3.9 Safe Closure of existing landfill sites

The purpose of safe closure of landfill sites is as follows.

(1) Protecting public health and the environment by proper management of landfill safe closure and post closure land use
(2) Prevention of environmental pollution and risks from the closed landfill sites
(3) Prevention of environmental pollution and risks from the uncontrolled development of closed landfill sites

Municipal solid waste landfills generate environmental pollution and hazards long after the waste landfill ceases in operation. Degradation of the waste layers takes a long time whilst they continue to produce leachate and landfill gases. It is necessary to manage the site properly after the operations and to manage the post closure land use in order to protect the public health and preserve the environment.

The technical requirements included such activities as the installation of the necessary facilities, i.e. the leachate treatment facility; the provision of adequate protection, i.e. top covering; and the environmental monitoring activities. The operation and maintenance of the landfill facilities and monitoring will have to be continued even after the new land use has been implemented for the closed landfill site.

The “Post-closure Land Use” is also addressed and it recommends that all future post-closure land use of closed landfill sites should be carefully considered based on the clear understanding of the landfill during its term of operation and closure as well as the impacts it has had on the surroundings. The proposed land use should not endanger the lives of the public and the users.

3.9.1 Technical requirements for safe closure of landfill site

The technical requirements for safe closure of landfill sites are as follows.

(1) Landfill sites should be closed safely and the post-closure management should be carried out properly.

(2) Measures for safe closure of landfill sites.

a. To prevent wastes from littering or overflowing from the landfill site
b. To prevent fire or explosion that may be caused by landfill gases
c. To minimize offensive odours emitting from landfill site
d. To provide storm water run-off and drainage facilities
e. To minimize environmental pollution caused by leachate from landfill site
f. To prevent groundwater contamination
g. To take measures for wastes stabilization

(3) Measures for post-closure management of landfill sites.

a. To implement appropriate operation and maintenance activities of landfill facilities such as providing the final cover soil
b. To continuously operate the landfill facilities such as the leachate treatment facility
c. To continue with the environmental monitoring works
d. To continue with the waste stabilisation monitoring

(4) Appropriate measures and activities required to achieve safe closure should be determined based on the conditions of the site including operation conditions, existing facilities, surrounding environment and post closure land use.

3.9.2 Closure level applied for the landfill sites

The appropriate closure level should be assigned and applied for the prevention of environmental pollution and hazards. The relevant authorities should be responsible to determine target closure level for each landfill site. The closure levels are classified into 4 categories as follows.

Level C1: Minimal closure level (to provide final cover and drainage system around the site)
Level C2: Low closure level (similar to C1, but with the addition of enbankment, controlled slope and gas ventilation system)
Level C3: Middle closure level (similar to C2, but with the addition of semi-aerobic landfill system with leachate re-circulation)
Level C4: High closure level (similar to C3, but with the addition of groundwater pollution control measures with leachate treatment)

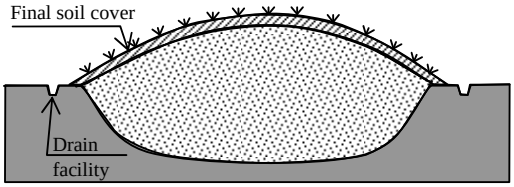
The measures necessary to be taken for each of the closure levels are tabulated in table below. Schematic diagram of each landfill safe closure level is shown in figure below.

Table XXX Closure Levels and Required Measures/Facilities

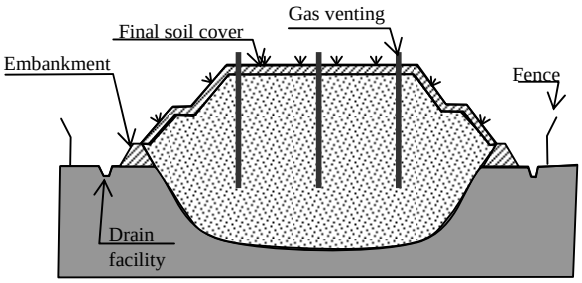
Measures	Safe closure Level			
	C1	C2	C3	C4
Final cover soil	++	+++	+++	+++
Storm-water drainage	+	++	+++	+++
Safely storage	+	++	+++	+++
Gas vent		++	+++	+++
Leachate		+	+++	+++
Groundwater			++	+++
Early stabilization		+	+++	+++
Post closure measures		+	+++	+++
Monitoring	+	++	+++	+++
Landfill system			Semi-aerobic System	

Notes: 1. +: minimum equipped/ operated, ++: fair, +++: fully equipped/operated
2. As for C3 and C4, in line with the semi-aerobic landfill concept, aerobic area of existing

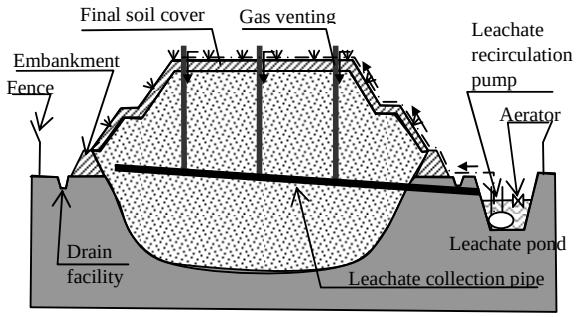
landfill site will be expanded by safe closure measures.



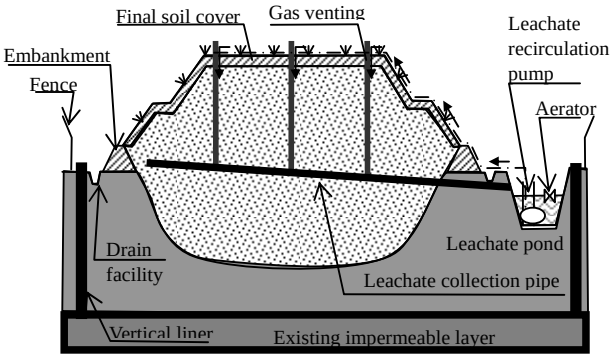
Landfill safe closure level: C1



Landfill safe closure level: C2



Landfill safe closure level: C3



Landfill safe closure level: C4

Note: For C3 & C4, aerobic area of existing landfill site will be expanded by safe closure measures.
(Source: The Study on the Safe Closure and Rehabilitation of Landfill Sites in Malaysia, 2004)

Figure XXX Landfill Safe Closure Level

3.9.2 Requirements for physical closure and post closure management

In order to implement the safe closure of landfill site, proper physical closure and post closure management should be carried out.

- The Physical Closure consists of the measures or facilities necessary for the safe storage of waste, prevention of environmental pollution and early stabilization of waste.
- The Post Closure Management consists of the operation of landfill facilities such as leachate treatment plant, the maintenance of the facilities including covering soil, and the monitoring of environment pollution and stabilization of waste.

(1) Requirements of Physical Closure

The closed landfill should be provided with the necessary facilities for the safe storage of waste, to prevent environment pollution and to accelerate early stabilization of waste. Also the facilities for post closure management, such as control building for operation and maintenance and the monitoring facilities should be provided.

The facilities required for landfill safe closure should be planned, designed and implemented based on the following requirements

1) Reformation for Landfill Shape/Slope and Waste Storage Facility

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 1:2. In order to prevent soil erosions, gentler slope will be preferred.

The waste storage embankment and/or retaining wall should be constructed if the shape of the filled waste is not stable, and if the boundary of the site is limited.

2) Final Cover Soil

The final cover soil should be provided for environmental protection measures, i.e. to minimise the leachate production, prevention of waste scattering, minimize odour and prevention of fire. The recommended thickness of the final cover soil should be more than 750mm. In areas where trees and scrubs are to be planted, the thickness should be increased to be more than 1500mm. Regular maintenance of the cover soil will be necessary.

3) Storm Water Drainage

Storm water drainage system should be installed at the upper part, at the slopes and at the surroundings of the landfill site. This is to prevent the water from seeping into the waste layers and reduce the leachate production amount and protect the landfill site. Regular maintenance of the storm-water drainage will be necessary.

4) Gas Ventilation Facility

Gas ventilation facility should be provided and the venting pipes should be installed at 50m intervals. The purpose of the venting pipes is to allow the landfill gas to be released into the atmosphere and thus preventing gas explosion. This facility will also assist the acceleration of the landfill stabilisation by enhancing the waste decomposition process.

5) Leachate Collection Pipes and Leachate Re-circulation Facility

The leachate collection pipes and leachate re-circulation facilities should be installed in order to provide semi-aerobic conditions to the landfill waste layers. The effects of these facilities to the landfill site are as follows.

- To minimize the groundwater contamination by removal of leachate accumulated in the waste layers
- The improvement of leachate quality through contact with air and aeration
- Promote early stabilisation of the landfill waste by accelerating the waste decomposition process

- Reduction in the generation of methane gas

6) Leachate Treatment Facility

The leachate treatment facility should be installed to treat the leachate in order to comply with the environmental effluent discharge standards prior to discharging the effluent into the public water bodies via the drainage system. The purpose of the facility is to prevent contamination of the public waterways and the groundwater sources.

7) Groundwater Protection Facility (liner)

The groundwater protection facility, such as artificial liner systems, should be installed in order to prevent leachate seeping into the groundwater sources and contaminating the groundwater.

(2) Requirement of Post Closure Management

The facilities installed for safe storage of waste, prevention of environmental pollution and accelerating early stabilization should be operated and maintained properly, up until the closed landfill site has stabilised.

a. Top cover

Major subsidence may occur during the first two years after completion of waste filling works, therefore, special care for landfill facilities shall be taken into considered of this period.

After a period of time, major subsidence may not occur, but risk of minor subsidence and damage to the top cover will still remain. It is necessary to maintain the top cover to prevent the percolation of rainwater into the waste layers and to protect the landfill site.

b. Surface drainage

The surface drainage system should be inspected and maintained regularly over the long period of time. This facility will channel the surface water to the drains and resulting in the reduction in leachate production and also protecting the landfill site.

c. Gas ventilation

The landfill gas ventilation system should be operated for a long time to prevent the build up of toxic gases and to prevent fire/explosion hazards.

The gas ventilation pipes will also act as air pipes and provide air (oxygen) to the waste layers and accelerate the waste degradation process. Therefore, the gas ventilation pipes should be maintained over the long term and new ventilation pipes be installed where necessary.

d. Leachate treatment

The proper operation and maintenance of the leachate treatment facility is important to prevent any further environmental pollution that may occur after the physical closure.

The concentration and the amount of the leachate will eventually decrease and improved gradually with time, and it may take a long time to do so. When the concentration of leachate has improved and comply with the relevant environmental effluent discharge standards and will not cause serious damage to the surroundings, then the leachate treatment process may be changed or even terminated. However, it should be noted that the Nitrogen levels in the leachate could remain at high concentration for a long time.

e. Groundwater monitoring wells

The groundwater monitoring wells should be maintained over a long period of time in order to preserve the well for use periodic monitoring activities.

f. Other supporting facilities

Other supporting facilities like the access road and the vegetation growth on the top/slopes should be maintained where necessary for a long period of time.

The typical example of the maintenance items of the landfill facilities, method and scale/frequency are shown table below.

Table XXX Summary of Maintenance Items

Facilities	Items	Methods	Scale/ Frequency
Top cover & dykes	Cracks, pools and soil erosion on the surface, State of plants	Periodic visual inspections	The entire site, weekly
Surface drainage on the top cover	Clogging by soil/leaves, Damage by sedimentation	Periodical visual inspections	The entire site, weekly (more frequent during the rain season)
Cut-off drainage around the site	Clogging by soil/leaves, Damage by traffic	Periodical visual inspections	The entire site, weekly (more frequent during the rain season)
Gas ventilation pipes	Clogging, damage to pipes, corrosion	Periodical visual inspections	all pipes, weekly
Leachate collection pipes	Clogging, damage to pipes, corrosion	Periodical inspections & comparison of the effluent quantity data	daily
Leachate treatment facility	Quality of treated effluent	Daily inspections (colour of effluent) Periodical effluent analysis	daily monitoring frequency
Monitoring facility	Conditions of the monitoring wells	Periodical inspections	all wells, weekly