GUIDELINES FOR HAZARDOUS WASTE LANDFILL OPERATION, MONITORING AND AFTERCARE IN HYPER-DRY AREAS

REGIONAL CENTER FOR TRAINING AND TECHNOLOGY TRANSFER FOR THE ARAB STATES IN EGYPT (BCRC-EGYPT)

First Edition 2006

GUIDELINES FOR HAZARDOUS WASTE LANDFILL OPERATION, MONITORING AND AFTERCARE IN HYPER-DRY AREAS

Prepared by

REGIONAL CENTER FOR TRAINING AND TECHNOLOGY TRANSFER FOR THE ARAB STATES IN EGYPT (BCRC-EGYPT)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Editorial Note

The present document was compiled jointly by Dr. **Ashraf M. El Mhagraby** in collaboration of the Project Team; **Dr. Said Dahroug and Geologist Ahmed Farouk**.

Prof. Dr. **Mortada Murad El Aref** reviewed the technical contents of the document.

Participants (Annex-1) of the Expert Group Meetings contributed much to the ideas developed in the present document.

Foreword

The Cairo-BCRC as the implementing agent of the project "Preparation of a set of tools for the selection, design and operation of hazardous waste landfills in hyper-dry areas" funded under the Strategic Plan of the Basel Convention with the financial and technical support from the Secretariat of the Basel Convention; has the honor to release as an output of the project, a set of three guidelines entitled:

- Guidelines for hazardous waste landfill site selection and EIA in hyper-dry areas.
- Guidelines for hazardous waste landfill site design in hyper-dry areas, and
- Guidelines for hazardous waste landfill site operation, monitoring and aftercare in hyper-dry areas.

These guidelines have been prepared with the overall objective of promoting principles and practices for environmentally sound management of hazardous waste in the Arab Countries. They address the specific, but widespread problem of hazardous waste and the need for their containment and disposal. They offer guidance on site-selection, EIA, design, operation, and monitoring of hazardous waste landfills in hyper-dry areas. They also warn against improvised disposal methods that may cause severe environmental and health problems, as the cost of mitigating the effects of irresponsible disposal can be many times higher than the cost of safe and environmentally sound disposal as recommended in these guidelines.

The guidelines are published in Arabic and English with easy to use indexing and/or relevant decision support charts. The guidelines are designed to be used by those who are engaged in careers that address hazardous wastes, such as landfill designers, engineers from the chemical and process industries, waste treatment system managers and designers, and public officials interested in waste management planning. They are also of interest to government departments responsible for hazardous waste management and chemical pollution control. The guidelines should be regarded as a further instrument to enhance implementation by the local agencies and municipalities, even though; the guidelines should not be used as a substitute for consultation with professional and competent advisors.

The technical information and recommendations presented in these guidelines have the status of "**Final**" which means it has been reviewed by a panel of experts nominated by BCRC-Cairo as well as by the Experts of the Arab Countries participated in the project and the Secretariat of the Basel Convention. Even though, these guidelines will be updated regularly with the intention to revise or to issue addenda when important new disposal methods and technologies become available to be used safely and cost-effectively in Arab Countries. I am pleased to release these documents which now supersede the draft version.

Prof. Dr. M.M. El Aref
Director BCRC-Egypt

PREFACE

Hazardous waste management policies and strategies in many countries of the Arab region is still underdevelopment. Most of the countries focus in dealing with hazardous wastes on the land disposal option. Few consider cleaner technology alternatives. When it comes to institutions and regulating bodies for the implementation of immediate actions or policy directives, one finds that the problem of financing prevails. Many donors provide assistance towards developing policies and strategies, capacity building training and occasionally towards pilot projects implementing hazardous waste management components including basic infrastructures.

The problem of implementing efficient and/or successful waste management policies and strategies in the Arab region is noted to belong to three main issues

1- Lack of financial resources.
2- Lack of the know-how and technical resources.
3- Political well against awareness/ and priority actions.

The problem of financial resources varies from one country to another. For example, sophisticated technology and industrial plants that comply with the international environmental standards can be found in some of the Gulf States of the Arab region for their good economic status. In countries with economic problems like many countries in the region, the problem for allocating proper funds for implementing environmental protection policies (including sound management of hazardous wastes) and cleaner production alternatives is still outstanding.

Technology is always a refulgent word that attracts the attention of decision makers especially in developing countries. Many decision makers encourage and give incentives to investors to import technology under the temptation of improved quality and quantity seeking economic development. However, assessment of cleanliness of technology exported is still a challenging issue in developing countries. Failure of technology and associated accidents recorded in the past two decades in developed and developing countries have inflected serious environmental impacts. As a result, big tolls and occasionally total losses have been noted. Technology and know-how link all the times to financial and technical resources. They also, very often; link to monopolization.

Even countries (capitals) of the region that have the financial resources should deal with industrial technologies very carefully because of the lack of local technical resources and expertise for maintenance. Fears emanate from the fact that the operation and maintenance cost of technology, in the absence of the know-how, can be highly exaggerated; and can stress budgets that in some cases closing or suspending business and lose the investment.

Having understood the different variables that impede the enthusiastic shift towards technology and towards sound management of hazardous wastes, the BCRC-Egypt decided to compromise the situation regarding hazardous waste management via addressing the option of waste disposal by landfilling. The center encourages waste disposal option as a short and intermediate term policy which is thought to be popular in the region under the above mentioned circumstances.

Considering the conditions of the region and current undefined practices in dealing with different types of wastes, the BCRC-Egypt decided to consider the landfill option only to be used after every effort has been made to minimize, reduce, mitigate or eliminate the hazards posed by such wastes. The Center encourages waste disposal option as a short and intermediate term policy.

The need to develop the guidelines for the landfill disposal option as a short term policy is expressed by several member countries in the region as stated in the feasibility study conducted by the Basel convention (1996) for the establishment of the region BCRC. The Guidelines are outputs of a project awarded by the SBC to the center. The project tackles the problem of lacking technical guidelines proper for the region economic and geographic conditions.

Acknowledging the geographic, demographic, geomorphic and meteorological conditions of the region the project concentrated on developing standards for the landfill option in hyper- dry areas as the main natural characteristic of the region. The project concept has been prepared and presented for finance to the Open-Ended Technical Working Group of the Basel Convention in late 2002. The project was approved in late 2003 and started implementation at the beginning of March 2004.

The project aimed at developing Guidelines for the landfill option in hyper- dry areas including:

- Guidelines for site selection and EIA of landfills
- Guidelines for landfill design
- Guidelines for landfill operation, monitoring and aftercare

These guidelines are prepared and approved in three expert group meetings held sequentially over 14 months of the 18 month project total duration. These meetings contributed a lot to the capacity building and information share among countries of the region which participated in the meetings. Also, they helped in raising the awareness regarding hazardous waste management.

The present guidelines represent one out of three documents published by the project. The standards appeared in the guidelines are the result of a continuous work by the project staff since the start of the project, the heated discussions during the expert group meetings held in connection with the project; and finally, the scrutiny revision of renowned consultants. The document was meant to be comprehensive but still simple, that can be used both by technicians and non technicians; and also for training purposes. It is worth noted here that this document and the other guidelines published by the project will remain open files for update and improvements as information and knowledge increased, and the BCRC-Egypt will appreciate receiving feedback from users of these guidelines so that future editions can be more useful.

The document is divided into independent sections to facilitate quick and concentrated reading. These sections take the reader from basic concepts to approaches and to the technical issues. All documents contain for further readings and for easy reference a bibliography of the subject.

Said Dahroug
Project Manager

ACRONYMS

AIP	Affected and Interested Parties
B^-	Water deficit climate, resulting in only sporadic leachate generation
B^+	Water surplus climate, resulting in significant leachate generation
C	Communal Landfill
CR	Co-disposal Ratio
EIA	Environment Impact Assessment
G	General Waste or Landfill for General Waste
H	Hazardous Waste or Landfill for Hazardous Waste
HWLF	Hazardous Waste Landfills
H:h	Hazardous Waste Landfill that can receive wastes with a hazard rating of 3 and 4
H:H	Hazardous Waste Landfill that can receive wastes with a hazard rating of 1 and 2
HELP	Hydrological Evaluation of Landfill Performance
IAPs	Interest and Affected Parties
IRD	Initial Rate of Deposition
L	Large Landfills
M	Medium Landfill
MRD	Maximum Rate of Deposition
NGO	Non Governmental Organization
RILC	Representative IAP Liaison Committee
S	Small Landfill

1. INTRODUCTION

There are a number of different ways of depositing hazardous waste in a landfill. Each method has advantages and disadvantages. 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, operating and monitoring the site. The Basel Convention Technical Guidelines on Specially Engineered Landfills, 1997 recommends that wherever possible, hazardous wastes be pre-treated to render them less hazardous or inert before landfilling. Many pre-treatment possibilities are available, but a discussion of them is beyond the scope of this document. Widely used pre-treatment operations are, in particular, incineration and physico-chemical processes.

The present guidelines provide for the Minimum Requirements for the operation, monitoring and aftercare of landfill sites in hyper-dry areas; with special emphasis as to Hazardous waste landfill sites. Additional information on landfill operation, monitoring and aftercare may be found in (UK Department of Environment, 1995, Department of Water Affairs and Forestry (RSA), 1998, World Bank, 2002, and the Basel Convention Technical Guidelines on Specially Engineered Landfills. It is worth mentioning that the present text structure follows that one of the Department of Water affairs and Forestry (RSA), 1998, with proper modifications to suit the concept of the hyper dry areas.

In addition to this short introduction, the document is divided into three main sections namely, operation, operation monitoring, and aftercare (rehabilitation and end use), this in addition to the table of contents, list of table, list of figures, annexes and a bibliography.

The operation section discusses operation objectives and basic elements related to operation. It gives an overview as to the minimum requirement to landfilling operation including methods of landfilling and operation measures to control operation impacts.

The operation monitoring section addresses objectives of monitoring, the institutional aspects of monitoring and the compliance monitoring elements.

The final section discusses the aftercare as the final step of operation. The aftercare includes rehabilitation, closure and end-use aspects of a landfill.

It is to be mentioned here that the present document aimed to assist both specialists working in environmental department, those who are responsible for landfill operations and for other **AIP** landfill operation performance monitoring.

2. OPERATION

In terms of the environmental protection and conservation practices, only a landfill; approved with a permit, may operate. In the case of new landfills and extensions, site preparation and construction have to be approved by the concerned Department prior to commencing the operation.

The objectives of the Minimum Requirements for landfill operation are:

- To ensure that all waste is disposed of in an environmentally and socially acceptable manner.
- To ensure that the disposal operation is acceptable to those whom it affects.

The operation thus must conform to both the Permit conditions and to the Minimum Requirements associated with the site classification. It is the duty of the Responsible Person to ensure that the Minimum Requirements for the operation of a landfill site are effective and are applied to the degree commensurate with its class and hence to the satisfaction of the concerned Department.

It is very important that hazardous waste landfills should operate under strict operation management to avoid common problems associated with municipal or solid waste landfills. To ensure sound operation management of landfills, the operational plan, prepared as a part of the design, is a primary resource because it provides the technical details of the landfill and procedures for constructing various engineered elements. Because a landfill is constructed and operated over several years, personnel must continually consult the plan to assure conformance over the long-term.

2.1 Facilities, Equipment and Resources Required for Landfill Operation

There must be sufficient facilities, equipment and resources to ensure that the landfill operation conform to both the permit conditions and the relevant Minimum Requirements. For example, there should be sufficient trained staff supported with proper equipment to operate, monitor, control and record incoming waste all the time.

In the case of hazardous waste disposal sites services such as water, sewerage, electricity, telephones, security and infrastructure such as weighbridges, site offices and plant shelters, in addition to an on-site laboratory would be a Minimum Requirement.

The plant and equipment on site must be commensurate with the size and type of the operation. Typically, HWLF sites would have a combination of purpose-built landfill compactors, bulldozers, front-end loaders and trucks for waste compaction and to transport cover material. The plant and equipment must provide the means whereby the waste can be disposed of in. accordance with the Minimum Requirements.

2.1.1 Signposting and Road Access

Site access measures (security gates and fencing) should be in place to prevent unauthorized entry, illegal waste disposal, and scavenging practices.

Signs in the appropriate official languages, and with appropriate size and colors, must be erected in the vicinity of the landfill, indicating the route and distance to the landfill site from the nearest main roads. These traffic signs must conform to the requirements of the Road Ordinance. Suitable signs must also be erected on site, to direct vehicle drivers appropriately and to control speed.

A general notice board must be erected at the site entrance. This notice board must be in the appropriate official languages, stating the names, addresses and telephone numbers of the Permit Holder and the Responsible Person, the hours of operation, and an emergency telephone number. It is of particular importance that the sign clearly states the class of landfill and the types of waste that can be accepted. Wastes that cannot be accepted must also be stated. It must be stated that disposal of non-acceptable waste types is illegal and can lead to prosecution. In the case of hazardous waste landfills, clearly visible signposts warning of the associated hazards must be erected along the fence line at intervals not exceeding 100 m.

Access road to the site must be maintained at all times, in a manner suitable to accommodate the vehicles normally expected to utilize the facility. All roads, particularly on-site roads, must be so surfaced and maintained as to ensure that waste can reach the working face with the minimum of inconvenience in all weather conditions. Two-way traffic must also be possible in all weather conditions.

Unsurfaced roads must be regularly graded and watered to control dust. No mud from the site may be tracked onto public roads. If access to the site is directly off the public highway and large numbers of vehicles will be using the landfill, it may be advisable to construct a service road from the highway to the site entrance in order to avoid the risk of large vehicles obstructing a highway when entering the site.

2.1.2 Controls Waste Acceptance

One of the purposes of the landfill classification system is to ensure that all hazardous waste is disposed of only on hazardous waste disposal sites.

Prior to waste being accepted at a waste disposal site, it must be inspected by suitably qualified staff and the transporter must confirm the type of waste. In the case of doubt, any industrial waste should be considered as potentially hazardous until proven otherwise. The operator at the working face of general waste sites must ensure that no hazardous wastes (e.g. hazardous liquids, sludge, solids or even sealed drums) are disposed of. Such controls are particularly important at general waste landfill sites (i.e. landfill sites for municipal/domestic wastes) in the vicinity of industrial areas.

In the event of hazardous waste being intercepted at a general waste landfill site, it must be diverted to a hazardous waste landfill site. The source, vehicle registration and a description of the waste must be reported immediately to the concerned Department. In the event that medical wastes are intercepted at either a general or a hazardous waste landfill site, it is a Minimum Requirement that the Responsible

Person or the permit holder immediately contacts the concerned Department for a directive in this regard.

At hazardous waste sites, all new enquiries for disposal of dry and liquid hazardous waste must be submitted to the Responsible Person with representative samples and a completed waste information sheet. Each load of such waste which subsequently arrives at the site must be sampled and tested for correlation with results of the original enquiry, prior to disposal. Waste which does not conform to the original specifications must be properly identified by testing in a laboratory, prior to its disposal on site. Any discrepancies must be reported to the client and appropriate steps must be taken to ensure the proper disposal of the waste. **In case that a waste cannot be identified, the precautionary principle must be applied and the waste must be regarded as falling into the most hazardous category**. This is particularly important in the case of **H:h** sites which are only permitted to accept waste with Hazard Ratings 3 and 4. Any unidentified wastes or wastes with Hazard Ratings of 1 and 2, arriving at an **H:h** site, may not be accepted and must be referred to an **H:H** site.

A record and a report on all wastes received, by the hazardous waste disposal site, must be sent periodically to the Concerned Department by the Site Operator. It must classify all hazardous wastes in terms of a recognized hazardous waste classification system and outline the disposal method used. Special care and consultation with the Concerned Department are necessary in the disposal of delisted hazardous wastes at **H:h**, **G:L:B$^+$** and **G:M: B$^+$** sites (see Site Selection and EIA guidelines).

Access control

In order to facilitate the above waste acceptance procedures, access to the site must be controlled. It is therefore a Minimum Requirement that vehicle access to a site be limited to a single controlled entrance, to prevent the unauthorized entry and illegal dumping of waste on the site. The site entrance must comprise a lockable gate (at least 7.5 m wide) which must be manned during hours of operation. Additional security, after operating hours, is required at all hazardous waste disposal sites. In addition to the gate, all sites must have the portion of the site currently in use adequately fenced and/or secured. In hazardous waste landfills, fences must be 1.8 m high, with an overhang and must be constructed of galvanized steel wire, or of other suitably sturdy and durable material. Where normal fencing is removed, or is not practicable because of continued theft despite security measures, barbed wire fences, earth berms and/or shallow trenches must be used to prevent vehicle access. In all events, however, the site boundaries must be clearly demarcated and measures must be taken to prevent unauthorized vehicle access.

Collection of disposal tariffs

Since the Minimum Requirements improve the standards of waste disposal, they as a result increase the cost. In order to offset these costs, waste disposal tariffs should be levied and collected at all landfill sites. Tariffs should be displayed on the notice board. They should be based on mass, where a weigh bridge exists, or on estimated volumes.

Security

In addition to access control, suitable security must be provided to protect the facilities and resources on site. It is a Minimum Requirement to prohibit unauthorized pedestrian access at hazardous waste disposal sites. Primarily, for the purpose of protecting public health and safety, waste reclamation should not be allowed at hazardous waste disposal sites.. Since fencing is not always effective, additional measures may be necessary in order to achieve this Minimum Requirement.

2.1.3 Operating Plan

An Operating Plan is a site specific document that will be developed as part of the Landfill Licensing Procedure. It describes the way in which the landfill is to be operated, commencing at the level and detail of daily cell construction and continuing through to the projected development of the landfill with time. Everything pertaining to the operation of a landfill should therefore be included in the Operating Plan, which is subject to regular update.

The complexity of the Operating Plan will vary with the class of site; this varies from a very simple plan, in the case of a **G:S** site, to a very detailed and sophisticated document for an **H:H** site. The Operating Plan would include, *inter alia*, the phasing, the excavation sequence and the provision of wet weather cells, site access and drainage. It would also include all operation monitoring procedures (see Section 3 on operation Monitoring) and a plan for mitigatory actions in response to problems detected by monitoring.

In drawing up the Operating Plan, cognizance must be taken of the input of Intrest and Affected Parties (IAPs) during the Feasibility Study and Permit Application Procedure. If necessary, certain issues, for example, the phasing of the operation, must be discussed and agreed with the IAPs, to whom access to the final plan will be given. In addressing the monitoring of operation, the Operating Plan must make reference to the role of a Monitoring Committee, which is to include IAPs (see Sections 3 on operation Monitoring). In the case of all hazardous waste disposal sites, a Response Action Plan is required to form part of the Operating Plan (see guidelines for Site selection and EIA). The Response Action Plan will detail procedures to be followed in case of failure in the design or operation. It will also include an emergency evacuation plan.

For hazardous waste landfills the Operating Plan must also address all items stipulated in Major Hazard Installation Regulations, governed under the Occupational Health and Safety local regulations. All failure modes and effects must be quantified in a risk assessment and on-site and offsite emergency plans developed.

2.1.4 Resources

Adequate facilities, equipment and suitably trained staff are required in order to ensure an ongoing environmentally acceptable waste disposal operation. It is therefore a Minimum Requirement to have sufficient resources towards sound operation.

Infrastructure

The facilities at a landfill site will vary in accordance with the size of the operation. Hazardous waste landfill sites would typically have services such as water, sewerage, electricity, telephones, security and infrastructure such as weighbridges, site offices

and plant shelters. In addition, an on-site laboratory would be a Minimum Requirement.

Plant and Equipment

The plant and equipment on site must be commensurate with the size and type of the operation. The type of equipment employed for all phases of the operation must therefore be of suitable capacity, specifications, and construction. Typically, larger sites would have a combination of purpose-built landfill compactors, bulldozers, front-end loaders and trucks to transport cover material. The Minimum Requirement is to provide sufficient suitable equipment, drivers and back-up to ensure environmentally acceptable waste disposal at all times. The plant and equipment must provide the means whereby the waste can be disposed of in accordance with the Minimum Requirements. It must also be maintained in good order, so as not to cause nuisances such as noise and air pollution.

Staff

It is a Minimum Requirement that the operation of all landfill sites be carried out under the direction of a Responsible Person. In the case of **H:h** sites and **H:H** sites, the Responsible Person must have the academic equivalent of a B. Sc. Degree with a Chemistry major and suitable experience. He/she must also be fully aware with the Hazard Rating system and its application. The Responsible Person must, in all cases, be supported by suitably qualified and competent staff. This staff complement would be commensurate with the size and type of the operation, as well as with the facilities and plant involved.

Sufficiently qualified staff and back-up are required to ensure that the Minimum Requirements relating to the operation are met. Where applicable, the Responsible Person must also ensure that the requirements of the local Occupational Health and Safety Regulations are met, with regard to visitors and site staff.

2.2 Landfill Operation

Waste deposition is carried out generally by following the sanitary landfill principles. In the case of hazardous waste, however, more stringent waste acceptance procedures, pre-treatment, co-disposal and encapsulation are addressed. The principles of sanitary landfilling and the variations on this method thus apply predominantly to general waste. These principles are, however, also applied to hazardous waste landfills in conjunction with other procedures, such as co-disposal, waste load allocations, pre-treatment etc.

2.2.1 Standard Operation (Landfilling)

To attain economically, environmentally and public acceptance requirements, all landfills, including hazardous waste ones, must be operated in accordance with the following sanitary landfill operating principles: i.e. waste must be compacted, and - covered at the end of each day of operation.

Compaction

Compaction is best achieved if the waste is spread in thin layers and compacted by a purpose-built landfill compactor. This compaction procedure is a Minimum Requirement at hazardous waste disposal sites.

Daily cover

The sanitary landfill definition specifies daily cover. It is therefore a Minimum Requirement that the waste be fully covered at the end of each working day. In certain instances, such as existing small or remote sites with a shortage of cover material, the Concerned Department may allow this Minimum Requirement to be appropriately amended. The consent of the IAPs would, however, be necessary before relaxation could be considered.

Most sanitary landfill operations are based on a series of trenches or cells which are prepared to receive the waste (figure 1). In either case, the general layout must be in accordance with the Operating Plan. Waste is deposited in trenches or cells, spread, compacted and covered, so that each day's waste is effectively isolated from the environment. The material to be used for cover may be on-site soil or builders' rubble or construction waste. With the approval of the concerned department, ash or other artificial covering can be used. In all cases, a strategic stockpile of cover, enough for at least three days, should be maintained close to the working face for use in emergencies.

Suitable equipment and resources must also be available to ensure that there is sufficient cover material, so that no area is left uncovered at the end of the day's operation. In the case of proposed sites, it is a Minimum Requirement in terms of both siting and design that provision is made for sufficient cover for landfill operation, throughout the projected life of the facility.

It is a Minimum Requirement that daily or periodic cover be sufficient to isolate the waste from the environment. A minimum thickness equivalent to the effective covering of 150mm of compacted soil is required. This thickness may, however, have to be increased in the case of poor quality cover. If the area is to be left for an extended period, but ultimately to be covered again with waste, the compacted thickness of this intermediate cover must be increased to 300mm. This is not as thick as final cover, but affords the additional protection required in the longer term.

2.2.2 Methods of landfilling: General waste

Sanitary landfilling standards can be applied using the following methods:

Trench system

In Class **G:C** and **G:S** landfills, where relatively small volumes of waste are disposed of, trenches are often made in preference to cells. Such trenches must be excavated on an ongoing basis during the operation. Nonetheless, this must always be done in accordance with the original design parameters and the Operating Plan. There must always be sufficient trench capacity on site to accommodate at least two week's waste. Trenches must always be suitably fenced or protected, and off-loading must be such that persons or vehicles cannot accidentally fall into the excavation. Waste is deposited into the trench, spread and compacted as much as possible, until it reaches a depth of between 0,5m and 1,0m. With the trench method, daily covering is always a Minimum Requirement, as spoil from the excavation makes this possible.

Standard cell operation (area Method)

The basic landfill unit is a cell of compacted waste which, when completed, is entirely contained by cover material. The sides are usually formed by 1,5m to 2,0m high

berms, constructed from soil, rubble, or sloped waste covered by proper cover. A series of adjoining cells of the same height is termed a lift. The working face is the active part of the landfill, where waste is deposited by incoming vehicles. ***The working face must be kept as small as possible for control and covering purposes.*** The width, however, is determined by the maneuvering requirements of the vehicles depositing waste. It should thus be sufficiently wide to avoid traffic congestion. There must also be sufficient cell capacity on site to accommodate at least one week's waste.

Where the cell system is applied, best compaction results are obtained when the waste is deposited at the bottom of the working face and worked up a 1 in 3 slope. Cover is then deposited and spread on the top of the cell during the day and extended to cover the working face at the end of the day. This is termed the Ramp or Area Method (figure 1).

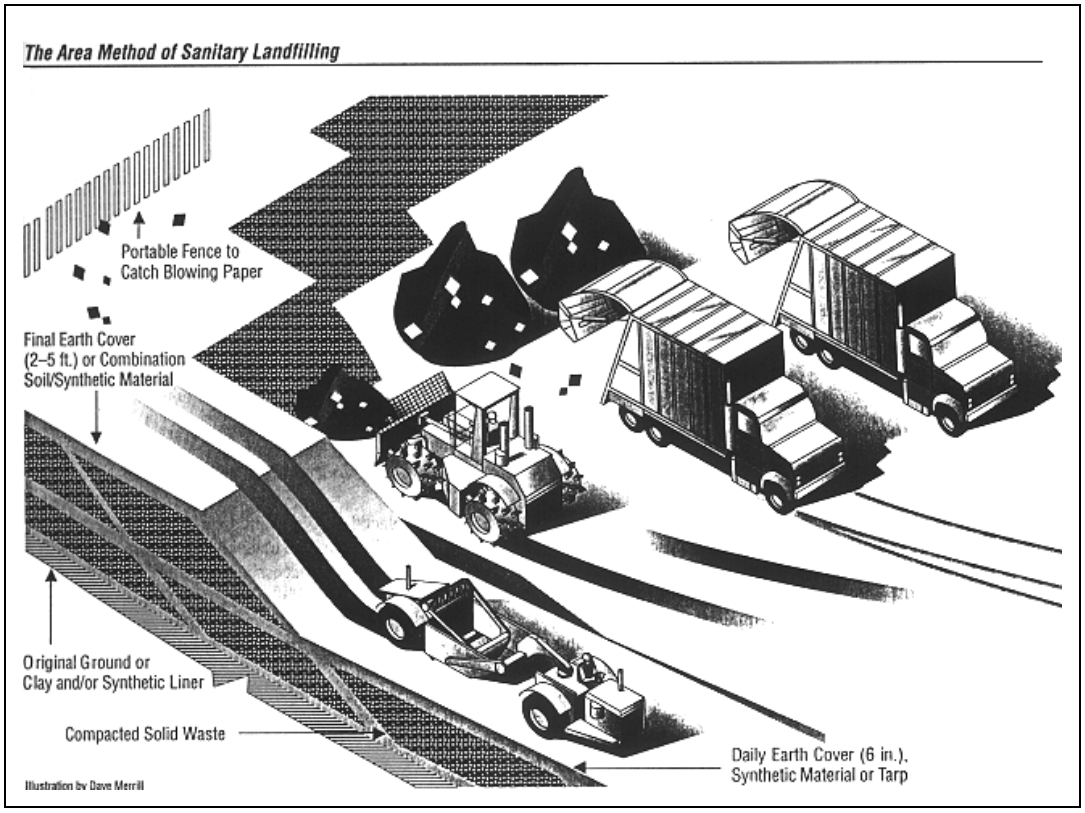

Figure 1: Ramp or Area Method of Sanitaery Landfilling

Wet Weather Cell

An easily accessible wet weather cell may be constructed close to the site entrance or close to an all weather road, for use under wet weather conditions (storms). The wet weather cell must have sufficient capacity to accommodate one week's waste. The cell should be constructed in the same manner as the standard cell. It should, however, have a well drained gravel type base in order to ensure vehicle access in wet weather. As far as possible, the wet weather cell should be operated in the same manner as the standard cell.

Methods other than standard cell operation

'End tipping' is the method whereby waste is pushed over the edge of an extended advancing face. This is not permitted on a normal landfill because it results in slope instability, minimal compaction and many other related problems. Exceptions to this may include some **G:C** and **G:S** sites, where waste has to be end-tipped into trenches.

2.2.3 Methods of landfilling: Hazardous waste

Hazardous wastes are disposed of on **H:H** or **H:h** landfills, depending on their hazard ratings. **H:H** landfills are specifically designed to accept wastes of Hazard Rating 1 or 2. They may, however, also accept all other wastes, including those with Hazard Rating 3 or 4 and general waste. **H:h** landfills are designed to accept hazardous waste with Hazard Rating 3 or 4. They may also accept general wastes, but they may **not** accept wastes with Hazard Rating 1 or 2. In cases where a waste is unidentified, the precautionary principle is applied and the worst case is assumed. The waste would therefore be assigned a hazard rating of 1 and diverted to an **H:H** site. It is a Minimum Requirement that hazardous waste landfills be designed and lined to the standards for **H:H** and **H:h, (see Guidelines For Hazardous Waste Landfill Design).** The requirements for hazardous waste site design and construction are intended to provide the most stringent level of containment. These requirements may apply to the whole site, to a specially lined or engineered cell, or to a section of the landfill designed specifically to accommodate hazardous waste.

Pre-treatment of hazardous wastes

The properties of certain hazardous wastes are such that they cannot be safely deposited directly into a landfill. In such cases, the wastes must be pre-treated to render them immobile, less toxic or less reactive.

A variety of treatment options exist. These are often interrelated but may be generally categorized into physical, chemical and biological treatment methods. Chemical processes include neutralization, precipitation, fixation and oxidation. Physical processes include incineration, blending and encapsulation. Biological processes include aerobic and anaerobic degradation of organic materials. Once a waste has been pretreated, the residue is disposed of in accordance with its hazard rating on the appropriate landfill. Unidentified wastes are also regarded as unacceptable for landfilling and will require identification, followed by appropriate treatment, pre-treatment or encapsulation.

Delisting of hazardous wastes

Delisting of hazardous wastes, involves treatment and/or hazard rating tests to confirm that the waste is of such low mobility or concentration, that it can be reclassified to a lower hazard rating. Such delisted wastes can then be safely disposed of on a lower class of landfill.

Co-disposal

Co-disposal refers to the mixing of liquid and dry wastes or to the mixing of general and hazardous wastes. **In modern hazardous waste landfill practices, co-disposal is not an acceptable method and should be avoided**. Please note that co-disposal ratios of liquid to dry waste are addressed in a separate document annexed with a software tool for its operation.

If co-disposal is carried out and approved by the Responsible Authorities, liquid wastes may be co-disposed with dry waste in order to soak up excess liquid and to avoid pool formation or unauthorised lagoon situations. General waste is frequently disposed of at hazardous waste landfills with a view to establishing a substrate in which to excavate trenches into which liquid hazardous waste is deposited. Co-disposal may also be used to advance the anaerobic degradation of leachate and to reduce its toxicity and that of any hazardous wastes involved.

The following special wastes may be subject of co-disposal in a secured hazardous waste landfill, unless otherwise prohibited by law or local Environmental Affairs Agencies.

- Bulk liquids and semisolid sludge which contain free liquid;
- Liquid or semisolid wastes including septage, black water, sewage treatment sludge, etc.;
- Biomedical waste as defined by local Environmental Affairs Agencies.
- Dead animals and slaughter house, fish hatchery and farming wastes or cannery wastes and byproducts.

Burial of these wastes in dedicated locations (i.e. avoiding co- disposal) at a landfill site may be approved only if there is no other viable alternative such as treatment/disposal, recycling, reprocessing or composting. Viability of alternatives is to be determined by the Responsible Authorities.

Miscellaneous

Three alternative types of waste disposal are grouped under this heading as they do not constitute standard landfilling practice. These are mono-disposal, lagooning and encapsulation. Mono-disposal refers to the disposal of a single waste type into a dedicated facility. Where a waste can be re-used, mono-disposal is a preferred option as it allows the waste to be easily reclaimed in the future. Mono-disposal may also be used as a way of delisting certain hazardous wastes, by ensuring that they are not disposed of with other wastes, which enhance their mobility. Although only one waste type is involved, a mono-disposal landfill must meet all the Minimum requirements associated with its class.

Lagooning, which is the practice of disposing of liquid wastes in lined lagoons, is sometimes classed as landfilling. Lagooning is considered to be beyond the scope of this document, since there are no set procedures for the operation of lagoons. However, it is a Minimum requirement that operations be approved by the Concerned Department prior to commencement in order to ensure environmental and public health protection.

Encapsulation is the practice of containing waste in concrete capsules. This is because, on account of the extreme hazards involved, certain wastes cannot be disposed of directly into a landfill. Where encapsulation is practiced it is a Minimum Requirement that the Permit Holder submits the specifications to the concerned Department for approval, prior to commencement (Refer to *Requirements for the Handling, Classification and Disposal of Hazardous Waste* in cited references).

Standard operating procedures

It is a Minimum Requirement that the off-loading of hazardous waste and co-disposal operations be executed under the jurisdiction of the Responsible Person. The Responsible Person must ensure that appropriate standard operating procedures are met. Aspects include:

- Ensuring the use of protective clothing (e.g. gloves, goggles and breathing apparatus) by workers
- Ensuring that no incompatible wastes, for example those which could cause explosions or the generation of poisonous gas, (e.g. cyanide and hydrochloride acid) are co-disposed
- Ensuring that the hazardous waste load allocation is not over permissible limits. Ensuring that the correct liquid/solid co-disposal ratio (that does not favor leachate generation) is adhered to.
- Ensuring immediate and/or daily covering
- Ensuring that there are no free liquid surfaces left at the end of the day's operation.

It is also essential that the Responsible Person and the workers know and can execute the content and the requirements of the Response Action Plan for the site, in case of an emergency.

2.2.4 Co-disposal

In order to regulate the practice of co-disposal, it is a Minimum Requirement that documentation be drawn up describing the waste load allocations and liquid co-disposal ratios. An operating procedure and a Response Action Plan, suitable for the hazardous waste disposal operation under consideration, are also Minimum Requirements**.**

The waste load allocations, liquid co-disposal ratios, operating procedure and Response Action Plan must be written into the Environmental Impact Control Report. This must be presented to, and accepted by the Concerned Department before the operation commences.

More details on Co-disposal can be found in annex 2

2.2.5 Disposal of Medical Wastes

The disposal of medical wastes at any landfill site is prohibited. Incineration of medical waste is a prerequisite to disposal. The ash must be disposed of under dry conditions at an approved hazardous waste site, unless negotiated otherwise with the Concerned Department. In the event of an emergency and in the interests of public health and the environment however, the Concerned Department will consider applications for the disposal of medical waste into a specially constructed dry cell within an approved site. Such disposal would be under controlled conditions and for a limited period of time, and it is a Minimum Requirement that the Concerned Department be approached for directives in this regard and that all key role players and IAPs be consulted. Where past practice has been to dispose of medical waste on general waste landfills, the Concerned Department must be informed and consulted for directives for the future management of the situation. It is recommended to consider the Basel Convention Technical Guidelines on the Environmentally sound Management of the Biomedical and Healthcare Wastes (Y2; Y3) and the Preparation of National Health Care Waste Management Plans in Sub-Saharan Countries; Guidelines Manual.

2.3 Other Elements of the Operation

2.3.1 Excavation for Cover

Where cover is excavated on site, the Responsible Person must ensure that the separation between the floor of the excavation and the wet season high elevation of the ground water, as specified in the design, is maintained. This will ensure that an adequate separation between the future waste body and the ground water will be maintained, should the excavation be used for waste disposal in the future. Excavations must also be properly drained to avoid ponding of accumulated surface water, especially near the waste body. Where the base of such an excavation forms the base of the landfill, it should be sloped to direct leachate to a control point. In all cases, but particularly in the case of **B**$^{+}$ and hazardous waste landfills, the base should also be appropriately lined (see Guidelines for landfill design).

2.3.2 Drainage

The principles of landfill site drainage are as follows:

- Upslope run-off water must be diverted away from the waste, to prevent water contamination and to minimise leachate generation.
- Where contaminated water or leachate does arise on a site, it must be managed. This means that it must be kept out of the environment. This also applies to the drainage from wash bays and spills at hazardous waste landfills.
- Clean, uncontaminated run-off water must not be permitted to mix with, and increase the volume of, contaminated water. The principles of the main drainage system are presented in the site design (see Guidelines for landfill design). All upslope cut-off and toe drains, must be in place before the landfill is commissioned.

The following are Minimum Requirements:

- Run-off and storm water must always be diverted around one or both sides of the waste body, by a system of berms and/or cutoff drains.
- Water contaminated by contact with waste, as well as leachate, must be contained within the site. If it is to be permitted to enter the environment, it must conform or be treated so as to conform to the general effluent standards set in local laws.
- The bases of trenches and cells must be so designed that water drains away from the deposited waste. Alternatively, cells must be so orientated as to facilitate drainage away from deposited waste. The resulting contaminated water, together with all other contaminated run-off arising from the landfill, must be stored in a sump or retention dam. It may be pumped from the dam and disposed of if it conforms to the, general or specific effluent standards stipulated in the local laws.
- A 0.5m freeboard, designed for the 1 in 50 year flood event, must always be maintained in the case of contaminated water impoundments and drainage trenches.
- All temporarily and finally covered areas must be graded and maintained to promote run-off without excessive erosion and to eliminate ponding or standing water.
- Clean, uncontaminated water, which has not been in contact with the waste, must be allowed to flow off the site into the natural drainage system, under controlled conditions.

- All drains must be maintained. This involves ensuring that they are not blocked by silt or vegetation.

2.3.3 Control of Nuisances

Nuisances resulting from the landfill operation should be controlled as follows:

Burning of waste

At present, the burning of waste is a common practice at many landfills. This is to reduce the volume of waste and its attraction to vermin and livestock. The burning of waste is not allowed (forbidden) at hazardous waste landfills.

Litter

It is a Minimum Requirement that all litter be contained within the site. This may be achieved by compaction and cover. On sites characterised by high winds, however, movable litter fences are a Minimum Requirement. Windblown litter must be picked up and removed from fences and vegetation routinely.

Odors

Odors must be combated by good cover application and maintenance. Furthermore, the prompt covering of malodorous waste to reduce odor problems is a Minimum Requirement. In extreme cases, odor suppressants such as spray curtains may be required. Where breaches in the cover from which significant volumes of landfill gas escape are identified by their odor, proper investigation is a Minimum Requirement. This may be followed by properly engineered passive or active gas venting and flaring, to alleviate odor problems.

Noise

All equipment used on site must conform to the local authority's by-laws concerning noise levels and hours of operation. In the absence of by-laws, national regulations on noise control must be complied with.

Vermin and disease vectors

It is a Minimum Requirement that landfill sites be kept free of vermin. Appropriate measures must be taken to eliminate or minimize disease vectors such as rats or flies.

Dust

Unsurfaced roads and un-grassed or unpaved areas, which give rise to dust problems, must be regularly watered to restrict dust to levels which do not pose a nuisance to workers or users of the facility.

Waste reclamation

At present, both uncontrolled salvaging and controlled reclamation take place at many landfills. While the ethic of reclamation from the waste stream is supported, reclamation at hazardous waste landfills can endanger the health and safety of the reclaimers. On account of the risks to health and safety, therefore, **waste reclamation is discouraged at hazardous waste landfill sites.**

Specifically, it is a Minimum Requirement that no waste reclamation be permitted at hazardous waste landfill sites. **It is noted that responsibility for the safety of any reclaimers on the site rests with the site manager or the permit holder, who will be required to enter into an indemnity agreement with concerned departments.**

It is a Minimum Requirement that any reclamation operation be formalised in the Operating Plan. This would include regular consultation with and registration of reclaimers and the provision of appropriate safety measures. Safety measures would include the separation of reclamation from compaction and covering activities, and the provision of safety clothing.

2.3.5 Leachate and Gas Management

In $\mathbf{B^+}$ landfill sites, significant leachate is generated and leachate management is mandatory. The design for such sites will include a leachate management system. As with the drainage system, however, the leachate management system requires to be maintained and continuously adapted and developed, as the landfill develops. Where treatment is involved, a whole separate operating procedure must also be adhered to. This procedure would be written up in the Operating Plan.

At hyper dry and/or $\mathbf{B^-}$ sites, any sporadic leachate generated on account of unusual circumstances must be both reported to concerned department and properly controlled (see Section on drainage). This could also include leachate recycling.

Where a gas management system exists at a site, it must be correctly operated, maintained and monitored to ensure that any landfill gas emanating from the site is properly managed.

2.3.6 Progressive Rehabilitation of Completed Areas

The progressive rehabilitation of landfills by means of capping and the subsequent establishment of vegetation is a Minimum Requirement. Capping should be implemented on all areas where no further waste deposition will take place, and vegetation should commence as soon as possible.

Screening berms are the first areas where vegetation must be established. This ensures that waste disposal operations take place behind vegetated berms. These are extended upwards in advance of the disposal operation to ensure continued screening. This is referred to as the 'rising green wall' approach. All final levels and slopes must be in accordance with the landfill design and an End-use Plan. Slopes should not be steeper than 1 in 2,5, as this will promote erosion.

2.3.7 Final Cover

Immediately on completion of an area, the final cover must be applied. The thickness of the final cover must be consistent and in accordance with the design. The final cover must comprise material capable of supporting the vegetation called for in the End-use Plan. In order to prevent erosion and improve aesthetics, re-vegetation should commence as soon as possible after applying the final cover in order to rehabilitate on an ongoing basis. All covered surfaces on the landfill must be so graded as to promote run-off to prevent ponding. Desert plants should be foreseen for hyper dry areas, so that the need for irrigation water is minimal.

2.3.8 Public Participation in the Operation

The standard of operation at a given landfill may be monitored and enforced by a Monitoring Committee. This should comprise representatives of the concerned departments, the operator and representatives of those affected by the landfill. The objective of this committee is to provide a mechanism whereby the needs and concerns of the IAPs can be addressed in the operation of the facility. In the interests of transparency, IAPs should, through the Monitoring Committee, be given access to the site and information relating to the operation.

Table (1) summarizes minimum requirements for landfill operation.

Table 1: Minimum Requirements for Landfill Operation

(After Department of water affairs and Forestry (RSA),1998).

LEGEND **B -= No significant leachate produced** **B+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Comunal Landfill**		**S** **Small Landfill**		**M** **Medium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
Minimum Requirement	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**		
Facilities & Resources Signposting	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
All weather roads	**N**	**N**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**
Controls Waste acceptance procedure	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Fencing	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Control of vehicle access	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Site security	**N**	**N**	**F**	**F**	**F**	**F**	**R**	**R**	**R**	**R**
Operating Plan	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Response action plan	**N**	**N**	**N**	**N**	**F**	**F**	**F**	**F**	**R**	**R**
Waste load allocations	**N**	**N**	**N**	**N**	**N**	**F**	**N**	**F**	**R**	**R**
Liquid Co-disposal ratios	**N**	**N**	**N**	**N**	**N**	**F**	**N**	**F**	**R**	**R**
Encapsulation specifications	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**R**	**R**
Resources & Infrastructure Weighbridge	**N**	**N**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**

Cont. Table 2: Minimum Requirements for Landfill Operation

(After Department of water affairs and Forestry (RSA),1998).

LEGEND **B -= No significant leachate produced** **B+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Comunal Landfill**		**S** **Small Landfill**		**M** **Medeium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
Minimum Requirement	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**		
Collection of Waste disposal tariffs	**N**	**N**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**
Site office	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Laboratory	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**R**	**R**
Adequate plant and equipment	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Responsible Person	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Sufficient qualified staff	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Operating Plan	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill Operation Compaction of waste	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Daily cover	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Two week's cell or trench capacity	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Protection of unsafe excavations	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
One week's wet weather cell capacity	**N**	**N**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Immediate covering of putrescibles	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
End-tipping prohibited	**N**	**N**	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**
Three days' stockpile of cover	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Final cover	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Waste reclamation prohibited	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**R**	**R**

Cont. Table 3: Minimum Requirements for Landfill Operation

(After Department of water affairs and Forestry (RSA),1998).

LEGEND **B -= No significant leachate produced** **B+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Comunal Landfill**		**S** **Small Landfill**		**M** **Medeium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
Minimum Requirement	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**		
Any reclamation operation formalised in Operating Plan	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**n/a**	**n/a**
Registration of reclaimers	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**n/a**	**n/a**
Protection of reclaimers	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**n/a**	**n/a**
Protective clothing	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**n/a**	**n/a**
Control of nuisances	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Waste burning prohibited	**F**	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**
Draining water away from the waste	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Contaminated run-off contained	**F**	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**
Leachate contained	**N**	**F**	**F**	**R**	**F**	**R**	**F**	**R**	**R**	**R**
Storm water diversion measures	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
0,5m freeboard for diversion and impoundments	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Grading Cover/ avoiding ponding	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
General site maintenance	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Sporadic leachate reporting	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill gas control	**N**	**N**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
Rehabilitation and vegetation	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

3. OPERATION MONITORING

The general objective of landfill operation monitoring is to verify that the landfill impact is minimum and that the operation complies with standards of the site Permit.

More specific objectives are:

- To ensure that the approved site design is properly implemented.
- To quantify any effect that the operation has on the environment, and, in particular, any effect on the water regime.
- To serve as an early warning system, so that any problems that arise can be *timely* identified and rectified.

The standards referred to are those required by the Minimum Requirements and the site Permit. They might include the proper compaction and covering of waste, the integrity of drainage systems and the consideration of site impact. Major impact would include ground or surface water pollution as a result of malfunctioning drainage systems, cracks in the cover, or leaking liners.

Any problems identified must be rectified as soon as possible. In addition, monitoring serves as a performance indicator, and hence as a control or management tool, for the landfill operator. In this context, monitoring is a general term used as described above. Monitoring may be carried out by means of site inspections or audits, data collection, sampling, analysis and interpretation. It also involves monitoring the response of IAPs.

3.1 Background

There are several ways in which waste disposal sites may be monitored or audited, the most common are:

- Via Landfill Monitoring Committee which includes IAPs may be formed to assist in monitoring landfill operations, to identify problems and to keep the public informed of activities/developments on the landfill. Landfill Monitoring Committees are a Minimum Requirement at all Hazardous and Large landfills.
- Via routine inspections of waste disposal sites by the regulating or environmental concerned departments to identify unacceptable situations.
- Via clients (waste generators) who frequently audit the operation of private sector hazardous waste landfills to ensure that their waste is being properly disposed of. This is because they remain responsible for the waste which they generate, in terms of the Duty of Care principle.
- Via institutes of Waste Management that can be used by a Permit Holder to audit a site for the
- Purposes of accreditation.
- Via the use of consultants (by Permit Holders) to conduct external audits of their facilities or to monitor their operations or those undertaken by contractors on their behalf. It is a Minimum Requirement that all Hazardous and Large landfills keeps yearly audits.
- Via internal inspections or audits instituted by the permit holders.

The above applications of auditing, or monitoring, may be used individually, or in various combinations. However, they all provide means of control.

3.2 The Required Extent and Frequency of Monitoring

The extent and frequency of monitoring will depend on the site classification and will be indicated in the permit. It is the duty of the Responsible Person to ensure that the Minimum Requirements for operation monitoring are applied to a degree commensurate with the class of landfill, the situation under consideration and the risk of polluting the environment, more specifically the water regime.

Monitoring must be carried out to the satisfaction of the concerned department or authorities. The Responsible Person may be required to provide additional information. This could include details about airspace utilisation and cover volumes used or waste stream data analyses. The information required would be determined by site-specific needs and the Responsible Person would have to liaise with the Concerned Department in this regard.

3.3 Landfill Site Auditing

The waste disposal operation is usually monitored by means of a landfill site audit. All landfills should be audited and inspected to ensure the maintenance of acceptable standards. At hazardous waste landfills, the audit committee may consist of the Permit Holder, or the Responsible Person, the Concerned department's regional or national office inspectorate and, where applicable, relevant consultant(s).

At general waste landfills, the audit committee may be reduced. All audit committees should be set up in consultation with the concerned department. The initial frequency of the audit must be agreed upon by all the parties concerned, during the planning stages when the IAPs are consulted. Audits should occur at monthly intervals for hazardous waste sites. Where problems occur, this frequency may be reviewed in consultation with the Concerned Department and the IAPs.

General aspects of a landfill site audit would include consideration of site security, site access, condition of roads and traffic control. The actual waste deposition would be addressed in terms of cell construction, waste deposition, spreading, compaction and covering.

At hazardous waste sites, pretreatment and co-disposal would also be addressed. Operating procedures as specified in the Operating Plan would also be carefully appraised, as would aspects such as drainage, litter control and aesthetics. Similarly, all site specific Permit conditions and design requirements would be addressed. Details of how such an audit is conducted should be developed by the concerned department.

The audit programme should, however, include the following:

- A checklist of items to be audited
- A report on the findings of the audit
- A record of performance.

A record of any identified problem areas and the recommended actions to rectify these problems must be submitted to the Responsible Person for implementation. The

audit results must be made available to the IAPs through Landfill Monitoring Committees, so that any problems identified can be discussed and addressed. A record of complaints received and actions taken must also be maintained.

3.4 Other Monitoring

In addition to the landfill site audit, monitoring may comprise the collection, processing and interpretation of certain data. The required data, the format and the frequency with which it must be presented to the concerned department would be specified in the Permit conditions.

Most of the procedures outlined here would be included in the Operating Plan, which would also make provision for certain actions to be taken in response to any problems identified during monitoring.

3.4.1 Gate or Weighbridge Recording Procedures

Landfill site operators, facility users and the concerned department will all require waste disposal records for different reasons. Over and above the measurement of incoming waste for commercial purposes, records are also necessary for site management and control. Such records are obtained from record keeping at the gate or weighbridge. The method of waste recording must be appropriate to the nature and the volume of the wastes entering the site. The degree of sophistication required will be dependent on the class of site involved. In general, however, records must be kept of all waste entering the site. Waste must be categorised by the number of loads (defined by volume or mass), the type of waste and the source. Hazardous waste must also be defined in terms of its hazard rating. Records must be kept on both a daily and a cumulative basis. These should be maintained and archived. With the accumulation of records, a data base must be established and maintained at the landfill site. In the case of hazardous waste landfills this must be extended to the recording of the position of all hazardous waste disposed on site, on a weekly basis, in terms of both plan and elevation, i.e. in three dimensions. In the case of the encapsulation of waste with a Hazard Rating of 1 or 2, the exact co-ordinates of the encapsulation cells must be recorded.

3.4.2 Volume Surveys

At all landfills, some idea of the remaining volumetric capacity is required.. At all hazardous waste sites, however, surveys must be performed with the appropriate instruments and accuracy. The entire site must be surveyed prior to commencement of waste disposal and annually thereafter.

3.4.3 Collection and Processing of Other Data

Certain climatic statistics must be collected and analysed for control purposes and for the successful operation of landfills where co-disposal of waste with high moisture content or liquids takes place. These may include rainfall from rain gauges, wind speed and direction, and A-pan evaporation rates. Such information would provide the insight required to manage the site water balance.

3.4.4 Monitoring Leachate and Water Quality (see Section 3.5)

Regular sampling and analysis of leachate, ground and surface water, and the interpretation of the findings, must be ensured by the Permit Holder. Records must be maintained of any impact caused by the landfilling operation on the quality of the

water regime in the vicinity of the site. This is very often required by the concerned department in terms of the Permit conditions. Additional samples may be taken at other times, if this is considered necessary.

3.4.5 Monitoring Gas Emissions

Landfill gas has a distinctive and unpleasant odour, which is frequently the reason for complaints by IAPs. Landfill gas can, however, also pose an explosion hazard, where methane gas reaches concentrations of between 5% and 15% of atmospheric gas composition. The risk of gas explosion must therefore be continually monitored. If monitoring indicates that there is any safety risk on account of landfill gas accumulation and/or migration, controls must be considered in consultation with the concerned departments.

While gas monitoring is a Minimum Requirement at all Hazardous and Large landfills, monitoring systems must be installed whenever potential gas problems exist .These must be monitored at three monthly intervals during the operation and at the discretion of the concerned department after site closure. If the soil gas concentrations exceed 1% by volume at Standard Temperature and Pressure (STP), the concerned department must be informed. Methane concentration in the atmosphere inside buildings on or near the site should not exceed 1% (by volume) in air, i.e. 20% of the Lower Explosive Limit (LEL). If the methane levels are found to be between 0,1% and 1% in air (i.e. between 2% and 20% of the LEL) then regular monitoring must be instituted. If levels above 1% (i.e. 20% of LEL) are detected, then the building must be evacuated and trained personnel consulted. Methane levels on landfill boundaries should not exceed 5% in air (i.e. the LEL). This should apply to the air above the surface and also to the air in a hole dug into the earth on the boundary. If the methane levels are found to be between 0,5% and 5% in air (i.e. between 10% of LEL and LEL) then regular monitoring of the boundary should be instituted. If the methane levels are found to be greater than 5% in air, then a permanent venting system should be implemented. Apart from explosion potential, however, landfill gas also contains a wide range of volatile organic compounds that are classified as hazardous air pollutants. Where significant landfill gas is present, therefore, samples must be taken at various positions at the landfill site, and characterised for volatile organic compounds. Sampling can be direct at gas wells, or using the standard techniques. The volatile organic compound compositions of the landfill gas must then be subjected to occupational and environmental health risk assessments. This must be done at the discretion of the concerned department to ensure against unacceptable health risks to workers or communities. Gas monitoring should continue after landfill closure, until the concerned department is satisfied that landfill gas no longer represents a risk.

3.4.6 Monitoring Air Quality

At all landfills the risk of dust and the escape of contaminants by wind action does exist. Hazardous pollutants may be dispersed from a landfill site as dust, or as gaseous substances. These have to be monitored separately.

Dust monitoring

Because of many sources of dust and variations in wind characteristics and other meteorological parameters, ambient air monitoring for dust concentrations at landfill sites has limitations. It is preferable to characterize the possible sources of dust on the

landfill site in terms of hazardous metals, anions, and semi-volatile organic compounds that are normally particulate-associated, and then to model dispersion.

This approach entails sampling of dust that can be suspended, using a sampling approach that would ensure statistically that samples are representative of all possible sources of hazardous substances. Chemical analyses must cover all substances that may be relevant to the materials and activities, using validated methods in a formal quality assurance structure.

Mathematical modelling of dust released from an area source, using the source profiles of hazardous substances, must then be conducted to provide the necessary information to assess human exposure, and health risks. The mathematical dispersion modelling can be done at the beginning of the monitoring programme, and the model can then be used with new input data after each analytical survey. The on-site dust at the landfill site must be characterised at least once per year, or more frequently when activities on the site may change the dust compositions. The Concerned department may request analyses of dust sources, followed by mathematical dispersion modelling and human health risk assessment, at more frequent intervals if hazardous substances are present at levels that may lead to unacceptable health risks to workers or communities.

Monitoring for releases of volatile substances

Volatile substances include organic and inorganic substances. These may be released as constituents in the landfill gas, or through mass transfer from the liquid or solid phases of the waste to the gas phase. There are four basic assessment approaches for assessing emission rates of hazardous substances from landfill sites, i.e.:

- Direct measurement technologies
- Indirect measurement technologies
- Fence line monitoring and modeling technologies
- Predictive emission modelling.

Direct measurement using a surface emission isolation flux chamber has been selected as the preferable technique in the USA to characterise area source facilities with hazardous fugitive emissions. It can be used on any liquid or solid surfaces that are accessible for testing. Other methods endorsed by the concerned department can be used. The location and number of test points must be adequate to enable calculation of the emission rates of substances from the total area. Sampling and analysis must cover the complete range of substances that are relevant to the source. The data must then be used in a mathematical dispersion model to predict exposure levels for the quantification of occupational and environmental health risks. Sampling and analytical techniques that are used to monitor emission rates of hazardous substances must satisfy data quality objectives, i.e. the technologies must be applicable for testing area source emission rates, and must account for the key factors that influence the variability in the area source estimate. The frequency of sampling and analysis would depend on the level of identified risk, but must be at least once per year when activities and waste profiles do not change. After changes that could influence the emissions profiles, measurements must be made to establish the new profiles and associated occupational and environmental health risks.

3.4.7 Monitoring of rehabilitated areas

Completed areas require ongoing inspection and maintenance. This includes the repair of cracks and erosion gullies which allow water to access the waste and from which malodorous gases escape, and the filling in of settlement depressions and/or cavities due to subsidence or caused by fire. Ongoing maintenance of the established vegetation is required for a period specified by the concerned department.

3.4.8 Health of Workers

In terms of the Occupational Health and Safety, the Employer should be responsible for the health and safety of the people under his or her jurisdiction. Whenever workers or waste reclaimers are exposed to waste on a regular basis, a health risk may exist. This risk is, however, greater at a hazardous waste landfill than at a general waste landfill. The Responsible Person must therefore use his or her discretion in applying the health and safety regulations and monitoring the health of workers. In the case of the hazardous waste landfill sites, this will involve routine medical examinations.

3.5 Monitoring Quality of Water

The principal objective of minimum requirements for waste disposal by landfilling is to ensure full protection to usable surface and ground water resources. Monitoring ground water quality starts prior to construction of the landfilling facility and continues during operation and extends after landfill closure. Water quality monitoring enables permit holder to comply with regulations and serve as early warning system for leaking through the lining system. Water quality monitoring is the responsibility of the permit holder who has to develop and implement an efficient monitoring plan. Groundwater monitoring program should include parameters to be measured, sampling, analysis, and reporting.

3.5.1 Parameters

The parameters to be analyzed in the samples taken must be derived from the expected composition of the leachate and the groundwater quality in the area. In selecting the parameters for analysis, account should be taken of mobility in the groundwater zone. Parameters could include indicator parameters in order to ensure an early recognition of change in water quality. Table (2) depicts parameters to be monitored. Other parameters can be added by the responsible person or the concerned department.

Table 4: Water Quality Monitoring Parameters

Electrical Conductivity (EC)	Ammonia (NH_3as N)
Free and Saline Ammonia as N (NH_4-N)	Alkalinity (Total Alkalinity)
Magnesium (Mg)	Lead (Pb)
Mercury (Hg)	Boron (B)
Nitrate (as N) (NO_3-N)	Cadmium (Cd)
pH	Calcium (Ca)
Phenolic Compounds (Phen)	Chemical Oxygen Demand (COD)
Potassium (K)	Chloride (Cl)
Sodium (Na)	Chromium (Hexavalent) (Cr_{6+})
Sulphate (SO_4)	Chromium (Total) (Cr)

Total Dissolved Solids (TDS)	Cyanide (CN)

The impact of the landfill on water quality is assessed when comparing between water quality before (ambient water quality) and after disposal activities, and the down gradient concentrations. This will infer whether the pollution is due to contaminated surface water or to leachate leaving the site.

3.5.2 Sampling

The measurements must be such as to provide information on groundwater likely to be affected by the discharging of waste, with at least one measuring point in the groundwater inflow region and two in the outflow region. This number can be increased on the basis of a specific hydro geological survey and the need for an early identification of accidental leachate release in the groundwater. In the case of both surface and ground water sampling, clean bottles should be used. These should be rinsed with the sample water, prior to taking the sample. Sample treatment prior to analysis would be the same in both cases and is indicated in the above references. Sampling must be carried out in at least three locations before the filling operations in order to establish reference values for future sampling. Sampling and treatment of samples, and analysis should follow international standards for water analysis.

3.5.3 Analysis and Reporting

The analysis of the samples must be performed in accordance with the international Standards. Alternatively, the analyses may be performed using equivalent methods which are to the satisfaction of the Concerned Department. Analyses must be performed by accredited analysis laboratories. Any use of non-accredited laboratories shall require acceptance from the concerned department.

The need for adjustment of the analysis programme for groundwater control should be evaluated on an ongoing basis in the light of the results of the leachate control. For example, in the event of significant changes in the composition and degree of pollution of the leachate, there might be a need for adjustment of the analysis programme.

After commissioning of the landfill the fundamental basis for determining the analysis frequency is that any pollution from leachate must not be able to move so far during the interval between two samplings that measures cannot be taken to stop the pollution.

This means that the frequency of analysis becomes dependent on the flow rate of the groundwater and, for each landfill, must be determined on the basis of an estimate thereof. The minimum frequency is two groundwater checks per year during the active phase of the landfill.

The ground and surface water quality results from the pre-operation monitoring, together with the annotated designs of the monitoring systems, must be submitted to the Concerned Department as part of the Permit Application Report, i.e. the Water Quality Monitoring Plan.

Table (3) summarizes minimum requirements for landfill operation monitoring, while table (4) summarizes minimum requirements for water quality monitoring.

Table 5: Minimum Requirements for Landfill Operation Monitoring

(After Department of water Affaires and Forestry (RSA), 1998.

LEGEND **B -= No significant leachate produced** **B_+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G General Waste								**H Hazardous Waste**	
	C Comunal Landfill		**S Small Landfill**		**M Medeium Landfill**		**L Large Landfill**		**H:h Hazard Rating 3 & 4**	**H:H Hazard Rating 1-4**
Minimum Requirement	**B_-**	**B_+**	**B_-**	**B_+**	**B_-**	**B_+**	**B_-**	**B_+**		
Responsible person	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill monitoring committee	**N**	**N**	**F**	**F**	**F**	**F**	**R**	**R**	**R**	**R**
Conduct audit	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Conduct external audit twice per year	**N**	**N**	**N**	**N**	**N**	**N**	**R**	**R**	**R**	**R**
Appropriate records and data collection	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Record deposition Rate	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Waste stream records	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Landfill volume survey	**N**	**N**	**N**	**N**	**R**	**R**	**R**	**R**	**R**	**R**
Collect climatic statistics	**N**	**N**	**N**	**F**	**N**	**R**	**N**	**R**	**R**	**R**
Water quality monitoring	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Gas monitoring and control	**N**	**N**	**F**	**F**	**F**	**F**	**R**	**R**	**R**	**R**
Air quality monitoring	**N**	**N**	**F**	**F**	**F**	**F**	**F**	**F**	**R**	**R**
Monitoring of progressively rehabilitated areas	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Ongoing maintenance	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Table 6: Minimum Requirements for Water Quality Monitoring

(After Department of water Affaires and Forestry (RSA), 1998.

LEGEND **B -= No significant leachate produced** **B+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G General Waste								**H Hazardous Waste**	
	C Comunal Landfill		**S Small Landfill**		**M Medeium Landfill**		**L Large Landfill**		**H:h Hazard Rating 3 & 4**	**H:H Hazard Rating 1-4**
Minimum Requirement	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**		
Designate a Responsible Person	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Pre-operation monitoring Surface water	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Groundwater monitoring	**N**	**N**	**F**	**R**	**F**	**R**	**R**	**R**	**R**	**R**
Documented ambient water quality	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Water analysis for Investigative parameters indicated	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Standard analyses methodology	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Operation Monitoring Surface Water Monitoring	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Groundwater monitoring	**N**	**F**	**R**	**F**	**R**	**R**	**R**	**R**	**R**	**R**
Leachate monitoring	**N**	**F**	**N**	**R**	**N**	**R**	**N**	**R**	**R**	**R**
Report sporadic leachate	**F**	**F**	**F**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Post Closure Monitoring Surface water monitoring	**N**	**F**	**N**	**R**	**F**	**R**	**R**	**R**	**R**	**R**
Post closure groundwater monitoring	**N**	**F**	**N**	**R**	**F**	**R**	**R**	**R**	**R**	**R**

4. AFTERCARE (REHABILITATION, CLOSURE AND END USE)

The landfilling process does not come to end when attaining the final contour. A transitional phase for final covering should be commenced prior to closure. This includes covering the uppermost waste layer with a relatively thick and composite soil layer that facilitate the end- use of the site.

Closure is the final step in the operation of a landfill. In order to close a landfill properly, however, rehabilitation should precede closure to ensure that the site is environmentally acceptable. The site must also be prepared for its proposed end-use set out in the End-use Plan.

Where bad practice has occurred, this must be rectified by means of remedial measures. Once the operation has ceased, aftercare is necessary to ensure sustained acceptability.

The objectives of landfill closure phase are:

- To ensure public acceptability of the implementation of the proposed End-use Plan.
- To rehabilitate the landfill so as to ensure that the site is environmentally and publicly acceptable and suited to the implementation of the proposed end-use.

Where it is intended to close a landfill, the Permit Holder (operator) must inform the concerned department of this intention prior to closure and to allow for time necessary for rehabilitation and closure activities. This is because certain procedures must be implemented and criteria met before closure. If the site is permitted, it must be rehabilitated in accordance with the Permit conditions and the relevant Minimum Requirements for closure.

Regardless of whether a landfill is permitted or not, it must be investigated before rehabilitation and closure can commence, so as to identify any closure requirements that must be implemented.

Based on the results of the investigations, a closure or upgrade design may be drawn up and presented in a Closure Report. In this report, the current status of the landfill is compared with the identified end-use and closure requirements, and recommendations are made regarding required rehabilitation.

The Closure Report must be approved by the concerned department and the IAPs before rehabilitation can start. Once the landfill has been rehabilitated in accordance with the Closure Report, the Permit Holder must notify the concerned department in writing of the intended closure of the site, at least 60 days prior to the event or as required by the concerned department. Should the concerned department approve the condition of the landfill, the Permit Holder will be provided with written acceptance

to close the site. The site may then be closed and the End-use Plan may be implemented. Thereafter, the site must be monitored on an ongoing basis.

4.1 Determination of End-use Requirements

The end-use of a landfill refers to its after-use, i.e. how it will be developed after closure. The most common landfill end-use is open space, which may be used for sport and recreation. Other end-uses also exist and will be accepted if they are safe.

In hyper dry and desert areas the most common end use is recreation. No public access or constructions will be permitted onto closed hazardous waste landfills, because of the hazardous nature of the wastes contained therein. This must be clearly indicated by signposting. In exceptional circumstances, where very conservative designs are involved, however, relaxations may be motivated and considered.

The end-use requirements are determined from the Requirements and needs of the IAPs. The IAPs are consulted regarding their end-use requirements during the feasibility study. The End-use Plan is usually drawn up as part of the design. With time, however, the situation associated with the landfill may well have changed. The end-use requirements must therefore be reassessed and redefined. Consequently, before closure, the IAPs must again be consulted regarding the end-use.

4.2 Investigation of the Landfill to Determine Closure Requirements

The closure investigation must be carried out to identify the causes of any existing problems and to provide the basis for the closure requirements. The extent of the investigation will depend on the amount of investigation already completed, the existing problems and the potential environmental impact of the site. The investigation would adhere to the principles set out in the EIA section.

Closure requirements are those rehabilitation measures that must be taken to render a landfill environmentally suited to its proposed end-use. Where problems have resulted from bad practice, remediation is required. This may include remedial work with regard to drainage, leachate management and cover integrity. The closure requirements are included in the remedial or Closure Design.

4.3 Closure Design

The Closure Design takes all closure requirements into account and should adhere to the design principles set out in the Landfill Design document. In the case of un-permitted operating or closed landfills, it may represent the first landfill design submitted, while in the case of a permitted landfill it will involve amendment to an existing design. Closure Designs usually entail remedial design. In some cases, where landfills were not designed or operated in accordance with the Minimum Requirements, significant remediation may be required. In all cases, the concerned department must be consulted.

Aspects addressed in the Closure Design would typically include the following:

- Remedial design to address identified problem areas

- Final shaping, landscaping and vegetation
- Final landfill cover or capping design
- Permanent storm water diversion measures, run-off control and anti-erosion measures
- Any infrastructure relating to the End-use Plan.

In considering each of the above aspects, reference must be made to any earlier End-use Design. Any variations from the original concept must be noted and their effect analysed. The design must ensure that the closed landfill complies with the Minimum Requirements and the relevant legal requirements. In the case of a landfill that was not designed in accordance with the Minimum Requirements, it will be necessary to assess all the above features. If these are non-existent or inadequate, they must either be designed from the beginning or appropriate remedial measures must be designed which, when implemented, will ensure that the closed landfill complies with the Minimum Requirements for closure.

4.4 Closure Report

The state of a landfill at closure will seldom comply with the desired end-use and closure requirements, reflected in the Closure Design. The Closure Report therefore compares the current status of the landfill with the Closure Design and End-use requirements. Based on this comparison, recommendations are made regarding measures to upgrade the existing condition of the landfill to that desired. Recommendations of the Closure Report involve the implementation of the Closure Design and would typically include details of rehabilitation measures. The Closure Report would also include details of management, inspection, monitoring and maintenance plans.

4.5 Written Acceptance

Written acceptance of both the Closure Design and the Closure Report must be obtained from the concerned department. In order to obtain this, an inspection of the landfill by the Responsible person and a representative of the concerned department will be required. Once the Closure Design and the Closure Report have been accepted by the Concerned Department and the IAPs, site rehabilitation may commence.

4.6 Rehabilitation of Landfill

The rehabilitation of the landfill will ensure that the final condition of the site is environmentally acceptable and that there will be no adverse or long-term impacts on the surrounding areas, the water regime or the population. It includes final cover, capping, placing top soil and vegetation. Any long term leachate, gas, storm water and erosion control systems required should also be in place and in working condition before the landfill is closed. In a landfill designed and operated in accordance with the Minimum Requirements, progressive rehabilitation will have been carried out. In instances of poor landfill siting, design and/or operation, however, extensive remedial work may be required prior to closure. This will be detailed in both the Closure Design and the Closure Report.

4.7 Closure and Implementation of the End-use Plan

The closure of a landfill will only be considered once the Concerned Department is satisfied that the rehabilitation of the site has been properly carried out. This will include the implementation of the Closure Design and the carrying out of all the recommendations contained in the Closure Report. This will be assessed at a final site inspection attended by representatives of all the relevant state departments and the Monitoring Committee. It is seldom possible or necessary to implement the End-use Plan prior to gaining approval for closure. However, all of the preparations necessary to implement the End-use Plan and to maintain the landfill in an environmentally acceptable condition must have been completed before closure. Once the Concerned Department is satisfied with the status of the rehabilitated landfill site, it will issue the Permit Holder with a letter approving the closure of the facility. This letter will allow the operator to physically close the landfill and will state that no further waste can be accepted. It will also set conditions for the implementation of the End-use Plan and for the ongoing inspection and maintenance of the landfill.

4.8 Ongoing Inspections and Maintenance of the Landfill

The long term environmental impacts, public health, safety and nuisance problems associated with a landfill may persist long after the site has been closed. Ongoing inspections and maintenance are therefore required after site closure to ensure that such problems do not continue unidentified and unabated, and that the End-use Design is properly implemented. Ongoing inspections must be carried out at regular intervals to monitor cover integrity, subsidence, fires, vegetation, drainage, erosion, and any other aspects of the closed site which could cause nuisances. Post-closure water quality monitoring must also take place. The inspections will be carried out at six or twelve monthly intervals, as specified in the Minimum Requirements Table 5.

In the case of hazardous waste disposal and G:L:B+ sites, the frequency of inspections or post closure audits will be determined in consultation with the Concerned Department. The frequency will be determined on a site specific basis, and monitoring will continue for a period stipulated by the Concerned Department, as written into the approval of the Site Closure report. Based on the findings of the ongoing inspections, maintenance would address the following aspects:

Integrity of cover

The integrity of a landfill cover can be breached by several mechanisms, including settlement, fires and erosion. Settlement takes place continuously in a landfill because the waste is subject to ongoing decomposition. While good compaction will ensure that such settlement is reasonably uniform, any uneven settlement will result in cracks or depressions in the cover. In landfills where fires have occurred, it is possible that smouldering fires can undermine areas which then either subside or collapse. Alternatively, erosion caused by surface water run-off can also expose waste.

In the event of the landfill cover being breached, three main effects may occur. First, relatively large concentrations/volumes of flammable landfill gas may vent to the atmosphere, with associated odour problems and a danger of fire or even explosion. Second, exposed and/or undermined smouldering waste may create dangerous, unsafe

situations. Third, surface water may be channelled into depressions, where it may collect and infiltrate the waste, or it may gain access to the waste directly via the breaches. Both of these situations could result in the generation of leachate. Post-closure monitoring must therefore address all the above aspects of landfill cover integrity. Wherever there are breaches, these should be identified, the cause investigated and the situation rectified by infilling.

Drainage systems

It is essential to ensure that drains are not excessively eroded or filled with silt or vegetation.

They must function in order to ensure that excess surface water does not enter the waste body.

Subsidence

Any subsidence or cracks, due to settlement or any other cause, must be identified and rectified by infilling.

Fire

Any fires that result on the site should also be identified, exposed and smothered with soil as soon as possible.

Vegetation

Vegetation planted for the purposes of rehabilitation, erosion control, beautification or the end-use must be maintained to ensure that it achieves its purpose.

Security

It is essential to ensure that illegal access and dumping does not occur on the closed waste disposal facility.

4.9 Ongoing Monitoring and Public Participation

Any gas or water monitoring systems must be maintained and monitored on an ongoing basis, after the landfill site has closed. Gas monitoring should comply with both the Permit conditions, while water monitoring should be carried out in accordance with Section 3.5. Post closure monitoring may be carried out under the auspices of a Monitoring Committee. Where this is the case, the results of ongoing monitoring should be submitted to the Monitoring Committee and made available for public scrutiny. The public may, through the Monitoring Committee, also monitor the landfill and report any problems that are observed to the Responsible Person.

Table 7:Minimum Requirements for Rehabilitation, Closure and End-use

(After, DWAF, 1998)

LEGEND **B -= No significant leachate produced** **B+= Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Comunal Landfill**		**S** **Small Landfill**		**M** **Medeium Landfill**		**L** **Large Landfill**		**H:h Hazard Rating 3 & 4**	**H:H Hazard Rating 1-4**
Minimum Requirement	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**		
Determine/reassess End-use Requirements	N	N	R	R	R	R	R	R	R	R
Investigate landfill to determine closure requirements and to identify impacts	R	R	R	R	R	R	R	R	R	R
Obtain input on End-use Design by IAPs	N	N	R	R	R	R	R	R	R	R
Confirmation of End-use Design by Department	N	N	R	R	R	R	R	R	R	R
Design for upgrade/ rehabilitation, if necessary	R	R	R	R	R	R	R	R	R	R
Design final shaping and landscaping	N	N	R	R	R	R	R	R	R	R
Design final cover or capping	R	R	R	R	R	R	R	R	R	R
Design permanent storm water diversion	R	R	R	R	R	R	R	R	R	R
Design anti-erosion measures	F	F	R	R	R	R	R	R	R	R

Cont. Table 8:Minimum Requirements for Rehabilitation, Closure and End-use

(After, DWAF, 1998)

LEGEND **B -= No significant leachate produced** **B+= Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Comunal Landfill**		**S** **Small Landfill**		**M** **Medeium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
Minimum Requirement	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**		
Closure Report	N	N	R	R	R	R	R	R	R	R
Compare actual condition of landfill to required condition	N	N	R	R	R	R	R	R	R	R
Written acceptance of Closure Report	N	N	R	R	R	R	R	R	R	R
Ongoing leachate management	N	N	F	R	F	R	F	R	R	R
Ongoing gas management	N	N	F	F	F	F	F	F	F	F
Ongoing inspection and maintenance	N	N	R	R	R	R	R	R	R	R
Implementation of Closure Report/Rehabilitation	N	N	R	R	R	R	R	R	R	R
Application for Permission to Close Letter approving closure	N	N	R	R	R	R	R	R	R	R
Inspection and Monitoring Frequency intervals (in months)	12	12	12	12	6	6	F	F	F	F

Cont. Table 9:Minimum Requirements for Rehabilitation, Closure and End-use

(After, DWAF, 1998)

LEGEND **B - = No significant leachate produced** **B+ = Significant leachate produced** **R = Requirement** **N = Not a requirement** **F = Flag: special consideration to be given by expert or Departmental representative** **n/a = Not applicable**	**CLASSIFICATION SYSTEM**									
	G **General Waste**								**H** **Hazardous Waste**	
	C **Comunal Landfill**		**S** **Small Landfill**		**M** **Medeium Landfill**		**L** **Large Landfill**		**H:h** **Hazard Rating 3 & 4**	**H:H** **Hazard Rating 1-4**
Minimum Requirement	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**	**B-**	**B+**		
Cover integrity	R	R	R	R	R	R	R	R	R	R
Integrity of drainage	R	R	R	R	R	R	R	R	R	R
Control of ponding	F	F	R	R	R	R	R	R	R	R
Control of fire	R	R	R	R	R	R	R	R	R	R
Monitoring vegetation	N	N	R	R	R	R	R	R	R	R
Monitoring security and prevention of illegal dumping	R	R	R	R	R	R	R	R	R	R

5- BIBLOGRAPHY

Department of water affairs and Forestry (RSA),1998. Minimum Requirements For Waste Disposal By Landfill, Department of Water Affairs and Forestry Republic of South Africa, Second Edition, 1998.

Environment Canada. 1977: Code of good practice on dump closings or conversion to sanitary landfill at Federal Establishments. Report EPS 1-EC-77-4. Environment Canada: Ottawa, Canada.

SBC (2002), Secretariat of the Basel Convention: Technical Guidelines on Specially Engineered Landfill (D5), Basel Convention series/SBC No. 02/03 First Published in 1997 and reprinted in November 2002.

UK Department of Environment, 1995: *Waste Management, Paper 26B*, HMSO Publications, 1995]. *Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste.*

U.K., Environmental Agency, Waste Management Paper No. 26E, *Landfill Restoration and Post Closure Management, Consultation Draft*, August 1996.

World Bank , 1999, Solid waste landfills in middle- and lower-income countries: a technical guide to planning, design, and operation

6- ANNEXES

Annex (1)
Attendance Sheet for Participants of Expert Group Meetings

Email	*Third Expert group meeting 23-26/5/2005*	*Second Expert group meeting 22-25/11/2004*	*First Expert group meeting 5-8/7/2004*	*Name*	*Country*
Participants from member countries					
Adel221261@yahoo. com	√	√	√	Eng. Adel ElShafi	**Egypt**
Kme2004@myway.com	√	√	√	Mr.Abdual Karim Hassan Rashed	**Bahrain**
Sayousry@ yahoo.fr	√		√	Mr. Samir Yousri	**Morocco**
ajirabdo@yahoo.fr		√		**Egair Abdel Khader**	
Fa-ok@scs-net.org	√	√	√	Eng. Fouad El Alq	**Syria**
mkhashashhneh@yahoo.com	√	√	√	Dr. Mohamed Akla Khashashna	**Jordan**
hkhowar@hotmail.com			√	Mr. Hassan El Khawar	**Qatar**
hkhowar@hotmail. com		√	√	Abdel Hady Naser	
Kmsalsiy@omantel.net.om		√	√	Mr.Khamis Ben Marhon	**Oman**
n.qhtal@yahoo.com	√			Eng. Nasr Abdullah Kohtan	**Yemen**
dobhani2822@ yahoo.com	√	√	√	Mr. Ali Abdulla El Zabhani	
derhemmansor@ yahoo.co	√			Dr. Derham Mansour Abu Hatem	
Fatima 1965@hotmail.com	√			Eng. Fatma Frhan Owyed	**Kuwait**
Wish_ubest@yahoo.com			√	Eng. Manal Ahmed saleh	
Sidi_taleb78@ yahoo.com.fr	√			Mr. Sidi Weld Al Taleb	**Moritania**
Hosa65@hotmail.com			√	Mr.Hamoud Weild Said Ahmed	
Smz2002@hotmail. com	√		√	Mr. Soliman El Zebn	**Saudi Arabia**
F_elmabrouk@ yahoo.co.uk			√	Dr. Farag Abou Bakr El Mabrouk	**Lybia**
OmerApril@ hotmail.com	√			Eng. Amr Abu El Kasim Kharawta	
Rajaa_alassaf@ yahoo.com	√			Ms. Ragaa Abdel	

				Wahab	**Iraq**
Moen_iraq@yahoo.com			√	Dr. Gozwa Abdel Kareem	
mshammaleh@ yahoo.com	√			Dr. Mohamed Abu Shamala	**Palastine**
amjaber@hotmail.com			√	Eng. Ataf Mohamed Gaber	
marzoukazbderrazak@yahoo.fr	√			Mr. Abdul Razik Al Marzouki	**Tunis**
Imenass952004@yahoo.fr			√	Mrs. Hanous Nasema	**Algeria**
Secretariat of the Basel Convention					
Jeremy.richardson@unep.ch			√	Mr. Jeremy Richardson	**SBC**
Ibrahim.Shafii @ unep.ch	√	√		Dr. Ibrahim El Shafii	**SBC**
From BCRC Cairo					
elaref@baselegypt. org	√	√	√	Prof. Mortada El Aref	**Egypt**
saidlec@ig-eg.com	√	√	√	Dr. Said Abo El Ela	**Egypt**
sdahroug@ baselegypt.org	√	√	√	Dr. Said Dahroug	**Egypt**
amoe@baselegypt.org	√	√	√	Dr. Ashraf Elmaghrabi	**Egypt**
afarouk@ baselegypt.org	√	√	√	Geol. Ahmed Farouk	**Egypt**
Elraey@ link.net	√	√	√	Prof. Mohamed Ezz El Din Al Rae	**Egypt**
I_shamy@hotmail.com	√	√		Prof. Ibrahim Al Shami	**Egypt**
m_elzarka@hotmial. Com	√			Prof. Mohamed Al Zarka	**Egypt**
Nefisa_sayed@hotmail.com		√		Prof. Nafesa Abu El Seoud	**Egypt**
maelsharkawi@yahoo.com		√	√	Prof. Mohamed El Sharkawi	**Egypt**
	√		√	Dr. Essam Abdel Halim	**Egypt**
	√			Dr. Tarek Al Araby	**Egypt**
	√			Dr. Adely Helba	**Egypt**
shaw kusakran@ yahoo.com	√			Dr. Shawki El Sakran	**Egypt**
			√	Prof. Ahmed Abu Khadra	**Egypt**
	√		√	Dr. Eid Ragab	**Egypt**
Research Development Center-Cairo					
Inas2001us@yahoo.com	√	√	√	Prof. Inas Moustafa	**Egypt**

dayhospl@internetegypt. com	√			Dr. Mohamed Abdel Salam	**Egypt**
noha_hamdy@ yahoo. com	√			Chem. Noha Abdel Hamid	**Egypt**
Private Sector					
green@green grouf. info	√	√		Dr. Tarek Abdel Hamid	**Egypt**
environies@link.net	√	√		Eng. Ragia Affifi	**Egypt**
Ministry of State for Environmental Affairs -Egypt					
aahmed_hm@yahoo.com			√	Eng. Ahmed Abu El Seoud	**Egypt**
moussai@link.net	√	√	√	Dr. Mousa Ibrahim	**Egypt**
mhenv@yahoo.com	√			Chem. Mohamed Hamed Ali	**Egypt**
Tarek_elruby@yahoo.com	√	√	√	Dr. Tarek Eid	**Egypt**
National Authority for Remote Sensing					
aosherif@navsr.sc.eg			√	Prof. Atef Sheriff	**Egypt**
			√	Dr. Mamdouh Abdin	**Egypt**
Egyptian Geological Survey and Mining Authority					
			√	Dr. Zeinhom Al Alfi	**Egypt**
Anoor51@yahoo.com	√	√		Dr. Ahmed Mohamed Nour	**Egypt**
kaissersaleh@yahoo.co.uk	√			Dr. Cesar Hussien Saber	**Egypt**
Hzardous Waste Landfill Project - Alexandria					
Markku.aaltonen@poyry.fi		√		Dr. Marco Altonen	**Egypt**
		√		Eng. Deif Mansour	

ANNEX 2

WASTE CO-DISPOSAL

Co-disposal of General and Hazardous waste

Where general waste is disposed of on hazardous waste landfills, the standard cell operations at a general waste landfill apply. Co-disposal could be by mixing general and hazardous waste at the working face, spreading on deposited waste prior to covering, or mixing in trenches excavated in *insitu* waste. Where trenches or engineered cells are used, they must always be suitably protected and off-loading must be such that persons or vehicles cannot accidentally fall into the trench or cell.

Co-disposal of liquid and solid waste

At any landfill where the co-disposal of liquids is permitted lining and leachate management system which can contain, extract and preferably treat the resultant leachate flow, are minimum requirements.

Liquid wastes may be co-disposed by end tipping into trenches excavated into the waste body, or into engineered cells containing predominantly solid waste. The co-disposed waste is subsequently covered with dry general waste, which may also be end tipped. It is a Minimum Requirement that, by the end of the working day, there is sufficient dry waste in the cell to permit vehicle mobility and covering activities. There must be no lagooning or free liquid surfaces which create odours and possibly air pollution. In order to achieve this, an appropriate solid/liquid waste co-disposal ratio is required. Where trenches excavated into the waste body remain filled with liquid, they must be secured and covered by a constructed frame cover.

Calculation of the site specific solid/liquid co-disposal ratio

The variation of the co-disposal ratio, i.e. the ratio of solid to liquid waste, has both economic and environmental implications. Increasing the volume of dry waste reduces leachate generation, potential environmental impacts and leachate management costs. However, expensive landfill airspace associated with lined landfill sites is used up by the dry general waste. Reducing the volume of dry waste saves airspace utilization, but creates a greater need for leachate management, including additional lined airspace for storage of leachate in leachate ponds. If too much liquid is disposed of, the situation could prove environmentally unacceptable and leachate management could become very expensive. It is therefore in the interests of the landfill operator to optimize the co-disposal ratio by minimizing the sum of the airspace utilization and liquid management costs. The co-disposal ratio used, however, must ensure that the operation is environmentally acceptable, i.e. that all leachate is managed and that there are no free liquid surfaces, causing odor and

possibly air pollution problems. Also, the build up of a hydraulic head within the landfill can affect its stability and therefore must be avoided by operating the landfill at the appropriate co-disposal ratio.

In order to take site specific factors into consideration and to allow efficient utilization of additional liquid storage capacity in landfills situated in hyper dry $\mathbf{B^-}$ areas, no co-disposal ratio is prescribed. The approach rather is to link co-disposal to the concept of the Water Balance and to limit leachate generation to manageable quantities, taking local climate into account. This applies to the co-disposal of hazardous liquids in hazardous waste landfills as well as the possible co-disposal of non-hazardous or delisted liquids at $\mathbf{G:M:B^+}$ and $\mathbf{G:L:B^+}$ sites.

It is therefore a Minimum Requirement that no more than 200mm/year of leachate be generated at a given landfill site. The rationale behind this approach is that a landfill which receives liquids in a hyper dry ($\mathbf{B^-}$) climate will (all things being equal) produces less leachate than an identically operated landfill in a $\mathbf{B^+}$ climate. It is therefore possible to co-dispose of more liquid per ton of dry waste in a hyper dry ($\mathbf{B^-}$) area without necessarily producing any more leachate than is produced under identical conditions in a $\mathbf{B^+}$ area. In general, a landfill in a hyper dry ($\mathbf{B^-}$) area may produce leachate sporadically, but will not necessarily produce leachate in an average year. However, in wetter $\mathbf{B^+}$ areas of the country, significant leachate will be produced even in a drier than average year, even if no liquids are co-disposed. In either case, the approach is to limit leachate generation to 200 mm/year over the area of the waste body, or to a figure for which the leachate treatment capacity may be designed.

The limit of 200 mm per year is a figure which will ensure socially and environmentally acceptable conditions. It may only be exceeded if it can be shown that the overall design of the landfill, the leachate generation, the leachate management and the leachate treatment systems can easily accommodate this flow.

Regardless of the co-disposal ratio used or the amount of leachate generated, **it is a Minimum Requirement that there are no free liquid surfaces on the landfill and that the fill is trafficable.**

The BCRC-Egypt is presenting these guidelines to assist in the development of sound environmental practices for the disposal of hazardous wastes in the Arab hyper-arid regions. It is needed that those who read these guidelines and would like to contribute to their improvement in future editions to contact BCRC-Egypt at

baselegypt@baselegypt.org
http://www.baselegypt.org

The Basel Convention Regional Center For Training and Technology Transfer To the Arab States
Cairo University, Giza- Egypt
P.O Box: 453 Al Orman, Giza 12612

ISSN: 19545-2005