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Training Module

Closing an Open Dumpsite and Shifting from Open Dumping to Controlled Dumping and to Sanitary Land Filling

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PREFACE

Managing solid waste is one of the most daunting tasks for local governments worldwide. It is complicated by the failure to properly manage the continuing increase in waste generation, on one hand, and the decreasing availability of space for waste disposal, on the other. Failure to properly manage solid waste not only affects political careers, but also devalues land and, most importantly, contributes to communicable diseases. In spite of its crudeness and the health hazards, open dumping in pits, vacant lands, or water bodies has become a prevalent practice in developing countries because it is initially less expensive and easier than adopting an environmentally sound waste disposal system. Much progress has been attained in reducing the volume of waste that go to the disposal facilities through waste reduction, recovery, recycling and other programmes, but the residual wastes invariably end up in an open dumpsite.

Notwithstanding the constraints confronting local authorities, for the sake of human health and welfare, natural resources, especially land and freshwater, open dumpsites should not be allowed as a public facility. It is a matter of national policy that dumpsites be closed because of the adverse effects on society and the environment. It is incumbent upon both national and local authorities to adopt better and environmentally sound waste disposal methods by shifting from their current policy and practice of open dumping to controlled dumping and transition to sanitary landfilling. The sooner governments, especially at the local level, make and implement this decision, the sooner their towns and cities will enjoy sound waste management and disposal, and the less the risks will be to the health and lives of their communities.

A policy shift from open dumping to sanitary landfilling has implications on local preparedness to operate and manage a landfill as well as how the current dumpsites will be abandoned. Consequently, there is a need to build and enhance the technical and management capacities of local authorities. In recognition of this need and as part of the United Nations Environmental Programme's (UNEP) global effort to promote environmentally sound technologies, the International Environmental Technology Centre (IETC), develops training programmes for capacity building. This publication is a Training Module on Solid Waste Management designed especially for local authorities and their staff.

This Training Module has two parts, which are complementary:

(1) How To Decommission or Close an Open Dumpsite in an Environmentally Sound Manner, Including Rehabilitation and Redevelopment
(2) How To Shift from Open Dumping to Controlled Dumping and Eventually into Sanitary Landfilling.

The two parts have been combined into one training package since they refer to consequential activities that should not be treated independent of each other; many of the basic principles carry forward from one method to the next.

The Training Module is intended to provide local authorities with the basic knowledge and understanding of the skills required to close dumpsites and shift to controlled dumping and to sanitary landfilling so that they can make good policy analyses and informed decisions. Local chief executives, city or municipal planning officers, solid waste managers, landfill engineers and other decision makers involved in solid waste management will find the fundamental activities, procedures and recommendations necessary to make this transition and address their local situation.

This Training Module is a joint publication of UNEP-IETC and the Department of Environment and Natural Resources (DENR) of the Philippines. It is the result of a recommendation from the ASEAN Regional Workshop on Solid Waste Management, held at Clark Field, Pampanga, Philippines, in September 2001, and co-organized by UNEP-IETC and DENR.

This Training Module is not intended for use as reference or basis for designing a landfill facility. The services of a competent and professional landfill engineer should be engaged for such a purpose.

ACKNOWLEDGEMENT

The preparation of the training module was the result of a collaborative effort by many individuals and institutions. The project was co-funded by the UNEP Division of Technology, Industry and Economics (DTIE-IETC) and the Department of Environment and Natural Resources (DENR), Philippines.

Other organizations that provided important support include: United States-Asia Environmental Partnership (US-AEP) – U.S. Agency for International. Development (USAID); UNEP-Regional Office for Asia and the Pacific (ROAP); United Nations Centre for Human Settlement (UNCHS (Habitat))–Fukuoka Regional Office; Asian Institute of Technology (AIT), Thailand/GTZ; Solid Waste Management Association of the Philippines (SWAPP), and; United Nations Development Programme-Strengthening Local Environmental Planning & Management (EPM).

LIST OF ACRONYMS

ASSHTO	American Society of State Highway Transportation Organization
COD	Chemical Oxygen Demand
DTIE-IETC	Division of Technology, Industry and Economics-International for Environmental Technology Centre
DENR	Department of Environment and Natural Resources
EnRA	Environmental Risk Assessment
EPM	Environmental Planning and Management
ESD	Environmental and Sanitation Division
GSO	General Services Office
LGUs	Local Government Units
MRF	Materials Recovery Facility
ROAP	Regional Office for Asia and the Pacific
SDS	Total Dissolved Solids
SWAPP	Solid Waste Management Association of the Philippines
SWM	Solid Waste Management
TOC	Total Organic Carbon
UNCHS	United Nations Centre for Human Settlement
US-AEP	United States-Asia Environmental Partnership

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INTRODUCTION

Open dumpsites are known to pose a significant risk to public health and the environment. With few engineering measures whatsoever, these disposal facilities can contaminate groundwater and surface waters, pollute the air, attract insects, vermin and other potential carriers of diseases, devalue properties and a host of other negative impacts. Since each city, municipality or town has at least one open dumpsite (or shares one with its neighbors), these disposal facilities are one of the largest sources of potential pollution to the communities hosting them.

It is imperative that these open dumpsites be closed as soon as practical. However, closing an open dumpsite does not simply mean abandoning it. Decomposition by-products are produced long even after its closure, thereby, requiring appropriate planning and adequate long-term maintenance. Otherwise, these open dumps will continue to pose risks to communities long after it has ceased operations.

Rationale

In early times, when the population was still small and the land available to assimilate the wastes was large, waste disposal did not pose a problem. But when man began to form groups, villages and communities, wastes became a consequence of life that needed to be taken cared of.

Unfortunately, epidemics like the bubonic plague and many more fatal events had to happen before man realized that he had to properly manage the wastes he produced. From careless open dumping practices to engineered sanitary landfills, proper and effective solid waste management has evolved into what it is today and continues to transform as society evolves.

Open dumping is still the most prevalent method of waste disposal for many countries, most particularly the less developed ones. The foremost reasons for this practice are lack of knowledge and financial constraints. Nonetheless, it should not require another epidemic, sickness, or contamination before national and local governments give proper solid waste management the priority and urgency it deserves.

Purpose of the Training Module

Solid waste management is one of the basic services provided by local government units (LGUs) to the public, and disposal is one of the more critical aspects since it has a great potential to impact the public health and the environment. Thus, there is an urgent need to build the institutional and technical capabilities of local governments to address this need.

Solid waste management should be financially, environmentally, technically, socially and often, politically acceptable to the LGUs. For local chief executives, community leaders, decision-makers, and others tasked to implement solid waste management services, a better degree of success may be achieved if the stakeholders:

- are informed of the dire consequences of open dumping and understand the environmental, technical, social and other impacts consequent to the operation of such disposal facilities;
- understand that the problem can be solved as long as they have enough desire and determination, and;

- become aware of the options, strategies and alternatives available to them to solve the problem.

The purpose of the training module, therefore, is to provide LGUs the knowledge to implement the closure of their open dumpsites in an environmentally acceptable manner, and the necessary requisites for upgrading to controlled dumping and eventually, to sanitary landfilling.

The training may be used in whole or in part, in accordance with the specific requirements and resources of the LGU concerned.

Notes to Trainers

The training module serves as both a guide to the trainers presenting its contents as well as a reference to the participants and others interested in improving their solid waste management programme. If you plan to use the materials presented here, please inform UNEP-IETC by email at [ietc@unep.or,jp]. Trainers/speakers may vary their presentations as long as they do not deviate from the objectives or basic principles of the training module, or lack of content based on the general topics in the module.

Apart from presenting the technical, environmental and other aspects of open dumpsite closure and shifting to controlled dumps and sanitary landfills, trainers/speakers should emphasize on the critical role of the local government unit(s) concerned with solid waste management, particularly the local chief executives. For without their action and effort, little can be accomplished.

Trainers/speaker should read all of the Sections in the Training Module before making their presentation or varying the order of the module content.

EXECUTIVE SUMMARY

Part 1: How to Decommission or Close an Open Dumpsite in an Environmentally Sound Manner, Including Rehabilitation and Redevelopment

Planning for Closure. As in any successful endeavor, planning is essential to closing open dumpsites. The roles and responsibilities of those to be affected by the closure, such as the LGU, the dumpsite operator (if not the LGU), the community and others, should be defined. Prior to actual closure of the dumpsite, an investigation of the existing conditions of the site is conducted. The findings and assessment will enable planners to draw up the practical options or alternatives to meet the objectives, and will be used in the development of a closure plan.

Elements of a Closure Plan. A closure plan details the various activities that will be implemented during the actual closure of the site. Elements of the plan include the stabilization of steep slopes to prevent erosion hazards, the implementation of leachate and gas management systems, and the design of the final cover. Other activities in a plan should consider the measures to be adopted to prevent future illegal dumping at the site, plan for informal settlers (if any), installation of monitoring wells, and the security measures to be implemented to prevent unauthorized access to the closed site.

Post Closure Management Programme. The decomposition of biodegradable wastes in open dumpsites will result in the production of leachate and gas long after the site has stopped receiving wastes. Thus, a post closure plan is developed to allow for continued maintenance and monitoring of the site for a period of at least ten years.

Attendant Costs of Closing a Disposal Site. Closing a disposal site entails costs. Expenditures for closure cover capital and operational expenses. Capital expenses include those for final cover materials, drainage, leachate and gas management systems, and relocation of informal settlers, among others. Operational expenses generally include rental of equipment and manpower requirements. Expenditures for post closure management are also considered in this section.

Afteruses of a Closed Dumpsite. A closed dumpsite may later be used as a green area, recreation area, or for construction purposes. However, its planned afteruse will need to consider such factors as differential settlement, bearing capacity, gaseous emissions, and corrosion of metals. These factors often dictate the potential uses of the site, such as the kind of structures that can be erected over it, the kind of vegetation, and the types of materials that may be buried underneath it. Because open dumpsites are unplanned and haphazardly operated, the practical beneficial afteruse are often limited.

Remediation/Cleanup Options. These are required when problems develop at a closed dumpsite. Problems such as severe leachate leakage, waste slippage and exposure, or fires and explosions often result from improper and/or inadequate closure and post closure procedures. Solutions may vary from simple excavation to more aggressive and costly remediation or cleanup technologies like groundwater isolation, soil washing, and the use of microorganisms.

Part 2: How to Shift from Open Dumping to Controlled Dumping and Eventually into Engineered Landfilling

Upgrading of an Open Dump into a Controlled Disposal Facility. As with the closure of open dumpsites, upgrading into controlled disposal will require planning. A site assessment has to be conducted first in order to determine if the open dumpsite is convertible to a controlled dump. If conversion is not practical based on several criteria/considerations, a new site will have to be developed.

Development of a controlled dump on a new site has to comply with several criteria such as siting and design requirements. Because of the minimal infrastructure requirements for controlled dumps (e.g. no liner with required permeability), finding a site with suitable hydrogeologic conditions is essential. Preparation of the disposal area mainly involves the provision of adequate gradient, minimal compaction of the soil, and the construction of drainage management systems.

Conversion of an open dump into a controlled dump means that disposal will be on a site previously used for open dumping. Thus, preparation of the area will consist of leveling and compacting existing garbage heaps and construction of drainage canals/ ditches, among others.

Prescribed operational procedures include limiting the working face area, application of daily cover and miscellaneous provisions such as installation of litter barrier and others. The facility is also monitored for incoming waste volumes, water quality, condition of drainage systems, and others.

Shifting from Controlled Dumping to Sanitary Landfilling. This stage is the most demanding for LGUs in terms of financial resources, technology, and expertise. The development of these disposal facilities requires thorough planning and design, from its inception to its planned afteruse. Siting, design, construction and operation requirements are much more broad and stringent than other modes of land disposal. Sanitary landfills have the least impact to public health and the environment as compared to open dumpsites or controlled disposal facilities.

The Cost of Waste Disposal. Waste disposal cost can be categorized into capital and operating costs. The former includes costs for land acquisition, machinery and equipment, designers/consultants fees, site preparation and construction, and closure and post closure requirements. Operational costs are associated with the daily operational requirements of the facility, including salaries, maintenance costs, and others. These are generally recovered through tipping fees.

Public Participation. The involvement of communities impacted by a proposed project is essential to the project's realization and success. The decision to develop waste disposal facilities is not only for a few to make but for all who will be affected by it. Thus, decision-makers and planners should involve all stakeholders right from the siting process up to the facility's post closure phase. Otherwise, there may be problems during the facility's construction and operation, or the project may not materialize due to public opposition.

Part 1

How to Decommission or Close an Open Dumpsite in an Environmentally Sound Manner, Including Rehabilitation and Redevelopment

I. INTRODUCTION

The basic requirements for closing an open dumpsite include providing final soil cover, vegetation layer, drainage control system, leachate and gas management systems, monitoring systems and site security. Post-closure management on the other hand, requires a maintenance programme to ensure the proper functioning of the facilities/infrastructure (such as final cover, surface drainage facilities, monitoring and leachate and gas management systems) for a period of at least ten (10) years.

The basic requirements listed above are ***minimum requirements***. There may be additional activities for implementation during closure and post-closure management of an open dumpsite, not necessarily required by local regulations. Actual field application should be adjusted or modified to suit the particular case.

It should also be noted that unlike sanitary landfills, open dumpsites are generally unplanned, haphazardly operated and do not have environmental controls. Therefore, the standards to be adapted or applied for their closure and post-closure care should be similar, if not more stringent, than for sanitary landfills because the contaminants that emanate from them are greater.

This module will cover closure of an open dumpsite only. Determination of whether an open dumpsite may be converted into a controlled disposal site is addressed in Part 2 of this document.

II. SPECIFIC OBJECTIVES

At the end of this module, the participants will be able to:
Identify and describe the factors to be considered before, during and after closure of an open dumpsite;
Describe the cost requirements of closing a dumpsite;
Determine the most appropriate afteruse of a closed dumpsite; and
Prepare a closure plan for an open dumpsite, including rehabilitation measures as necessary.

III. PARTICIPANTS

1. Local government units (in order of preference):
    - City/Municipal Mayors
    - Head of Office/Division in charge of solid waste management service
      (Ex. General Services Office, Environment and Natural Resources Office, Environment. & Sanitation Division.)

- City Engineer’s Office (City Engineer or senior technical staff who must be an engineer)
- Dumpsite Operations Manager
- Chairman, SWM Board/Technical Working Group

2. National agencies (and their regional offices) in charge of solid waste management

IV. DURATION

16 HOURS

V. TOPICS FOR PRESENTATION

1. Planning for Closure
2. Elements of a Closure Plan
3. Post-closure Management Programme
4. Costs of Closing a Disposal Site
5. Afteruses of a Closed Dumpsite
6. Remediation/Cleanup Options

VI. SUGGESTED METHODS

1. Lectures and Discussions
2. Slide/Video Show
3. Sharing of Experiences
4. Case Studies
5. Practical Exercises
6. Field Visits
7. Mentoring

VII. THE WASTE DECOMPOSITION PROCESS AND ITS BY-PRODUCTS

A. The Waste Decomposition Process

In order to fully appreciate why open dumpsites have to be closed, it is essential to understand the basic processes involved in waste decomposition and its by-products.

The biodegradable components of waste (food and yard wastes) generally undergo three (3) stages of waste degradation in a disposal site. These are the *aerobic* phase, *acetogenic* phase, and the *methanogenic* phase. These processes are brought about by the actions of microorganisms on the waste, and are summarized below.

A.1 Aerobic Phase (in the presence of oxygen)

- This process occurs during the initial placement of the waste, while oxygen is still available.

- Aerobic bacteria use the organic fraction of the wastes as substrate (food), rapidly multiplying in the process.
- Because of intense microbial activity during this stage, heat is generated and the temperature may rise to as high as 70°C - 80°C.
- The main decomposition products in this stage are water and carbon dioxide (CO_2), with the latter causing the pH to be acidic.
- This phase is quite rapid (usually few days to few weeks), and depends on the availability of oxygen.

A.2 Acetogenic Phase

- As the oxygen supply becomes depleted, the aerobic bacteria die off and are replaced by facultative microorganisms. These microorganisms can tolerate low levels of oxygen and continue the decomposition process.
- The main decomposition products in this stage are organic acids and CO_2. This results in further lowering of the pH, which in turn, causes the dissolution (dissolving) of organic and inorganic materials.
- A chemically aggressive leachate is produced at this stage.

A.3 Methanogenic Phase

- As the depletion of oxygen continues, anaerobic conditions develop and the facultative microorganisms are replaced by the obligate anaerobic (requiring no oxygen) microorganisms.
- These microorganisms feed on waste very slowly over many years to decompose remaining organics from the acetogenic phase.
- The main decomposition products in this stage are CO_2, methane (CH_4), which is highly combustible, water and some heat.
- This stage may occur within 6 months to several years after waste placement.

These decomposition processes are dynamic, with each succeeding phase very much dependent on the creation of a suitable environment from the preceding stage. In a disposal facility, all three stages may be occurring simultaneously at various locations within the waste fill. This is due to the fact that placement of wastes occurred at different times, the wastes are heterogeneous in nature and have different rates of biodegradability, and the spatial variability in the physical and chemical environment of the waste materials.

B. The By-products of Waste Decomposition and Their Impacts to Public Health and the Environment

B.1 Leachate

Leachate is a liquid produced when wastes undergo decomposition, and when water (due to rainfall, surface drainage, groundwater, etc.) percolate through solid waste undergoing decomposition. As the water percolates downward, biological and chemical constituents of the waste leach into solution.

The percolating water may also mix with the liquid that is squeezed out of the waste due to the weight of the material. Thus, leachate is a liquid that contains dissolved and suspended materials that, if not properly controlled, may pass through the underlying soil and contaminate sources of drinking water, as well as surface water. The treatment of such a contamination can be very difficult, lengthy, and expensive. Often, the only recourse is the abandonment of the affected groundwater wells. Figure 1 shows how contaminated water from a waste disposal facility contaminate surface waters and groundwater.

The composition of leachate depends on the stage of degradation and the type of wastes within the disposal facility. In the first few years, leachate contain readily biodegradable organic matter, resulting in an acidic pH and high biochemical oxygen demand (BOD_5). With time, leachate become simple dissolved organics and decrease in strength.

B.2 Gases

The decomposition of the waste also brings about the generation of gases, mainly **methane** (about 50-65%) and carbon dioxide (about 35-45%). As methane is formed, it builds up pressure and then begins to move through the soil, following the path of least resistance. Often it moves sideways for a time before breaking through to the surface of the ground. Methane is lighter than air and is highly flammable. If it enters a closed building and the concentration builds up to about 5 to 15% in the air, a spark or a flame is likely to cause a serious explosion.

Aside from being a flammable gas, methane released to the atmosphere greatly contributes to the depletion of the ozone layer since it has approximately 15 to 20 times the global warming potential of carbon dioxide.

B.3 Other impacts

Aside from the generation of leachate and methane gas, the exposed waste in open dumps can become a breeding ground for vermin, flies, and other potential carriers of communicable diseases. Open dumpsites without daily soil cover can also be a source of odor, dust and litter.

If open burning of solid waste is practiced (usually, to reduce volume), it could result in the emission of toxic substances to the air from the burning of plastics and other materials. The toxic fumes can cause chronic respiratory and other diseases, and it will increase the concentration of air pollutants such as nitrogen oxides (NO_x), sulfur oxides (SO_x), heavy metals (mercury, lead, chromium, cadmium, etc.), dioxins and furans, and particulate matter.

Open dumpsites also reduce property value, not only of the dumpsite area itself, but also the properties adjacent to or near the disposal area due to the factors listed above as well as visual degradation.

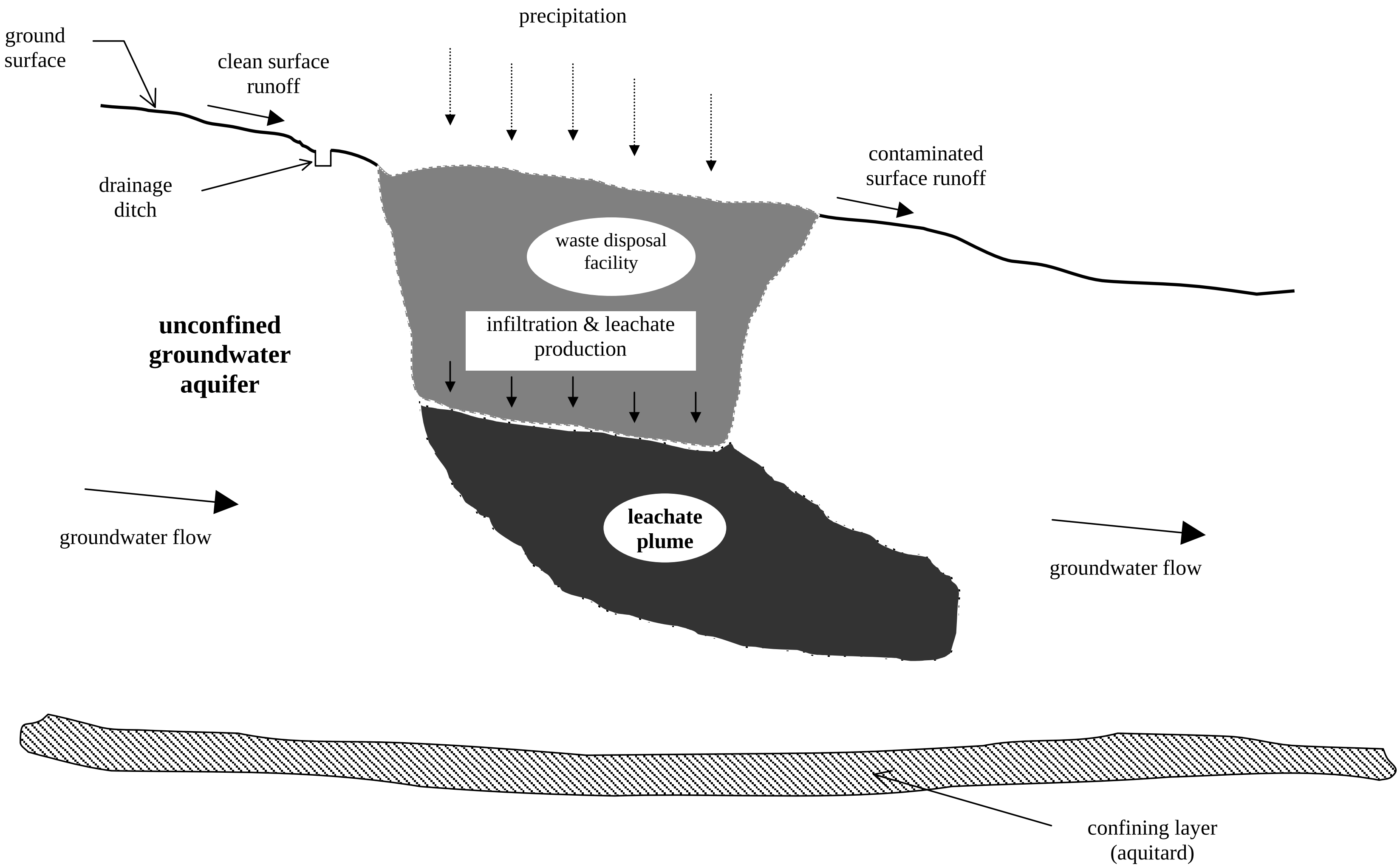


Figure 1. Water Pollution from a Waste Disposal Facility (over an unconfined aquifer)

VIII. LAND DISPOSAL PRACTICES

The disposal of solid wastes on land can be generally categorized into three types. It can either be an open dumpsite, a controlled dump, or a sanitary landfill. The principal differences of each are discussed in this section and are summarized in Table 1.

A. Open Dumps

Open dumpsites entail the least development and operational cost requirement among the three types of land disposal, and thus, are the most prevalent type of disposal facilities in most developing countries. And among the three, they also pose the greatest threat to public health and the environment. The health and environmental impacts attendant to the operation of an open dumpsite are mainly due to the following:

- *They are unplanned, particularly with respect to siting considerations.* Open dumpsites are usually located in areas not feasible for such facilities because of the absence of proper siting considerations or criteria. They are usually located in any available vacant area, and are usually within a government-owned property.
- *They are haphazardly operated*. There are no general operational guidelines governing proper operation of the facility and many operators of these dumpsites lack equipment as well as the necessary expertise. Often, burning of waste is done to reduce the volume of waste and preserve disposal space at the site.
- *There are no controls over waste inputs, either in quantity or composition (or both).* Often, there is no control over the amount and/or type of waste that is disposed of in the site. If wastes other than municipal solid wastes, such as medical and toxic and hazardous wastes, are permitted for disposal in the site, the risks to public health and the environment become more significant.
- *There are no controls over emissions of pollutants released due to waste decomposition*. Open dumpsites do not have the necessary facilities and measures to control and safely manage liquid and gaseous by-products of waste decomposition.

Aside from the health and environmental impacts, open dumpsites have serious negative impacts on the property values of the site and its adjacent properties. The pride of the host community is also often affected by the stigma attached to being near an open dumpsite.

Figure 2 shows an open dumpsite along a ravine. Note the absence of soil cover, the proliferation and uncontrolled activities of scavengers, and the practice of open burning to reduce waste volume. The site is also close to residential houses.

Figure 2. Open dumpsite

B. Controlled Dumps

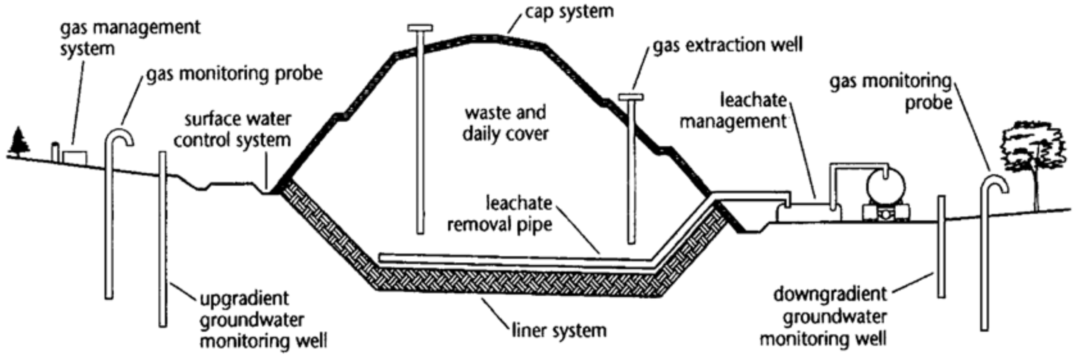
A controlled dump is a non-engineered disposal site where improvement is implemented on the operational and management aspects rather than on facility or structural requirements, which would otherwise require substantial investment. Controlled dumps evolved due to the need to close open dumpsites and replace them with improved disposal facilities, and in consideration of the financial constraints of LGUs. Controlled disposal of wastes may be implemented over existing wastes (from previous open dumping operations) or on new sites (Figure 3).

Figure 3. Controlled Dump

C. Sanitary Landfills

A sanitary landfill is an engineered disposal facility designed, constructed, and operated in a manner that minimizes impacts to public health and the environment. In contrast to open dumpsites and controlled dumps, sanitary landfills undergo thorough planning right from the selection of the site up to post-closure management. Thus, although it requires substantial financial resources, it is the most desirable and appropriate method of final waste disposal on land. Figure 4 below shows a typical schematic of a sanitary landfill and its main components, while Figure 5 shows the different phases of a sanitary landfill under construction. The upper part of the photo shows the geomembrane-lined leachate treatment ponds and the lower part shows the placement of a layer of sand to protect the geomembrane layer of the landfill cell.

Figure 4. Schematic of a Typical Sanitary Landfill



Note: the use of a tanker truck may not be practical as a method of leachate removal in areas of high rainfall and piping to a treatment facility is more appropriate.

Figure 5. Sanitary Landfill

C.1 Types of Sanitary Landfills

There are two basic types of sanitary landfills classified according to the method of landfilling operations employed. These are the: (a) Area Method, and; (b) Trench Method; other approaches are only modifications or a combination of these two types.

Additionally, a landfill may be operated as a semi-aerobic landfill where air is introduced to the waste to accelerate decomposition. An anaerobic landfill does not incorporate in the waste, and anaerobic and facultative organisms dominate. The aerobic landfill has the advantage of reducing the organic loading in the leachate thererby reducing the facility requirements for leachate treatment. The anaerobic landfill is the more common method of managing the digestion of the wastes.

Common to both the area and trench methods is the spreading and compaction of the waste in a confined area known as the **cell**. At the end of each day, a layer of soil is spread over the waste and then compacted. The compacted waste and soil cover constitute a cell. A series of adjoining cells, all of the same height, make up a **lift**. A completed sanitary landfill is made up of one or more lifts.

The physical conditions of the particular site, and the amount and type of municipal solid waste to be handled are the main factors that determine the method (Area or Trench) to be selected. *However, because the liners and leachate collection systems must be in place prior to any waste disposal, the area method is now more commonly used.*

Table 1. A Summary of the General Characteristics of Land Disposal Facilities

Criteria	Open Dump	Controlled Dump	Sanitary Landfill
Siting of facility	• Unplanned and often improperly sited	• Hydrogeologic conditions considered	• Site chosen is based on environmental, community and cost factors
Capacity	• Site capacity is not known	• Planned capacity	• Planned capacity
Cell planning	• There is no cell planning • The waste is indiscriminately dumped • The working face/area is not controlled	• There is no cell planning, but the working face/area is minimized • Disposal is only at designated areas	• Designed cell by cell development • The working face/area is confined to the smallest area practical • Disposal is only at designated cells
Site preparation	• Little or no site preparation	• Grading of the bottom of the disposal site • Drainage and surface water control along periphery of the site	• Extensive site preparation
Leachate management	• No leachate management	• Partial leachate management	• Full leachate management
Gas management	• No gas management	• Partial or no gas management	• Full gas management
Application of soil cover	• Occasional or no covering of waste	• Covering of waste implemented regularly but not necessarily daily	• Daily, intermediate and final soil cover applied
Compaction of waste	• No compaction of waste	• Compaction in some cases	• Waste compaction
Access road maintenance	• No proper maintenance of access road	• Limited maintenance of access road	• Full development and maintenance of access road
Fencing	• No fence	• With fencing	• Secure fencing with gate
Waste inputs	• No control over quantity and/or composition of incoming waste	• Partial or no control of waste quantity, but waste accepted for disposal is limited to MSW	• Full control over quantity and composition of incoming waste • Special provisions for special types of wastes
Record keeping	• No record keeping	• Basic record keeping	• Complete record of waste volumes, types, sources and site activities/events
Waste picking	• Waste picking by scavengers	• Controlled waste picking and trading	• No on site waste picking and trading
Closure	• No proper closure of site after cease of operations	• Closure activities limited to covering with loose or partially compacted soil and replanting of vegetation	• Full closure and post-closure management
Cost	• Low initial cost, high long term cost	• Low to moderate initial cost, high long term cost	• Increased initial, operational and maintenance costs, moderate long term cost
Environmental and health impacts	• High potential for fires and adverse environmental and health impacts	• Lesser risk of adverse environmental and health impacts compared to an open dumpsite	• Minimum risk of adverse environmental and health impacts

(a) Area Method

This method is used for most sites, including those with shallow groundwater conditions making it unsuitable for the excavation of cells in which to place the waste, and where the volume of solid waste to be disposed of is very large. It is generally adopted on flat or gently sloping land, as well as ravines, valleys, quarries, abandoned strip mines, and other land depressions. In this method, the waste is spread over the working face and compacted by a landfill compactor or bulldozer. After each day, a soil cover is applied and compacted (Figure 6).

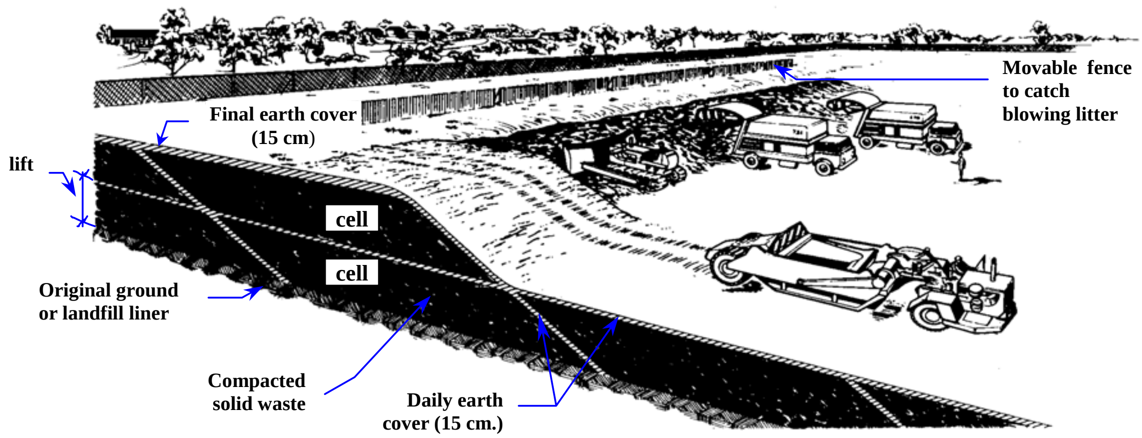


Figure 6. Area Method

(b) Trench Method

The trench method is best suited for areas where the groundwater is sufficiently deep to allow for the excavation of trenches. After spreading and compaction of the waste, the soil excavated from the site is used as the daily cover material. A second trench parallel to the first one is then excavated and the excavated soil is used as daily cover for the second trench, as well as additional cover for the first trench. A space of at least 0.60m (2 ft.) is provided to separate the trenches.

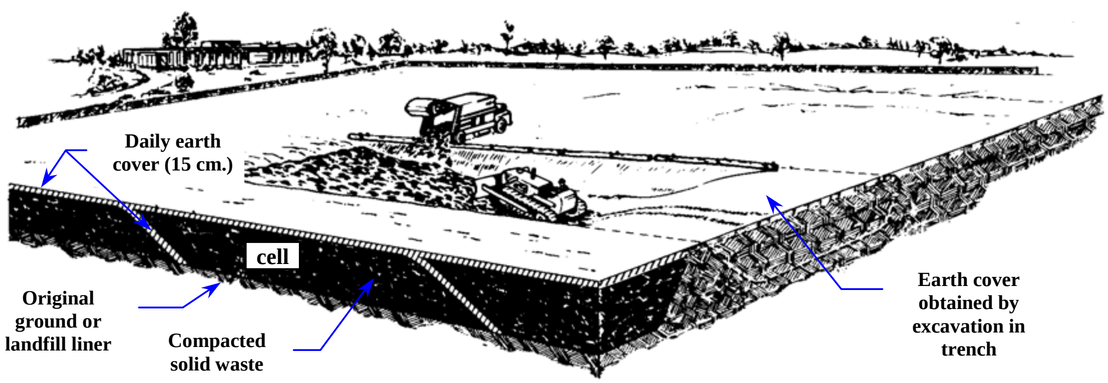


Figure 7. Trench Method

(c) Progressive Slope or Ramp Method

A variation of the area and trenching techniques, this method involves the spreading and compaction of the waste on a slope. The cover material is excavated directly in front of the working face then spread over it and compacted. The small excavation then becomes a part of the cell for the next day's waste (Figure 8). *Although this method is simple and practical, it is not commonly used since the liners and leachate collection systems must be in place prior to any waste disposal*.

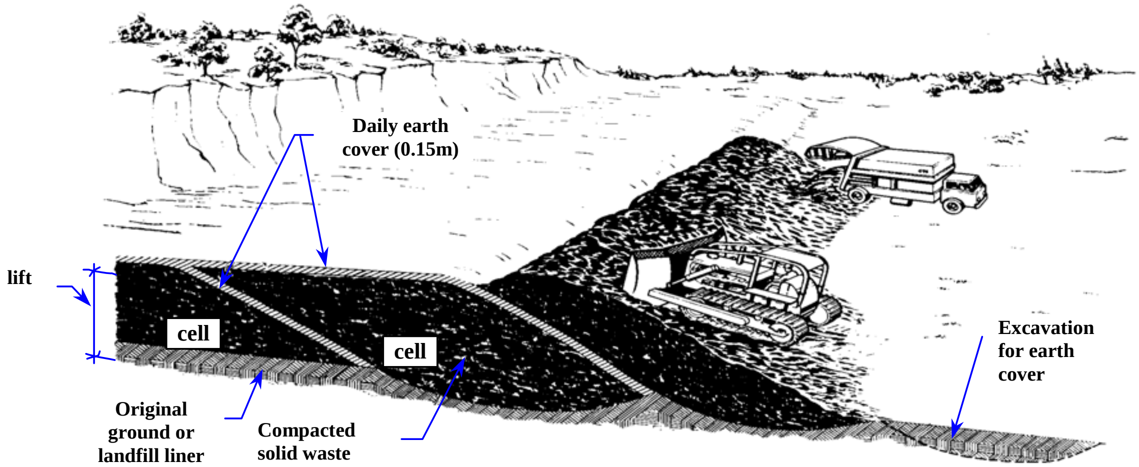


Figure 8. Ramp Method

IX. PLANNING FOR CLOSURE

A. Stakeholders' Roles

Decommissioning or closing an open dumpsite is not solely the role of local government units (LGUs) or the private operators of the dumpsites. It should be a coordinated effort that involves the participation of the national government, as well as the local community where the disposal site is located since they are the ones who are and will be directly affected by its existence. Table 2 shows a matrix of the main responsibilities of the various stakeholders.

Table 2. Responsibilities of Stakeholders in Dumpsite Closure

Stakeholder	Responsibility/Concern
Local Government Unit	• Implement the actual closure of the open dumpsite • Coordinate with pertinent local and national entities to implement closure • Enact regulations/ordinances as necessary to implement closure • Implement other necessary activities/plans to facilitate and effect closure
Public/Community	• Participate in the planning for the closure of the open dumpsite • Participate in the monitoring of these open dumpsites after closure
National Government	• Through the waste management authority, formulate the necessary policies, standards, criteria and guidelines relative to closure of open dumpsites • Coordinate with pertinent local and national entities to implement closure of open dumpsites • Monitor (and may even supervise) the closure of these open

	dumpsites • Extend necessary technical and other allowable and viable forms of assistance to LGUs
Business	• Support closure of open dumpsites and opening of new sites • Introduce recycling programmes at the new sites • Introduce appropriate technologies, services, and equipment for landfill closure and/or design, construction and operation

There may be many offices, units or bodies in an LGU handling waste management concerns, and proper coordination among them is essential in the success of this endeavor. These entities may include Solid Waste Management Boards, the General Services Office (GSO), Environment and Natural Resources Office, Environment and Sanitation Division (ESD), Municipal Health Office, and others.

A.1 The Crucial Role of Local Chief Executives

A city/municipality may have a unit (or several units) tasked with waste management concerns, but more often, the mayor/local executive has the last say on critical issues such as financial or even technical matters. And, his/her degree of support or "political will" will determine the level of efficiency and effectiveness of a community's waste management programme.

***Since LGUs are responsible for solid waste management in most developing and in industrialized countries, local chief executives are often the determining factor in the success, or failure, of a solid waste management programme*.**

But because many local chief executives are too vulnerable to political pressures, they often tend to favour short-term, but visible and publicity-oriented projects. They prefer projects that are newsworthy, will be completed within their terms of office, bear their names, or be solely attributed to their leadership, rather than solutions that will require long term planning and implementation, such as solid waste management.

Providing for a more sanitary and environment-friendly method of waste disposal for a community poses significant challenges to local government units, particularly to its leaders. Among others, it will require:

- Coming up with a plan that will identify workable alternatives, strategies and programmes to solve the problem;
- Identification of the steps necessary to carry out the plan, and the corresponding timetable/schedule for the activities identified in the plan;
- Allocation of resources to carry out the plan, and;
- Formulation of enabling legislation and ordinances specifying appropriate mechanisms to support the plan.

Local chief executives should, therefore, look beyond their personal (or political) interests and actively and vigorously pursue ways and means to achieve this end. It is not an easy task and there will be seemingly insurmountable obstacles. But it is something that has to be confronted and dealt with appropriately, and with firm resolve. In short, if community leaders do not draw a line between political pressure and commitment to solid waste management service, it is bound to fail.

B. Responsibilities/Liabilities of the Site Operator

B.1 Need for an Alternative Site

Planning the closure of a disposal site should be made many months (or years) before actual closure. The local government unit concerned should first identify an alternative site(s) where it will dispose of the waste it generates. The new disposal site may be developed by the LGU, or it can use the disposal sites of neighboring municipalities (where appropriate) and pay the tipping fees required. Whatever option the LGU takes, early planning is essential in order to have enough time to raise the necessary funds or look for sources of funds.

For private operators of disposal facilities, they should notify their customers months or years ahead if they plan to close the facility or when they expect the facility to reach its capacity. This will give their clients adequate time to consider the options available to them.

B.2 Legal and Financial Responsibility

When disposal facilities close, the owner and/or site operator are legally and financially accountable for post-closure maintenance. Laws require or should require that waste disposal sites, whether they are public or privately owned, have a post-closure maintenance plan and the mechanisms and means for financing the activities in the plan. It may also be appropriate to assign liabilities to large waste generators of specific types of wastes, such as commercial establishments and industries, who use the disposal site. Residential wastes, however, remain the liability of the local government unit where the waste was generated since these types of wastes are generally mixed upon collection and disposal.

In order to sustain post-closure maintenance and monitoring activities, owners and operators of waste disposal facilities should incorporate a financial assurance plan in order to provide sufficient funds for the said activities. The cost estimate for the latter is included in the post-closure maintenance plan. It should be noted that closure and post-closure maintenance costs should have been considered in the development plan (if any) of the disposal site prior to its operation in order to set aside a certain amount during the facility's operation (e.g. from tipping fees) to pay for closure and as post-closure maintenance fund.

B.3 Transfer of Ownership

In case a closed disposal site is sold and property ownership changes, the new owner must be made aware of the transfer of liability for post-closure maintenance. Some land buyers or developers may be interested in the property in the hope that they could develop the area for some financially beneficial use. Thus, the responsibility of the party who acquired the property should be explicitly defined in the land deed in order to ensure continuity of environmental controls over the former disposal area, in accordance with the approved closure and post-closure maintenance plan.

C. Site Assessment/Investigation

Before any closure plan can be developed, a site assessment/investigation is conducted to assess the existing conditions of the site. The site investigation process is a necessary step in the development of a better and more comprehensive closure and post-closure plan as knowledge of the actual conditions at the site, the operational procedures practiced during its operation, and other issues relative to the site, are studied. Site investigation may also help in identifying the extent of potential contamination and the likely pathways of contaminants.

Site investigation includes the following activities:

- Review of pertinent data such as the geology of the site, depth of groundwater, volume and types of wastes disposed, reports, studies, historical records concerning the dumpsite (operations, unusual events such as fires, dumping of hazardous wastes, etc.);
- Review of pertinent available maps (map of the dumpsite and its surroundings, topographical, geological, hydrogeological, etc.);
- Interview with those directly involved with the operation of the dumpsite, waste pickers, and residents near site;
- Inventory of existing settlements, structures, surface water bodies, water wells, etc.;
- Determine points of leachate seepage and ponding within and beyond the disposal facility;
- Identify existing land uses around the area;
- Conduct topographic survey of the dumpsite, extending some distance from its boundaries;
- Conduct geotechnical investigation to determine stability of slopes;
- Identify sources of soil or other cover material for the site;
- Determine, if practical, the depths of the dumped wastes;
- Determine gas leakage within and on the areas surrounding the dumpsite;
- Conduct leachate and gas sampling (if practical); and
- Conduct water quality sampling of surface waters, water wells, groundwater (if practical).

D. Evaluation of Options/Alternatives

After the conduct of the site investigation, the information gathered is analyzed and the practical solutions or alternatives are drawn up. The regulatory requirements, as well as the technical, financial, environmental and social considerations will generally dictate closure and post-closure plans. Figure 9 shows a graphical presentation of the issues for consideration when evaluating options.

D.1 Minimum Regulatory Requirements

Existing laws governing waste disposal facilities generally include provisions for closure and post-closure maintenance. In the absence of such guidelines, owners and operators of disposal facilities should implement generally accepted activities or measures for proper dumpsite closure and post-closure management.

D.2 Technical Feasibility

This pertains to technically "doable" activities based on the existing conditions at the dumpsite. The key is to use those that are reliable and cost effective. The assistance of a competent engineer with appropriate experience is essential.

D.3 Financial Viability

Closure and post-closure activities entail costs. And although it is unfortunate to note, financial limitations of local government units often determine which activities may or may not be included in a closure and post-closure programme.

D.4 Environmental Soundness

Closure and post-closure activities should not add to the damage that the open dumpsite is already exerting on the surrounding environment. These activities are intended to provide environmental controls to mitigate the adverse effects caused by the dumpsite as well as enhance its appearance for potential redevelopment later.

D.5 Social Considerations

If an open dumpsite is close to a developed area, there is generally more pressure for the site owners and/or operators to implement more acceptable or stringent closure and post-closure measures. Owners and operators of waste disposal facilities, especially financially-constrained local government units, should determine what is most appropriate based on several other factors as described above rather than solely on initial costs.

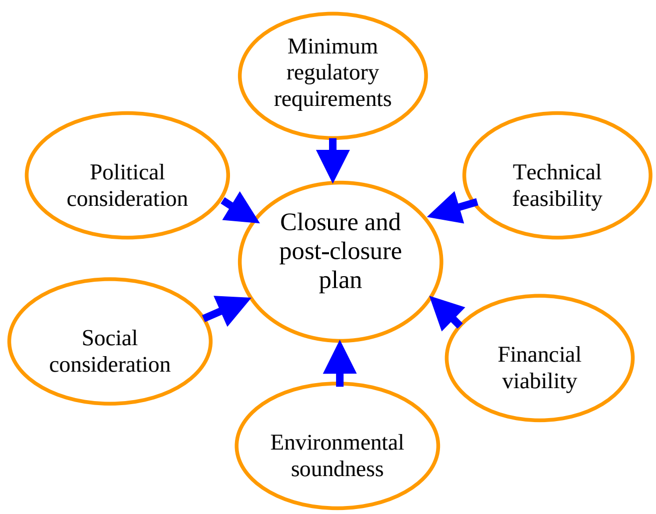


Figure 9. Evaluation of Closure Options/Alternatives

Other options and alternatives:

- Gas and Leachate Recovery and Utilization
- Landfill Mining

- Bioreactor Landfills

X. ELEMENTS OF A CLOSURE PLAN

Before a disposal facility stops receiving wastes, it is important that a final closure plan is prepared, approved, and available for implementation. The main components of the plan include, but are not limited, to the following:

- Stabilization of critical slopes;
- Final cover;
- Drainage control systems;
- Leachate and gas management systems;
- Fire control;
- Prevention of illegal dumping;
- Resettlement action plan; and
- Security.

A. Stabilization of Critical Slopes

The absence of proper operational procedures in most open dumpsites often result in dangerously high heaps of garbage. Thus, it may be necessary to level the heaps of garbage in order to reduce the hazards posed by unstable slopes. The final surface of the fill should be graded to about 2 - 4%, while the side slopes should have a vertical to horizontal ratio less than 1:3. Please see Figure 10.

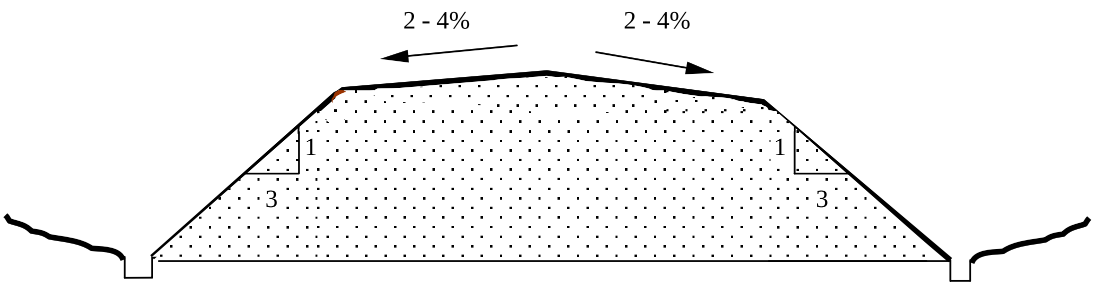


Figure 10. Grading of the Final Surface

B. Final Cover

The final soil cover (or cap) is applied to a completed disposal facility to act as a barrier in order to:

- Reduce infiltration of water into the disposal area;
- Reduce gas migration;
- Prevent burrowing animals from damaging the cover;
- Prevent the emergence of insects/rodents from the compacted refuse;
- Minimize the escape of odors, and;
- Support vegetation.

A uniform layer with a minimum depth of 0.60m (2 ft.) is recommended as final soil cover. It is usually composed of a layer of compacted soil with a depth of at least 0.45m (1.5 ft.) and a topsoil of at least 0.15m (0.5 ft.). The topsoil, which is usually not compacted, will serve as protection layer for the compacted soil cover, as well as support plant growth. (Figure 11).

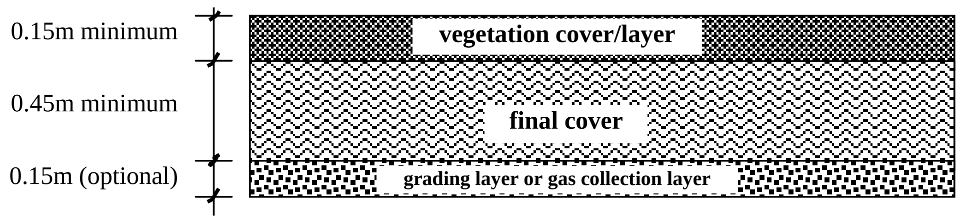


Figure 11. Recommended Final Soil Cover

C. Drainage Control Systems

Run-on and runoff of surface waters can cause erosion and scouring of the final cover, as well as water ponding. Thus, to mitigate these effects, drainage control systems are installed in and along the periphery of the disposal area.

When planning and designing the drainage control systems, the following should be considered:

- Surface waters should be diverted away from the disposal site at the shortest distance practical;
- The path or route of the drainage system should convey the surface waters at adequate velocities to prevent stagnation or deposition;
- Hydraulic gradient should be sufficient to maximize removal of surface waters but at the same time not too steep as to cause scouring, and;
- The design of the drainage systems and the materials used should consider the effects of settlement.

D. Leachate Management Systems

Where feasible (economically and technically), leachate pipes may be installed to collect the leachate for subsequent treatment. However, this will depend on several factors such as depth of the waste, topography of the area, underlying soil, and age of the deposited waste.

The following general procedures may be applied in addressing leachate problems due to the absence of leachate collection and/or treatment facilities:

1. A site survey and investigation should first be conducted and the following items determined:
    - Sources of leachate seepage at and around the surface of the disposal site. This should be determined before application of the final soil cover to determine the points of potential leachate seepage or ponding;
    - General topography of the area, and;
    - Inventory of existing water wells in the area.
2. For leachate seepages on the surface, these may be intercepted by constructing canals/ditches to collect the leachate. The collected leachate is then channeled towards a leachate retention basin/pond located downgradient of the site.

3. To intercept leachate movement below ground, an interceptor trench, cutoff wall, and collection pipes may be constructed downgradient of the disposal site.

These measures do not ensure that ground or surface water contamination near the site will not occur. They are only simple and inexpensive remedial measures that are intended to reduce as much as practical, the potential contamination that may occur.

The collected leachate is usually treated using biological or chemical methods (or a combination of both). Biological methods involve letting the wastewater pass through a series of stabilization ponds or the use of vegetation to absorb or digest the pollutants, while chemical methods involve the use of chemicals to treat leachate. The latter is less preferred since it is more costly. However, it maybe implemented if the situation warrants because of limited space for the treatment ponds, high organic characteristics of the influent, and if the chemicals are available and affordable. Leachate treatment is discussed more thoroughly under sanitary landfills in Subsection C.5 of Chapter IX, Part 2.

E. Gas Management Systems

Landfill gas, such as methane and carbon dioxide, will continue to be generated as long as waste decomposition occurs. Methane is a highly combustible gas and may cause explosions if it accumulates in an enclosed structure such as houses and buildings. Thus, depending on the environmental sensitivity of the area, it may be necessary to collect the gas and vent it freely, flare it, or recover it for energy use. Extracting gas from a waste fill has the additional advantage of reducing the concentration of various chemicals in the leachate thereby improving its quality. This is one way to lessen the impact of the leachate on area ground and surface waters. Gas extraction, however, entails a significant capital investment, and for many LGUs may not be an option.

Vent pipes may be made of perforated polyvinyl chloride (PVC), bamboo, or discarded oil drums welded together at the edges. Figure 12 shows a closed disposal area with vent pipes for gas management.

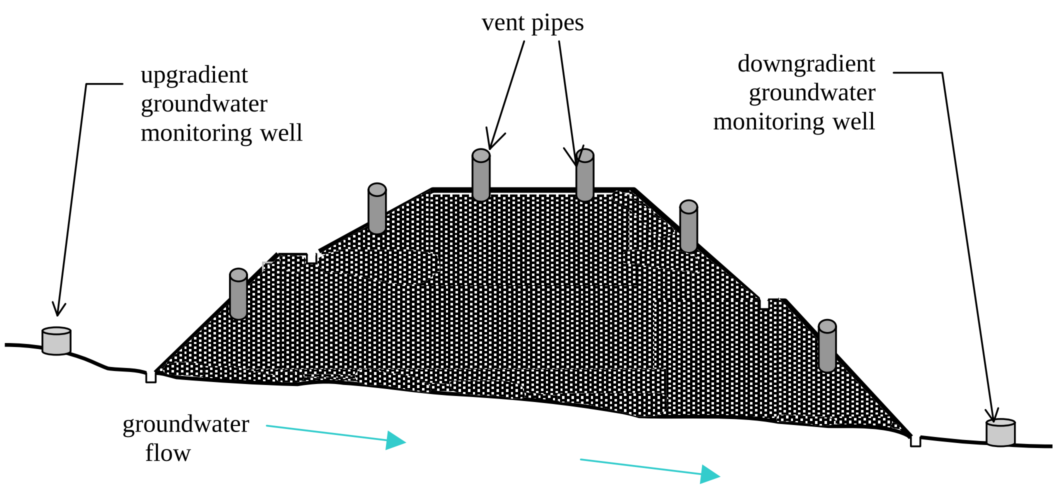


Figure 12. Vent Pipe and Monitoring Well Installation

F. Extinguishing Fires

If waste is burning in the dumpsite, or burning has been practiced for a long time, it is essential that the fire be thoroughly extinguished first before applying final cover or capping. Where the depth affected by burning is relatively shallow, the waste in the affected area is spread out to allow for complete combustion and after which, water may be applied prior to applying the final cover. Sand may also be applied instead of, or with water.

If the depth affected by burning is relatively deep, it may be necessary to isolate the burning area by excavating trenches around it. The waste is then spread or regularly agitated to allow for complete combustion. The ashes subsequently produced are then smothered with sand or soil.

G. Prevention of Illegal Dumping

It is possible that there will still be some individuals or private haulers who will attempt to dispose of their wastes on the closed disposal site. It may be because the new or alternative disposal facility is quite far from the source of waste and they may be reluctant to travel the distance. To control illegal dumping, the following may be implemented:

- A public awareness programme may be conducted to inform and encourage the public and private haulers to use the new facility. At the same time, steps are taken to ensure that illegal dumping is prevented such as signage, inspection and penalties; and
- A temporary/permanent facility or transfer station may be provided at the site to accept wastes from the general public or private haulers. The wastes are then transferred by the LGU to the new or alternative disposal site. The service may be provided for free to the general public, but commercial or industrial users should be obliged to transport their own wastes to the new site.

H. Resettlement Action Plan

If there are informal settlers (scavengers/waste pickers) at the disposal site, they should be relocated and an alternative livelihood provided for them. If the LGU operates or will operate a Materials Recovery Facility (MRF), these people can be formally hired since they are efficient in waste segregation. If organized waste picking is allowed at the new disposal site, a small space can also be allocated for these displaced families. Organized or managed waste picking may be allowed at controlled disposal sites with certain procedures in place.

I. Additional Recommended Activities

- Upgradient and downgradient wells from the closed dumpsite should be constructed to determine the existence of any gas or water contamination. Periodic testing of these wells is recommended until such time as the waste stabilizes.
- Security should be provided to control access and to prevent stray animals into the area.
- Signage/billboards should be installed informing the public that no structures should be erected and no excavations/burrowing is permitted in the area. The signage should use the local dialect(s) so that the residents easily understand them.

XI. POST-CLOSURE MANAGEMENT PROGRAMME

When disposal operations have ceased and final cover or capping has been applied to the waste, the disposal facility is considered as “closed”. Wastes should no longer be accepted at the facility for disposal and post-closure management is effected.

The long-term effects of settlement, gas emissions and leachate production, among others, will require aftercare measures for a closed disposal site long after it has ceased operations. Thus, post-closure activities are important in ensuring the proper functioning of the final cover, drainage control systems, leachate management systems, and other environmental controls.

Maintenance and monitoring programmes should be carefully planned so that it will meet the following:

- Regulatory requirements (allowable emissions/effluents, minimum period for such an activity);
- Annual budgetary constraints of the LGU; and
- Other factors (ex. environmental and community sensitivity of the facility).

A. Maintenance Programme

In order to effectively meet post-closure maintenance requirements, it is essential that a post-closure maintenance plan be developed. An ideal post-closure plan should have the following elements:

- Afteruse plan;
- Inspection schedule;
- Preventive maintenance; and
- Monitoring for groundwater, surface water, final effluent, and gas quality

B. Monitoring Programme

Long-term monitoring of closed disposal sites is conducted to ensure that there is no release of contaminants from the disposal site that may significantly affect public health and the surrounding environment. Although not specifically required by law in some countries, it is highly recommended that a monitoring programme for the quality of groundwater, surface waters nearest the closed disposal facility, final effluent (leachate), as well as gaseous emissions, be implemented.

XII. ATTENDANT COSTS OF CLOSING A DISPOSAL SITE

Decommissioning a disposal site will entail costs on the closure activities and post-closure management programme. Closure costs will occur at the end of the life of the disposal area, while post-closure costs will be incurred for at least the first ten 10) years after closure.

A. Closure Costs

Closure cost is composed of the capital and operational expenses. Figure 13 illustrates the costs that may be incurred when closing dumpsites.

Capital Expenses

- final cover material (if need to be imported into the site)
- drainage control systems
- fencing of the area
- leachate and gas management systems
- monitoring wells
- signage/billboards
- relocation of informal settlers
- planting
- grading

\+

Operational Expenses

- Heavy equipment rental – If the LGU owns the equipment, only maintenance costs may then be incurred. Otherwise, this may prove to be substantial.
- Manpower requirements – this includes laborers, utility men, and experts/consultants that may be hired.
- Electrical Service – this will be required for the operation of pumps and lighting requirements of the area.

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Closure cost

Figure 13. Closure Costs

B. Post-closure Maintenance Costs

Post-closure maintenance costs include the following:

- Manpower requirement – this includes personnel who will be tasked to: (a) secure the area; (b) conduct routine inspections; (c) conduct repair and preventive maintenance of site infrastructure such as the final cover, drainage control systems, and leachate and gas management systems, and; (d) conduct monitoring programmes for groundwater, surface water, leachate, and air quality.
- Repair and preventive maintenance costs – if there are damages to the cover, drainage control systems and other site facilities, repairs may need to be done. Preventive maintenance includes activities such as hauling of soil into the site to repair and seal cracks due to waste settlement, maintain grading of surface to facilitate surface runoff, and maintenance of leachate treatment ponds. Vermin control may also be needed to prevent or reduce damage to the cover. The procedures implemented and the chemicals applied (if any) for this should be clearly posted and displayed in conspicuous areas within and around the facility.
- Laboratory fees – groundwater, surface water and effluent and gas monitoring programmes will require testing for quality in public or private laboratories.

XIII. AFTERUSES OF A CLOSED DUMPSITE

A. Planning Considerations

A.1 Differential Settlement

As the waste in a disposal facility decomposes, it is reduced in size and settlement occurs. This settlement results into a final grade that may be as much as 30% (or greater) lower than the initial grade was during closure. Most of the expected settlement usually occurs within the first five (5) years after closure.

Settling can produce wide cracks in the cover of the disposal facility, exposing the wastes to vermin, flies and stray animals. It also allows gas and odors to escape and water to infiltrate, the latter causing increased settlement or even collapse of the waste mounds. Differential settling can also cause depressions, which may result into the ponding of water. Figure 14 shows a closed disposal area prior to settlement, while Figure 15 shows the effects of settlement and not maintaining proper grades.

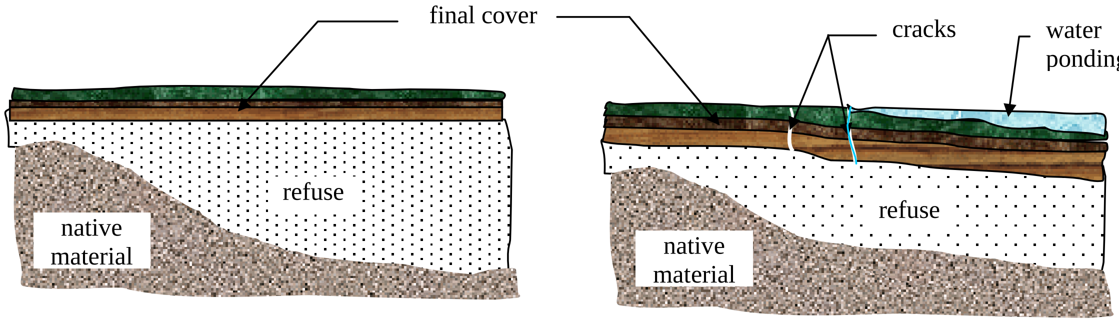


Figure 14. Before Settlement

Figure 15. After Settlement

A.2 Bearing Capacity

Simply put, the bearing capacity of a completed disposal site is the measure of its ability to support foundation. The bearing capacity of the cover material depends on the characteristics of the underlying waste and the compaction achieved during operation and closure. To construct substantial structures over an old disposal site generally requires deep footings to assure a firm foundation.

In contrast to natural soils, which are not as heterogeneous as wastes and produce a predictable pattern of deformation, solid wastes do not produce a uniform pattern of deformation when subjected to stress (loads) but instead, continues to alter its structure and composition over a long period of time. Thus, it is prudent that extreme caution be taken when conducting bearing capacity tests of completed disposal sites in the hope that heavy structures can be erected over it.

A.3 Gases

Gaseous by-products of decomposition will continue to be produced long after closure of the disposal site. Methane can accumulate in confined areas, structures and cause explosions. It can also kill or stunt the growth of vegetation. Consequently, structures over and nearby should have ventilation and monitoring systems in their foundations to detect gas buildup.

A.4 Corrosion

Because of the organic acids produced during waste decomposition, liquids from a completed disposal site are very corrosive. Unprotected steel, underground pipes, structural foundations and utility lines are subject to these corrosive elements. The acids can also deteriorate concrete surfaces, and in the process, expose the reinforcing bars of the structure and cause the concrete to fail. To mitigate these effects, all materials belowground at a closed disposal site that have the potential to corrode should be protected from these deleterious effects.

B. Potential Uses

Unlike sanitary landfills where an end use is already contemplated even in the planning stages (hence, the operation is properly managed to achieve the desired end use), open dumpsites are usually unplanned and haphazardly operated. Indiscriminate dumping, burning, and little or no compaction at all are common practices in open dumpsites. These practices greatly limit the potential for beneficial afteruse(s) of the site.

A proposed afteruse should be evaluated carefully from a technical and economic point of view. If more suitable land is available elsewhere that would not require the expensive construction techniques that may be required at a former disposal site, then it may be prudent to look for other sites. Selection of an end use for a closed disposal site is often dictated by availability of funds for a redevelopment project and the needs of the community. Any planned afteruse(s) of a closed or completed open dumpsite should take into account the planning considerations in the previous discussion.

Among the possible uses of a closed disposal site are the following:
- Green area/open meadows;
- Recreation area, and;
- Structures designed to accommodate the fill.

XIV. REMEDIATION/CLEANUP OPTIONS

Some problems may develop at a closed disposal site (or even during its operation) that may require remedial action. These problems may include severe leaking from leachate, fires and explosions due to methane gas, odor, litter, exposure of large areas due to waste slippage, or chronic health problems experienced by nearby communities that may be attributed to the site. The remedial action(s) taken will depend on the nature and degree of problem(s) that needs to be addressed. Some may require simple measures such as excavation or installation of additional materials such as vent pipes, while others may require the application of more aggressive remediation or cleanup technologies.

Cleanup technologies include the isolation of groundwater, soil washing, thermal treatment, vitrification, and the use of microorganisms, all of which may be very costly for most local government units.

Site rehabilitation/remediation invariably costs more than prevention.

The main considerations in selecting a cleanup technology include the following:
- Types of contamination present;
- Cleanup objectives and planned afteruse of the site;
- Length of time needed to achieve cleanup objectives;
- Post-treatment care needed; and
- Budget.

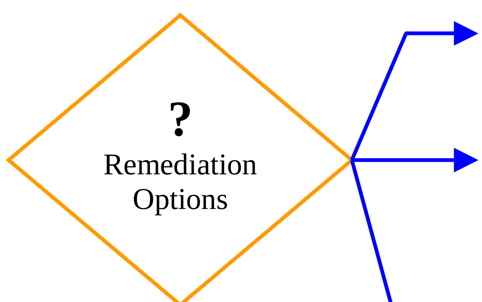
Generally, the more intensive the cleanup approach, the more quickly the contamination will be mitigated and the more costly the effort. For most LGUs, financial constraints will most likely dictate the actions taken (or not taken).

A. Evaluating Alternatives

To evaluate the remediation options available, you have to:

1. *Establish Remedial Goals.* The objectives or reasons for remediation should be defined. Remediation goals or objectives are very much related to the intended afteruse of the site. Example: If the end use of the site will be as an open meadow or green area, the degree of cleanup may not be as aggressive or as intensive as one where lightweight structures will be erected. Available funding and the timeframe for the project (ex. construction) are also important factors in defining the objectives for remediation.
2. *Develop a List of Options.* In order to know what remediation steps to take, you need to know what options you have. Determine the cleanup technologies available and the applicability of these technologies. A specialist will be required to determine the most appropriate technology for the given situation. Figure 16 illustrates a general concept on remediation alternatives.

The selection of the best remedial option can be achieved by integrating management alternatives with reuse alternatives to identify the potential constraints on the afteruse(s) of the site. Time constraints, cost, and risk factors should also be considered. Risk minimization should be balanced against redevelopment objectives, future uses and the needs of the community. In the evaluation of alternatives and options, there is generally some compromise in one or several aspects in order to achieve a desired result.



Institutional Controls - Controlling or limiting the current and future use of, and access to, a site.

Containment Technologies - Reduce the potential for migration of contaminants from the site to avoid exposing the public and the environment to the deleterious effects of such contaminants.

Cleanup Technologies - These can either be *in-situ* or *ex-situ*. *In-situ* technologies treat contamination on-site, without removal of the wastes. Technologies include bioremediation, soil flushing, and air sparging. *Ex-situ* technologies on the other hand, treat contamination off-site. A combination of both may be implemented.

Figure 16. Evaluation of Remediation Options

B. Conduct of Site Assessment/Investigation

Prior to any site rehabilitation/remediation, a site investigation is first conducted in order to assess the present condition of the disposal site. The activities described in Section C of Chapter IX are also applicable in this case.

Part 2

How to Shift from Open Dumping to Controlled Dumping And Eventually into Engineered Landfilling

I. INTRODUCTION

Upgrading from open to controlled dumping does not generally require significant capital investments as compared to upgrading from controlled dumping to sanitary landfilling. The former deals mainly with improvements on the operational and management aspects of the disposal site to lessen adverse environmental and health impacts (as compared to an open dump). Hence, it is imperative that the operation of controlled disposal facilities be properly implemented. Otherwise, they are bound to revert to or become just another open dumpsite.

Some of the procedures or activities recommended in the succeeding discussions may not be applicable to certain cases. As such, this module will give a general discussion on the issues that must be addressed when upgrading from open to controlled dump and from controlled dump to sanitary landfill. Actual field application should be adjusted or modified to suit the particular case.

Since some of the sections in this module are more thoroughly discussed in Part 1 (particularly on dumpsite closure), it is advised that the trainer should read the latter to facilitate discussions.

II. SPECIFIC OBJECTIVES

At the end of this module, the participants will be able to:

1. Describe the main differences among open dumps, controlled dumps, and sanitary landfills;
2. Identify and describe the necessary elements in upgrading from open dumping to controlled dumping and to sanitary landfilling, and;
3. Discuss other factors that greatly promote solid waste disposal practices.

III. PARTICIPANTS

1. Local government units (in order of preference):
   - City/Municipal Mayors;
   - Head of Office/Division in charge of solid waste management service (Ex. General Services Office, Environment & Natural Resources Office, Environment & Sanitation Division);
   - City Engineer's Office (City Engineer or senior technical staff who must be an engineer);
   - Dumpsite Operations Manager; and
   - Chairman, SWM Board/Technical Working Group.
2. National agencies (and their regional offices) in charge of solid waste management

IV. DURATION

16 HOURS

V. TOPICS FOR PRESENTATION

1. The Waste Decomposition Process and its By-products
2. Land Disposal Practices
3. Upgrading an Open Dumpsite to a Controlled Dump
4. Upgrading a Controlled Dump to a Sanitary Landfill
5. The Cost of Waste Disposal
6. Public Participation

VI. SUGGESTED METHODS

1. Lectures and Discussions
2. Slide/Video Show
3. Sharing of Experiences
4. Case Studies
5. Practical Exercises
6. Field visits
7. Mentoring

VII. THE WASTE DECOMPOSITION PROCESS AND ITS BY-PRODUCTS

Please refer to Chapter VII in Part 1 for a full discussion of this topic.

VIII. UPGRADING OF AN OPEN DUMPSITE TO A CONTROLLED DUMP

As described in Section D of Chapter VIII, Part 1, controlled dumps are non-engineered disposal sites where improvements made are mainly on the operational and management aspects of the site. Minimal site infrastructure or facilities are installed.

A. Planning Considerations

A.1 Site Options

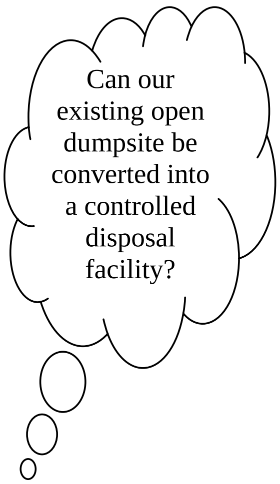
There are several reasons why an owner/operator of an open dumpsite may want the facility closed. Among which are the following:

- Area has reached its full capacity;
- Regulatory requirements;
- Pressure from interest groups, especially the public;
- Contamination has been detected, and;

- Concern of the owner/operator over its impact to public health and the environment.

When a local government unit decides to abandon the practice of open dumping and implement controlled disposal operations, it may either convert its existing open dumpsite into a controlled disposal facility, or close it and develop a new site. The new site may mean either an area adjacent to the closed open dump or to a different site.

Conversion of an open dumpsite indicates that disposal operations will be implemented over an area where open dumping was previously practiced.



Major Considerations

Area capacity – the available disposal area should be able to accommodate wastes from the service area: (a) for at least three (3) years; (b) until the period the controlled dumpsite is allowed to operate, or; (c) when a sanitary landfill shall have been developed.

The open dump is in an area where groundwater pollution is not critical. This is usually determined by the characteristics of the underlying formations beneath the dumpsite.

The present open dumpsite is not within or proximate to sensitive receptors such as: built-up areas, groundwater reservoir or watershed areas, geological hazards such as active faults, erosion prone areas, and flood-prone areas.

If the existing open dump does not meet most of these criteria, especially the groundwater pollution potential, it is not recommended for conversion into a controlled disposal site. Instead, a new site should be developed.

In order to assess whether the existing open dump may be converted into a controlled disposal site, a site investigation/assessment should be conducted. The procedures for site investigation/assessment as described in Section C of Chapter IX, Part 1 are also applicable.

A.2 Closure and Rehabilitation of the Open Dumpsite

If a new site is developed and ready for waste disposal, the old open dump is properly closed and rehabilitated as necessary. Considerations necessary for the proper closure and rehabilitation of open dumps are presented in Part 1.

B. Development of a Controlled Dump on a New Site

This Section covers only proposed controlled disposal facilities on new sites. It does not cover conversion of existing open dumps into controlled dumps (which is discussed on the next Section).

B.1 Siting Requirements

Except for the conduct of an environmental risk assessment (EnRA), the siting requirements for new controlled disposal sites are essentially the same as that for sanitary landfills. At a minimum, the siting of new controlled disposal facilities take into consideration the hydrogeologic conditions of the site.

The trainer/reader is referred to Section B of Chapter IX for the siting requirements for sanitary landfills since these are also applicable for controlled disposal facilities. The rationale for this is that, unlike sanitary landfills, controlled dumps rely on natural attenuation and have minimal environmental controls. Therefore, the standards to be adapted or applied in selecting a site for them should be similar, if not more stringent, than for sanitary landfills.

B.2 Design Requirements

The following are the minimum design requirements for controlled disposal facilities. More stringent measures may be implemented.

- Area capacity – the following formula may be used to estimate the life span of a proposed controlled disposal site:

$$LS = \frac{1}{365}\left\{ \left(A \text{ x } d \text{ x } 1.33 \text{ x } 0.85 \right) \div \left((WGR \text{ x } P) \div \rho \right) \right\}$$

where:

LS = estimated life span of the controlled dumpsite (years)
A = area of the disposal site (m^2)
d = average depth of the disposal site (m)
WGR = waste generation rate (kg/person/day)
ρ = loose density of the waste (kg/m^3)
P = population to be served (persons)

Note:

- A waste generation rate of 0.50 kg/person/day may be used for developing countries (World Bank Study).
- The 1.33 factor in the equation accounts for an assumed average compaction factor of 33% achieved during landfill operations. For controlled dumpsites, it will be lower or nil.
- The 0.85 factor in the equation accounts for a soil cover to waste ratio of 1:6 (for a given volume, 15% is soil cover and 85% is waste).
- A loose/uncompacted density of about 330 kg/m^3 is used to convert kg/day to m^3/day, as per World Bank study. It may vary in some areas.

The estimate does not include land area for leachate treatment facilities, buffer zone and other auxiliary facilities.

B.3 Site Preparation

The following is the minimum site preparation required for controlled disposal facilities. More stringent measures may be implemented.

- Trees, plants and other vegetation that are within the proposed disposal area should be removed. Trees and plants along the property's periphery will not be touched since they also serve as buffer zone for the facility.
- The bed of the disposal area should be graded to about 2–4%, and preferably be compacted and/or overlain with clay material in order to attain a suitable surface as much as practical prior to controlled disposal operations.
- Drainage canals/ditches should be constructed along the periphery of the site in order to collect and divert surface water away from the disposal area. Drainage should also be provided along the access road and areas prone to ponding in order to avoid accumulation of water during heavy rain.
- In order to prevent illegal entry to the site, including that of stray animals, a perimeter fence should encompass the disposal area. Fencing also prevents light materials, such as plastics, from being blown away from the disposal area. A buffer zone is also provided by planting appropriate species of native trees and plants along the periphery of the site.
- Provision of a well-maintained access road to and within the site in order to facilitate waste transport even during inclement weather. A layer of tractive material such as gravel, crushed stone, and construction debris may also be provided, especially during rainy weather.
- Ancillary facilities such as a guardhouse, maintenance building, weigh scale, and a field office may also be provided as well as basic utilities such as water and electricity.

B.4 Additional Recommended Activities

- It is recommended that at least one (1) upgradient and one (1) downgradient - monitoring well be installed to serve as sampling points for groundwater quality. These monitoring wells may be concrete lined and should penetrate down to the groundwater table.

C. Conversion of an Open Dump into a Controlled Dump

As discussed in Subsection A.1 of Chapter VIII, <u>conversion</u> should be taken to mean that controlled disposal operations is be implemented over an area previously used for open dumping. Therefore, it will not be covered by siting requirements. Improvements will mainly be on the operational aspect as well as some infrastructures and practices as discussed in Subsection B.3 of Chapter VIII and summarized in Table 1.

Although the actual procedures may vary in accordance with the conditions of each disposal site, the following procedures are generally applicable in the conversion of an open dumpsite for controlled disposal operations:

C.1 Site Preparation

- Due to indiscriminate dumping and limited planning during previous open dumping operations, some portions of the area need to be leveled off and graded in order to attain as much as practical, a suitable surface prior to controlled disposal operations.
- Structures such as storage areas for recyclables by scavengers, shanties and others that are within the boundaries of the disposal facility should be relocated outside of the disposal area.

Except for grading of the bottom of the disposal area, all other provisions for site preparation under Subsection B.3 of Chapter VIII will also be applied for the conversion of an existing open dumpsite.

D. Operation of a Controlled Dump

This Section, as well as the succeeding Sections, covers both new sites and open dumps converted into controlled disposal sites. Table 3 shows the operating guidelines for controlled disposal sites.

Table 3. Operating Guidelines for Controlled Dumps

Criteria/Activity	Guidelines
Operating hours	• Operating hours should be in accordance with the collection schedules of the garbage collection vehicles. • Night- time operations should be avoided as much as practical.
Use of the facility	• Only municipal solid wastes are accepted. • Toxic or hazardous wastes are not allowed. • Vehicles entering the facility register, weighed upon entry, and checked before being allowed to proceed to the present working area. • Site personnel record all pertinent data, such as the truck number, time it entered the facility, etc.
Unloading of the waste	• Waste is unloaded at the working area/face. • Unloading of the waste is supervised.
Spreading and compaction of the waste	• The active filling area or "working face" is minimized as much as practical. An appropriate size is about 2 to 3 times the width of the compactor vehicle. • Waste is spread and compacted in layers not greater than 0.6m (2 ft.) after compaction. • Compaction of the waste should be on a slope of about 20-30% and worked from the bottom of the slope to the top (see Figure 27 p. 48).
Application of daily cover	• A soil cover of at least 0.15m (0.5 ft.) thick is placed over the waste and compacted, preferably at the end of each working day. • Inert material such as carbonized rice hulls or non-hazardous ash may also be used as cover material. • Daily cover material is provided near the disposal area to facilitate covering of the waste. • Inactive areas are covered with an intermediate cover of at least 0.30m (1 ft.).
Litter barrier	• A movable litter barrier is installed downwind of the active area.
Record keeping	• Basic record keeping includes the volume of waste received daily, special occurrences such as fires, accidents, spills, unauthorized loads, and daily waste inspection logs.
Waste picking (if allowed)	• Waste picking is managed and controlled in order not to disrupt operations and prevent accidents.
Operations supervision	• Trained personnel supervise site operations • An Operations Manual should be available to guide field personnel.

E. Monitoring of Dumpsite Performance

Monitoring activities are important in order to determine and evaluate dumpsite operations. The information gathered can be used to correct any deficiencies and reduce impacts to public health and the environment, as well as to predict remaining site life. Monitoring activities include regular:

- Recording of the incoming waste volumes;
- Land surveying of the waste disposal area;
- Monitoring of groundwater quality near the disposal facility;
- Inspection of drainage canals and ditches; and
- Availability of earth cover material.

F. Post-Closure Management

The trainer/reader is referred to Part 1 for discussions on post-closure management. The activities and discussions are essentially the same as for a controlled dump.

G. Site Afteruse

The trainer/reader is referred to Part 1 for discussions on site afteruses. Again, the activities and discussions are essentially the same as for a controlled dump.

H. Attendant Costs of Upgrading from Open to Controlled Dumping

The conversion of an open dump into a controlled dump is usually less costly than developing a new site since transferring to a new site will entail closure, post-closure, and remediation costs of the old site as well as acquisition cost for the new site. However, the decision to convert an open dump into a controlled dump instead of developing a new site should not be based on costs alone, but rather on the conditions described in Section A.1.

H.1 Controlled Dumping on a New Site

Although the actual figures are site specific, the cost elements that may be incurred in developing a controlled dump in a new site are illustrated in Figure 17.

Capital Expenses		***Operational Expenses***		
• land acquisition • closure, post-closure, and remediation (as necessary) of the old dumpsite • ancillary facilities like roads, guardhouse, field office, etc. • fencing, signage and lighting of the site (including litter barrier and buffer zone) • leachate and gas management systems • monitoring wells	+	• Heavy equipment rental – If the LGU owns the equipment, only maintenance costs may then be incurred. Otherwise, this may prove to be substantial. • Manpower requirements – This includes laborers, utility men, and experts/consultants that may be hired. • Hauling of soil cover material (if necessary). • Electrical Service – this will be required for the operation of pumps and lighting requirements of the area • Closure and post-closure maintenance	=	**Closure cost**

Figure 17. Costs for Developing Controlled Dumps

H.2 Conversion of an Open Dumpsite for Controlled Dumping

The costs associated with the conversion of an open dump into a controlled dump are essentially the same as that described in Section H.1. The main differences would be; (a) the land acquisition cost, and; (b) the closure, post-closure and remediation costs for the existing open dumpsite.

IX. UPGRADING FROM CONTROLLED DUMPING TO SANITARY LANDFILLING

Among the methods applied today to dispose of municipal solid wastes on land, sanitary landfilling is considered to be the most desirable and most appropriate method. It has the least impact on public health and the environment compared to an open or controlled dump, and it entails the least cost compared to newer technologies for final waste disposal.

The degree of engineering implemented in the development of a sanitary landfill will depend on several factors such as the physical conditions of the site, economics and socio-political constraints. This section presents a general discussion on the design, construction, operation, maintenance, and closure and post closure care of sanitary landfills. A higher degree or level of engineering may be implemented as necessary.

A. Planning Considerations

Converting an existing controlled dump to a sanitary landfill is generally not practical. This is due to the fact that, the development of a sanitary landfill requires the installation of bottom liners and leachate collection systems prior to disposal of waste. And unless the volume of waste is very minimal, excavation or stabilizing existing waste heaps in order to use the site as a sanitary landfill entails unnecessary effort and expenditure. The development of a sanitary landfill, therefore, is usually on a new site.

B. Siting Requirements

The location and characteristics of a proposed site will determine the extent and nature of the overall potential impacts of a sanitary landfill on public health and the environment. This in turn affects the degree of engineering measures required and consequently, the associated cost for such measures. In order to keep costs to a minimum, the selection of a landfill site has to meet several location and geotechnical design criteria, as well as public acceptance. Some fundamental criteria that need to be considered are described in Table 4.

Table 4. Siting Requirements for Sanitary Landfills

Criteria	Considerations/Limitations
Capacity of the area	• The capacity of the site should be sufficient to recover capital investment, and for this reason, the recommended minimum design life is at least 10 years. • Total land area required is the actual disposal area required plus an additional area of 20%-40% for buffer zone, access roads, auxiliary facilities and others.
Public involvement	• The acceptability of affected communities is crucial to the success of a proposed project. Therefore, they should be involved in the siting process, as well as on the other stages of landfill development.
Proximity to built-up areas	• No residential development within 250m from the perimeter of the proposed facility. • Landfill operations should not be visible from residential communities within 1 km. (0.625 miles) of the site. Otherwise, a buffer zone of trees, landscaping, and other ways to minimize visibility of operations may be incorporated in the design.
Hydro-geologic conditions	The site should not be located: • in areas with a high water table. The groundwater table's seasonally high level should be at least 1.5m below the base of the landfill. • within 500m up gradient of private or public drinking, irrigation, or livestock water supply wells • in areas considered part of a 10-year recharge area for existing or future potable water sources • within 300m up gradient of perennial streams, unless the stream is protected from potential

Criteria	Considerations/Limitations
	contamination • along geological faults or areas which experience frequent seismic activity • where the underlying rock formations are porous such as limestone, carbonate, fissured or other porous rock formations • in areas with sinkholes, caverns or solution channels • in wetlands or floodplains The site should preferably be located: • in areas where the underlying soil is clay • above igneous or metamorphic rock formations (not fractured and/or jointed) that have low permeability such as shist, gneiss, quartzite, obsidian, marble, and granite
Availability of cover material	• The site should have adequate amount of cover material to minimize or avoid importing from outside sources.
Topography	• An area with gently sloping topography is preferred in order to minimize earthworks necessary to achieve the recommended landfill bottom grade of about 2% for leachate drainage.
Accessibility	• The site should ideally be at a maximum distance of 15-20 km. or a travel time of less than 30 minutes from the service area. Beyond these, larger capacity collection vehicles or a transfer station may be necessary. • The site should be close to well-paved major roads.
Proximity to ecologically sensitive areas	• Not within ecologically sensitive areas such as national parks, forest reserves, protected areas, breeding areas for endangered species, and others. There should be no significant protected forests or areas with known rare or endangered species within 500m of the operation area.
Proximity to airports	• Not within 3 km. of an airport servicing turbojet aircraft, or 1.6 km. of an airport servicing piston driven or turboprop aircraft. If a site is located more than 3 km. but less than 8 km. from an airport servicing turbojet aircraft, permission from the aviation authority should be sought.
Other considerations	• Areas with very windy conditions most of the time should be avoided. • No major electrical, gas, sewer or water lines should cross or be located close to the proposed site, unless it can be assured that the landfill will not present a problem to such infrastructure or if rerouting is practical and economically feasible. • Future trends in land development or land use in the area should also be considered in order to avoid problems later.

In order to select the most appropriate site for a sanitary landfill, several sites should be initially considered and investigated. These sites should be evaluated and ranked according to the siting criteria discussed above. Ranking may be done by assigning weights for the different criteria, depending on the level of importance as deemed by the planners and stakeholders of the facility. Once the final site is selected, an environmental risk assessment (EnRA) is made.

Because proper engineering measures can mitigate most of the inadequacies of a proposed site, it may be selected even though it does not meet all of the above criteria. However, the added costs required to make the site comply with the criteria should be considered.

C. Design Considerations

After a site has been selected, the design of the sanitary landfill is undertaken. The factors to be considered in the design of the facility are discussed below.

C.1 Type of Waste to be Handled

It should be determined if the facility will accept wastes other than municipal solid waste in order to be considered in the facility's layout. Special wastes such as household hazardous wastes (e.g. asbestos, batteries, tires, etc.) are segregated from ordinary wastes and are disposed of in separate cells.

C.*2 Layout of the Site*

In planning the layout of the facility, the following should be determined:

- Location of access roads;
- Disposal area;
- Areas for auxiliary facilities such as site office, motorpool, etc.;
- Location of weigh scale (if any);
- Waste processing areas, such as for waste segregation, composting and other facilities if incorporated within the site;
- Disposal cells/sites for special wastes;
- Drainage facilities;
- Leachate treatment facilities;
- Landfill gas management facilities;
- Monitoring wells; and
- Buffer zone/plantings.

The layout of each facility is site-specific and should be carefully planned by designers of such facilities. A typical layout for a sanitary landfill incorporating the items above is shown in Figure18. An all-weather access road and security fence encompasses the landfill for access to the different phases of the site and for security. The different components of a landfill are also shown such as the drainage ditches along the perimeter of the site, leachate treatment facility, monitoring wells, weigh scale, special wastes cell, a stockpile of soil cover, and others. The landfill also has an active disposal area for wet operations and this is usually close to the main access road to facilitate operations during rainy weather.

C.3 Landfill Capacity

A more thorough determination of the capacity of a proposed site considers the nominal volume of the site (which is the sum of successive lifts), the impact of waste compactibility, daily cover, and waste decomposition.

The nominal volume is a preliminary estimate of the capacity of the landfill. The actual total capacity should take into consideration the initial weight of the waste as it is placed in the landfill, the impact of waste compaction, and waste decomposition.

C.4 Local Geology and Hydrogeology

The geologic and hydrogeologic characteristics are determined by boring holes at the site and obtaining core samples. Sufficient boreholes should be made in order to establish the underlying geologic formations from the surface up to the upper portions of the bedrock or other confining layers. The information obtained from the samples will be used to determine:

- Depth and types of soils;
- The general direction of groundwater flow at the site;
- If any unconsolidated or bedrock aquifers are in direct hydraulic connection with the proposed site, and;
- The type of liner system that may be required.

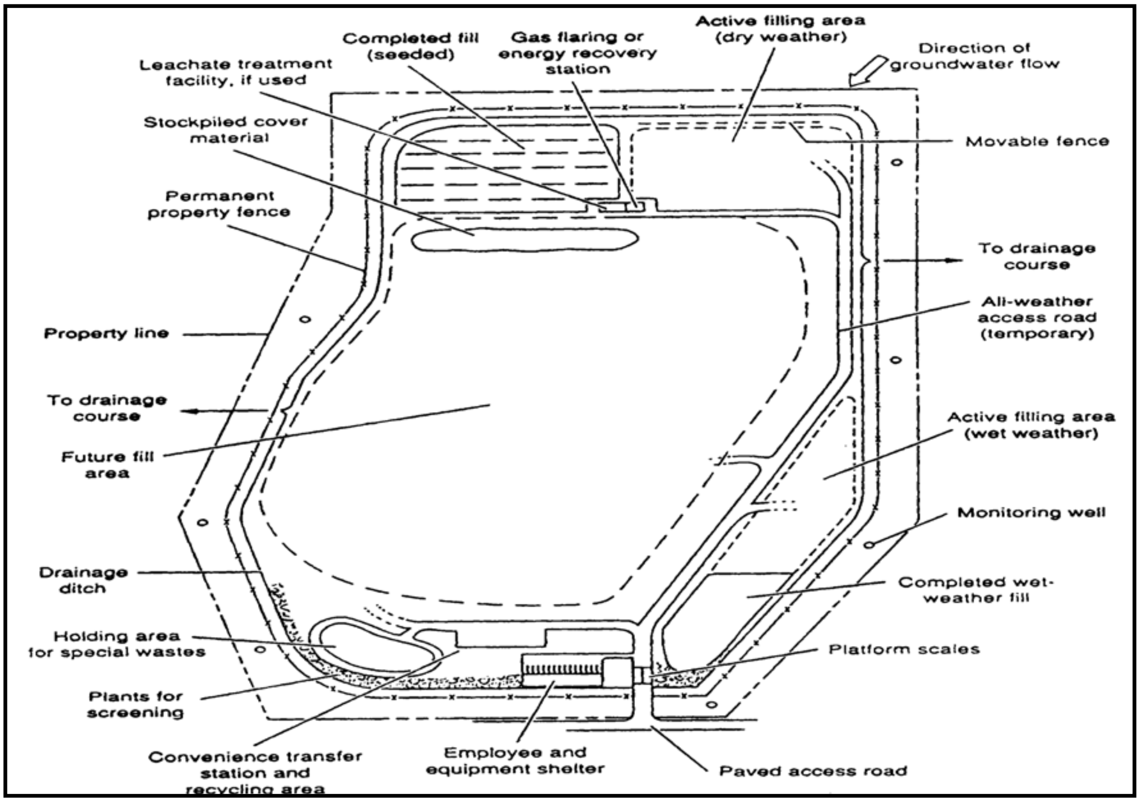


Figure 18. Typical Layout of a Sanitary Landfill

C.5 Leachate Management

Leachate management is one of the major factors in safe landfill design and operation. As discussed in Section B of Chapter VII, Part 1, leachate is a contaminated liquid that needs to be properly managed to avoid contamination of groundwater as well as surface waters. The following discussion will describe landfill lining systems and leachate collection and treatment systems.

Soil Liners

Liners act as barriers to eliminate leakage, or minimize the rate at which leachate within the waste facility escapes into the surrounding environment. Apart from being of low permeability, liners should be durable and resistant to puncture and to chemical attack. The types of liners used for landfills are: (a) clayey soils; (b) geosynthetics (geotextiles, geomembranes, geonets, geogrids), and; (c) amended soil (usually with ash or bentonite). These materials may be used singly or in combination. Availability and cost are usually the key factors involved in material selection.

The properties of clay liners and their susceptibility to changes with time are major concerns in the design of waste containment systems. The factors that affect these properties are: (a) soil composition; (b) chemical compatibility between the clay liner and the leachate; (c) placement conditions and effects of construction, and; (d) post-construction changes. Items (c) and (d) are discussed later in Section D under Site Preparation and Construction.

Soil Composition

- The material used to construct the liner must be carefully selected in order to obtain a clay liner that is durable, stable, and attain a hydraulic conductivity of not greater than 1 x 10^{-7} cm/sec. (at a minimum thickness of 1m).
- There should be no soil particles with a diameter greater than 0.025-0.05 m (0.08-0.17 ft.) since well-graded soils achieve higher densities upon compaction and have a uniform distribution of small pores.
- The plasticity index (PI) should be greater than 10%, but should not exceed 30 – 40% since at higher PI, construction is more difficult.

Chemical Compatibility

The long-term effect on the hydraulic conductivity of a clay liner in contact with leachate is generally not adversely affected. However, pure organic chemicals (e.g. solvents) may cause shrinkage and cracking, increasing its hydraulic conductivity.

Amended Soil

If the soil in a proposed disposal site is not suitable for liner construction, suitable soil (such as clay) may be brought in to the site or, certain materials could be used to amend the existing soil and reduce its permeability. Bentonites have often been used for this purpose since it swells heavily upon addition of water and thus, forms a low-permeability medium.

Geosynthetics

Geosynthetics is a general term that includes geomembranes, geotextiles, geonets, and geogrids. These synthetic membranes may be used on their own, or as part of a composite liner. Depending on its required function, geosynthetics may be used for isolation, filtration, drainage, and slope stability.

(a) Geomembranes

Geomembranes have very low-permeability properties and are therefore used as a barrier to intercept leachate. They range in thickness from 30mil (0.75mm) to 120mil (3.0mm) and have lengths of up to 500m. The chemical compatibility of a synthetic membrane with the waste leachate must be determined, either from historical and/or test data to determine its susceptibility to the leachate.

Geomembranes may fail due to punctures caused by voids, falling objects, movement of equipment on the liner, abrasion, and movement against sharp objects. These problems may be avoided by:

- Ensuring that the ground surface is flat, compacted, and free of sharp stones or debris;
- Applying a layer of fine soil approximately 0.60m over the membrane to cushion it against damage.
- Applying herbicide to prevent certain grass species from germinating.

(b) Other geosynthetics

Geotextiles

Geotextiles are used as filters to prevent the movement of soil and waste fines into drainage systems, or to act as a cushion to protect geomembranes against damage. These are permeable textiles that allow a fluid to flow through it, but prevent the movement of adjacent soil particles.

Geonets

These are used for lateral drainage and often, are substituted for sand layers. The grid-like character of the material provides extensive flow opportunity as compared to a layer of sand with the same hydraulic transmissivity (Figure19). The use of a geonet, therefore, reduces the volume requirements while maintaining the necessary transmissivity, and it is much easier to place than sand.

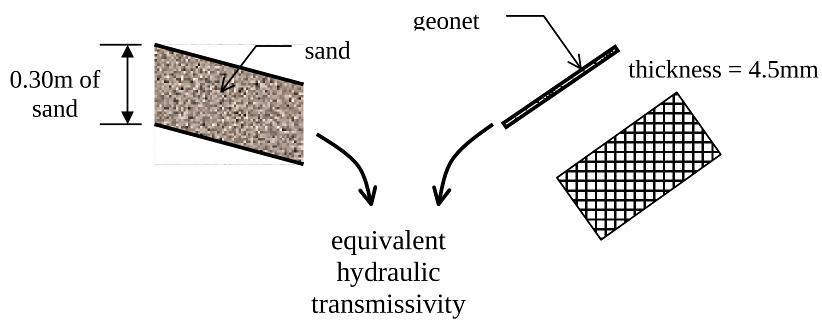


Figure 19. Geonet Compared With a Layer of Sand

Double-Liners and Composite Liners

(a) Composite Liners

Composite liners refer to a liner system incorporating two or more liners of different materials in direct contact with each other. A typical arrangement is the placement of a geomembrane on top of a compacted clay liner (Figure 20). A composite liner is not a double liner.

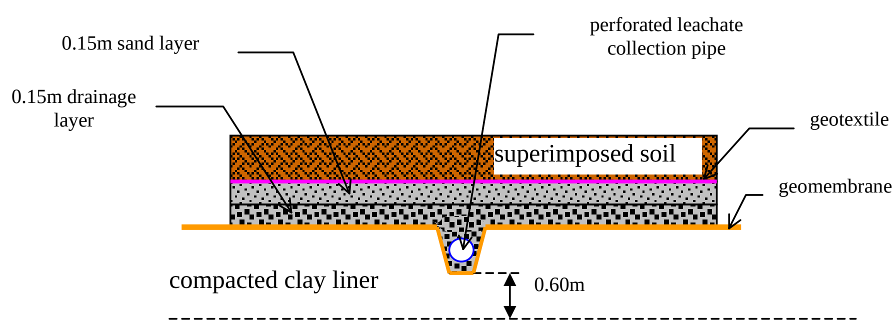


Figure 20. A Composite Liner

(b) Double-Liners

Double-liners have been used for hazardous waste landfill sites and are now increasingly being used for municipal wastes. A double-liner system consists of two liners with a highly permeable drainage layer (for leachate detection) between them. The upper liner contains majority of the leachate, while the lower layer is to contain any leachate that may have leaked through the upper liner.

Leachate Collection Systems

The landfill bed is sloped to allow leachate to flow towards the leachate collection pipes. From the pipes, the leachate could either be gravity-drained or pumped to a leachate treatment plant. Figure 21 shows a typical pipe network for leachate collection. The figure on the left is used for piped bottom designs while the one on the right is for sloped bottom designs.

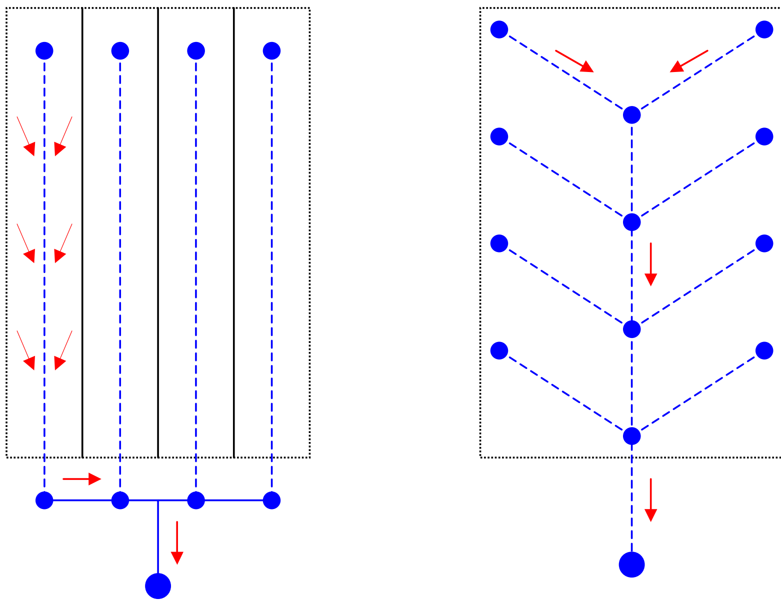
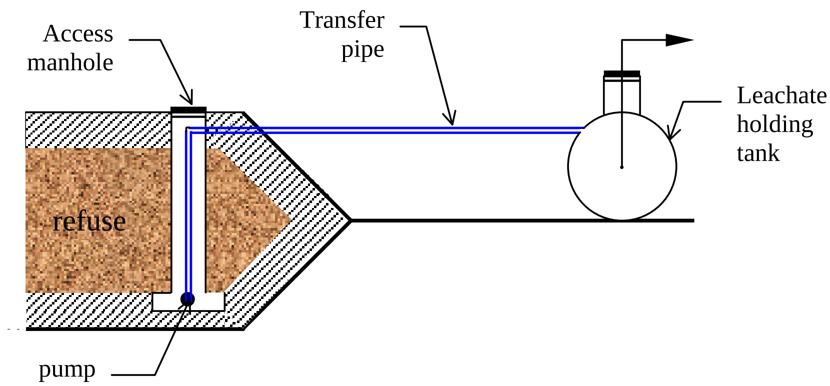


Figure 21. Typical Pipe Network for Leachate Collection

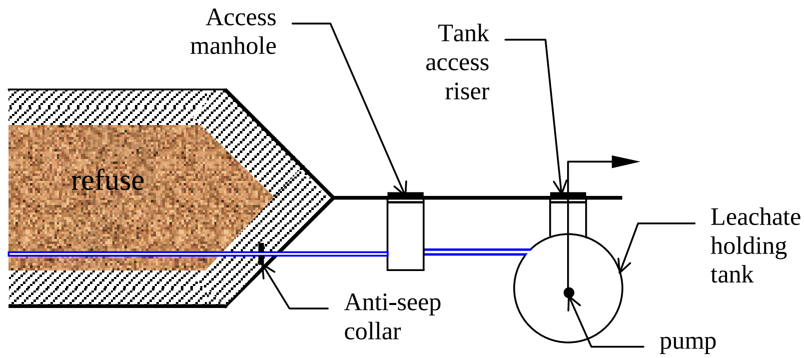
Some important points in the design of leachate collection systems include the following:

- The base of the landfill should have a minimum final slope of 2% to encourage lateral migration.
- The drainage layer should have a minimum hydraulic conductivity of 1×10^{-3} cm./sec.
- A layer of gravel is laid above and below the perforated pipe to maximize the amount of leachate diverted to, and collected by the network of perforated collection pipes.
- The perforated pipes should have a minimum diameter of 0.15 m. (0.5 ft.), and should have a minimum slope of 0.5%.

Figure 22 shows how leachate is conveyed to the treatment plants. Figure 22a is applicable when the leachate treatment plants are at a higher elevation than the bottom of the landfill, and therefore, removal by pumping is used. Figure 22b uses gravity to convey leachate to the treatment plants.



(a) Leachate Removal/Storage Above Grade



(b) Leachate Removal/Storage Below Grade (alternative)

Figure 22. (a) Leachate removal by pumping; (b) Leachate removal by gravity

Leachate Treatment Ponds

Stabilization ponds are often used to biologically treat the leachate collected by the network of collection pipes. The hot climate in tropical countries, as well as the availability of land, makes biological treatment of the leachate in *stabilization ponds* very ideal. Stabilization ponds are simple to build, reliable, are not energy–intensive, does not require complex machinery, and easy to maintain. They can effectively reduce up to 80% the biological oxygen demand (BOD) concentration of leachate, as well as effect suspended solids and pathogen removal. Table 5 summarizes the different characteristics of these ponds while Figure 23 shows a typical layout of the different ponds.

Table 5. Characteristics of Stabilization Ponds

Pond	Characteristics
Anaerobic	• usually the first in a series of ponds that treat leachate • used for high organic-loading rates generally greater than 240 parts per million (ppm of BOD_5 • 2 – 4 meters deep and have a small surface area relative to its depth • design is based on volumetric BOD loading
Facultative	• usually receive the effluent from the anaerobic pond • organic loading rates range from 160 to 240 ppm BOD_5 • 1.5 - 2.5m deep • design is based on the maximum BOD load per unit area at which the pond will still have a substantial aerobic zone
Maturation	• receive the effluent from facultative ponds • used for polishing of the effluent • very light load of less than 50 ppm BOD_5 • 1 – 1.5m deep

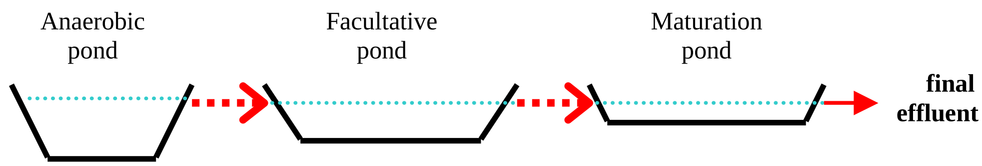


Figure 23. Layout of Waste Stabilization Ponds

Leachate volume varies according to precipitation more than any other factor. Leachate volume should be calculated and the pond prepared according to the anticipated leachate volume in the rainy season. The following is a rational method for calculating the capacity of a leachate containment/treatment pond:

1) Anticipated precipitation

Precipitation time-series data used for the site (latest available).

2) Daily leachate volume: Qj

Using the rational formula, Qj is sought by the following equation.

$$Q_j = \frac{1}{1000} \cdot I_j \cdot (C_1 \cdot A_1 + C_2 \cdot A_2)$$

Where:

Qj: Daily leachate volume (m^3)
Ij: Daily precipitation (mm/day)
A1: Area of landfill section (m^2)
A2: Area of waste-filled section (m^2)
C1: Leachate coefficient of landfill section
C2: Leachate coefficient of waste-filled section

As the landfill stabilizes, the proportion of readily biodegradable organic compounds in the leachate decreases. Thus, biological treatment processes become less effective in treating the wastewater and other forms of physical and/or chemical treatment methods may be more appropriate.

Physical and chemical methods include the addition of chemicals known as coagulants to coagulate or precipitate inorganic and organic fractions; the use of activated carbon and ion exchange resins to adsorb the pollutants; and using reverse osmosis. Usual coagulants used for chemical precipitation include lime, alum, and ferric chloride. Carbon adsorption treats wastewaters through sorption onto powder or granular activated carbon. Reverse osmosis involves forcing the wastewater to pass through a membrane (natural osmotic pressure), thereby separating water and ions.

C.6 Gas Management

As discussed in Section B of Chapter VII, Part 1, methane is a major concern for sanitary landfills since it is an explosion hazard if it accumulates. For this reason, gas extraction facilities are be provided to collect the gases and, either flare them or recover them for use as an alternative energy source. Gas extraction may either be passive or active.

Passive Venting System

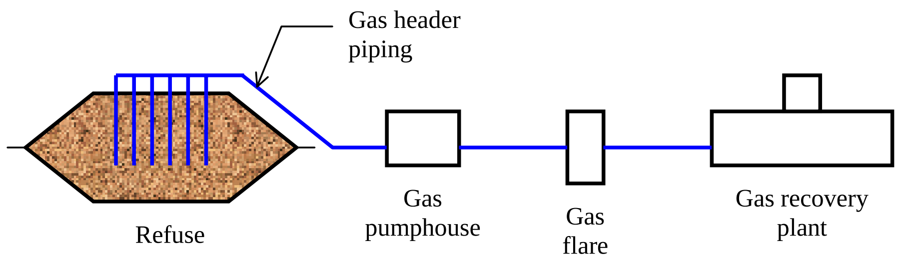
Passive venting system consists of a number of perforated pipes installed vertically and uses the natural pressure of the gas to collect and vent or flare it at the surface. Such systems are installed where gas generation is low and off-site migration of gas is not expected. It is suitable for small municipal landfills (less than 40,000 m^3) and for most non-municipal containment type landfills. The system may consist of a series of isolated gas vents, with at least one (1) vent provided for every 7,500 m^3 of waste.

Active Venting System

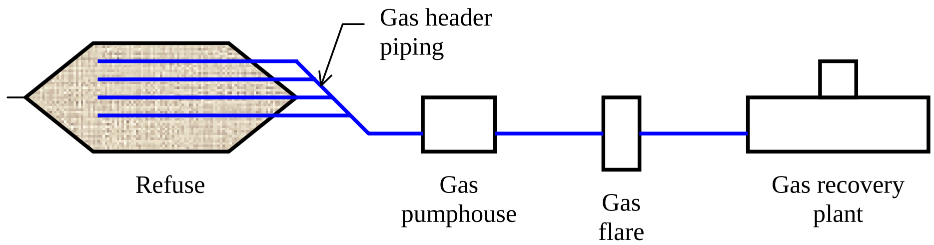
An active venting system consists of a network of wells, pipes and pumps to extract the gas and process it for heating or electricity generation. The feasibility of recovering gas to produce energy should consider the:

- Quantity and quality of the gas that can be recovered;
- Availability of a market for the recovered gas or electricity;
- Distance to economically transport this gas or electricity; and
- Unit price that can be obtained for the energy produced.

Figure 24 shows typical active gas collection systems, the main difference of the two schemes being the piping method used.



(a) Vertical Piping



(b) Horizontal Piping

Figure 24. Typical Gas Collection Systems

C.7 Surface Drainage Facilities

An overall drainage plan should be developed as part of landfill design in order to effectively divert surface waters from the landfill. Surface water control is usually accomplished by constructing open channels/ditches to divert runoff from surrounding areas, along access roads, and areas prone to ponding.

When planning and designing the drainage control systems, the following should be considered:
- Surface waters should be diverted away from the disposal site at the shortest distance practical;
- The path or route of the drainage system should convey the surface waters at adequate velocities to prevent stagnation or deposition;
- Hydraulic gradient should be sufficient to maximize removal of surface waters but not to steep as to cause scouring, and;
- The design and materials should consider the effects of settlement.

C.8 Monitoring Programmes

Monitoring programmes are normally implemented in order to determine the degree to which a landfill is functioning in accordance with its design objectives. And because leachate and landfill gas are the two main concerns of landfill operation, monitoring facilities are installed mainly for these constituents. A more thorough discussion on environmental monitoring is presented in Section F of this chapter.

C.9 Aesthetic Design Considerations

Aesthetic design considerations relate to the appearance of the disposal site, including the control of birds, blowing litter and dust, and vectors and pests. The application of soil cover will mitigate most of these concerns, but some other measures are necessary, especially during landfilling operations. These include:
- Perimeter berms, planting trees and other landscaping measures;
- Configuring the access road in such a way that visibility of landfill operations from the main road is avoided;
- Problems with birds may be controlled by using noisemakers, using recordings of the sounds made by birds of prey, trained predators, or using overhead wires;
- Using portable or movable screens or fence to control windblown litter;

- Spraying water on the access roads to control dust, and;
- Daily soil covering may control pests and vectors.

C.10 Equipment Requirements

The size of the landfill and the method of operation will determine the type, size, and number of equipment required. Heavy equipment usually used in landfill operations include crawler tractors, steel-wheeled compactors, compactors, and scrapers. Equipment requirements are further discussed in Section G.

D. Preparation and Construction

The amount and type of construction mainly depends on the physical conditions of the site and on the regulatory requirements for such facilities. Preparation and construction issues include:

D.1 Clearing and Grubbing

Trees, shrubs, and vegetation that hinder the operation of landfill equipment should be removed. For large areas, clearing should be implemented in phases in order to avoid erosion and scarring of the land. Trees and plants along the property's periphery generally should not be touched since they also serve as buffer zone for the facility.

D.2 Construction of Access Roads

Access roads may be generally classified into either permanent or temporary. Permanent roads are paved with concrete and are usually provided from the main highway to site, or for large sites, from the entrance to the vicinity of the working area. Generally, permanent roads consist of two lanes with a minimum width of 4m per lane.

Temporary roads are usually used to transport the wastes from the permanent road to the working face, since the location of the working face changes. Simple compaction of the native soil with adequate slope for proper drainage is often acceptable. The soil may be overlain with gravel, crushed stone or construction debris, or other tractive material.

D.3 Preparation of the Landfill Bed

The ground surface to which a liner is to be constructed should be grubbed and cleared of all vegetation, and it should be compacted and graded so that the actual liner can be constructed easily. The placement of the liner during construction causes a change in its actual properties. The factors to be considered are:

Moisture content and density: Moisture content affects soil permeability considerably. The recommended design moisture content is from 0-3% wet of optimum, and at compactions equivalent to 95% Standard Proctor or 90% modified American Society of State Highway Transportation Organization (ASSHTO).

Compaction method and effort. The method of compaction preferred for clay liners is by kneading compaction with the use of a heavy sheep's foot roller. The liner should be compacted in thin layers so that the feet of the compactor can penetrate and impart shear strains to the full layer.

Size of clods (particle aggregations). Large clods result into greater hydraulic conductivity since the spaces between the aggregates are larger. Clods with a diameter larger than 0.025-0.05 m (0.08-0.17 ft.) should be reduced in size by mechanically pulverizing them prior to compaction, or during compaction.

Desiccation/Drying. Desiccation can cause the cracking of clay liners. To avoid desiccation, the compacted materials should be kept moist by applying water during the periods in which it is exposed, by covering the completed liner with a layer of another soil, or by using geomembranes as cover.

Bonding between lifts. The interface between successive lifts could aid in the transport of a liquid contaminant through a compacted clay liner. To minimize seepage along lift interfaces and to blend lifts together, the lift thickness should not be more than 0.23 m (0.75 ft.) before compaction and not more than 0.15 m. (0.5 ft.) after compaction. Figure 25 depicts how water moves through waste layers and lifts despite the daily cover and becomes contaminated in the process. This points out the need for a good liner to capture these liquids for containment and collection to a treatment facility.

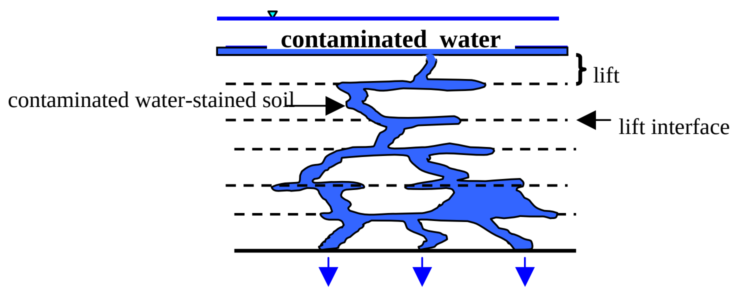


Figure 25. Liquid Flow Through Waste Cell Lifts

D.4 Leachate Collection Trenches

Some general procedures observed in the construction of leachate collection trenches are the following:

- The sand drainage blanket should be placed first on the entire liner, except for a distance of about 0.15m (0.5 ft.) from the leachate collection trench, before the leachate collection system is installed.
- The leachate collection pipes should be connected near the trench where they will be placed to avoid dragging of the pipes.
- If synthetic liners are used, seaming of the liners should be avoided within 0.90m (3 ft.) of the leachate collection trench.

D.5 Construction of Surface Drainage Facilities

Some general procedures observed in the construction of surface drainage facilities include:

- Open channels are usually concrete-lined or lined with crushed stone underlain with geosynthetics.
- Hydraulic gradients are sufficiently designed for maximum removal of surface water but not to steep as to cause scouring
- Side slopes of 1:1 are normally used for trapezoidal and v-shaped ditches

D.6 Erection of Fences, Gate

Peripheral fences limit or control access to the site by unauthorized persons and stray animals, as well as define the boundaries of the site. Litter fences help control blown litter from scattering and going to adjacent properties. Unlike peripheral fences, litter fences are temporary and movable since the working face changes.

E. Operation

E.1 Weighing of the Waste

Weighing of the waste prior to disposal provides useful information in landfill operations. Among the advantages of the weighing are:

- The efficiency of filling and compacting operations can be evaluated if the amount of solid waste delivered, the quantity of cover material used, and the volume occupied by the landfilled solid waste and cover, are known.
- The density of the fill and the amount of settlement that may occur can be estimated.
- Weight and volume data can be used to estimate the remaining capacity of the landfill and in the design of future landfills.
- Offers a basis for assessing charges for disposal.
- Presents an opportunity to inspect wastes prior to disposal for unacceptable materials.

E.2 Cell Construction

Disposals of wastes in a sanitary landfill are in confined areas known as **cells**. A cell is an area where the waste is spread, compacted, and covered by a thin layer of soil at the end of each day, or more frequently if necessary. A series of adjoining cells, all of the same height, make up a lift. A completed sanitary landfill is made up of one or more lifts Figure26 shows a cross-sectional view of a typical cell by cell construction of a landfill.

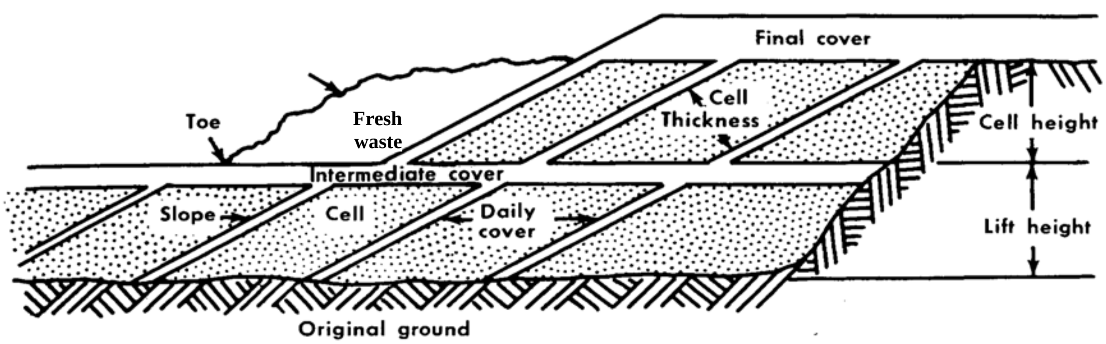


Figure 26. Cross-section of a Completed Landfill

Cell dimensions vary according to the volume of the waste to be compacted. This volume depends on the in-place density of solid waste. If achievable, a desirable compacted density of waste within a cell is about 600 kg/m^3. The volume, however, depends on the nature of the material to be handled and the degree of compaction.

Cell height varies from landfill to landfill, but a maximum height of about 3m is commonly recommended since this height will avoid severe settlement and slope stability problems

The working face (the portion of the cell currently receiving the waste) should be confined to the smallest area practical so that the operations can be easily managed, and the least amount of cover material will be required. A recommended size is about 2 to 3 times the width of the compactor vehicle.

E.3 Spreading and Compaction of the Waste

The proper procedure for spreading and compacting the waste during landfill operations is shown in Figure 27. Upon unloading of the waste at the toe of the landfill cell, the waste is spread in thin layers less than 0.60m deep. This is done since a better compaction is achieved by spreading the waste evenly in shallow layers and compacting them separately rather than trying to compact the material in a single deep layer. The waste is then compacted by running the landfill equipment over the waste on a slope of about 20-30% since gentle slopes afford better compaction.

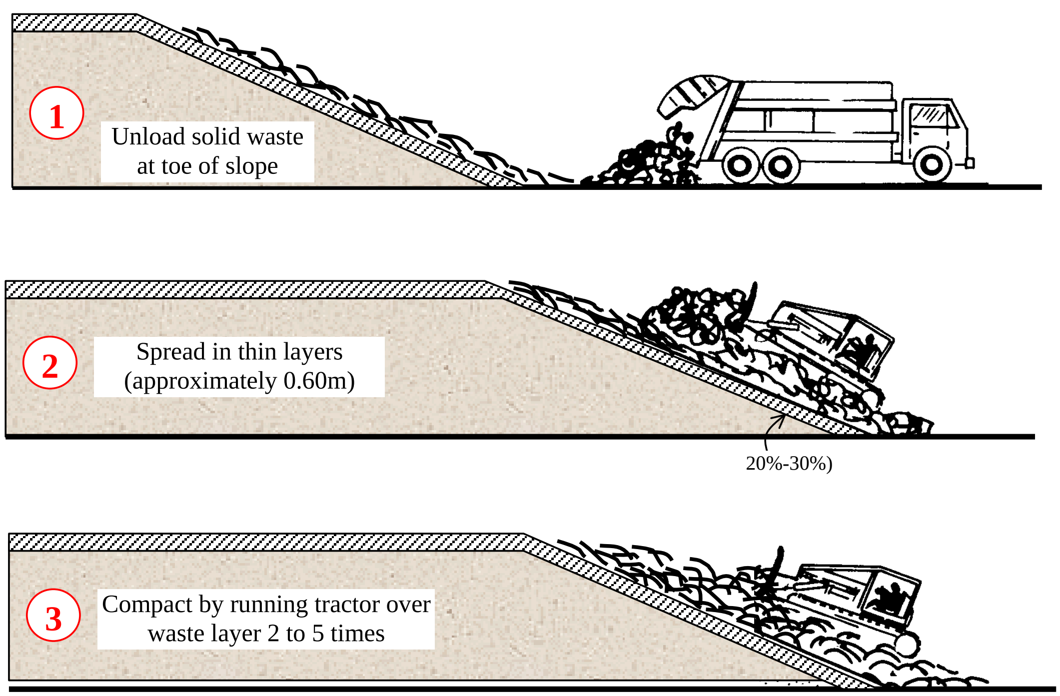


Figure 27. Waste Spreading and Compaction

E.4 Phased Development

A phase-by-phase development and operation is usually implemented for sanitary landfills. And an ideal phasing plan is where each phase is applied with final cover in the shortest time practical – which means that the waste is disposed in one phase until it reaches the final elevation desired (Phases 1, 2 and 3 in Figure 28). However, this may not be applicable for other landfills and multiple phases may be necessary (Phases 1 to 6 in Figure 28).

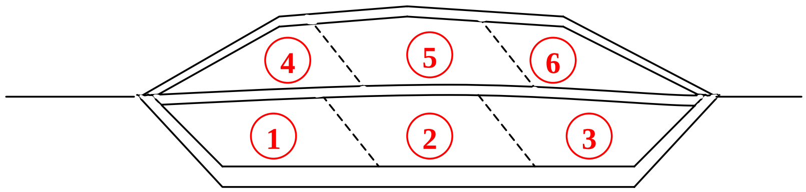


Figure 28. Multi-phase Landfilling

E.6 Covering of the Waste

Three types of cover material are used in a sanitary landfill. These are daily cover, intermediate cover, and final cover.

(a) Daily Cover

At the end of each working day (or more frequently if necessary), a uniform compacted layer of soil at least 0.15 m (0.5 ft.) is applied. Due to the large quantities needed for daily cover, and the additional required for intermediate and final covers, long-term planning should be done to ensure availability of the materials. Alternative materials that are suitable for daily cover, such as tarps, ash, seek hulls, compost and others, should also be considered especially if they are abundant in the site or easier and cheaper to obtain than soil material.

(b) Intermediate Soil Cover

Intermediate cover is applied to areas of the landfill that are inactive, or will be inactive for a long period of time (e.g. 1 year or more). A typical intermediate cover has a minimum compacted depth of 0.30m (1 ft.).

(c) Final Soil Cover

The final soil cover (or landfill cap) is applied to a completed landfill in order to reduce infiltration of water into the landfill and to reduce landfill gas migration. It also prevents burrowing animals from damaging the cover, prevent the emergence of insects/rodents from the compacted refuse, and minimize the escape of odors. A uniform layer with a minimum compacted depth of 0.60m (2 ft.) is recommended as final soil cover (Figure 29). Specifications for the cap is similar to the ones recommended for clay liners.

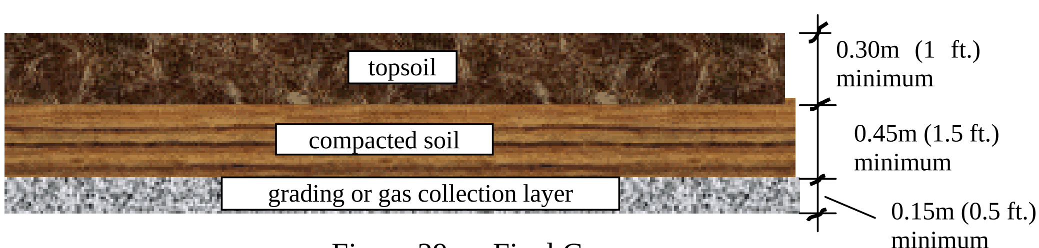


Figure 29. Final Cover

E.7 Handling of Special wastes

Provisions for the handling of special wastes should be included in the operation plan. Site personnel should know which materials might or may not be accepted for disposal at the facility. Special wastes include:

- Bulky wastes such as discarded appliances and furniture
- Construction and demolition wastes
- Automobile tires
- Pesticide waste containers
- Other wastes of unknown characteristics (sludge, asbestos, ash, etc.)

E.8 Dust, Litter, Bird, Vectors and Pests Control

Please see Subsection C.9 of this chapter.

F. Environmental Monitoring

F.1 Groundwater Monitoring

Wells for groundwater monitoring are installed in order to determine the rate and direction of flow, permeability, and if groundwater contamination is occurring. The monitoring wells are usually installed: (a) up gradient of the landfill to monitor background/baseline water quality; (b) down gradient of the landfill (areas that may have been impacted by the landfill), and (c) areas between the site and any other possible sources of contamination.

For a sanitary landfill, at least five (5) sampling wells should be installed: two (2) up gradient, and three (3) down gradient. It is important to install and sample wells prior to the operation of the landfill to determine the background quality of the ground water. This helps establish a statistical baseline against which future measurements are taken to determine contamination or trends.

Monitoring at regular frequencies is needed to observe any change in quality of the groundwater down gradient of the landfill that may indicate contamination. Parameters that are usually monitored are: Arsenic, Cyanide, Selenium, total organic carbon (TOC), Barium, Hardness (as $CaCO_3$), Silver, total dissolved solids (TDS), Sodium, Manganese (dissolved), Magnesium, chemical oxygen demand (COD), Cadmium, Sulfate (SO_4^-), Potassium, Iron, Calcium, Electrical Conductivity, Lead, VOCs, Chloride, Bicarbonate ($HCO_3^{-)}$), Sodium, pH, and Chromium.

F.2 Gas Monitoring

Gas monitoring probes are installed around landfills to monitor gas movement, principally methane. Due to the variability of gas concentrations with time, gas monitoring should be done at least twice a day for about 7 consecutive days. Methane is explosive at concentrations of between 5 to 15%. However, there is little danger that a landfill will explode since at these concentrations, the amount of oxygen present in the landfill is very small. Explosions that do occur are generally associated with a working face or open cell where gases and oxygen can accumulate to explosive limits.

Probe Installation Requirements:

- The lateral spacing should not exceed 300m around the allowable boundary of the sanitary landfill.
- A shallow probe should be installed 1.5-2m below the surface.
- The probe should be placed adjacent to soils that are most conductive to gas flow.
- A minimum seal of 1.5m of bentonite at the surface and between the monitored zones should be provided.

F.3 Leakage Monitoring

The unsaturated zone between the liner and the groundwater table is usually monitored to detect for any leakage. Leakage may be detected by installing:

- Direct leakage monitors – These are instruments that collect leachate exfiltrate. Suction and basin lysimeters are the two types of direct leakage monitors. They are usually installed near the edge of the landfill so that the length of transfer piping is a minimum. Installation of more than one lysimeter below the subbase is recommended in order to enable continued monitoring even if one lysimeter fails.
- Indirect leakage monitors – These are instruments that detect water percolation either by: (a) detecting changes in the moisture content of the vadose zone, or (b) detecting changes in the chemical concentration in the vadose zone.

G. Equipment Requirements

Landfill operations require the proper equipment to:

- Spread the waste after dumping;
- Compact the waste, and;
- Spread and compact the daily or intermediate cover.

The types of equipment generally used in landfilling operations are the crawler dozer, crawler loader, rubber-tired dozer, rubber-tired loader, landfill compactor, scraper, and dragline.

Crawler dozer – normally used for grading and excavation works. These are the standard machines used in landfilling operations, with the blades usually fitted with a top extension to push more solid waste.

Crawler loader – can lift materials off the ground but has a narrower blade than the crawler dozer. It is usually used for excavation and to carry soil cover (Figure 30).

Rubber-tired dozer– performs the same function as the crawler dozer but at generally higher speeds, enabling them to complete more passes or cover a greater area. They are not commonly used though in landfill operations because they do not excavate and grade as well as crawler tractors.

Rubber-tired loader - preferably used to transport soil cover over long distances, or for putting cover material into haul trucks. Its advantage is its high speed and mobility, allowing it to be used for other purposes outside the landfill.

Landfill compactors – it is usually used for spreading and compaction of the waste. These machines are modifications of road compactors and log skidders. Its wheels are either rubber tires sheathed in steel or hollow steel cores, with both types studded with load concentrators. It imparts greater crushing and compaction than the crawler or rubber-tired machines and its speed is much greater than that of a crawler tractor. It is one of the more preferred machines for landfill operations (Figure 30).

Scrapers – are used for excavation, hauling and spreading of cover material. They may be self-propelled or towed models.

Dragline – used for excavation works. It can dig up moderately hard soils and put them aside so as not to hamper excavation works. It can also be used for spreading cover material over compacted solid waste. It is particularly useful in wetland operations and large landfills where the trench method is used or where cover material is obtained from a borrow pit.

Crawler dozer

Landfill compactor

Crawler loader

Scraper

Rubber-tired loader

Figure 30. Some Equipment Used in Landfilling Operations

H. Closure and Post-Closure

Except for a few items, most of the discussion on closure and post-closure of open dumpsites and controlled dumpsites are essentially the same. The discussions below describe closure procedures for a sanitary landfill that differ from those discussed in Chapters IX–X of Part 1. The reader/trainer is thus, referred to those chapters as well.

H.1 Leachate

The amount of leachate for treatment after closure will depend on the design of the final cover, the characteristics of the waste, and the climate. If the cover is well designed and constructed, the amount of leachate for treatment will decrease significantly since the leachate generated will mostly come from the decomposition of the waste.

The decrease in leachate volume is accompanied by a decrease in strength of the leachate as time goes on since the waste in the landfill will stabilize. Because the leachate collection and treatment facilities were designed and built to collect and treat the estimated amount of leachate generated during operations, the decrease in volume and strength after closure will cause the treatment facilities to be "underloaded". This may cause some undesirable odors and should be properly addressed by either reconfiguring the leachate treatment ponds or discharging the leachate to a wastewater treatment plant.

H.2 Gas Management

Landfill gases are controlled as long as they are generated after closure of the landfill. The landfill gas management system used during operation of the landfill is also used for landfill gas control and leachate improvement after closure. The materials used for piping should be flexible enough to withstand movement as the landfill settles and strong enough to withstand the load imposed by passing vehicles over the surface during landscape maintenance.

H.3 Environmental Monitoring

Environmental monitoring is important to ensure that the integrity of the landfill is maintained with respect to the uncontrolled release of contaminants to the environment. The environmental monitoring facilities installed during landfill operations are also used for monitoring after closure of the landfill.

The monitoring programmes discussed under Chapter XI of Part 1 are also applicable as explained on the first part of this section. The main difference is that sanitary landfills have leachate and gas management systems installed as opposed to open and controlled dumps that do not typically have these systems in place.

I. Site Afteruse

The trainer/reader is referred to Chapter XIII of Part 1 since the discussion for site afteruse are essentially the same.

J. Permitting Requirements

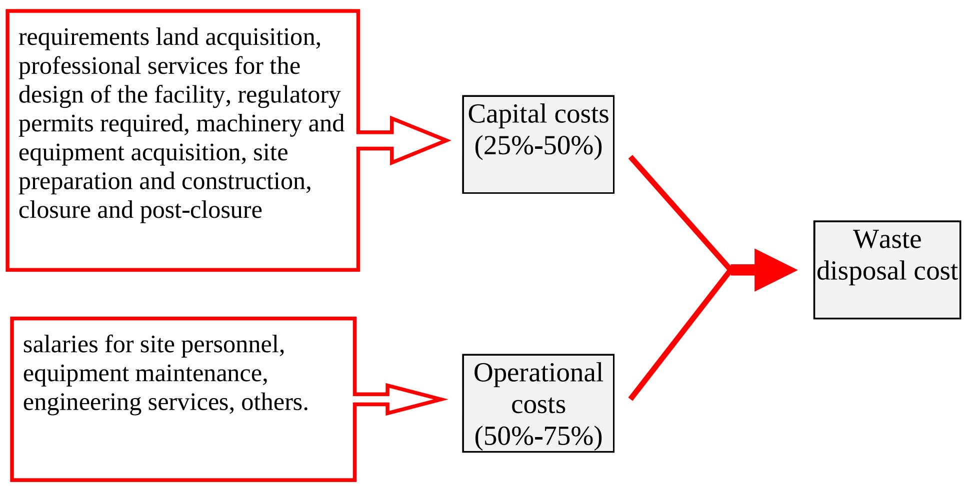
Permit requirements will vary from country to country, and often from state to state (or other political subdivisions). Waste management facilities, particularly sanitary landfills, have to go through prescribed processes to obtain permits and clearances for their operation. Before development and operation of a sanitary landfill, the proponents should:

- Identify the permit-issuing agencies (national and local) concerned with such facilities.
- Identify the requirements of these agencies.
- Comply with the requirements.

Most agencies have written guidelines and procedures for proponents to follow. These procedures often require the proponents to submit documents, undergo thorough review of the proposal by the agency and other experts, conduct public hearings, obtain approval from other concerned entities, and other requirements. Once the necessary permits are issued, the proponents may then commence development and operation of the facility, subject to the conditions enumerated on the permits.

X. THE COST OF WASTE DISPOSAL

The cost of waste disposal can be categorized into capital costs and operating costs.



<u>Some Important Issues on Waste Disposal Costs</u>

- The selection of the most technically suitable site for a sanitary landfill will greatly reduce the development costs since lesser stringent engineering measures may be implemented.
- Lesser technically desirable sites will entail greater costs since more interventions have to be done to make the site suitable for the purpose.
- Operational costs are all costs associated with the day-to-day operations of the facility and are generally recovered through tipping fees. Appropriate tipping fees can be determined by weighing incoming vehicles or measuring its volume.
- Tipping fees ideally should cover the operational costs.
- In areas where illegal dumping is rampant, the tipping fees may be lowered in order to discourage such dumping practices. The municipality may then subsidize the cost of

operation through taxes or other means, with an appropriation going to the authority that runs the landfill. The LGU should develop a financial assurance plan to provide the necessary monies at the end of the landfill life to care for its continued maintenance.

- For private operators of sanitary landfills, the LGU should ensure the availability of funds for closure and post-closure management by requiring a performance bond or by holding the company legally responsible for such costs. This would be part of the financial assurance plan that would be required from the operators.

Sanitary landfills are initially more expensive than open or controlled dumps. But the cost of remediating an open dump will be much more, and its service life is much less. In the end, a sanitary landfill can be a more cost-effective alternative than open or controlled dumps

.

XI. PUBLIC PARTICIPATION

The involvement and participation of various stakeholders is essential to the success any solid waste management endeavor. Participation enables a solid waste management plan to be:

More effective. A more appropriate plan design is formulated because of the consideration of various issues raised;

More sustainable. People are more likely to be more committed to participating in the plan since they themselves were involved with such a plan.

It is a given fact that many proposed sanitary landfill projects do not materialize due to public opposition. Thus, it is vital that the proponents must establish a dialog and working relationship with representatives from the communities involved right from the siting process, in the facility's design, operation, closure and post-closure management.

A model landfill siting process for local governments is presented below:

- Clearly identify the need for a sanitary landfill and develop consensus about the need.
- Identify the service area.
- Obtain the support of affected government entities for a study. (e.g. environment agencies)
- Establish an advisory committee composed of representatives from all affected government agencies, individual citizens, homeowner's associations, and other affected interests such as farmers, environmentalists, real estate developers, etc.
- Throughout the process, reach out to and invite residents from all potentially affected areas.
- Select an independent consultant to do technical studies and provide technical advice.
- Have the committee select and approve the site selection criteria and assign weights to them.
- Have the committee help select and approve candidate sites for review.
- Have the consultant study the candidate sites and evaluate technical issues.
- Merge the consultant's technical data with weighted criteria.
- Have the committee review and select a recommended site for approval.

- Conduct public hearings frequently throughout the process.
- Ensure media coverage at all stages.

Based on these processes, it is important to note that it will take quite a while before such a site is approved. Thus, planning for the development of a disposal facility should be done long before the existing site runs out of disposal space. Otherwise, if the situation becomes critical, shortcuts will be made that will lead to failure.

CASE STUDIES

Case Study No.1

Problem: Your municipality is developing a controlled disposal facility on a recently acquired property. In a few weeks time, the facility shall be ready for disposal operations and subsequently, the municipality will close its existing open dumpsite. As head of the LGU unit in charge of solid waste management, you are tasked to draw up a closure plan for the existing dumpsite. From this training, you learned that before you can develop a closure plan, a site assessment/investigation needs to be conducted to assess the existing conditions of the site.

Required: Develop a checklist that will enable you to conduct a more thorough and efficient assessment/investigation of the dumpsite. The checklist should be limited to a maximum of two (2) pages and should cover all issues necessary to enable you to develop a more comprehensive closure plan.

Case Study No.2

Problem: Due to numerous complaints from nearby communities and the passage of a new law, a municipality is compelled to close its open dumpsite.

Data on the open dumpsite:

- Figures 31 and 32 on page 66 shows the site map and approximate profile and cross-section of the dumpsite, with the given dimensions.
- It has encroached on the adjacent property, as indicated by area “1” on Figures 31 and 32.
- The eastern end of the dumpsite drops steeply towards the river.
- Burning of waste has been practiced.
- There is seepage of leachate at the toe of the disposal site.
- There are 10 families (waste pickers) living within the dumpsite and the nearest built-up community is about 1,000m away.
- Groundwater is sufficiently deep.
- It is about 400m from the main highway to the west.
- The access road is a barangay road and is in good condition.
- The property is owned by the LGU.

Required:

1. Based on what you have learned from Part 1, discuss how you would implement closure of the dumpsite. Please accompany your discussions with drawings. The drawings need not be scaled, but should indicate water/leachate flow directions, slopes, etc. The closure activities implemented should meet existing regulatory requirements. Assume the community has adequate financial resources for closure of the dumpsite:
   - Draw a closure plan for the dumpsite.
   - Draw a longitudinal and transverse section through the closed dumpsite.
2. Discuss post-closure management and maintenance programmes you plan to implement, and the afteruse of the site.
3. How do you plan to rehabilitate the area encroached by the dumpsite (adjacent property).
4. What do you plan to do with the waste pickers?
5. Estimate the cost of closure of the dumpsite and rehabilitation of the adjacent property (encroached-area only). A description of the procedures on how to estimate the closure cost is acceptable. However, actual cost calculations are preferred for rehabilitation cost estimate.
   Assumptions:
   - The municipality does not own any heavy equipment, including dump trucks.
   - Assume unit prices for the necessary costs (ex. equipment rental, etc.).
6. How will the necessary funds be raised to pay for these expenses?

Notes to Trainers (for Case Study No. 2):

1. The participants should be grouped into a maximum of 4 persons per group.
2. Duration of exercise is approximately 1.5 to 2 hours.
3. The participants should be provided workspace, calculators, notepads, colored pencils, pens, magic markers, and large drawing paper.

Case Study No.3

Problem: A municipality is planning to close its open dumpsite and develop a controlled dump on a new site. The pertinent data are the following:

Proposed Controlled Disposal Site

Average depth of disposal area = 8m
Loose waste density = 330 kg/m^3
A 30% compaction of the waste will be implemented

Municipality

Total population = 50,000
Area covered by collection service = 60% of population
Waste generation rate = 0.50 kg/person/day
Waste characteristics: 50% biodegradable; 15% recyclable; 35% inert residuals
All the wastes collected are immediately disposed

Required:

1. How much waste is being produced daily by the residents of the municipality (in m^3/day)?
2. What is the volume of waste being disposed daily at the existing open dumpsite by the garbage collection trucks (in m^3/day)?
3. Where do you think the rest of the waste generated will go?
4. What is the area required if the proposed controlled dump is able to accommodate all of the municipality's wastes for at least 3 years (in hectares)?
5. Draw/sketch a simple layout of the facility. Assume a rectangular area.
6. Give and describe at least five (5) operational requirements of a controlled disposal facility.
7. Because of the difficulty the municipality went through in developing the site due to opposition by some communities and financial constraints, what would you recommend to the municipality in order to lengthen the service life of the site.
8. During operation of the controlled dump, the site manager got careless and the controlled dump had problems with dust, odor, presence of rats and other insects, scattered paper, plastics, and other light materials on site and onto nearby areas. What measures can you take to address these problems?
9. Leachate and landfill gas are the two main by-products of waste decomposition. In a sanitary landfill, how are these managed so that they do not have adverse impacts to public health and the environment?
10. Enumerate and describe at least five (5) siting requirements for a sanitary landfill.

ANSWER KEYS

Case Study No.1

This is a sample checklist. The participants will develop a checklist with a different format, but should contain the necessary elements as described in Section C of Chapter IX, Part 1.

CHECKLIST FOR SITE ASSESSMENT/INVESTIGATION OF AN OPEN DUMPSITE DUE FOR CLOSURE

Date:

1.0 General Information

1.1 Dumpsite Name:
1.2 Location:
1.3 Dumpsite Operator:
1.4 Name of Operations Manager:
1.5 Address :
1.6 Telephone No:
1.7 Property owned by:
1.8 Start of Operations:
1.9 Expected date of closure:
1.10 Classification of the site based on the approved Zoning Plan:
1.11 Existing Land Use in the area:
1.12 Total area of the dumpsite :
1.13 Estimated area covered by actual open dumping operations:
1.14 Estimated average depth of waste (reckoned from ground surface):

2.0 Description of Environmental Setting

2.1 Physical environment of the area where the dumpsite is located

Components/ Parameters	**Remarks**
2.1.1 Geology/Soils	
1. Are there steep slopes (31 – 50%) and/or very steep slopes (above 51%) in the dumpsite? [ ] Yes [ ] No If yes, indicate their locations on a site map.	
2. What is the dominant type of soil in the area? [ ] sandy [ ] sandy loam [ ] clayey [ ] Others ____________________________	
2.1.2 Hydrology/Groundwater Resources	
1. Are there water bodies found inside or near the dumpsite? [ ] Yes [ ] No If Yes, enumerate them and indicate their locations on the site map. Indicate the distance of the water body as reckoned from the nearest point in the boundary of the site. (For creeks, indicate if this is perennial or intermittent). 1. . 2.	
2. What is the classification of these water bodies based on the environment agency's classifications. [ ] Class A [ ] Class D [ ] Class B [ ] Class E [ ] Class C [ ] Not yet classified	
3. If the water body(ies) have not been classified by the environment agency (Item 2), what is the present use of the said water body(ies)? [ ] Used as a source of drinking water – w/o any treatment [ ] Used as a source of drinking water – w/ treatment (e.g. sand filtration, chlorination, etc.) [ ] Used for recreational purposes such as bathing, swimming, skin diving, etc. [ ] Used for fishery, recreation (e.g. boating), industrial processes (process water) [ ] Used for industrial purposes (cooling water), irrigation, and other uses [ ] Others ____	
4. Are there communities immediately downstream of these water bodies? [ ] Yes [ ] No	
5. Does the area experience flooding during wet season or typhoons? What might have caused the flooding? [ ] water logged area [ ] low area/elevation	

Components/ Parameters	Remarks
[ ] poor drainage [ ] Others __________________________	
6. Indicate the use of the wells described in item 7. [ ] drinking purposes [ ] irrigation [ ] bathing, washing [ ] Others ___________________________	
7. Is the area proximate to sensitive groundwater resources (e.g. well fields, recharge areas, etc.) ? [ ] Yes [ ] No If Yes, how near is the site? ____	
8. What is the highest recorded depth of the water table in the vicinity of the site? __________________ meters	
9. Is the site located near the shoreline? [ ] Yes [ ] No If Yes, indicate its distance: _________________________________	
10. Are there existing structures or development around the project site? [ ] Yes [ ] No If Yes, list them in the space below.	

2.2 Biological environment of the dumpsite

Components/Parameters	Remarks
1. Are there fishery resources in the water bodies near the site? [ ] Yes [ ] No If Yes, is the activity commercial in scale or for subsistence only? [ ] commercial only [ ] subsistence only	
2. Is the site proximate to a watershed or forest reservation area? [ ] Yes [ ] No If Yes, how near is the site ___________ Km Identify the watershed or forest reservation: ____	
3. Is the project proximate to an ecosystem? [ ] Yes [ ] No If Yes, what is the type of ecosystem and indicate its corresponding distance from the site. [ ] forest ____ [ ] coastal/marine ____ [ ] grassland ____ [ ] mangrove ____ [ ] agriculture ____ [ ] lake and river ecosystem ________________________________	

2.3 Socio-Economic Environment

Components/Parameters	Remarks
1. Are there residents in the proposed site who need to be relocated? [ ] Yes [ ] No If Yes, how many families? ________________________________	
2. What is the distance of the proposed site with the closest residential area? ____	
3. What is the distance of the proposed site with the closest institutional establishments (e.g. schools, churches, hospitals, etc) in the area? ____	

3.0 Additional Points for Observation

3.1 Is there leachate seepage and ponding in the dumpsite? Indicate the points of seepage and ponding in the map.
3.2 Was burning practiced or is there evidence of burning in the dumpsite?
3.3 Is there evidence of gas migration at the surface and boundaries of the disposal site? (through noticeable odor of gas)
3.4 Has waste slippage occurred in the dumpsite? If yes, identify which areas, when, and degree (ex. negligible, severe, etc.).

4.0 Available Maps

		Yes	No
4.1	Location map	[ ]	[ ]
4.2	Cadastral Map	[ ]	[ ]
4.3	Topographic Map	[ ]	[ ]
4.4	Geological Map	[ ]	[ ]
4.5	Hydrogeological Map	[ ]	[ ]

5.0 Available Studies, Reports, Letters, Permits

		Yes	No
5.1	Site Inspection Reports	[ ]	[ ]
5.2	Water quality sampling	[ ]	[ ]
5.3	Operations Record Book	[ ]	[ ]
5.4	Letters/Communications (Letters of complaints, citation for violations, cease and desist orders, etc.)	[ ]	[ ]
5.5	Operational Permits issued	[ ]	[ ]

6.0 Interview with waste pickers and residents near the site

6.1 Name:
6.2 Age:
6.3 Sex:
6.4 Address:
6.5 Occupation:
6.6 How long have you been living within or near the dumpsite?
6.7 Remarks:

7.0 Photographs

Take pictures of the dumpsite showing at least the following:

- Panoramic view of the area (northern, southern, western and eastern faces)
- Steep slopes and evidence of waste slippages in the dumpsite
- Burning areas (if any)
- Topography of the adjacent areas relative to the dumpsite
- Points of leachate seepage/discharge
- Areas of leachate or water ponding

Case Study No.2

Requirement No. 1:

No group will have the same exact answer for all the questions.

The correctness of the answers to Question No. 2 will be based on the group's considerations for all necessary factors in the closure of dumpsites as discussed from Chapters IX to X of Part 1. As a guide, the table below may be used to assess a group's comprehension of the closure requirements. A majority of the criteria/activity indicated should have been considered and addressed by the group.

Criteria/Activity	Points	**Remarks**
1. Coordination with the national environmental agency(ies), other concerned units/offices in the LGU, and affected communities.		
2. An alternative disposal site should be identified and/or developed first before actual closure of the existing disposal site.		
3. A source of funds for post-closure maintenance and monitoring activities should be identified.		
4. A site assessment/investigation should be conducted.		
5. A closure plan is developed considering the necessary elements as discussed in Chapters IX and X. • Stabilization of critical slopes (final surface and side slopes) • Application of final cover • Drainage control systems • Leachate and gas management systems • Vermin control • Extinguishing fires • Prevention of illegal dumping • Installation of monitoring wells • Installation of signage/billboards • Resettlement action plan • Community involvement		

1. A drawing of the closure plan should be presented, indicating most of the following:
   - Drainage ditches/canals along the periphery of the site and their discharge outlets.
   - Earth bund at the toe (eastern edge) of the site to prevent waste spillage to the river.
   - Leachate collection pipe at the toe of the disposal site to intercept seepage of leachate.

- Leachate retention basin located at the eastern end of the site to receive the leachate intercepted. The leachate retention basin will afford partial treatment of the leachate prior to discharge to the river.
- Instead of a simple leachate retention basin, a series of stabilization ponds is preferred. The ponds would consist of an anaerobic pond, facultative pond(s) and maturation pond(s). Mechanical aeration of the wastewater on the facultative pond(s) may also be employed to aid in its treatment.

2. A drawing of the transverse and longitudinal sections of the closed disposal site should be presented, indicating most of the following:
   - Final surface slope/grade
   - Earth bund at the toe of the site
   - Drainage ditch at both sides of the sections
   - Leachate collection pipe at the toe of the site

Requirement No. 2:

Post-closure management and maintenance programmes will be those discussed under Chapter X of Part 1. The following should be included:

- An afteruse plan for the site.
- Routine inspection schedule for the: final cover, vegetation layer, surface drainage, groundwater monitoring, and others.
- Preventive maintenance for the surface grade, drainage control systems, revegetation (as required), etc.
- Groundwater and surface water and gas monitoring

Except for construction of enclosed or heavy structures and residential purposes, the participants may decide what's best they plan to use the site for after closure. The chosen afteruse should be evaluated from a technical and economic point of view.

Requirement No. 3:

Rehabilitation of the area encroached by the dumpsite will generally involve the following general activities:

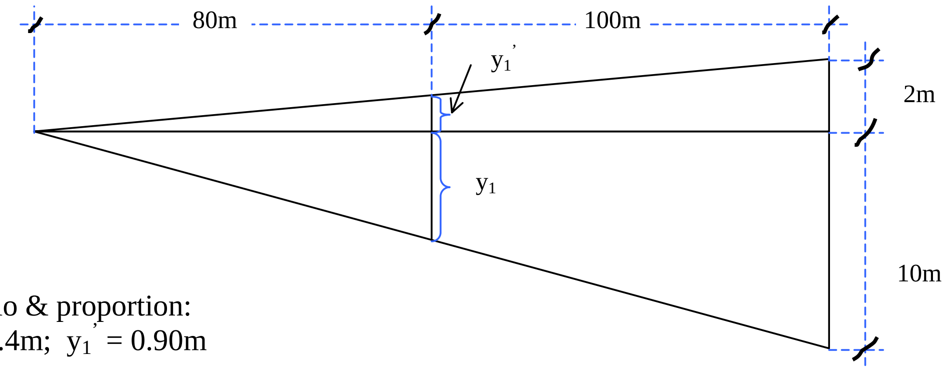
1. Removal of existing wastes outside the boundaries of the property of the LGU (at the adjacent property);
2. Filling with topsoil and grading of the surface upon removal of the existing wastes, and;
3. Planting of native vegetation upon filling with topsoil.

Requirement No. 4:

I. Cost estimate for rehabilitation:
   The costs to be incurred for rehabilitation will be for:
   - rental of equipment: 1 crawler tractor - to push/remove the waste from the adjacent property (Area 1) towards the LGU property;
   - hauling of soil to fill the area where waste was removed (Area 1).

   The exact cost estimate for rehabilitation will depend on the unit cost the participants will assume for equipment rental and hauling of soil to the site. However, the general procedure to determine rehabilitation cost is shown below.

(1) Estimate the volume of waste for removal



by ratio & proportion:
y_1 = 4.4m; y_1' = 0.90m

Based on the approximate profile and cross-section as shown in Figs. 28 and 29 and on the estimated depth of the waste on Area 1,

Vol. for removal = ½ (4.4)(80)(80) + ½ (0.90)(80)(80) = 16, 960 m^3

(2) Determine rental cost for heavy equipment (bulldozer): D6 = ₱ 8,000/hr
(3) Determine time required for removal of waste: estimated = 8 hours (1 day)
(4) Determine hauling cost for soil material (outside source):

estimated = ₱ 2,000/trip (10 m^3 capacity)

(5) Determine cost of plantings, signage, fencing, monitoring, etc..

Computations

1. Pushing of waste from Area 1 to LGU property:

₱ 8,000/hr x 8 hrs. = ₱ 64,000

2. Haul soil into the site to fill area where waste was removed:

$$\frac{16{,}960\ m^3}{10\ m^3/trip} = 1{,}696 \text{ trips} \times ₱\ 2{,}000/\text{trip} = ₱\ 3{,}392{,}000.00$$

3. Total………………………………………………. ₱ 3,456,000.00

II. Cost estimate for closure:

As discussed in Chapter XI of Part 1, closure costs are made up of capital and operating expenses. The participants may just describe the procedures to estimate the costs to be incurred. For the given case study, the following applies:

Capital Expenses:

1. Due to unavailability of soil cover, final cover material will be hauled into the site. The cost for cover material can be estimated by:

(a) Determine the surface area
(b) Assume thickness of cover material
(c) Compute volume required by multiplying (a) and (b)
(d) Multiply volume from (c) with hauling cost.

2. Soil material for construction of the earth bund will also be hauled into the site. Cost will depend on the volume required for bund construction and the haul distance.
3. Cost of plantings can be determined by determining the area for revegetation and the cost of the vegetative cover per unit square area. Native species are preferred.
4. Drainage control systems will only involve manpower requirements since the ditches/canals will be excavated manually. The ditches/canals do not have to be lined, assuming there is no contamination or erosive forces, although it is desireable to do so to avoid exacerbating leachate production.
5. Fencing cost is estimated by determining the perimeter of the property. Cost will depend on the fence material to be used.
6. Signage cost usually depend on the dimensions of the signage, the materials used and the number of colors used.
7. Leachate management systems cost is estimated by:
   - Determine the length of pipe required and multiply this with pipe cost per lineal meter.
   - Determine volume of gravel required. A gravel layer is placed below and above the leachate pipe to prevent clogging and to facilitate leachate flow.
   - If geosynthetic materials are used as a barrier or drainage material, its cost should also be included by determining the area required and the price per unit area of the material.
8. For the cost of gas management systems, the number of vent pipes required may be estimated by determining the volume of dumped waste in the site. At least one (1) vent should be provided for every 7,500 m^3 of waste. The type of material used, e.g. PVC pipes, discarded oil drums or bamboo, should also be accounted for.
9. Monitoring wells may only be installed/excavated upgradient (western end) of the site since the eastern end is a steep drop. There may be springs near the banks of the river that may be used to sample for groundwater quality.
10. The families living within the dumpsite will need to be relocated. If the LGU operates or will operate a Materials Recovery Facility (MRF), these people can be formally hired since they are efficient in waste segregation. A space can also be allocated at the new disposal site and they can be relocated there.

<u>Operating Expenses:</u>

1. Since the LGU does not have any heavy equipment, they will need to rent a bulldozer and a backhoe. Rental costs will depend on the duration of equipment use.

   The bulldozer will be used for:
   - rehabilitation of the adjacent lot
   - spreading of the waste to extinguish fires by allowing for complete combustion of the waste
   - leveling of the waste
   - application of final cover
   - grading of the final surface

The backhoe will be used for:

- excavation of the waste at the adjacent lot
- excavation of the leachate retention basin
- gas management systems

Manpower will be required for excavation of the drainage ditches/canals, leachate pipe canals, fencing of the site, construction of the earth bund, and other manual jobs. For maintenance, security and monitoring, LGU personnel should be assigned to do these to save on costs.

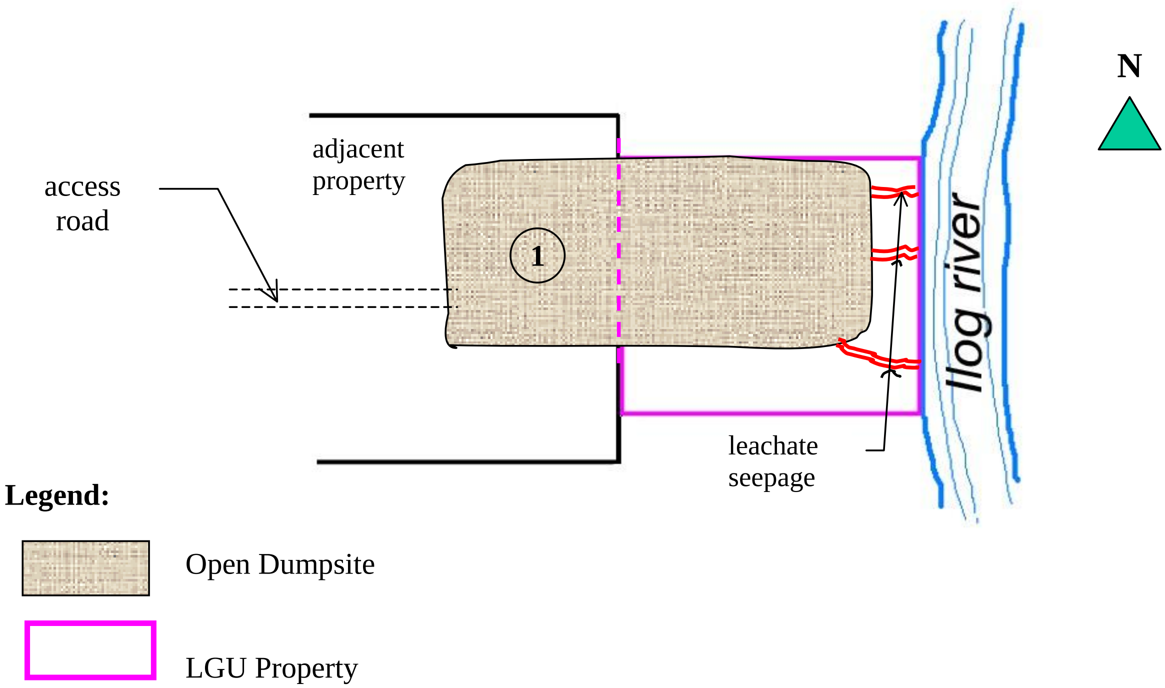


Figure 31. Site Map

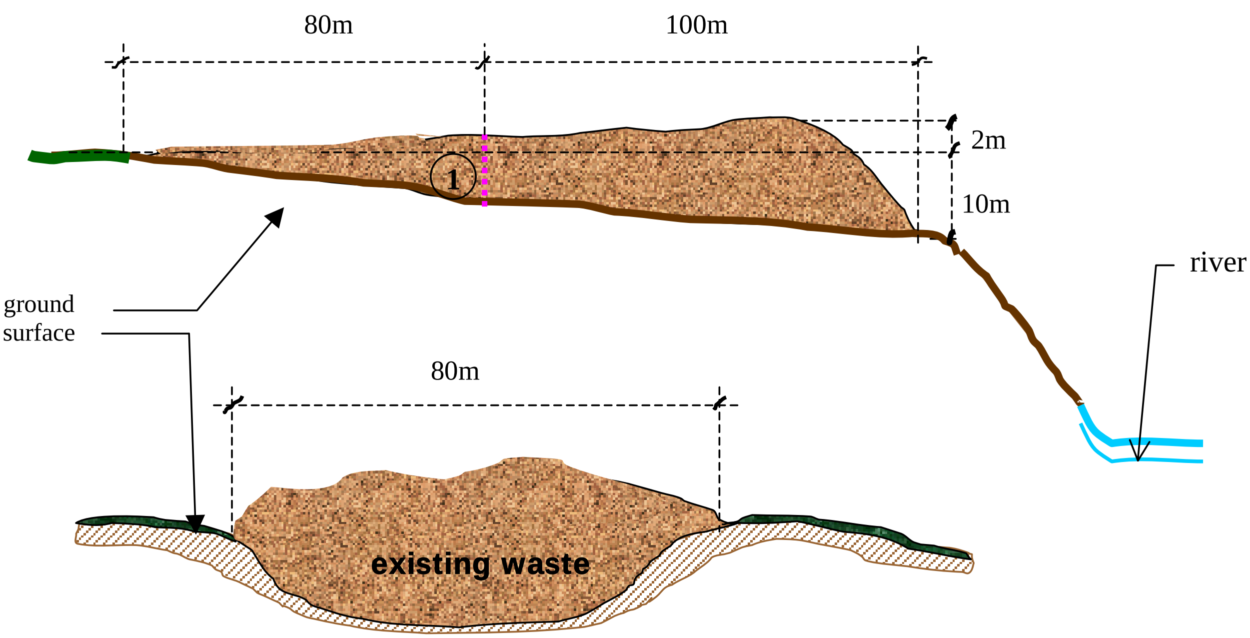


Figure 32. Approximate Profile and Cross-section of the Waste at the Site

1. The amount of waste produced daily by the residents is:

$$\frac{\text{population x waste generation rate}}{\text{waste density}} = \frac{50{,}000 \text{ x } 0.50}{330} = 75.75 \text{ m}^3\text{/day}$$

2. The volume of waste being disposed at the open dumpsite is:

60% of 50,000 = 30,000

$$\frac{30{,}000 \text{ x } 0.50}{330} = 45.45 \text{ m}^3\text{/day}$$

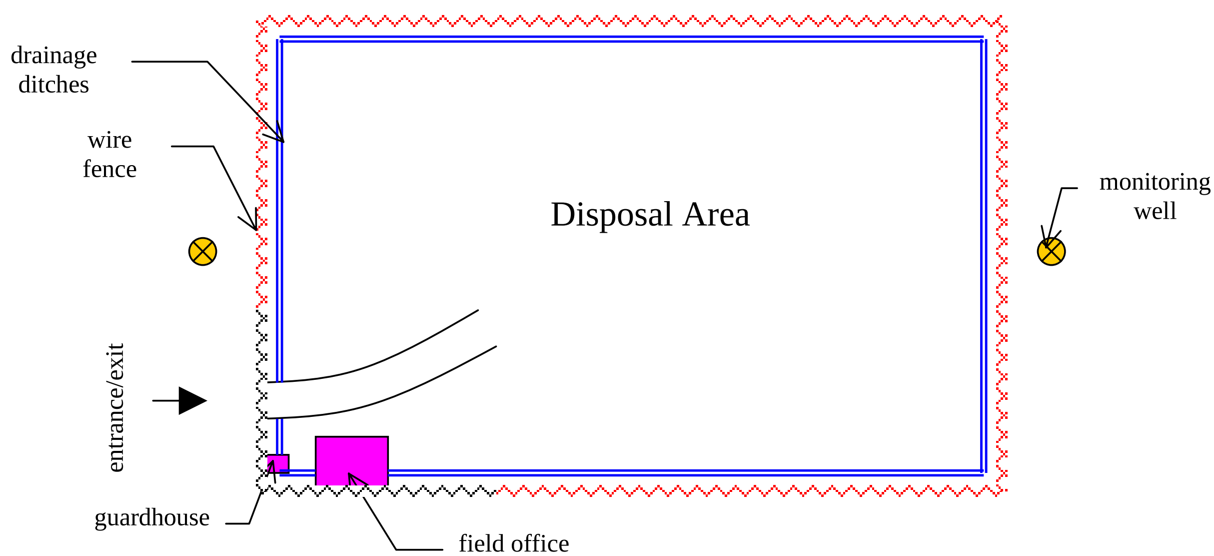
3. Area required for 3 years for all the waste generated is: (Please refer to Subsection B.2 of Chapter VIII, Part 2)

$$\text{LS} = \frac{1}{365}\left\{\left[\text{A x d x 1.33 x 0.85}\right] \div \left[(\text{WGR x P}) \div \rho\right]\right\}$$

$$3 = \frac{1}{365}\left\{\left[\text{A x 8 x 1.30 x 0.75}\right] \div \left[(0.50 \text{ x } 50{,}000) \div 330\right]\right\}$$

A = 1.06 hectares (plus additional area for access roads, office, etc.)

4. The layout of the facility should include all the items described under “Site Preparation” in Subsection B.3 of Chapter VIII, Part 2. A sample layout would look like this:



5. Operational requirements for controlled dumps are those discussed in Section D of Chapter VIII, Part 2. These include:
   - Application of daily cover material of at least 0.15m (0.5 ft.) in thickness at the end of each working day.
   - Control of the size of the working area so that operations can be easily managed.
   - Management and control of waste picking activities in the facility in order not to disrupt operations.
   - Proper inspection of incoming waste and recording of daily site operations.
   - Installation of a movable barrier downwind of the working area.
   - Waste compaction at a slope of about 20-30% and worked from the bottom of the slope to the top.
   - Spreading and compaction of the waste in layers not greater than 0.6m (2 ft).
   - Only municipal solid waste shall be allowed for disposal at the site.

6. The municipality should implement waste reduction, reuse and recycling programmes, and waste treatment such as composting in order to reduce the waste going to the disposal site. This will reduce more than half of the waste for final disposal.

7. The measures to take include:
   - Daily or more frequent covering of the waste with soil.
   - Installation of a movable barrier downwind of the working area. Also, provision of a buffer zone consists of trees and plants along the periphery of the site.
   - Spray water on the approach and access roads. Also, use speed bumps to reduce the speed of the vehicles.
   - Prevent and remove standing water within the disposal site.

8. Leachate management includes (see Subsection C.5 of Chapter IX, Part 2):
   - Installation of liners at the bottom of the landfill
   - Installation of leachate collection and treatment systems
   - Proper grading of the bottom of the landfill
   - Application of daily cover
   - Installation of groundwater monitoring wells

9. Gas management includes (see Subsection C.6 of Chapter IX, Part 2):

   Installation of gas collection systems
   - Venting of the gas to the atmosphere or flaring it
   - Monitoring of air quality within and at the boundaries of the landfill

10. Siting requirements for a sanitary landfill are those discussed in Section B of Chapter IX, Part 2 and include:
    - The capacity of the site selected should have a minimum design life of at least 10 years.
    - The citizens to be affected must be properly informed and involved as early as practical, and at every stage of the siting process.
    - There should be no residential development within 250m from the perimeter of the proposed facility.
    - The site should not be located:

- – in areas with a high water table. The groundwater table’s seasonally high level should be at least 1.5m below the base of the landfill
- – within 500m upgradient of private or public drinking, irrigation, or livestock water supply wells
- – areas considered part of a 10-year recharge area for existing or future potable water sources should also be avoided
- – within 300m upgradient of perennial streams, unless the stream is protected from potential contamination
- – along geological faults or areas which experience frequent seismic activity
- – within 500m of active fault lines or significantly fractured geologic structure
- – where the underlying rock formations are porous such as limestone, carbonate, fissured or other porous rock formations
- – in wetlands or floodplains

- Select a site with adequate amount of cover material.
- An area with gently sloping topography is preferred.
- The site should not be too far from the service area. Ideally, a maximum distance of 15 to 20 km. or a travel time of less than 30 minutes from the service area.
- Not within ecologically sensitive areas such as national parks, forest reserves, protected areas, etc.
- Not within 3 km. of an airport servicing turbojet aircraft, or 1.6 km. of an airport servicing piston driven or turboprop aircraft.

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GLOSSARY

Acetogenic phase	It is the second stage in the waste degeneration process where aeroic bacteria die off due to the depletion of oxygen supply and are replaced by facultative microorganism. The main decomposition phase in this stage are organic acids and carbon dioxide.
Active venting system	This consists of a number of perforated pipes installed vertically and uses the natural pressure of the gas to collect and vent or flare it at the surface.
Aerobic	A biochemical process or environmental condition occurring in the presence of oxygen.
Aerobic landfill	A landfill that has the advantage of reducing the organic loading in the leachate thereby reducing the facility requirements for leachate treatment.
Anaerobic	A biochemical process or environmental condition occurring in the absence of oxygen.
Anaerobic landfill	A landfill that does not incorporate air in the waste and anaerobic and facultative organisms dominate.
Bearing capacity	It is the measure of the completed disposal's ability to support the foundation. It depends on the characteristics of the underlying waste and the composition achieved during operation and closure.
Berm	An elongated pile of soil used to control and direct the flow of surface water run-off. Berms may also be used to block out noise and screen operations from public view.
Biodegradable material	Materials that can be broken down by microorganisms into simple, stable compounds such as carbon dioxide and water. Most organic materials, such as food scraps and paper, are biodegradables.
BOD	A standard water-treatment test for the presence of organic pollutants. The result of the test indicates the amount of dissolved oxygen in grams per cubic metre used up by the sample when incubated in darkness at 20ºC for five days.
Cell	An area where the waste is spread, compacted and covered by a thin layer of soil at the end of each day or more frequently, if necessary.
Cleanup	The term used for actions taken to deal with a release or threat of release of a hazardous substance that could affect humans and/or the environment.

Closure cost	The cost composed of the capital and operational expenses
Composting	The controlled biological decomposition of organic solid waste materials into a humus-like product known as compost.
Composite liners	A liner system that is composed of both natural soil liners and synthetic liners. The liner must be in direct and uniform contact with the clay.
Contaminant	Any physical, chemical, biological, or radiological substance or matter present in any media at concentrations that may result in adverse effects on air, water, or soil.
Controlled dumpsite	A non-engineered disposal site where improvement is implemented on the operational and management aspects rather then on the facility or structural requirements.
Decomposition	The breakdown of organic wastes by bacterial, chemical, or thermal means.
Disposal	To discharge, deposit, dumping, spilling, leaking or placing of any solid waste into or in any land.
Disposal site	A site where solid waste is finally discharged and deposited.
Double liner	A system consisting of two liners with a highly permeable drainage layer (for leachate collection) between them. The upper liner contains majority of the leachate, while the lower layer is to contain any leachate that may have leaked through the upper liner.
Effluent	Any solid, liquid or gas that enters the environment as a by-product of human activities.
Engineering control	It is a method of managing environmental and health risks, such as barriers placed between contamination and the rest of a site.
Facultative microorganism	Microorganism that tolerates low level of oxygen and continue the decomposition process.
Geosynthetics	It is a general term for geomembers, geotextiles, geonets and geogrids. Depending on its required function, it may be used for isolates, filtration, drainage and slope stability.
Geonet	A synthetic liner component that facilitates drainage. A geonet is analogous to the sand component in natural liners.
Geotextile	A synthetic component that is used as a filter to prevent the passing of the fine-grained material such as silt or clay. A

	geotextile may be placed on top of a drainage layer to prevent the layer from becoming clogged with the fine material.
Groundwater monitoring	A well placed at an appropriate location and depth for taking water samples to determine groundwater quality in the area surrounding a landfill or other use.
Hazardous waste	Wastes that by their nature, may pose a threat to human health or the environment. They include materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Hydraulic conductivity	The rate of flow of groundwater through unit cross-sectional area of an aquifer under unit hydraulic gradient.
Hydrogeology	The study of groundwater, including its origin, occurrence, movement, and quality.
Integrated solid waste management	The management of solid waste based on a consideration of source reduction, recycling, waste transformation, and disposal, arranged in a hierarchical order.
Landfill gas	A mixture of primarily methane and carbon dioxide that is generated in landfills by the anaerobic decomposition of organic wastes.
Land Disposal	Refers to the final placement, discharge, deposit, or dumping of any solid waste material on land.
Leachate	Liquid that has percolated through solid waste or another medium and has extracted, dissolved or suspended materials from it. Because leachate may include potentially harmful materials, leachate collection and treatment are crucial at municipal waste landfills.
Leachate pond	A pond or tank constructed at a landfill to receive the leachate from the area.
Lift	In landfilling, a lift is a completed layer of adjacent cells.
Liner	A system of low-permeability soil and/or geosynthetic membranes used to collect leachate and minimize contaminant flow to groundwater. Liners may also adsorb or attenuate pollutants to further reduce contamination.
Materials recovery facility	The physical facilities used for the further separation and processing of wastes that have been separated at the source and for the separation of commingled waste.
Methane	A colorless, nonpoisonous, flammable gas created by anaerobic decomposition of organic compounds.

Methanogenic phase	This is the third stage in the waste degradation process where anaerobic conditions develop because of the continues depletion of oxygen and the facultative microorganisms are replaced by the obligate anaerobic (requiring no oxygen) microorganisms. The main decomposition products at this stage are carbon dioxide and methane.
Municipal solid waste	Includes all the wastes generated from residential households and apartment buildings, commercial and business establishments, institutional facilities, construction and demolition activities, municipal services, and treatment plant sites.
Native plant	General term used for plants that grow in a region.
Natural attenuation	An approach to cleanup that uses natural processes to contain the spread of contamination.
Obligate microorganism	Microorganisms that requires no oxygen and feed on waste slowly over the years and decompose the remaining organics from the acetogenic phase.
Open dumpsite	A disposal area wherein the solid wastes are indiscriminately thrown or disposed of without due planning and consideration and health standards.
Organic materials	Chemical compounds containing carbon combined with other chemical elements. They can be of natural or anthropogenic origin.
Passive venting system	A system that consists of a network of wells, pipes and pumps to extract the gas and process it for heating or electricity generation.
Permeability	A characteristic that represents the qualitative description of the relative ease with which rock, soil, or sediment will transmit a fluid (liquid or gas).
Progressive slope or Ramp method	A variation of the area and trenching techniques. This method involves the spreading and compaction of the waste on a slope. It is not commonly used since the liners and leachate collection systems must be in place prior to any waste disposal.
pH	A measure of the acid or alkaline strength of a substance. The pH scale ranges from 0 to 14, with a value of less than 7 being acidic and a value greater than 7 being alkaline. A value of 7 indicates neutrality.
Reclamation	The restoration to a better or more useful state, such as land reclamation by sanitary landfilling, or the extraction of useful materials.

Recycling	Separating a given waste material from the waste stream and processing it so that it may be used again as a useful material for products that may or may not be similar tot he original.
Resource recovery	A general term used to describe the extraction of economically useable materials pr energy from wastes.
Sanitary landfill	An engineered disposal facility designed, constructed, operated in a manner that minimizes impacts to public health and the environment.
Semi-aerobic landfill	A landfill where air is introduced to the waste to accelerate decomposition.
Service area	The area being served by a waste collection system.
Sludge	A semisolid residue from air or water treatment processes.
Solid waste	Comprise all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted.
Special wastes	These include bulky items, consumer electronics, white goods, batteries, oil, paints, tires and others.
Transmissivity	A measure of the movement of groundwater through an aquifer, particularly in the vicinity of production wells. It is the product of the hydraulic conductivity and the aquifer thickness.
Vadose zone	The zone between the surface of the ground and the permanent groundwater.
Vermin	Any of various destructive insects or small animals regarded as pests, such as rats, lice, etc.
Waste generation	The act or process of generating solid wastes.
White goods	Large worn-out or broken household, commercial, industrial appliances such as stoves, refrigerators and others.

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

- Sustainable consumption and production,
- The efficient use of renewable energy,
- Adequate management of chemicals,
- The integration of environmental costs in development policies.

The Office of the Director located in Paris coordinates activities through:

- The International Environmental Technology Centre-IETC (Osaka, Shiga) which implements integrated waste, water and disaster management programmes focusing in particular on Asia;
- Production and Consumption (Paris) which promotes sustainable consumption and production patterns as a contribution to human development through global markets;
- Chemicals (Geneva) which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemicals safety worldwide;
- Energy (Paris) which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency;
- OzonAction (Paris), which supports this phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol;
- Economics and Trade (Geneva) which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information, see: www.unep.fr

Department of Environment and Natural Resources, Philippines

Executive Order No. 192, provides the mandate for the Department of Environment and Natural Resources (DENR) as the primary government agency responsible for the conservation, management, development and proper use of the Philippine environment and natural resources, including reservations, watershed areas and lands of the public domain, as well as the licensing and regulation of all natural resources in order to ensure equitable sharing of the benefits derived therefrom for the welfare of the present and future generations of Filipinos.

The DENR's mission is to be the dynamic force behind people's initiatives in the protection, conservation, development and management of the environment through strategic alliances and partnerships, participative processes, relevant policies and programs and information technology towards sustainable development.

The present DENR structure is headed by the Secretary of Environment and Natural Resources, assisted by five (5) Undersecretaries for Environment and Forestry, Policy and Planning, Lands Management, Mines, and Management and Technical Services and seven (7)) Assistant Secretaries each assigned to a key functional office. There are also a Public Affairs Office, Special Concerns Office and the Pollution Adjudication Board that provide support services to the Secretary.

There are six (6) sectoral bureaus under it, four (4) are doing staff functions (Forest Management Bureau, Lands Management Bureau, Ecosystems Research Development Bureau and the Protected Areas and Wildlife Bureau) while 2 are line bureaus (Environmental Management Bureau and the Mines and Geo-Sciences Bureau).These line bureaus have their counterparts in the regional offices headed by the Regional Director.

At the operational level, DENR organization reflects a line structure under the direct supervision of the Field Operations. Functions are decentralized down to three levels, namely:

a. regional level – Regional Environment and Natural Resources Offices (16 – one per region)
b. provincial level – Provincial Environment and Natural Resources Offices (73 – one per province))
c. community level – Community Environment and Natural Resources Offices (171 - covering several municipalities in a province)

A Regional Office is established in each of the sixteen (16) administrative regions. It is headed by a Regional Executive Director, supported by Regional Technical Directors (RTD), each heading a major service: Forest Management Services, Lands Management Services, Ecosystems and Research Development Services and Protected Areas and Wildlife Services.

There are also three (3) attached Agencies/Corporations, namely:

a. National Mapping and Resource Information Authority (NAMRIA)
b. Natural Resources Development Corporation (NRDC)
c. Laguna Lake Development Authority (LLDA)

The DENR also chairs the National Solid Waste Management Commission, the major agency tasked to implement Republic Act No. 9003, the Ecological Solid Waste Management Act of 2000. R.A. 9003 calls for the institutionalization of a national program that will manage the control, transfer, transport, processing and disposal of solid waste in the Philippines. It prescribes policies to effectively achieve the objectives of RA 9003. It oversees the implementation of appropriate solid waste management plans by end-users and local governments as mandated by law. The Commission is also mandated to establish the National Ecology Center which serves as the depot of information, research, database, training, and networking services for the implementation of the law.

For more information, see www.denr.gov.ph

In recognition of the need to manage solid waste and as part of the United Nations Environmental Programme's global effort to promote environmentally sound technologies, this training module on modern solid waste management is designed especially for local authorities and their staff. It was developed to understand why the practice of open dumping has to be abandoned and learn the basic knowledge and skills required to close dumpsites and shift to controlled dumping and to sanitary land filling.

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