practices in the countries in the region. The technical documentation was good.
- The workshop should be longer. Some exercises were too compressed. A field visit should be included.
- Additional emphasis should be given to providing answers and feedback on the working exercises.
- The administration of the workshop was deficient in some aspects, particularly with respect to selection of participants and their timely nomination so as to allow documents to be distributed in advance. Also a better location for the workshop should be found in future.
- Use of both Arabic and English is recommended in future. There should be increased use of audio-visuals.
- Resource persons should be familiar with the region, but also resource persons from outside the region give a good idea of practices elsewhere.
- The group work was effective and also enhanced the general atmosphere. Overall the workshop achieved its aim of effective training.

5.2 Summary of evaluation questionnaire

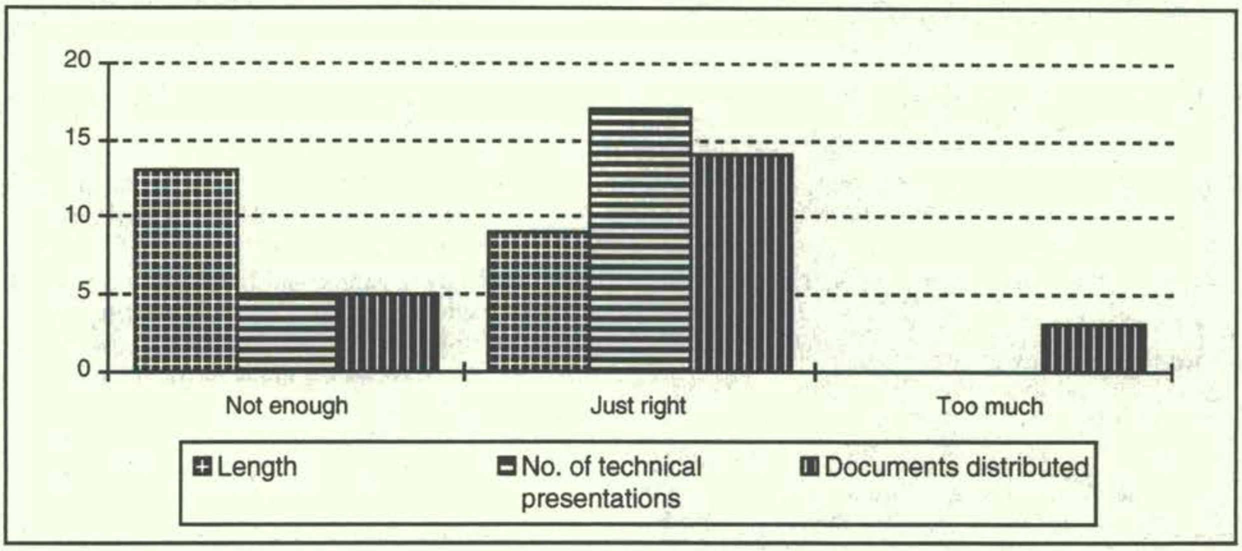
Twenty-two questionnaires were returned by participants. Summary figures are shown below.

[1] Based on notes taken at the oral presentation by workgroup chairmen, and comments from the questionnaire.

Evaluation of workshop by participants: Part 1



Evaluation of workshop by participants: Part 2



5.3 Workshop review by resource persons

The review by resource persons came to the following conclusions—

- *The workshop programme* had a good balance of the essential topics. In future, even more emphasis should be placed on immediately achievable results as well as the ideal.
- *Case study:* Udanax is a good concept, and this case study should remain to be continually improved. The groupwork exercises were generally good, but a few need to be reviewed to make them simpler and more focused on the case study. There could be more emphasis on feedback in groupwork exercises. Participants often want the 'answers' to exercises.
- *Technical presentations:* time was short for these, but on balance it was correct to allocate more time to groupwork than to lectures. If a separate introduction to the exercises is given, the lectures do not specifically need to relate to the central case study.
- *Country reports:* these were sometimes slow and very incomplete, but they are valued by participants. Perhaps they should be more carefully orchestrated by UNEP before the workshop.
- The *Resource Persons* panel sessions were useful, and appreciated by participants for their practical advice.

5.4 Workshop assessment by UNEP
(F. Balkau, F. Kanbour)

Overall, the format and arrangements worked well. The most productive sessions were the groupwork sessions and the resource persons panels. Participants responded well to the tight time constraints on groupwork, and often continued work in their own time, after formal sessions. The manual was well received, although further technical editing is needed on some of the exercises. There was a very positive atmosphere among all the participants. The resource persons worked well as a team, and related well to the participants.

Some aspects to which attention still needs to be paid—

- Pre-workshop consultation with host organisations needs to be greatly strengthened so as to ensure timely action on vital aspects of logistics, nominations, and documentation.
- More attention needs to be given to advising on and controlling the nominations by national focal points. Quite a few official nominations were inappropriate for this workshop, and diminished its value for the others. Criteria include language, work responsibility, technical competence and correct field of professional training.
- The pre-workshop preparation of country reports, introductory exercises, and preliminary reading needs much more attention, especially for short concentrated workshops.
- The workshop should be extended to allow time for a field visit. Such a visit could be the topic for a group analysis assisted by resource persons, in order to encourage material studied in the workshop to be applied to actual national problem situations.

APPENDIX A Detailed workshop programme

UNEP REGIONAL WORKSHOP

Landfill of Hazardous Industrial Waste

Amman, Jordan • 22–25 June 1992

Day 1 • Monday 22 June 1992

8.00 – 9.30	Registration of participants
9.30 – 10.00	Opening of the workshop *(Chair: Dr Mohammed Beni Hani, Deputy Minister)* • HE Dr Abdul Razak Tobaishat (Minister of Municipal, Rural Affairs & Environment, The Hashemite Kingdom of Jordan) • UNEP (ROWA; IE/PAC)
10.00 – 10.30	*Coffee break*
11.00 –11.30	Review of hazardous waste issues in the region. National and international issues; national actions. Management principles *[UNEP]*.
11.30 – 12.00	Review of case study exercises. Introduction to workshop procedure *[UNEP]*. Country Report N^{o} 1: Udanax
12.00 – 13.30	***Lunch in workgroups.*** *Meet group members; select chair, rapporteur.*
13.30 – 14.00	Presentation on technical theme 1: ***'Identifcation of hazardous waste generation and import and disposal options'*** *[F. Balkau, UNEP]* • Explanation of case study exercises.
14.00 – 15.30	Case study groupwork on Theme 1: *'Identification of hazardous waste and disposal options'* • Exercise 1.1; Exercise 1.4
16.00 – 17.00	Country reports • *Chair* F. Kanbour [UNEP/ROWA] • *Countries* Bahrain, Oman, Mozambique
From 19.00	UNEP cocktail

Day 2 • Tuesday 23 June 1992

8.30 – 9.15	Interim groupwork reports from Theme 1.
9.15 – 10.00	Presentation and discussion on Technical Theme 5: ***'Siting of landfills: site selection and EIA'*** *[J. Smith]* • Explanation of case study exercises
10.00 – 10.30	*Coffee break*
10.30 –12.00	Case study groupwork on Theme 5: *Siting of landfills* • Exercise 5.1; Exercise 5.2
12.00 – 13.30	***Lunch***
14.00 – 14.30	Presentation and discussion on Technical Theme 2: ***'Engineering aspects of industrial landfills'*** *[S. Blackley]* • Explanation of case study exercises
14.30 –15.30	Case study groupwork on Theme 2: *'Engineering aspects'* • Exercise 2.1; Exercise 2.3 • Coffee; Preparationof groupwork report for Themes 2 and 5.
16.00 – 17.00	Country reports • *Chair* F. Kanbour [UNEP/ROWA] • *Countries* Iraq, Syria, Yemen

Day 3 • Wednesday 24 June 1992

8.30 – 9.15	Interim groupwork reports from Themes 2 and 5.
9.15 – 9.45	Presentation and discussion on Technical Theme 3: ***'Operation and management of industrial landfills'*** *[S. Blackley/J. Smith]* • Explanation of case study exercises.
9.45 – 11.15	Case study groupwork on Theme 3: *'Operation and management of landfills'* • Exercise 3.4; Exercise 3.6
11.15 – 11.30	Country problem-solving: resource persons panel
11.30 –12.00	Presentation and discussion on Technical Theme 4: ***'Regulation, permitting and control'*** *[B. Gade]*
12.00 – 13.30	***Lunch***
13.30 – 14.00	Presentation and discussion on Technical Theme 6: ***'Landfill closure and site rehabilitation'*** *[B. Gade]* • Explanation of case study exercises
14.00 – 15.15	Case study groupwork on Themes 4 and 6: *'Regulation, permitting and control'* and *'Landfill closure and site rehabilitation'* • Exercise 3.2 (p118); Exercise 6.1
15.15 – 1600	Country reports • *Chair* F. Kanbour [UNEP/ROWA] • *Countries* Jordan, Dubai

Day 4 • Thursday 25 June 1992

8.30 – 9.30	Interim groupwork reports • presentation on ISWA *[Prof. Kriton Curi]*
9.30 – 11.00	Interaction: ***'Establishment and management of industrial landfills in developing countries'*** (Practical propositions and problem-solving using resource persons panel)
11.00 – 11.45	*Coffee break*
	Preparation of final groupwork reports: an appreciation of the workshop and its output
11.45 – 12.15	Workshop synthesis: ***'Management, disposal and minimisation of hazardous waste'*** *[UNEP]*
12.15 – 12.45	Appreciation of country reports *[J. Smith]*
	Introduction to CEHA *[M.A. Khan]*
12.45 – 13.00	Comments on workshop by group chairmen.
	Evaluation
13.00	Final address and farewell *(Chair* F. Kanbour, UNEP/ROWA) • Dr Mohamed Beni Hani (Deputy Minister for Municipal, Rural Affairs and Environment, the Hashemite Kingdom of Jordan) • Dr H. El Baroudi (Director, CEHA) • Mr Fritz Balkau (UNEP IE/PAC)

APPENDIX B Documents made available to participants and on display

Documents made available to participants

1 IE/PAC information folder; Introduction to Cleaner Production.

2 *Management and Control of Hazardous Waste*, IE/PAC [1990].

3 *Introduction to Landfill of Hazardous Industrial Wastes*, IE/PAC [1990].

4 *Landfill of Hazardous Industrial Wastes:* a workshop manual, UNEP IE/PAC [1992].

5 *The Safe Disposal of Hazardous Wastes: the special needs and problems of developing countries*, World Bank/UNEP/WHO [1989].

6 *Rapid Assessment of Air, Water and Land Pollution*, WHO [1982].

7 (i) *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal,*, [1989]; (ii) *The Basel Convention*, by ISBC [Hune 1992].

8 *Environmentally Sound Management of Hazardous Wastes*, UNEP [1987].

9 *International Progress in Hazardous Waste Management*, ISWA [1992].

10 *Adapting Hazardous Waste Management to the Needs of Developing Countries*, Waste Management and Research Vol.8 N° 2 [March 1990].

Documents on display

1 *Training Manual on Hazardous Waste Policies and Strategies*, UNEP IE/PAC [1991].

2 UNEP IE/PAC Technical Reports on Tanneries, Metal Finishing, Mining, Storage of Hazardous Materials, Energy Efficiency.

3 *Audit and Reduction Manual for Industrial Emissions and Wastes*, UNEP/IEO and UNIDO, Technical Report Series N° 7 [1991].

4 *Management and Control of the Environment*, WHO [1989].

5 *Industry and Environment* on siting of industry, industrial plant monitoring, environmental auditing, waste minimisation.

6 WHO/CEHA Activity Report: Description of Activities, and CEHANET *Special Bibliography on Hazardous Waste Management* [1992].

7 *Regional Consultation Meeting on Control and Disposal of Hazardous Wastes*, Amman, WHO/EMRO [1989].

8 *Land Disposal of Hazardous Waste*, Gronow, Schofield, Jain. Ellis Harwood Ltd [1988].

9 *Geotechnology of Waste Management*, Oweiss. Butterworth [1990].

10 Video *Cradle to Grave*, EPA Victoria.

APPENDIX C Content of country reports on hazardous waste

The report includes the relevant factors that influence waste generation and the options for disposal. Report length should not exceed eight pages. Tables may be attached.

1 *National profile:* population and growth rate, geographical and climatic conditions, resources, economic base, administration and government, technical services, environment [one page maximum].

2 *Industry profile:* types of existing industries, their location, output, employment.

3 *List of environmental problems being experienced due to hazardous waste dumping of disposal:* e.g. pollution, adverse health impact, unsafe handling, illegal dumping, unsafe transport, unsatisfactory storage, soil contamination, etc.

4 *Main types and quantities of hazardous wastes in the country*, including both industrial and other sources of waste. Mention explicitly any wastes imported or exported.

5 *Extent of current treatment, recycling or disposal facilities:* e.g. oil recovery plants, solvents recovery, incineration, storage sites, treatment plants, land disposal, and any similar installations.

6 *Present landfill practice:* number of landfills and dumpsites used for waste disposal or co-disposal, problems related to construction, operation and maintenance of landfills, technical description of existing landfill(s), types of landfilled wastes, site selection procedures, monitoring of landfill leachate and gas, monitoring of incoming wastes. Mention any sites used specifically for industrial wastes, including those on company premises. Mention any dumping at sea.

7 *Extent of infrastructures and services already available:* e.g. specialised chemical transport, emergency clean-up service, waste exchange service, experienced consultants, hydraulic and geological investigators, training institutes, laboratories, professional associations, research groups. List any companies running landfill services.

8 *Current system of policies, laws and regulations to reduce and control pollution, solid waste disposal and hazardous chemicals:* e.g. water standards, sewer standards, health laws, landfill regulations, waste transport, pesticides and chemicals controls, facility permits, EIA, etc.

9 *Which organisations have responsibility for:* landfill operation and control, pollution, solid waste, hazardous wastes, toxic chemicals, industry permits, export/import of wastes and chemicals, pesticides, environmental monitoring, industrial training, clean technologies, dissemination of information.

APPENDIX D Certificate of participation

The United Nations Environment Programme

UNEP

Industry and Environment Programme Activity Centre
(IE/PAC)

and

Regional Office for West Asia
(ROWA)

hereby award this

CERTIFICATE OF ATTENDANCE

to

....

for having particpated in the

Regional Workshop on Landfill of Hazardous Industrial Waste

held in Amman • 22–25 June 1992

in association with the

World Health Organisation
(WHO)

and

International Solid Waste and Public Cleansing Association
(ISWA)

Jacqueline Aloisi de Larderei
Director
Industry and Environment Programme Activity Centre

Adel Orabi
Director
Regional Office for West Asia

APPENDIX E Pre-workshop exercises

Table of Contents

Introduction

These *pre-workshop* exercises are designed to make workshop attendees familiar with the country report, and the other technical information in the workshop manual, *before* coming to the meeting.

Please study the country report—Udanax. Then carry out the pre-workshop exercises. You may wish to consult the workshop manual to obtain some technical information, but generally this should not be necessary.

Please bring the completed pre-workshop exercises with you to the workshop. You must also bring the workshop manual with you. This also has some exercises in it. You will carry out the exercises in the manual when you are at the workshop.

SESSION 1 Identification of hazardous wastes and disposal

Pre-workshop Exercise A
Identification of environmental problems

From the Udanax country report, identify the major environmental problems and concerns that can be attributed to dumping of industrial hazardous wastes on land. For each problem, list some possible consequences that may occur to human health or the environment.

Major environmental problems	Possible consequences
e.g. *Groundwater pollution*	*Human illness and cancer* *Interference with industrial processes* *Need for expensive water purification systems or relocation of deepwell pumps*
Now go on to list other problems ...	

Pre-workshop Exercise B *(reference page 58 of this manual)*
Hazardous properties

Using *Table 1* or other sources of information, identify the hazardous properties of some of the dumped wastes in *Table 2* (ref. p43)of the country report. Note that you may not find all relevant wastes listed in *Table 1*, so you cannot carry out this exercise fully.

Dumped waste	Health hazard	Landfill effect
e.g. *Sludge with heavy metals*	*Toxic*	*Toxic leachate*
Now go on to list other wastes ...		

SESSION 2 Engineering aspects of landfill

Pre-workshop Exercise C
Technical quiz [1]

1 *Recommend two types of liners used in hazardous waste landfill. What makes these superior to other liners?*

2 *In case of soil permeability to the order of 10^{-7} m/s, a site can be established for the discharge of—*

☐ Toxic industrial waste ☐ Inert waste ☐ Household refuse

3 *Can the nature of the waste discharged alter the permeability of the soil?*

☐ Yes ☐ No

4 *If leachate production is high, it is proportional to—*

☐ runoff ☐ evaporation
☐ transpiration ☐ infiltration

5 *Net infiltration is—*

☐ all infiltration that passes through the soil surface
☐ difference in rainfall and evapotranspiration rate
☐ describes the volume of leachate
☐ is the opposite of precipitation

6 *An integrated landfill facility should have—*

☐ waste reception, segregation, and storage units ☐ pre-treatment facilities
☐ landfill sites ☐ all of the above.

[1] Refer to the workshop manual for technical information if you wish.

Pre-workshop Exercise D
Landfill design

A site for a new hazardous waste landfill has been proposed. Soil boring indicates that there is a five to seven metres thick clay layer, overlain by three to ten metres of sandy silty material with some lenses of gravel. The water table is at a depth of about twelve metres.

How would you best build the disposal facility under these conditions? Prepare a one page sketch below—

SESSION 3 Operation and management of landfills

Pre-workshop Exercise E
Technical quiz based on your general knowledge

1 *During landfill site measure, it is sufficient if you monitor only the groundwater quality—*
☐ True ☐ False

2 *In a landfill site where rate of travel of pollutant is high, the monitoring frequency also has to be high—*
☐ True ☐ False

3 *In a landfill site, a minimum of three upgradient wells and one downgradient well should be located for monitoring—*
☐ True ☐ False

4 *After closure of a landfill site, it is not necessary to continue monitoring—*
☐ True ☐ False

5 *The depth of the monitoring well should be—*
☐ above groundwater level ☐ same level as groundwater ☐ below groundwater level

6 *The objective of a landfill site inspection is to—*
☐ ensure the safety of the site operator
☐ build up the credibility of the controlling authority
☐ ensure that environmental impacts are kept to a minimum
☐ all of the above

7 *An extended site inspection consists of—*
☐ visual site examination ☐ sampling of gas and water
☐ inspection of site records ☐ all of the above

8 *The landfill site safety is under the responsibility of—*
☐ site operator ☐ site inspector
☐ local environmental authority ☐ other authority.

SESSION 4 Siting of landfills

Pre-workshop Exercise F
Site impacts

Consider the location of the existing Eastern [E] or Western [W] dumpsites in Udanax. Indicate which of these is more favourably located with respect to—

- hydrogeology
- proximity to industrial waste generators
- residential areas
- climatic conditions (rain, wind direction, evaporation)
- coastal pollution

Which site accepts more industrial waste?

At first sight, is the proposed new *green* site better situated than the *blue* site on the above criteria?

SESSION 5 Regulations, permitting and control

Pre-workshop Exercise G
Technical quiz

1 *Is it clear from the Udanax Country Report which agency is responsible for controlling landfill operations?*

2 *You intend to develop a new landfill to accept potentially hazardous wastes in Udanax. Your first action is to—*

- ☐ inform the public by announcing your intentions
- ☐ determine what sites can be legally considered for the landfill under current land use rules
- ☐ decide what types of wastes are to be landfilled
- ☐ review licence applications and licences granted to landfill operators in your own country and/or in other countries

3 *Having obtained title to land which you consider can be used to landfill potentially hazardous wastes, you begin to prepare your campaign to obtain a licence by—*

- ☐ obtaining detailed background data concerning rainfall, groundwater and surface water in the area, soil types, levels of contamination already present and land use in adjacent areas
- ☐ performing a full-scale site health assessment and risk procedure with respect to the area
- ☐ arranging meetings and briefing with the licensing agency's personnel
- ☐ other actions (specify) ....

4 *Provisional permission has been granted for you to develop a parcel of land for landfilling of potentially hazardous wastes. You decide to begin by—*

- ☐ hiring a firm of outside consultants to develop the site
- ☐ determining transport access to the site
- ☐ preparing an Environmental Impact Assessment detailing probable effects of the landfill as a function of time
- ☐ seeking to employ trained personnel to help and operate the landfill

5 *Your request for official sanction to operate the landfill is under review by Udanax City, regional and national authorities; local citizens have logged a formal protest against your proposal. You—*

- ☐ arrange to offer economic incentives such as paying the local taxes of the host village, building a recreation centre, etc.
- ☐ provide a complete dossier of why your facility will meet all technical standards and requirements in an effort to convince the protesters they have nothing to fear
- ☐ ask local politicians to intervene on your behalf
- ☐ seek to involve community leaders to form a coordinating group to ensure full public involvement and knowledge of the project

6 *You have concluded that the company cannot expect a suitable return on investment for entering the hazardous waste landfill business. The region now has no prospect of an experienced company participating in hazardous waste disposal. The government should—*

- ☐ consider providing hazardous waste disposal as a public utility type of service
- ☐ offer your company a set of subsidies to provide the hazardous waste disposal
- ☐ enter into negotiations with the major generators of hazardous waste in order to determine the best approach
- ☐ encourage generators to develop on-site disposal units with government participation and approval

7 *Your company agrees to act as disposer of hazardous wastes provided Udanax City Council agrees to [i] a granted site; [ii] to indemnify the company in case of damage; and [iii] to be responsible for all post-closure issues seven years after the site ceases to accept wastes. The Udanax City Council should—*

- ☐ enter into negotiations with your company
- ☐ accept
- ☐ tell your company, "no way"
- ☐ operate its own site given these demands

8 *Despite best efforts to prevent it, a hazardous waste landfill is found to be releasing potentially toxic substances to air, groundwater and soil. The Udanax government should—*

- ☐ keep this a secret so as not to cause unrest and incur extra expense
- ☐ perform theoretical site health and risk procedure assessments
- ☐ inform the public and take basic steps to temp the releases
- ☐ have trained personnel and monetary resources in hand to deal with such problems.

SESSION 6 Landfill closure and site rehabilitation

Pre-workshop Exercise H
Technical quiz using your general knowledge as far as you can

1 *The landfill operating plan should be taken into consideration during—*

- ☐ closure
- ☐ preliminary design
- ☐ site operation
- ☐ site selection

2 *Post-closure records should contain information on—*

- ☐ type and quantity of waste disposed
- ☐ depth of fill at different locations
- ☐ location of waste
- ☐ all of the above

3 *Maximum recommended slope of top cover is—*

- ☐ 1%
- ☐ 5%
- ☐ 2%
- ☐ 10%

4 *It is advisable to limit access to a hazardous waste landfill site even after closure and rehabilitation—*

- ☐ true
- ☐ false

Pre-workshop Exercise I
Rehabilitation requirements

In recommendations to the Prime Minister, did the ad-hoc committee consider the need for site rehabilitation?

Did it also consider subsequent land-use of rehabilitated dumpsites?

Do current waste disposal regulations require site rehabilitation?

ANNEX II

Background on Management of Hazardous Waste

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CONTENTS

1 INTRODUCTION

Deteriorating environmental conditions in several parts of the world have more than ever before focused the attention of governments and the public on hazardous industrial wastes. Previously such wastes were disposed of without particular care. In some cases, wastes have been exported to countries that lack effective control systems.

The response of governments has been to attempt to quickly put into place national control systems over industrial wastes. Recent international agreements—such as the *Basel Convention*—themselves rely on effective national systems for their implementation. However, limited national experience with hazardous waste management often means that such new control systems are less effective than had been hoped. Most countries are therefore anxious to learn from the collected experience of others so as to reduce the time taken to put effective programmes into place.

This paper briefly examines the elements of an effective management strategy for hazardous waste, as well as outlining the contributions that some international organisations are making in putting such strategies into place.

2 WHAT IS HAZARDOUS WASTE MANAGEMENT?

Which wastes are hazardous? What do we mean by management?

More fundamentally, what are 'wastes'?

It is often tiresome to begin a discussion with definitions of terms. However, in the case of hazardous waste management, it is important that we all speak the same language. Hazardous waste comes from many sources, and many organisations will be involved in control actions. A variety of specialists from disciplines such as law, engineering, education and public relations are needed to contribute to action programmes. We must also remember that regulations and administrative control systems depend on clear and unambiguous definitions and classifications.

The definition of those wastes to be managed is crucial. Commonly, *hazardous waste* includes all wastes that are listed in a schedule, or that have hazardous properties such as toxicity, flammability, corrosivity, or ecotoxicity. Most of these wastes come from industry; however, agriculture, transport services, hospitals and research laboratories, and even households, will also generate such wastes.

Management means different things to different people. In general, it refers to the rational control over all aspects of the life cycle of a waste, in line with a well-defined set of objectives. It is important to define the management responsibilities of all partners in such life cycle control, from the generator through to the final disposal operator. Even the public has an important role to play in some strategies.

Each country must adopt its own definitions of terms and classification systems for wastes. As a guide, some working definitions are shown in *Appendix A*. The classification of wastes used in the Basel Convention is shown in *Appendix B*.

A controversial issue at the moment is whether wastes intended for recycling should be exempted from hazardous waste controls. Industry would prefer such an exemption so as to improve the economics of recycling; however, government agencies remember the pollution that has been caused by sham recycling schemes in the past, and are therefore reluctant to agree to exemption. The Basel Convention included wastes intended for recycling within its management system, and many national systems do likewise.

3 ASSESSMENT OF THE WASTE SITUATION

Before we can devise sensible solutions, we must first have a good idea of what the problem is, both in nature and in extent. Surprisingly this is often overlooked by many national authorities, who are in a hurry to get on with building a control system. However, without firm evidence that there is indeed a problem, we are unlikely to convince policy-makers to pass regulations and to commit money to build facilities. And without a good estimate of the waste sources, we are in any case unable to design and build the disposal facilities that are needed.

Surprisingly, good data on environmental impact are often difficult to find. This is particularly so in respect of the cost of health and other damage, the number of people affected, the value of natural resources destroyed, etc. A specific activity has usually had to be launched to collect such information, and such data as exist should be put into an assessment report in order to document the size of the problem. Such a report needs to keep its audience in mind. It should be simple, persuasive, must include cost estimates of damage, and draw some conclusions about immediate and future risks.

Assessment of waste sources is also more complex than it first appears. Neither the types nor the quantities of waste are always immediately obvious; waste generators are frequently ignorant of what they actually produce, and will in any case be secretive about their operations. Past waste surveys have been remarkably inaccurate. While direct measurements are more accurate, they are also more expensive. Waste assessment has thus become a highly skilled exercise that requires time, patience, training, and a high level of inter-agency and inter-sectorial cooperation.

In countries where comprehensive data on waste resources do not exist, rapid assessment methods can be used to give a first estimate, and to provide a starting point for further, more detailed examination. Such rapid assessment methods include both manual and computer-based calculation programmes. Direct monitoring and surveys can then follow, and subsequently the results of several methods are combined so as to increase reliability.

Once the problem (environmental impact) and its origin (waste source) have been identified, we can start to consider the options for action. It is, however, useful to first identify the administrative context in which the waste problem finds itself. This context includes those regulations that may already exist, the government agencies with responsibility for health and safety, and the technical infrastructure and support services available. An important aspect is what is sometimes called a 'key player analysis'; i.e. identification of those key individuals and agencies who may help or hinder in the eventual control of hazardous wastes.

The entire set of assessment steps above has recently been put by UNEP into the form of a *Situation Questionnaire*. This questionnaire is intended to be used by waste managers or consultants to identify the most relevant features of a country situation as it concerns the management of hazardous wastes. The table of contents of this questionnaire is shown in *Appendix C*. (The entire questionnaire appears as *Annex V* of this manual).

4 PREPARING A HAZARDOUS WASTE ACTION PLAN

Experience in countries that have implemented hazardous waste management programmes in the past shows that it is necessary to act on several different fronts simultaneously. In particular, the following are indispensable—

- establishment of waste treatment and disposal facilities
- legislation to set acceptable standards for waste handling facilities, and to require monitoring and reporting of waste operations
- an administration to enforce the legislation, to monitor wastes and to undertake some practical disposal operations
- adequate infrastructure and technical support services such as waste transport contractors, analytical laboratories, consulting and design services, training institutions, information services, databanks to monitor waste data, and so on.

These elements are mutually independent, and have to be matched to the demands of each other. Accordingly, one often talks of the need to prepare a *waste management strategy*. *Figure 1* shows the elements that were included in a waste strategy in Australia in 1985. *Figure 2* shows the waste handling operations that need to be considered when assembling such a set of control elements.

In view of the ease with which wastes can now cross borders, it is necessary for national strategies to pay regard to international developments in waste management, particularly concerning control over export and import of wastes and of trade in secondary raw materials (wastes sent for recycling or recovery).

The process of preparing a strategy will be as important as the contents. Many good proposals around the world have had to be abandoned because the ground had not been adequately prepared. Early public consultation on proposals is essential; discussions with cooperating agencies and regular briefing of politicians are indispensable. Industry must clearly understand what it is expected to do, and why.

Some elements of successful waste strategies

- Early discussions with the public
- Openness to public views and suggestions
- Strong emphasis on waste reduction actions
- Safe management of existing facilities
- Safe design of new facilities
- A facility operator who has public confidence

Even with such a consultative process, success is not guaranteed. However, the absence of such a process has negated whatever chance of success there might have been for many programmes which were technically sound. It is no longer true that engineers and politicians can 'persuade' the public of the merits of proposals on which the public has had no prior input.

This true even in developing countries, some of which have also found that public opposition can cause delay or even abandonment of projects which are inadequately presented. Projects that have been successful have tended to include the elements shown in the box.

A number of references have been prepared to help guide the preparation of waste management strategy, including the consultation process. In particular, a regional workshop held by UNEP in 1986 gave clear and succinct guidance on this issue in its final report *(Reference 10)*. The *Cairo Guidelines and Principles for the Environmentally Sound Management of Hazardous Wastes* (UNEP, 1987; Reference 7) subsequently summarised the major considerations of a strategy, which were ultimately incorporated into the three-volume manual on safe disposal prepared by UNEP, the World Bank and WHO in 1989 *(Reference 1)*. The main points of the Cairo Guidelines are shown in *Appendix D*.

The implementation of a waste management strategy takes time. Many countries have taken over a decade to assemble their programmes, and most are still not complete.

It is therefore important to consider how to phase in the various measures, and what temporary measures to put into place in the meantime. The adoption of interim measures was considered at an ISWA workshop in Honolulu in 1989 *(Reference 16)*, and is summarised in *Section 7* of this paper. Interim landfill arrangements will be among the immediate temporary measures adopted, as will options for co-incineration, recycling, and perhaps long-term storage. A strong waste avoidance and reduction programme can also do much at this stage to deal with some waste streams which are generated in excessive quantity, or which are difficult to dispose of.

We now go on to look briefly at the major components of a waste strategy.

5 THE COMPONENTS OF A WASTE STRATEGY

The main components were earlier listed as technology, regulations, administration, and infrastructure. We will examine each briefly in turn, to see how they contribute to an overall waste management strategy.

5.1 Technology for treatment and disposal

Contrary to common opinion, safe and efficient technology is already available to deal with most industrial wastes. In fact, information on technologies is the easiest waste management information to find in references and journals. Additional research and development helps to further reduce costs, to improve operating efficiencies and performance, and to develop variations such as mobile plants etc.

Table 1 shows some of the main disposal technologies which are commonly applied around the world. *Reference 1* gives a more complete discussion of the various options and their application.

The actual choice of treatment technology will depend on government policy as well as on scientific principles, and therefore it is important to clearly identify such policies at the outset. Examples of policies applied in some countries include—

- acceptance (or not) of co-disposal and co-incineration of industrial and other waste
- non-acceptance of liquids in landfills
- requirement of pre-treatment and stabilisation of all toxic waste prior to landfill
- ban on disposal of certain wastes that can be recovered
- use only of proven technologies.

These policies are often incorporated into a broader approach that promotes a hierarchy of waste priorities, such as [i] waste avoidance; [ii] recovery and recycling; [iii] treatment; [iv] disposal.

In choosing technologies, factors such as safe disposal of residues must be taken into account as well as treatment efficiency. Considerations of infrastructure, trained manpower for operation, and whether or not the plants are to be run for single waste streams or for a collective facility, are among the additional constraints.

Some countries have prepared guidelines and tables to guide in the choice of acceptable technologies. *Table 2* is taken from an Australian strategy of 1986. A more comprehensive set of tables can be found in *Reference 1*, as well as in other literature.

5.2 Legislation for waste management

The framing of effective regulations is a difficult task. A multitude of waste sources and handling operations have to be covered, yet the regulations have to be practical to enforce. New regulations on hazardous waste have to fit into an existing framework of laws on municipal waste, on chemicals and pesticides, on public health and safety, on industrial permits, on public sewer systems, on the management of air and water pollution, and on transport safety. Many of these have already developed their own classification and permit systems. In addition, regulations and classifications now need to pay regard to the Basel Convention so as to be compatible with the regulations in other countries.

The following are common elements of national legislation on hazardous waste:

Some Common Elements of Hazardous Waste Legislation

- Defining objectives of the legislation
- Defining responsibilities of generators, operators
- Classification of wastes and sources
- Permits for operators and facilities
- Standards for discharges to water, air, land
- Standards for waste transport
- Bans on certain operations
- Monitoring of generation, transport, disposal
- Clean-up of contaminated sites
- Penalties for non-observance of requirements
- Incentives for R&D and installation of plant

Legislation is ineffective unless there is adequate enforcement. Enforcement requires an inspectorate that is trained to recognise the special aspects of industrial waste, while at the same time continuing to deal with more traditional pollution problems. Guidance documents to drafting legislation are available from UNEP and from the Secretariat of the Basel Convention.

Each country has so far developed its own approach to regulation; however, there are a number of guidance documents and case studies which can be consulted. In particular, the Cairo Guidelines outline the main considerations (*Appendix D*).

5.3 Operation and administration

Many countries now prefer that waste disposal is carried out by the private sector (perhaps under government licence), while standard setting and monitoring rests with the government. Establishment of control legislation is, of course, also a government function.

Legislation is worthless unless there is effective enforcement. This is particularly true for hazardous waste legislation. Enforcement requires an inspectorate that is trained to recognise the special aspects of industrial waste, while continuing to deal with more traditional pollution problems. The creation of a separate waste inspectorate has proven to be less effective than this integration with pollution enforcement.

In addition to enforcement, there needs to be a special unit that has responsibility for policy development, for monitoring and data collection, and for making special arrangements for certain wastes that are difficult to dispose of. The unit must also take an active role in minimising the generation of waste production.

5.4 Infrastructure and technical services

This area is unfortunately sometimes overlooked when waste strategies are prepared.

Some examples are shown in the following box.

Examples of infrastructure and technical service

- Safe landfill activities for treatment residues, incinerator ash, soil and residues from site clean-up, and those wastes that cannot be avoided or treated
- Safe interim storage facilities for abandoned wastes and wastes collected from small generators
- Analytical laboratories capable of handling the complex samples from a waste control programme
- Training institutions for drivers, operators, inspectors, and site clean-up personnel
- Educators and trainers to handle sensitive communications programmes with the public, with NGOs, and with local politicians
- Monitoring and data collection facilities

6 WASTE MINIMISATION AND CLEANER PRODUCTION

It is now generally conceded that a proactive approach to waste minimisation has to be taken if a management programme is to be successful. This has been incorporated into the cradle-to-grave policy adopted by many countries; however, practical action has been slower to follow.

Waste minimisation sidesteps many of the problems with treatment and disposal. An effective programme incorporates both a tightening up of standards applying to waste operations, as well as incentive and information programmes to demonstrate that practical programmes of waste avoidance do work, are economic, and can be implemented in most industries. For example, a recent report from the Netherlands indicated that of 40 industry case studies, waste minimisation measures had an economic payback or were cost-neutral in 38. Only in two cases was there a long-term cost penalty to the industry concerned.

Waste minimisation within the industry requires first an assessment of the waste sources, and then a systematic examination of the reduction options. A number of references are available to guide such a process *(References 12, 19* and *20*).

A number of governments have recently taken a more proactive approach to waste reduction.

The Netherlands has adopted reduction targets for many industrial and domestic wastes, and is backing this up with strong action programmes. The State of Victoria in Australia has adopted an integrated programme of regulation, advice, enforcement and incentives. Various states in the USA have done likewise, and the US EPA has created a special Office of Pollution Prevention to oversee its national programme.

A part of the US EPA programme is a computer-based clearinghouse on pollution prevention information. This clearinghouse has recently been made available to UNEP IE/PAC as the basis of its International Cleaner Production Information Clearinghouse (ICPIC). ICPIC can provide examples of company and government programmes, as well as case studies of low-waste production technologies.

Access to ICPIC is available free of charge to users around the world. It is one component of IE/PAC's Cleaner Production programme (see *Appendix F*) which aims to assist countries and companies in implementing waste avoidance programmes around the world.

Likewise, ISWA has been active in publicising waste minimisation through special conferences and publications.

7 COUNTRY EXPERIENCES

A number of countries around the world have been gradually developing their hazardous waste management systems in recent years.

While the longest experience has been in industrialised countries (where the problem has been most acute), in recent years some developing countries have also moved to put control measures into place. The ISWA workshop in Honolulu in 1989 reviewed a number of country case studies which are described in *Reference 16*.

Very briefly, the experience can be summarised as follows—

- effective waste management relies on a combination of measures rather than a single technical or regulatory initiative
- the building of support for waste control measures among the public and government officials is critical to success
- cooperation with and between government, industry and public bodies is necessary if practical minimisation and disposal measures are to be effective
- a gradual building up of control measures is easier than the implementation of grandiose master plans.

A waste management strategy should include short term actions for immediate implementation, and a phased approach to longer term actions. An example of such a phased approach is shown in *Figure 3*.

8 TRANSPORT OF HAZARDOUS WASTE: THE BASEL CONVENTION

Following a series of well publicised incidents of waste export and attempted dumping, the world community moved to prevent such trade as far as possible.

In May 1989, 116 countries signed the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*, and this Convention came in to force during 1992.

Appendix E shows the main features of this Convention, which—in addition to regulating the transport of wastes—requires that less waste be produced and that any remaining residues be disposed of as close to the place of production as possible.

A secretariat based in Geneva has the responsibility for monitoring the implementation, and of advising countries about the practical measures they can take.

9 TRAINING IN HAZARDOUS WASTE MANAGEMENT

Training of national personnel is an important aspect of the implementation of the Basel Convention. UNEP IE/PAC, together with other organisations such as ISWA, commenced a series of training workshops in countries around the world.

Workshop themes ranged from policies and strategies to technical themes of landfill, treatment and disposal. In order to extend training opportunities to the largest possible audience, a training manual on *Hazardous Waste Policies and Strategies* has been prepared for use by other institutions. The manual consists of a country case study, followed by over 80 practical exercises on a range of technical subjects.

A second manual on *Landfill of IndustrialHazardous Waste* has also been produced.

Training is also important for waste prevention. Here, it is particularly the waste generators who must be influenced, so the target audience is much broader than just waste managers. It is important to include the strategic areas of industrial planning, product design, etc. Professional awareness and undergraduate education are two key areas to be addressed. Specific prevention skills must also be developed; for example, through waste reduction auditing (see *Reference 12*).

10 SUMMARY

A number of interrelated measures are needed for effective control of hazardous waste.

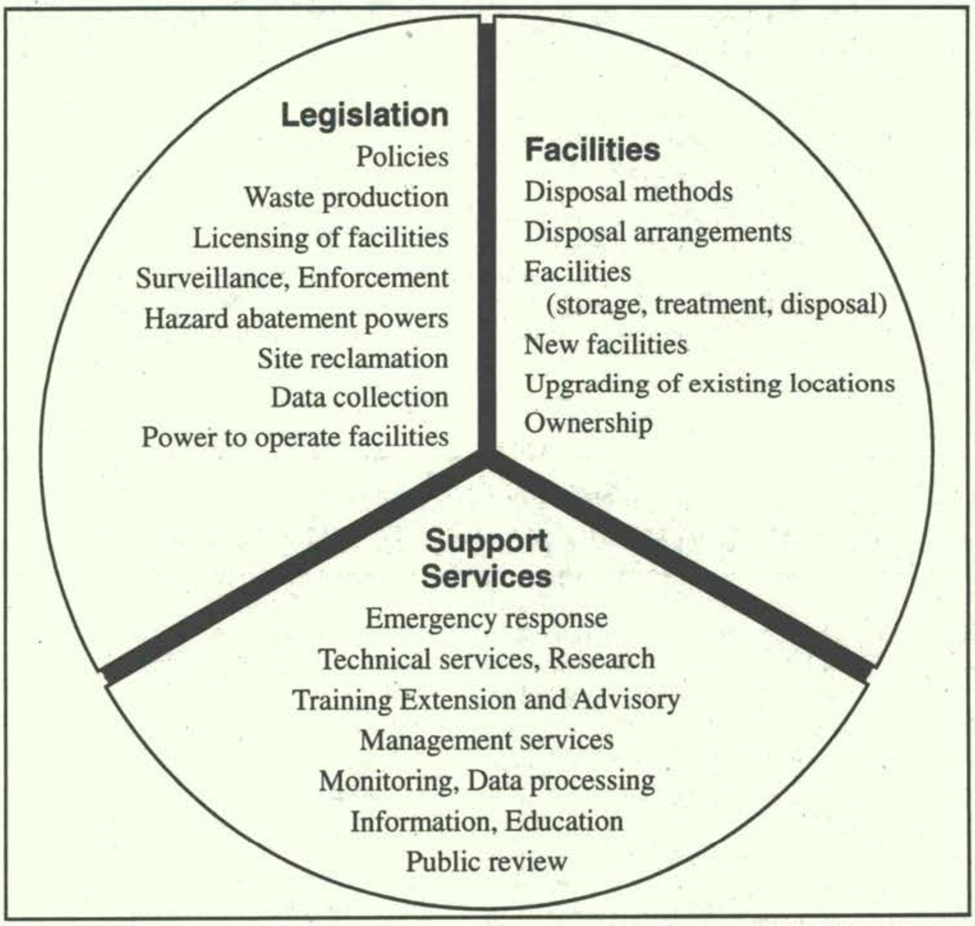
These measures can be combined into a strategy which is implemented in an evolutionary manner. Prior assessment of environmental impacts and of waste sources is essential for such a strategy to be correctly focused on the major environmental problems.

Waste minimisation through the concept of cleaner production is an essential element of a strategy. A number of international organisations such as UNEP and ISWA have prepared information and training materials to help national authorities pursue effective action programmes.

International aspects of such programmes includes the control of transfrontier transport of wastes.

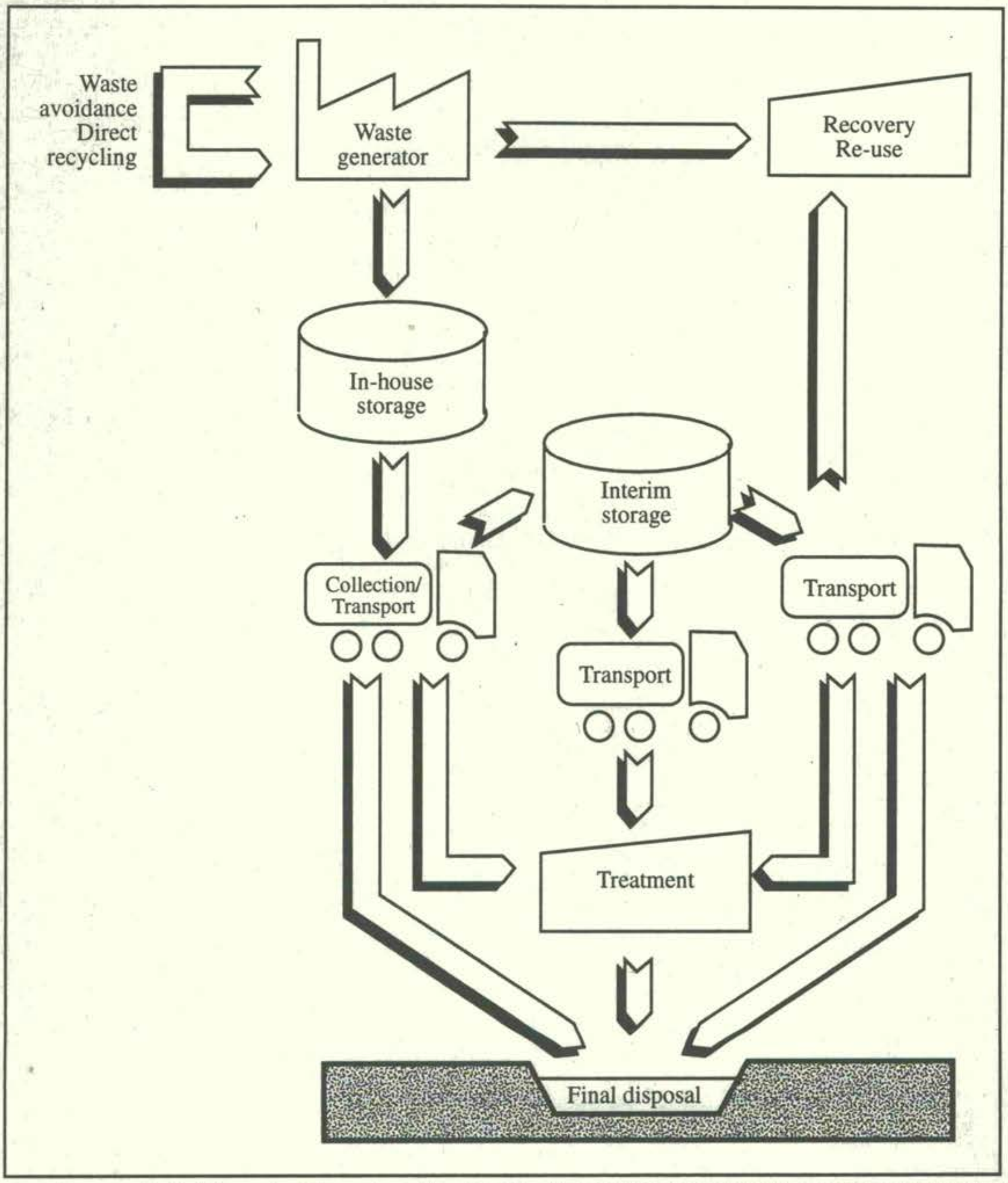
FIGURES AND TABLES

Figure 1: Example of a hazardous waste strategy



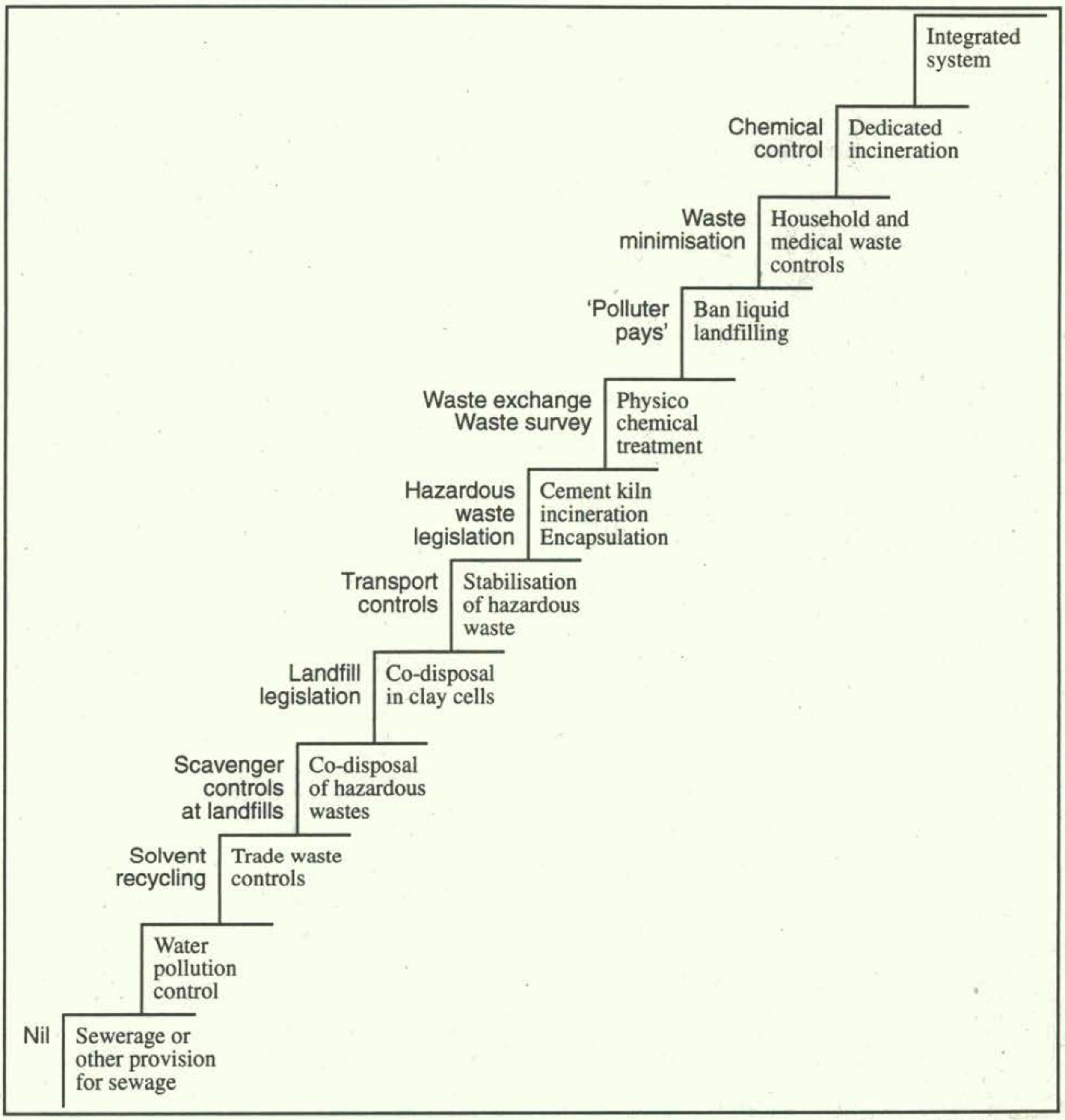
Source: State of Victoria, Australia, 1985

Figure 2: Hazardous waste handling operations



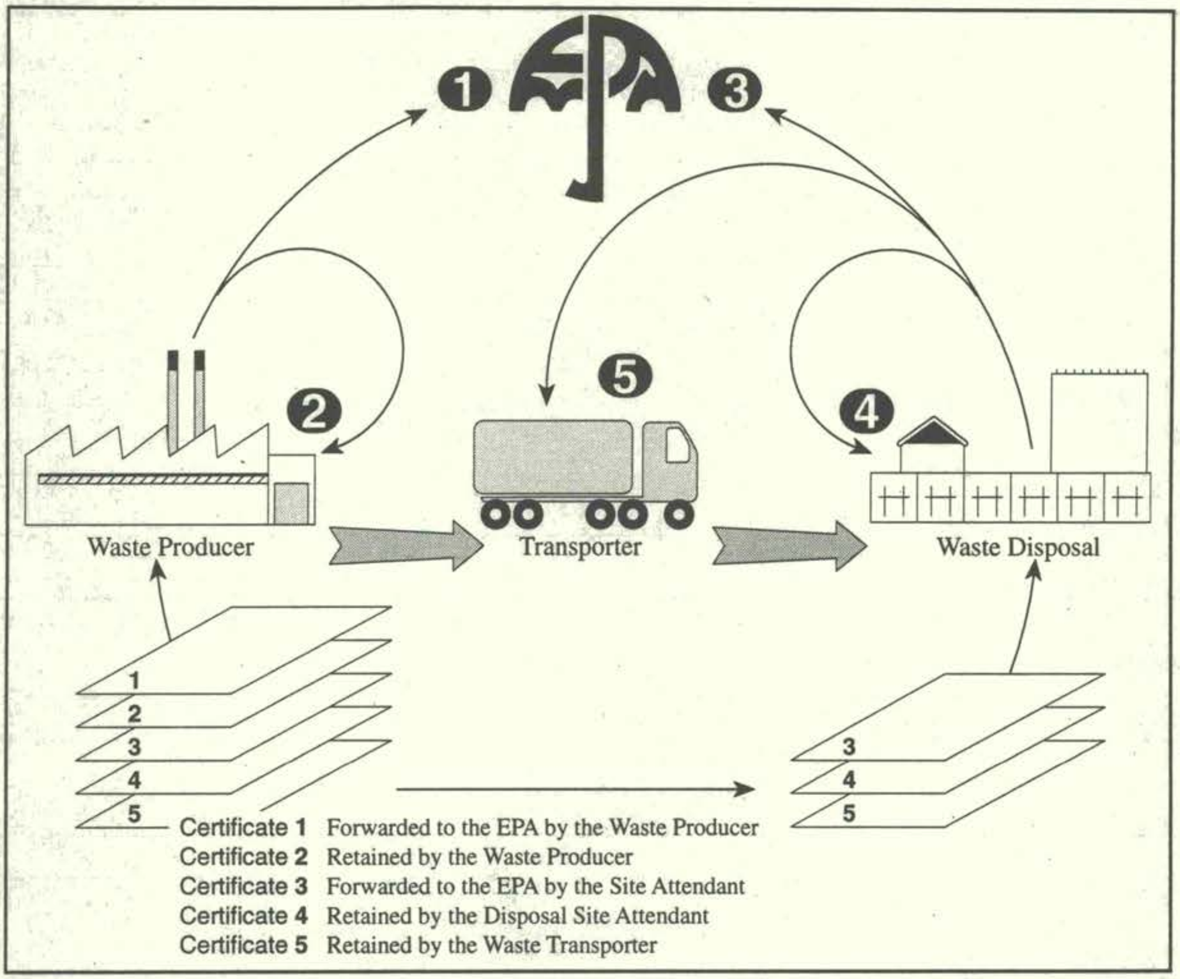
Source: *Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*, World Bank/WHO/UNEP, 1989

Figure 3: Example of the evolution of a waste management strategy



Source: J.B. Robinson

Figure 4: Example of a hazardous waste manifest



Source: EPA, Victoria, Australia

Table 1: Hazardous waste treatment and disposal technologies

General division	Subdivision	
Recycling	• Gravity separation • Filtration • Distillation	• Solvent extraction • Chemical regeneration
Physical chemical	• Neutralisation • Precipitation/Separation	• Detoxification (chemical)
Biological	• Aerobic Reactor • Anaerobic Reactor	• Soil Culture
Incineration	• High temperature • Medium temperature	• Co-incineration
Immobilisation	• Chemical fixation • Encapsulation	• Stabilisation • Solidification
Landfill	• Secure landfill • Normal landfill	• Co-disposal
Offshore	• Ocean incineration • Ocean dumping	• Export

Table 2: Disposal technologies for industrial wastes

	Recovery	Incineration	Treatment: physical, chemical, biological	Immobilisation Chemical fixation Encapsulation	Landfill
Effluents, washwaters			XXX		
Acids, alkalis			XXX		
Heavy metals			XXX	XXX	*residues*
Toxic inorganics			XXX	XXX	*residues*
Reactive wastes			XXX		
Non-toxic inorganics	XXX				XXX
Solvents, oils	XXX	XXX			
Resins, paints, organic sludge	XXX	XXX			
Organic chemicals	XXX	XXX	XXX		
Pesticides		XXX	XXX		
PCBs, chlorinated hydrocarbons		XXX			
Putrescible, biodegradable wastes		XXX	XXX		

Source: EPA, Victoria, Australia.

Table 3: Aspects of hazardous waste legislation

Purpose and Scope			
Public Health	Raising Funds	Control of Operations	
Pollution Prevention	Empower a Corporation	Establish Liabilities	
Workplace Safety	Coordinate Agencies		
Type			
Framework Law (enabling legislation)		Complementary Laws on Hazardous Waste	
		Waste Provisions in other Laws	
Subordinate Law		Subordinate Regulations	
Primary Laws on Hazardous Waste		Schedules	
Application			
Waste Handling		**Waste Information**	
Chemical Use	Treatment/Recycling	Definitions	Measurements
Waste Generation	Disposal	Assessments/Studies	Training
Storage	Dumping	Research	
Transport	Clean-Up		
Instruments			
Notification	Orders to Act/Not to Act	Standards	Release of Information
Certification	Bans	Guidelines/Codes/Policies	Assistance Measures
Labelling	Licensing/Permitting	Monitoring	Fiscal Measures
Fiscal Measures			
Fees and Charges	Compensations	Fines	
Tax Concessions	Subsidies	Levies	
Powers			
Obligations	Offences	Giving Directions/Orders	Right to Know
Responsibilities	Authorisations/Delegations	Right of Refusal	Right to Secrecy
Enforcements			
Which Agencies		Possible Conflict of Interest (self licensing of agencies)	
Extent of Proof			

Note: This list is not exhaustive

Source: *Hazardous Waste Policies and Strategies—a training manual*, UNEP/IEO [1991].

Table 4: Option menu for organisational measures for waste minimisation, recovery and disposal

Waste Avoidance/Reduction	Waste Recycling/Recovery
EIA to screen industries Publish technical guides Prepare consultant roster Employ extension staff Employ PR staff Give incentives, publicity Speak at business meetings Work with some plants as case studies On-line access to ICPIC Publish cleaner production information	*As for 'Waste Reduction' plus—* Set up a waste exchange Government purchase of recycled materials Tax reduction for recycling plant
Collection/Transport	**Treatment/Disposal**
Voluntary waste manifest Driver training programme Agriculture Dept. to collect pesticides Health Dept. to collect medical wastes and drugs Storage at municipal depots Government vehicles for some collection	Special treatment at sewage works or municipal depots Selected, supervised co-disposal Simple immobilisation Use of local cement kilns Extension staff
Evaluation	**Communication**
Monitor industrial waste at dumpsites Factory inspections Establish an interdepartmental group to collect data Start simple surveys	Print a regular waste bulletin Attend industry meetings Brief politicians on waste problems Publish educational features in newspapers Work with technical schools

Note Many other initiatives can also be developed. A supplementary exercise could be to list some possible additions to this table.

Source: *Hazardous Waste Policies and Strategies—a training manual,* UNEP/IEO [1991].

Table 5: Some factors encouraging waste minimisation by the generator

Technical	Legislation/Policy
New processes available New chemicals available New plant installed Improved product design New raw materials	Bans on specified wastes or raw materials Limits on waste production Compulsory waste audits Waste minimisation is criterion in plant permits
Operational	**Management**
Regular maintenance of plant Trained operators Printed company directives on minimisation Area set aside for collection and recovery Avoid over-ordering Storage areas kept safe	Waste minimisation policy adopted Staff incentives for minimisation Operational directives Waste audit procedures Positive publicity Public scrutiny Regular monitoring
Disposal	**Economic**
Lack of disposal sites Pre-treatment by generator required by authorities Chemical supplier obliged to accept return of surplus stock	High disposal fees High dumping fines High chemical costs Incentives for new plant
Informational	
Technical information is readily available Discussion at business meetings	Consulting expertise is available Training venues are organised

Note Many other arrangements could also be developed. A supplementary exercise could be to list some possible additions to this table.

Source: *Hazardous Waste Policies and Strategies—a training manual,* UNEP/IEO [1991].

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APPENDIX A Working definitions of common terms

Audit	A systematic check of relevant aspects of an operation. Audits may include energy, wastes, or a full environmental audit of all matters that influence environmental performance.
Chemical Fixation	A process whereby waste is bonded chemically to a stable inert matrix.
Clean Production	A concept of industrial production which minimises all environmental impacts through careful management of resources use, of product design and use, systematic waste avoidance and management of residuals, safe working practices, and industrial safety.
Clean Technologies	Production processes or equipment with a low rate of waste production. Treatment or recycling plants are not classed as clean technologies.
Corrosive	Ability to damage or destroy organic tissues or other materials by chemical action.
Disposal	The discharge of deposit of waste into the environment, or the complete destruction of waste without residue.
Disposal Facility	A plant or structure used for the destruction, removal and disposal of waste materials. Recycling plants are sometimes included under this definition.
Dump	An uncontrolled disposal site where no attention is given to safety or environmental factors.
Environment	The physical factors of the surroundings of human beings including the land, water, atmosphere, climate, sound, odours, tastes; the biological factors of animals and plants and the social factor of aesthetics.
Flammable Liquids	Liquids with a flashpoint below 61°C when determined by the methods designated by the Institute of Petroleum, England.
Hazardous	Harmful or dangerous.
Hazardous Waste	Any waste containing significant quantities of a substance which may present danger— • to the life or health of living organisms when released into the environment; • to the safety of humans or equipment in disposal plants if incorrectly handled. Hazardous properties include toxic, carcinogenic, mutagenic or teratogenic characteristics, as well as flammability, chemical reactivity or other biologically damaging properties (including radioactivity).
Landfill	A controlled site for disposal of wastes for land, run in accordance with safety and environmental requirements laid down by a regulatory authority.
Leachate	Liquid which has percolated through or drained from waste material and which contains soluble components of the waste.
Management	Effective control of activities involving waste materials. Cradle-to-grave management involves the supervision of all phases in the life cycle of a waste material.
Manifest	A certificate or trip-ticket, usually comprising multiple copies, which accompanies a load of transported waste so as to verify that it has reached its intended destination.
Minimisation	Actions to avoid, reduce or in other ways diminish the hazards of waste at their source. Recycling is, strictly speaking, not a minimisation technique but is often included in such programmes for practical reasons.
Off-Site	Away from the site of production of waste.
On-Site	On or adjacent to the site of production of waste.
Pre-Treatment	Initial treatment of waste materials to make them safe to handle, or precondition them for subsequent processing or disposal.
Reactivity	The potential of a substance to release energy by decomposition or by combination with other substances.

Recycling	The retrieval of materials or products either for re-use in their original form, or for re-processing into products of similar composition.
Risk	The chance of injury or loss, or of a hazardous event occurring.
Secure Landfill	A site chosen and prepared so as to ensure very high retention rates of wastes deposited there.
Stabilization	A general and non-specific term describing a chemical transformation to a more stable, or a less soluble, form.
Toxic Substance	Any substance producing a harmful effect on living organisms by physical contact, ingestion or inhalation.
Treatment	A change in the composition or concentration of a waste substance so as to make it less hazardous or to make it acceptable at disposal facilities. Sometimes treatment can result in complete elimination of waste components. It is then also a disposal technique.
Waste	Any matter prescribed to be waste under national legislation, any material listed as waste in appropriate schedules, and in general, any surplus or reject material that is no longer useful and which is to be disposed of.

APPENDIX B Categories of waste to be controlled under the Basel Convention

	Waste Streams
Y1	Clinical wastes from medical care in hospitals, medical centres and clinics.
Y2	Wastes from the production and preparation of pharmaceutical products.
Y3	Waste pharmaceuticals, drugs and medicines.
Y4	Wastes from the production, formulation and use of biocides and phytopharmaceuticals.
Y5	Wastes from the manufacture, formulation and use of wood preserving chemicals.
Y6	Wastes from the production, formulation and use of organic solvents.
Y7	Wastes from heat treatment and tempering operations containing cyanides.
Y8	Waste mineral oils unfit for their original intended use.
Y9	Waste oils/water, hydrocarbons/water mixtures, emulsions.
Y10	Waste substances and articles containing or contaminated with polychlorinated biphenyls (pcbs) and/or polychlorinated terphenyls (pcts) and/or polybrominated biphenyls (pbbs).
Y11	Waste tarry residues arising from refining, distillation and any pyrolytic treatment.
Y12	Wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish.
Y13	Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives.
Y14	Waste chemical substances arising from research and development or teaching activities which are not identified and/or are new and whose effects on man and/or the environment are not known.
Y15	Wastes of an explosive nature not subject to other legislation.
Y16	Wastes from production, formulation and use of photographic chemicals and processing materials.
Y17	Wastes resulting from surface treatment of metals and plastics.
Y18	Residues arising from industrial waste disposal operations.
	Waste having as constituents—
Y19	Metal carbonyls.
Y20	Beryllium; beryllium compounds.
Y21	Hexavalent chromium compounds.
Y22	Copper compounds.
Y23	Zinc compounds.
Y24	Arsenic; arsenic compounds.
Y25	Selenium; selenium compounds.
Y26	Cadmium; cadmium compounds.
Y27	Antimony; antimony compounds.
Y28	Tellurium; tellurium compounds.
Y29	Mercury; mercury compounds.
Y30	Thallium; thallium compounds.
Y31	Lead; lead compounds.
Y32	Inorganic fluorine compounds excluding calcium fluoride.
Y33	Inorganic cyanides.
Y34	Acidic solutions or acids in solid form.
Y35	Basic solutions or bases in solid form.
Y36	Asbestos (dust and fibre).
Y37	Organic phosphorous compounds.
Y38	Organic cyanides.
Y39	Phenols; phenol compounds including chlorophenols.
Y40	Ethers.
Y41	Halogenated organic solvents.
Y42	Organic solvents excluding halogenated solvents.
Y43	Any congenor of polychlorinated dibenzo-furan.
Y44	Any congenor of polychlorinated dibenzo-p-dioxin.
Y45	Organohalogen compounds other than substances referred to in this Annex (e.g. y39, y41, y42, y43, y44).

APPENDIX C UNEP hazardous waste situation questionnaire: table of contents

(See Annex V of this manual for the complete questionnaire)

APPENDIX D Contents of Cairo Guidelines and Principles for the Environmentally Sound Management of Hazardous Wastes

APPENDIX E Main points of the Basel Convention

The full text of the Basel Convention is found by consulting the references. Some key points are summarised below.

1	A signatory State cannot send hazardous waste to another signatory State that bans imports of it or to any country that has not signed the treaty.
2	No signatory country may ship hazardous waste to another signatory State if the importing country does not have the facilities to dispose of the waste in an environmentally sound manner.
3	Every country has the sovereign right to refuse to accept a shipment of hazardous waste.
4	Before an exporting country can start a shipment on its way, it must have the importing country's consent in writing. The exporting country must first provide detailed information on the intended export to the importing country to allow it to assess the risks.
5	The treaty asks that less hazardous waste be generated and what is generated be disposed of as close to its source as possible.
6	Where an importing country is unable to dispose of legally imported waste in an environmentally acceptable way, then the exporting State has a duty either to take it back or to find some other way of safely disposing of it.
7	The treaty states that 'illegal traffic of hazardous waste is criminal'.
8	Shipments of hazardous waste must be packaged, labelled, and transported in conformity with generally accepted and recognised international rules and standards.
9	Bilateral agreements may be made by signatory States with each other and with a non-signatory country, but these agreements must conform to the terms of the Basel treaty and be no less environmentally sound.
10	As authorities in many countries frequently do not have trained specialists and technical know-how about hazardous waste and how to handle it efficiently, the treaty calls for international cooperation on the training of technicians, the exchange of information, and the transfer of technology.
11	The treaty sets up a secretariat to supervise and failitate its implementation.
12	Signatory parties will report annually informaton about transboundary movements of hazardous wastes in which they have been involved.

APPENDIX F UNEP Industry and Environment Programme Activity Centre (IE/PAC)

Cleaner Production Programme

Cleaner Production is a comprehensive, preventive approach to environmental protection. It requires people to investigate all phases of manufacturing processes and product life cycles, including product usage in offices and homes. Cleaner production encompasses such actions as energy and raw material conservation, eliminating toxic substances (as raw materials and as product constituents), and reducing the amount of wastes and pollutants created by processes and products, thereby lowering the amounts emitted to air, land and water.

UNEP IE/PAC's *Cleaner Production Programme* has roots that date back to activities in the mid-1970s on low- and non-waste technologies. The Programme was formalised in 1989, in response to directives issued by the UNEP Governing Council that year. The Programme was officially launched in 1990 at the Canterbury Seminar in the United Kingdom. And in 1991, directives of the UNEP 16th Session Governing Council effectively institutionalised the Programme.

The objectives of the Cleaner Production Programme are—

- to increase worldwide awareness of the preventive environmental protection strategy embodied in cleaner production

  and

- to help government and industry develop cleaner production programmes and activities that will expand the adoption of cleaner production know-how, technology and management approaches.

The objectives are met by carrying out activities under several closely related programme elements—

- **Training and Technical Assistance**

  Workshops and seminars for government, industry and academia increase awareness and prompt action, educate people and help develop cleaner production programmes. Upon the requests of governments, the Programme can help by fostering links between experts, launching demonstration projects; promoting national and local activities; and providing expertise for audits.

- **Publications**

  The Programme offers documents that help disseminate information and experience. They include the Cleaner Production Newsletter; specific documents such as Cleaner Production Worldwide, Packaging and the Environment, Audit and Reduction Manual for Industrial Emissions and Wastes, and the Industry and Environment Review.

- **Working Groups**

  The Working Groups provide input on the direction of the Programme, facilitate the collection of information and its dissemination, and review ongoing activities. Specific industry working groups include leather tanning, textiles, metal finishing, pulp and paper, cleaner products and biotechnology. Other working groups are education and policies strategies, and instruments to promote cleaner production.

- **The International Cleaner Production Information Clearinghouse (ICPIC)**

  This is an electronic system accessible to anyone with a personal computer, a modem, communications software and access to a telephone line. The system contains information that explains and illustrates the cleaner production concept, and 'points' users to more specific sources of information.

For more information, contact—

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ANNEX III

UNEP

Draft Technical Guidelines on Specially Engineered Landfill

Guidelines prepared by the
Technical Working Group
for the
Secretariat of the Basel Convention

UNEP/CHW/WG.4/5/2/Rev:15/09/1993
Revision 3

September 1993

CONTENTS

1 FOREWORD

These technical guidelines are principally meant to provide guidance to countries who are building their capacity to manage waste in an environmentally sound and efficient way and in their development of detailed procedures or waste management plan or strategy. They should not be used in isolation by the competent authorities for consenting to or rejecting a transboundary movement of hazardous wastes as they are not sufficiently comprehensive for environmentally sound management of hazardous waste and other waste as defined by the Basel Convention. These technical guidelines concern waste generated nationally and disposed of at the national level, as well as waste imported as a result of a transboundary movement, or arising from the treatment of imported wastes.

It is necessary to consider this document in conjunction with the Framework Document on the preparation of technical guidelines for the environmentally sound management of wastes subject to the Basel Convention (UNEP document Na.93-7758 of 19.07.93) adopted provisionally by the first meeting of the Conference of the Parties. In particular, special attention should be given to the national/domestic legal framework and the responsibilities of the competent authorities.

These guidelines are meant to assist countries in their efforts to ensure, as far as practicable, the environmentally sound management of the wastes subject to the Basel Convention within their national territory and are not intended to promote transboundary movements of such wastes.

2 INTRODUCTION

1 These technical guidelines provide general guidance on specially engineered landfills used for the wastes which exhibit one or more hazardous characteristics. The technical guidelines also discuss the landfilling of other wastes, as defined in the Basel Convention, e.g. collected from households, to provide a more comprehensive picture on environmental and health problems arising from landfills. In addition to the requirements for establishing new landfills, the technical guidelines also consider the critical issue of existing or abandoned landfill sites which require strict control, monitoring and often remedial measures. They provide general guidance as to which hazardous wastes would be suitable for landfilling.

2 Landfill is by far the most commonly practised waste disposal method in the majority of countries. It lis the descriptor used for the placement of wastes into or onto the ground and, in many cases because of the nature of the materials involved, equates to long-term storage.

3 As a result of serious environmental and health problems experienced with historic and abandoned dump sites and the very high costs associated with cleanup measures at contaminated sites, many countries have introduced the 'specially engineered landfill concept', the wastes for which are only consigned to sites selected for their containment properties, these being natural, augmented by or provided directly by liners. The overall engineering being such as to ensure as far as possible the isolation of wastes from the environment. Such landfills are considered a final resort option only to be used after every effort has been made to reduce, mitigate or eliminate the hazards posed by such wastes.

4 Reducing dependence on land disposal through waste prevention, minimisation and other technical possibilities represents the first choice in the hierarchy of hazardous waste management options. Chapter 20 of UNCED Agenda 21 stipulates that prevention of the generation of hazardous wastes and the rehabilitation of contaminated sites are the key elements for environmentally sound management, and both require knowledge, experienced people, facilities, financial resources and technical scientific capacities. In this regard a precautionary approach should be applied to landfill disposal. Such approach could be summarised as follows:

Environmental protection should be undertaken whereby preventive measures are taken when there is reason to believe that substances, waste or energy introduced into the environment are likely to cause harm even when there is no conclusive evidence to prove a causal relation between inputs and their effects.

5 While waste avoidance is clearly the preferred management option, current patterns of waste generation mean that landfill as a disposal method will continue to be used. Many countries are faced with starting a hazardous waste management programme with the existence of unregulated dumping sites. They need in this case to focus on immediate remedial measures and improvements where these sites are continuing to operate as well as considering waste management strategies which should be based on the concept of providing long term security rather than short term expediency which is inappropriate in respect of the landfilling of wastes.

6 Short term actions must commence with a thorough site investigation and assessment of environmental impacts, the monitoring and reporting of wastes received and any problems caused by unregulated disposal. Some control must be exercised at dumping sites while simultaneously attempts are to be made to upgrade the site.

7 Existing and ongoing landfills, where a significant proportion of biodegradable or bioconvertible materials is contained in the wastes deposited, will benefit from improved controls over the moisture content, pH, compaction/density. These will allow for improvement in the chemical and biochemical degradation of the wastes leading to a more rapid stabilisation of the mass. The tendency is to increase pre-treatment processes prior to landfilling. Useful technologies which are increasingly used are solidification and chemical fixation. Very soon after (or even better, simultaneously) there should be an attempt to go back to the source of the wastes to see if some reductions cannot be made there. For many wastes where there is no satisfactory disposal option, source reduction provides the most viable management action, this being especially the case in small countries. In a number of countries, landfill disposal is likely to be the only method available for the disposal of significant quantities of hazardous wastes.

3 TYPES OF LANDFILL

8 Generally three situations are experienced in practice:

Historic, closed sites: The management of any problems associated with these will be influenced by the level of knowledge regarding inputs, past experience, when the site was closed, those post the early 1960s having greater problem potential, and what restoration and aftercare measures, if any, were installed.

Historic, still operating: Here how problems can be most effectively managed will be influenced by such factors as the level of knowledge in respect of previous inputs, when licensing/authorisation systems providing for improved controls and improved management regimes were put in place, pre or post the early 1960s, changes in the nature of input, etc.

Green Field sites: These are set up according to waste being handled and will be the subject of appropriate licence/authorisation conditions, which produce where appropriate for phased restoration, and operated under quality assured management regimes should present minimal operational, restoration and aftercare problems.

3.1 Specific operational types of landfill

9 Containment sites

These include those affording material containment are frequently found in naturally occurring clay deposits, involving the filling of the void spaces created by the extraction of clay for brick making or cement manufacturing. Those with engineered liners augmenting or substituting for natural containment. In both these cases it is also common to install liquid collection system below and above the liners so that any leachate which leaks through or is retained on them can be recovered.

10 Those providing for attenuated release

Here the underlying natural or artificially engineered strata provides an unsaturated zone which allows for physical, chemical and biochemical attenuated release processes to occur. The result of these minimising the pollution potential of any leachate and allowing the capacity of the recipient environment to accommodate any released species not to be exceeded. There are parallels here with the recipient-environment's ability to accommodate the fluxes of material arising for the weathering and exposure to water flow of naturally occurring materials.

11 In the context of this paper a specially engineered landfill is seen as one customary providing for containment; having such features as installed drainage to recover any leakage, providing for leachate management including recirculation and gas control systems where appropriate. Also almost certainly operating on a cell system employing progressive restoration. Successful containment is achieved through [a] the selection of a suitable site, [b] high standards of operation, and [c] a strict selection and/or pre-treatment of the wastes to guarantee (by way of their chemical properties) a long term minimisation of releases to the environment.

3.2 Specially engineered landfill

12 This form of landfill however, which provides the means for the controlled deposit of wastes on land is sometimes the only practicable disposal option for wastes, in particular for hazardous wastes. In principle, and for a defined time period, a landfill site can be engineered to be environmentally safe subject to appropriate siting, proper precautions and efficient management. Preparation, management and control of the landfill must be of the highest standard to minimise the risks to human health and the environment. Such preparation, management and control procedures should apply equally to the process of site selection, design and construction, operation and monitoring, closure and post closure care.

3.3 Operational methods

13 There are a number of different ways of depositing hazardous waste in a landfill. Each has advantages and disadvantages.

14 Any landfilling of hazardous waste poses a potential threat to human health and the environment, and must therefore be undertaken with great care. A high level of technical competence is required in designing, operating and monitoring the site.

15 Wherever possible, hazardous wastes should be pre-treated to render them less hazardous or inert before landfilling. Many pre-treatment possibilities are available, and a discussion of them is beyond the scope of this paper. However, the most widely used pre-treatment is incineration.

16 Two specific ways of landfilling hazardous waste are mono-disposal and co-disposal:

- Mono-disposal means placing a single waste stream (or closely related streams) either in a landfill or in an individual cell in a landfill. For non-degradable wastes this is, in effect, permanent storage. For that reason, close attention must be paid to the long term engineering stability of the site, and to precautions to be taken against the site being accidentally breached. The consequences of any release must be evaluated.
- Co-disposal uses the processes of degradation of municipal waste to destroy or stabilise hazardous waste. Eventually, after many decades, such a site can become stable and operate as permanent storage. However, the reactions involved are complex and not well understood. For that reason only wastes which are amenable to destruction in this way should be co-disposed, and comprehensive monitoring of emissions from the site should be undertaken during its active period.

17 It is strongly recommended that different wastes should not be mixed in a landfill site unless some significant reduction in hazard is expected to result from their mutual interaction. Even then, any such mixing should be carried out in a controlled and monitored way.

4 ENVIRONMENTAL AND HUMAN HEALTH ASPECTS

18 In assessing the risks associated with landfill activities the landfill needs to be characterised in terms of the factors which will affect the degree to which human exposure may occur. In this regard, an immediate and long-term environmental impact assessment has to be carried out as required under national legislations or procedures. The environmental impact assessment which is applied to 'specially engineered landfill' should cover scoping, objectives and policy making, assessment of baseline status, identification, prediction and evaluation of impacts on major and sensitive components of the environment. Issues like long-term impacts, aftercare management and long-term land use policies should be considered. In characterising the landfill, three important areas can be identified:

- *Wastes involved;* what type of wastes have been or are being deposited and in what quantities and forms? What are the disposal methods employed? Also, any new waste coming into the landfill should be sampled and analysed.
- *Chemicals involved;* what chemicals are present in the wastes and in what form and concentration do they occur? Subsurface conditions; what type of materials are present below the landfill?
- *Control systems;* for instance what type of cover exists over the landfill, and what types of leachate and surface run off controls are present.

4.1 Chemicals

19 Typically, a large number of chemicals will be present within a landfill. Unless specific sampling has been carried out on the contaminated materials, it will be very difficult to determine exactly which chemicals are present and at what concentrations they occur. In order to provide analysis for sites where no sampling has been done, it is necessary to outline groups of indicator chemicals associated with different waste streams. A procedure can be used with estimation of the annual amounts of different types of wastes deposited at the landfill and the landfill volume utilised to provide approximations of selected indicator chemicals in the waste. This procedure must be modified to account for the disposal of drummed and liquid wastes which may or may not be restricted to portions of the landfill area. In the case of landfills that are still operating, a sampling and analytical programme should be carried out for any incoming wastes.

4.2 Subsurface and surface conditions

20 At many landfills no leachate controls were implemented during landfill construction. In these cases therefore the subsurface conditions have to be generally defined by the local geology and soil characteristics. Where liners and leachate control systems were in place, they can be effective in preventing groundwater contamination. Most landfills are covered with a temporary cover during operation, and final soil or clay cover prior to closure or abandonment. The presence of a clean cover over the waste can reduce exposures via wind-borne dusts, erosion of the contaminated deposit by surface runoff, and by direct contact to persons using the site. The cover may or may not be vegetated and maintained; factors which will have an effect on the overall efficacy of the cover.

4.3 On-site and off-site exposure

21 In order for contaminants residing in a landfill to have an impact on human health, there must exist the potential for the chemical to come into contact with individuals. This contact can occur either as on-site exposures as a result of the receptor entering the landfill itself, or as off-site exposures as a result of chemicals migrating from the landfill to off-site exposure points.

4.4 Pathways

22 The link between chemicals in the landfill and the potential receptors constitutes an exposure pathway. There are three essential components of a pathway which must be present for the pathway to complete:

- A chemical release mechanism
- A transport route for chemicals to migrate to an exposure point
- An exposure point, where human or environmental exposures may occur.

23 The nature of a chemical release depends heavily on the form and conditions in which the chemicals exist in the landfill. Release

mechanisms are different for liquids in containers losing their integrity than for chemicals bound to soil particles by adsorption, dissolved with residual soil moisture, or present in perched groundwater within the landfill. Many waste sites are characterised as having contaminated soil areas where chemicals previously released in liquid form are adsorbed onto the soils and are released slowly by leaching. A surface impoundment containing contaminated liquids might release chemicals through volatilisation to the atmosphere and by infiltration of the contaminated liquids through the unsaturated soil zone.

24 Often, on-site exposures are not the most significant hazards associated with a site, since site access is usually restricted to a point where exposures are rather infrequent. Once the release of chemicals has been evaluated, the next step is to examine their transport to points where more substantial evaluating chemical movement through several media including transport routes if dependent on both release mechanisms and exposure points of concern. Exposure points may be identified as points where individuals would indicate the likelihood for future contact. Common exposure points evaluated at waste disposal sites include nearby water supply wells, points of discharge of groundwater to surface waters, local surface waters used recreationally or as drinking water supplies or as a source of fish, and property boundaries or nearest residences where population may be exposed to airborne contaminants.

4.5 Potential exposure pathways

25 There are many pathways by which exposure to wastes in landfill can occur. Experience with site-specific risk assessments based on exhaustive site investigations in the usa has shown that it is common to find upwards of 95% of the exposure associated with a particular site attributable to one exposure pathway. Identification of applicable exposure pathways begins with the identification of possible release mechanisms for wastes contained in the landfill. These include:

- *Leachate production;* chemicals may leach from soils and wastes contained in the landfill and be carried out of the contaminated area via percolating water.
- *Contaminated surface runoff;* chemicals may leach from soils and wastes contained in the lândfill and be carried out of the contaminated area via percolating water.
- *Contaminated surface runoff; chemicals* may leach from soils and wastes and be carried by surface runoff. Surface runoff may also carry contaminated soils as suspended particulates.
- *Gas production;* gases produced within the landfill may migrate due to pressure gradients carrying volatile chemicals outside the contaminated area.
- *Volatilisation;* volatile chemicals may be given off directly into the atmosphere.
- *Dust emissions;* wind-borne particulates may carry absorbed chemicals.

Persons who come into direct contact with the landfill may carry away contaminated material on their skin and clothes.

26 Landfill operations should be part of an integrated overall system of waste management which include the steps involved in a 'cradle to grave' and 'after disposal care' approach. Residuals from treatment process or disposal operations that are not discharged as treated effluent or emissions to the environmental media and which are still hazardous are deposited in a specially engineered landfill. All landfill operations require careful planning in advance of the first deposit of waste. How a landfill is operated determines to a large extent the environmental effects. One basic factor influencing the planning of site operations is the nature and quantity of incoming waste. *Figure 1* provides for a typical operational plan for landfill site (from UK Department of the Environment, Waste Management Paper No 26).

27 **The major disadvantages of landfill disposal include:**

- The potential risks for polluting water resources
- The potential risks of contaminating the soil
- The generation of landfill gas i.e. methane and carbon dioxide
- Potential human exposure to volatile chemicals
- Destruction of natural/virgin sites
- Long term and cost intensive clean-ups remediation and monitoring (aftercare, close-up).

Landfill has several advantages:

- Landfill can represent a long-term storage method
- It is not an unduly capital intensive disposal method over time, although setting up costs could be high
- It is widely available

- It is comparatively insensitive to day-to-day variations in the quantity and nature of the wastes deposited
- It is appropriate in a wide range of circumstances (i.e. equipment, technology and skills are available virtually worldwide at local levels).

28 Proper site selection, design of the landfill, control and management of operations, control on input waste, installation of appropriate means for avoiding leachate outside the fill and reducing escape of landfill gas would be necessary to minimise the potential harmful effects of a landfilling on public health and the environment and minimisation of free [1] liquids placed in the landfill as well as minimisation of precipitation and run-on into the fills is achieved.

29 As stated earlier, specially engineered landfills could be used as a disposal option for selected hazardous wastes provided adequate safety measures including pre-treatment of the waste in question are being taken to protect human health and the environment, and minimisation of free liquids placed in the landfill as well as minimisation of precipitation and run-on into the landfills is achieved. There are, however, a number of hazardous wastes for which landfill disposal is not appropriate and cannot be recommended;

- liquids and materials containing free liquids;
- highly volatile and flammable liquid wastes;
- wastes containing mineral oils;
- spontaneously flammable or pyrophoric solids;
- clinical wastes (such as infectious wastes, sharps etc.)
- persistent organo-halogen compounds;
- strongly smelling materials;
- volatile materials of significant toxicity;
- substances that react with water, air or dilute acids and alkalis to produce hazardous gases or hazardous reactions;
- concentrated acids, alkalis;
- empty containers unless they are crushed, shredded or similarly reduced in volume.

30 At most landfills it is also best to avoid the deposition of significant quantities of soluble materials that are not, or are only slowly bioconvertible. Similarly, the deposition of chelating agents that can solubilise heavy metals should be avoided.

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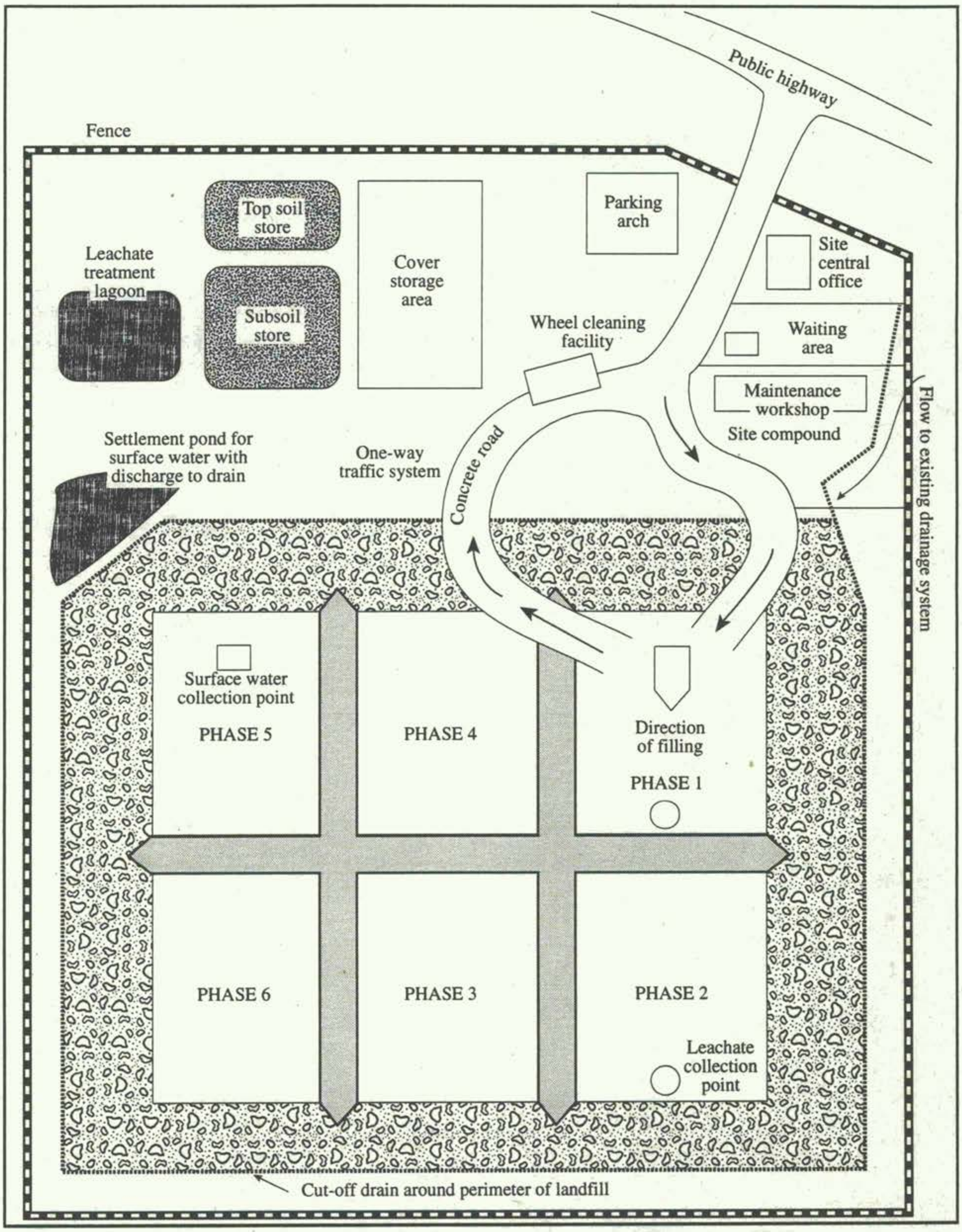
[1] Free liquid means uncombined or interstitial liquids.

Figure 1 Typical operational plan for landfill site



5 SAFE LANDFILL MANAGEMENT PRACTICES

5.1 General consideration

31 Liquids placed in a landfill can contribute significantly to leachate generation. To minimise this generation, it is recommended that liquids and materials containing free liquids be excluded from landfills unless provision is made for their treatment within the landfill. This prohibition should be extended to include liquids absorbed in materials. At the pressures that could exist in the depths of a landfill, liquids could be 'squeezed out' of the absorbent material to become uncombined and unabsorbed liquids (free liquid) once again. Dilution or blending of a hazardous waste with a non-hazardous material should not be permitted for the sole purpose of diluting it to meet any specified consideration limit.

32 Empty containers such as drums and canisters should not be placed in landfills unless crushed, shredded, or processed by some other means to reduce their volume. This will eliminate the chance of subsidence occurring in the completed landfill due to collapse of the containers under the pressures experienced after burial. If subsidence were to occur, it could threaten the integrity of the landfill cover which would then require ongoing maintenance to ensure the security of the landfill.

33 Consideration should be given to the establishment of trace levels of organic hazardous wastes, level of contaminants, particularly halogenated organic compounds which can be landfilled.

34 In principle, hazardous wastes to be deposited in a landfill should receive treatment and/or processing consistent with the best demonstrated available technique appropriate to the type of waste. The objective in applying such a technique should be to minimise the potential release of contaminants to the environment if the security of the landfill system is breached. The appropriate management methods and treatment/processing technology that could be applied to hazardous wastes could include:

- reduction in waste volumes produced at the source by installing modifications to the industrial process producing the waste or reduction in volume on the landfill site.
- recycling, recovery and/or reuse of various components of the waste.
- physical/chemical treatment for liquids solid separation and detoxification.
- biological treatment for removal of biodegradable/bioconvertible organic components.
- solidification/stabilisation/fixation for converting liquid wastes to solid form and for encapsulating hazardous components, and
- thermal treatment for destruction of organic wastes.

35 A number of technical measures which are interdependent should be taken to mitigate the impacts of landfill operations on the environment and human health; they concern:

a *Site selection.* Landfills should be sited, where possible to avoid the possibility of groundwater pollution. Where this is not possible, landfills should be designed and constructed to prevent the migration of leachate from the fill to groundwater.

b *Design of operations.* Landfills can be designed and operated in ways that minimise the generation of leachate, by for example tipping vertically rather than horizontally, and by the prompt application of appropriate intermediate cover over the deposited waste, graded to encourage runoff rather than infiltration. Effective compaction of the deposited waste is also important.

c *Design of landfill* and its proper engineering.

d *Control on incoming waste.* The amounts of waste that directly increase leachate volumes (e.g. wet wastes) should be reduced to a practical minimum.

e *Landfill closure.* The final closure for the landfill can be designed and laid in such a way that infiltration of rainfall into the fill will be greatly reduced.

f *Careful construction and operation* are essential.

g *Monitoring.* A comprehensive programme of monitoring will be required for all landfill sites. It should cover inputs to, contents of and emissions from the site and the surrounding environment. It should be designed to provide advanced warning of any unexpected problems and guidance on remediation possibilities. It should also indicate the point at which the landfill has become stable.

5.2 Site selection

36 In selecting a site for the construction of, for instance, a hazardous waste landfill, several geographical and hydrogeological factors of the location must be considered as well as several potential sites. These factors will have a significant bearing on the level of environmental protection provided by the landfill. Consideration on the future use of the landfill area should be made. Geographical and hydrogeological factors of a site will also influence the design of the landfill including the type of liner system drainage work, and groundwater monitors installed.

37 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 (contaminated by leachate, noise levels, odour levels, vermins, scavengers) and traffic patterns. Also, great care must be taken in developing an emergency preparedness plan in the event of a gas leak or other accident.

38 The site selection process for establishing a hazardous waste landfill must address geotechnical, land use, biological, socio-economic (it is a widely held assumption that public opposition to waste management facilities has become one of the critical problems faced in site selection), human and environmental factors. In addition, the process must be carried out in accordance with the environmental assessment requirements specified by regulation or legislation or any relevant jurisdictions. Programme planning, for hazardous landfill sites should be conducted in such a way as to involve local communities and get their input into the process.

39 With the general land area needs and locations identified, approximate costs can be estimated. These costs should include the costs of design, operation, closure, aftercare, financial guarantees for potential damage to third parties, and remediation. Such costs and pertinent factors such as ownership and social acceptability can be used to make an informed decision whether a site represents an economically viable hazardous waste disposal option. If a positive conclusion is reached, detailed technical, biological, social, economical and political analysis of the feasible site could be undertaken.

40 No site should be used for the landfill disposal of hazardous wastes unless the geological and hydrogeological properties of the site have been carefully investigated and found to offer maximal safety for public health and the environment. For instance, a hazardous waste landfill should not be located in a floodplain or be in contact with groundwater. The seasonal height and flow of the groundwater should be established so that the potential for water contamination can be assessed and the location of monitoring wells be established. The site should not be in an area of seismic activity or an area that includes cavities, faults or sinkholes. The integrity of the landfill may be compromised in such areas. The soils at the bottom of the hazardous waste landfill site should be clays and should be several feet thick and relatively impermeable. Thickness of a clay liner of the above dimension delays the problem of losing the protective capacity of the landfill but will not be sufficient to ensure full and complete protection. If such clay soils are not available, appropriate clays or materials may have to be brought to the site to serve as liner material and/or a synthetic flexible membrane liner will have to be installed. Suitable soils should be available as landfill cover material otherwise appropriate soils will have to be brought to the site. There is a concern over the long term integrity, reliability and operability of liner systems, leachate control systems, and other engineered components of a landfill facility. Both clay and synthetic liners can be damaged during placement of the wastes. In addition, the properties of clay and synthetic liners can be altered by contact with certain wastes such as solvents. The site should not be located where normal runoff will inundate the site. Drainage from the surrounding land should be diverted around the site.

41 *Appendices 1a* and *1b* to these guidelines provide a description of the factors required to select a site and the criteria for landfill site selection. *Appendix 1b* is extracted from the World Bank Technical Paper No 93 (see *Reference No 1*).

5.3 Design considerations

42 Conceptually, there are two basic approaches to the safe landfilling of problem waste: natural attenuation and containment. In the first approach, landfills designed to receive hazardous wastes are located only in areas where containment attenuation in the environment can be achieved naturally. This approach allows for the possibility of achieving a condition where maintenance is not required over the long term. The major disadvantage in the natural attenuation approach is that it is based largely upon the accuracy of predictions of the level of

protection provided by the natural environment. Natural attenuation also requires the presence of suitable hydrological and geological conditions.

43 In the second approach, reliance is placed on engineered facilities rather than on natural attenuation to protect the environment. Typically, landfills designed using this approach combine engineered liners, covers, leachate and/or gas collection and treatment systems to control the release of contaminants into the environment. While engineered containment reduces the potential risk associated with contaminant migration into the environment, questions remain concerning the integrity and functionality of such systems over the long term. The additional cost and responsibility associated with the maintenance and operation of such systems have to be accounted for.

5.4 Specially engineered landfill

44 For specially engineered landfill, receiving wastes, in particular hazardous wastes, a complete site assessment, including development of a contaminant transport model, should be conducted to estimate the potential environmental impact of contaminant migrating from the site at specific locations of concern such as site boundaries and monitoring installation. The landfill site would then be designed in such a manner as to mitigate any impacts identified in the environmental impact assessment.

45 Safe landfill management requires the design of a number of systems, the main purposes of which are to control and minimise leachate, runoff and landfill gas evaporation. The main features of a specially engineered landfill include:

Liner systems

After a landfill site has been selected, a system to line the landfill must be chosen. The liner system is the 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. Increasingly, double and sometimes even triple liner systems are being selected with liquid collection systems above, below and between liners. Choosing the liner materials compatible with the wastes to be put in the landfill is important. The estimated service life of a liner in a particular exposure condition is also an important factor in selecting a liner material. A variety of complete systems for landfill liners and leachate removal have been designed to protect the environment surrounding the landfill site. The topic of landfill liner systems and leachate control concepts has been the subject of considerable debate and as yet, no consensus has emerged on what the preferred approach should be in general and/or in specific circumstances.

Leachate control

46 As far as possible, leachate should be avoided. In general, the composition of leachate will be function of the types and ages of wastes deposited, the prevailing physico-chemical conditions, the microbiology and the water balance of the landfill. The main components in the leachate from landfill sites may be grouped into four classes, as follows:

- major elements and ions such as calcium, magnesium, iron, manganese sodium, ammonia, carbonate, sulphate and chloride,
- trace metals such as mercury, chromium, nickel, lead and cadmium,
- a wide variety of organic compounds which are usually measured s Total Organic Carbon (TOC) or Chemical Oxygen Demand (COD); individual organic species such as phenol and chlorinated organic compounds can also be of concern,
- micro-organisms.

All household waste and most industrial waste will give rise to leachate. Leachate monitoring plays a central role in the management of landfills. The long life of a properly operated landfill, during which time significant changes could take place in landfill practices and in the character of the wastes deposited necessitates monitoring to ensure that the measures taken for environmental protection remain effective. Leachate accumulated within a landfill or collected from drainage systems designed to protect surface waters may need to be disposed of to the environment, and treatment may first be needed to reduce its polluting potential (on-site and off-site treatment may be necessary). Leachate is collected in a drainage system, and then exits the landfill. Depending on the nature of the waste and the way the landfill is constructed, the water picks up various contaminants as it passes through the different layers of the landfill. Rainfall, the absorptive capacity of the wastes and the closure cover and capping at the site are critical with regard to the production and control of leachate. A drainage and collection system for leachate must be installed within the landfill that will allow leachate to be pumped to the surface for treatment prior to discharge to water systems. Leachate collected from a problem waste landfill should be examined if it exhibits hazardous characteristics and be treated accordingly.

Landfill gas

47 In the first instance, landfill gas should be avoided as far as practicable as it represents a potential risk to people. In this respect, monitoring of landfill gas is most important in particular for chlorinated hydrocarbons, mercury and arsenic. If the specially engineered landfill contains biodegradable/bioconvertible material, measures are needed to allow for the collection, venting, flaring or use of landfill gases that will be produced. These gas control measures must not impair the integrity of the isolation system. Although landfill gas recovery is seen as one of the end-of-the-pipe solutions to the problem of escaping landfill gas such as methane, trends in a number of countries is to discourage or prohibit the landfilling of organic wastes so that any future methane generation in the sites would be minimal or negligible. It should be noted, however, that landfill gas generation will continue because a large volume of gas will continue to be formed in existing landfills. Landfill gas may contain up to about 60% methane with the balance being about 40% carbon dioxide with other materials present in trace quantities. The rate of landfill gas generation is very dependent on all the circumstances, but modern landfill practice requires that steps are taken to manage this emission to prevent hazards and when viable recover the gas for use as an energy source. Depending on the nature of the gas released, some form of gas treatment may be desirable. Incineration should be employed if the gas is rich in methane and/or volatile hydrocarbons. Other gas treatments involve wet scrubbing if the gas has a significant hydrogen sulphide content or carbon absorption in relatively small amounts of volatile hydrocarbons are present in the gas. Gas samples should be obtained and where possible the source 'fingerprinted' by identification of constituents. By measuring gas quality in cracks in the soil for monitoring known or anticipated vegetation damage cause by landfill gas. Gas migration control systems should include the monitoring of peripheral boreholes for landfill gas concentration; for more details on monitoring see *Appendix B* (extract from the 1986 Waste Management Paper No 26, Landfilling Wastes, from the UK Department of the Environment).

Security management

48 Access to the site should be strictly controlled. The general public should not normally have access to a problem waste landfill site as is sometimes the case with municipal landfills. Both incoming and outgoing traffic should pass through a single control point for manifest verification, sampling and any other regulatory and administrative actions. A suitable buffer zone should be provided around the perimeter of the site, no development should occur near the landfill (apart from buildings on the site). The buffer zone could incorporate berms and/or trees planted to serve as a visual screen and noise barrier. It will also serve as a margin of safety for neighbours in the event of an accidental release of contaminants. The width of the buffer zone and the visual/noise attenuation features to be incorporated into it may vary according to adjacent land use. The security of the site should be maintained by a perimeter fence to keep out unauthorised people as well as itinerant wildlife. The fence should be posted with signs to identify the site and warn trespassers to stay away. A telephone number to contact in case of emergency should be posted in an obvious place.

Closure of the site and long term care

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

- vegetative cover (protection of the covering soil from erosion, maximisation of the evapotranspiration rate and landscape quality maintenance)
- a top substrate (with surface drainage to protect the sealing system from damage, frost, etc.)
- a sealing system to prevent infiltration
- gas and leachate drainage
- a levelling layer (compensating for the irregularities of the waste surface).

Site monitoring

50 Site monitoring will consist of, inter alia, placing monitoring boreholes to permit the selection of landfill gas migration from the waste; wells may be established for monitoring leachate quality and levels; portable explosion-proof methane detectors should be used.

Monitoring is particularly important because it is through long term monitoring, which may continue for many years, that data is gathered to verify the hydrogeologic assessment and permit the final closure of the site. In order to serve as the reference point for subsequent monitoring efforts, the proposers of new sites should conduct a thorough baseline profile for the proposed site and immediate surrounding areas prior to the establishment of the site. The guarantee of long term care, until the site can be finally decommissioned, is a particularly difficult an d complex problem, depending on site conditions this post-closure period could well exceed 100 years. Specific closure procedures should ensure that the long term integrity and security of the site is maintained. The closure programme should be directed towards minimising the need for maintenance of the site after closure. The potential costs for long term maintenance can be considerable and is an important factor to take into account when selecting a landfill concept. Prior to commencing operation, some form of contingency financing, which would also cover costs of remediation, should be provided in the event that the integrity of the landfill is breached and repairs are required either during its active life or following closure. The amount of financing required will depend on the size of the landfill, the types of wastes placed therein and pertinent site-specific factors.

5.5 Operations

51 The successful implementation of a landfill for the disposal of hazardous wastes hinges on strict control over operating and monitoring procedures. Basic elements of a quality control plan include:

- a good definition of responsibilities for the people involved in the planning, authorisation, construction and management of the landfill
- appropriate site working plan
- the qualifications of the workers operating the landfill
- work inspection modalities
- working inspection modalities for construction materials
- documentation demonstrating that the construction works have been carried out under a quality control regime
- the preservation of all the information on the quality control of the construction works
- the documentation of management activities and types of wastes.

A number of essential administrative procedures should be followed, such as procedures for all operations at the landfill site should be included in a comprehensive manual prepared specifically for the facility; a waste materials inventory control and record keeping system should developed and rigorously followed at the site; a comprehensive vehicle and equipment maintenance manual should be prepared and kept for all mobile and stationary equipment on the site. The placement of hazardous wastes in the landfill should follow the requirements set forth in the landfill development plan. This would give due consideration to the preferred landfill concept, cell design including a leachate control system, cell development, capping and closure requirements. Placement of wastes must also give due consideration to the segregation of incompatible materials in order to minimise the risk of dangers such as explosions, fires, and the evolution of toxic gases. An emergency procedures plan for dealing with all realistically foreseeable mishaps at the landfill site which could endanger human health or the environment should be prepared and updated on a regular basis. Examples of such incidents include fires, explosions, accidental spills of contaminants in non-active areas, and the generation of contaminated runoff and/or leachate. Instruction on the emergency procedures plan should be an integral part of the training programme for all employees at the landfill. The inventory of equipment necessary for immediate response to the mishaps outlined in the emergency procedures plan should be kept readily available at the landfill site. Equipment for medium and long term response actions need not be immediately available on site. However, the emergency procedures plan should note specific locations nearby where it can be obtained on short notice. In this regard, the plan should be prepared in consultation with community emergency response authorities in the vicinity of the landfill site. Copies of the plan should be distributed to all nearby agencies such as police and fire departments, provincial and municipal emergency response teams which might be called upon, and local hospitals.

5.6 Landfill costs and costs for containment landfill

Landfill costs *(both high and low costs)*

52 A study done in the United Kingdom on urban and rural municipal waste disposal situation indicated that:

Cost of land ranged between
.... 7 to 51 % of total cost per tonne
Fixed plant ranged between
.... 3 to 10 % of total cost per tonne
Site operation ranged between
.... 18 to 47 % of total cost per tonne

Costs

Post-closure costs ranged between
.... 5 to 42 %
Based on margins .... 4 to 20 %

—with the total costs ranging between £7.50 and £22.50 per tonne, these being seen as set to rise between £9.50 and £38.50 (1 UK£ = US$1.50 approximately).

In the case of the landfilling of hazardous wastes into a proper engineered landfill site, the various costs involved could be much higher.

The cost elements in more detail are:

- cost of land which includes the capital cost of land purchased, leasing costs and land use royalties
- fixed plant costs including site buildings, fencing, access roads and stationary equipment and machinery such as weighbridges
- site operational costs which includes costs relating to the ongoing activity of landfill operations; e.g. labour, engineering, administration costs, etc.
- post-closure costs which includes the actual closure costs in addition to ongoing landfill gas monitoring and leachate control, reinstatement, general site maintenance and aftercare as well as provisions for the future liabilities or insurance premiums in relation to this
- transport costs which include all haulage related costs, both of a capital and revenue nature, as well as costs associated with transfer stations where applicable, and
- margin which is the element of profits from the total price per tonne of landfill waste.
- *Costs of environmental impact assessment can be considerable for specially engineered landfills*.

Significant factors which will influence cost elements

53 • If existing landfill facilities are short-lived, demands for new sites in a region will be higher as will be the operating costs for the remaining input if tighter operating costs are applied and if more post-operational maintenance is required as a consequence of planning and/or licensing or authorisational conditions.

- The ease of development of voids impacts on all identified cost elements except transport. Additional planning requirements or higher closure standards will increase the costs of developing and operating the landfill. It encompasses all aspects of administration for the preparation of landfill sites, i.e. obtaining planning permission and licensing requirements.
- The ease of engineering which is partly linked to the ease of development in that tighter operating requirements will necessitate more expensive or complicated engineering works to ensure compliance with the conditions of site licenses/authorisations.
- The proximity of the disposal site to the point of waste arising which affects the transport cost element, and
- Economics of scale which measures the impact of changes in the overall volume of waste to be disposed of on all cost elements except transport rather than how costs per tonne vary as a function of landfill site size.

Costs for containment landfill

54 Design requirements of a containment system is the most costly form of landfill construction. The principal components being as follows:

Liner

Leachate Collection System (LCS)

Recirculation system (where appropriate)

Landfill Gas Collection System

Cap

Environmental Monitoring System

Long term maintenance of all comfort systems

	Base Area £/m²
Liner purchase; transport, place and compact clay	2.50
2.5mm HDPE, provide and place	6.00
Leachate collection system, herringbone HDPE pipe and drainage, protection blanket	2.50
Gas collection wells (say, 10m deep site)	1.00
Cap purchase; transport, place and compact clay	2.50
	£14.50/m²

55 A recent costing exercise was carried out in the United Kingdom on five rural dilute-and-disperse sites of shallow depth 5–10m and average waste inputs of between 80,000 and 200,000 tonness per annum. Estimates were made of costs to build new cells in each site to a full containment principle and to a specification incorporating a composite liner.

56 In addition, operating costs were increased to take account of a full Environment Protection Act (EPA 1990) Specification, e.g. supervision by a fit and proper person, Quality Assured (QA) site management, full gate control, leachate and gas removal and treatment, roads and security, pest control and comprehensive environmental monitoring. As the sites were of varying depths and had different waste input characteristics, it was found that the increase in total capital and operating costs amounted to £4/t and £7/t. As it now tends to be only the larger sites which can afford the necessary development and infrastructure investment it can be seen that for

depths of between 20–40m, these increased costs would be in the much lower range at £1–£2/t for containment, a very small price to pay on the overall costs of waste disposal.

Lateral containment

57 Gravel extraction operations suggested minimum distance to housing creating void space for waste disposal 150m

Landfill operations suggested minimum distance to housing 250m

Hence in general there would be at least 100m of excavations around the property (and up to 250m in some locations) which would not accept waste for disposal.

6 ELEMENTS TO BE CONSIDERED FOR ENVIRONMENTALLY SOUND MANAGEMENT

58 Within a comprehensive waste management system, it should be possible to reduce to a minimum the problem potential by pre-treatment of the waste finally disposed of in a specially engineered landfill. In relation to using specially engineered landfill, it is important to consider affordable techniques that correspond to the needs and capacity of developing countries and which are environmentally sound; assessment of the environmental soundness of affordable technologies should be a prerequisite.

59 Once site selection, design of the landfill and the operative measures have been agreed upon, the fundamental question of deciding which wastes are acceptable for disposal in the hazardous waste landfill remains to be answered. Although site selection and design have taken due consideration of the types of wastes that would be disposed of at the site, rationale for determining acceptability needs to be carefully thought of.

60 Some useful data which may be helpful in establishing appropriate loading (input) rates can be found in the European Commission (EC) amended proposal for a Directive on the Landfill of Wastes COM (93) 275, see *Appendix C*. In this there are figures based on the use of a leachate test to assess whether wastes are hazardous or non-hazardous, the latter being disposable into a wider range of disposal sites. The analytical procedures proposed are based on ISO or DIN tests; other methods are however considered more appropriate in many circumstances and this is recognised. Where hazardous (problem) wastes are to be jointly disposed of in a beneficially interactive mode with municipal waste, a different approach is allowed for. This is based on allowable inputs per ton of municipal waste subjected to a number of qualifications. In addition, limit values given in respect of heavy metals and in some cases organic compounds in soil and sewage sludge in the EC Directive on the Use of Sewage Sludge in Agriculture (Directive 86/278/EEC) may also be found helpful. See *Appendix D*.

61 On the basis of past experience the following substances should as far as possible be prevented from entering the water system:

1 Organohalogen compounds and substances which may form such compounds in the aquatic environment.

2 Organophosphorous compounds.

3 Organotin compounds.

4 Substances which possess carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment.

5 Mercury and its compounds.

6 Cadmium and its compounds.

7 Mineral oils and hydrocarbons.

8 Cyanides.

62 It would be important to limit the deposit of a number of substances which represent a threat to human health and the environment and are susceptible of causing serious pollution of all environmental media, such as:

1 Metalloids, metals and their compounds: zinc, copper, tin, barium, nickel, beryllium, chrome, boron, lead, uranium, selenium, vanadium, arsenic, cobalt, antimony, thallium, molybdenum, tellerium, titanium, silver, biocides and their derivatives

2 Biocides and their derivatives

3 Substances which have a deleterious effect on the taste and/or odour of groundwater, and compounds liable to cause the formation of

such substances in such water and to render it unfit for human consumption

4 Inorganic compounds of phosphorous and elemental phosphorous

5 Fluorides

6 Ammonia and nitrates/nitrites.

It should be noted that *ammonia* represents a particularly serious and growing threat in terms of water quality and pollution.

7 TECHNICAL COOPERATION

63 Even the countries with years of experience in the disposal of hazardous wastes in specially engineered landfill are faced with great difficulties in ensuring sound and efficient disposal of such wastes.

Cooperation among countries is seen as an essential element to aim at the environmentally sound management of landfills. Training and exchange/sharing of experience, and in particular providing technical and financial assistance to developing countries are considered as an important part of the immediate and more long term measures to take.

64 Chapter 20 of UNCED Agenda 21 recommends that states through bilateral and multilateral cooperation, including through the United Nations and other relevant international organisations, should:

a Identify, develop and harmonise methodologies and environmental quality and health guidelines for safe waste discharge and disposal.

b Review and keep abreast of developments and disseminate information on the effectiveness of techniques and approaches to safe waste disposal and ways of supporting their application in countries.

8 CONCLUSION

65 It can be seen from the foregoing material that the setting up, operating and closing of any landfill requires a highly professional approach. This is even more the case for specially engineered landfills where up to 36 scientific and technological disciplines may need to be accessed in pursuit of an optimal environmentally sound overall operation.

66 The essential core disciplines are seen as geology, hydrogeology, civil and mechanical engineering, chemistry and biochemistry, and because active deposits are by way of being macro reactors chemical and biochemical engineering are also involved. It is this macro aspect which makes the application of an efficient unit operational process to landfill difficult and as a consequence of this is promoting an increasing degree of pre- and post-deposit treatment to render materials to be deposited environmentally inert or to optimise the in-situ stabilisation process.

GLOSSARY

Aerobic decomposition	Occurs in moist conditions in the presence of, i.e., oxygen (produces strong leachate and no gas).
Anaerobic decomposition	Occurs in moist conditions in the absence of i.e. oxygen (produces landfill gas and weak leachate).
Attenuation	Gradual reduction in concentrations of contaminants in leachate, due to physical, chemical and biological activities as it passes through soil and various subsoils.
Biodegradable	Organic material which can be broken down chemically by biological action.
Cap	A layer of clay or other material to prevent ingress of rainwater.
Clay layer	A layer of clay applied to the base of walls of a site to prevent leachate or gas migration. Also applied to surface: see *Cap*.
Cover material	Any inert material used to cover waste during landfill; usually applied towards the end of the working day.
Containment site	One where the bottom and sides are or have been made impermeable to liquids using natural elements or synthetic liner.
Groundwater	Water occurring naturally, below the surface.
Hazardous wastes	Those wastes which are listed in Annex I to the Basel Convention and exhibit one or more of the hazardous characteristics specified in Annex III to the Convention.
Heavy metals	Usually refers to lead, zinc, cadmium, copper.
Hydrogeology	The study of groundwater movement, chemistry, etc.
Lagooning	A technique for settling out fine solids by forming a settling pond with a long residence time, usually days or weeks.
Landfill gas	Generated under anaerobic conditions and is a mixture of methane (CH^4) and carbon dioxide (CO^2), approximately 60:40 by volume.
Leachate	Liquid drainage from a landfill site containing dissolved solids and products of decomposition of organic matter.
Leachate recycling	Pumping of leachate from a collecting sump back over the surface of the waste and letting it run into the waste in order to accelerate decomposition of both the waste and of organic compounds in the leachate.
Municipal waste	Wastes collected by municipalities or by their order, including wastes from households (not household hazardous waste) and similar wastes from commercial activities, office buildings, institutions and industry that dispose of waste at municipal facilities.
Stabilisation	Achieved when all organics have decomposed.

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APPENDIX A Siting characteristics and landfill site selection criteria

Selection of siting characteristics prepared by ISWA Series 1991 No.1 *Safe Hazardous Waste Management: a state-of-the-art guide for decisions makers*. ISWA Working Group on Hazardous Wastes.

Siting characteristics

In selecting a site for the construction of a hazardous waste landfill, several geographical and hydrogeological factors of the location must be considered. These factors will have a significant bearing on the level of environmental protection provided by the landfill. Geographical and hydrogeological 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 preparedness plan in the event of a gas leak or other accident.

Hydrogeological characteristics

All drinkable 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 water aquifer that could be contaminated.

The surface hydrology of an area should also be considered, so as to avoid areas prone to flooding or susceptible to erosion. At a minimum, 100 years of return time of frequency is recommended for flooding.

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 metres above the maximum water table increase.

Geographical characteristics

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

Landfill site selection criteria

Engineering

Geophysical site (geographical criteria): Should be large enough to accommodate waste for life of production of facility.

Proximity: Locate as close as possible to production or treatment facility to minimise handling and reduce transport cost. Locate away from water supply (suggested minimum 500 feet) and property line (suggested minimum 200 feet; more for landfill gas).

Access: Should be all-weather, have adequate width and loan capacity, with minimum traffic congestion; one-way system on site whenever possible.

Topography: Should minimise earth-moving; take advantage of natural conditions. Avoid natural depression and valleys where water contamination is likely.

Geology: Avoid areas with earthquakes, slides, faults, underlying mines, sinkholes, and solution cavities.

Soils: Should have natural clay liner or clay available for liner, and final cover material available.

Environmental

Surface water: Locate outside 100-year floodplain. No direct contact with navigable water. Avoid wetlands.

Groundwater: No contact with groundwater. Base of fill must be above high groundwater table. Avoid sole-source aquifer. Avoid areas of groundwater recharge.

Air: Locate to minimise fugitive emissions and odour impacts.

Terrestrial and aquatic ecology: Avoid unique habitat area (important to propagation of rare and endangered species) and wetlands.

Noise: Minimise truck traffic and equipment operation noise.

Land use: Avoid populated areas and areas of conflicting land use such as parks and scenic areas.

Cultural resources: Avoid areas of unique archaeological, historical and paleontological interest.

Legal/regulatory: Consider national, regional and local requirements for permits.

Public/political: Gain local acceptance from elected officials and local interest groups.

Economic

Property acquisition: Actual land plus related costs.

Site development: Excavation, grading, liner, new roads, and other development costs.

Annual costs: Fuel costs, operating labour, maintenance, land preparation, utilities, and overheads.

Salvage value: Do not consider—site will probably not be an asset.

Conflicts with the objective of setting up and operating towards a stable system, particularly in respect of organic matter and in some cases heavy metals (comment seen as relevant to mono deposit with long term storage prospects).

APPENDIX B Monitoring

At all sites where permeable strata surround the waste, a series of appropriately spaced monitoring boreholes should be provided to permit the detection of landfill gas migration from the waste. At new sites such boreholes should be installed prior to waste deposition, to allow background concentrations to be measured, and to warn of the onset of gas migration. Measuring gas concentrations in such systems should be undertaken with care as the volumes of gas present may be small. Air intrusion through the borehole too should be avoided by limiting the rates of gas withdrawal to the measuring instrument. Gas may be migrating at discrete horizons in the strata and localised depth sampling techniques may be required. The effects of changes in atmospheric pressure or water table levels may be important; such changes may cause fluctuations in the rate of gas migration from the site which may not be immediately detected at the monitoring point. Both oxygen and methane concentrations should be measured using portable apparatus with occasional more detailed analyses to confirm the data.

The water authority and the disposal authority may require at least one well to be installed in the waste for monitoring leachate quality and levels. These wells might subsequently be used for leachate abstraction. In many cases such monitoring points consist of large concrete rings with perforations over at least the lower portion of the chamber. Because of the problems of gas escaping from these chambers it is recommended that the cover and upper sections be sealed to prevent localised high concentrations of gas escaping from the well. If these chambers are also used to monitor gas quality and quantities they should be fitted with a suitable, valved, monitoring point. Recent experience of the use of concrete rings for monitoring wells has shown that they may be attacked by leachate. For gas monitoring purposes it is preferable to install a proper well within the waste after final restoration levels have been reached which may also be used for gas abstraction. Suitable safety precautions should be taken when sinking wells into waste. Such wells should contain a central perforated tube the diameter of which should not exceed 0.15m, thus not permitting personnel entry, and should be sealed at the surface and provided with a valve. Such wells would enable leachate monitoring to be carried out. Well design should take into account the possibility of settlement and lateral movement of the waste.

When monitoring, care should be taken to use suitable instruments such as 'non-flame' detectors. Staff taking readings must avoid direct contact with gas plumes at these monitoring points and observe the various safety precautions described above.

Where it is suspected that gas migration may be causing problems in buildings, service ducts etc., or posing a risk of nuisance or damage to vegetation, the monitoring procedures described in the following paragraphs should be adopted *(these procedures are summarised in Figure 1; see paragraph 3.1 of source document).*

The concentrations of gas within enclosed spaces should be ascertained initially by using portable explosion-proof methane detectors, before more sensitive detectors, perhaps incorporating flame ionisation techniques, are used. Sources of gas intrusion into, or build-up within, buildings include points where services enter or leave the building, cavity walls and normally enclosed spaces such as cupboards. Various external monitoring points may include drains, ducts, electrical and telephone service points. Gas concentrations at such locations can fluctuate from time to time due to variations in climatic conditions, gas generation rates and other factors. Therefore, complete reliance should not be placed on a single set of recorded data from one monitoring exercise. This also applies to the monitoring of gas in boreholes or wells within or near the site as described below.

One further complication is identification of the source of gas. In some circumstances methane gas may be from fossil fuel sources such as coal mines or natural gas. Gas samples should be obtained and where possible the source 'fingerprinted' by identification of constituents. *Examples of typical gas compositions where the gases are derived from sources other than a landfill are shown in Appendix VIII of source document.*

Monitoring with respect to known or anticipated vegetation damage caused by landfill gas can sometimes be carried out by measuring gas quality in cracks in the soil, but more commonly the installation of probes extending into the plant root zone and the extraction of gas from such probes is necessary.

If gas migration is suspected but has not been positively confirmed sufficient boreholes must be installed, extending to the full depth of the waste and in the strata surrounding the site, to identify the extent of any unacceptable gas concentrations. This might require boreholes at close spacings and/or at increasing distances from the landfill boundary, especially if the strata are particularly non-uniform in composition and perhaps are fissured.

Useful data can be obtained from wells installed within sites, which may help in the interpretation of the behaviour of a site with respect to gas generation. Such data include: gas composition and rates of evolution; gas pressure and temperature; the temperatures and composition of leachate if present in the drilled well. Chemical and microbiological analysis of the waste material extracted during drilling may be useful in determining the status of gas production. Monitoring during field testing will include gas composition, temperature and rates of abstraction.

Gas migration control systems should include the monitoring of peripheral boreholes for landfill gas concentration. Odour identification can also be carried out if necessary and the atmosphere may be monitored to determine ambient air concentrations after the gas has been collected and flared.

Monitoring of installed gas control or utilisation schemes will form part of the operation of the plant and equipment. However, it should be realised that each well or trench will not only have individual characteristics, but that rates of gas abstraction will vary with time as the decomposition of landfilled waste proceeds. Thus, some resetting of well head conditions (flow/pressure) using the installed valve controls will be inevitable.

If property had been affected by landfill gas, prior to any control measures becoming operational, continued monitoring on a regular basis is essential to confirm that the remedial measures taken continue to be effective.

Source: Waste Management Paper No.26, *Landfilling Wastes*, UK Dept. Environment, 1986.

APPENDIX C Loading rates

For hazardous wastes to be jointly disposed with municipal waste, their rate of deposition will be limited by the attenuation capacity of the accepting bulk of municipal waste. Although general guidelines can be given, the loading inevitably will be site specific. Effective monitoring of the conditions in the landfill provide the best guidance for setting appropriate loading rates.

Loading rates are normally quoted as a quantity of hazardous waste which may be deposited either in a given period (e.g. as per m^3 of municipal waste per day), or related with a given quantity of the accepting bulk (e.g. as g per m^3 of municipal waste) for a once-only base filling. This is the loading or rate which could be degraded or attenuated by a unit volume ([3]) of methanogenic refuse. The landfill loading potential should then be applied to the reaction zone volume to derive a total loading limit for one site.

The loading rate controls shall apply to wastes containing: acids, heavy metals, cyanides, soluble organic carbon, phenols and other prescribed organic compounds. Ammonia and chloride inputs shall also be assessed, on the basis that all of the applied loading will appear in the leachate. Applied loadings must not lead to the capacity of leachate treatment and disposal systems being exceeded.

Default values (as mentioned in the criteria values given hereunder) are to be applied for the calculation of the maximum landfill loading potential, unless site/waste-specific data submitted by the operator justify higher loadings.

Criteria for calculating landfill potentials

Waste component	Default value
Acids [1]	100 equiv./tonne of municipal waste
Heavy metals [2][3]	100g/tonne of municipal waste
Zn	100g/tonne of municipal waste
Cu	100g/tonne of municipal waste
Ni	100g/tonne of municipal waste
Cr	100g/tonne of municipal waste
Pb	100g/tonne of municipal waste
Cd	10g/tonne of municipal waste
Hg	2g/tonne of municipal waste
As, Se	1g/tonne of municipal waste
Cyanide (as CN)	1g/m^3 of municipal waste per day [3]
Phenol	5g/m^3 of municipal waste per day [4]
**/Hydrocarbons	2.5kg/tonne of municipal waste
TOC	10g/m^3 of municipal waste per day [5]
Specified organics [6]	10g/m^3 of municipal waste per day

Source: EC Amended Proposal for a Directive on Landfill Waste, COM (93) 275.

1 Loadings to be calculated on a once-only basis, unless site monitoring in reaction zone demonstrates regeneration of buffer capacity. Acids shall be deposited in a separate area from wastes containing cyanide or sulphide.

2 Loadings to be calculated on a once-only basis. A prior precipitation test shall be applied to any wastes containing >100mg/l soluble heavy metals. This should consist of a pH adjustment to 10.5, mixing for five minutes, followed by settlement for 30 minutes. If the soluble metal content then exceeds 20mg/l, the waste shall not be jointly disposed unless the operator can provide practical evidence to show its attenuation in refuse.

3 The maximum defalut value for the total of heavy metals shall not surpass the 100 grammes of municipal waste.

4 Organic compounds of List 1 from the Directive 10/63/EEC on groundwater.

5 Unless site/waste-specific data on particular wastes show them to be completely degraded. No waste containing >mg/l as coluble CN shall be jointly disposed.

6 Unless site monitoring shows the reaction zone ability to degrade completely the phenols.

7 Unless specific data on particular wastes show them to be highly degradable.

The table below fixes the ranges by which wastes will be characterised for the purpose of landfilling according to the composition of their eluates.

- wastes whose eluate concentration is not above the maximum values fixed for inert wastes will be considered as such,
- wastes whose eluate concentration falls in the range between inert wastes and the minimum value for hazardous wastes will be considered non-hazardous.

		Hazardous waste range	Inert waste
1.01	pH value	4–13	4–13
1.02	TOC	40–200mg/l	<200mg/l
1.03	arsenic	0.2–1.0mg/l	<0.1mg/l
1.04	lead	0.4–2.0mg/l	}
1.05	cadmium	0.1–0.5mg/l	}
1.06	chromium	0.1–0.5mg/l	} *the total of*
1.07	copper	2–10mg/l	} *these metals:*
1.08	nickel	0.4–2.0mg/l	} <5mh/l [1]
1.09	mercury	0.02–0.1mg/l	}
1.10	zinc	2–10mg/l	}
1.11	phenols	20–100mg/l	<10mg/l
1.12	fluoride	10–50mg/l	<5mg/l
1.13	ammonium	0.2–1.0mg/l	<50mg/l
1.14	chloride	1.2–6.0g/l	<0.5g/l
1.15	cyanide [2]	0.2–1.0mg/l	<0.1mg/l
1.16	sulphate [3]	0.2–1.0g/l	<1.0g/l
1.17	nitrite	6–30mg/l	<3mg/l
1.18	AOX [4]	0.6–3.0mg/l	<0.3mg/l
1.19	solvents [5]	0.02–0.10mg Cl/l	<10µg Cl/l
1.20	pesticides [5]	1–5µg Cl/l	<0.5µg Cl/l
1.21	lipoph.sub.	0.4–2.0mg/l	<1mg/l

Notes:

1 For characterisation purposes the components to be analysed in the eluates shall be chosen in function of the qualitative composition of the waste.

2 In addition to these eluate criteria, a determination of asbestos on a representative sample of the crude inert waste shall be performed, according to the annexes of the Council Directive 87/217/EEC on the prevention and reduction of environmental pollution by asbestos.

Source: EC Amended Proposal for a Directive on Landfill Waste, COM (93) 275.

1 And no single value above the minimum fixed for hazardous waste.

2 Readily released.

3 If possible <500mg/l.

4 Adsorbed organically-bound halogens.

5 Chlorinated.

APPENDIX D Limit values for concentrations of heavy metals in soil

Limit values for concentrations of heavy metals in soil

(mg/kg of dry matter in a representative sample, as defined in Annex II C, of soil with a pH of 6 to 7)

Parameters	Limit values
Cadmium	1 to 3
Copper	50 to 140
Nickel	30 to 75
Lead	50 to 300
Zinc	150 to 300
Mercury	1 to 1.5
Chromium	—

Limit values for heavy metal concentrations in sludge for use in agriculture

(mg/kg of dry matter)

Parameters	Limit values
Cadmium	20 to 40
Copper	1 000 to 1 750
Nickel	300 to 400
Lead	750 to 1 200
Zinc	2 500 to 4 000
Mercury	16 to 25
Chromium [1]	—

Limit values for amounts of heavy metals which may be added annually to agricultural land, based on a 10-year average

(kg/ha/yr)

Parameters	Limit values
Cadmium	0.15
Copper	1.2
Nickel	3
Lead	1.5
Zinc	30
Mercury	0.1
Chromium	—

[1] It is not possible at this stage to fix limit values for chromium. The Council will fix these limit values later on the basis of proposals to be submitted by the Commission within one year following notification of this Directive.

Source: EC Directive on the Use of Sewage Sludge in Agriculture (86/278/EEC).

ANNEX IV

UNEP

Example of Operational Procedures for a Sanitary Landfill accepting Hazardous Industrial Wastes

Please read Author's Note before studying this example

Author's Note

The operational procedures here are from an existing landfill in Johannesburg, Republic of South Africa. The region does not so far have special facilities for the treatment and disposal of hazardous industrial waste. The operational procedures described here are interim measures to improve environmental safety by utilising an existing, well-managed domestic landfill for controlled co-disposal of industrial waste.

The purpose of this example is to demonstrate the high level of management control of a site and of the incoming wastes that is needed if co-disposal methods are used, even on an interim basis.

The Republic of South Africa is currently (1993/94) putting in place a comprehensive industrial waste management strategy which emphasises waste avoidance and minimisation as well as the use of specially designed industrial waste facilities. When this strategy is fully implemented the use of co-disposal methods will be discontinued.

Further details are available from the Department of Environmental Affairs, Private Bag X447, Pretoria, RSA

Operational Procedures *for the* Class I Disposal Facility *at* Margolis

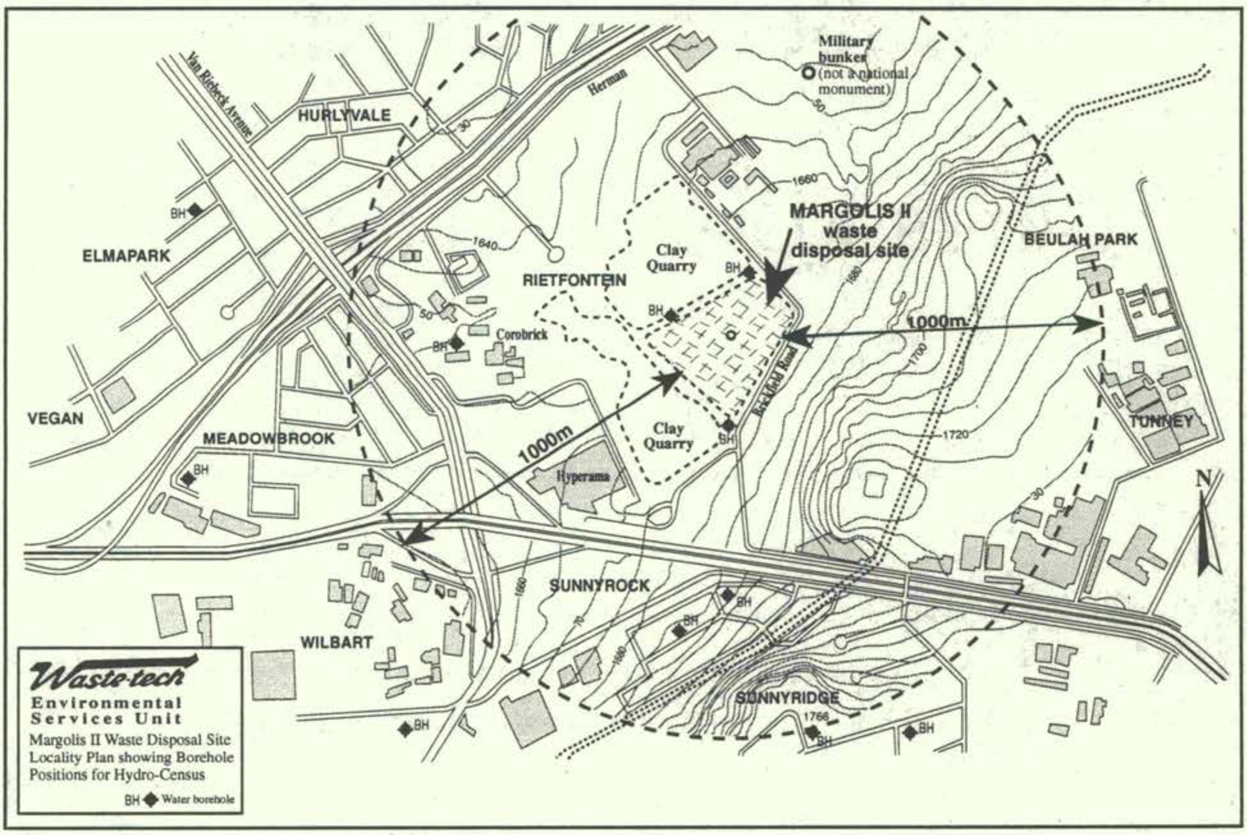
Please note that this document has been compiled using the following documents as reference—

1 **The proposed minimum requirements document**

2 **Consent use conditions set by the Germiston Municipality.**

CONTENTS

Margolis Sanitary Landfill at Johannesburg



1 PRINCIPLES OF OPERATION

1.1 Non-hazardous waste

Dry domestic waste is being disposed and compacted immediately to minimise any pollution or nuisances. The waste is compacted into a cell and covered daily.

Solids which include papers, plastic and garden refuse acts as an absorbent for any liquid waste received on site. Selected builder's rubble received on site is used as an intermediate cover or for the construction of berms.

1.2 Hazardous waste

1.2.1 Solids and sludges

Solids and sludges are treated and disposed of as per requirements set out in *Appendix A*. The sludges are co-disposed with dry domestic waste which will act as an absorbent.

1.2.4 Liquids

Liquids are treated and disposed of as per the requirements set out in *Appendix A*. The volume of liquid waste accepted on site is determined by the volume of dry domestic waste on site. The aim is to maintain a ratio of one part liquid to 10 parts dry waste.

1.3 Equipment

The following equipment is utilised on site as and when required.

Note: adequate equipment is available on site to handle the waste streams at all times.

1.3.1 Wheel loader (bucket loader)

A wheel loader is used on site for:

i. treatment and blending of waste

ii. loading of soil

iii. loading of chemicals

iv. trenching

v. covering when required.

1.3.2 Tipper trucks

A tipper is used on site to move cover material and ash when required.

1.3.3 Graders

A grader is used on site to maintain on-site roads when required.

1.3.4 Compactor

A landfill compactor is permanently on site to ensure adequate compaction densities.

1.4 Compaction of waste

All waste is disposed of in a controlled manner and compacted into layers of ± 300mm thick to an optimal density. Compaction is done—

i. to minimise rainwater infiltration

ii. to prevent spontaneous combustion

iii. to avoid breeding of insects

iv. to minimise wind scatter.

The co-disposal of liquids takes place into trenches in front of the working face and solid waste is compacted into these trenches as an absorbent. The cell size is determined by the volumes of waste handled per day; estimated cell size at (18mx16mx1.8m).

1.5 Cover

1.5.1 Daily cover

- The working face is covered daily to minimise the above mentioned nuisances (refer 1.4).
- Cover is spread to a minimum thickness of 150mm.
- Suitable builders' rubble from contractors is utilised as cover.
- Stockpiles of cover is maintained if possible.

1.5.2 Final cover

Final cover will be placed on areas where final contours have been reached. The site will be capped with a minimum of one metre of cover consisting of:

- 600mm of a clayey, silty sand with an approximate permeability of 10^{-4} cm per second.
- 400mm of a suitable growing medium.

1.6 Drainage

1.6.1 Surface

A system is being maintained on site where all adjacent storm or rain water is diverted around the site (clean water drainage), while all water from the waste is treated as contaminated water and contained in a dam on site.

The construction of cells minimise ponding and contaminated water is directed away from the working face and into the containment drum. Refer to drawing 5381/5.

Leachate generated is handled together with the contaminated rain water.

1.6.2 Management of contaminated runoff water

Any contaminated water runoff is collected in a containment dam on site. This water will either be:

i. evaporated,

ii. used for dust control on site,

iii. treated and disposed of to sewer.

Refer to drawing no 5381/3.

1.7 Closure and rehabilitation

The daily operation of the site is planned to provide for closure and rehabilitation as soon as final contours have been reached. Outside berms will be grassed and selected trees and shrubs will be planted to minimise any infiltration of water as soon as possible.

Refer to drawing no 5381/6 and drawing no 5381/7 for the final contours and landscaping plan.

2 SITE PREPARATION

2.1 Staff

2.1.1 On site

The staff on site is as follows:

- Landfill Supervisor
- Assistant Landfill Supervisor
- Compactor Operator
- FEL Operator
- Tipper Driver
- Gate Clerks
- General Workers.

2.1.2 Off site

The off-site staff are assisted by the following staff:

- Landfill Manager
- Technical Manager
- Environmental Services Manager
- Laboratory Supervisor
- Head Office Technical Personnel.

2.2 Access road and on-site roads

The access road and on-site roads are maintained in a suitable manner to accommodate all types of vehicles normally expected to use the facility.

2.3 Security (including fencing and signs)

2.3.1 Signs

Signs in the official languages are erected advising on:

- route to the site,
- hazard warning,
- contact details of the responsible person,
- operational hours.

2.3.2 Fencing

The entire site is fenced off with a gate of the same height at the entrance, to prevent unauthorised entry and the control of wind-scatter.

2.3.3 Security

Twenty-four hour security is maintained on the site.

2.4 Site facilities

The following facilities are available on site:

2.4.1 Security office,

2.4.2 Site offices (including ablution facilities);

2.4.3 Store for chemicals,

2.4.4 Washbay.

2.5 Main laboratory

The main laboratory is equipped to analyse for the following:

- flammability
- flashpoint and ash-blending ratios
- pH
- lime equivalents
- constituent spot tests (arsenic, chromium, heavy metals, cyanide, sulphides etc.)
- analyses of leachate
- initial comprehensive analyses for waste samples
- gas analyses of the site perimeter.

The laboratory is supervised by the laboratory supervisor (BSc.Hons.) supported by the Technical Director.

2.6 Safety and emergency procedures

2.6.1

Procedures are in place in the event of a spillage or emergency. Spillage procedures are determined by the nature of the waste.

2.6.2

The required safety equipment is available on site which includes the standard acid-proof overalls, gloves, boots, goggles and dustmasks. Additional safety equipment is specified by the laboratory for specific events. Full face masks and respirators with combination filters are available on site for these events.

3 WASTE MANAGEMENT

3.1 Waste screening and control

3.1.1 FROT code

Please refer to Appendix II for a copy of the FROT code which is used by our laboratory to classify all hazardous waste loads. According to the classification the load is given a specific disposal instruction. The International Maritime Dangerous Goods Code (IMDG) is used together with the FROT code.

New developments in the classification of hazardous waste for the Republic of South Africa will soon be implemented.

3.1.2 Laboratory procedures/control of hazardous waste

i. A datasheet together with the sample is submitted to the laboratory.

ii. Samples are analysed by the Laboratory Technician.

iii. The Laboratory Supervisor issues disposal instructions and compiles a tremcard, determined by the results.

iv. The Control Authorisation Sheets (CAS) are issued by the Laboratory with disposal instructions for all the daily hazardous waste loads received on site. Only loads authorised on the CAS will be allowed to be disposed on site.

v. Daily samples of all hazardous loads are checked by the Laboratory and irregular samples are followed up with the Sales Representative and Customer.

vi. Refer to Appendix III for a flow diagram of the above mentioned.

vii. Refer to Appendix IV for the procedures used by the Laboratory.

viii. Refer to Appendix V for a summary of the Waste Manifest System.

3.1.3 Classes of acceptable waste

Refer to Appendix VI for this list.

3.1.5 Classes of unacceptable waste

Refer to Appendix VII for this list.

3.2 Pre-treatment methods

3.2.1 Incineration of medical waste

All medical waste received is incinerated by the medical waste incinerator. In the event of a breakdown, these boxes are landfilled under supervision with lime.

Refer to Appendix VIII for the specifications of the incinerator. The ash removed from the incinerator is disposed on site together with domestic waste. A study was done on the stack emissions from the incinerator and please refer to Appendix IX for this report done by the AEC.

3.2.2 Inorganic treatment plant

All inorganic liquid waste, e.g. acids, are pre-treated at the Rietfontein Inorganic Treatment Plant (ITP).

3.2.2.1: Neutralisation of acids Liquid acids are neutralised and precipitated by adding a lime slurry to the acid and raising the pH to 8–9 for the heavy metals to be precipitated out.

3.2.2.2: Reduction of chrome (VI) Chrome (VI) is reduced to chrome (III) with ferrous sulphate. Ferrous sulphate is added to the chrome solution in a low pH medium and once the chrome has been reduced to <30ppm, the solution is neutralised with a lime slurry to precipitate the chrome (III).

3.2.2.3: Disposal of effluent The effluent water and filtercake from the ITP is disposed of on site. All these processes are closely monitored by the laboratory.

3.3 Disposal methods

Please refer to Appendix X for a detailed description of all the disposal procedures used on site.

3.4 Landfill records

3.4.1 Landfill books

These records are kept on site at the gate by the gate clerks of all waste entering the site. This information is used by the Landfill Supervisor to calculate daily and monthly statistics regarding volumes, waste types and sources.

3.4.2 Daily laboratory reports

These reports are compiled by the Landfill Supervisor and is a complete list of the type and volumes of hazardous waste received on site per day. These records are kept on site and by the laboratory. The laboratory supervisor uses these records to monitor the site's management of hazardous waste.

3.4.3 Daily laboratory analyses

Each load of hazardous waste which arrives on site is sampled and checked by the gate clerk prior to disposal to ensure that the correct disposal procedure is followed. No unknown or unauthorised loads are accepted on site. All records of analyses done are available in the laboratory.

3.4.4 Complaints

All complaints are reported to the Landfill Manager/Supervisor and recorded in the complaint book. Complaints are followed up with the complainant and the local authority.

3.4.5 Weather conditions

A small weather station has been installed on site to record daily weather conditions. These results can be verified if necessary with the weather station at Jan Smuts. Conditions monitored include:

- rainfall
- windspeed and direction
- humidity
- temperature.

4 CONTROL, MONITORING AND AUDITING

4.1 Control

4.1.1 Scavengers and squatters

No scavenging or unauthorised entry is permitted on site.

4.1.2 Litter control

The litter is contained on site and picked up on a regular basis.

4.1.3 Dust control

The site is watered on a regular basis to control the dust. Where final levels have been reached, areas will be grassed to control excess dust on site.

4.1.4 Pest control

Appropriate measures are taken to eliminate any flies, rats, etc.

4.1.5 Odour control

The site is covered daily as specified in point 1.5.1 and loads with potential smell problems are treated in such a manner to minimise an odour problem.

4.1.6 Noise control

Site equipment conforms with the by-laws of the local authority concerning noise levels and operational hours.

4.1.7 Fires

No burning of any sort is permitted on site and emergency procedures are in place to be implemented in the event of a fire.

4.2 Monitoring

4.2.1 Surface water

Clean surface water is directed around the site and contaminated surface water is contained in a dam and then treated and disposed of to either the sewer or used on site.

The contaminated water is monitored by the main Laboratory and treated as required.

4.2.2 Groundwater

4.2.2.1: For details of the boreholes refer to the geohydrological report.

4.2.2.2: Refer to Appendix XIII for a borehole location map.

4.2.2.3: Analyses of the borehole water is submitted to the Department of Water Affairs and Forestry on a three-monthly basis.

4.2.2.4: Monitoring during operation Three-monthly sampling with full analyses is being done on all boreholes. Currently the samples are bailed but the pumping of the boreholes is being addressed.

4.2.2.5: Post-monitoring Ongoing monitoring is done as required by the Department of Water Affairs and Forestry.

4.2.3 Landfill gas monitoring

The generation of landfill gas is closely monitored. If the site conditions encourage the generation of landfill gas, appropriate control systems will be installed.

4.3 Auditing

4.3.1 Formal

The site is formally audited on a six-monthly basis by the Environmental Protection Manager together with the Landfill Manager, Technical Manager and Landfill Supervisor.

4.3.2 Informal

Informal daily checks are done by the Technical Manager and as required the Environmental Services Manager does an informal audit check.

APPENDIX A Waste acceptance criteria

Types of waste which require special handling or pre-treatment before disposal on a Class I site

1 Asbestos waste must be packed in special plastic bags in accordance with the asbestos regulations No. R773 in the Government Gazette No. 10700, dated April 1987.

2 Wastes that will be accepted for fixation with pulverised fuel ash or boiler ash according to technology approved of by the Department of Water Affairs and Forestry:

- Bituminous wastes
- Oil sludges which do not contain lead
- PVA and oil paint sludges
- Adhesives
- Vegetable oil wastes
- Hydrocarbon solvents
- Organic resins
- Phenolic sludges
- Fats, waxes and greases.

3 Wastes which shall be encapsulated in concrete in accordance with the standards of the Department of Water Affairs and Forestry.

- PCBs (oils from transformers or capacitor spills), dioxins and all PCB and dioxin derivatives.
- Organohalides including organohalide pesticides.
- The soluble salts of mercury, arsenic, cadmium, antimony, lanthanum and actinium.

4 Wastes which shall be encapsulated or require special treatment (written approval to be obtained from the Department of Water Affairs and Forestry):

- Organolead sludges originating from leaded petrol storage tanks, oil recycling and solvent recovery processes in the paint industry; organochorine pesticides.

5 Waste for which the pH of the waste or the pH of a 1:1 w/w extract with water are below pH 6 or above pH 12.

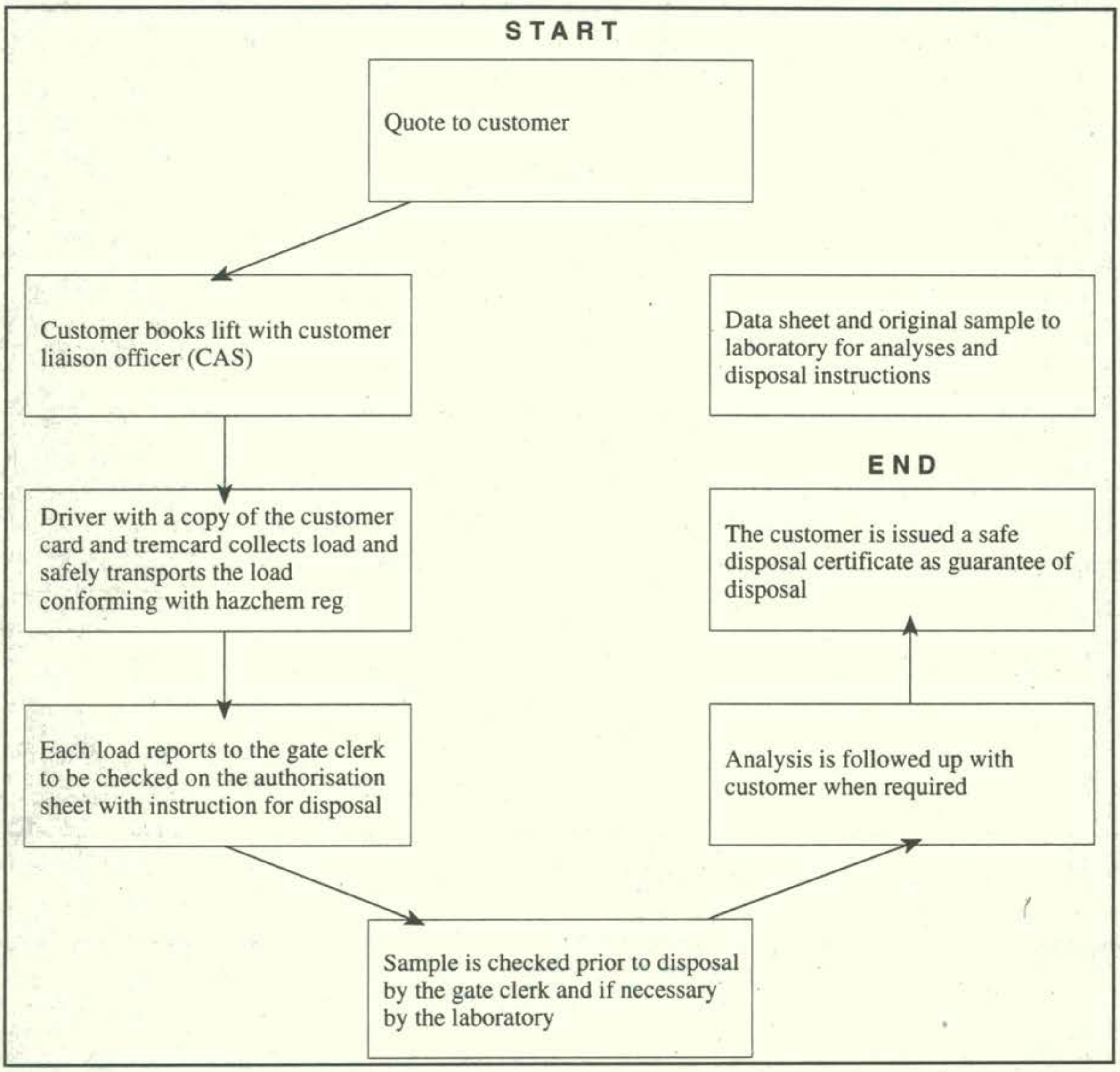
6 Waste with a free cyanide concentration greater than $0.4 mg l^{-1}$.

7 Waste with a free sulphide concentration of more than $10 mg l^{-1}$.

8 Waste with a free Chrome (VI) content of more than 30ppm.

9 Waste which contains highly reactive redox compounds.

APPENDIX B Hazardous waste site management procedure



APPENDIX C Classes of acceptable waste

A list of hazardous or toxic materials which may only be disposed of onto a Class I disposal site

- Acids and alkalis
- Antimony and antimony compounds
- Arsenic compounds
- Barium compounds
- Beryllium and beryllium compounds
- Biocides and phytopharmaceutical compounds
- Boron compounds
- Cadmium and cadmium compounds
- Chromium compounds
- Copper compounds
- Heterocyclic organic compounds containing oxygen, nitrogen or sulphur
- Hydrocarbons and their oxygen, nitrogen and sulphur compounds
- Inorganic cyanides
- Inorganic halogen-containing compounds
- Inorganic sulphur-containing compounds
- Laboratory chemicals
- Lead compounds
- Medical waste (tissues, blood, swabs, needles etc.)
- Mercury compounds
- Nickel and nickel compounds
- Organic halogen compounds, excluding inert polymeric materials
- Paints and paint sludges
- Peroxides, chlorates, percholorates and azides
- Pesticides and insecticides
- Pharmaceutical and veterinary compounds
- Phosphorous and phosphorous compounds
- Selenium and selenium compounds
- Silver compounds
- Tarry materials from refining and tar residues from distilling, including petroleum products
- Tellurium and tellurium compounds
- Thallium and thallium compounds
- Vanadium compounds
- Zinc compounds

APPENDIX D Classes of unacceptable waste on a Class I disposal site

1 All materials which fall in Class I (explosives), Class II (compressed gases), and Class VII (radioactive materials) of the IMDG classification are prohibited.

2 Wastes for which the pH of the waste or the pH of 1:1 w/w extract with water are below pH6 or above pH12.

3 Waste with a free cyanide concentration greater than 0.4mg l^{-1}.

4 Waste with a free sulphide concentration of more than 10mg l^{-1}.

5 Waste with a free chrome (VI) content of more than 30ppm.

6 Waste with a flashpoint, as measured by the closed cup method, below 60°C.

7 Waste which reacts with air or water within the pH range pH 6 to pH 12, to produce inflammable, explosive or toxic gases.

8 Waste which contains highly reactive redox compounds.

APPENDIX E Disposal methods

1. Co-disposal

The practice of co-disposal, disposing of liquids and solids in a ratio of 1:10, will take place on site. Trenches will be prepared in front of the working face and liquids will be discharged into these trenches and covered with waste to act as an absorbent for the liquids.

2. Trench and cover immediately

A trench is prepared in front of the existing working face and waste with a potential odour risk is covered immediately with dry domestic waste.

3. Trench and treat with lime

A trench is prepared in front of the existing working face and solid waste with a pH>6 and waste with a high bacteria content will be disposed together with lime at a ratio prescribed by theLaboratory. Heavy metals are also trenched with lime to minimise the possible mobilisation of heavy metals through the site. Finally it is covered with waste.

4. Trench and treat with ferrous sulphate

A trench is prepared in front of the working face and it is compacted and lined with clay. Solid wastes containing either cyanide or chrome is treated and blended with the prescribed ferrous sulphate solution. The trench is covered with domestic waste.

5. Trench and treat with sodium sulphide

A trench is prepared in front of the working face and is compacted and lined with clay and lime. Solid wastes containing low concentrations of mercury are treated and blended with the prescribed sodium sulphide solution and finally covered with waste. The immobilisation of copper is done in the same manner.

6. Front of working face and do not crush

Asbestos which has been double-bagged and labelled and labpacs are tipped in front of the working face. These wastes are then covered with at least one metre of waste to ensure that the labpacs and bags are not crushed.

7. Ashblend/trench with ash

All flammable wastes and waste with a flashpoint <60°C are either blended with ash by FEL or trenched with ash. The ash will absorb the liquids and the ashblending ratio is predetermined by the Laboratory in order to maintain a flashpoint >61°C. This process will take place in a separate area on the site.

8. Ashblend and weather

Leaded sludges are blended with ash for absorption and then the blended product is weathered to reduce the organic lead content to <20ppm through oxidation. The weathered product is co-disposed of on site. This process will take place in a separate area on the site.

9. Separate cell

A limited number of drums will be buried upright on a bed of ash in a separate clay cell.

10. Safe disposal

See attached procedure.

11. Encapsulation

See attached specification.

APPENDIX F Safe disposal procedure

1 The customer will notify the waste-tech customer liaison officer by 15h00, at least 12 hours prior to the time of collection, that a Safe Disposal is to take place and supply all the relevant details. This will also apply to Own Transport Customers.

2 The Customer Liaison Officer will:

[a] Prepare a Waste Manifest Document

[b] Inform the involved waste-consultant or other responsible person of the details of the Safe Disposal to take place.

3 The Waste Manifest Document, accompanied by the following, will be handed to the driver by controls prior to collection.

[a] Copy of Customer Card.

[b] Copy of Tremcard.

[c] Set of Hazchem Decals.

[d] Information of the Waste-tech representative who will accompany the vehicle transporting the waste for safe disposal.

4 The driver must be in the possession of:

[a] Hazchem file.

[b] Correct protective clothing as per customer card.

5 The driver will follow the specified route to the customer.

6 The driver will report to security/reception and will meet the Waste-tech representative and they will both proceed to the collection point.

7 The Waste-tech representative will ensure that:

[a] The driver and assistant are wearing the correct protective clothing;

[b] The driver is in the possession of the correct documentation and Hazchem decals.

APPENDIX G Project specifications

PROJECT SPECIFICATION PORTION 1 PART 1: SPECIAL SPECIFICATION

Important Note

This Specification utilises the SABS 1200 series Standardised Specifications for Civil Engineering Construction. These Specifications are *not* bound with the specification.

Scope

The Project Specification is set out in two portions. Portion 1 (Part 1) covers general descriptions of the project, plus any special specifications not covered by SABS 1200 Specifications.

Portion 2 covers variations and additions to the Standardised Specifications that are applicable to the contract.

NOTE: The siting of the encapsulation cells within a site will be site specific and must be addressed during permitting of that site.

The works

PS1: This project comprises the structural and builder's work associated with the construction of:

Standard Encapsulation procedures for hazardous waste

The procedure for encapsulation is as follows:

1 On a prepared impervious clay foundation, a 200mm thick slab shall be cast in 35MPa concrete, with two layers of 245 mesh turned up at the edges in accordance with the drawings. Cover to the mesh shall be 40mm. An approved 200mm PVC external waterbar, mechanically jointed adjacent to one corner, shall be cast in at the edge. Within four hours after casting, the slab shall be roughened for 250mm around the periphery, by removing laitance with a water spray. If more than seven days elapse before the rest of the concrete is cast, this area must be painted with an approved slow-setting wet-to-dry epoxy immediately before casting. The slab shall be cured by spraying with water in accordance with the Specification.

2 Approved drums or containers containing hazardous waste shall then be placed on 75x75x50mm high concrete blocks, three per drum. Drums shall not be placed closer to the outside edge of the slab than 200mm, and there shall be a gap between drums of not less than 150mm.

3 Two layers of 245 mesh shall be fixed in the side walls, lapped at the corners as shown in the drawings, and side shutters, coated with an approved shutter release agent, fixed rigidly in place. Two layers of 245 mesh shall then be fixed over the top of the drums. Minimum laps at corners and junctions of mesh panels shall be 60 diameters of the 6.3mm wires i.e. 375mm, and cover from the top shall be 40mm.

4 35MPa concrete, with a superplasticiser added, shall then be poured in the shutter. As soon as water is no longer visible on the surface, an approved spray curing compound shall be applied to the top surface.

5 After not more than 24 hours, the side shutters shall be stripped, and the concrete sprayed at the sides with an approved curing agent.

PS9: Applicable Standardised and particular specifications

SABS 1200 A	General
SABS 1200 G	Concrete (Structural)

PS10: PVC waterbars shall be in accordance with CKS 389 of 1973 Flexible PVC waterstops, and shall be 200mm wide type Supercast Rearguard R or equal approved, fixed in accordance with the manufacturer's instructions. Waterbars shall be jointed with a corrosion resistant mechanical fastening at a point adjacent to a corner. At the other corners the waterbar shall be bent, and the lugs only carefully cut to enable a sharp corner to be formed.

ANNEX V

UNEP

Hazardous Waste Situation Questionnaire

UNEP

UNITED NATIONS
ENVIRONMENT PROGRAMME
PROGRAMME DES NATIONS UNIES
POUR L'ENVIRONNEMENT

IE/PAC • CAP/IE

INDUSTRY AND ENVIRONMENT
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39–43, quai André Citroën
75739 PARIS CEDEX 15
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Hazardous Waste Situation Questionnaire

Country/Region: ....

Period/Year: ....

Prepared by: .... Date: ....

Information Note to Users

This questionnaire seeks to collect basic, country-specific information in order to give an overview of hazardous waste generation rates and disposal needs. This information will allow an appraisal of the environmental problems, the sources of hazardous waste, and the management elements already in place.

The first part of this document consists of a simple two-page overview questionnaire that can be used alone or in conjunction with a second, more detailed survey. When used alone, it can be widely distributed in order to quickly obtain an appreciation of the general situation in a country. This overview questionnaire can be completed by country personnel without requiring a great deal of research. They will rely on their own knowledge and experience, and perhaps on easily accessible documentation.

The second part consists of a more detailed questionnaire for in-depth investigation of the factors important to the management of hazardous waste. It is designed for use by consultants or experienced national experts. It is not suitable for mail-out.

Both parts can be used in actual country studies. They are also useful in preparing trainees for a forthcoming course by collecting information in advance that can then be used in association with this manual.

In order to complete all the information asked for, it will often be necessary to contact special information directories, handbooks and annual reports, and to contact information sources in various government departments. These sources should be indicated in appropriate places in the tables to allow follow-up later.

CONTENTS

1 OVERVIEW QUESTIONNAIRE

National hazardous waste situation overview

Depending on the question, mark the appropriate box, write the correct answer or provide key words in the space provided.

National Profile

Population .... GDP ....

Main economic activity:

Main industries:

Checklist of Problems

- ☐ water pollution
- ☐ toxic air emissions
- ☐ landfill problems
- ☐ contaminated sites
- ☐ fires, spills of chemicals
- ☐ waste dumping
- ☐ waste import
- ☐ transport problems
- ☐ safety risks/ poisoning
- ☐ animal/fish kills

Mark [1] if the problem is minor; [2] if it is serious.

Regulations/Standards

Legislation* is in force on:

	yes	no
hazardous waste disposal	☐	☐
hazardous waste transport	☐	☐
water pollution	☐	☐
solid waste disposal	☐	☐
EIA	☐	☐
export/import of wastes	☐	☐
Waste Classification system exists?	☐	☐

* If answer is *yes*, attach details.

Waste Generation

Main problem wastes ....

Major industrial waste sources .... *identified/not identified*

Other hazardous waste sources .... *known/not known*

Waste Surveys:
Survey Agency(s) ....
....

Waste import .... *not known/unconfirmed/confirmed*

Waste Transport/Disposal

Specialised transport operators .... *exist/not exist*

Specialised disposal facilities exist for ....
....

Industrial waste recycling exists for ....
....

Garbage dumps receive .... *much/some/no industrial hazardous waste*

Administration

Environmental Agency/Ministry:

Agency responsible for hazardous waste management:

Enforcement agency(s):

Agency for industrial development:

Contact agency for Basel Convention:

National waste generation overview

List below the main types of waste known by you to be generated. Use the common classification in use in your country.

Waste	Quantity
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....
....	....

If known, list the quantities of wastes shown below.

Waste	Quantity
Acids/alkalis	....
Heavy metal wastes	....
Toxic inorganics	....
Reactive/corrosive	....
Solvents wastes	....
Oil wastes	....
Organic chemicals	....
Pesticide residues	....
PCBs, chlorinated hydrocarbons	....
Contaminated soil or equipment	....

List the number and location of treatment/disposal facilities known to you—

Oil recovery plants ....
....
Solvent recovery ....
....
Non-ferrous metal recovery ....
....
Cyanide treatment ....
....
Other physical/chemical treatment ....
....
Incineration ....
....
Co-incineration ....
....
Special landfill ....
....
Co-disposal landfill ....
....
Solidification/encapsulation ....
....
Stockpiling ....
....
Export of wastes ....
....
Discharge to .... sewer ☐ river ☐ sea ☐

Contact names for further information on waste surveys and disposal facilities—

1 ....
....
....

2 ....
....
....

3 ....
....
....

2 BACKGROUND INFORMATION

National profile

Give a very brief description of your country under the headings below:

1 **Geographical** (area, terrain, climate, population)

2 **Resources**

3 **Urban servies** (transport, water, sewerage, electricity)

4 **[a] Economic activity and industries**

[b] GDP

5 **Political structure**

6 **Administration**

7 **Technical services available**

8 **Environmental quality** (major issues)

Attach names of relevant Yearbooks, Statistical Digests, Country Profiles, and Environmental Reviews which have been published.

Background on industry

Indicate below the main types of industry found in your country with: *none/some/many*

Textile	Sulphuric acid	Vehicle manufacture ....
Leather/tanning	Nitrogen fertiliser	Electrical machinery ....
Wood products	Phosphate fertiliser	Electronic components ....
Wood preserving	Speciality chemicals	Cement ....
Pulp and paper	Petrochemicals	Shipbuilding/repair ....
Printing	Aluminium	
Chemicals (list)	Iron and steel	Others (indicate) ....
Plastics (PVC)	Base metals	....
Plastics (others)	Battery manufacture	....
Chlorine	Metal fabrication	....

Which Ministry or Department is responsible for keeping employment statistics? ....
....

If available, attach employment and production output for each of the above industries.

Background on specific activities

The following sections deal with some activities that may, under some circumstances, give rise to hazardous wastes. Please list the information requested in the space indicated, using available handbooks and reports to provide the data.

1 Agriculture

Main crops grown .... Main crops exported ....
....
Irrigated crops .... Pesticides used ....
....
Number of pesticide production/formulation plants ....

2 Mining and minerals

Minerals mined .... Minerals processed ....
....
Minerals smelted .... Metals fabricated ....
....

3 Energy

Type of fossil fuel produced .... Number of refineries ....
Number of storage/distribution centres .... Number of service stations ....

4 Transport

Number of registered trucks .... buses .... cars ....
Shipping
Number of ports .... Total tonnage handled ....
Number of bulk terminals .... Tonnage ....

5 Cement

Number of plants .... Total output ....

6 Medical

Number of major hospitals .... Number of private clinics ....
Number of medical laboratories ....

List information sources consulted ....
....

Background on employment

As employment rates can give an approximate indication of waste generation, please show employment in the sectors below.

Industry Sector ISIC code	Description	Employees (x1000)
31	Food	
	Beverage	
	Tobacco	
32	Textile	
	Footwear	
	Leather	
33	Wood	
	Wood production	
	Processing	
34	Paper, paper products	
	Printing	
35	Chemicals	
	Petroleum	
36	Non-metallic mineral products	
37	Basic metal production	
38	Metal fabrication products	
	Machinery	
39	Other manufacturing	
D	Services utilities	
	Total	

Source: Specify whether (i) Industry Ministry or (ii) other.

Background on environmental problems

It is important to know the types of environmental problems being caused by hazardous wastes. Please complete the questionnaire form on the next page as indicated. Initially try to complete the form using your own knowledge. Subsequently, copies of pages 292-293 *(Environmental problems due to hazardous waste)* should be sent for reply to ministries, departments, or other organisations competent in the sectors shown in the table below. The table allows you to keep a record of your contact with these organisations.

Sector/Organisation	***Date sent out***	***Date of reply***
Water and sewerage	....	....
Waste disposal	....	....
Pollution control	....	....
Health	....	....
Agriculture	....	....
Fisheries	....	....
Fire services	....	....
Factory inspectorates	....	....
Shipping	....	....
Transport	....	....
NGOs	....	....
Environmental research institutes	....	....
State of environment units	....	....
Industry federations	....	....
Municipalities in industrial regions	....	....

Environmental problems due to hazardous waste

	Problem Group	Severity: None	Some	Much
1	**Pollution**			
	Toxic effluents are affecting marine or river life?	☐	☐	☐
	Oils and chemicals are burnt under uncontrolled conditions?	☐	☐	☐
	Toxic discharges are affecting sewers or sewage treatment?	☐	☐	☐
	Leachate has been detected escaping from landfill?	☐	☐	☐
	Excessive chemical residues are detected in fish or in crops?	☐	☐	☐
	Vehicles sometimes discharge wastes to land or to water?	☐	☐	☐
	Odours are detected from factories?	☐	☐	☐
	Toxic emissions escape to air from factories?	☐	☐	☐
2	**Landfill**			
	No control exists at landfill sites?	☐	☐	☐
	Drums of chemicals sometimes found at the site?	☐	☐	☐
	Liquids being discharged to landfill?	☐	☐	☐
	Fires from chemicals occur at landfills?	☐	☐	☐
	Leachate is escaping from some landfills?	☐	☐	☐
	Serious odour problems occur at landfills?	☐	☐	☐
	It is common for people to scavenge on landfill sites?	☐	☐	☐
3	**Export/import**			
	Confirmed export/import operations?	☐	☐	☐
	Unsubstantiated claims?	☐	☐	☐
	Wastes are shipped overseas for treatment/disposal?	☐	☐	☐
4	**Dumping**			
	Dumping of wastes is detected along roadsides?	☐	☐	☐
	Drums have washed up on the beach?	☐	☐	☐
	Wastes are known to be dumped at sea?	☐	☐	☐
	Wastes are dumped on factory premises?	☐	☐	☐
	Old contaminated factory sites are known to exist?	☐	☐	☐
5	**Unsafe operations**			
	Some people have been injured/killed by industrial wastes?	☐	☐	☐
	The handling of industrial wastes is unsafe?	☐	☐	☐
	The transport of industrial wastes is unsafe?	☐	☐	☐
	Waste materials are often not labelled, and in poor quality containers?	☐	☐	☐

continued ...

continued...

	Problem Group	Severity: None	Some	Much
6	**Storage**			
	Surplus pesticides are known to be stockpiled?	☐	☐	☐
	Chemicals are often stored under unsafe conditions?	☐	☐	☐
	Waste chemicals are accumulating in storage?	☐	☐	☐
	PCBs are stored by some companies?	☐	☐	☐
	Treatment sludges are being stored?	☐	☐	☐
	Abandoned waste storages exist?	☐	☐	☐
7	**Soil contamination**			
	Contaminated industrial land identified?	☐	☐	☐
	Other contaminated land is known?	☐	☐	☐
	River or harbour sediments are polluted?	☐	☐	☐
	Surveys are carried out before industrial land is redeveloped?	☐	☐	☐
8	**Transport**			
	Accidents involving hazardous wastes?	☐	☐	☐
	Spills of industrial chemicals?	☐	☐	☐
	Vehicles well maintained?	☐	☐	☐
	Containers in good condition?	☐	☐	☐
9	**Cost**			
	The cost of treatment is high?	☐	☐	☐
	The cost of clean-up is high?	☐	☐	☐
	There is no good market for recovered material?	☐	☐	☐
10	**Publicity**			
	There has been adverse publicity about hazardous wastes?	☐	☐	☐
	There have been reports about injuries and damage to the environment?	☐	☐	☐
	Public concern about wastes?	☐	☐	☐
	Public opposition to new treatment plants?	☐	☐	☐
	Are certain public groups active on waste issues?	☐	☐	☐
	Have newspaper or media reports been frequent?	☐	☐	☐

Background on environmental sensitivity

Estimate below as far as you are able the information requested as: *none/some/much.*

1 Sensitive environments

Enclosed harbours/bays .... Estuaries ....

Coral reefs .... Inland lakes ....

Rivers used for fishing/drinking/agriculture ....

Groundwater used for drinking/agriculture ....

Groundwater is shallow .... Flooding/inundation ....

Stable air/air inversions over towns and industry areas ....

Important national parks or nature reserves ....

2 Human environments

Urban habitation close to industry? .... River water used for drinking supply? ....

Subsistence fishing is common? .... Tourism is important? ....

Scavenging on landfills/dumpsites? .... Human habitation adjacent to dumpsites? ....

Agriculture close to industrial estates?.......... Re-use of empty containers is common? ....

Background on waste classification

Show below (or in attached documents) the method of classification of hazardous wastes and chemical residues in your country. If no official system exists, write down the names of those hazardous waste types that are of greatest concern to you.

Waste types	Code Number (if any)	Quantity produced (if known)

TABLE 1: Hazardous waste generation

The tables in the following pages ask in various ways for data on hazardous waste generation from a number of sources, and also for details of non-hazardous waste, as far as is known.

As data on waste generation is collected differently in various countries, you may not be able to respond to all the tables shown. In this case, please provide whatever data is available on the most appropriate tables.

Indicate any source documents from which data was taken.

Table 1a: Hazardous wastes generation rates

Estimate the total amount of the following waste types produced.

Waste type	**Quantity** (give units)
Washwaters (if hazardous constituents)	....
Acids/alkalis	....
Metallic residues, sludges, salts	....
Cyanides	....
Inorganic chemicals, salts, residues	....
Corrisive, oxidising, reducing wastes	....
Solvents	....
Oils (non-PCB)	....
Organic sludges, resins, paints	....
Organic chemicals	....
Pesticides	....
PCBs, chlorinated hydrocarbons	....
Contaminated soils and equipment	....
Total	....

Source: ....

Table 1b: Hazardous wastes from other sources

If you have any data on the following items, please show in the table below or attach a list.

	Waste type	**Source**	**Quantity** (give units)
1	Lubricating oil	Public and private transport	....
	Other oils	Machinery	....
		Ships	....
2	Pesticides	Agriculture, municipalities	....
		Public health programmes	....
3	Solvents, paints	Domestic households	....
	Chemicals (misc		....
	Oxidising agents		....
	Cleaners, disinfectants		....
4	Solvents, pharmaceuticals, drugs, chemicals	Hospitals, laboratories, schools	....
5	Medical wastes	Hospitals, laboratories, schools	....
6	Others (specify)	(Specify)	....

Source: ....

Table 1c: Other wastes from industrial sources

Please give any available details on the following general non-toxic waste sources, as far as known.

	Waste type	Source	Quantity (give units)
1	High strength liquid wastes	....	....
2	Untreated effluents	....	....
	Dilute washwaters	....	....
	Effluent discharged to sewers or rivers	....	....
3	Agricultural residues	....	....
4	Inert solid wastes	....	....
	Factory rubbish	....	....
5	Mining spoil	....	....
	Mineral processing waste	....	....
	Excavation and demolition waste	....	....
6	Dredging spoil and sediments	....	....

If no figures are available, please provide a short description in writing of any relevant information, and attach to this table.

Source: ....

Table 1d: Hazardous wastes as specified by the Basel Convention

This table looks at wastes classified in the Basel Convention. Provide to the fullest extent possible information on the wastes listed below.

	(i) **Waste Streams**	**Quantity** * (give units in each case)
Y1	Clinical wastes from medical care in hospitals, medical centres and clinics	....
Y2	Wastes from the production and preparation of pharmaceutical products	....
Y3	Waste pharmaceuticals, drugs and medicines	....
Y4	Wastes from the production, formulation and use of biocides and phytopharmaceuticals	....
Y5	Wastes from the manufacture, formulation and use of wood preserving chemicals	....
Y6	Wastes from the production, formulation and use of organic solvents	....
Y7	Wastes from heat treatment and tempering operations containing cyanides	....
Y8	Waste mineral oils unfit for their original intended use	....
Y9	Waste oils/water, hydrocarbons/water mixtures, emulsions	....
Y10	Waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs) and/or polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs)	....
Y11	Waste tarry residues arising from refining, distillation and any pyrolytic treatment	....
Y12	Wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish	....
Y13	Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives	....
Y14	Waste chemical substances arising from research and development or teaching activities which are not identified and/or are new and whose effects on man and/or the environment are not known	....
Y15	Wastes of an explosive nature not subject to other legislation	....
Y16	Wastes from production, formulation and use of photographic chemicals and processing materials	....
Y17	Wastes resulting from surface treatment of metals and plastics	....
Y18	Residues arising from industrial waste disposal operations	....

* If not known, write NOT KNOWN. If not quantified, write NOT QUANTIFIED.

Source: ....

Table 1e: Wastes as listed by the London Dumping Convention

Waste type	**Quantity * (give units in each case)**

* If not known, write NOT KNOWN. If not quantified, write NOT QUANTIFIED.

Source: ....

Table 1f: Other waste types

List information as appropriate.

1	**Waste quantities as available from local information**	
2	Waste quantities involved in—	
	Export	**Import**

Sources: ....

....

TABLE 2: Hazardous wastes treatment and disposal

The tables in the following pages ask for data on current hazardous waste treatment and disposal practices and on infrastructure.

Different tables may ask for the same information several times, and in different ways. Complete *all* the tables as far as you can.

Table 2a: Types of waste treated and disposed of by industry on its own premises

Please show the most common forms of ON-SITE treatment given to the wastes listed in column 1, and also show the industries which most commonly use such treatment.

	Waste type	Industry sector/source treating this waste	Type of treatment/disposal/ storage on site
1	Effluents, washwaters	....	....
2	Acids, alkalis	....	....
3	Heavy metal-bearing wastes	....	....
4	[a] Inorganic chemicals	....	....
	[b] Inorganic sludges	....	....
5	Cyanides	....	....
6	Solvents	....	....
7	Oils	....	....
8	Paints, resins	....	....
9	[a] Organic chemicals	....	....
	[b] Organic sludges	....	....
10	High BOD wastes	....	....
11	Other (describe)		
	....	....	....
	....	....	....
	....	....	....
	....	....	....
	....	....	....

Table 2b: Fate of common industrial and other residues

Describe the disposal methods currently used for the following residues or wastes, as far as you know.

1	Waste lubricating oils
2	Unwanted or surplus pesticides
3	Scrap tyres
4	Scrap metal
5	Old batteries
6	Treatment plant sludges
7	Empty containers for chemicals
8	Refinery sludges
9	Ship cleaning wastes, slops, contaminated blast water
10	Incinerator ash or dust
11	Hospital wastes

Table 2c: Fate of waste listed in the Basel Convention

	(i) **Waste Streams**	**Current disposal * method**
Y1	Clinical wastes from medical care in hospitals, medical centres and clinics	....
Y2	Wastes from the production and preparation of pharmaceutical products	....
Y3	Waste pharmaceuticals, drugs and medicines	....
Y4	Wastes from the production, formulation and use of biocides and phytopharmaceuticals	....
Y5	Wastes from the manufacture, formulation and use of wood preserving chemicals	....
Y6	Wastes from the production, formulation and use of organic solvents	....
Y7	Wastes from heat treatment and tempering operations containing cyanides	....
Y8	Waste mineral oils unfit for their original intended use	....
Y9	Waste oils/water, hydrocarbons/water mixtures, emulsions	....
Y10	Waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs) and/or polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs)	....
Y11	Waste tarry residues arising from refining, distillation and any pyrolytic treatment	....
Y12	Wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish	....
Y13	Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives	....
Y14	Waste chemical substances arising from research and development or teaching activities which are not identified and/or are new and whose effects on man and/or the environment are not known	....
Y15	Wastes of an explosive nature not subject to other legislation	....
Y16	Wastes from production, formulation and use of photographic chemicals and processing materials	....
Y17	Wastes resulting from surface treatment of metals and plastics	....
Y18	Residues arising from industrial waste disposal operations	....

* If disposal method is not known, write NOT KNOWN. If the waste is not produced, write NO WASTE.

Table 2d: Disposal facilities available

Please list any facilities which are available to treat waste off-site, i.e. away from the place of generation. Include both commercial and public authority facilities. Indicate throughput if known. If no facilities of a particular type exist, show 'NONE'.

	Facility type	**Capacity/throughput** (give units)
1	Incinerators for industrial wastes	....
2	Co-incineration e.g. cement kiln, industrial boilers	....
3	Treatment of cyanide wastes	....
4	Storage site for wastes requiring incineration or treatment	....
5	Arrangements for high temperature incineration of waste in Europe or elsewhere	....
6	Special industrial waste landfill	....
7	Municipal landfill accepting industrial waste (number _____)	....
8	Ship cleaning facility or slop storage	....
9	Any other (specify)	....

Table 2e: Waste minimisation and recycling

Show below any initiatives in waste reduction, exchange, reclamation and recycling.

	Facility type	**Capacity/throughput** (give units)
1	Oil recovery plants accepting lubricating and industrial oils for reclamation and resale	....
2	Co-incineration facilities	....
3	Solvent recovery plants	....
4	Non-ferrous metal recovery	....
5	Battery recycling/recovery	....
6	Other (specify)	....
	Management initiatives	**Details**
1	Waste reduction	....
2	Recycling/recovery initiatives	....
3	Waste exchange service or operator	....
4	Other (specify)	....

Table 2f: Disposal facilities available (as per Basel Convention: Annex IV)

This uses a different format for listing disposal facilities. Again, indicate throughput if known.

	Disposal facility	Capacity/throughput (give units in each case)
D1	Deposit into or onto land (e.g. landfill, etc.)	....
D2	Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)	....
D3	Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)	....
D4	Surface impoundment (e.g. placement of liquid or sludge discards into pits, ponds or lagoons, etc.)	....
D5	Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)	....
D6	Release into a water body except seas/oceans	....
D7	Release into seas/oceans including sea-bed insertion	....
D8	Biological treatment not specified elsewhere in this table which results in final compounds or mixtures which are discarded	....
D9	Physico-chemical treatment not specified elsewhere in this table which results in final compounds or mixtures which are discarded	....
D10	Incineration on land	....
D11	Incineration at sea	....
D12	Permanent storage (e.g. emplacement of containers in a mine, etc.)	....
D13	Blending or mixing prior to any disposal operations	....
D14	Repackaging prior to any disposal operations	....
D15	Storage pending any disposal operations	....
R1	Use as a fuel (other than in direct incineration) or other means to generate energy	....
R2	Solvent reclamation/regeneration	....
R3	Recycling/reclamation of organic substances which are not used as solvents	....
R4	Recycling/reclamation of metals and metal compounds	....
R5	Recycling/reclamation of of other inorganic materials	....
R6	Regeneration of acids or bases	....
R7	Recovery of components for pollution abatement	....
R8	Recovery of components from catalysts	....
R9	Used oil re-refining or other re-uses of previously used oil	....
R10	Land treatment resulting in benefit to agriculture or ecological improvement	....
R11	Uses of residual materials obtained from any of the operations numbered R1-10	....
R12	Exchange of wastes for submission to any of the operations numbered R1-10	....
R13	Accumulation of material intended for any recycling or recovery operation	....

Table 2g: Waste management services available

Please indicate the level of service: i.e. *none/some/much*, in each of the categories below.

1	Sewers accepting industrial effluents	accepts all wastes ....
		pretreatment required ....
2	Special chemical services	
	Hazardous waste transport services	
	Other waste contractors	
3	Chemical laboratories capable of analysing wastes	
4	Consultants for waste treatment	
	Consultants for environment, EIA	
5	Emergency response team for chemical fires and spills	
6	Programme of community awareness and preparedness (APELL)	
7	Chemical or environmental engineering departments exist at university	
8	Professional associations exist for—	
	waste management professionals (e.g. ISWA)	
	chemical engineers	
	scientists	
	environmental professionals	
9	Technical training institutes exist	
	for professionals	
	for drivers	
	for emergency services	
10	A pollution complaint service exists for the public	
11	A waste exchange service exists	
12	A technical information service/library exists	
13	Industry associations/productivity councils exist	
14	Citizen-based advice bureaux/NGOs exist	

Table 2h: Hazardous waste transport

		Yes	No
1	Are there transport services which specialise in the transport of:		
	—hazardous industrial chemicals?	☐	☐
	—flammable liquids?	☐	☐
	—hazardous wastes?	☐	☐
2	Is a special permit required to transport such materials?	☐	☐
3	Is a load manifest or other special documentation necessary?	☐	☐
4	Are transport vehicles identified with:		
	—UN hazard symbols?	☐	☐
	—other warning placards?	☐	☐
5	Are special containers used for hazardous wastes?	☐	☐
6	Are there special training courses for drivers of such vehicles?	☐	☐
7	Which authorities are notified in case of a spill or accident?		
	Is such notification mandatory?	☐	☐
8	Is there:		
	—an association of transport operators?	☐	☐
	—a special union for drivers?	☐	☐

TABLE 3: Regulations and discharge standards

The tables on the following pages summarise the environmental and health standards applying to hazardous waste treatment facilities, as well as to industry generally.

Table 3a: Principal laws and regulations

Please list current laws applying to or which include mention of the following items. Note for each the government agency * responsible for administration.

1	Environment protection generally, including EIA
2	Water pollution, including marine pollution and oil spills
3	Air pollution
4	Management of industrial waste
5	Solid waste disposal, including dredge spoil and mining spoil
6	[a] Transport and storage of dangerous goods
	[b] Transport of hazardous waste
7	Export/import of hazardous waste
8	Chemicals and chemical wastes
9	Soil contamination, clean-up of sites
10	Pesticides
11	Occupational health

* If more than one agency is involved, indicate the role of each.

Table 3b: Standards applying to environmental media

	1 Discharge to water* (mg/l)	2 Discharge to sewer* (mg/l)	3 Discharge to air* (mg/m^3)	4 Occupational* exposure
Cadmium				
Chromium				
Mercury				
Copper				
Lead				
Zinc				
Nickel				
Cyanide				
Phenols				
Oil				
Solvents				
Suspended matter				
COD				
pH range				
Dust/particulates				
Any other (specify or attach)				

Name of regulations applying to:

[1] above ....
....

[2] above ....
....

[3] above ....
....

[4] above ....
....

* If more than one set of standards applies, attach further details

Table 3c: Controls applying to solid waste disposal

Specify below the requirements and standards currently applying to landfill and other solid waste disposal.

Include domestic garbage, industrial waste, mining spoil, dredge spoil—

Name of legislation which applies to the controls above ....
....

Table 3d: Standards applying to treatment and disposal of specific wastes

Please attach details of any special environmental standards or requirements that are in force for disposal of the following.

PCBs ....

Dioxins/furans ....

Oils ....

Solvents ....

Cadmium ....

Mercury ....

Surplus pesticides ....

Surplus drugs, pharmaceuticals ....

Any other (specify) ....

....

....

Name of regulations applicable: ....

....

....

....

Table 3e: Controls applying to specific treatment and disposal options

Indicate the types of permits, approvals, restrictions, and other controls that apply to the operations below.

Operation		[i] Type of control or approval required [ii] Name of regulation which applies	Issuing agency
Hazardous waste generation		[i] .... [ii]	....
Factory emissions to air		[i] .... [ii]	....
Factory discharges to water		[i] .... [ii]	....
Factory discharges to sewers		[i] .... [ii]	....
Transporter		[i] .... [ii]	....
Transport manifest		[i] .... [ii]	....
Disposal facilities	landfill	[i] .... [ii]	....
	others	[i] .... [ii]	....

Table 3f: Standards or controls applying to specific industries

Type of Industry	Types of emissions, discharges or operations controlled or banned	Implementing Agency

Give names of regulations which apply ....

....

Table 3g: Important policy considerations

List any official policies which apply to the following.

1 Waste export ....
....

Waste import ....
....

2 Offshore dumping ....
....

3 PCBs ....
....

4 Ownership of facilities ....
....

5 Treatment preference ....
....

6 Source of financing of treatment facilities ....
....

7 Permit and approval fees ....
....

TABLE 4: Implementation

The tables below cover a number of aspects of administration, inspection, monitoring and surveillance concerning hazardous waste.

Table 4a: Administrative responsibilities

Please indicate which ministries, departments, agencies and other organisations have designated responsibilities for the following.

1 Environmental Impact Assessment ....

....

2 [a] Setting environmental standards (air, water, land) ....

....

[b] Enforcement of standards ....

....

3 Standards for discharge to sewers ....

....

4 Approval permits for [a] industrial sites ....

....

[b] hazardous waste facilities ....

....

5 Environmental monitoring ....

....

Hazardous waste monitoring ....

....

6 Control over toxic chemicals and pesticides ....

....

7 Import of chemicals, wastes ....

....

8 Disposal of urban wastes ....

....

Managing/supervising landfill sites ....

....

9 Policy for pollution and hazardous wastes ....

....

10 Treatment, disposal of hazardous wastes ....

....

continued ...

continued ...

11 Clean-up of dumpsites and chemical spills ....

....

12 Oil spills ....

....

13 Transport of [a] hazardous wastes ....

....

[b] dangerous goods ....

....

14 Export/import checking of wastes ....

....

15 Focal point for Basel Convention ....

....

16 Focal point for IRPTC ....

....

17 Chemical exposure in the workplace ....

....

18 R & D in environment ....

....

19 Government laboratories ....

....

20 State of environment reporting ....

....

21 Conservation strategy ....

....

Table 4b: Inspection services

Please indicate below details as requested about environmental inspectorate.

1	*Agency/department responsible for inspection/enforcement of:*	No. of personnel
	water pollution	
	solid waste	
	chemical wastes	
	air pollution	
	pesticides	
	transport of hazardous materials	
	chemical storage	
	waste storage (if different from above)	
	site clean-up	
2	Coordination of inspections above, and any inter-agency cooperative arrangements	
3	Training/qualifications generally required for inspection personnel	
4	Training facilities available in the country for inspection personnel	
5	Do inspection personnel have the power to initiate prosecution against offenders?	

Table 4c: Monitoring and surveillance

Please indicate the monitoring operations carried out in your country, and the names of the agencies responsible.

	Item	Regular monitoring and surveillance		Agency
		Yes: give interval	*No:* spot checks?	
1	**Raw materials monitoring**			
	—chemicals imported	....	....	....
	—chemicals manufactured	....	....	....
	—lubricating oil contamination	....	....	....
2	**Facility and plant inspections**			
	—hazardous installations	....	....	....
	—waste treatment plants	....	....	....
	—major waste generators	....	....	....
	—other (specify)	....	....	....
		....	....	....
3	**Waste generation**			
	—registered waste generators only	....	....	....
	—waste import/export	....	....	....
	—other (specify)	....	....	....
		....	....	....
4	**Waste discharge monitoring**			
	—sewer discharges	....	....	....
	—effluents	....	....	....
	—air emissions	....	....	....
	—wastes at landfill	....	....	....
	—waste transport	....	....	....
5	**Environmental monitoring**			
	—water quality (list no. of stations)	....	....	....
	—air quality	....	....	....
	—groundwater quality	....	....	....
	—food residues: pesticides/metals	....	....	....
6	**Health monitoring** (chemicals/poisoning)			
	—public health	....	....	....
	—occupational health	....	....	....

Table 4d: Studies and research

1	List below the names (and publishers) of any official reports dealing with environmental pollution or waste disposal that have been published in the last five years
2	List below the names of any research institute or official enquiries dealing with environment, pollution or wastes

Table 4e: Support services

Please indicate *none / few / many* regarding the following services.

1 Laboratories able to analyse chemical constituents of waste	
—commercial	—government ....
—university/institutions	—private companies ....
—pesticide laboratories	
2 Consulting services	
—water treatment	—air emission control ....
—waste disposal	—environmental engineering/science ....
—public relations, media, communication	
3 Emergency services	
—fire services	
—chemical spills	
—oil spills	
4 Training/education (specify institutions or courses)	
—environmental	
—waste disposal	
—public health	
—industrial safety	
—occupational health	
—transport safety	
—emergency services	
5 Technical documentation services	
—public technical library	
—IRPTC contact	
6 Professional associations	
—municipal services	
—engineers	
—chemists	
—environmental	
7 Trade associations (give names)	
—chemical	
—manufacturing	
—transport	
—waste management	
—productivity council	
8 Environmental groups (give names)	
—professional	
—public	
—industry	
9 Recycling/waste exchange (give names)	
....	
....	
10 R&D	
—research departments	
—consulting	

Table 4f: Key player analysis

Indicate below the names, titles and organisations of some key players in environmental and waste management affairs.

1	Political figures who have made important pronouncements in favour of environmental issues
2	Key citizens campaigning on environment and pollution control, or who are known to have strong views
3	Key NGOs
4	Influential business persons interested in environment, pollution and wastes
5	Prominent researchers, scientists and educators
6	Media persons, journalists and writers
7	Union leaders concerned about health and safety
8	Important administrators in environment, chairmen of environment committees or enquiries
9	Key consultants, designers

ANNEX VI

Contents of UNEP Training Manual

Hazardous Waste Policies and Strategies

Technical Report No. 10

The publication described in this Annex is the first of the hazardous waste training manuals to be prepared by UNEP IE/PAC. This manual provides the basic introduction to management issues concerning hazardous waste. The document is available from UNEP IE/PAC or UN Sales Centre in Geneva and New York.

1 CONTENTS OF THE MANUAL

2 PREFACE

The need for improved management of hazardous waste everywhere is clear. Such management requires not only technical resources and regulations, but also skilled personnel. The lack of sufficient personnel is unfortunately delaying the implementation of proper management regimes, and to make things worse, there are few facilities to teach the necessary skills. This lack is particularly obvious in developing countries, although even in the industrialised world there is a serious shortage of trained personnel.

This manual is intended to assist with the further training of decision-makers who have already—or are likely to have soon—direct responsibility for the management of hazardous waste. The manual is the result of collaboration between UNEP's Industry and Environment Programme Activity Centre (IE/PAC) and ISWA's Working Group on Hazardous Wastes (WGHW). A particular emphasis of this collaborative programme is on information exchange and training.

The idea for the manual came from the training workshops run by IE/PAC during the 1980s. The Environmental Education and Training Unit of UNEP supported the concept and contributed to the preparation of the manual.

Support from ISWA came through the technical expertise of the WGHW, particularly the orientations provided by expert meetings in Honolulu (1989) and Barcelona (1990).

The manual simulates the problems and options for solutions that are faced by many national administrators. It is directly applicable to the implementation of national and international initiatives in hazardous waste management, as for example the Basel Convention.

The present manual can be used in a number of ways; for example—

- professional trainers and educators will find a proposed training programme and technical material that can be used in its entirety, or adapted to short courses on specific subjects
- environmental and waste control administrations can build in-house training sessions around the simulation exercises in the manual
- national administrations will find advice on waste situation reports, and where to locate relevant information in their countries
- individuals can obtain a more detailed appreciation of how hazardous waste management is carried out at the national level
- technical personnel will find guidance on waste management procedures such as assessments and surveys, reduction measures, disposal options, administration and so on
- consultants will particularly find the waste survey exercises and annex useful in their work with national authorities
- all users will find in the manual important background information, tabular data, and key information on management options.

Nevertheless, the manual is not perfect, nor is it static. It will adapt as the hazardous waste situation changes, and in response to changes in the needs of its readers. Further material on specific technical subjects, and on industry-specific themes, may be added later.

UNEP hopes that this manual will assist all those concerned with improving the management of hazardous waste worldwide, and welcomes suggestions for improvements and updates to the manual, as well as active participation in its various training activities.

3 A NOTE FOR SESSION LEADERS

What follows consists of six Casework Sessions—

Session 1	Assessment of the Hazardous Waste Situation
Session 2	Technology for Hazardous Waste Minimisation, Treatment and Disposal
Session 3	Legislation and Administration
Session 4	Administrative and Organisational Measures
Session 5	Building up a Hazardous Waste Strategy
Session 6	Implementing the Basel Convention

The notes we provide in this manual are centred around a series of tasks that need to be completed in order to prepare a hazardous waste strategy. Such a strategy was foreshadowed by the task force described in the early part of this document.

The notes for each Session—

- specify the tasks to be carried out

  and

- give some further information that will assist you in carrying them out.

However, the information is not necessarily complete. Similarly, you needn't always follow the examples we give.

Often, guidance by Session Leaders will be necessary to interpret and adapt the practical exercises.

Many of the exercises are open-ended.

A time limit should be set for the exercises chosen. Not all the exercises may be completed in the time available.

The notes are intended to stimulate—but not substitute for—group work.

Local experience of participants may be valuable in guiding the discussion.

THE TASKS UNDERTAKEN IN SESSION ONE

In all, there are four tasks involved in this Session. The working group should report on the following—

Task One

Report on the major environmental problems that can be attributed to hazardous waste in Udanax

Exercise 1.1	Environmental problems
Exercise 1.2	Social problems

Task Two

Report on environmental hazards and consequences

Exercise 2.1	Environmental hazards
Exercise 2.2	Effects

Task Three

Report on waste materials (types and quantities) generated in Udanax, and the sources

Exercise 3.1	Direct observation
Exercise 3.2	Indirect estimation of industrial sources (method A)
Exercise 3.3	Indirect estimation of industrial sources (method B)
Exercise 3.4	Indirect estimation of industrial sources (method C)
Exercise 3.5	Indirect estimation of industrial sources ('INVENT' computer model)
Exercise 3.6	Comparison of models
Exercise 3.7a	Industrial waste survey
Exercise 3.7b	Small-generator survey
Exercise 3.8	Non-industrial sources
Exercise 3.9	Other forms of estimation

Task Four

Identify the key socio-economic influences likely to impact on future waste management strategy

Exercise 4.1	Key player analysis
Exercise 4.2	Key agency analysis
Exercise 4.3	Other socio-economic influences

Further information and references needed to carry out the tasks are included in each exercise where necessary.

THE TASKS UNDERTAKEN IN SESSION TWO

In all, there are three tasks involved in this Session. The working group should report on the following—

Task One

Report on the general treatment and disposal method for hazardous wastes generated in Udanax

Background Exercise	Important properties of waste
Exercise 1.1	Treatment and disposal options: I
Exercise 1.2	Treatment and disposal options: II
Exercise 1.3	Treatment scheme: I
Exercise 1.4	Treatment scheme: II
Exercise 1.5	Treatment scheme: II — Basel Convention

Task Two

Alternatives to disposal

Exercise 2.1	Unacceptable disposal options
Exercise 2.2	Wastes which can be avoided
Supplementary Exercise 2.2a	Cleaner Production Technologies
Exercise 2.3	Waste recovery

Task Three

Disposal facilities for Udanax

Exercise 3.1	Disposal facilities for Udanax
Exercise 3.2	Facility concepts
Exercise 3.3	Immediate disposal options
Exercise 3.4	Interim facilities and arrangements

Further information and references needed to carry out the tasks are included in each exercise where necessary.

THE TASKS UNDERTAKEN IN SESSION THREE

The working group should report on—

Task One

The need for, purpose and application of legislation

Exercise 1.1	Identification of environmental problems
Exercise 1.2	Identification of policy matters
Exercise 1.3	Waste handling activities to be controlled

Task Two

A package for legislation

Identification of measures to be implemented straight away, and those to be left to later.

Exercise 2.1	Legislative instruments
Exercise 2.2	Existing regulations

Task Three

Implementation of legislation (institutions)

i.e. Existing and/or new institutions which should be responsible for implementing these measures.

Exercise 3.1	Existing agencies
Exercise 3.2	Implementing agencies
Exercise 3.3	Permitting arrangements
Exercise 3.4	Example of a storage site: I
Exercise 3.5	Example of a storage site: II

Task Four

Review of a regulation proposal

Exercise 4.1	Review of a proposal

Further information and references needed to carry out the tasks are included in each exercise where necessary.

THE TASKS UNDERTAKEN IN SESSION FOUR

The working group should report on—

Task One

Review and recommend useful administrative measures and practical arrangements for waste management in Udanax

Exercise 1.1 Useful measures: I

Exercise 1.2 Useful measures: II

Task Two

Consider several options for waste reduction and recovery

Exercise 2.1 Waste exchange proposal

Exercise 2.2 Waste oil collection

Exercise 2.3 Waste minimisation: I

Supplementary Exercise 2.3a
Implementing cleaner production technologies

Exercise 2.4 Waste minimisation: II

Task Three

Consider field arrangements to improve treatment and disposal

Exercise 3.1 Pesticide collection

Exercise 3.2 Pesticide disposal

Task Four

Transport arrangements

Exercise 4.1 Transport monitoring

Exercise 4.2 Transport safety

Task Five

Coordination

Exercise 5.1 Coordination

Further information and references needed to carry out the tasks are included in each exercise where necessary.

THE TASKS UNDERTAKEN IN SESSION FIVE

The working group should report on—

Task One

Environmental objectives

Exercise 1.1 Issues to be addressed

Exercise 1.2 Goals

Task Two

Identify external constraints and influences

Exercise 2.1 External factors

Task Three

Strategy elements: policies, instruments, actions, responsibilities

Exercise 3.1 Strategy elements

Exercise 3.2 Implication of regulatory actions

Exercise 3.3 Coordination

Task Four

Interim measures

Exercise 4.1 Interim measures

Exercise 4.2 New strategy elements

Task Five

A timetable for implementation

Exercise 5.1 Implementation

Exercise 5.2 Consultation

Further information and references needed to carry out the tasks are included in each exercise where necessary.

THE TASKS UNDERTAKEN IN SESSION SIX

Preliminary Exercise
Application of the Basel Convention

The Task Force should pursue three lines of investigation—

Task One

Review the current situation of trade of hazardous waste

Exercise 1.1 Current export/import

Task Two

Consider the administrative implications of the Basel Convention

Exercise 2.1 Reporting sheet

Exercise 2.2 National surveillance programme

Exercise 2.3 Information management

Exercise 2.4 Transport regulations

Exercise 2.5 Other regulations

Task Three

Consider the regional implications

Exercise 3.1 Regional disposal options

Exercise 3.2 Regional agreements

Further information and references needed to carry out the tasks are included in each exercise where necessary.

CONTENTS OF RESOURCE SECTION

UNEP Industry and Environment Programme Activity Centre

About UNEP IE/PAC

The Industry and Environment Programme Activity Centre (IE/PAC)—previously the Industry and Environment Office (IEO)—was established by UNEP in 1975 to bring industry and government together to promote environmentally sound industrial development. IE/PAC is located in Paris. Its goals are—

[i] to encourage the incorporation of environmental criteria in industrial development plans;

[ii] to facilitate the implementation of procedures and principles for the protection of the environment;

[iii] to promote the use of safe and 'clean' technologies; and

[iv] to stimulate the exchange of information and experience throughout the world.

IE/PAC provides access to practical information and develops cooperative on-site action and information exchange backed by regular follow-up and assessment. To promote the transfer of information and the sharing of knowledge and experience, IE/PAC has recently developed three complementary tools—

- technical guides and manuals
- the quarterly review *Industry and Environment*
- a technical query-response service.

In keeping with its emphasis on technical cooperation, IE/PAC facilitates technology transfer and the implementation of practices to safeguard the environment through—

- promoting awareness and interaction
- training activities

  and
- diagnostic studies.

Some recent UNEP IE/PAC publications

Industry and Environment Review (quarterly), ISSN 0378-9993. Issues deal with topics such as hazardous waste management, technological accidents, environmental auditing, industry-specific problems, and environmental news.

Guidelines for Assessing Industrial Environmental Impact and Environmental Criteria for the Siting of Industry. UNEP IEO, ISBN 92-1015-X. 122pp. 1980.

Hazardous Waste Policies and Strategies—a training manual. Technical Report No. 10. UNEP IEO, 1992.

The Impact of Water-BasedDrilling Mud Discharges on the Environment: an overview. UNEP IEO, ISBN 92-807-1080. 50pp. 1985.

Environmental Aspects of Alumina Production: an overview. UNEP IEO, ISBN 92-807-1088-5. 42pp. 1985.

Environmental Management Practices in Oil Refineries and Terminals: an overview. UNEP IEO, ISBN 92-807-1108-3. 103pp. 1988.

Environmental Aspects of the Metal Finishing Industry: a technical guide (Technical Report Series No 1). UNEP IEO, ISBN 92-807-12160. 91pp. 1989.

Environmental Auditing (Technical Report Series No 2). UNEP IEO, ISBN 92-807-12535. 125pp. 1990.

Audit and Reduction Manual for Industrial Emissions and Wastes (Technical Report Series No 7). UNEP and UNIDO, ISBN 92-807-1303-5. 127pp. 1991.

Storage of Hazardous Materials: a technical guide for safe warehousing of hazardous materials (Technical Report Series No 3). UNEP IEO, ISBN 92-807-12381. 80pp. 1990.

Directory of Information Sources on Air and Water Pollution. INFOTERRA/IEO. ISBN 92-807-12330. 378pp. 1989.

APELL: Awareness and Preparedness for Emergencies at Local Level: a process for responding to technological accidents. UNEP IEO, ISBN 92-807-11830. 62pp. 1988.

Industry and Environment Programme Activity Centre: 39–43 quai André Citroën, 75739 Paris Cedex 15, France