Unit-6 LANDFILL CLOSURE AND REHABILITATION OF SITE

Structure

6.1 INTRODUCTION

Landfills may need to be closed for various reasons, including unacceptable environmental impacts such as groundwater pollution, and/or unmanageable air pollution such as dust or odours. In many cases, improving landfill management and operations is a necessary step but, if this proves unsuccessful, closure becomes necessary. Landfills are usually designed with a specific life span determined by the volume of waste that can be handled. Once filled to capacity, landfills must be closed and decommissioned as stipulated in

the waste management licence. However, effective landfill remediation poses a challenge for both public and private entities. Landfill site problems are often bigger than the eyesore created by the huge pile of waste. At some point, landfill sites will have to be closed. The process of landfill closure and remediation is legislated by the National Environmental Management Waste Act, the Water Act and the Waste Management Series, as promulgated by the Department of Water and Sanitation.

Objectives:

After studying this unit, you should be able to

- Understand the concept of Capping and its design
- Specify requirement ,establishments and procedures for Landfill safe closure
- Make Landfill closure report after checking required parameters
- Learn Landfill post closure management and Rehabilitation of that area

Figure 6.1: Landfill sites in the process of covering the top

Figure 6.2: Landfill sites after closure

6.2 CLOSURE AND POST-CLOSURE MAINTENANCE PLAN

6.2.1 Objectives of Capping

Capping involves placing a cover over contaminated material such as landfill waste or contaminated soil. Such covers are called "caps." Caps do not destroy or remove contaminants. Instead, they isolate them and keep them in place to avoid the spread of contamination. The main objectives of capping are

a) Manage leachate production by controlling the ingress of water into the waste.
b) Prevent uncontrolled escape of landfill gas and odours or the entry of air into the wastes.
c) Provide protection for the wastes
d) Accommodate environmental control measures such as gas vents, etc.
e) Provide physical separation between waste and humans, animals and plants.

6.2.2 Phased capping

An alternative to capping at the end of the life of the landfill is phased capping. This involves capping portions of the waste body that are at final height. The main motivation for phased capping is given below:

a) Capping the site will ensure no additional liquids enter the waste body from surface, which reduces the quantities of leachate generated.
b) Seepage from the side slopes will be minimised.
c) Partial rehabilitation will result in the removal of large areas from the contaminated catchment resulting in less contaminated water requiring management.
d) It will help prevent oxygen entering the site once the gas wells are placed under suction, improving yield and reducing the risk of a landfill fire.
e) Vegetation of the side slopes will mitigate sedimentation of the storm water infrastructure.

The advantages and disadvantages of applying final capping must therefore be weighed to determine the optimal timing for final capping placement. Phased rehabilitation and capping is recommended, so that capping of a phase should take place within five years of a phase being complete. This will reduce contaminated storm water and leachate generation, spread rehabilitation and closure costs during the life of the site, and allow for initial settlement to take place before final capping is placed. It will also improve the site aesthetics if suitably vegetated. It is noted that the design of the dams includes for final capping placement on each phase within five years of completion. A typical capping design is shown in figure 6.3.

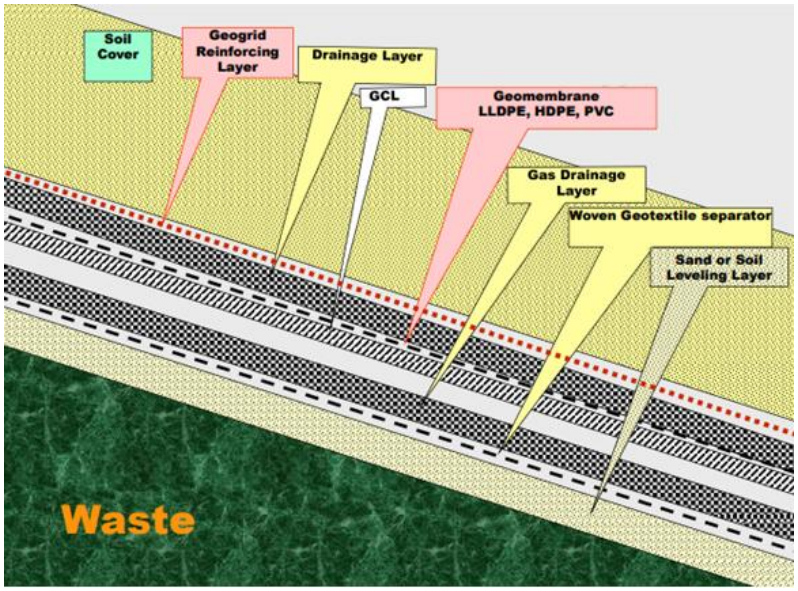

Figure 6.3: Typical Geosynthetic capping

6.2.3 Capping Design

The material properties required for a clay cap, in terms of the minimum requirements for Waste Disposal by Landfill, are as follows:

a) Plasticity Index (PI) of between 5 and 15%.
b) No particles larger than 25 mm.
c) Saturated permeability must be less than 1.585×10^{-6} cm/sec.

The siltstone materials tested on site are more than meets the permeability requirements, but the plasticity index is higher than allowable, at 27%. Other material on site may be suitable, such as the calcrete material. While calcrete has been included in the capping design, it is recommended that additional material testing take place to source suitable capping material. The site is to be capped in accordance to Minimum Requirements incorporating a shaping layer followed by a gas drainage layer and composite geosynthetic and clay liner. Starting from the vegetation placed in the topsoil, the capping is described below:

- Vegetation
- Topsoil
- 2 x 150 mm thick compacted calcrete layers
- 1 mm linear low density polyethylene (LLDPE) geomembrane liner
- 1 x 150 mm thick compacted calcrete layer
- Separation geotextile
- 19 mm stone gas drainage and capillary break layer
- Separation geotextile
- 1 x 150 mm thick compacted calcrete layer for foundation and shaping
- Waste body

6.3 LANDFILL CLOSURE

Determination of the end-use of a landfill site is an essential part of the plan for landfill closure and post-closure maintenance. Some possible uses of closed landfill sites near urban centres include parks, recreational areas, golf courses, vehicle parking areas and sometimes even commercial development. As each

phase is completed and as the final cover level is reached in successive phases, the following interconnectivities should be established.

a) the leachate collection system of each phase is sequentially connected (if so designed)
b) the surface water drainage system at the cover of each phase is sequentially connected (if so designed)
c) the temporary surface water drainage system constructed at the base of each completed phase is dismantled.
d) the gas collection system (if provided) of each phase is sequentially connected.

Upon completion of all phases, a final check is made of the proper functioning of all inter connected systems. An access road is provided on the landfill cover to enable easy approach for routine inspection of the landfill cover.

6.3.1 Requirements of Safe Closure

The Objectives for the safe closure of different disposal sites are as follows:

a) To prevent wastes from littering or overflowing from these disposal sites
b) To reduce gas pressurization or uncontrolled gas migration within the deposited waste beneath the capped surface to prevent fire or explosion within the facilities
c) To minimize offensive odours emitting from these disposal sites d) To provide storm water run-off and drainage facilities
d) To minimize environmental pollution caused by leachate from these disposal sites
e) To prevent groundwater contamination

6.3.2 Establishment of Safe Closure System

All disposal sites should be assigned with the targeted safe closure system at the initial stages of its safe closure plan. The procedure to identify the safe closure system for each disposal site is as follows:

1) Site assessment survey should be carried out in order to determine the general conditions, environmental conditions and land use conditions of the site. From the results of the survey, the environmental pollution potential and land use potential can be evaluated. For further information, refer to Annex 3 for the sample evaluation /assessment form for Disposal Sites.
2) From the evaluation, the closure priority of the disposal site and applied closure system should be setup.
3) The proper safe closure plan should then be formulated and the physical closure works and the post closure management activities should be carried out.

To take measures for wastes stabilization In order to implement the safe closure of disposal sites, proper physical closure and post closure management should be carried out where, the extensiveness of closure shall vary on the type of disposal site.

(1) The Physical Closure (PC) consists of the measures or facilities necessary for the safe storage of waste, prevention of environmental pollution and early stabilization of the waste at the dump site.
(2) The Post Closure Management (PCM) consists of the operation of disposal facilities such as leachate treatment plant, the maintenance of the facilities

including soil cover, fence, drainage canal, embankment and the monitoring of environmental pollution and stabilization of waste.

6.3.2.1 Physical Closure

The closed disposal site should be provided with the necessary facilities for the safe storage of waste, to prevent environmental pollution and to accelerate early stabilization of the waste at the dumpsite. Also the facilities for post closure management, such as control building for operation and maintenance and the monitoring facilities should be provided as much as possible. The facilities required for safe closure should be planned, designed and implemented based on the following requirements.

a) Stabilization of Critical slopes or Reformation of Shape/Slope and Waste Storage Facility

The exposed waste should be compacted. The shape or slope of the filled waste should be modified if they are deemed to be unstable and/or when the waste has been overfilled. The gradient of the slopes should be less than 1:3 or slopes ranging from 2 to 4% to facilitate drainage and prevent ponding and soil erosions. The waste storage bank, suitable retaining wall or embankment structures should be constructed if the shape of the filled waste is not stable, and if the boundary of the site is limited. Whereas, the side slopes can be generally set at the ratio of 1 vertical to 3 horizontal or gentler depending in the nature of waste and actual site conditions. Step or terraces should be provided where necessary at 5 m intervals at the slopes, whereas the terrace width should be about 2 m to 3 m as shown in Figure 6.4. In addition, the slopes and terraces should be provided with topsoil suitable for turfings and plantings to protect from erosion and as aesthetic landscape.

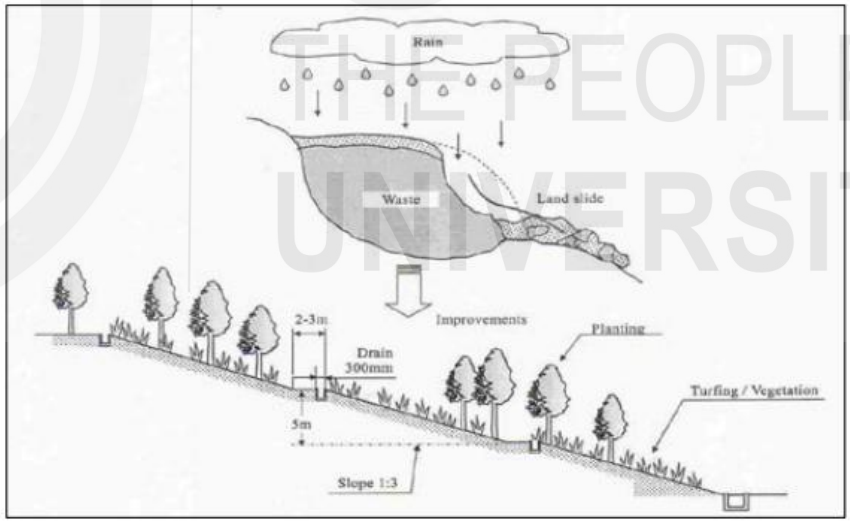

Fig. 6.4: Slope Improvement of landfill closure

b) Final Soil Cover and Vegetation

The final cover should be the cover soil laid on top of the final waste layer, after the disposal site has been completed. The purpose of final cover is to provide improvement to the sanitary conditions, the landscape, post-closure land use, the reduction of the leachate quantity as shown in Figure 6.5, reduction of offensive odour, prevention of outbreak of fire, reduce the breeding of vectors, minimize leachate generation, serve as vegetation layer, etc. The final soil cover should be

at least 60 cm which include 15 cm topsoil and 45 cm compacted soil. Suitable vegetation for planting on top of closed disposal sites include vegetative covers, the most effective of which is Vetiver grass. Another type of vegetation is known as "living filters" or those plants that minimize the amount of toxic gases. These are suitable for planting in areas surrounding closed disposal sites or buffer areas. For post-closure land use (as a park, for example) these may also be planted on top of the closed site. For planting trees and shrubs, the final soil cover should be more than 150cm.

The topsoil, which is usually not compacted, will serve as protection layer as well as support for the plant growth. In areas where trees and scrubs are to be planted, the thickness should be increased to be more than 150cm. Regular maintenance of the cover soil will be necessary. The soil material should possess permeability not less than $1x10^{-6}$ cm/sec, resistance to erosion and suitable for vegetation growth and with an inclined slope of about 2 to 5% gradient as shown in Figure 6.6. However, the soil's final thickness is dependent on the post-closure land use plan of the disposal site.

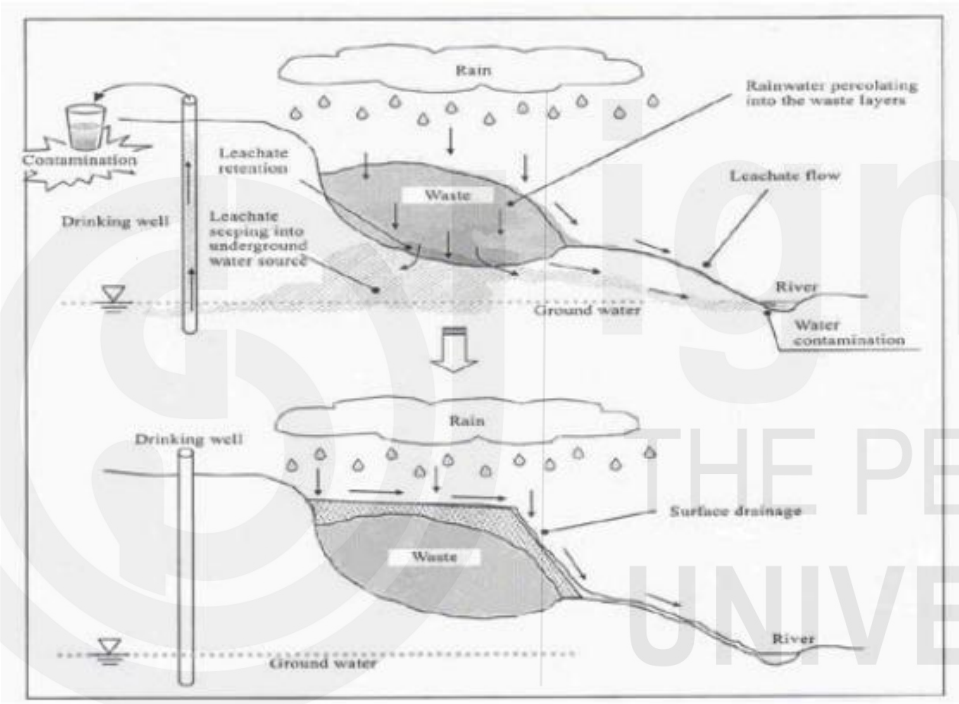

Fig.6.5: Purpose of Soil Cover

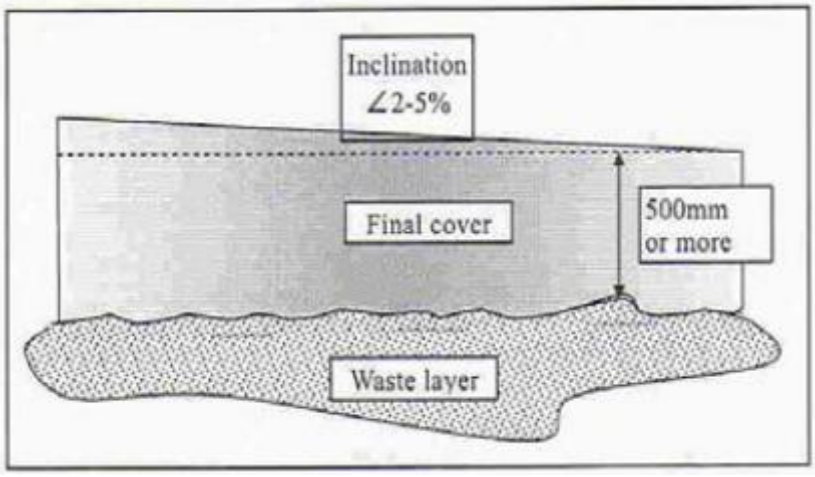

Fig.6.6: Specification of Final Cover

c) Drainage Facility

The proper drainage system should be provided to channel the rainwater from the disposal site to the discharge drains. This will reduce the surface water percolating into the waste layers, prevent soil erosion and reduce the leachate production. Storm water drainage system such as peripheral canals and ditches should be installed at the upper part, at the slopes and at the surroundings of the disposal site to divert runoff. Although the slope of drainage is influenced by geographical feature conditions, generally it becomes 1-2%. At a steep slope or a rugged place, since it is easy to cause erosion or overflow by the torrent and the curve, special caution are required in a design. Other drains should be provided such as cast-in-site concrete channel, U-shaped drains, concrete pipes, etc. Earth trenches or drains may be provided at the areas where the ground is hard and impermeable. Trenches are simple to excavate and economical to provide and to maintain. However, regular maintenance of the storm-water drainage will still be necessary.

d) Gas Vents

The waste decomposition process will generate a large amount of gasses such as methane and carbon dioxide, which rises and escapes through the surface. The gas vents should be provided and installed at 50m intervals to allow the gasses to escape and vented to the atmosphere and thus preventing gas explosion. These vents will also supply air deep into the waste layers to promote the decomposition process and to accelerate the stabilization of the disposal sites. These vents may be made up of local materials such as bamboo or PVC pipes or perforated polyethylene pipe or perforated PVC covered by gravel or crushed rock with a diameter of 7.5 to 30cm. as shown in Figure 6.7.

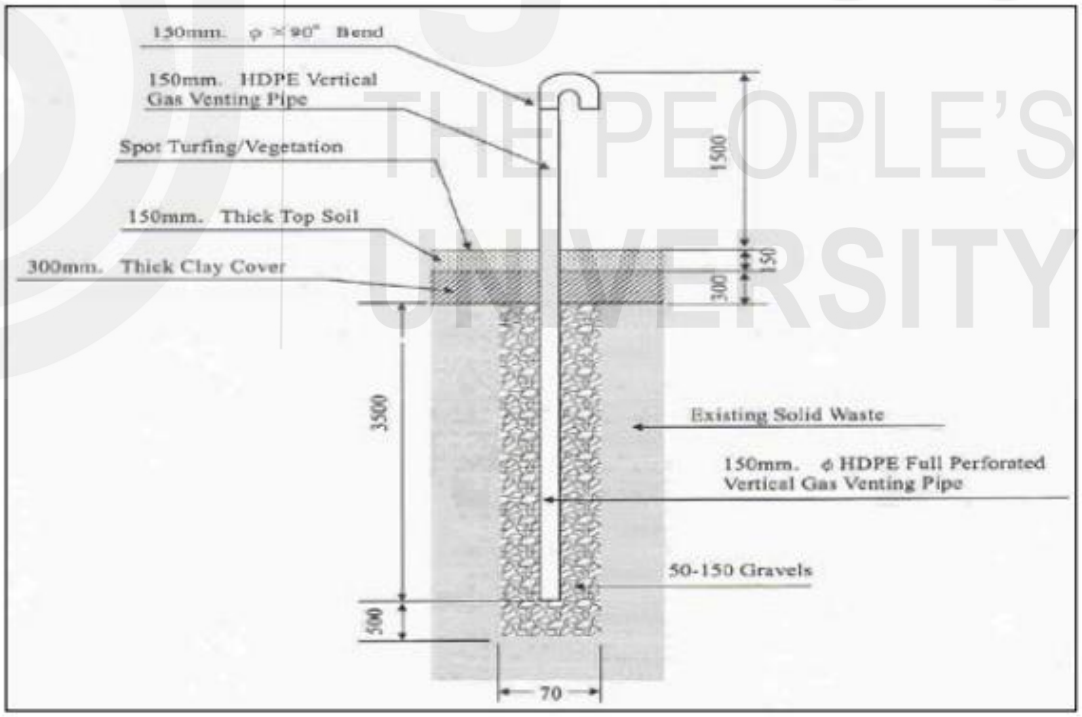

Fig.6.7. Typical Vertical Gas Venting Pipe Detail

e) Leachate Collection Pipes and Leachate Re-circulation Facility

The leachate collection/drainage pipes are installed as much as possible in the bottom of disposal sites to accelerate the stabilization of the disposed waste by gas

vent and to supply inside the disposal site to create a semi-aerobic condition. The pipe lies down with a gentle slope so that it can drain by the natural flow as shown in Figure 6.8. The pipes are made of perforated pipe or perforated synthetic resin conduit and with cover materials composed of cobble stone or crushed rocks which prevent clogging. In case of installing the leachate collection/drain pipe will be installed at the closure stage of the disposal sites, the waste is excavated with heavy industrial machines, such as excavator with hoe equipment, then leachate collection/drainage pipe is installed where the depth of a leachate pipe is restricted to the depth the machines can excavate, approximately 5 m from the surface. On the other hand, when using existing leachate collection drainage pipe, or when installing a pipe at the position where the construction height of a pipe is higher than water level of retaining of leachate, it is scarcely effective for drainage of leachate. Another effective way to drain the leachate is by installing a leachate drainage pipe by horizontal boring though the disposal site condition cannot become semi-aerobic by using this method. The leachate collection pipes and leachate re-circulation facilities should be installed in order to provide semi-aerobic conditions to the waste layers of the disposal sites. The re-circulation equipment pumps out leachate from the collection pond and draws back to the surface of the facility as shown in Figures 6.9 and 6.10. These facilities minimize the groundwater contamination by removing leachate accumulated in the waste layers; by 1) improving leachate quality through contact with air and aeration; 2) accelerating waste decomposition process and 3) reducing the generation of methane gas.

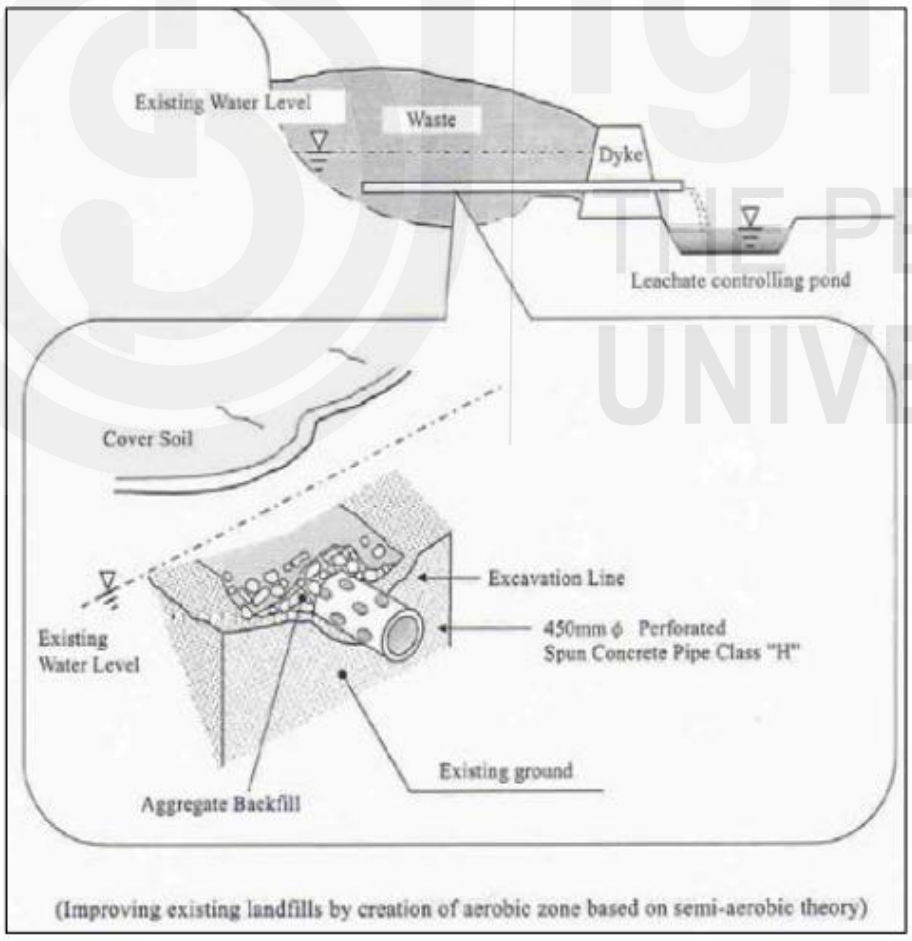

Fig.6.8: Typical Image of Installing the Leachate Pipe

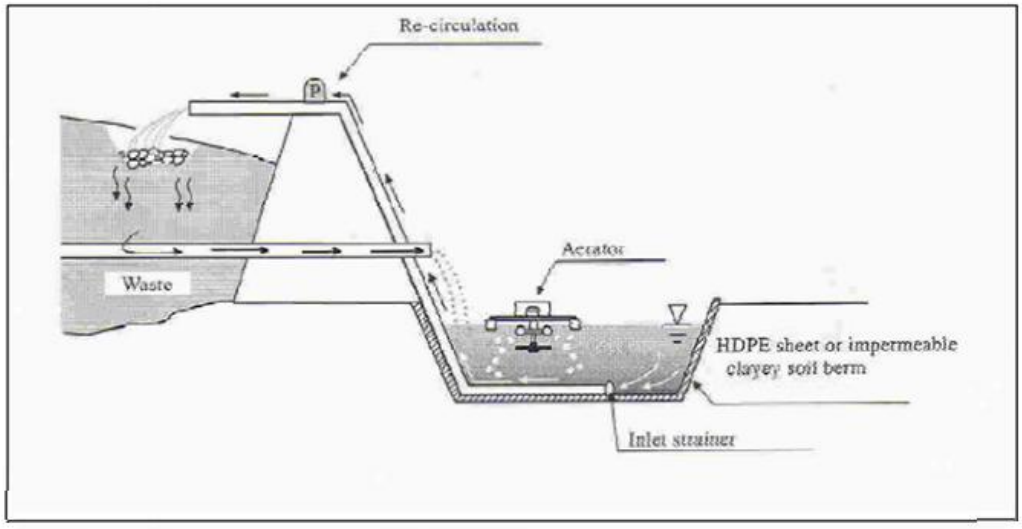

Fig.6.9: Typical image of Leachate Re-circulation

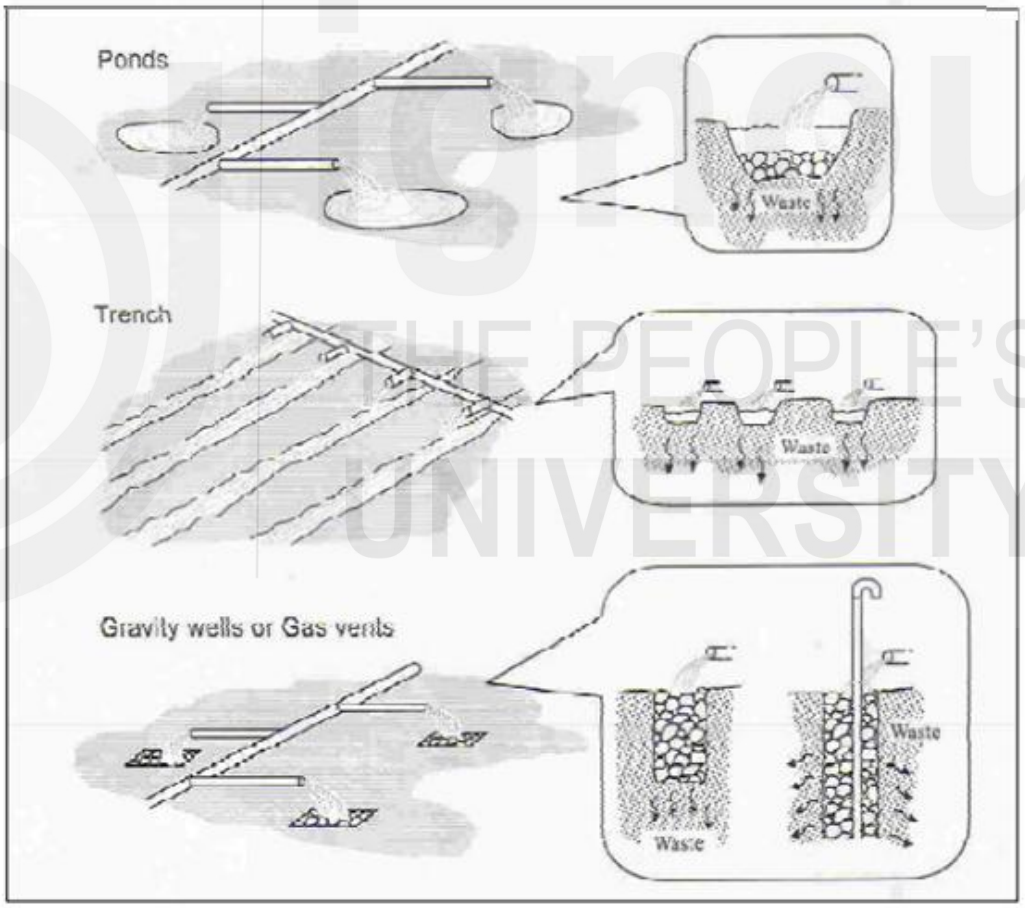

Fig. 6.10: Type of Infiltration Equipment

6.3.3. Procedures for Closure of Disposal Facility

6.3.3.1 Pre-Closure Assessment

The activities covered by the pre-closure assessment shall include the following points and the steps of closure are shown in figure 6.11.

a) Review of available records, files and information regarding the disposal site
b) Evaluation of potential or existing impacts on the ecological and human environment
c) Determination of potential contaminants (if any) which could get into the local environment and the formulation of appropriate mitigating and remedial measures.

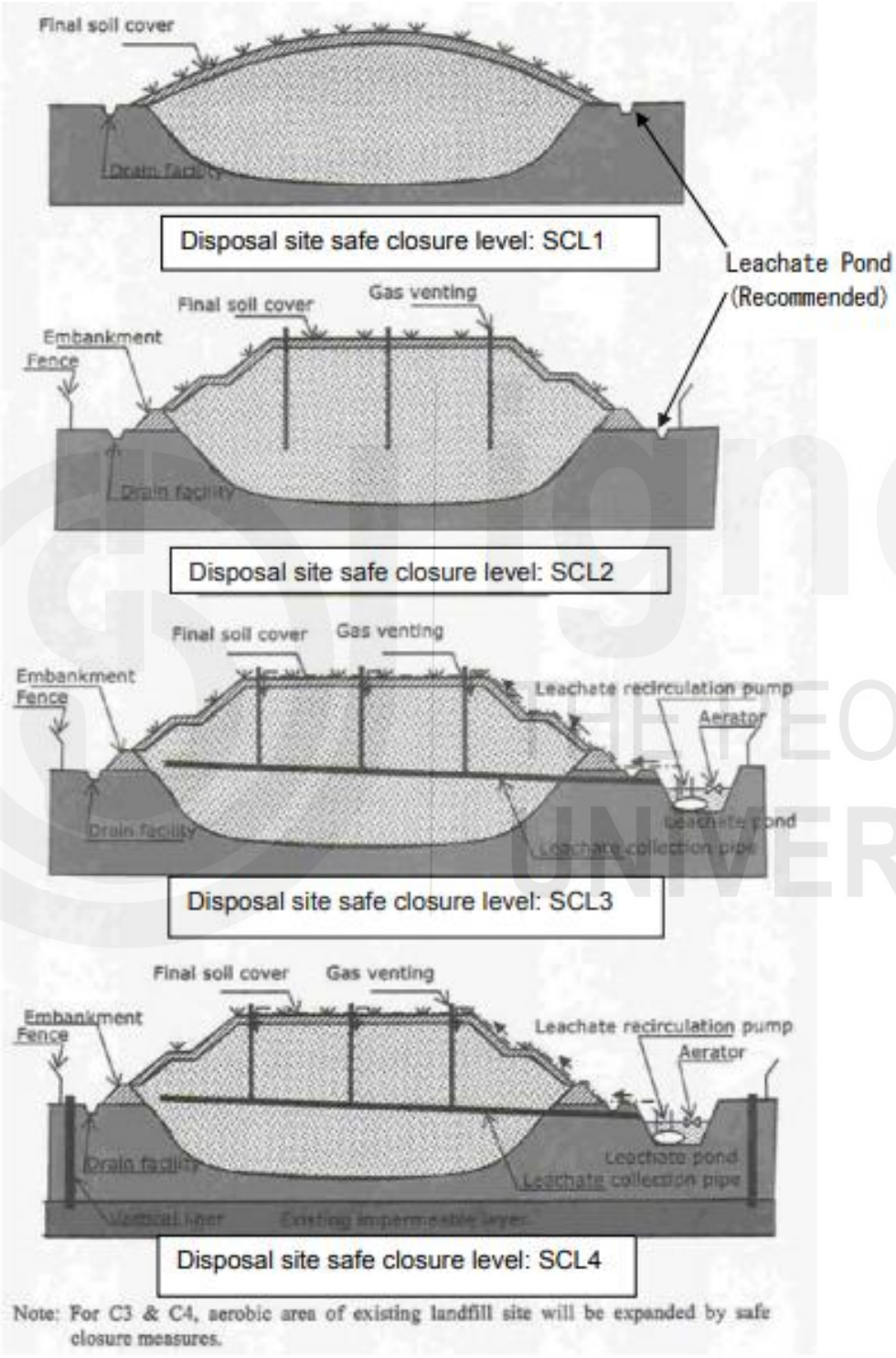

Fig.6.11. Schematic Diagram of Safe Closure Levels of Disposal Sites

6.3.4. Assessment Parameter

a) Review of the geology of the site, depth of groundwater, total volume/capacity and types of wastes disposed, reports, studies, historical records concerning the disposal site (operations, unusual events such as fires dumping of hazardous wastes, etc.)
b) Review of relevant available maps (map of the dumpsite and its surroundings, topographic, geologic, hydrogeologic, land use)
c) Identification of existing land uses around the area
d) Interview of those directly involved with the operation of the dumpsite, waste pickers, and residents near site.
e) Inventory of existing settlements, structures, surface water bodies, springs and water wells. If practical, water samples may be taken to determine extent of contamination
f) Determination of points of leachate seepage and ponding within and beyond the disposal facility g. Where appropriate and for larger disposal sites, conduct topographic survey of the disposal sites, extending some distance from its boundaries.
g) Conduct geotechnical investigation of large open disposal sites to determine stability of slopes.
h) Identification of sources of soil or other covers material for the site.
i) Determination, if practical, of the depths of the dumped wastes.
j) Determination gas leakage within and on the areas surrounding the disposal site.
k) Conduct leachate and gas sampling (if practical)

6.3.5 Safe Closure Plan

After conducting the site assessment, the safe closure plan for the disposal site should be prepared based on the priority and the closure level. The plan should include:

6.3.4.1 General information of the disposal site

- Name and Location of the disposal site
- Owner and operator of the disposal site
- Location/Vicinity map of the disposal site
- Area and height of the disposal site
- Brief descriptions of the disposal facility (from the start of operation to closure)
- Plans or site maps and cross-sections
- Period of waste acceptance (date of start of operation and final waste acceptance)
- Tonnage and volume of the filled waste

6.3.4.2 Physical Closure Plan

- Stable shape/ slope and elevation plan
- Covering soil and other facilities (gas ventilation, leachate, wastewater, etc)
- Final Soil Cover and Vegetation Cover
- Drainage Facility and Drainage Plan
- Gas Ventilation/Gas Management Facility
- Leachate Collection and Treatment Facility
- Perimeter fence, signage's and access road d. Post closure management plan
- Site Management plan

- Environmental Monitoring plan
- Tentative land use (e.g. Eco Park)

The Post closure management includes establishment of an Ecological Park (ECO-PARK). An ECO-PARK shall refer not only to a post closure site converted into an integrated facility designed for processing, treating, sorting, retrieving, extracting or recovery of recyclable materials, biodegradable wastes, non-hazardous/non toxic solid wastes and disposal of residual wastes but also applicable for new identified area which passes the standard/criteria in establishing the said facility. The facility should composed of: Materials Recovery Facility (MRF) for composting of any of the following: vermi-culture, windrow type, backyard pit, rubber tire, compost rotary drums, storage area for recyclable non-hazardous/non-toxic solid waste materials, processing using any of the following alternative technologies: bioreactor, biodigester, charcoal briquetting, plastic/Styrofoam oven melter among others and disposal facility as may be feasible and necessary.

6.3.6 Closure Report

The Minimum Requirements defines that the objectives of landfill closure are:

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

Where it is intended to close a landfill, the Permit Holder must inform the permitting authority of this intention at least one year prior to closure. This is because certain procedures must be implemented and criteria met before closure. It is obvious that prior to a site being closed, alternative airspace must be provided for the waste streams. Extensions could be possible on the site, and could be investigated at that time. The landfill must then be investigated before rehabilitation and closure can commence, so as to identify any closure requirements that must be implemented. Based on the results of the investigations, a closure or upgrade design must be drawn up and presented in a Closure Report. Written acceptance of both the Closure Design and the Closure Report must be obtained from the authority. In order to obtain this, an inspection of the landfill by the Responsible Person and a representative of the authority will be required. Once the Closure Design and the Closure Report have been accepted by the authority and the I&APs, site rehabilitation may commence. Once the landfill has been rehabilitated in accordance with the Closure Report, it is a Minimum Requirement that the Permit Holder notifies the authority in writing of the intended closure of the site, at least 60 days prior to the event. Should the authority approve the condition of the landfill, the Permit Holder will be provided with written permission to close the site. The site may then be closed and the end-use plan implemented. Thereafter, the site must be monitored on an ongoing basis, for which the Permit Holder is responsible. Provided that the landfill has been well operated, rehabilitation and closure are relatively straight forward, as no significant compaction and re-shaping exercises are required. Monitoring of adherence with the final landform shape during the operation is crucial in ensuring that major re-shaping is not required. Rehabilitation that may be required includes:

a) Repair of any erosion damage.
b) Compaction of low density areas.
c) Repairs to diversion drains.

d) Filling in of low areas that have resulted from differential settlement.
e) Filling in areas where the final landform has not been achieved, and cutting in areas of overfill.
f) Liner repairs in storage dams, and so forth.

However, the above items should be addressed on an ongoing basis as part of site maintenance.

6.4 Post-Closure Stabilisation, Operation and Care

6.4.1 Disposal Site Stability Indicators

(a) Physical Conditions

The rate of subsidence on a disposal site would normally depend on the qualitative and quantitative analyses of the waste deposited. The rate of subsidence for the stabilized disposal site and other disposal sites should be less than 20 mm per year. The subsidence rate should be monitored regularly and the level survey should be carried annually. Benchmarks should be installed at suitable locations on the surface of the top soil. The minimum recommended number of benchmarks is two (2), or one (1) for each hectare of the site. The subsidence should be monitored and observed for more than two years. Other stability procedures and indicators include ground attenuation, compaction rate, liquefaction, etc. The top cover also should not exhibit any surface cracks, pools or signs of soil erosion. The soil cover should be of sufficient thickness to protect the filled waste layer. The recommended thickness should be at least 600mm and should be well compacted. The top cover should be planted with shrubs, vegetation or grasses that are indigenous to the area are recommended to prevent dust and soil erosion.

(b) Chemical Conditions

Regarding quality of the raw leachate, the site has reached stability when the quality of the untreated raw leachate discharged from the disposal site has remained constant for at least two years and is within the approved limits and complies with the relevant effluent discharge standards. Records of the leachate quality are significant factor in the determination of the extent of closure and rehabilitation activities to be accorded in the dumpsite.

(c) Quality of disposal site gas

The disposal site gas should be monitored at the ventilation pipes at least twice a year after the filling works has completed. The concentration of the gas could become higher during low atmospheric pressure conditions. It is recommended that the frequency and number of gas monitoring activities during such low pressure conditions be increased to be more than twice the frequency of the normal monitoring activities. The concentrations of disposal site gas should satisfy the following conditions.

i) Not volatile and explosive: The safe concentration levels of methane gas are between 5%-15% (by volume).
ii) Not cause suffocation: The oxygen levels should be higher than 18% (by volume).

(d) Quality of groundwater around the site

No pollution to the groundwater around the site should be observed. It is advisable to install monitoring wells at the upstream (as for background monitoring well) and downstream (as for detection well) areas in the dumpsite.

(e) Temperature of the waste layers

There should be no significant increase in the temperature detected in the waste layers. The temperature in the waste layers should be monitored by using the gas ventilation pipe or by installing special temperature monitoring wells. The subsurface temperature 5 m below the surface should be between 25° C to 30° C. If the temperature of the waste layers is higher than 30° C, then the waste degradation process is still active and the stabilization has not been reached.

(f) Post-closure Care

- Post-closure care period typically 30 years
- Must maintain integrity and effectiveness of cover
- Must maintain leachate collection
- Must monitor groundwater
- Must maintain and operate gas monitoring

6.4.2 Long-Term Vegetative Stabilisation

If a landfill cover is intended to be used for a specific purpose e.g. park or golf course or vehicle parking area, then the cover will be stabilised in such a manner that the end-use is achieved. However, if no specific end-use is envisaged, then long-term vegetative stabilisation will be undertaken to return the land to its original and natural vegetative landform. Vegetation is by far the most common and usually the preferred stabilisation option after closure of landfills. If a self-perpetuating vegetative covercan be established, not only can wind and water erosion be minimized, but also the landfill can be returned to some semblance of its original appearance and land use. In favourable climates, re-vegetation may require only modest effort or may occur by natural process during a reasonably short period of time. However, in aridclimates or a harsh environment, establishment of vegetation may be a lengthy, difficult and costly process. Typically, vegetation efforts follow a series of steps. While the specific procedures are unique to each landfill and climatic regime, the following are usually representative elements of the process:

a) **Seedbed Preparation:** Seedbed preparation is necessary to set the stage for establishment of the short-term community. Initial operations may include grading, furrowing, or grouping to enhance microclimate and addition of nutrients and soil amendments, if required.
b) **Short-Term Vegetation:** It is common practice, in both humid and dry environments, to rely largely on grasses for the primary initial source of short-term land cover. Usually several species are included in the initial seeding mixture to increase diversity and reduce the chance of total community failure. Short-term vegetation is usually assisted by irrigation.
c) **Long-Term Vegetation:** To achieve the ultimate goal of attaining a self-sustaining and stable community, a transition between short-term and long-term vegetation must occur. In some cases, this may be left to invasion by native species after short-term vegetation is assured and soil development is well under way. In other cases – for example, when irrigation has been used temporarily to establish the short-term community – it may be necessary or desirable to enhance the natural succession process by replanting with a more diverse mix of species suited to the next stage of community succession, such as shrubs.

All vegetation efforts, however, should work toward self-generation and minimum management in the long term. Several factors limit the growth of plants on

landfills. These include toxicity of landfill generated gases (methane and carbon dioxide) to root systems, low soil oxygen due to heavy compaction, thin cover layer inhibiting root penetration, low nutrient status of cover soil, high soil temperatures and poor soil structure. Some of these factors can be eliminated or their effect on plant growth reduced. Active gas extraction or proper use of gas barriers with venting system prevents gas migration to the root zone. Waste may be removed from certain areas to enable planting of islands of trees. By separating biodegradable waste from non-biodegradable, it may be possible to create zones free of toxic gases.

6.4.3 Operation after Closure

The indicators of leachate quality and landfill gas quality must be decided after conducting a study relating to the type of the waste, the age of the waste, the composition of leachate and gas likely to be generated and the geotechnical as well as hydro-geological features of the area. All monitoring programmes must first establish the baseline/background conditions prior to landfill monitoring. The frequency of monitoring will vary from site to site but it must be so fixed that it is capable of detecting unusual events and risks in the initial phases of their appearance so as to give time to diagnose and localise the cause and enable early steps to be taken for containment or remediation. Usually a monthly or a bi-monthly monitoring frequency is considered suitable during the operational phase of a landfill as well as for 3 to 4 years after closure; this frequency can be decreased to 2-3 times a year in later years, if all systems perform satisfactorily. The monitoring frequency may have to be increased if higher concentrations than expected are detected, if control systems are changed or if drainage systems become clogged/non-functional. The frequency of monitoring may also be increased during those periods in which gas generation or leachate generation is higher, such as during the monsoon periods.

The following facilities will be operated routinely after closure:

(a) leachate management system.

(b) surface water management system.

(c) environmental monitoring system.

(d) cover rehabilitation and repair system.

Qualitative parameters to be monitored are:

(a) leachate quality within the landfill (at the base).

(b) leachate quality after treatment.

(c) ground water quality (up gradient and down gradient).

(d) surface water quality at the exit of landfill.

(e) gas quality within the landfill.

(f) air quality above the landfill and at gas vents.

(g) air quality at gas control facilities.

6.5 STORM WATER MANAGEMENT POST-CLOSURE

Once the site has been rehabilitated, closed and final capping constructed, storm water runoff from the site will be uncontaminated and will be drained into the environment off site. As part of construction, drainage systems should allow for

the flow of clean storm water runoff from capped areas off site. Accordingly, storm water drains, berms and down chutes would typically be constructed.

6.5.1 Drainage Design

a) Surface water drainage design is critical to prevent erosion and instability of the cover system. Also it is to restrict free slope runoff by means of contour drains at calculated intervals (typically 30 to 50m).
b) Drain cover seepage into contour drains.
c) Size drains for 1 in 20 year rain event, plus freeboard to handle the 1 in 50 year rain event.
d) Design down chute drains to handle high velocities (supercritical flow). Provide energy dissipaters.
e) Design drains as flexible structures with adequate slopes to handle landfill settlement.

6.5.2 Maintenance and Monitoring

Once rehabilitated, closed and capped, ongoing monitoring and maintenance will be required to ensure that the capping integrity is maintained required as stipulated in the Operating Manual. Damage by erosion, differential settlement, and, on occasion, fauna such as moles, can occur.

6.5.3 Periodic Inspection and Maintenance

Periodic inspection and routine maintenance at a closed landfill site should be carried out for a period of 25 years after closure. The following components of a closed landfill are inspected visually after landfill closure to confirm that all functional elements are working satisfactorily. A maintenance schedule with specified reporting formats is drawn up after each inspection. Cover System: The final cover is inspected 2 to 4 times a year (a) to check that vegetation growth is occurring satisfactorily and that plants are not showing stunted growth, (b) to detect if any erosion gullies have been formed thereby exposing the barrier layers, (c) to earmark depressions that may have developed with time and (d) to identify ponding of water on the landfill cover. At least one inspection should be carried out during or immediately after the peak of the monsoon season. Closed landfills show significant settlement. Rectification measures must not only re-establish the initial slope of the cover (for proper surface water runoff) but must also ensure that all the components of the landfill cover system continue to perform as originally envisaged. Site managers must have sufficient equipment and funds to periodically carry out maintenance work in the form of soil filling, re-grading the cover and revegetating the landfill cap. In areas where extensive erosion gully formation is observed, filling of cover material, regarding of cover slopes and revegetation must be routinely undertaken.

For surface water drainage system, it should be also inspected 2 to 4 times a year (a) to identify cracks in drains due to settlements, (b) to delineate clogged drains requiring immediate clean-up and (c) to study the level of deposited soil in the storm water basin and initiate excavation measures. Broken pipes and extensively cracked drains may require replacement after filling soil beneath them to establish slopes for gravity flow. In extreme cases where long term settlement may be excessive, it may become necessary to make sumps and operate storm water pumps for removal of accumulated water in the drainage system. Gas and Leachate Management Systems: Periodic inspection of the gas and leachate collection systems is undertaken to identify broken pipes, leaking gas (if any) and damaged or clogged wells/sumps. Repair work for gas and leachate management

systems requires skilled manpower and should be carried out by the agencies operating the gas treatment and leachate treatment facilities. One may often have to install new gas extraction wells and leachate collection wells if the damaged/clogged facilities are inaccessible and irreparable.

For Environmental Monitoring Systems, Ground water monitoring wells, air quality monitoring systems and zone monitoring instruments are periodically inspected to check that all systems are functioning satisfactorily and that well caps and sampling ports are not subjected to damage due to excessive settlement or vandalism. Environmental monitoring systems have to be maintained during the entire post-closure period as per the requirements of the local environmental regulatory agencies. Wherever possible, monitoring instruments must be periodically recalibrated. Sampling devices must be routinely detoxified and also regularly checked for proper functioning of the opening and closing of valves or spring loaded mechanisms.

6.6 POST-CLOSURE LAND USE OR REHABILITATION

Points to be considered for post closure land use include the following points.

a) The type of post-closure land use of closed disposal sites should be carefully considered based on the clear understanding of the disposal conditions during operations, closure, and together with impacts it may have had on the surroundings. The post-closure land use should also take into consideration the aspects pertaining to environmental protection and the health and safety of the users and the public.
b) The "Post-closure land use plan" (including the land use plan, safe measures and post-closure management) will have to be formulated and submitted to the relevant authorities for approval. Once approval has been obtained, only then, the new land use for the closed disposal site can be implemented.
c) Operation and maintenance of the disposal site facilities and other disposal sites should be continued throughout the post closure land use redevelopment. Those facilities that may have been affected by the redevelopment works, such as the gas ventilation pipes and surface drainage, must be re-installed at suitable locations in order to preserve their functions.
d) The stabilization period of landfill site or other disposal sites after waste filling has completed is expected to be a minimum of 10 years. Therefore, post-closure land use shall be considered and can proceed after this period. This is to minimize the effects of land subsidence and disposal site gas generation on the development site. However, for the disposal sites 5 years after which waste filling was completed, provisional land-use might be applied under the following conditions.
    - Utilization of only surface layers of the closed disposal site and access of the people to the site shall be very limited; such as green space, parking etc.
    - Prior to the utilization, monitoring of environment and disposal site stabilization shall be carried out and then the site's condition shall be clarified.

6.6.1 Post-closure management of different disposal sites.

The objectives of Post-closure management of different disposal sites are as follows:

a) To implement appropriate maintenance activities of disposal sites such as providing or application of the sufficient final soil cover. The provision of minimum 0.60 m final soil cover at closure, and post closure maintenance of cover, drainage and vegetation; post closure maintenance shall be for a period of ten (10) years.
b) To continuously maintain the facilities in the disposal site such as the operation of the leachate treatment plant/facility and continuous flaring of installed gas collection system.
c) To continue with the environmental monitoring work such as water quality including leachate generation from surface water and groundwater, disposal site gases and air quality of these disposal sites.
d) To continue with the waste stabilization monitoring such as the prevailing topography and slope stability of the completed filled areas.
e) To continue to maintain the good access road surface of these disposal sites.
f) To continue to maintain the drainage system of the disposal sites.
g) To continue to maintain the vegetative layer of the final cover of the disposal sites using indigenous plants.
h) Appropriate measures and activities required to achieve safe closure should be determined based on the conditions of the site including operation level, existing facilities, surrounding environment and post closure land use.

SAQ 1

What is capping? Explain its importance.

SAQ 2

Why is landfill closure required? Explain the requirement of safe closure.

SAQ 3

Discuss in brief the procedures for Closure of Disposal Facility.

SAQ 4

Explain why storm water management is essential after land filling?

6.7 SUMMARY

Landfill is one of the practicable and easier methods for the treatment of solid waste as compared to composting, pyrolysis and incineration. However, proper management of landfill is of upmost importance to prevent the pollution of surface and ground water pollution due to toxic leachates. Therefore, proper design of landfill sites and monitoring of operation and maintenance is very essential. The construction and material of landfill cover must be given importance. Improper cover or capping of the landfills timely will results in undesirable flows of storm water from nearby areas and effects the biodegradation of the solid waste inside the system. Also, the volume of leachate generation will be increased in manifolds. This chapter highlights all the factors to be considered for proper design, construction and maintenance of landfill covers.

6.8 KEY WORDS

Rehabilitation: Process of restoration to bring an area of land back to its natural state after it has been damaged or degraded, making it safe for wildlife and flora as well as humans.

Capping: Placing a cover over contaminated material such as landfill waste or contaminated soil. Such covers are called "caps." Caps do not destroy or remove contaminants.

Seedbed: Seedling bed is the local soil environment in which seeds are planted. Often it comprises not only the soil but also a specially prepared cold frame, hotbed or raised bed used to grow the seedlings in a controlled environment into larger young plants before transplanting them into a garden or field.

Ecological Park: Eco parks are large, connected landscapes with high nature conservation and environmental protection ambitions. They are parks which use ecological landscape features to reduce watering maintenance while enhancing wildlife and human values.

Remedial measures: Measures or actions required or undertaken to investigate, monitor, clean up, remove, treat, prevent, contain or otherwise remediate the presence or Release of any Hazardous Substance.

6.9 ANSWERS TO SAQs

SAQ 1

Caps do not destroy or remove contaminants. Instead, they isolate them and keep them in place to avoid the spread of contamination. The main objectives of capping are

- Manage leachate production by controlling the ingress of water into the waste.
- Prevent uncontrolled escape of landfill gas and odours or the entry of air into the wastes.
- Provide protection for the wastes
- Accommodate environmental control measures such as gas vents, etc.
- Provide physical separation between waste and humans, animals and plants.
- For detailing refer sec 6.2.

SAQ 2

Safe closure requirement

- To prevent wastes from littering or overflowing from these disposal sites
- To reduce gas pressurization or uncontrolled gas migration within the deposited waste beneath the capped surface to prevent fire or explosion within the facilities
- To minimize offensive odours emitting from these disposal sites d) To provide storm water run-off and drainage facilities
- To minimize environmental pollution caused by leachate from these disposal sites
- To prevent groundwater contamination
  Refer sec 6.3 to understand landfill closure

SAQ 3

Refer section 6.3.3.

SAQ 4

Storm water management is essential to prevent erosion of land and flooding of inhabited urban or rural areas. Both cases can cause severe damages and

contamination of the environment if sanitation facilities are flooded. This results in high costs and notably massive suffering for the local communities. For detail refer sec 6.5.

FURTHER READINGS

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3. Handbook of Environmental Engineering, by Rao Y. Surampalli, Tian C. Zhang, Satinder Kaur Brar, Krishnamoorthy Hegde, Rama Pulicharla, Mausam Verma, ISBN: 978125986022, McGraw-Hill Education.
4. Landfill Gas to Energy: Technologies and Challenges*,* by Vasudevan Rajaram, Faisal Zia Siddiqui, Mohd Emran Khan, Publisher CRC Press*,* ISBN-10 : 0415664748.
5. Municipal solid waste management. (2009). *Introduction to Environmental Management*, 255–264. https://doi.org/10.4324/9781315736761-26
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