Chapter 8 The Landfilling Process

8.1 General

Factors that shall be considered in the operation or process of landfilling works are such as the methods and order of landfilling, control of landfill slopes, application of cover soils etc.

Landfilling process includes the whole series of activities from the delivery of solid wastes into the landfill sites, spreading, mixing, applying final cover soil and all other works related to landfilling activities. A summary of the landfilling process is shown in **Figure 11-36** below.

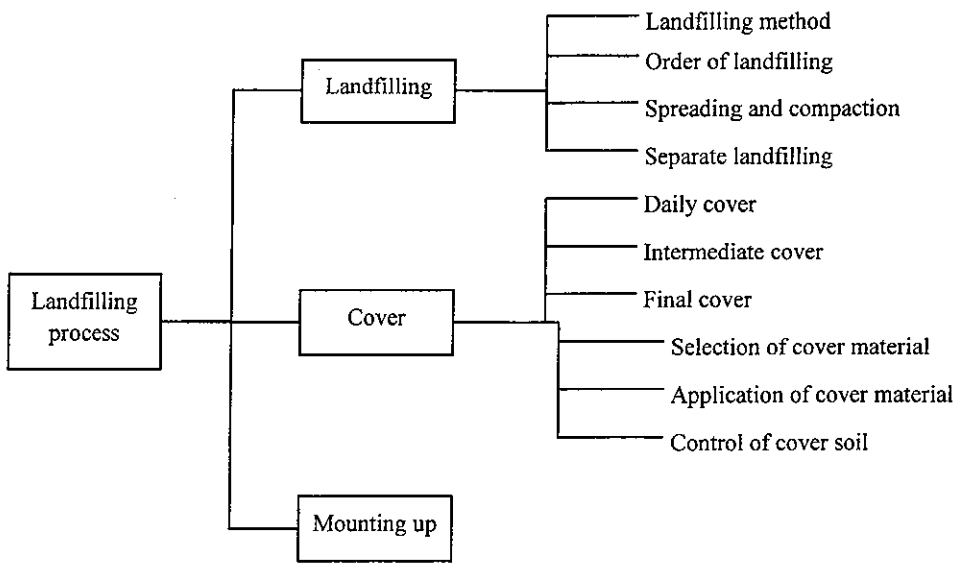

Figure II-36 Composition of Landfilling Process

Natural conditions such as the surrounding environment, geography of the landfill site, weather, the type and amount of solid wastes disposed per day, financial and technical aspects etc. are factors that shall be considered in the design and planning of appropriate landfilling process.

The relationships between the landfilling process and the objectives to be achieved at landfill sites are shown in **Table 11-24** below.

When the landfill disposal efficiency is to be given priority, landfill lifespan, ability to compact solid wastes, the thickness of the landfilled waste, thickness of the cover soil etc. shall be given due consideration.

In the case when stabilization of the landfilled wastes is to be given priority, the landfilling method, selection of cover soil materials and compaction methods as well as the solid waste composition shall be considered.

On the other hand, when leachate and gas quality or quantity is important, the order of landfilling, cover soil and maintenance facilities shall be given priority. In the particular case when liner facility is used, special care shall be taken so that the liner sheets are not being damaged during landfilling works such as spreading or compacting the solid wastes.

Table II-24 Relationships between Landfilling Process and the Objectives

Landfilling Process \ Objectives		Efficiency of Sanitary Landfill	Stabilization of Landfilled Waste Layers	Preservation of Environment: Leachate Quality	Preservation of Environment: Leachate Volume	Preservation of Environment: Gas Generation	Preservation of Environment: To Prevent Settlement of Landfilled Ground	Preservation of Environment: To Prevent Littering of Wastes by Wind	Physical Characteristics of Landfilled Ground	Post closure land use Plan	Workability	Cost Effectiveness	Maintenance and Control	Fire Prevention
Landfilling	Landfill Method	++	++				+		++	++	++	++		
	Order of Landfilling		+	+	++					+	+		+	+
	Spreading/Compaction	++	++	+	+	+	++	++	++	++	++	++	++	+
	Separate landfill		++	+	+	+	+		++	++	+	++	++	
Covering	Selection of Cover Material		++	++	++	++	+	+	+	+	++	++		+
	Daily Cover	++	+	+	++	+	+	++	+	+	+	+		++
	Intermediate Cover	++	+	+	++	+	+		++	+	++	+		+
	Final Cover	++	+	+	++	++	+		++	++		+		+
Mounting-up		++								++	++	++		++

Notes: + : Related
++ : Strongly Related

8.2 Methods of Landfilling

The solid wastes shall be landfilled following the most appropriate method. The landfilled wastes need to be sufficiently compacted so as to stabilize the landfill foundation and to prolong the lifespan of the landfill sites. Layers of cover soil shall be systematically placed after landfilling of solid waste for each layer.

There are several kinds of landfilling methods as well as cell construction methods etc. The most suitable method needs to be selected depending on the location and topographic conditions of the landfill site, daily landfilled waste volume as well as the daily soil cover so as to improve stabilization of the landfill site, create a physically strong foundation, improve the usability of the completed landfill site, etc.

At the same time, proper landfill equipment must be used to sufficiently compact the landfilled wastes. To improve the potential usage of the completed landfill site, separate landfill methods shall also be used when necessary. Data on the amount and type of landfilled solid waste, their changes with time must also be noted for future reference or for maintenance of the landfill site.

(1) Landfilling Method

a) Area Method

Area method is used when the terrain is unsuitable for the excavation of trenches. Earth dike with a height of 2-3m as one lift is first constructed to get the support for compaction. The wastes are unloaded at the toe of the earth dike and then be spread and compacted on the slope of the dike in a series of layers that vary from 30 to 60cm in depth. The recommended slope of these layers is 1:3. The width of the working face (see **Figure II-37**) shall be as narrow as possible to confine the wastes to the smallest possible area but at the same time it shall be wide enough to give necessary movement space for bulldozers.

At the end of each day's operation, a 15 to 30cm layer of cover soil shall be placed. This completed filled area for one day including the cover soil is called a cell. However, in the case of large landfill sites with the amount of solid wastes more than 200 tons per day, two or more cells shall be constructed each day.

The wastes shall be unloaded at the top of the last cell, spread and compacted using the slope of that cell as the support for compaction. When all the areas are converted by one layer of cells it is called a lift. One more lift can be constructed on the top of the preceding lift as long as it does not surpass the designed final topography of the areas. If a small amount of usable cover soil is available from the landfill site, a combination of ramp method and area method can be used as shown in **Figure II-38**. In this method solid wastes are placed and compacted as described for the area method and partially or wholly covered with earth scrapped from the bottom of the ramp.

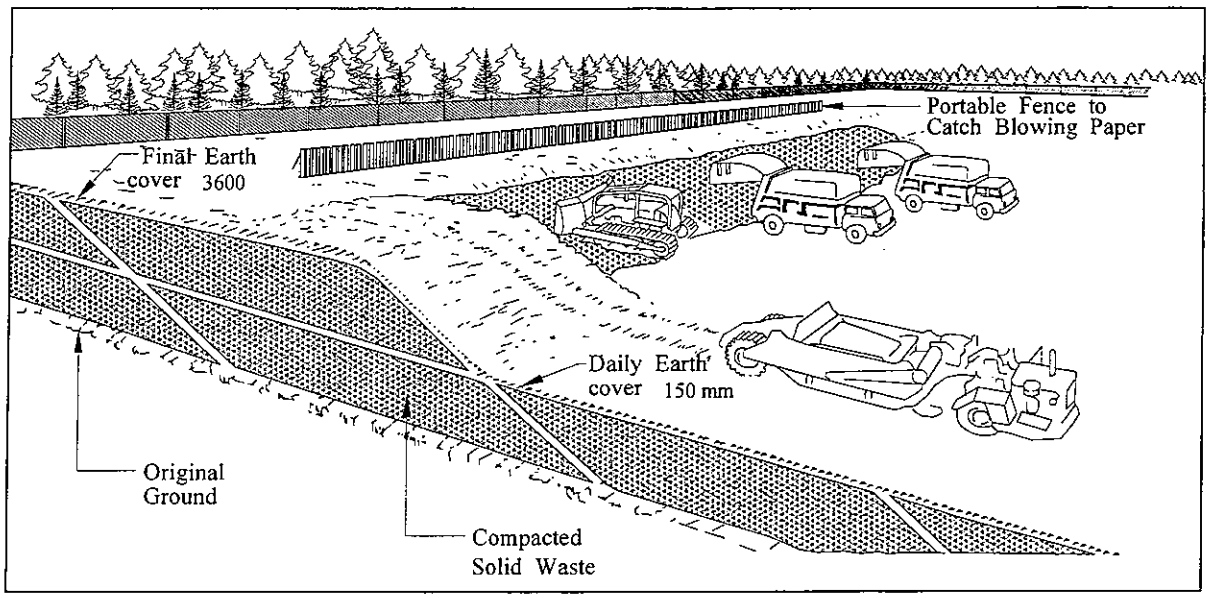

Figure II-37 Area Method

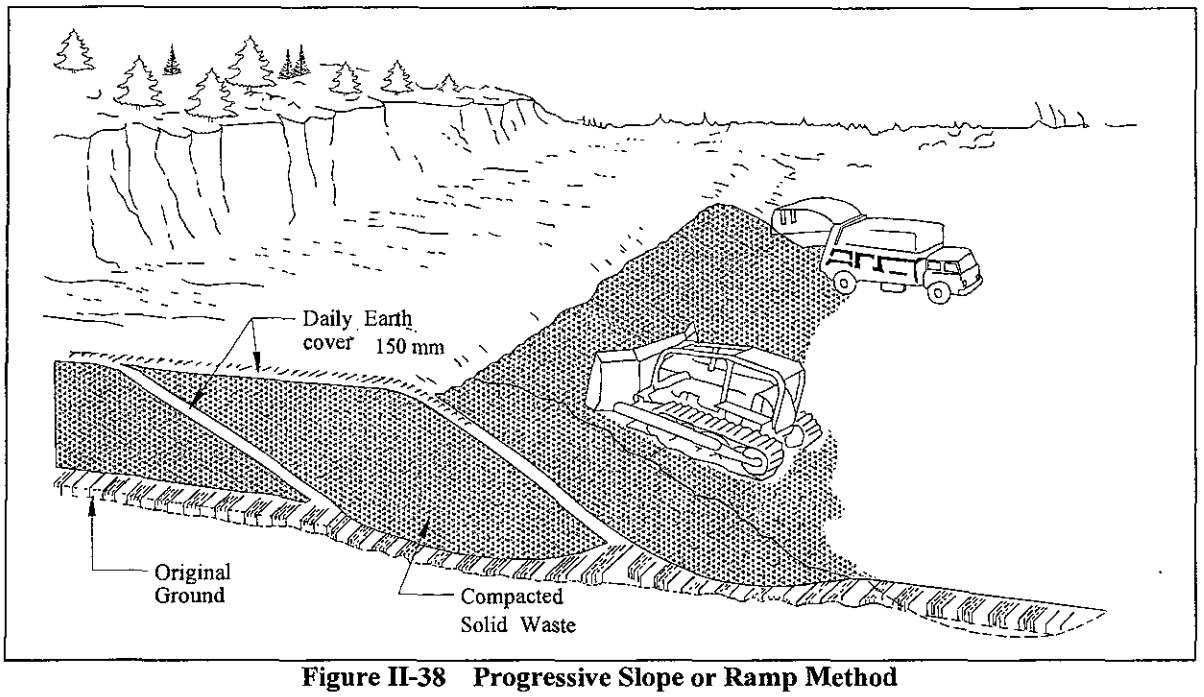

Figure II-38 Progressive Slope or Ramp Method

b) Trench Method

This method is suitable for areas where the water table is not near the surface and terrain can be excavated for landfilling. The excavation of trenches gives on-site cover soil as well as support for compaction. Solid wastes are placed in trenches varying from 30 to 120m in length, 1 to 2m in depth and 5 to 8m in width. To start the process, a portion of the trench is dug and the earth is stockpiled to form an embankment behind the first trench. Wastes are then placed in the trench, spread and compacted into thin layers of 30 to 60cm with the slope of 1:3. Cover soils shall also be placed at the end of each day's operation. Cover soils can be obtained by excavating an adjacent trench or continuing the trench that is being filled. **Figure II-39** shows the details of the trench method.

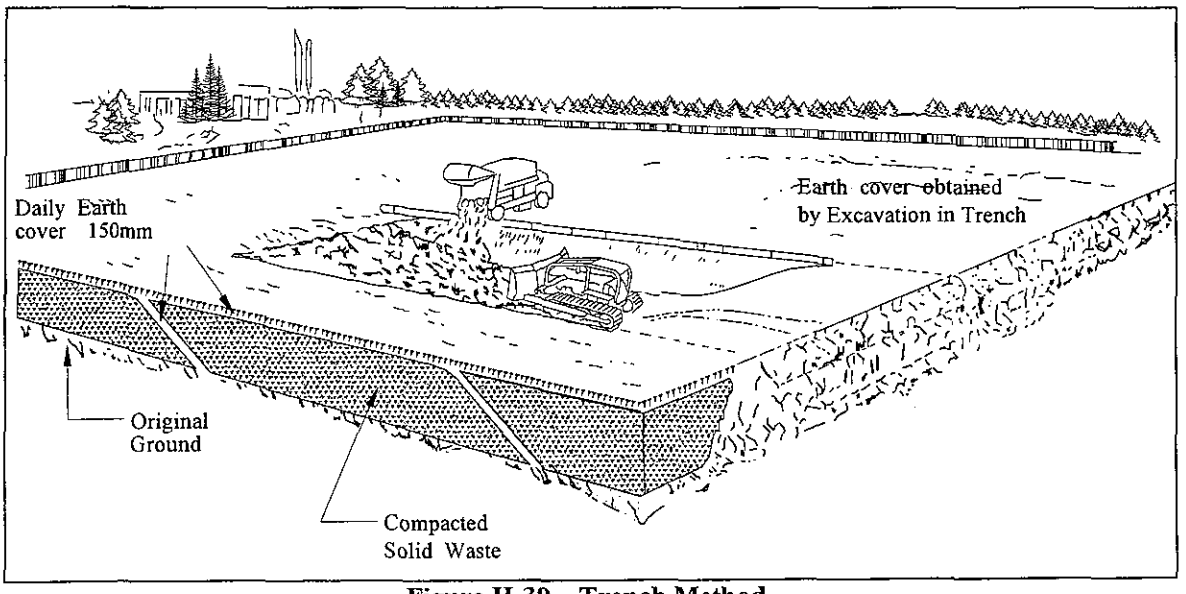

Figure II-39 Trench Method

c) Depression Method

This method is applied in areas where natural or artificial depressions exist. Canyons, ravines, dry borrow pits and quarries have been used for this landfilling method. Example of landfilling in a canyon or a ravine by using depression method is shown in **Figure II-40.**

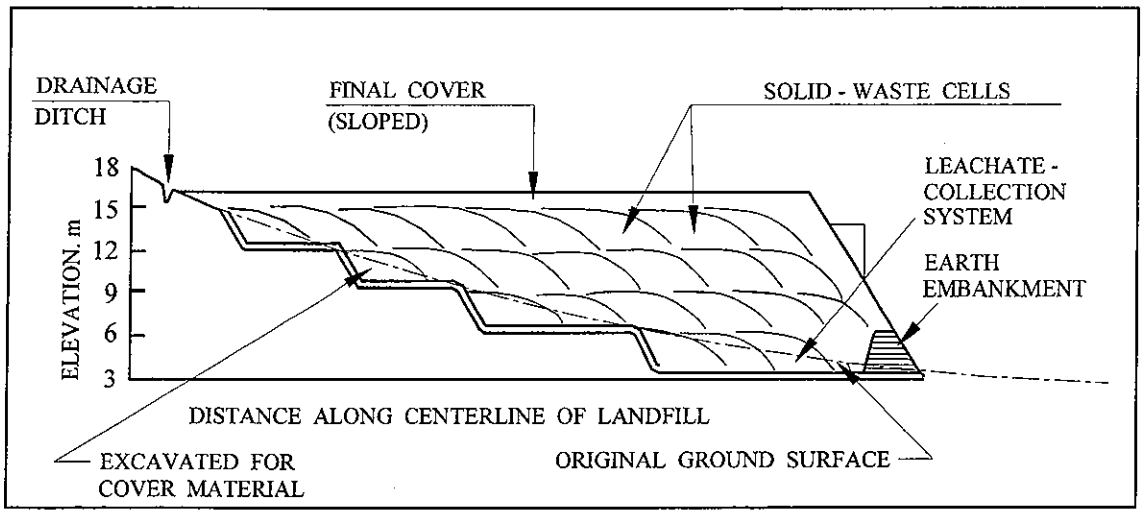

Figure II-40 Depression Method

(2) Cell Construction

a) Sandwich Method

This method is shown in **Figure II-41** where the solid wastes are laid horizontally with cover soil layers placed over each solid waste layer. This method is commonly used to landfill at narrow valleys.

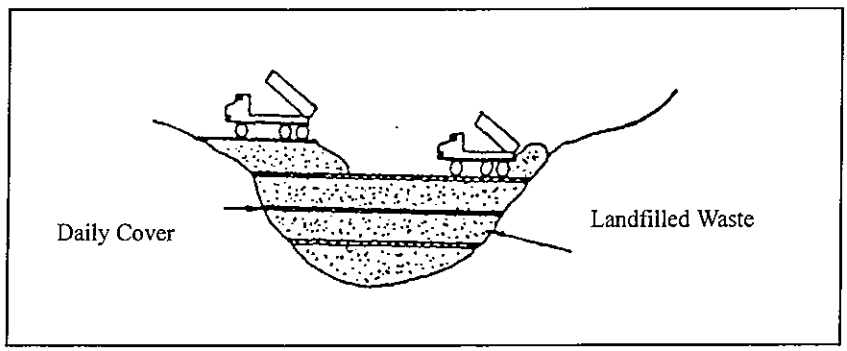

Figure II-41 Sandwich Method

b) Cell Method

This method as shown in **Figure II-42**, has a cell of solid wastes covered with a layer of cover soils. The size of each cell is determined by the volume of solid wastes disposed per day. Since each cell is an independent landfill area, each cell acts as a fire breaker. It also prevents the solid wastes from being scattered, emission of bad odours and harmful vectors from breeding.

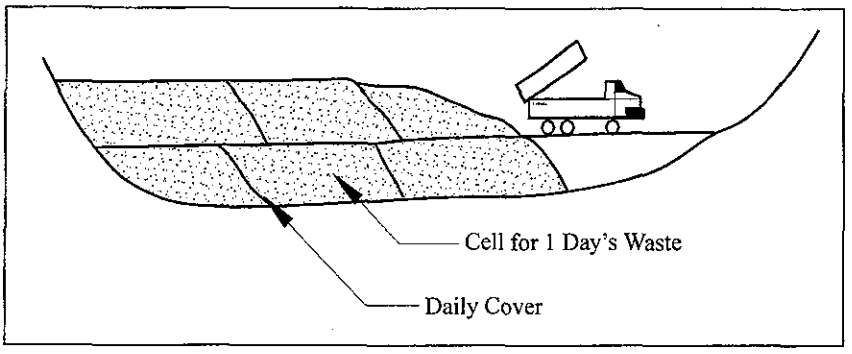

Figure II-42 Cell Method

c) Dumping Method

This method as shown in **Figure II-43**, dumps the solid wastes directly into the landfill site. Since the solid wastes are not compacted, the foundation of the landfill site will be physically weak, the solid wastes will be scattered and emissions of bad odour and harmful vectors occurred. This method is not recommended for hygienic and systematic landfilling.

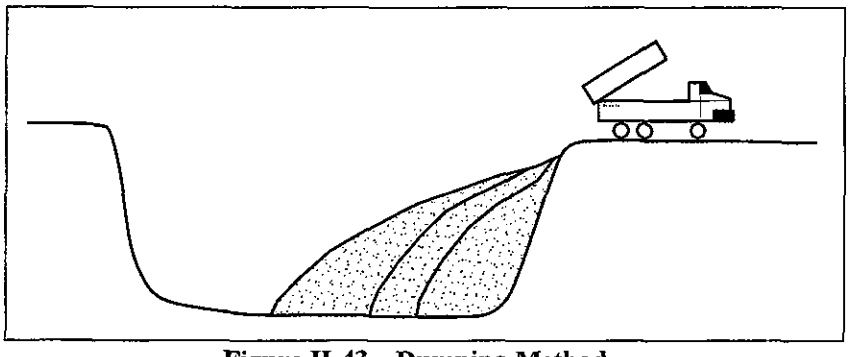

Figure II-43 Dumping Method

(3) Order of Landfilling

In mountains or valleys, there are generally 2 orders of landfilling process as depicted in **Figure II-44**, namely:

- Landfilling from upstream to downstream
- Landfilling from downstream to upstream

In the first method, easy access to the landfill site through the exiting landfilled area is possible. The rainwater absorbed into the landfilled layers during the early stages of landfilling would have time to seep out. In addition, it would be difficult to discharge the rainwater from the unfilled areas. Collapse of the landfilled layer due to rainwater on the liners at the bottom of the landfill site may happen. Sometimes the liners may even be damaged.

On the other hand, the second method of landfilling from downstream to upstream does not face the problems abovementioned in the first method. Therefore, when considering the order of landfilling, the geography of the area, the rainfall patterns, solid waste volume, leachate treatment methods as well as rainwater treatment methods shall be considered

thoroughly.

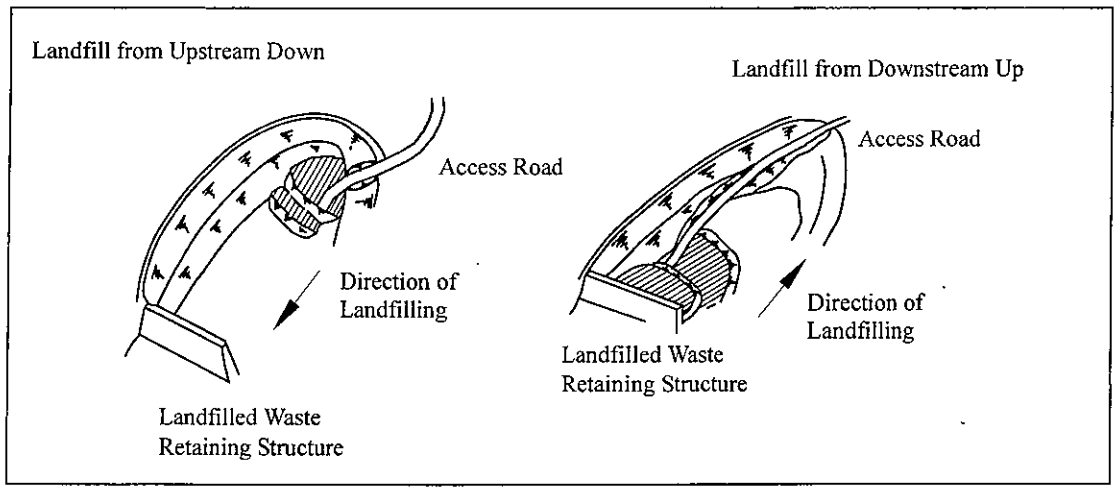

Figure II-44 Order of Landfilling (Concept)

(4) Spreading/Compaction

Methods of spreading and compaction shall be determined by considering the waste compositions, landfilling methods. landfilling order, machinery used etc.

The methods of spreading and compacting are depicted in **Figure II-45** where the solid wastes dumped from the collection vehicles are "Push Down" or "Push Up" a slope by bulldozers. Another method of "Mounting Up" is shown in **Figure II-46**.

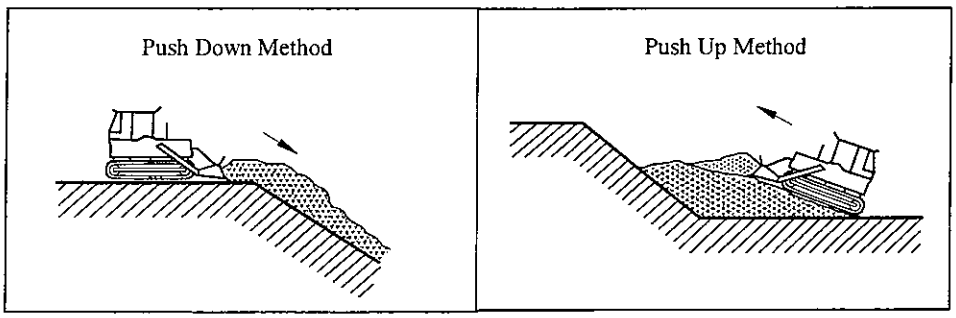

Figure II-45 Spreading/Compaction Method

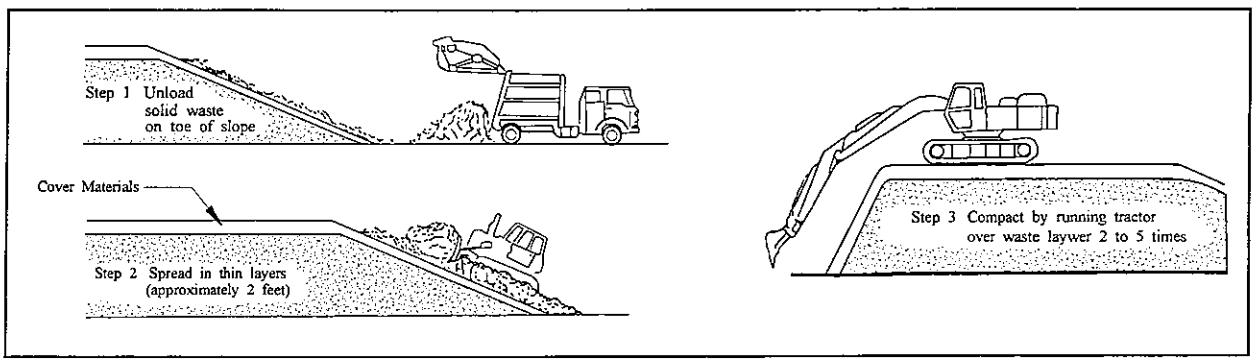

Figure II-46 Mounting Up Method

In the case of pushing the solid waste down the slope, it is difficult to spread the solid wastes into a uniform thickness because the bottom parts of the slope will usually be thicker. Mixing and compaction are also difficult. On the other hand, making uniform landfill layers will be easier when using a pushed up method. Spreading and compaction are also easier.

Therefore, in order to achieve faster stabilization of the landfilled waste, the push-up method is recommended. However, factors such as the solid wastes compositions, method and order of landfilling, equipment used and land conditions shall be given consideration together with the following aspects:

- The spreading shall not be too thick. Normal thickness of 30 to 50 cm by using compaction machines will be sufficient.
- The landfill layers shall be made as uniform as possible and when necessary, the solid wastes can be pushed up a slope when spreading and compacting the solid waste. A slope gradient of 3:1 (about 20 degrees) is recommended.
- The thickness of each layer shall be determined after considerations given to the compositions and types of waste, the post closure land use etc. However, each layer shall be less than 3m thick. If the site is planned to be used as early as possible after landfill completion, then the thickness of layers shall be about 2m.

The compaction and spreading methods are shown in **Figure II-47** and **Figure II-48.**

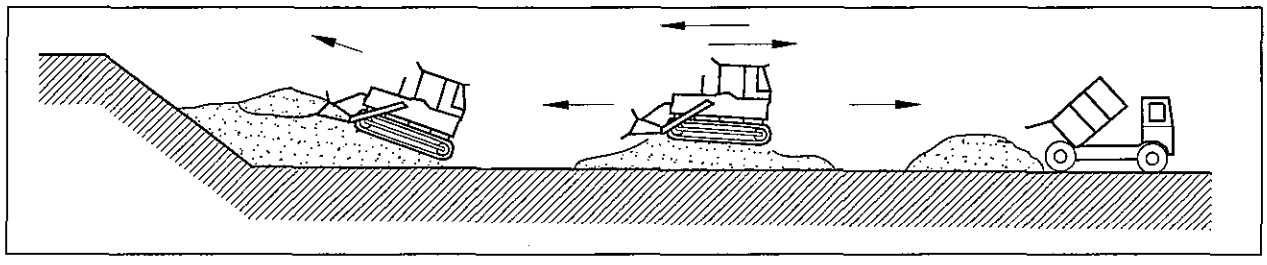

Figure II-47 Spreading/Compaction Method

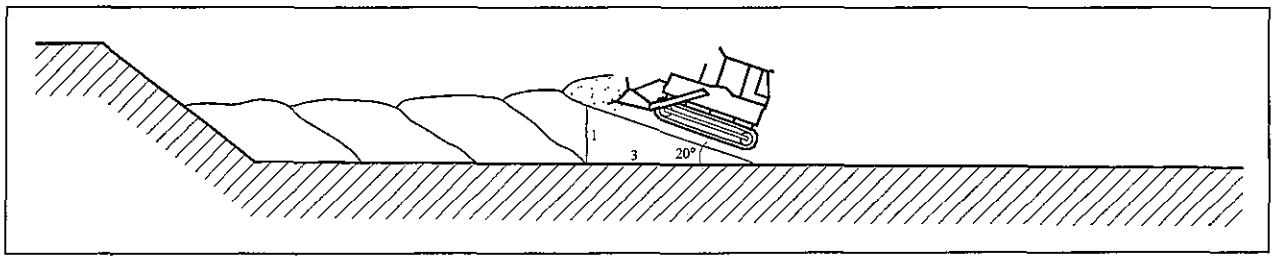

Figure II-48 Pushing Up and Compacting the Wastes Simultaneously

8.3 Section Landfilling

When the scale of a landfill site is large and landfilling duration is expected for a relatively long time, it is then desirable to plan the section landfilling and install section dyke or embankment if necessary.

(1) Basic Concepts

In many cases, a landfill site takes about 15 years or more for the entire landfilling process. In order to achieve reduction of leachate, to ensure easiness for operation and maintenance as well as to achieve early stabilization of landfill site, stepwise approach such as section landfilling is necessary.

Stepwise approach of landfill site management and planning such as section landfilling varies widely depending on topography and size of the landfill sites.

When the scale of sanitary landfill is large and landfilling process continues for a long period, it is desirable to plan for section landfilling with installation of section dyke or embankment if necessary, in order to achieve leachate volume reduction, early stabilization of landfill, prevention of deterioration of liner facility, as well as reduction of overall operation and maintenance cost of landfilling. It also ensure easy operation and maintenance of the landfill site such as easy control of leachate quantity and quality by dividing the landfill site into sections according to completed landfilled section, on-going landfilling section and non-landfilled section.

Feasibility of implementation section landfilling is determined by taking into consideration the following matters: topographical conditions of the landfill sites; landfill planning, capacity of leachate treatment facility, and cost implication of landfill space reduction caused by installation of section dyke etc.

(2) Section Dyke/Embankment

Section dyke or embankment for section landfilling is an important and useful structure, which has several functions such as 1) separating stormwater dropped onto non-landfilled section from leachate and preventing stormwater from flowing into on-going landfilling section, 2) storing leachate temporarily at non-landfilled section at emergency time such as during extraordinary rainfall. Besides, it also increases the leachate quality and reduces the leachate volume generation by implementing the landfilling work in proper order.

In other words, section dyke is used as temporary solid waste retaining facility. The dyke shall be strong enough to control the slope pressures and impermeable which prevents stormwater from entering or leachate from flowing out of the landfill sites. In most of the cases, earth dam can be used as section dyke.

(3) Separate landfilling

The landfilling practice where the mixed solid wastes are divided into several categories according to types of material and each category is landfilled separately at different sections is called separate landfilling.

In order to achieve early stabilization of landfill sites and from the view point of environmental conservation such as the promotion of recycling, it is desirable to implement separate landfilling system at all the general landfill sites if possible, which will ensure easy operation and maintenance of the on-going and post closure of landfill sites. However, separate landfilling system requires extensive role played by the society where a recycled-oriented society is compulsory.

8.4 Working Face

During the landfilling process, the working face shall be clearly demarcated and the area of working face shall be maintained as small as possible.

Securing a good working face is of utmost importance for landfilling works. By maintaining a clearly defined working face and restricting the working area to the smallest possible, it will be able to eliminate the problems of blowing papers, achieve better control of scavengers, and increase the efficiency in the application of cover soil and waste compaction. The maintenance of the smallest possible working face is a highly effective measure to reduce the leachate generation.

Based on the survey data on the present situations of landfill sites in Malaysia, the relationships between the daily landfilled wastes, size of working face and equipment required can be summarized as in **Table II-25** below.

Table II-25 Average Working Face Required for Landfill Sites

Daily wastes (t)	Volume (m^3) If $2m^3/t$ ($0.5t/m^3$)	Width (m)	Height (m)	Length (m)	Equipment
10	20	6	1	5	1
20	40	6	1	7	1
50	100	6	1.5	11	1
100	200	10	1.5	20	2
150	300	10	1.5	20	2
200	400	15	1.5	20	2
300	600	20	1.5	20	3

Generally, the landfilling works shall be performed in such a way to make thin layers of wastes spread over a wide area during the dry season, and thick layers of wastes dumped on small area during the rainy season. This way of landfilling will ensure lesser leachate generation volume and requiring less excavation work to be carried out.

8.5 Construction of Landfill Slopes

The gradient of slopes at the landfill sites shall be determined by taking into consideration the safety factors and workability of the slopes for landfilling process.

(1) Construction of Slopes by Landfilling

The size and gradient of landfill slopes are depending on the geography and soil characteristic of the landfill site areas as well as the quantity of solid wastes to be landfilled. When the quantity of wastes for landfilling is abundant, the slopes built will be generally large in size and steep in gradient. When a slope is not properly made, it may collapse or eroded by rainwater. Therefore, the following factors shall always be considered when constructing a landfill slope:

- As far as possible, the slopes shall be small in scale with gentle gradient.
- The slopes shall be free from the effects of retaining facility, thus the retaining facility shall be positioned at the bottom of the slopes.
- Proper protective measures shall be taken to prevent erosion of the slope surface by rainwater, etc.
- The slope gradient and appearance shall be in harmony with the surrounding environment.

When determining the gradient of a slope made by landfilled wastes, the abovementioned factors shall be considered seriously. The "slip circle" method is usually used to calculate the safety of the slopes. This method is strongly governed by the solid wastes dynamics, solid waste types, mixing of landfilled layers, thickness of each landfilled layer, the water contents in the landfilled layers, the number of years after landfilling, etc.

(2) Types of Landfill Slope

Figure II-49 (1) shows an example which uses only solid wastes as landfill slope, while **Figure II-49 (2)** shows an example of earth mounts above the landfilled layers.

In case (1), the landfill operation creates the slopes itself. This method is easy but compaction would be difficult. It is also difficult to complete the slope by laying the final cover soil because it takes longer time to achieve the final planned height.

In case (2) where the embankments are mounted onto the landfilled layer, the slopes can be sufficiently compacted and the wastes can be easily spread and compacted. This kind of embankments structure has a very strong foundation which will not cause settlement. Therefore, the landfill slopes shall be made by earth mounts over the landfilled layers.

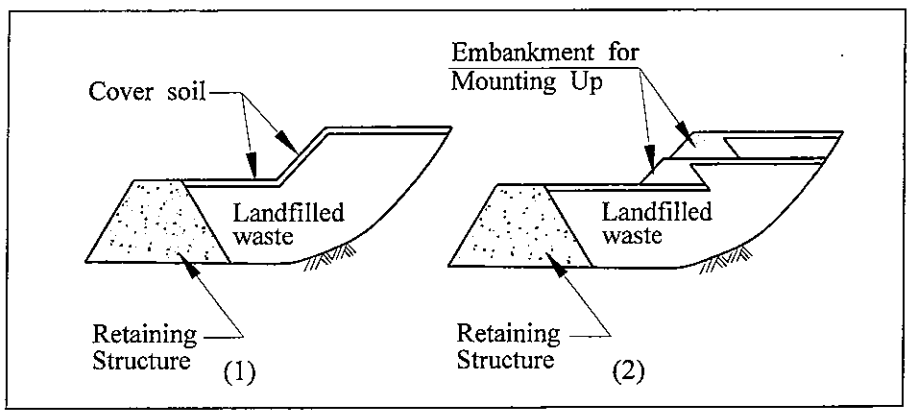

Figure II-49 Types of Landfill Slopes

(3) Construction of Landfill Slope by Earth Bund

a) Structure of Earth Bund

The earth bund is the final soil cover on a landfill slope. It is better that the bund be piled progressively depending on the availability of landfilled waste and the height of each bund shall be about 2 to 3m high.

In mounting method, a beam of more than 1m long shall be constructed at each level. In the case of large scale bunds, certain horizontal distance shall be allowed at the middle of the slopes when necessary. In order to prevent crumbling of the bunds as well as to prevent the retaining facility from being overloaded, the originally planned landfill structure or position of the earth bunds shall be strictly followed.

Figure II-50 shows an example of the structure of a slope.

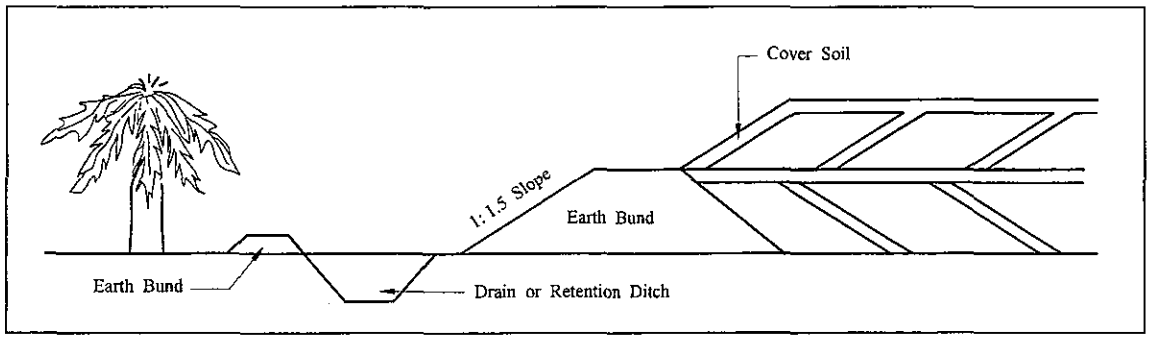

Figure II-50 Example of the Structure of Slopes and Earth Bunds

b) Stability of Landfill Slope

A landfill slope is usually built on a landfilled waste layer and therefore, the stability of a slope will greatly depend on the stability of the landfilled wastes.

When determining the gradient of a slope, the overall stability of the slope together with the landfilled waste layers shall be taken into consideration. In stability calculations of a slope, potential structures and positions of the slope shall be assumed. The minimum value for the stable coefficient will give a stable slope. The forces that move the slope include the weight of the slope itself. In addition, the water pressures in between shall also be considered in order to reduce the shear resistance.

Stability calculations are usually performed by applying the "circular slip plane" method. Safety coefficient is represented by the ratio between shear resistance and shear force. In most cases, it will also be necessary to use the "multiple circular area slip plane" method or the "multiple slip plane" method where straight lines are used for the calculations. When calculating the stability of a landfill slope, it shall be done over a large area especially when the slope is made by piling of small mounts. Although the safety of a slope is also depending on the surrounding environment, the safety coefficient shall always be above 1.2.

c) Rainwater Collection & Drainage of Landfill Slope

A slope will be easily eroded by rainwater. It also crumbles easily and therefore, proper

rainwater collection and drainage facility shall be provided. The slope shall be able to collect and drain the rainwater on the slope in order to lessen the load of leachate entering the treatment facility.

If the rainwater has seeped into the landfilled waste layers and then seeped out again, the rainwater shall be collected as leachate. The stability and appearance of the slope will then be poor. Crushed stones can also be laid within the inner parts of the slopes so as to establish a water draining layer.

The water drainage gradient may change due to sinking of the landfilled waste layer. After the landfilled waste layers have stabilized, side culvert made of concrete may then be used. Drainage culvert shall be as wide as possible to accommodate quick flow or sedimentation of earth and sands.

(4) Appearance of Landfill Slopes

a) General

The landfill slope shall be safe. But it is also important that the shape of the slope matches with the surrounding environment.

b) Measures to Beautify Slopes

Exposed sand and earth on a slope will not only spoil the appearance but also causes erosion due to strong winds and rainfall.

The following are some measures for prevention:

- Slope protection by structures around the slope
- Planting of trees and bushes
- Seed Planting

The third method of seed planting is a popular method. When applying this method, the following technical aspects shall be considered:

- Structure of slope (gradient, length, etc.)
- Quality of soil (hardness, fertility of earth, etc.)
- Weather conditions (temperature, rainfall, wind strength)
- Local conditions (saline pollution, locations, humidity, etc.)
- Workability

8.6 Cover Soil

Cover soil at the landfill site plays important roles in sanitation, fire prevention, reduction of leachate volume, odour and vermin control etc.

(1) General

In general, it is necessary to carry out the landfilling process in consideration of the following aspects related to cover soil:

- As far as possible, the landfilled waste shall never be exposed. It shall be covered as soon as possible with cover soil.
- Cover soil shall be laid at specified areas to prevent gas dispersion, fire and also for movement of collection vehicles, when necessary.
- A final cover soil shall be laid on the top layer of the landfill site. In this case, the thickness of the final cover soil depends on the proposed usage of the completed landfill site.
- The cover soil shall cover the landfilled wastes properly, sufficiently spread and compacted with proper thickness and gradients.

(2) Functions of Cover Soil

The cover soil prevents bad odour from dispersing, reduces the littering and flowing out of wastes, eliminates the breeding of vectors etc. It also acts as a fire breaker to prevent fire from spreading. It also provides good appearance for the landfilling areas as a mean of protecting the environment. In addition, it also ensures easier spreading and compaction works, prevents rainwater from seeping into the inner layers of the landfill site etc. However, when a large amount of cover soil is used, the capacity of landfill becomes lesser and it also reduces the permeability of the landfill site and subsequently reduces the waste decomposition rate. Therefore, the thickness and type of cover soil shall be properly selected.

The availability of cover materials depends on the location of the landfill site and the financial capability of the operator. If new cover soil material is not available, old landfilled wastes buried for about 3 to 6 months can be utilized effectively as cover soil.

(3) Categories of Cover Soil

Depending on the purpose, cover soil can be classified into daily, intermediate and final cover soil.

a) Daily Cover Soil

When a landfill layer has reached its specified thickness or when one day's portion of the landfilling works is completed, a daily cover soil is laid to prevent:

- littering of wastes
- bad odour from spreading
- harmful vectors like flies from breeding.

b) Intermediate Cover Soil

Intermediate cover soil is laid as the landfill works progress. The function is more on providing foundation for roads for the collection vehicles as well as draining the rainwater

away from the landfill sites which are to be left for considerably long period.

c) Final Cover Soil

When all the overall landfilling works have completed in a landfill site, final cover soil is laid on the top of the landfilled waste layers. The types and thickness of final cover soil depends on the planned usage of the completed landfill site.

(4) Selection of Cover Soil

In general, cover soil is classified into grainy type and clayish type. The permeability of the cover soil is different based on different types of soil used (See **Figure II-51** and **Table II-26**).

In most cases, earth is used as it is easily available. Extremely acidic or alkaline soil type, or which contains harmful substances or anything that deteriorates the leachate quality shall be avoided. Earth which contains substances which are harmful to plants shall also be avoided. The different types of soil are listed as follows:

a) Daily Cover Soil

As far as possible, permeable and porous sand types shall be used to ensure easy spreading and compaction of the solid wastes, stabilize the landfill waste layers as well as not hindering the waste decomposition process. Porous cover soil is not suitable for preventing bad odours from dispersing. Therefore, when such types of soil are used, the cover layers shall be made as thin as possible so as to prevent the soil from becoming anaerobic.

b) Intermediate Cover Soil

Clayey soil is suitable to prevent gases from dispersing or rainwater from seeping into the waste layers. However, if the area is to be used as a foundation for roads, then crusher stones are recommended as cover materials.

c) Final Cover Soil

The final cover soil shall be resistant to corrosion by rainwater, low permeability and suitable for plants.

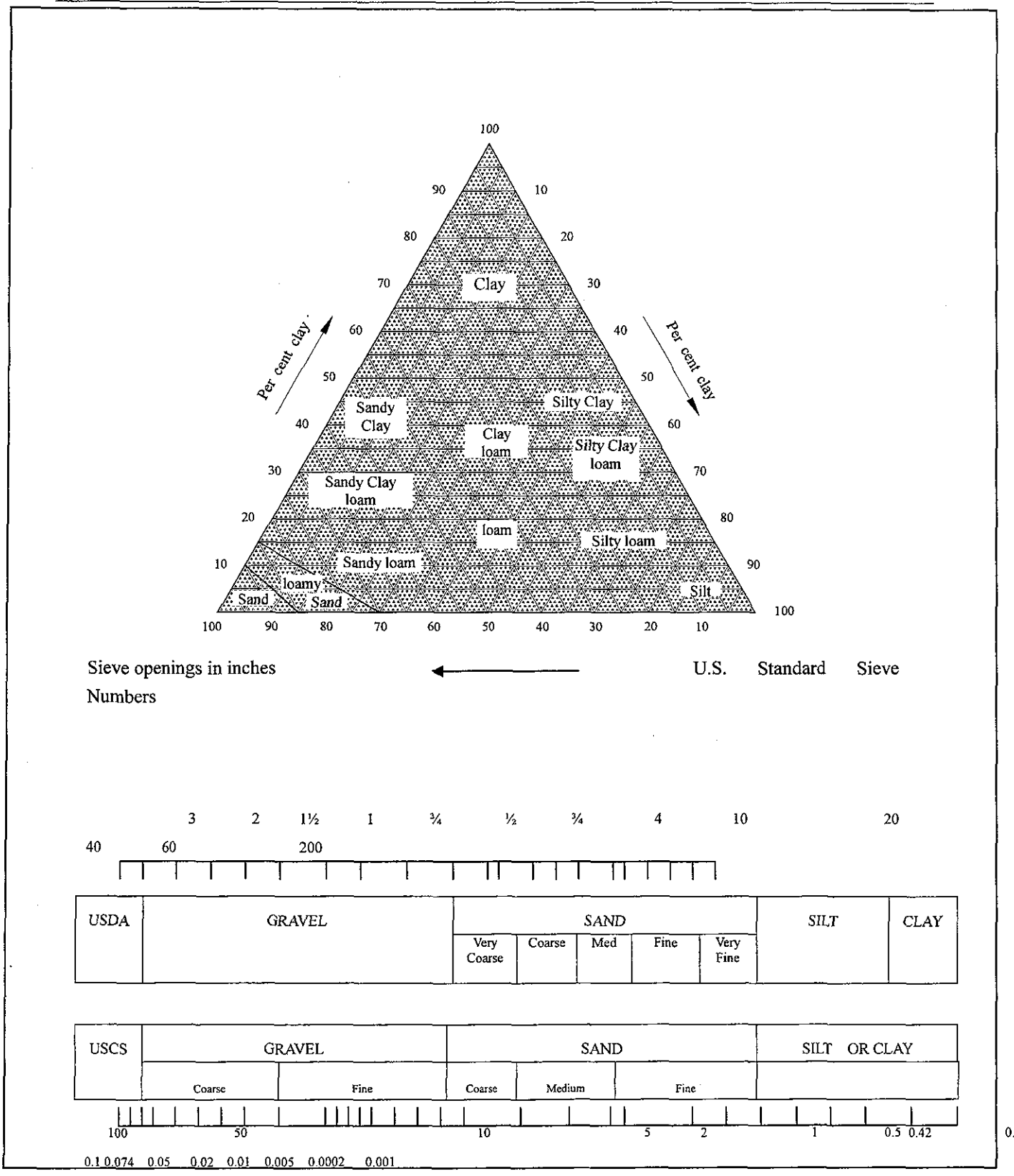

Figure II-51 Textural Classification Chart (U.S. Department of Agriculture) and Comparison of Particle Size Wastes

Major Divisions		Symbol: Letter	Symbol: Hatching	Symbol: Color	NAME	Potential Frost Action	Drainage Characteristics *	Value For Embankments	Permeability cm per sec	Compaction Characteristics **	Std AASHO Max. Unit Dry Weight lb per cu ft ***	Requirments for Seepage Control
COARSE-GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		RED	Well-graded gravels or gravel-sand mixtures. Little or no fines	None to very slight	Excellent	Very stable, pervious shells of dikes and dams	$k > 10^{-2}$	Good, tracktor, rubber - tired steel-wheeled roller	125 - 135	Positive cutoff
		GP		RED	Poorly graded gravels or gravel-sand mixtures. Little or no fines	None to very slight	Excellent	Reasonably stable, pervious sheels of dikes and dams	$k > 10^{-2}$	Good, tracktor, rubber - tired steel-wheeled roller	115 - 125	Positive cutoff
		GH		YELLOW	Silty gravels, gravel-sand-silt mixtures.	Slight to medium	Fair to poor Poor to practically impervious	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets	$k = 10^{-3}$ to 10^{-6}	Good with closed control, rubber-tired, sheepsfoot roller	120 - 135	Toe trench to none
		GC		YELLOW	Clayey gravels, gravel-sand-clay mixtures.	Slight to medium	Poor to practically impervious	Fairly stable, may be used for impervious core	$k = 10^{-6}$ to 10^{-8}	Fair, rubber-tired, sheepsfoot roller	115 - 130	None
	SAND AND SANDY SOILS	SW		RED	Well-graded sand or gravelly sands little or no fines	None to very slight	Excellent	Very stable, pervious sections slope protection required	$k > 10^{-3}$	Good, tractor	110 - 130	Upstreem blanket and toe drainage or wells
		SP		RED	Poorly graded sand or gravelly sands little or no fines	None to very slight	Excellent	Reasonably stable, may be used in dike section with flat slopes	$k > 10^{-3}$	Good, tractor	100 - 120	Upstreem blanket and toe drainage or wells
		SH		YELLOW	Silty sand, sand-silt mixtures.	Slight to medium	Fair to poor Poor to practically impervious	Fairly stable, not particularly suited to shells, but may be used for improvious core for flod control struvtures	$k = 10^{-3}$ to 10^{-6}	Good with closed control, rubber-tired, sheepsfoot roller	110 - 125	Upstreem blanket and toe drainage or wells
		SC		YELLOW	Clayey sands, sand-clay mixtures.	Slight to medium	Poor to practically impervious	Fairly stable, use for impervious core for flood control structures	$k = 10^{-6}$ to 10^{-8}	Fair, rubber-tired, sheepsfoot roller	105 - 125	None
FINE-GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	WL		GREEN	Inorganic silts and very fine sands rock flour, silty or clayey fine sands or clayey silts with slight placticity.	Medium to very high	Fair to poor	Poor stability, may be used for embankments with proper control	$k = 10^{-3}$ to 10^{-6}	Good to poor closed control, essential, rubber-tired roller, sheepsfoot roller	95 - 120	Toe trench to none
		CL		GREEN	Inorganic clays of low to medium placticity, gravelly clays, sandy clays, silty clays, lean clays	Medium to very high	Practically impervious	Stable, impervious cores and blankets	$k = 10^{-6}$ to 10^{-8}	Fair to good, rubber-tired, sheepsfoot roller	95 - 120	None
		OL		GREEN	Organic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silty	Medium to very high	Poor	Not suitable for embankments	$k = 10^{-4}$ to 10^{-6}	Fair to poor, sheepsfoot roller	80 - 100	None
	SILTS AND CLAYS LL IS LESS THAN 50	WH		BLUE	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts	Medium to very high	Fair to poor	Poor stability, core of hydraulic dam, not desirable in rolled fill construction	$k = 10^{-4}$ to 10^{-6}	Poor to very poor, sheepsfoot roller	70 - 95	None
		CH		BLUE	Inorganic clays of high placticity, fat clays	Medium	Practically impervious	Fair stability with flat slopes, thin cores, blankets and dike sections	$k = 10^{-6}$ to 10^{-8}	Fair to poor, sheepsfoot roller	75 - 105	None
		OH		BLUE	Organic clays of medium to high plasticity, organic silts	Medium	Practically impervious	Not suitable for embankment	$k = 10^{-6}$ to 10^{-8}	Poor to very poor, sheepsfoot roller	65 - 100	None
HIGHLY ORGANIC SOIL		Pt		Orange	Peat and other highly organic soils	NOT RECOMMENDED FOR SANITARY LANDFILL CONSTRUCTION						

* Values are for guidance only : design should be based on test result.

** The equipment listed will usually produce the desired densities after a reasonable number of passes when moisture condition and thickness of lift are properly controled.

*** Compacted soil at optimum moisture content for Standard AASHO (Standard Proctor) compactive effort

Table II-26 Unified Soil Classification System And Characteristics

(5) Selection of Thickness of Cover Soil

The thickness of the cover soil is determined depending on the purpose, solid waste compositions, environmental conservation etc. Generally, the thickness is recommended as follows:

a) Daily Cover Soil

- When the solid wastes are mainly combustible and large in size: 30 ~ 50 cm
- Crushed wastes and ash: 15 ~ 20 cm
- When uncrushed wastes are used: 45 cm
- When crushed waste are used: 20 cm
- When impermeable soil such as silt or clay is used, the cover soil shall be as thin as possible

b) Intermediate Cover Soil

- When the cover soil is to be exposed for a fairly long time: about 50 cm

c) Final Cover Soil

- For planting of grass or low plants and bushes: more than 50 cm
- For planting of medium height to tall trees: more than 1 m

(6) Applying Cover Soil and Maintenance

The cover soil shall be uniformly spread and compacted by using appropriate type of landfill equipment depending on the thickness of the cover soil, the area and quality.

In particular, it takes some time before the final cover soil on a slope to be stabilized. Therefore, care shall be taken to prevent the final soil from being eroded by rainwater. One measure is to make the slope in the gradient of 20 ~ 30 degrees while on the plain areas, a gradient of about 2 ~ 3% is reasonable.

The surface of the final cover soil may sink, crack or forming potholes. This will result in increase in leachate volume, gas leakage, erosion, landslides, fire etc. Therefore, maintenance shall b done by taking into consideration the following aspects:

- The site settles deeper when combustible wastes are landfilled and shallower when incombustible wastes (e.g. construction debris) are landfilled.
- The deeper the landfill waste layers are, the deeper the site settlement is.
- The settlement process continues for several years.
- Settlement rate ranges from a few percent to 30% of the landfill thickness.

In particular, when the surface of the landfill site depresses or cracks, rainwater will seep into the inner waste layers and gas will be released from the landfilled waste layers. Therefore, the surface of the final cover soil shall always be inspected, maintained and repaired. The appropriate cover soil thickness for various sizes of working face is given in

Table II-27.

Table II-27 Average Requirements of Cover Soil in Completed Cells

Daily wastes (t)	Volume (m^3) 1.25m^3/t (0.8t/m^3)	include cover soil (m3) (30%)	width (m)	Height (m)	Length (m)	Cover soil (m^3) (20-30%) thickness [cm]
10	12.5	16.2	6	1	3	4 [22]
20	25.0	32.5	6	1	6	8 [22]
50	62.5	01 .2	6	2	7	15 [35]
100	125.0	163.5	10	2.5	7	30 [42]
150	187.5	243.7	10	3	0	40 [50]
200	250.0	325.0	15	3	0	60 [50]
300	375.0	407.5	20	3	9	90 [50]

8.7 Landfill Equipment

Landfill equipment required for landfilling process includes the machines used for spreading, compacting, excavating or digging purposes. The type, size and amount of equipment required is depending on the size of the landfill site, method of operations etc.

(1) Selection of Landfill Equipment

Landfill equipment shall be selected based on the size of the landfill site, landfilling method, solid waste composition etc. Generally, landfill equipment can be classified according to their functions into the following:

Type A : equipment used to spread and compact landfilled waste layers
Type B : digging equipment, cover soil spreading equipment
Type C : other equipment required for landfill operations

Tractors such as crawler tractors and wheel tractors are usually used in Types A and B. The crawler tractor is called a bulldozer or tractor shovel depending on the type of arm attached to the crawler tractor such as buckets or blades for different purposes. **Table II-28** shows some of the equipment and their suitability to be used for different landfilling process. Landfill blades are commonly used for spreading and compaction of solid wastes. Landfill compactor is also required for landfill sites with bulky or construction debris. Although landfill compactor can crush and compact very well, this equipment is not effective on soft layers.

Therefore, different equipment has different characteristics and type of equipment used has to be properly selected according to its usage. Besides, Type C equipment such as watering trucks, disinfecting trucks, fire fighting trucks etc. are also required especially at large scale landfill sites.

Most of the equipment used for landfilling process are equipment used for construction purposes. However, this equipment sometimes breakdown in a manner that is different as compared to equipment used in construction sites. For example, machines used at landfill sites are exposed to corrosive gases like hydrogen sulphide or ammonium salts which may

cause breakdown of machine parts. It is therefore always advisable that spare equipment or spare parts shall be made available in good condition at all time.

Table II-28 Comparison of Equipment for Landfilling Works

Machine / Work	Capacity	Waste		Cover Soil				Size of Landfill	Location	Characteristics
		Spreading	Compaction	Excavation	Spreading	Compaction	Moving			
Crawler Dozer (Bulldozer)	Weigh 3.5~40 t Speed 0~14km/h Plate 0.5~10 m^2	+++	++	+	+++	++	-	Big Small	Inland Sea	*Best for spreading. Suitable for compaction.* Can also work on soft ground. Power nobility. Compaction effect is best achieved on hard ground foundation. Most commonly used piece of equipment.
Crawler Dozer (Tractor Shovel)	Bucket Capacity 0.2~4 m^2 Speed 0~14km/h	++	++	+++	++	++	-	Big Small	Inland	Suitable for excavation. Suitability for spreading / compaction work is lower than bulldozer.
Wheel Dozer	Weigh 5~6.2 t Speed 0~35km/h Plate : About 1 m^2	+++	++	+	++	++	-	Big Small	Inland Sea	Best for spreading. Compaction effect is lower than bulldozer. High mobility.
Wheel Loader	Bucket Capacity 0.2~9 m^2 Speed 0~10km/h	++	+	+	++	+	-	Big Small	Inland Sea	Not suitable for compaction. High nobility. Mainly used for packing
Scrapper Dozer	Weigh 8~25 t Speed 0~12km/h Bowl Capacity 4~6m^2	-	-	++	+++	++	-	Big	Inland Sea	Suitable for moving long distance and removing a lot of sand or earth. Not suitable for garbage
(Self-motored)	Capacity 10~34 m^2 Speed 60km/h	-	-	++	+++	-	++	Big	Inland Sea	Most suitable for moving large volume of sand but not suitable for working on landfill site.
Power Shovel	Bucket Capacity 0.2~9 m^2	-	-	+++	+	-	-	Big	Inland	Best for excavation work. Use to transport cover soil from nearby borrow pit.
Drag Line	Bucket Capacity 0.7~12 m^2							Small	Sea	
Compactor	Weight Height of Teeth	+++	+++	-	++	++	-	Big Small	Inland Sea	Effective in contacting and crushing stones. Effectiveness is lost if ground is not hard. Normally used to landfill uncrushed waste.

Note : +++ Most Suitable, ++ Good, + Can be used but not good, - Not Suitable

(2) Number of Equipment Required

The number of equipment required. in a landfill site depends on the following:

- The daily amount of solid wastes disposed at the landfill site
- The amount of solid waste delivered at peak times
- Size of the sanitary landfill system
- Efficiency of the landfill equipment
- Number of operation hours per day
- Maintenance and repair measures
- Financial availability

Table II-29 shows the average equipment requirement for a sanitary landfill system.

Table II-29 Average Equipment Requirements for a Sanitary Landfill

Daily wastes (tons)	Equipment			Accessory
	Number	Type	Size, lb	
4-40	1	Tractor, crawler or rubber-tired	10,000-30,000	Dozer blade Front-end loader (1 to 2 yd) Trash blade
40-130	1	Tractor, crawler or rubber-tired	30,000-60,000	Dozer blade Front-end loader (2 to 4 yd) Bullclam Trash blade
	#	Scraper, dragline, water truck		
130-260	1~2	Tractor, crawler or rubber-tired	30,000+	Dozer blade Front-end loader (1 to 5 yd) Bullclam Trash blade
	#	Scraper, dragline, water truck		
260+	2+	Tractor, crawler or rubber-tired	45,000+	Dozer blade Front-end loader Bullclam Trash blade
	#	Scraper, dragline, steel wheel compactor, road grader, water truck		

Note: # Optional - depending on individual need

Chapter 9 Landfill Control Facilities

9.1 Types of Control Facilities

To ensure proper management and operation of sanitary landfill system, additional facilities to control operations and monitoring shall be established such as a site office, weighbridge and access roads etc.

(1) Management of Sanitary Landfill System

The entire management of a sanitary landfill system involves proper control of solid waste quality and quantity, landfill operations, management of landfilled layers, facilities included in the sanitary landfill system as well as other facilities as shown in **Figure II-52**.

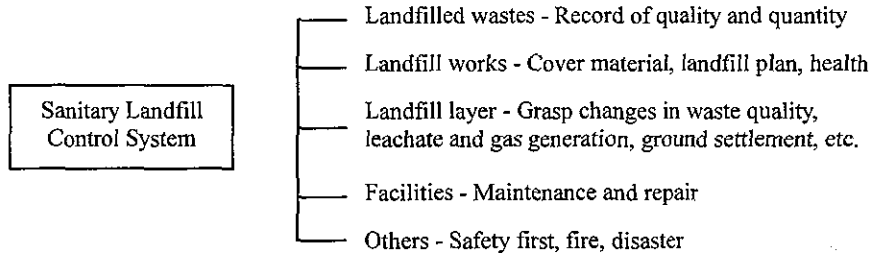

Figure II-52 Checklist of Items to be Controlled at a Landfill Site

(2) Structure of Control Facilities

The control facilities required at a landfill site include the site office to record and control the quality and volume of incoming wastes, inspection of landfill vehicles used for landfill operations, petrol storage tanks, places for washing vehicles, monitoring facilities, access roads etc. as shown in **Figure II-53**.

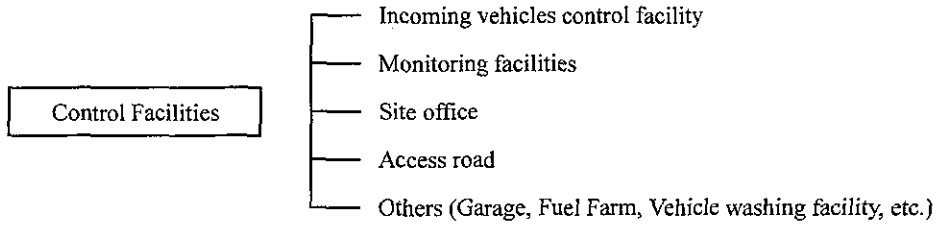

Figure II-53 Structure of Control Facilities

9.2 Waste Inspection and Measurement

Waste inspection is necessary to monitor and ensure that the wastes delivered to the landfill sites are acceptable to be disposed off at the landfill site. The quantity of the accepted wastes shall be measured by using a weighbridge to ensure that the landfilled waste meets the requirement stipulated in the plan where the amount of landfill waste is measured and recorded.

(1) Incoming Wastes Inspection

Solid wastes to be disposed off to the landfill sites shall be checked to ensure smooth operations as well as to prevent land pollution due to unacceptable harmful substances. Therefore, the types and qualities of the incoming waste shall be inspected carefully.

Incoming wastes without passing through any intermediate treatment facility are usually inspected by its physical appearance. A platform or simple structure can be built near the weighbridge so that the waste loads on the incoming truck can be inspected. When necessary, the solid wastes can be unloaded for inspection. A space for inspection is thus necessary.

(2) Weighbridge

Weighbridge is the basic requirement at a landfill site to record the quantity of incoming wastes to the landfill site. Weighbridge shall be installed at the entrance of the landfill site to measure and record the incoming wastes. As a general guideline, a landfill site receiving more than 50 tonnes/day of solid wastes shall have a weighbridge installed.

a) Structures of the Weighbridge

The weighbridge measures the truck loaded with the incoming wastes to the landfill site. There are three different systems of weighbridge, namely mechanical system, load cell systems and lever load cell system. The mechanical system has a digital scale (pulse system). While the load cell and lever load cell systems also have digital scales (electrical system). The general structure of weighbridge is shown in **Figure II-54**.

The load cell weighbridge is more popular as the mechanism is simple (with four supporting points) and it requires easy maintenance.

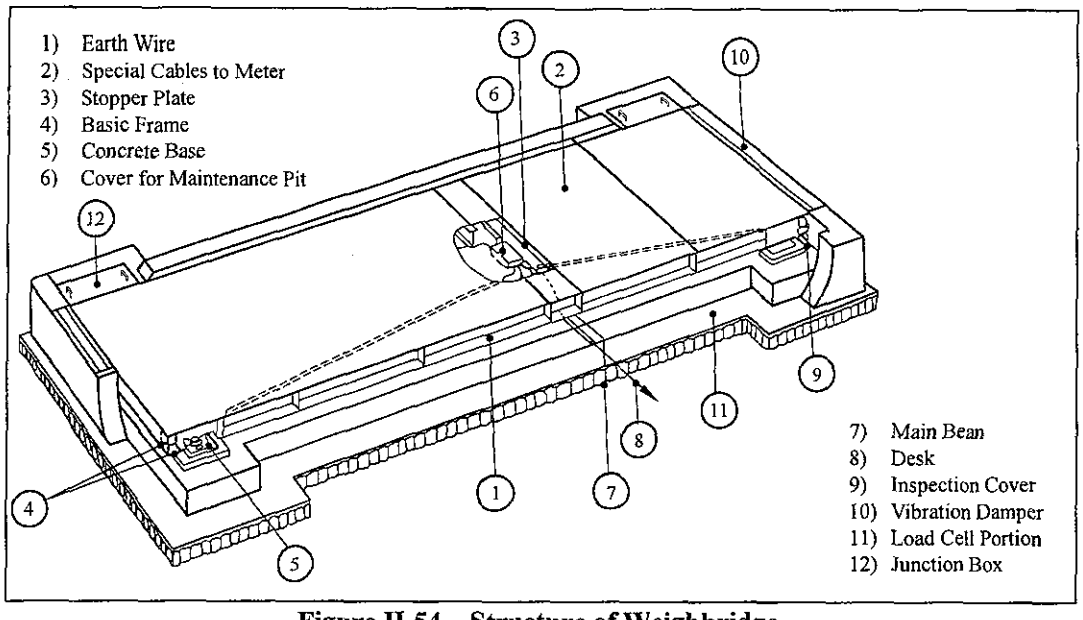

Figure II-54 Structure of Weighbridge

b) Weighbridge Design

The following factors shall be considered before selecting the weighbridge system.

i) Number of Weighbridge to be Installed

The total number of collection vehicles per day, solid waste collection systems and the maximum number of collection vehicles at peak delivery hours are factors to be considered before deciding on the number of weighbridge to be installed at a landfill site. In particular, if the weighbridge is located near the public roads, then the maximum number of collection vehicles at peak hours shall be considered at intervals of 15 to 20 minutes. When necessary, separate weighbridge can be installed at the entrance and the exits of the landfill sites in order to measure the loaded and empty trucks respectively.

ii) Maximum Weighing Capacity of Weighbridge

The maximum weighing capacity of the weighbridge shall be several times more than the total weight of the collection vehicle in order to provide excessive room for unusually heavy collection vehicles.

iii) Position of Weighbridge

Weighbridge shall be placed at strategic locations where the vehicles pass through whenever entering and leaving the landfill sites.

c) Automatic Weighing System

Automatic weighing systems using computers are becoming more popular. **Tables II-29** shows the information processed by the automatic weighing system.

d) Regular Inspection

When a weighbridge is used as a toll gate, regular inspection of the system shall be done to ensure proper and accurate measurements.

Table II-30 Example of Input Information for Automatic Weighing System

Outgoing Vehicle		Incoming Vehicle	
(1)	Date	(1)	Contractor's Name
(2)	Contractor's Name	(2)	Vehicle Registration Number
(3)	Vehicle Registration Number	(3)	Driver's Name
(4)	Driver's Name	(4)	Waste Type
(5)	Waste Type	(5)	Entry Time
(6)	Collection Route	(6)	Gross Load (kg)
(7)	Departure Time	(7)	Unloaded Weight (kg)
(8)	Gross Load (kg)	(8)	Nett Load (kg)
(9)	Unloaded Weight (kg)		
(10)	Nett Load (kg)		

(3) Investigation of Solid Wastes Quality

Besides the inspection to check whether the incoming wastes are acceptable to be disposed off at the landfill sites, the quality of the wastes shall also be investigated. By knowing the quality of the wastes, the types of gas generated in the landfill, the leachate quality, the amount of settlement due to compaction of the landfilled layer etc. can be estimated. This is also important information for planning of the future usage of the completed landfill site. Samples of the solid wastes shall be taken for investigation. An unloading place to take the samples shall be prepared.

(4) Analysis of Control Data

The data collected on the waste volumes as well as the results of the inspection shall be analysed on a regular basis. Daily, monthly and yearly reports are recommended.

(5) Data Recording/Management

Information on the landfilled waste volumes, quality, locations, time of landfilling, waste types etc. are all important data which shall be recorded and kept in a systematic way.

9.3 Monitoring

Monitoring works need to be carried out periodically on various aspects such as the landfill waste, leachate, underground water, discharged water, gas generation, bad odour etc. in order to achieve proper management and control of the sanitary landfill system.

9.3.1 Function of Monitoring

The main function of carrying out monitoring works is to observe and understand the changes condition of the landfill sites from various aspects such as changes in landfill waste layers, leachate quality, odours and environment impacts etc.

(1) Monitoring the Landfilled Waste

The landfilled wastes will change with the years. Therefore, it is important that a samples at certain specified landfilled layer be collected, analysed and its quality change be recorded at regular intervals. Monitoring of the waste quality change has to be taken on a macro basis because the landfilled waste is not homogenous and thus a typical landfilled waste sample would be very difficult to be obtained.

The monitoring of landfilled wastes layers shall be carried out during the operation as well as after landfill completion, particularly on its changes in the solid waste compositions, settlement rates in the waste layers etc. The data obtained from monitoring of landfilled waste will be useful for designing future leachate treatment plants as well as planning of future use after landfill completion.

(2) Monitoring the Leachate and Discharged Water

As part of the management and maintenance of the sanitary landfill system, the quality and frequency of the discharged water shall be monitored. In the case of leachate, monitoring shall be done for the water flowing into the leachate treatment facility. The amount of pollutants and harmful substances in the leachate flowing out of a landfill site shall also be measured particularly at the discharge point where the treated leachate is released to the environment. **Table II-31** shows example of monitoring items for leachate and discharged water.

Table II-31 Example of Monitoring Items and Frequency

Monitoring Items	Frequency at Each Location								
	Leachate			Discharge Water			Pre-treatment Leachate		
	A	B	C	A	B	C	A	B	C
Volume	O			O			O		
Temperature	O			O			O		
pH	O			O			O		
BOD		O			O			O	
COD		O			O			O	
SS		O			O			O	
E-Coli									
N-Hexane			O			O			O
NH_4^+–N		O			O			O	
T – N		O			O			O	
T – P		O			O			O	
Hazardous Items			O						O
TOC			O						O
Cl^-			O						O
Other (Fe^{2+} Mn^{2+} etc.)									

Frequency A : Daily B : Weekly C : Monthly or Quarterly

Note : Leachate shall be collected from leachate retention pit. If leachate flows directly into the leachate treatment facility, then the leachate and pre-treatment leachate are the same.

(3) Monitoring of Groundwater

The monitoring of groundwater in areas surrounding the landfill site shall be carried out for the following reasons:-

- To check the quality of the groundwater to ensure that the liner systems of the landfill site are functioning well without any leakage.
- To detect any pollution at earliest possible so that remediation works can be carried out immediately to prevent the extent of the impacts of pollution on the groundwater and the surrounding environment.
- Therefore, the groundwater monitoring wells established is crucial in order to determine the quality and possible usage of the groundwater in the areas around the landfill sites. The number of wells, positions and depth required are of primary important and shall be determined carefully.

a) Position and Number of Monitoring Wells

Monitoring wells shall be constructed directly below the subterranean water flow direction in the landfill sites so that the amount of seepage can be detected before the dispersed into the groundwater.

In addition, monitoring wells shall also be constructed downstream of the landfill sites where the dispersion of pollutants has the highest possible and fastest effects. This allows the comparison of groundwater quality between upstream and downstream. The monitoring wells shall be as deep as possible but usually a depth that enables the detection of pollution in the groundwater level will be sufficient. The wells shall be more than 100mm in diameter with a mesh or screen at the water level.

b) Parameters to be Monitored and Frequency

The water quality monitoring by using monitoring wells can be divided into regular and routine monitoring.

Regular monitoring is carried out for checking seasonal changes in the groundwater quality. The water quality shall be checked at the same time each year at each monitoring well. Regular monitoring includes inspections on the land-use in the neighbouring areas.

Routine monitoring requires immediate detection of pollutants and therefore, instruments such as pH meters or electric conductivity meters to measure changes in the water quality are required.

Figure II-55 shows an example of the structures of monitoring well.

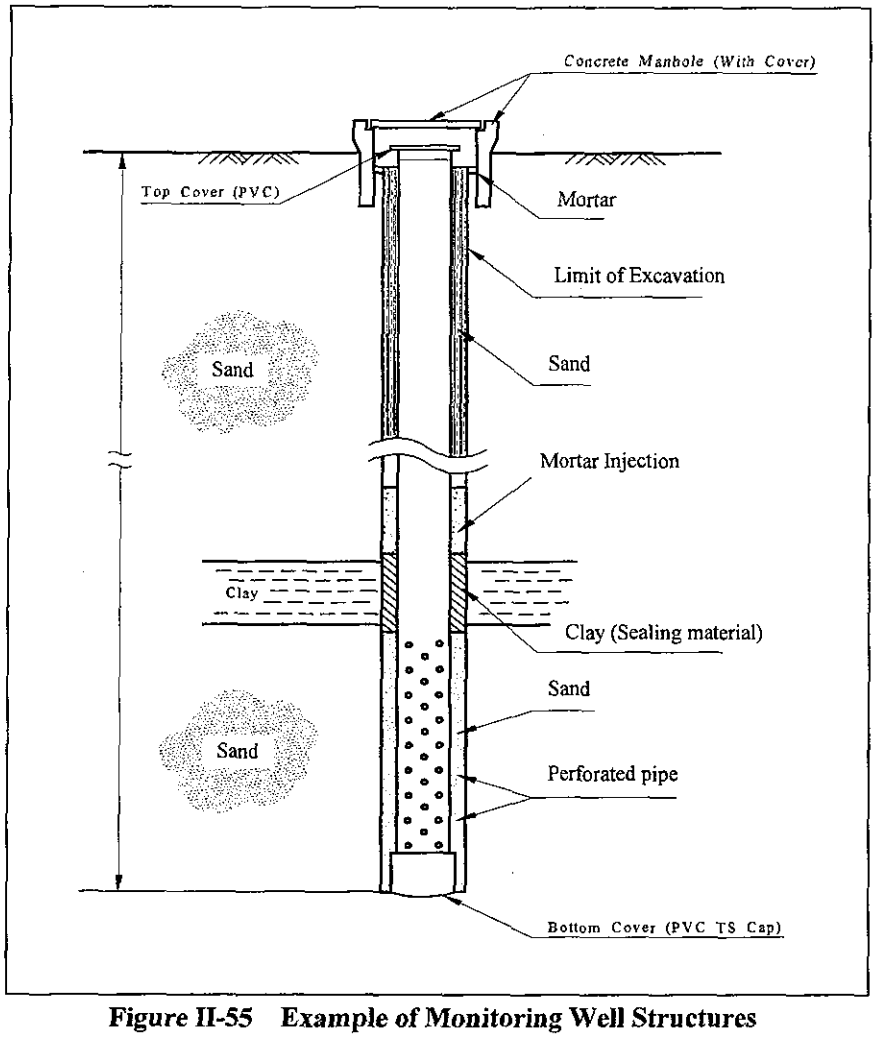

Figure II-55 Example of Monitoring Well Structures

(4) Monitoring of Gas Generation

Monitoring of the gas generated will help to determine the decomposition condition of the landfilled wastes. Even in a landfill site which contained mainly incombustible waste, the landfilled waste shall also be monitored since the wastes may include organic substances.

The gas generated can be monitored by using the gas venting facility installed at the landfill site. The gas generated shall be monitored frequently when active generation of gas occurs. During stable periods, monitoring frequencies can be reduced. In other words, a flexible monitoring program shall be planned.

Table II-32 shows some gas parameters to be monitored at a landfill site.

Table II-32 Monitoring of Gas Generation

Measurement		Frequency
Outdoor Temperature		++++
Outdoor Humidity		++++
Gas Temperature		++++
Gas Generation Volume		++++
Gas Component	Methane	++++
	Carbon Dioxide	++++
	Carbon Monoxide	++++
	Ammonia	+
	Hydrogen Sulphide	+
	Oxygen	++++
Is there evaporation ?		++++

Notes: ++++ : Four times a year until the 2nd year of operation

\+ : *Once a year after the 2nd year of operation*

(5) Monitoring of Bad Odours

The monitoring locations and frequency for bad odours shall be planned by taking into consideration the living environment in the surrounding areas as well as the weather conditions. Bad odours monitoring is usually done once a day in 3 months at 2 to 3 different places at the landfill site boundaries.

Monitoring parameters shall include the analysis of ammonia, thiorumethane, hydrogen sulphide, methyl sulphide, triethylamine, aceto aldehyde, styrene and methyl disulfide as well as tests on their effects on human senses. The selection of monitoring method is depending on the local conditions, solid waste quality etc.

(6) Monitoring the Surrounding Environment

Other possible impacts on the surrounding environment such as noise, vibrations, animals, plants and aesthetic etc. shall also be monitored when necessary. The quality of the surrounding environment shall be monitored during and after landfilling operations so as to ensure that the environmental impacts of the landfill sites are prevented and minimized.

(7) Monitoring for Future Plans

The data collected and analysed from monitoring will be used to determine future projects that can be planned on the landfill sites. Therefore, it is important that data on solid waste compositions, leachate quality, underground water quality, gas generation, bad odours etc. be regularly monitored and collected.

9.4 Site Office

The site office must be able to control all treatment facilities. Facilities like locker rooms, rest rooms, showers, etc. for workers must also be installed when necessary.

(1) Functions of Site Office

Site office shall be the overall control centre that supervises the activities of inspection and weighing of the incoming wastes, checking of landfilling work progress and conditions, securing of cover soil materials, installation of section walls, operation, maintenance and monitoring of leachate treatment facility at the landfill sites, that shall be performed systematically so as to protect the environment, promote safety of the plant and improve the cost effectiveness.

The site office shall include at least a management office equipped with utilities such as water supply and electricity, as well as complete communication systems such as fax, telephone etc. Depending on the needs, when necessary, other facilities can also be incorporated with the site office such as test laboratory and analytical room, workers' rest room, locker room, showers, canteen, toilets, conference room, etc.

In many cases, the type of facility required at a site office are depending on the scale of the landfill sites, the number of employees as well as the management policies etc.

(2) Design of Site Office

Site office can be as simple as only a metal cabin, or as good as a few-storey concrete building. Some site office at small scale landfill sites are also used as leachate treatment facility. The site office shall be placed at a convenient location to enable easy control of the entire landfill operations. **Figure II-56** shows an example of a site office, where the main part of the weighbridge is placed next to the site office which also houses the measuring system.

In order to prevent the collection vehicles from carrying dirt onto the public roads, a vehicle washing facility shall be installed at the exit roads. Whenever necessary, garages, petrol stations, warehouses, and other maintenance facilities shall also be installed.

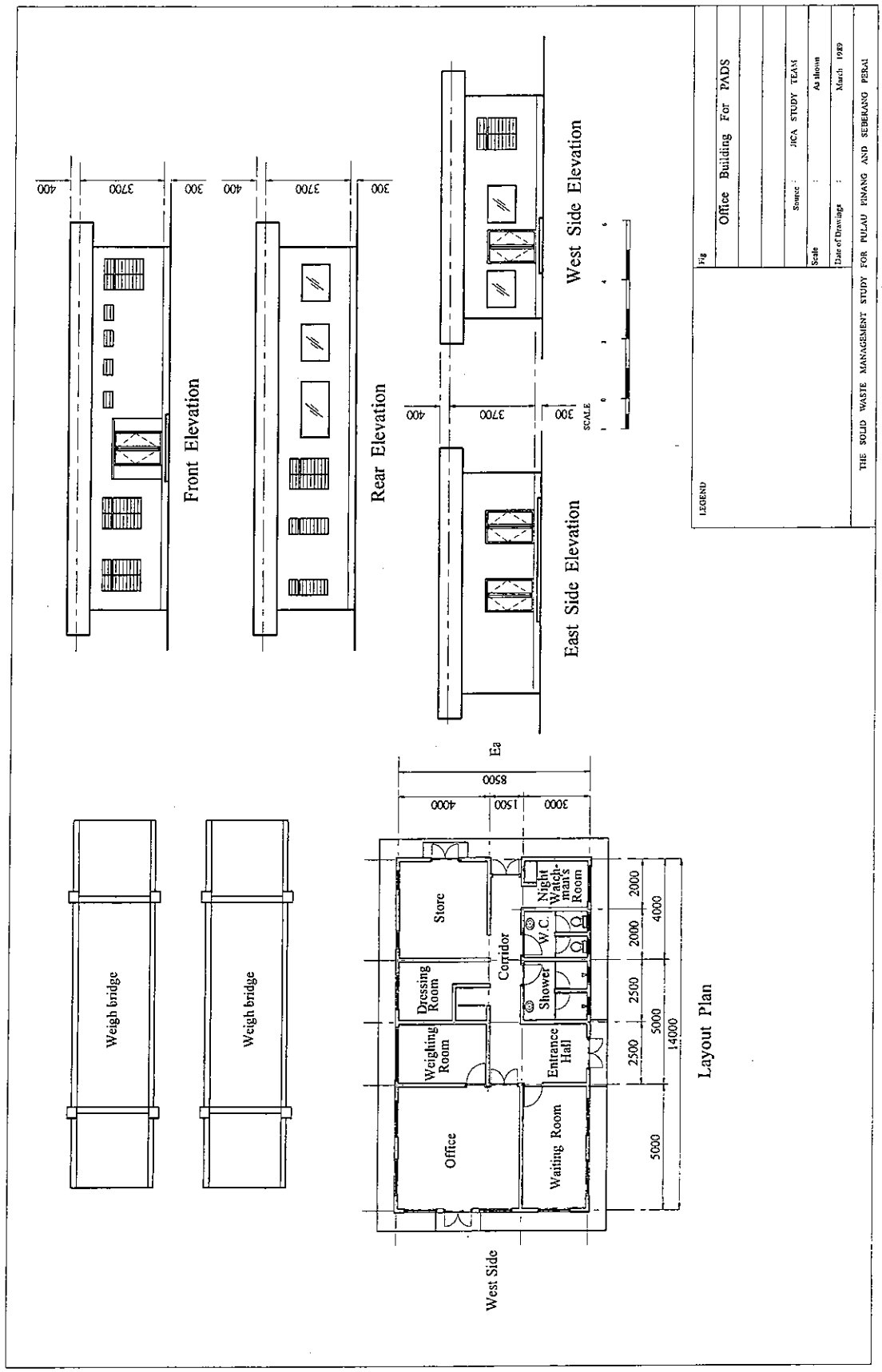

Figure II-56 Design of Site Office

9.5 Safety Measures

Safety measures are of primary important at landfill sites in order to prevent accidents or any unwanted incidents to happen such as explosion, dump fire, illegal dumping as well as human death.

Landfill sites shall be fenced off to prevent illegal trespassing. The fencing system is also to prevent from illegal dumping of unacceptable wastes at the landfill sites such as hazardous or explosive wastes. In addition, landfill sites shall have clear notice board that indicates important information of the landfill sites such as a list of acceptable wastes etc. Descriptions on the notice boards, fencing, gates and security at landfill sites are discussed in Section 10.4 of this guideline.

Inspection and safety management of landfill sites shall include the control of scavengers who enter the landfill sites illegally. The following dangerous places at a landfill site and the safety measures shall be considered:

- Dangerous substances such as insecticides etc. shall be kept properly and locked under a roof.
- Leachate treatment facility and leachate control pond shall be fenced off and locked properly.
- Gas venting facility shall be fenced off and a warning signboard shall be placed on the fence indicating the danger of the vent.
- Landfill equipment must be steered in specified places and when necessary, a buffer area established.
- The sands and soils used for cover materials shall be piled to a safe height.

In addition, any part of the landfill sites shall be strictly no smoking at all time and this rule shall be strictly followed by anyone working or visiting the landfill sites.

Lighting during night time is also important for safety and to prevent illegal dumping. Security guards shall be stationed at the landfill sites at all time throughout the years.

Chapter 10 Other Related Facilities

10.1 Composition of Other Related Facilities

A complete sanitary landfill system shall be equipped with other related facilities such as proper access roads, fencing and security system, signboard, fire prevention facility, etc.

Other related facilities at a landfill site are necessary for effective management and operation of the entire sanitary landfill system. Other related facilities at a landfill site shall basically include the following depending on the size of the landfill site, land conditions, etc.:

- Proper access roads designed for effective transportation of wastes or other necessary materials into the landfill site.
- Facilities to prevent littering of wastes at the landfill site.
- Proper fencing system surrounding the landfill site and notice boards with clear indications at the main entrance or gates for security purposes as well as to prevent illegal entrance or illegal dumping in the area.
- Fire prevention facility for fire fighting and emergency use.
- Bunds, walls to prevent rocks, earth etc. from slipping or crumbling down from slopes due to heavy rain.
- Temporary rainwater control ponds to prevent rainwater overflow or flooding.

Other facilities such as noise abatement walls, measures against insects and crows etc. may also be considered whenever necessary depending on the local characteristics of the landfill site.

Some of these related facilities shall be built during landfill operations while the other can be built even after completion of landfill if they are use mainly for control and management of a completed landfill site. **Figure II-57** shows an example of related facilities at a landfill site.

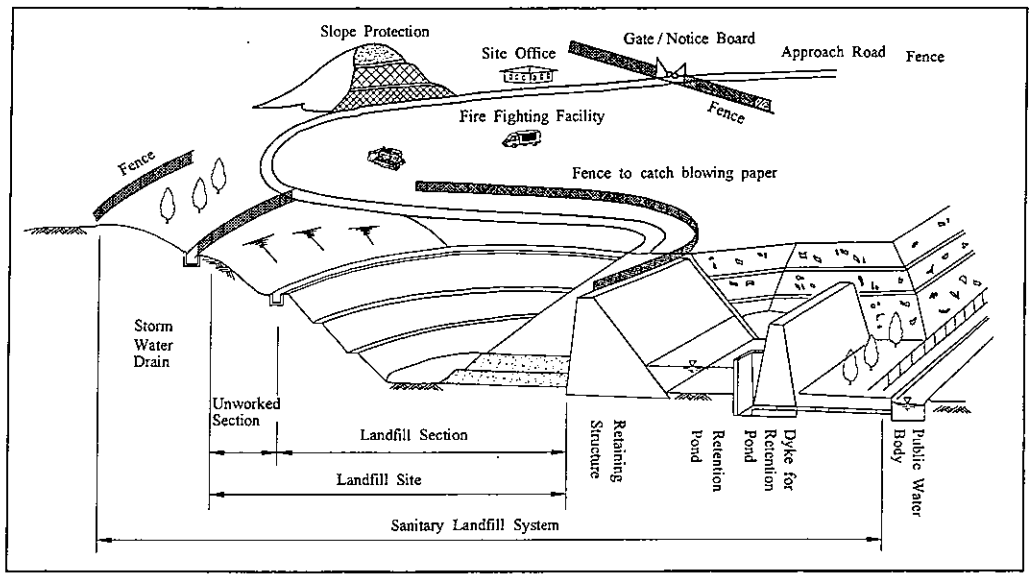

Figure II-57 Layout of Related Facilities at a Landfill Site

10.2 Access Roads

The access roads for transportation of wastes, cover soils etc. into the landfill site shall be proper designed in a way that it does not pose any problem in the transportation process at all time, as well as does not hinder the overall landfilling activities.

(1) Characteristics and Types of Access Roads

Generally, the access roads shall have the following characteristics:

(1) Access roads shall be constructed within the landfill site for transporting solid wastes.

(2) Access roads shall be built after determining order of landfilling, frequency of waste delivery, time required for dumping and loading, etc.

(3) Access roads shall be made smoothly passable to collection vehicles during all type of weather.

The access roads to the landfill site can be divided into few categories, namely the public roads, roads leading from the public roads into to the landfill site, and also trunk roads and branch roads within the landfill sites.

Surveys on the use of existing public roads shall be done so as to determine the existing road and traffic conditions of the area. The road width and structure etc. shall be investigated to ensure that it is suitable for the transportation of solid waste. When the public road is to be used for transporting solid wastes, proper signboards shall be erected and the junction shall be modified if necessary so that it does not obstruct the free flow of the existing public roads.

(2) Design of Access Roads within Landfill Site

Although access roads built within a landfill site usually have a short lifespan, it is still better to consider building roads with a comparatively long lifespan. The access roads for long lifespan can be used as trunk access roads while those built during the process of landfilling can be used as branch access roads.

a) Function and Structure of Access Road

It is necessary to ensure that access roads are safe for collection vehicles as well as acceptable to provide smooth traffic flow especially on rainy days. Therefore, the following are some of the factors to be considered:

- Road Structure: road width, number of lanes, horizontal and vertical cross section
- Road paving: Thickness of paving, type (asphalt concrete, cement concrete, gravel etc.)
- Other safety measures, road signs, water, drainage facilities, etc.

To ensure proper design and construction of access roads, it is important to know:-

- The number of vehicles using the road (per day or at peak hours)
- Size of vehicles and their speed

- Geography of the land
- Service standards to be maintained.

b) Design Standards

Access roads shall be built to meet the JKR standards. **Figure II-58** shows a typical cross-section of an access road.

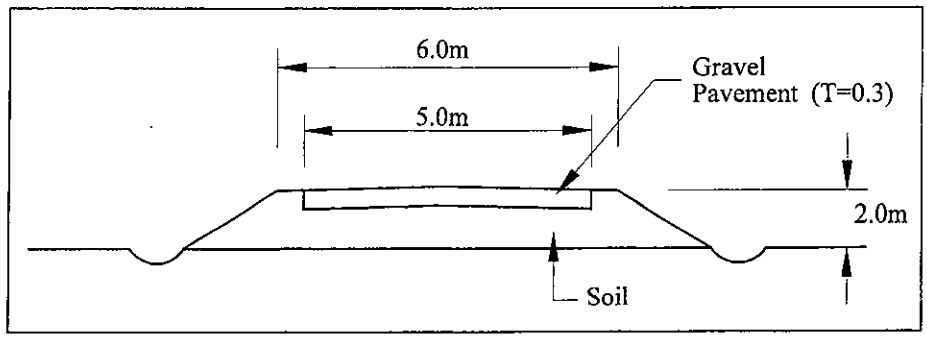

Figure II-58 Access Roads (Typical Cross-section)

c) Trunk Roads in Landfill Sites

Since trunk access roads may be used for a comparatively long period, the following shall be considered before designing the roads.

(i) Estimated Traffic Flows

Collection vehicles are usually concentrated at a certain time of the day, the traffic volume shall be estimated more than the traffic volume during the peak hour. When the volume is particularly high or when the trunk access roads are leading to a public road, then the maximum number of vehicles at 15~30 minute intervals shall also be considered.

(ii) Number of Lanes

The number of lanes required depends on the traffic volume. When there is only one lane, the road alignment (curves, gradients, etc.) shall be considered and when necessary, rest areas shall be provided.

(iii) Road Width

The road width required depends on the road alignment and/or the traffic volume but it shall be at least 3.5m for the case of one lane road and 6m for 2 lanes roads.

(iv) Vertical Cross-section Gradient

This vertical cross section gradient shall be as low as possible. Even in valleys or mountainous areas which have geographical limitations, access roads shall have a gradient of less than 7:1.

(v) Horizontal Cross Section Gradient

The access road shall have a horizontal cross section gradient of at least 3% for

easy maintenance and able to drain off the rainwater efficiently.

(vi) Paving

Access roads shall be appropriately paved after determining the traffic flow, site condition, strength of the road surface, etc.

(vii) Safety Measures

Trunk access roads in hilly areas such as cliffs, etc. shall have safety measures such as guard rails to prevent traffic from being plunged off into the ravines. When building roads on cut-off or built-up slopes, safety measures and reinforcements shall also be considered to prevent crumbling due to slopes failures.

Table II-33 lists the minimum widths and gradients for access roads.

Table II-33 Design Criteria for Access Roads

Design Speed	Width	Gradient	Waiting Lane		
			Spacing	Width	Effective Length
30-40 kph	4.0 m	4 – 5%	Within 300m	More than 5.0m	More than 20m
20-30 kph	3.0 m	5 – 6%	Within 500m	More than 5.0m	More than 20m
20 kph	2.0 m	6 – 7%	Within 500m	More than 4.0m	More than 10m

d) Temporary Access Road in Landfill Site

Temporary access roads are used for only short period, usually only during the landfilling process at certain areas. The following factors shall be considered when constructing temporary access roads:

- Temporary access roads shall be efficiently built to ensure smooth traffic flow and landfill operations. The traffic flow condition on a rainy day shall be considered.
- When temporary access roads are built above liner system, their layout, method of construction, materials used etc. shall be taken into consideration.
- If necessary, road materials used can be the landfilled wastes or recycled wastes.
- A platform shall be built on the branch access road to improve landfill operations efficiency.
- It is preferable to use crushed stones to prevent slipping on these temporary access roads and also prevent dust. Proper water drainage system shall also be considered.

10.3 Littering Prevention Facility

Littering prevention facility is installed to prevent littering of solid waste from the landfill site to the surrounding environment, especially by wind blow. The size, structure etc. shall be determined depending on the weather and geographical conditions of the landfill site.

(1) Concepts of Lettering Prevention

In order to prevent the solid waste from littering or flowing out of the landfill site to the surrounding areas, cover soils shall be laid as soon as possible during the landfill operation. Sometimes due to reasons such as insufficient cover soil etc., the solid wastes will be exposed and not covered. In this case, littering prevention facility shall be installed. Littering prevention fence shall be about 3 to 4 times the height of the perimeter fencing. Trees can also be planted surrounding the landfill site as wind breakers to reduce the littering of solid waste by wind blow during strong wind events.

In the case of ash or dusts which disperses easily, they can be mixed with other wastes or soils and landfilled immediately. Water can be sprayed to prevent suspended dust but it is important to ensure not over spraying.

Figure II-59 show typical designs for installation of fence as littering prevention facility to catch blowing wastes such as papers and plastic sheets. The fences must be strong against the wind but from the cost effectiveness point of view, a height of less than 3m will be sufficient. In landfill sites where there are a lot of trees, the trees may also be used as a fence for littering prevention.

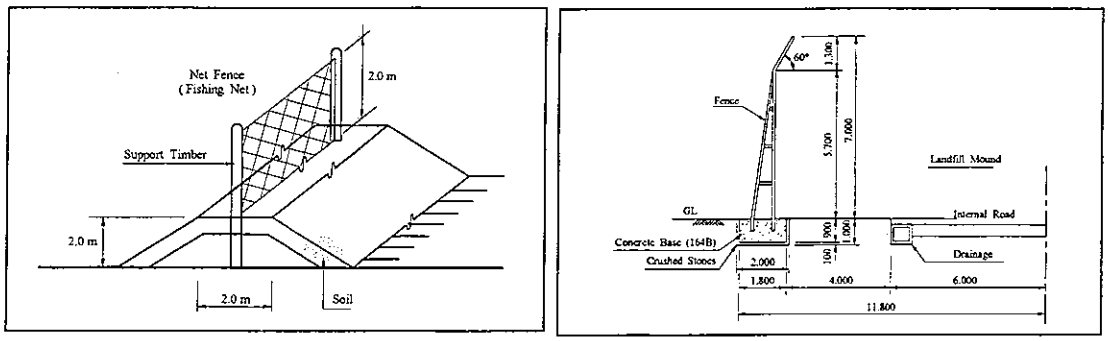

Figure II-59 Typical Design for Installation of Fence

10.4 Notice Boards, Fencing, Gates and Security

Proper gates with security shall be built at the entrance of the landfill site with clear and appropriate notice boards indicating the activities, rules and restriction of the landfill site. Proper fencing system shall be installed surrounding the landfill site to prevent illegal trespassing.

(1) Notice Boards

Notice boards shall be built to clearly indicate the purpose, activities and other information of the landfill site.

(2) Gates and Security

Proper gates shall be built at all entrances or exits of the landfill site with security guards etc. to prevent any illegal trespassing. At the end of a daily operation, the landfill site shall be closed and locked with 24 hours security.

(3) Fencing System

Proper fencing system surrounding the landfill site shall be installed if necessary depending on the location of the landfill site. The fence acts to control the landfill site from any illegal trespassing and illegal dumping. It shall be inspected and maintained regularly for any damage.

10.5 Fire Prevention Facility

Fire prevention facility at landfill sites shall be available at all time so that it can be used to extinguish fire when necessary to prevent outbreak of fire at the landfill sites.

Fire happens at landfill sites is spreading extremely fast because of the generation of methane gas and also other combustible materials. In order to prevent outbreaks of fire, it is therefore recommended that gases generated from the waste layers shall be removed by using proper gas vents, and the wastes shall be covered with soil as soon as possible. By releasing the gas into the atmosphere, explosions and fire in the waste layers can be avoided.

Once fire happens at landfill sites, it will be extremely difficult to be extinguished. Pouring of water directly into the gas venting pipes is prohibited, because dangerous subterranean explosion may occur. Fire extinguishers, water reservoir, sands etc. shall be made available at the landfill at all time. Bulldozers, water spraying trucks etc. shall also be fully equipped. It would be an advantage if the cover soil used is fire-proof. Stocks of cover soil shall be made available so that when a fire breaks out, the cover soils can be used to put off the fire.

Detection of fire at the initial stages is most important in a landfill site so that the fire can be put off before it becomes a serious dump fire. Therefore, daily routine inspection surrounding the landfill site is important in order to detect any hot spot or fire.

10.6 Disaster Prevention Facility

Disaster prevention facility shall be available at all time at the landfill sites and it is necessary in order to prevent damages due to unusual disaster such as heavy rainfall, landslide etc.

(1) Flood Control Ponds

The sanitary landfill system shall be equipped with a flood control facility either a control pond or control trench. When the final or the intermediate surface cover soil is effective in removing the surface runoff which will then be discharged by the stormwater drainage facility, the outflow of rainwater from the landfill site will be greater than the expected discharge volume. Therefore, the flood control facility at the landfill site will be very

important particularly after the landfill is completed. Besides, the flood control facility is also important when there are uncommon heavy rainfall events.

The planning and design of a flood control facility shall be taking consideration the geography of the area, soil quality, final use of the completed landfill site, size of the landfill site, storage facility, etc.

(2) Other Prevention Facilities

During site selection of landfill sites, places with natural disasters such as flood, landslide or avalanche shall be avoided. If a landfill site is constructed in a location where there is possibility for natural disaster like landslide to happen, precaution measures shall be taken such as construction of appropriate disaster prevention facilities.

For example, if a landfill site is located at a mountainous area, there is possibility that overflow of earth and sand or landslide may occur by disastrous rainfall or when cutting through the surface of a mountain to obtain soil for covering work. In such case, masonry retaining wall shall be constructed as preventive measures.

Chapter 11 Capital Costs for Construction of New Landfill Sites

11.1 Basis for Estimation

This chapter is intended to provide a general understanding of the various costs items involved in the provision of the related facilities.

Very few landfill sites in Malaysia have been constructed as Level 3 or Level 4 sanitary landfills. The costs of construction may differ greatly based on the particular conditions of the site, the systems to be included and the surrounding environment.

Table II-34 shows the various criteria that will influence the selection of the facilities and the associated cost.

Table II-34 Criteria for Selection of the Facilities

Criteria	Alternatives	Comments
Topography	1. Mountain area	
	2. Valley area	
	3. Flatland	Assumed for ease of estimation
Cover soil	1. All materials excavated at the site	Valley and trench method for landfill
	2. Materials imported to the site	Mainly flat terrain
	3. Partial import of materials	Soil testing to confirm suitability
Weighbridge	*1. Single unit*	Small incoming waste amount
	2. Two units	Large incoming waste amount
	3. 30 ton capacity	Direct waste transport
	4. 50 ton capacity	Waste transport via transfer station
	5. Connected to computer system	
Site Office	*1. 25m^2 area*	Waste amount of 200t/d
	2. Increased area as waste increases	
Fence	*Chain link fencing*	
Bund	*Partial import of materials to the site*	Confirm based on soil testing
Storm water drains	*450 x 450mm RC U drain*	Confirm based on meteorological data analysis
	300 x 300mm RC V drain	
Gas vents	*HDPE 150mm*	Confirm based on gas estimates
	HDPE 225mm	
On-site road	*1. Crusher run*	Suitable for small scale landfills
	2. Asphalt pavement	
Leachate collection	*1. Main pipe RC perforated 1,000mm*	Selected because of large area. Confirm based on hydrology study.
	2. Main pipe RC perforated 450mm	
	3. Branch pipe RC perforated 450mm	
	4. Branch pipe RC perforated 225mm	
Retention pond	Pond dimensions estimated based on hydrology study	To be confirmed
Re-circulation system	Pump capacity and piping requirements estimated based on hydrology study	
Monitoring well	*1. Two groundwater wells depth 20m*	To be confirmed based on soil investigation and topography
	2. Two gas wells depth 10m	
Aerator	*1. 7.5 kw*	To be confirmed based on pond dimensions required
	2. 15 kw	

Liner	1. Vertical liner	Depends on soil conditions
	2. Horizontal liner (liner sheet plus impermeable layer)	More politically acceptable
Leachate treatment plant	1. Treatment Standard A	In proximity of water intake
	2. Treatment Standard B	Less stringent than Standard A
	3. Biological treatment	
	4. Physical-chemical treatment	

Note: Alternatives in bold letters and italics were selected for the cost estimation purpose

11.2 Cost Estimation

The estimated capital expenditure, CAPEX, for the procurement, installation and construction of the core facilities are tabulated in **Table II-35** and **Table II-36** below.

The cost estimation excluded the cost of procurement of the land or any other engineering design and supervision costs. The engineering and contingency costs may account for 20% of the project costs.

The total costs for the cover materials (for daily and intermediate applications) have been included in the CAPEX. However, during actual operations, the cover material will be not procured all at once but spread throughout the operational life of the site. Nevertheless, the total cost must be budgeted and included as a CAPEX item.

The estimation shall be based on assumptions for the landfill to be constructed on a 10 hectares flat area and the waste to be piled to a height of 9 meters. It is further assumed that the site shall receive 200 ton per day of waste and serve a population of about 330,000 for approximately 7 years.

Table II-35 Summary of CAPEX for Sanitary Landfill

Cost	Level 1	Level 2	Level 3	Level 4
Base on Waste (RM/ton)	9.6	11.2	14.0	38.9
Base on area (RM/ha)	460,000	532,000	665,000	1,855,000

Table II-36 Estimated CAPEX

Item	Cost (RM)	Comment
Level 1		
1. Cover material	4,346,120	Includes daily and intermediate cover layers and assumes half required amount will be imported into the site
2. Weighbridge	150,000	
3. Site office	31,250	Simple 1 storey structure of area 5m x 5m, excluding furniture, etc.
4. Fence	70,000	Fence to be constructed along the total site entire perimeter and includes 2 gates
Sub Total A	*4,597,370*	*RM 9.6/ton or RM 459,000 /ha*
Level 2		
5. Bund	315,000	Surrounding site perimeter
6. Storm water drain	85,692	Includes perimeter drain, cascade drains along slope and pipe drains
7. Gas vents	314,250	Both vertical and horizontal vents
8. On-site road	11,040	Along the site perimeter
Sub Total B (incl. A)	*5,323,352*	*RM 11.2/ton or RM 532,000/ha*
Level 3		
9. Leachate collection	910,000	Main pipes spaced at 20m intervals and branch pipes
10. Retention pond	90,180	Pond dimensions 100m x 10m x 2m depth. Berm and maintenance road provided along the pond.
11. Re-circulation system	30,500	Includes pump and piping system
12. Store-room	126,600	Area of 210m^2
13. Monitoring wells	27,000	Drilling and installation of wells and casing
14. Aerator	147,000	Procurement and installation with mooring
Sub Total C (incl. B)	*6,654,032*	*RM 14/ton or RM 665,000/ha*
Level 4		
15. Liner	5,850,000	Application of horizontal liner (Cover soil 30cm + Liner sheet + Impermeable layer 60cm on a compacted sub grade. Drainage pipe installed under the liner at 20m intervals.
16. Leachate treatment plant	6,053,000	Construction of leachate treatment plant, including building, foundations, and tanks. Aerator cost (item 14) is reduced.
Overall Total (incl. C)	*18,557,032*	*RM 38.9/ton or RM 1,856,000/ha*

Part III

Management of Sanitary Landfill

Part III Management of Sanitary Landfill

Chapter 1 General

The proper management of sanitary landfill sites is essential to preserve the functionality of the landfills as safe solid waste disposal sites and to prevent environmental pollution caused by leachate and the landfill gas.

After the completion of landfilling activities, the sanitary landfills should be closed in a safe and proper manner. Appropriate measures should also be taken to ensure that any future post-closure land use would be carried out effectively and managed properly.

1.1 Management of the Sanitary Landfill Site

The management of sanitary landfill site should be carried out properly to preserve the functionality of the landfill. The important tasks to consider are:

1) Inspection of the Incoming Wastes
2) Management of the Facilities
3) Management of the Landfilling Activities
4) Management of the Environmental Impact
5) Management of the Post Closure Landfill Utilisation
6) Management of the Information and Administrative Structures

Chapter 2 Inspection of the Incoming Wastes

2.1 Necessity for Inspection of the Incoming Wastes

The incoming wastes should be inspected to identify and record the quantity and the type of wastes the being disposed off at the landfill site.

2.2 Items for Inspection

The following items should be inspected, identified and recorded:

1) The Type and Composition of the Incoming Wastes
2) The Quantity of the incoming Wastes
3) The Type and Quantity of the Cover Material Delivered to the Site
4) The Waste Collectors / Transporters
5) The Type and Details of Vehicles Used

(1) Type and Quantity of Waste

The type and quantity of the incoming wastes should be inspected and the data recorded.

(2) Cover Material

The type and quantity of the landfill cover material should also be inspected and recorded.

(3) The Waste Collectors/Transporters

The names of the waste collection/transportation companies should be recorded, together with the information on the sources of the waste.

(4) The Type and Details of Vehicles Used

The type and details of vehicles used for delivery of the waste or the cover material should be recorded, together with the registration numbers of the vehicles.

2.3 Investigation of Wastes Type and Composition

It is recommended that type and composition of the incoming wastes should be identified and analysed periodically.

(1) Items for Investigation

The recommended items to be identified and analysed are;

1) The type and composition of the wastes

2) The moisture content

(2) Frequency of Investigation

The recommended frequency of investigation and analysis are;

1) For the type and composition of the wastes	More than 4 times per year
2) For moisture content	More than 4 times per year

2.4 Inspection Procedures

In order to carry out the proper management of the inspection of the incoming wastes, the proper inspection procedures should be implemented.

(1) Procedures for Inspection

The general procedures for inspection of the incoming waste are as follows:

i. Checking of the documentations of the waste collectors/transporters

ii. Visual inspection of the incoming waste

iii Detailed inspection by taking random samples.

(2) Frequency for Inspection of Incoming

1) Evaluation of preliminary document shall be implemented once a year for incoming wastes throughout the year, and at the time for application for temporary incoming wastes.

2) In principle, inspection of incoming shall be applied to all vehicles except those for incoming wastes collected by municipalities or concessionaires.

3) Detailed inspection using random pick-up method shall be done properly for target vehicles of inspection of incoming.

(3) Measurement of Inspection of Incoming

1) Evaluation of preliminary document shall check types of wastes, etc. according to declaration.

2) Inspection of incoming shall check types of wastes, etc. by inquiry and visual observation.

3) Detailed inspection using random pick-up method shall be done by dumping test and waste composition test.

Chapter 3 Management of The Facilities

3.1 Necessity of Management of the Facilities

The proper operation and maintenance of the facilities in the landfill is an essential part of the management activities of the sanitary landfill.

All the facilities must be operated properly with regular preventive maintenance carried out. Any damages or modifications should be investigates and the necessary repairs or remedial actions be determined and implemented.

3.2 Solid Waste Retaining Structures

3.2.1 Management of Solid Waste Retaining Structures

The solid waste retaining structures should be properly managed to prolong and maintain their functions. Regular maintenance should be carried out to minimise the effects of wear and damage to the structures.

(1) Prevention of Damage

Suitable measure must be carried out to prevent damage to the retaining structures. Some of the recommended actions are;

1) To set up operating procedures and establish the landfill operation manual
2) To provide training for the landfill equipment operators
3) To provide explanation on best practices for landfill management to the operators
4) To investigate the suitability of the retaining structure in response to changes in operations techniques.
5) To investigate the impact to the retaining structure with varying types and compositions of the waste.
6) To have adequate backup measures to response to emergency and disasters, such as heavy rain or flooding.

(2) Inspections

1) The visual inspection should be carried out to determine the conditions of the structure. The necessary tasks are;
   a. To ascertain the extent of the damage
   b. To determine the causes of the damage
   c. To decide on the urgency of remedial actions or repair

d. To formulate the suitable repair plan and schedule of implementation

2) The type and frequency of inspection are as follows:

a. Daily inspection

b. Detailed inspection

c. Emergency inspection

(3) Evaluation of Inspection Results

The results of the inspection should be use to determine the tasks for carrying out the necessary remedial actions. They are;

1) To determine the necessity for emergency measure

2) To determine measure to prevent future occurrences

3) To formulate detailed inspection plan

4) To determine the necessity for repairs

5) To establish the method of repairs

(4) Repair Plan

The repair plan should be established with considerations to the following:

1) The impact on the surrounding environment

2) The impact on other structures

3) The impact on the landfilling activities

4) The estimated cost of repairs

3.2.2 Inspection and Repair of Mound

(1) Daily Inspection

The daily inspection of the mound should be carried out to determine the following:

1) The conditions of sedimentation of the wastes and the earth on the mound

2) The vegetation growth on the mound

3) The signs of seepage through the mound

4) The presence of cracks on the mound

5) The signs of bulging on the mound

6) The signs of subsidence of the mound

7) Conditions of erosion on the surface and slop

8) The presence of soil-slide or slope instability

9) The signs of subsidence of the foundations

10) The signs of water leakage from the ground and from the mound

11) The presence of soil-slide and collapse of the mound

(2) *Detailed Inspection*

The detailed inspection should be carried out to determine the actual conditions of the mound. The tasks to be performed are as follows:

1) To measure the amount of water leakage

2) To measure the rate of subsidence (Mound)

3) To measure the infiltration line (Mound)

4) To measure the pore water pressure (Mound)

5) To measure the force of the wastes exerting on the mound

6) To measure the water level of the landfill site

7) To measure the groundwater levels

8) To investigate the bearing force on the foundations

9) To investigate the core/inner condition of the mound

(3) Repair of Mound

Suitable methods for repair of mound shall be selected according to cause and condition of damage.

3.2.3 Inspection and Repair of Concrete Mound and Concrete Retaining Wall

(1) *Daily Inspection*

Daily inspection of concrete mound should be carried out to determine the following:

1) The condition of sedimentation of the wastes and the earth on the mound

2) The presence of cracks on the surface

3) The signs of flaking of the concrete

4) The signs of damage or gaps at the joints

5) The signs of denudation and corrosion of the reinforcement bars

6) The signs of seepage of Leachate from the mound

7) The signs of subsidence of the mound

8) The signs of declination and extrusion of the mound

9) The signs of movement of the mound

10) The signs of water leakage from the ground and from the mound

(2) Detailed Inspection.

The detailed inspection should be carried out to determine the actual conditions of the mound. The tasks to be performed are as follows:

1) To inspect the material of the structure
2) To measure the stresses of the structure
3) To measure the flexibility of the structure
4) To measure the rate of subsidence, the degree of slanting, and the movement of the structure
5) To measure of amount of water leakage
6) To inspection the ground foundations
7) To measure the force of the wastes exerting on the mound
8) To measure the water levels
9) To inspect the environmental condition such as water quality, aspect of wastes, etc.

(3) Repair of Concrete Mound

Suitable methods for repairing the concrete mound should be selected according to cause and condition of damage.

3.3 Stormwater Drainage Facility

(1) Management of Stormwater Drainage Facility

The stormwater drainage facility should be properly managed to prolong and maintain their functions. Regular maintenance should be carried out to minimise the effects of wear and damage to the facility.

(2) Cleaning of Stormwater Drainage Facility

The stormwater drainage facility should be cleaned regularly to maintain the facility in good working conditions. The necessary tasks are as follows;

1) To remove the sedimentation of wastes and earth in the drains, corrugated flume, collection pit, connection pit, tap work, etc.
2) To remove the plant growth at surrounding and on the drains, etc
3) To move the sediments at disaster prevention reservoir
4) To move the weeds grown at disaster prevention reservoir

(3) Daily Inspection

The daily inspections should be carried out to determine the following:

1) Storm water drainage
   a. The extent of damage and uneven subsidence of drains, etc.
   b. The condition of sedimentation of wastes and earth at the drains, etc.
   c. The locations and conditions of the overflow or points of stagnation
   d. The presence of abnormal conditions of the joints with lining facility
   e. The water inflow conditions and the sediments from surrounding
   f. The conditions of the surrounding plant growth weeds
2) Disaster prevention reservoir
   a. The existence of damage of guard fence
   b. The level of retaining water
   c. The sedimentation condition at the bottom of the reservoir
   d. The sedimentation condition on the slope
   e. The growing condition of weeds on the slope
   f. The condition of dam and slope
   g. The condition of sedimentation at the outlet and discharge channel
   h. The existence of damage of the outlet and discharge channel

(4) Repair of Stormwater Drainage Facility

The repair plan should be established with considerations to the following:

1) The impact on the surrounding environment
2) The impact on the structures of the other buildings
3) The impact on the landfilling activities
4) The estimated cost of repairs

3.4 Leachate Collection Facility

(1) Management of Leachate Collection Facility

The leachate collection facility should be properly managed to prolong and maintain their functions. Regular inspection should be carried out to check on conditions of the leachate and to prevent ponding and stagnation. Regular maintenance should be carried out to minimise the effects of wear and damage to the facility.

(2) Prevention for Damage of Leachate Collection Facility

Suitable measure must be carried out to prevent damage to the leachate collection facility. Some of the recommended actions are;

1) To set up operating procedures and establish the landfill operation manual
2) To provide training for the landfill equipment operators
3) To provide explanation on best practices for landfill management to the operators
4) To investigate the suitability of the facility in response to changes in operations techniques.
5) To investigate the impact to the facility with varying types and compositions of the waste.
6) To provide regular greasing and testing of equipment, valves, etc.

(3) Daily Inspection

Leachate collection facility shall be inspected for following items:

1) Collection pipes and water conveyance pipes at the surface of the earth
   a. The presence of cracks or damaged to the pipes
   b. The build up of scales inside the pipes
   c. The signs of pipe leakage at the joints
   d. The clogging of the of pipes (inspection of the inside of the pipes by observations from the outlet and the manhole)
   e. The jammed or clogging of the valves
2) Collection pipes buried in landfill layers

The visual inspection of the buried pipes may not be easy. The conditions of the pipes will have to be determined based on certain tell-tail signs as follows:

a. Check on the amount of water at the outlet of leachate collection facility
b. Check on the water level retained in landfill site
c. Check for signs of localised surface subsidence or cavities forming on the surface of

the earth

d. The clogging of the of pipes (inspection of the inside of the pipes by observations from the outlet and the manhole)

(4) Repair of Stormwater Drainage Facility

The repair plan should be established with considerations to the following:

1) The impact on the surrounding environment
2) The impact on the structures of the other buildings
3) The impact on the landfilling activities
4) The estimated cost of repairs

3.5 Leachate Treatment Facility

(1) Management of Leachate Treatment Facility

The operation and maintenance and repair of the leachate treatment facility should be carried out properly so that the facility is able to treat and discharge the treated effluent to comply with the relevant environmental standards.

(2) Daily and Detail Inspections

The leachate treatment facility should be inspected to determine the following:

1) The quantity and quality of leachate and the treated effluent water
2) The most appropriate operational conditions
3) The adjustments and repairs necessary for each facility and the equipment

(3) Frequency of Inspection

The recommended frequency of the inspection is as follows:

1) The daily inspection activities should be carried out once a day.
2) The periodical inspection activities should be carried out ranging from once a week to once a month.

3.6 Lining Facility

3.6.1 Management of Lining Facility

The lining facility should be protected and managed properly so that the facility is able to maintain its function and prevent leachate from seeping further into the ground. Proper landfilling activities must be adhered to so that the lining will not be damaged during operations.

(1) Prevention of Damage of Lining Facility

Suitable measure must be carried out to prevent damage to the lining facility. Some of the recommended actions are;

1) To set up operating procedures and establish the landfill operation manual
2) To provide training for the landfill equipment operators
3) To provide explanation on best practices for landfill management to the operators
4) To investigate the suitability of the lining facility in response to changes in operations techniques.
5) To investigate the impact to the retaining structure with varying types and compositions of the waste.
6) To protection the lining facility that has been exposed to the air or a long time, i.e. by using cover soil, etc.

(2) Inspections

1) The visual inspection should be carried out to determine the conditions of the lining facility. The necessary tasks are;
   a. To ascertain the extent of the damage
   b. To determine the causes of the damage
   c. To decide on the urgency of remedial actions or repair
   d. To formulate the suitable repair plan and schedule of implementation
2) The type and frequency of inspection are as follows:
   a. Daily inspection
   b. Detailed inspection
   c. Emergency inspection

(3) Evaluation of Inspection Results

The results of the inspection should be use to determine the tasks for carrying out the necessary remedial actions. They are;

1) To determine the necessity for emergency measure
2) To determine measure to prevent future occurrences
3) To formulate detailed inspection plan
4) To determine the necessity for repairs
5) To establish the method of repairs

(4) Repair Plan

The repair plan should be established with considerations to the following

1) The impact on the surrounding environment
2) The impact on other structures
3) The impact on the landfilling activities
4) The estimated cost of repairs

3.6.2 Methods for Inspection and Repair of Liner Sheet

(1) Daily Inspection of Liner Sheet

The daily inspection of the lining sheet should be carried out to determine the conditions of the liners. The tasks to be performed are as follows;

1) Exposed condition
   a. To inspect the rate of sedimentation of wastes and earth
   b. To inspect the integrity of the joints
   c. To inspect for puncture marks and torn surfaces
   d. To check for cracks appearing on the surface
   e. To check for abnormal stretching or shrinkages of the sheets
   f. To check for the degradation of the material of the sheet, i.e. softening or hardening
   g. To check for surface eruptions or deformation.
2) Covered condition by soil

The visual inspection of the covered liners may not be possible. The conditions of the liners will have to be determined based on certain tell-tail signs as follows:

a. The presence of cracks or cavity on the surface
b. The presence of groundwater leaking through or the detection of escaping landfill gas
c. The sign of floating
d. The sign of slipping and collapse

3) Buried condition under the landfill layer

Similarly, the inspection of the buried liners is not possible. The conditions of the liners will have to be determined based on certain tell-tail signs as follows:

a. Check on the amount and quality of the water at the outlet of leachate collection facility

b. Check on the amount and quality of the water at the outlet of groundwater collection facility

c. Check on the quality of the water samples in the inspection well

d. Cracks and cavity-on the surface soil

(2) Detailed Inspection of Liner Sheet

The detailed inspection should be carried out to determine the actual conditions of the liner sheet. The tasks to be performed are as follows:

1) To check on the condition of the joints

2) To carry out the tensile test on the material

3) To check on the rate of elongation, the variation in thickness and abnormal deformation

4) To check on the groundwater level

5) To check on the sliding and collapse of the foundations

6) To measure the bearing capacity of the soil (for uneven subsidence)

(3) Repair of Liner Sheet

Suitable methods for repairing the damaged liner sheet should be determined and carried out according to the causes and condition of damage.

3.6.3 Measure of Inspection and Repair of Earth Lining Facility

(1) Daily Inspection of Earth Lining Facility

The daily inspection of the earth lining sheet should be carried out to determine the conditions of the liners. The tasks to be performed are as follows:

1) Exposed condition

a. To inspect the rate of sedimentation of wastes and earth

b. To inspect the plant growth

c. To check for cracks appearing on the surface

d. To check on holes or cavity

e. The presence of groundwater leaking through or the detection of escaping landfill

gas

f. To check on the sliding and collapse

g. To check the floating

h. To check the flowing out of the earth lining

i. Surface erosion caused by flow of water

2) Covered condition by soil

(Refer to Item 2) of subsection 3.6.2(1))

3) Buried condition under the landfill layer

(Refer to Item 3) of subsection 3.6.2 (1)).

(2) Detail Inspection of Earth Lining Facility

The detailed inspection should be carried out to determine the actual conditions of the earth lining. The tasks to be performed are as follows:

1) To check on the inner condition of the lining facility

2) To check on the thickness of the lining facility

3) To determine the coefficient of permeability of the lining facility

4) To check on the swelling of the lining facility

5) To check on the condition between the lining facility and the foundation

6) To measure the groundwater level

7) To check on the sliding and collapse of the ground

8) To measure the bearing capacity of the ground (for uneven subsidence)

9) To check the crack of the ground

(3) Repair of Earth Lining Facility

Suitable methods for repairing the damaged earth liner sheet should be determined and carried out according to the causes and condition of damage.

3.6.4 Measure of Inspection and Repair of Paths and Road Surfaces

(1) Daily Inspection of Paths and Road Surfaces

The daily inspection of the earth lining sheet should be carried out to determine the conditions of the liners. The tasks to be performed are as follows:

1) Exposed condition

a. To inspect the rate of sedimentation of wastes and earth

b. To check for cracks appearing on the surface

c. To check for depression and cavity

d. To check for peeling and collapse

e. To check on the deterioration

f. To check on the swelling

g. To check on the condition of the asphalt that may be eluted by leachate or wastes

2) Covered condition by soil

(Refer to Item 2) of subsection 3.6.2(1))

3) Buried condition under the landfill layer

(Refer to Item 3) of subsection 3.6.2 (1)).

(2) Detail Inspection of Paths and Road Surfaces

The detailed inspection should be carried out to determine the actual conditions of the earth lining. The tasks to be performed are as follows:

1) To measure the coefficient of permeability

2) To measure the groundwater level

3) To check for the sliding and collapse of the ground

4) To check for depression or cavity in of the ground

5) To measure the bearing capacity of the ground soil

6) To Investigation the effects of the waste and leachate on the surface

(3) Repair of Paths and Road Surfaces

Suitable methods for repairing the damaged earth liner sheet should be determined and carried out according to the causes and condition of damage.

3.7 Incoming Wastes Monitoring Facilities

(1) Management of Incoming Wastes Monitoring Facilities

The operation and maintenance of the incoming wastes monitoring facilities should be carried out properly so that the facility is able to function efficiently. The facilities should be inspected regularly to check on the wear and tear of the equipment. Any damages or modifications should be investigates and the necessary repairs or remedial actions be determined and implemented.

(2) Cleaning of Incoming Wastes Monitoring Facilities

The incoming wastes monitoring facilities should be cleaned regularly to maintain the facility in good working conditions. The necessary tasks are as follows:

1) To clean the area around weighbridge
2) To clean and to remove any water found inside the weighbridge pit
3) To cleaning the area around the incoming wastes monitoring facilities
4) To cleaning the inside of the administrative office

(3) Daily Inspection

The daily inspection of the incoming wastes monitoring facilities should be carried out to determine the conditions of the facilities. The tasks to be performed are as follows:

1) To inspect the weighbridge
   a. To check on the operation of the equipment instrumentations such as the load cells
   b. To check on the operation of the computer systems for data collection, etc.
   c. To check for malfunction of machinery, material fatigue or damage
   d. To measure the electrical resistance of the circuits
   e. To measure the humidity inside the pit
   f. To check on the conditions of the concrete structure and the surroundings

(4) Repair Plan

The repair plan should be established with considerations to the following:

1) The impact on the surrounding environment
2) The impact on other structures
3) The impact on the landfilling activities
4) The estimated cost of repairs

3.8 Access Road

(1) Management of Access Road

The maintenance and cleaning of the access road should be carried out properly so that the ingress and egress activities can be carried out smoothly and efficiently. The access road should be inspected regularly to check on the wear and tear of road. Any damages or modifications should be investigates and the necessary repairs or remedial actions be determined and implemented.

(2) Cleaning of Access Road

The access road should be cleaned regularly to maintain the facility in good working conditions. The necessary tasks are as follows:

1) To clean of the wastes or earth and sand scattered on the road
2) To clean and remove the wastes or earth and sand deposited in the roadside drains
3) To remove the wastes or earth and sand deposited on the slopes by the side of the road
4) To remove the plant growth on the slope

(3) Daily Inspection

The daily inspection of the access road should be carried out to determine the conditions of the road. The tasks to be performed are as follows:

1) Road surface
   a. To inspect for falling rocks and earth on the surface
   b. To inspect for holes, ruts, cracks, and ballasting condition
2) Drains
   a. To check on the deposits or sediments
   b. To check for trapped or stagnate water puddles
   c. To check for damage to the drains
3) Building structures (Retaining wall, bridge, etc.)
   a. To check on the conditions and damage to the structures
   b. To check on the rate of subsidence of the structures
4) Road shoulder, slope, etc.
   a. To check on the condition of the road shoulders
   b. To check on the sliding and collapse of slope
   c. To check on the spring water on the slope
5) Others facilities
   a. To check on the damages
   b. To check on the degree of cleanliness

(4) Repair of Access Road

The repair plan should be established with considerations to the following:

1) The impact on the surrounding environment
2) The impact on other structures
3) The impact on the landfilling activities

4) The estimated cost of repairs

(5) Management of Bridge

1) Te bridges and the surrounding slopes should be inspected periodically and checked for any unusual signs of wear or damage.

2) The repair plan should be formulated and be implemented.

3.9 Other Supporting Facilities

(1) Management of Other Supporting Facility (Littering Protection Facility, Sign Board, Gate, Fence, Fire Protection Facility, etc.)

The other supporting facilities should also be inspected. All these facilities are an integral part for the smooth operations of the site. The facilities should be inspected periodically to check on the wear and tear. Any damages or modifications should be investigates and the necessary repairs or remedial actions be determined and implemented.

(2) Daily Inspection

The daily inspection of the other supporting facilities should be carried out to determine the conditions of the facilities. The tasks to be performed are as follows:

1) To check on the general cleanliness of the facilities

2) To check on the wear and tear or damage of the facilities

3) To check on the operational conditions of the facilities

(3) Repair Plan

The repair plan should be established with considerations to the following:

1) The impact on the surrounding environment

2) The impact on other structures

3) The impact on the landfilling activities

4) The estimated cost of repairs

3.10 Landfill Gas Venting Facility

(1) Management of The Landfill Gas Venting Facility

The landfill gas venting facility should be managed properly to ensure the toxic and hazardous gases are vented and removed in a safe manner. The facility should be inspected periodically to check on the wear and tear of vent pipes. Any damages or modifications should be investigates and the necessary repairs or remedial actions be determined and implemented.

(2) Prevention of Damage to the Landfill Gas Venting Facility

Suitable measure must be carried out to prevent damage to the gas venting facility. Some of the recommended actions are;

1) To set up operating procedures and establish the landfill operation manual
2) To provide training for the landfill equipment operators
3) To clarify the installation method of gas venting facilities during landfilling works
4) To take measures to prevent clogging of the pipes

(3) Daily Inspection

The daily inspection of the gas venting facility should be carried out to determine the conditions of the facility. The tasks to be performed are as follows:

1) To inspect the gas venting facility for signs of distortion
2) To inspect the gas venting facility buried in landfill layer

The inspection of the buried pipes may not be possible. The conditions of the pipes will have to be determined based on certain tell-tail signs as follows:

a. The change in the amount and quality of gas emissions from the vents
b. The release of landfill gas from landfill surface other than from the vents
c. The change in the water quality of the leachate

3) To inspect the gas treatment facility at the final process

(4) Repair Plan

The repair plan should be established with considerations to the following:

1) The impact on the surrounding environment
2) The impact on other structures
3) The impact on the landfilling activities
4) The estimated cost of repairs

Chapter 4 Management of the Landfilling Activities

4.1 Necessity of Management of the Landfilling Activities

In order to maintain and prolong the life span of the landfill, proper operations and management of the landfilling activities should be carried out. Effective management of the landfill process will have a positive impact on the waste decomposition and stabilisation process, and an improvement in leachate and gas qualities.

4.2 Management of Landfilling Activities

(1) Landfilling Process and Management of the Landfilling Activities

The landfilling process encompasses all the activities necessary for the proper and safe operations of the landfill. The management of the landfilling activities should include the monitoring of the incoming wastes, the prevention of environmental pollution, planning for closure and post closure land use, and the protection of the health and safety of workers and public.

The management activities can be divided into Performance Management and Safety Management.

(2) Levelling and Compaction

As part of the daily operating procedure, the proper landfill activities must be carried out, i.e. the spreading and levelling of the incoming waste, compaction and putting on the soil cover. All these will prolong the lifespan of the site and also to prevent uneven settlement and subsidence.

(3) Selection of Landfill Equipment

In order to carry out the landfilling management activities, it is important that the right types of equipment or machinery are being used. The selection of the machinery should be based on the type of waste received by the landfill and the degree of compaction required. The selection process should also take into account of the closure and post-closure utilisation of the site so that the appropriate measure could be taken.

4.3 Performance Management

The management of performance activities generally related to the management of degree of subsidence of the landfill. The subsidence rate can be used to determine the stabilisation of the waste decomposition process. The results can then be used to determine the remaining life span of the site, and to prepare for closure of the site. It can also be used to determine the appropriate post closure land use.

The daily operational and performance data and information must be recorded and documented.

(1) Benchmarking of the Performances

The benchmarking or measurement of the performances of the different zones in the landfill site should be carried out to ensure that the proper management activities have been carried out. The data can also be used to determine the remaining lifespan of the site and allow the operators to plan for the future landfilling works, and for the post closure land use.

(2) Management of Land Subsidence

The monitoring and measurement of the rate of land subsidence should be carried out in order to determine the degree of stabilisation of the ground. Basic topographical surveys should be carried out periodically to record the varying ground levels.

4.4 Safety Management

Safety-at-work procedures must be established at the site in order to prevent any accidents. Proper safety management must be carried out to ensure a safe and healthy working environment for the operators.

4.5 Management of Information on Landfilling

The information and data gathered during landfill operations must be recorded and documented. The assessment of the data can then be used to formulate the best operating practices and new improved management techniques. The data can also be used for reference for future closure and post closure activities.

Chapter 5 Environmental Management

5.1 Necessity for Environmental Management

It is necessary to manage the operations of the landfill properly in order to protect the environment, and to manage and minimise the impact caused by the waste, leachate and the landfill gas.

5.2 Leachate Control

The amount and quality of the leachate should be monitored and analysed periodically in order to determine the conditions of the landfill and the potential impact to the environment. The data can also be used to determine the rate of stabilisation of the landfill.

(1) Monitoring Points for Leachate Measurements

Monitoring points for leachate measurements shall be outflow point of leachate from the landfill site. In case the landfill site consists of several land filing phases, each phase shall be covered for the measurements.

(2) Leachate Monitoring

The monitoring and measurement of the leachate production should take into account of the following:

1) The weather conditions
2) The temperature and humidity during sampling
3) The amount and frequency of rainfall
4) The amount of the leachate
5) The quality of the leachate

(3) Frequency of Monitoring

The recommended frequencies for the leachate monitoring measurement activities are as follows:

1) For measuring the parameters that are easy to be measured automatically - once a day
2) For measuring the parameters which are necessary for daily operation control due to keep the efficiency of water treatment facility and fluctuate in a wide range: Once a week - once a month
3) For measuring the parameters which are not directly needed for operation management of water treatment facility, but fluctuate in a wide range: Once a month

4) For measuring the parameters which are hardly fluctuate: Once a year

(4) Sampling of Leachate

The sampling method must be in accordance to internationally accepted good practices and procedures. Sampling activities should not change or affect the quality of the leachate.

5.3 Monitoring of the Effluent

The effluent discharged form the leachate treatment facility should be monitored. The quality of the discharge should comply with the relevant environmental standards.

(1) Monitoring Points for Effluent Measurements

In practice, the monitoring point for effluent monitoring should be at the discharge point of the leachate treatment facility to the parameter drains or to the waterways. If the case where the effluent is not directly discharged to the waterways, i.e. discharged to a retention pond etc, then a new monitoring point will be required and should be at the discharge point where the effluent is actually discharged to the outside drains or waterways.

(2) Effluent Monitoring

The monitoring of the effluent should consist of the following:

1) The amount of the effluent discharged
2) The quality of the effluent

(3) Frequency of Monitoring

The monitoring of the effluent should be carried out periodically. Generally, the frequency should correspond to the frequency of the leachate monitoring activities. However, regular measurements may be taken and recorded in order to check on the performance of the leachate treatment facility.

(4) Sampling of Effluent

The sampling method must be in accordance to internationally accepted good practices and procedures. Sampling activities should not change or affect the quality of the effluent.

5.4 Monitoring of the Landfill Gas

The amount and quality of the landfill gas should be monitored and analysed periodically in order to determine the conditions of the landfill and the potential impact to the environment. The data can also be used to determine the rate of stabilisation of the landfill.

(1) Monitoring Points for Landfill Gas Measurement

Suitable landfill gas monitoring wells should be provided. Such wells should be independent and should not be connected to the leachate pipes. The monitoring wells should be located at an interval of about 50 to 100 meter apart.

(2) Landfill Gas Monitoring

The monitoring and measurement of the landfill gas production should take into account of the following:

1) The weather conditions
2) The ambient temperature of the environment
3) The barometric pressure of the environment
4) The temperature of the sampled gas (depending on temperature inside waste layer, depth, etc.)
5) The flow rate of gas discharge
6) The composition of generated gas (by laboratory analysis)
    a. Methane (CH4)
    b. Carbon dioxide (CO2)
    c. Nitrogen (N2)
    d. Oxygen (O2)

(3) Frequency of Monitoring

The landfill gas monitoring exercise should be carried out not less than twice a year.

(4) Sampling of Landfill Gas

The sampling method must be in accordance to internationally accepted good practices and procedures. Sampling should take into account of the atmospheric conditions of the surrounding.

5.5 Prevention of Water Pollution

It is important that the water quality of the surrounding area should be monitored regularly to ensure that the contaminated water from the landfill site has not polluted the surrounding water sources.

(1) Monitoring Points for Water Quality Measurement

The water quality monitoring points should be located down stream of the landfill site. However, it may be necessary to take control samples at the upstream as well so that the comparison of the differences in quality can be carried out.

(2) Water Quality Monitoring

The monitoring and measurement of the water quality of the surrounding areas should take into account of the following:

1) The proximity of the sampling point to the landfill
2) The amount and frequency of rainfall

(3) Frequency of Monitoring

The monitoring of the surrounding water quality should be carried out periodically. Generally, the frequency should correspond to the frequency of the leachate and effluent monitoring activities. The recommended frequency should not be less than four times a year.

(4) Method of Sampling

The sampling method must be in accordance to internationally accepted good practices and procedures. Sampling activities should not change or affect the quality of the original source.

5.6 Prevention of Offensive Odour

The landfilling activities should be carried out properly and management effectively to reduce the emission of the unpleasant odour and minimise the impact to the surrounding residents.

(1) Monitoring Points for Odour Measurement

It is not possible to quantify the odour emitting from the landfill. The state or degree of unpleasantness can only be determined by smelling the air and also dependant on the prevailing atmospheric conditions. The "measurement" of the odour can only be expressed in the distance from the source where the odour can still be detected.

(2) Odour Monitoring

Since the odour cannot be quantified, the "smell" or "unpleasantness" will have to be determined by odour concentration and substance, i.e. how bad it smells and what does it smell like.

(3) Frequency of Monitoring

Since the odour is not quantifiable, there is no prescribed frequency of monitoring. Generally, the odour should be monitored daily or as-and-when necessary, as long as it is not having a major impact on the surrounding.

5.7 Prevention of Noise and Vibrations

The landfilling activities should be carried out properly and management effectively to reduce the excessive noise and vibrations caused by the movement of vehicles and operations of the machinery. The noise and vibration levels should be minimal and comply with the relevant regulation as set out for the protection of occupational safety and health.

(1) Monitoring Points for Noise and Vibration Measurements

The noise and vibration monitoring measurement should be carried out at or near the generation source. Other monitoring locations could be along the perimeter of the landfill or at the nearby residents.

(2) Frequency of Monitoring

The recommended frequency of monitoring should be carried out not less than once a year.

(3) Method of Measurement

The measurement method must be in accordance to internationally accepted good practices and procedures.

5.8 Management of Prevention of Breeding of Vectors and Animals

The landfill should be managed and protected against the propagation of vectors and animals. Suitable preventive measures should be carried out such as installation of fences, providing daily soil cover and the spraying of insecticide (if necessary).

5.9 Prevention of Littering of Wastes

The landfilling activities should be carried out and managed properly in order to prevent the scattering and littering of the waste. Suitable preventive measures should be carried out such as providing daily soil cover and carrying the compaction work.

Chapter 6 Management of Post Closure Landfill Site

6.1 Necessity of Management of Post Closure Landfill Site

Even long after the landfilling of the wastes has been completed, the degradation process of wastes will continue. Leachate and landfill gas will still be produced. The management of the landfill facilities should be continued even after the closure of landfill site and through out the post closure land use phase.

6.2 Leachate Control

Even after the closure of the sanitary landfill, the amount and quality of leachate may still remain at high levels. Regular monitoring should be carried out until it is considered that the leachate levels are sufficiently low that it has no major impact on surrounding environment.

6.3 Control of Generated Gas

Similarly, the monitoring of the landfill gas should be carried out until it is considered that the gas levels have no major impact on surrounding environment.

6.4 Control of Land Subsidence

The landfilled area may subside due to the degradation and compaction of the wastes during the decomposition process. The ground conditions and levels should be monitored and measures periodically in order to determine the state and the rate of subsidence.

6.5 Monitoring of the Degradation and Stabilisation of the Waste

The conditions of the degradation and stabilisation of the wastes should be monitored periodically in order to prevent further environmental pollution during the closure and post closure land use phases.

(1) Assessment of the Degradation and Stabilisation of the Waste

The conditions of the degradation and stabilisation of the wastes should be assessed periodically in order to determine state and rate of degradation of landfilled waste layers.

1) Sampling of landfilled wastes

Sampling location of the landfilled waste shall be decided taking into account the year waste disposed of, waste types etc. In case the landfill site consists of several phases, each phase shall be covered for the sampling.

(2) Items for Measurement

To determine the degradation and stabilization of wastes, following items should be measured.

1) The composition of the waste
2) The moisture content
3) The water quality inside waste layers
4) The gas quality inside waste layers
5) The temperature inside waste layers

(3) *Frequency of Monitoring*

The recommended frequency for monitoring the conditions of degradation and stabilisation of wastes should be once every two or once every three years.

6.6 *Utilization and Management of Post Closure Landfill Site*

The proper land use plan should be formulated in consideration of the characteristics of the ground of the landfill site. The post closure management should also be implemented to minimise the impact on the users of the land.

Chapter 7 Management of Information and Administrative Structure

7.1 Management of Information

Information gathered during the operation of the sanitary landfill should be documented and managed properly so that the data may be utilised by the other management departments.

7.2 Administrative Structure

A dedicated administrative structure should be set up to oversee and carry out the proper operations of the landfill.