Appendix 11

Indicators for The Stability of Closed Landfill Sites

(1) Physical Conditions

a) Rate of subsidence

The rate of subsidence for the stabilized landfill should be less than 20mm per year.

The subsidence rate should be monitored regularly and the level survey should be carried annually. Benchmarks should be installed at suitable locations on the surface of the top coil soil. The minimum recommended number of benchmarks is two (2), or one (1) for each hectare of the site. The subsidence should be monitored and observed for more than two years.

b) Top covers

The top cover should not exhibit any surface cracks, pools or signs of soil erosion. The soil cover should be of sufficient thickness to protect the filled waste layer. The recommended thickness is more than 750mm and should be well compacted. The top cover should be planted with scrubs, vegetation or grass to prevent dust and soil erosion. Especially the thickness is recommended to be more than 1500mm for planting trees.

(2) Chemical Conditions

a) Quality of the raw leachate

The sites have reached stability when the quality of the untreated raw leachate discharged from the landfill has maintained constant for at least two years and is within the approved limits and complies with the relevant effluent discharge standards. If the effluent discharge does not meet with the standards, then the leachate treatment facility should continue to be operated.

b) Quality of landfill gas

The concentrations of landfill gas should satisfy the following conditions.

(i) Not volatile and explosive: The methane levels should be less than 5% (by volume)

(ii) Not cause suffocation: The oxygen levels should be higher than 18% (by volume)

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

c) Quality of groundwater around the site

No pollution to the groundwater around the site should be observed. The number of the monitoring wells is one for upstream (as for background monitoring well) and two for downstream (as for detection well).

d) Temperature of the waste layers

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

Appendix 12

Stabilization Process of Landfill Site (Old sites in Japan)

(1) OUTLINE OF INVESTIGATION SITE

Investigation of the landfill site at the Tokyo harbour in Japan was implemented from 1981 about four sites (The No.8 site, The No.14 site, The No.15 site, The Inner central-breakwater landfill site). In these four sites, the observation base is installed. The outline of landfill sites for investigation is as follows.

Table A12-1 Outline of Investigation Site

	Term of landfill works	Landfill area	Amount of waste disposal	Thickness of landfill layer
The No.8 site	1927-1962	36.4 ha	3,710,000 t	14 m
The No.14 site	1957-1967	45 ha	10,340,000 t	14 m
The No.15 site	1965-1974	71.2 ha	18,440,000 t	14-20 m
The Inner central-breakwater landfill site	1973-1987	78 ha	12,300,000 t	30-32 m

Most of the waste filled in these sites was raw MSW and some incineration residues filled in the fourth site, because the sites were operating more than 20 years ago. The characteristics of these wastes may not be much different from the waste generated in Malaysia at present time.

(2) SUBSIDENCE OF LANDFILL SITE

In the case of the inner central-breakwater landfill site, the amount of subsidence has occurred about 40mm per year in early stages of the landfill when the decomposition of waste is active. The amount of subsidence decreases slowly over time.

When 20-25 years pass after landfilling was completed, the amount of annual subsidence per 10m of waste layers is about 10mm or less. In the result which analyzed the observation result by regression analysis, the amount of subsidence of a landfill site tends to become small according to the hyperbola.

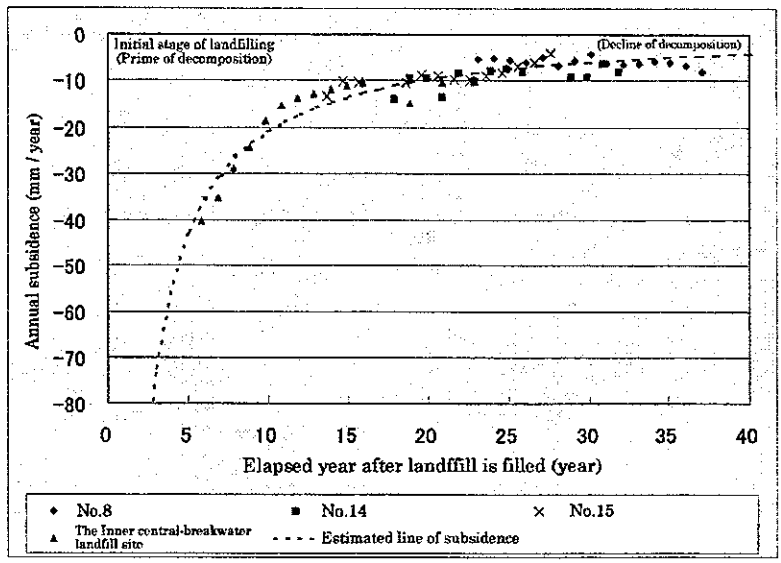


Figure A12-1 Change of Annual Subsidence

(3) CHANGE OF TEMPERATURE INSIDE LANDFILL

The distribution of temperature inside landfill site changes as decomposition of landfilled waste,

In early stages of the landfill, there are about a maximum of 70 degrees of temperature.

When decomposition is completed at the most part, temperature will become 20 degrees or less like the natural ground which is deeper than a landfill layer.

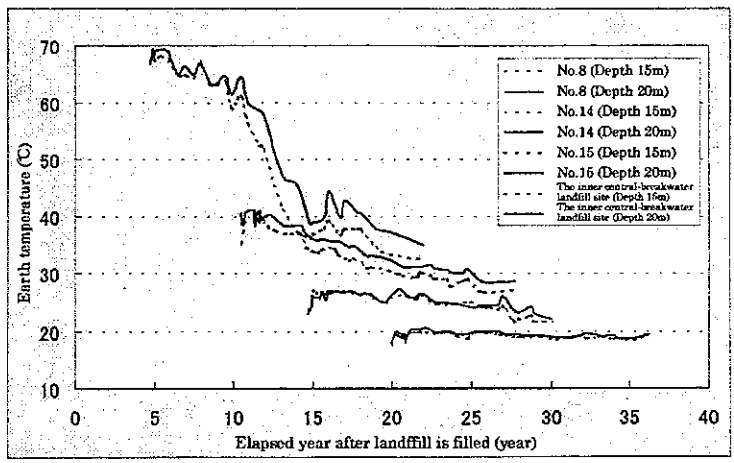


Figure A12-2 Change of Temperature Inside Landfill

(4) CHANGE OF GAS GENERATION

In early stages of landfilling (prime of decomposition), the amount of gas generation is 70-90 L/min. The amount of gas generation changes as decomposition of landfilled waste, it becomes almost 0 L/min in last stage of decomposition.

As for the concentration of the various gas components which constitute landfill gas, methane and carbon dioxide occupy the great portion of generating gas in early stages of landfilling. In last stage of decomposition, the concentration of methane becomes about 5% and the concentration of carbon dioxide becomes about 10%.

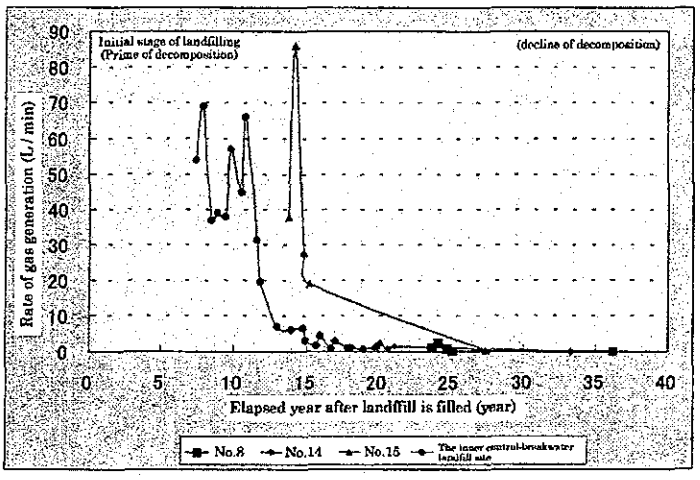


Figure A12-3 Change of Gas Generation Rate

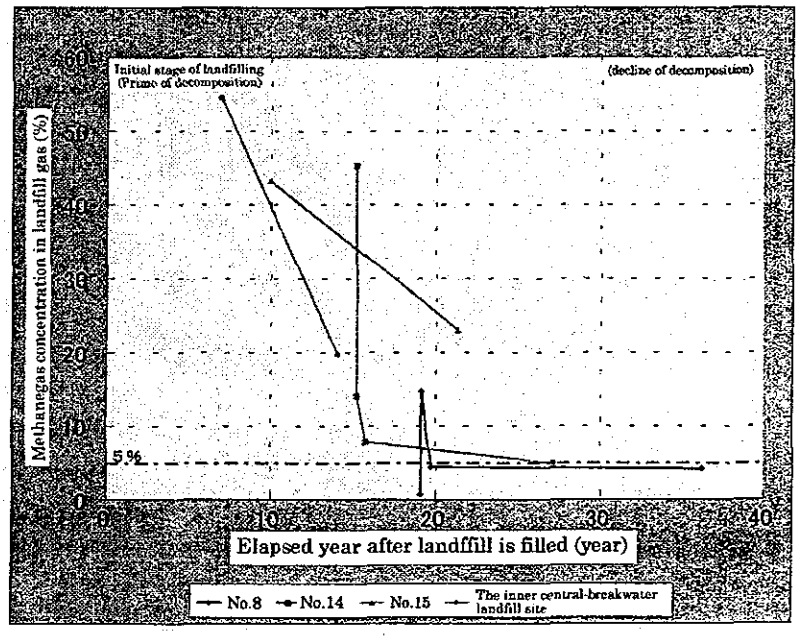


Figure A12-4 Change of Methane Gas Concentration

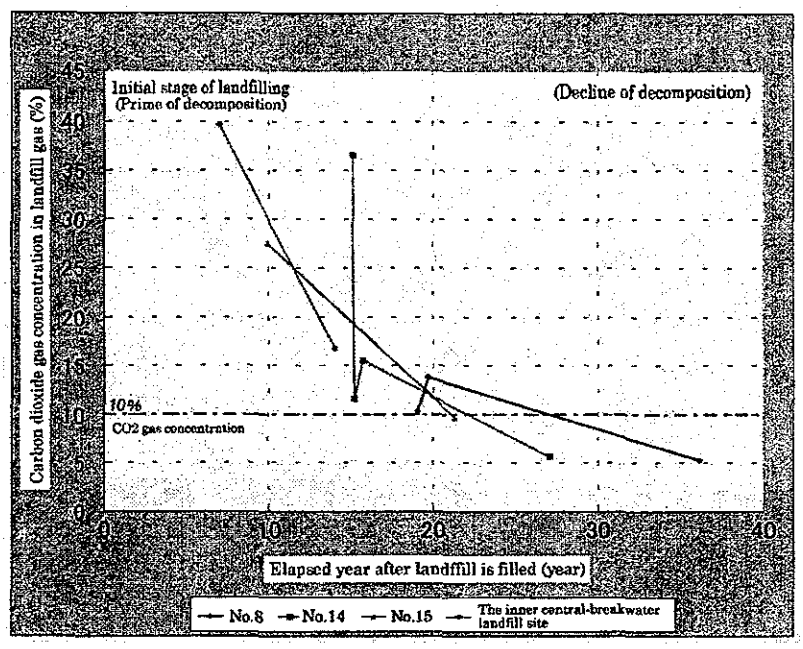


Figure A12-5 Change of Carbon Dioxide Gas Concentration

Appendix 13

Maintenance of Landfill Facilities

(1) TOP COVER & DYKES

Since damage of top cover or a storage structure causes the following troubles, maintenance of the top cover and dykes is needed.

- Scattering or outflow of waste
- Occurrence of offensive odour or vectors
- Disaster which has direct influences in the life of the person such as the collapse of the landfilled waste
- Obstruction for the post-closure land use by the erosion of ground
- Destruction of the landscape
- Increase of the leachate quantity by the increase of the soaking of the rain water into landfilled layer

As the inspection of top cover and dykes, visual inspection to the portion which has appeared on the ground shall be performed about the following items. Frequency of regular inspection shall be decided in view of the condition of these facilities. In addition, extra inspection shall be performed in case the heavy rain took place. Areas where stress is concentrated for structural reasons shall be designed in advance as areas requiring inspection.

- Leakage from dykes
- Cracks in the top cover and dykes
- Subsidence of the top cover and dykes
- Erosion of the top cover and dykes
- Swelling of the slope
- Collapse or slip down of slope
- Dead of vegetation on the top cover and dykes

When damaging is confirmed, repair shall be performed.

If a crack and corrosion are left, corrosion will be accelerated by rain and repair will become difficult. Therefore, brisk check and quick repair are important. The frequent check and the quick repair are necessary.

(2) SURFACE DRAINAGE ON THE TOP COVER

Surface drainage is damaged by the subsidence of the landfill site which is caused by the stabilization of the landfilled waste.

The damage of surface drainage causes the damage of a top cover and a retaining structure by rain water and causes the increase of leachate by the soaking of the rain water into landfilled layer.

As the inspection of the surface drainage, visual inspection shall be performed about the following items.

- Damage of the surface drainage
- Existence of differential subsidence
- Deposition situation of waste or earth and sand
- Existence and its situation of overflow point or stagnant water point

Frequency of regular inspection shall be decided in view of the condition of surface drainage. In addition, extra inspection shall be performed in case the heavy rain took place.

(3) CUT-OFF DRAINAGE AROUND THE SITE

When the fault occurs to the function of the cut-off drainage with the blockade by the discharged earth and sand and so on, it is caused the increase of the leachate quantity by the soaking of the rain water into landfilled layer.

As the inspection of the cut-off drainage, visual inspection shall be performed about the following items.

- Damage of cut-off drainage
- Deposition situation of waste or earth and sand
- Existence and its situation of overflow point or stagnant water point
- Inflow situation of rain water and the earth and sand from the surrounding area

Frequency of regular inspection shall be decided in view of the condition of cut-off drainage. In addition, extra inspection shall be performed in case the heavy rain took place.

Management roads shall be built and measures for improving access to other cut-off drainage shall be taken as required so that maintenance work, such as removal of earth and sand that accumulated in the cut-off drainage can be performed promptly.

(4) GAS VENTILATION PIPES

Gas ventilation pipes are damaged by the subsidence of the landfill site which is caused by the stabilization of the landfilled waste, and is clogged by the discharged earth and sand and so on. When the damage or clog of gas ventilation pipes occurs, it becomes difficult to vent the landfill gas properly and becomes the factor which discourages stabilization of landfill site.

About gas ventilation pipes exposed from the landfill surface, the following item shall be checked by visual inspection.

- Transformation and damage of gas ventilation pipes exposed from the landfill surface

About gas ventilation pipes located below the landfill surface, since it is difficult to perform the visual inspection, it shall be judged synthetically from the following item.

- Change of the amount of gas generation and concentration of landfill gas from gas ventilation pipes
- Gush of gas from the landfill surface except the gas ventilation pipes
- Change of the leachate quality

(5) LEACHATE COLLECTION PIPES

When the damage or clog of leachate collection/drainage pipes occurs, it becomes difficult to manage and treat the leachate properly. Moreover since the groundwater level inside the landfill rise up, infiltrating risk of leachate into underground becomes higher, and the water pressure which is bigger than designed pressure is put on retaining facilities.

About leachate collection/drainage pipes exposed from the ground, the following item shall be checked by visual inspection.

- Crack and hole of pipes
- Scale deposit inside pipes
- Leakage from the joint of the pipes
- Clogging of the pipes (Check inside the pipe from end of pipe)

Since the most part of the leachate collection/drainage pipes is buried underground, it shall be judged synthetically from the following item.

- Leachate quantity at the end of leachate collection/drainage pipe
- Groundwater level inside the landfill
- Crack and subsidence of the landfill surface

- Clogging of the pipes (Check inside the pipe from end of pipe)

(6) LEACHATE TREATMENT FACILITY

When the leachate treatment facilities is not functioning appropriately, it is difficult to perform sable treatment of the leachate which satisfies designed treated water quality and it causes water pollution at the downstream region.

As the inspection of the leachate treatment facility, it shall be performed about the following items.

- Quantity and quality of raw leachate
- Quantity and quality of treated water
- Water level of leachate controlling facility
- Setting of operating conditions and adjustment based on water quality and operation data (pH, DO, ORP, MLSS, etc.)
- Moisture content of dehydrated cake, SS of squeezed water, operating conditions of equipments (in case of installing sludge treatment facility)
- Check of chemicals, lubricants and fuel
- Check, adjustment and repair of each equipment and machines

(7) MONITORING FACILITY

When the damage or failure of groundwater monitoring well or other monitoring facilities occurs, it becomes impossible to understand appropriately the condition inside landfill or influence to the surrounding environment, and it tends to cause the misjudgement about maintenance of landfill site.

As the inspection of the groundwater monitoring well, it shall be performed about the following items.

- Existence of damage or failure
- The inflow situation of the rain water from the opening mouth of groundwater monitoring well

As the inspection of the monitoring facilities, it shall be performed about the following items.

- Existence of damage or failure of equipments
- Calibration of equipments
- Existence of damage or failure of sensing element
- Replacement of sensing element

Appendix 14

Environmental Monitoring

GENERAL OBJECTIVE AND METHODOLOGY OF ENVIRONMENTAL MONITORING

1. Role of Monitoring

Role of monitoring for landfill sites can be categorized based on the purposes. While environmental impact monitoring is primary objective, monitoring for safety of the site at operational phase and monitoring of stabilization process at closure phase are also important. Practical monitoring parameters, however, may be overlapped for different purposes. For example, leachate monitoring is required both for environmental impact monitoring as well as for stabilization process monitoring. **Figure A14-1** shows the concept of role of monitoring.

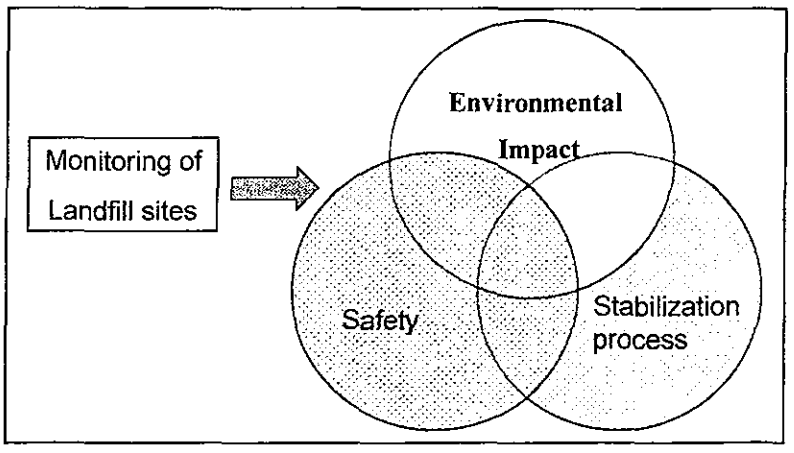


Figure A14-1 Concept of Role of Monitoring

Table A14-1 is the summary of each monitoring parameter related to the purposes.

Table A14-1 Summary of Each Monitoring Parameter related to Purpose

Monitoring media/parameters	Environmental impact	Safety	Stabilization process
Preliminary Site inspection	+	+	++
Leachate	++		++
Landfill gas	+	++	++
Soil subsidence		+	++
Groundwater	++		
Surface water	++		
Subsurface temperature			++

Note : + : magnitude of relation (+ : related, ++ : primarily related)

2. Monitoring Parameters and Frequency

Following table summaries recommended monitoring parameters and frequency for the above noted media.

Table A14-2 Recommended Monitoring Parameters and Frequency for Medias

Monitoring media/parameters	Item and parameters	Frequency	Location
Preliminary Site inspection	Surrounding environment Facility condition Nuisance condition	Once before monitoring	-
Leachate	• pH • BOD • COD • Nitrogen (Ammonia, Nitrate, Nitrite) • ORP • EC • TOC	4 times / year	1 point / leachate pond
Landfill gas	• Oxygen (O_2) • Nitrogen (N_2) • Methane (CH_4) • Carbon Dioxide (CO_2) • Hydrogen Sulphide • Temperature	2 times/ year	2 points / site
Land subsidence	Topographic height of the top of landfill	Once / year	1 point / landfill block
Groundwater	Groundwater benchmark parameters	Once / year	3 points / site
Surface water	Effluent standard parameters	Once /year	2 points / stream

Groundwater benchmark and Effluent standard parameters are shown in **Table A14-3.**

Table A14-3 National Guideline for Drinking Water Quality applied for Groundwater

No	Parameters	Unit	Benchmark value
1	Sulphate	mg/l	400
2	Hardness	mg/l	500
3	Nitrate	mg/l	10
4	Coliform	MPN	10
5	Manganese (Mn)	mg/l	0.2
6	Chromium, hexavalnet(Cr^{+6})	mg/l	0.05
7	Zinc (Zn)	mg/l	1.5
8	Arsenic (As)	mg/l	0.05
9	Selenium (Se)	mg/l	0.01
10	Chloride (Cl)	mg/l	250
11	Phenols	mg/l	0.002
12	TDS	mg/l	1,500
13	Iron (Fe)	mg/l	1
14	Copper (Cu)	mg/l	1
15	Lead (Pb)	mg/l	0.1
16	Cadmium (Cd)	mg/l	0.005
17	Mercury (Hg)	mg/l	0.001

Table A14-4 Parameter Limits of Effluent of Standard A and B

No.	Parameters	Unit	Standard A	Standard B
1	Temperature	Degree C	40	40
2	pH value		6.0-9.0	5.5-9.0
3	BOD at 20 degree C	mg/l	20	50
4	COD	mg/l	50	100
5	Suspended Solids (SS)	mg/l	50	100
6	Mercury (Hg)	mg/l	0.005	0.05
7	Cadmium (Cd)	mg/l	0.01	0.02
8	Chromium, hexavalent (Cr^{+6})	mg/l	0.05	0.05
9	Arsenic (As)	mg/l	0.05	0.1
10	Cyanide	mg/l	0.05	01
11	Lead (Pb)	mg/l	0.10	0.5
12	Chromium, trivalnet (Cr^{+3})	mg/l	0.20	1.0
13	Copper (Cu)	mg/l	0.20	1.0
14	Manganese (Mn)	mg/l	0.20	1.0
15	Nickel (Ni)	mg/l	0.20	1.0
16	Tin (Sn)	mg/l	0.20	1.0
17	Zinc (Zn)	mg/l	2.0	2.0
18	Boron (B)	mg/l	1.0	4.0
19	Iron (Fe)	mg/l	1.0	5.0
20	Phenol	mg/l	0.001	1.0
21	Chloride ion	mg/l	1.0	2.0
22	Sulphide	mg/l	0.50	0.5
23	Oil and Grease	mg/l	Not Detectable	10.0

3. Preliminary Site Inspection

Prior to prepare the monitoring plan, site visit to inspect to followings are recommended.

(1) Surrounding Environment

Site's specific condition around the landfill site shall be clarified firsthand as specified followings.

Topography and geology provides basis for evaluating potential propagation of environmental risk. Residence and workers are potential receptor of environmental pollution. Likewise these points are fundamental to evaluating and planning environmental monitoring.

- Topography and geology (near-surface soil profile)
- Residence and community nearby (how close and how many?)
- Workers for landfill operation
- Surface river and ponds (location, water quantity, water quality)
- Water intake point (as used for water supply)
- Groundwater well (other than monitoring well of the site)
- Public complaints (yes/no and contents of complaints)
- Vegetation condition (if affected by the gas or discharged water from the sites)

(2) Facility Condition

Condition of the landfill site facility has to be inspected to evaluate the environmental risk and to prepare the monitoring plan. Without expensive chemical measurement and analysis, many issues could be identified and recognized for proper countermeasure. Also such inspection will ensure the proper monitoring plan for maximum effectiveness. For example, leachate treatment facility and its discharge point to surface river will indicate where and how surface water monitoring should be done. Condition of band structure as well as landfill slope will provide base to evaluate the risk of waste collapse and outflow of the waste to outside. In this view, following points shall be inspected.

- Waste top cover
- Surface drainage
- Cut-off drainage around the site
- Leachate collection system
- Leachate treatment facility
- Gas vent
- Monitoring well
- Landfill slope and band structure

(3) Nuisance Condition

Apart from facility condition, nuisance condition as noted below also shall be checked.

- Odour
- Vector
- Land subsidence
- Leachate discharge
- Land fill gas
- Fire and smoke
- Slope collapse

Based on the result of the site inspection, monitoring plan shall be developed, focusing on the important risk issues of the site. Monitoring plan shall include sampling location, sampling schedule for each media/parameters as well as management action required (See **Figure A14-2**).

Quality control is an important aspect of the monitoring activity. Plan for quality control shall be included. This includes, but not limited to, field sampling and laboratory management. Detail explanation of each monitoring medium will be given in the following section.

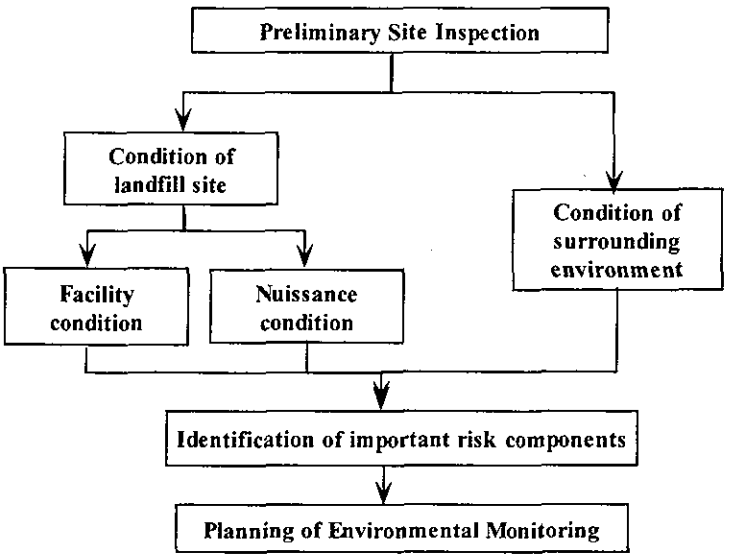


Figure A14-2 Schematic Diagram of Monitoring Plan

4. Leachate

(1) Objective

Rainwater penetrated into the landfill site is contaminated with the leaching substances from the waste materials and then effuses from the pore of the landfill. Therefore such contaminated water shall be treated before discharge into the public water body to prevent environmental contamination. Water quality of leachate varies by the nature of waste materials, structure of the landfill, metrological condition as well as the period elapsed after landfill. For example, at the landfill site on land, leachate quality in the early stage is at high concentration and contaminated, while in the later stage is at less concentration. Therefore leachate shall be monitored not only for environmental impact but also for stabilization process.

(2) Methodology

Leachate shall be sampled from the inlet point to the leachate treatment facility or directly from the monitoring well installed within the waste layer. It should be noted that sample taken from the re-circulation pond or aeration pond might have different water quality from the fresh leachate.

The most important monitoring parameters for leachate are 1) pH, 2) BOD, 3) COD and 4) Ammonium (NH_3-N). Other priority parameters include ORP, EC, TOC and total nitrogen. Other water quality parameters regulated by the Environmental Quality Act shall be also monitored. Depending on the parameters, sample taken shall be preserved properly at the site. Refer to the Effluent standard parameters shown in the previous table.

(3) Evaluation/Remarks

Followings are the meaning of important parameters and reason for monitoring.

1) pH

pH is the most basic water quality parameter and will provide the indication of generation of organic acid from the waste decomposition. It is also an important control factor of anaerobic methane generation process.

2) BOD (Biological Oxygen Demand)

It is an important parameter for understanding the quantity of biologically decomposable organic material in the original waste and leachate.

3) COD (Chemical Oxygen Demand)

It is an important parameter for understanding the quantity of chemically decomposable organic material in the original waste and leachate.

4) NH_3-N

Ammonia is generated from the decomposition of the waste. It can be used to evaluate the stage of decomposition of landfill waste, as Ammonia is high concentration at early stage, but gradually decreased.

5) ORP (Oxidation Reduction Potential)

ORP provide indication if the inside of the landfill site is aerobic or anaerobic condition.

6) EC (Electric Conductivity)

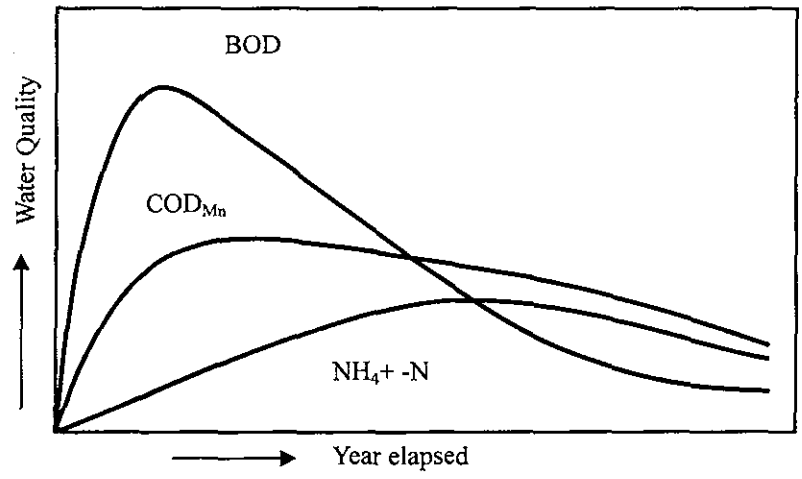
EC provide indication of the quantity of dissolved substances (ion) in the solution.

7) TOC (Total Organic Carbon)

TOC provide quantity of total organic in leachate. It includes both biologically degradable organic substance and humic substances which is difficult for degradation. Ratio of TOC and BOD can provide indication of quantity for biodegradation inside the landfill.

8) Nitrogen

Nitrogen controls the biological metabolism. Organic quantity and Ammonia are related to the stabilization process of the landfill site.



Source: Guideline for final waste disposal site, Ministry of Public Health, Japan 1989

Figure A14-3 Conceptual Graph Showing Change in Water Quality

5. Landfill Gas

(1) Objectives

Organic decomposition at the landfill generates carbon dioxide under aerobic condition and methane under anaerobic condition. Trace of hydrogen sulphide and ammonium are also generated. Volume of the gas generation will decrease while decomposition proceeds and remaining organic decreases. Therefore landfill gas measurement can provide qualitative indication of the stabilization of landfill in terms of organic decomposition of waste.

Methane is explosive gas and should be monitored for safety reason. Lower concentration limit of explosion for Methane – Air mixture at 20 degree C is approx. 5%. Hydrogen sulphide is also hazardous and gives offensive odour even at the low concentration at 1-2ppm. Therefore it should be monitored for safety and environmental reason.

(2) Methodology

Gas sampling shall be done using gas vent pipe. Gas sample can be colleted in sampling container or can be directly measured for the composition by the multi-sensor unit. Gas to be monitored includes methane, carbon dioxide, nitrogen, hydrogen sulphide and ammonium. Also gas volume can be estimated by measuring pressure. Twice a year monitoring is recommended. More landfill gas emitted from the boundary section of the landfill as well as the upper edge of leachate accumulation within the waste.

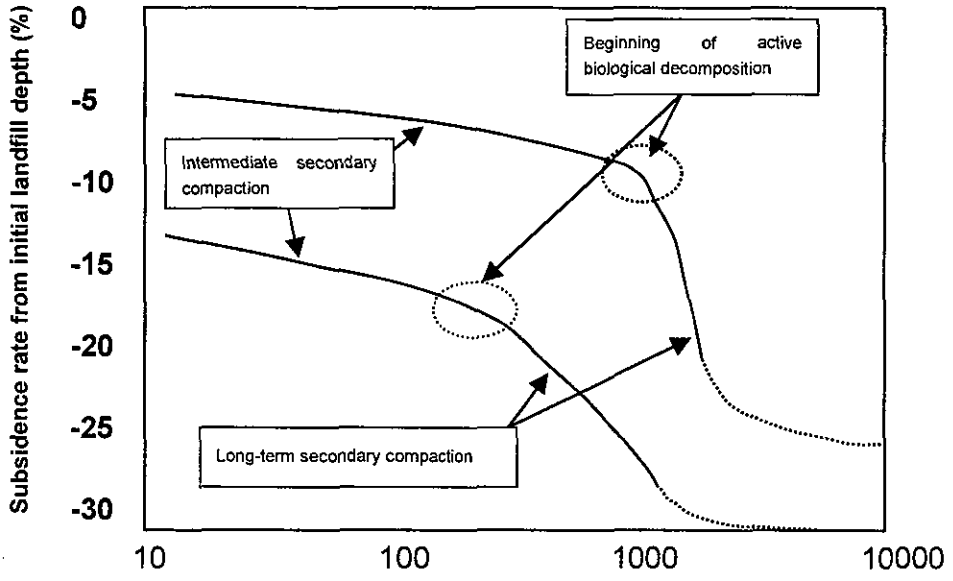
(3) Evaluation/Remarks

The most important issues are to avoid the explosive incidents from the methane. To avoid the explosive limit of methane, 5% of methane in the gas is an indication of safe criteria.

6. Land Subsidence

To prevent the problem in post closure land use, subsidence of the landfill site shall be monitored. Subsidence is caused by the compaction due to the weight and by the decomposition the waste as shown in the following figure.

For monitoring of the site, measuring base point shall be set on top of the landfill as well as at the original ground surface. Such base point shall be set at least one per each landfill zone/ phase. Levelling survey shall be done to measure the subsidence. After the closure, survey shall be done once a year.



Source: Method of evaluating closure criteria of waste disposal sites, Japanese Society of Waste Management, 2002

Figure A14-4 General Pattern of Land Subsidence at Landfill Sites

Above figure illustrates the general pattern of land subsidence at the landfill sites. Two line indicates the different landfill cases with varies compaction rate, but with similar pattern in terms of presence of rapid compaction phase initiated by active biological degradation.

7. Surface Water

(1) Objective

Surface water is the most visible environmental parameters. Leachate from the landfill site has potential to contaminate the river and/or pond water. Therefore surface water has to be monitored for such potential contamination by the landfill sites.

(2) Methodology

DOE set a standard for effluent discharged to public waterways. Monitoring parameters shall be basically those set in the standard.

Location of sampling shall be primarily at the downstream of the discharge point of effluent from the site. Water quality at the upstream also shall be monitored to evaluate the impact of effluent from the site. Usual practice applied for general water quality sampling such as preparation of preservative, cleaning of bottles, storage of sample in cold place, on-site calibration and measurement of pH, ORP, EC, DO and so on shall be applied. Analysis of the samples shall be according to official method at the accredited laboratory. QC/QA plan shall be integrated in the analytical plan.

(3) Evaluation/Remarks

Potential influence of the surface water contamination is through drinking water. Therefore presence of water intake point is primary importance to evaluate the impact of the contamination. DOE has separate effluents standard if water intake is at the down stream.

Also, especially in northern part of peninsula Malaysia, there are various fish/shrimp farming along the major rivers. As they introduce the river water into the farm pond, hazardous chemicals in the water may be bio-accumulated within the fish and shrimp. Therefore if such farming is near the site, it is also important.

8. Groundwater

(1) Objectives

Groundwater pollution may be the most serious problem caused by the landfill sites in terms of difficulty in remedy and long duration of the contamination. Also as groundwater is not easily seen, problem often is neglected or ignored.

In Malaysia, unlike many other countries, dependence on groundwater for drinking purpose is very low. In one sense, it makes lesser problem. On the other hand, it means there are less need for monitoring and hence lack of monitoring. Nevertheless, groundwater is the very important water resources because of its relatively good quality regardless of current use. It is strongly recommended that groundwater shall be properly monitored around the landfill sites

(2) Methodology

Groundwater shall be sampled from the monitoring well. Proper planning for the installation of monitoring well is of critical importance. Inadequate wells can not be used for groundwater monitoring. There are several important issues. This includes depth, location and structure of the monitoring well.

1) Depth:

Groundwater flows in aquifer (sand and gravel layer which is permeable). There is groundwater present in silt and clay layer which is less permeable, but such groundwater hardly flows. Therefore groundwater well should be drilled and placed at

the depth of aquifer. Aquifer is not a single layer at the given location. In many cases, there are multiple aquifers at different depth each separated by the silt and clay layer.

Information on the approximate depth of aquifer can be found in previous geological record and literature elsewhere. (Library of Mineral and Geo-science Department is one of the good sources of information). During the drilling of the well, core sample should be examined and geological log shall be prepared to confirm the depth of aquifer where the screen of the well should be placed.

The shallowest aquifer is the most vulnerable to the contamination caused by the landfill site, and in most cases it will be the priority for monitoring. When the shallowest aquifer was already contaminated by other reasons and source, and is not adequate for drinking purpose, the next aquifer may be the target for the monitoring. Also, if there is a groundwater well used for drinking purpose near the site, the aquifer of the well may be the priority for monitoring. It is not unusual to set multiple monitoring wells for different aquifers.

2) Location:

Monitoring wells shall be constructed at both upstream and downstream of the groundwater flow. Monitoring data of the upstream provide the baseline of the groundwater quality. Groundwater flow in the shallow aquifer is generally parallel to the topography of the surface. The depth of water table of three wells can measure accurate direction and gradient of groundwater flow. Topographic survey to determine the elevation of the platform of the well is required prior to the water table measurement. However, in the absence of the existing wells to confirm the flow direction, topography and general geological setting are the basis to plan the location of the monitoring wells.

When there is production well(s) near the site, water table may be influenced by the extraction from the well and may not be same as natural condition.

In case of topographically flat sites such as swamp area, groundwater flow may be estimated by larger regional topographic pattern.

3) Structure of the well:

"GUIDELINES FOR WELL DRILLING, GROUNDWATER ABSTRACTION and MONITORING" by the Department of Mineral and Geo-Science (2002) provides the general information and requirement for the monitoring well.

In order to use submergible pump during the sampling work, casing pipe diameter shall be larger than 2 inch or 50mm at minimum case, and is better if larger than.75mm.

Also it is important to seal the gap between borehole and casing pipe properly at the silt/clay layer so that any contamination in the shallow section will not migrate to the screen section through this gap.

4) Pumping test:

At the completion of the monitoring well, pumping test has to be done to obtain permeability or hydraulic conductivity of the aquifer. Hydraulic conductivity is

expressed as m/sec. This is the distance of groundwater flow at the given hydraulic gradient of 1:1. (1m-height difference at 1m separated point). This test is important in evaluating how fast groundwater contamination spread.

5) Sampling and analysis:

An important note on sampling of groundwater from monitoring wells is prior replacement of the stagnant water in the pipe of the well. As the water in the pipe stayed long time in contact with the headspace air, some chemical composition may have changed and thus it can not represent the original water quality in the aquifer.

For example, some groundwater in aquifer is at reducing condition where Fe is in the form of dissolved Fe^{2+} ion. Once water is in contact with oxygen in air, Fe^{2+} ion is quickly oxidized to form $Fe(OH)_2$ precipitation. In this process, some other metal element may co-precipitate and removed from the water. Obviously, there may be significant change in chemical composition. Another example is volatile organic compounds in water. These compounds may escape from the water quickly once they are equilibrium with air.

In order to replace the stagnant water in the pipe, it is recommended to pump up three times the volume of the water in the pipe. Many cases, this is quite hard work if one has to do only with bailer. Therefore submergible pump is recommended.

Proper preservation for the sample is also required as noted for surface water sampling.

(3) Evaluation/Remarks

When groundwater contamination is detected in the monitoring well, necessary management action shall be taken. First step of the action is assessment of urgency of the problem. Urgency depends on 1) how fast the groundwater flow is, and 2) if any well is used at the downstream, and if so, how quick the contamination reaches the point of the well.

The assessment of groundwater flow is straight forward, if hydraulic gradient and conductivity are taken at the field monitoring. For example, if hydraulic gradient is 1/100 (= 1m difference in water table height between wells of 100m distance) and hydraulic conductivity is 10^{-3} m/sec, then flow velocity (per year) will be as follows; (assuming effective porosity as 20%)

$$1/100 \times 10^{-3} \text{ m/sec} \times 1/0.2 \times 60 \times 60 \times 24 \times 365 = 1{,}575 \text{ m/year}$$

Therefore groundwater contamination moves and spread at the speed of approx. 1,575m/year. If the well is 1km downstream of the site, the contamination will reach there within a year. If the hydraulic gradient is 1/500, the hydraulic conductivity is 10^{-4} m/sec, then;

$$1/500 \times 10^{-4} \text{ m/sec} \times 1/0.2 \times 60 \times 60 \times 24 \times 365 = 31.5 \text{ m/year}$$

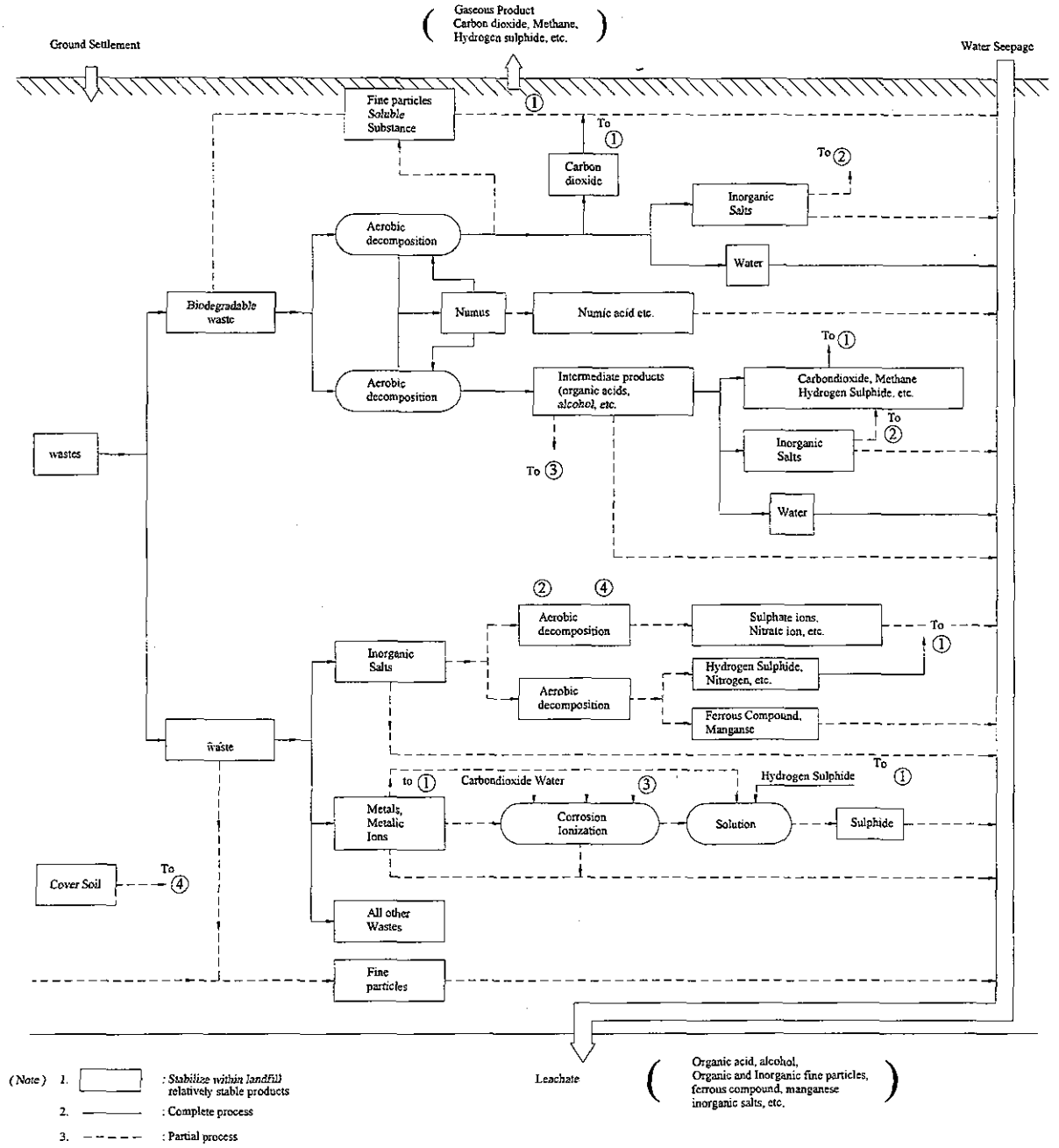
In this case, contamination will reach the well only after 30 years or so. Clearly the urgency to take actions is very different.

Precise assessment is more complex as other parameters such as retardation by soil, natural degradation of contaminant, dispersion have to be considered. However, to assess the urgency of the problem, the simple approach noted above will be sufficient.

Depending on the urgency, water intake from the well shall be stopped and alternative water supply shall be provided. Protection measure such as installation of vertical liner, hydro-geological barrier well system, which best suites the site specific condition should be planned and implemented.

9. Waste Decomposition and Stabilization Process

General understanding for the process of waste decomposition and stabilization process is required for the management and monitoring of the landfill sites. **Figure A14-5** summarizes the waste decomposition and stabilization process.



Source: Research Report on Management Technology for Landfill Site, Ministry of Public Health, Japan, 2000

Figure A14-5 Waste Decomposition and Stabilization Process

Appendix 15

Indicators for Risk of Post-closure Land Use

(1) Risk of landslide or collapse

The developer/designer shall design the shape of site as it can stand by itself. During the planning of the redevelopment of the site, the designer should consider the weight of the traffic, buildings, etc. of future use. Weight balance and physical stability of the slope shall be checked.

The Stability factor shall be more than 3.0 (including the safe factor).

If there is some risk of landslide or collapse by the new buildings, etc., the designer should modify the future land use plan or take the improvement measures, for example, the geological anchor system, soil improvement of the dikes and their bottoms, surplus fill at the dike, and etc. The authority should check the adequacy of these measures.

(2) Risk of subsidence

The subsidence at the site is always heterogeneous. Therefore, there will be some differences of subsidence between the points of landfill surface. For the buildings and basements, these differences cause the serious stress on the building material. Sometimes there will be the cracks on the wall or pipes. Especially, the damages on the pipes of water supply, sewage, electricity, etc. are serious problems for the residents and users.

a. *If the yearly subsidence rate is more than 20cm/year, there will be serious hollows and cracks.*
b. *If the yearly subsidence rate is more than 10cm/year, the building structure will be seriously damaged.*
c. *If the yearly subsidence rate is less than 3cm/year, there may not be serious damage on the building structure.*
d. *If the yearly subsidence rate is less than 1cm.year, there may not be serious damage on any structures.*

The developer/landowner should not use the site for houses or buildings while the site still has the significant subsidence.

(3) Risk of groundwater pollution

The developer/ designer shall design the post closure land use with careful prevention system against the groundwater pollution. The common measures of landfill for groundwater pollution control are bottom liners and leachate collection systems. The developer of the site should maintain these two facilities even after the post closure land use.

Construction of the foundation piles, which break the bottom liner (synthetic and/or natural ones), shall be strongly prohibited, if the degradation of waste is still going.

(4) Risk of leachate

After the completion of filling work, there will be leachate production by the percolated water and degradation of wastes. Leachate has many and heavy pollutants at initial period of the site operation, but they will be decreased as the waste will be degraded. The quality of leachate will be stabilized as times goes by. Therefore, the developer/owner should certify the followings.

(a) Quality of effluent of leachate will not cause the surface water pollution.

(b) Quality of leachate may not change to worse again.

It is very common the leachate inside the waste layer still has high concentration of pollutants, although the quality of effluent of leachate is stabilized and low. The quality of effluent will change to high concentration of pollutants, if there is some disturbing works on the site, just like excavation, drilling, etc.

Therefore, (a) and (b) shall be certified under the special condition of no disturbing works in the waste layer. That is special cares will be needed when disturb the waste layer like excavation, drilling, etc. These cares will be noted at the PCM plans for post-closure landfill site.

If the effluent water at the border of landfill site cannot meet the water standard or may cause serious damage on the surface water body, the leachate treatment facility shall be operated.

(5) Risks of gas explosion and fires

The landfill gas contains the explosive and combustible matter; i.e. methane (CH_4), hydrosulphide (H_2S), hydrogen (H_2), and so on. These gases go out to the air through the ventilation pipes mainly and through the cover soil slightly. A main dangerous gas is methane. The methane is explosive at the concentration from 5 to 15 %(v/v) in normal air, and is combustible when it is over 15 %.

Therefore, the developer/owner shall certify the concentration of methane gas at the ventilation pipe is below the 5%. The concentration of methane and another dangerous gas will decrease as time goes by in accordance with the degradation of waste. It is similar to the effluent of leachate.

a. If there is no gas ventilation and gas collection system, the public access and the construction works which use fires shall be prohibited strictly.
b. If the combustible content of gas in the ventilation pipe indicates more than 15%, the public access shall be prohibited.
c. If the combustible content of gas below the cover soil is more than 5%, the gas collection and ventilation system shall be installed.
d. Even though the combustible content of gas below the cover soil is less than 5%, the landfill gas could be accumulated and the concentration will get higher.
e. The combustible content of gas in the space below floor shall be less than 1.5%. If not so, the landfill gas collection and ventilation system shall be installed under the building.

Therefore, the developer/owner should certify the followings:

(a) Quality of landfill gas will not cause the explosion and fire

(b) Quality of landfill gas may not change to worse again

(6) Damages of the plants on the site and surroundings

It was commonly observed that some plants on the landfill site did not grow up well and the plants near the site were damaged or died sometime. Main reasons of these phenomena seem to be caused by landfill gas and soil contamination.

The landfill gas contains some phylotoxic matters, ethylene, acetylene, hydrosulphide, etc. These chemicals will prevent the germination, growth of roots, etc.

The soil contamination will also prevent the growth of plants. The famous metals to prevent the growth are copper (Cu), cadmium (Cd), arsenic (As), selenium (Se), etc. If these metals were observed at high concentration, the plants will not grow up well.

a. For the vegetation, the characteristics of landfill gas and soil shall be checked in advance.
b. In order to prevent the contacts of roots to the filled waste, the top cover shall have sufficient thickness.

(7) Risk of corrosion for construction materials and basement

During the degradation of waste, the many by-products are produced. Some of them have risks to cause the corrosion on the construction materials like mortar, steel and so on. Hydrogen Sulphide (H_2S) is well known for their corrosiveness on cement and steel.

The building materials faced the landfill gas, waste, and leachate may have a risk of corrosion. Acidity and H_2S could be good indicators.

(8) Temperature inside the waste layer

Most of the degradation process of waste is heat production reaction. Therefore, the heat production is high inside the waste layer, when the degradation process is active. Sometime the temperatures inside the waste layer reach to 80°C. In case the degradation reaction calms down, the temperatures inside the waste layer decrease.

The temperature inside the waste layer is a good indicator to evaluate the progress of degradation of waste. Therefore, the temperature inside the waste layer using the gas ventilation pipes or another observation wells in the site. The temperature of leachate is also helpful.

If the temperature inside the waste body is higher than 50 °C, the degradation rate may be still high and is not suitable for re-development work.

Sometime the unexpected increase of temperature is observed during the re-development work. This phenomenon is often occurred at the waste excavation stage, because the excavation will induce the fresh air into the waste and promote the degradation rapidly. Therefore, the careful monitoring should be also required during the construction works.

(9) Accidental chemical reaction

The waste layer contains many kinds of chemicals. While during a re-developing and/or rehabilitation of landfill site, its construction works use some chemicals, such as lime, steel, concrete, etc. There is some risk of chemical reaction between construction work materials and chemicals in waste.

One of famous accidental reaction is ammonia stripping. When the waste have so much of ammonium ion in liquid phase, if someone adds an strong alkali matters, like lime and concrete, into the waste, ammonium ion becomes ammonia in gaseous phase. Accordingly, ammonia rich gas, which is very irritating and dangerous, comes from the waste. Another one is hydrogen generation by the reaction of metals and acids in waste. Sometimes there is much hydrogen gas comes from waste.

Therefore, these accidental reactions shall be checked beforehand by laboratory test, when they try to use some chemicals or matters as additives for waste layer or basements. Most common test method is head-space test in flask. In this test, researcher shall take a small amount of samples of waste and other chemicals/matters into flask and mix them in flask. Then the researcher shall observe the phenomenon inside the flask. For example, changes of colour, bubbles on a surface of waste, and etc. After 10 to 30 minutes passed, the gas inside the flask shall be sampled and checked.

The materials, which plan to be use for the development works of the landfill sites, shall be checked and possible chemical reaction between the materials and waste/leachate shall be verified, in order to prevent the accidental chemical reaction cause new pollution and hazards.

(10) Change of surface covers

Even after the physical closure of landfill site, there still might have gas generation from waste layer. If there is cover soil on the top of waste layer, the gas migrates through the cover soil. On the other hands, the air goes into the waste layer through the cover soil. Therefore, if the top of waste layer is covered with impermeable matters, like concrete or asphalt pavement for re-development, the gas try to go through the permeable parts of surface, like the vegetation fields, flower garden, etc. If the landfill gas comes to a small area at high concentration, it will damage the plants and etc. Some time it causes the fires and/or explosion.

Therefore, in some cases, change the characteristic of surface covers shall be considered. If there is very limited permeable area, they should install the gas ventilation/collection system.

If the surface of top cover will be occupied with the impermeable matters like buildings and pavements, the gas collection and ventilation system shall be installed as a substitution of gas migration through the occupied area.

Appendix 16

Type of Development for Post-closure Land Use

There are several patterns of development of closed landfill sites. The level of necessary countermeasures depends on the site condition and the patterns of post closure land use.

(1) Classification of Post-closure Land use

Post-closure land use patterns can be classified into two aspects as follows.

a. Public access and time of exposure

(i) Levels of public access

Few:	Very limited people will enter into the area like an agricultural field.
	It is easy to inform the risks relevant to their use.
Controlled:	Some people will enter into the area under the control like a warehouse.
	It is possible to inform the risks relevant to their use.
Open:	Everybody can enter into the area like a park and a shopping market
	It is difficult to inform the risks and control the entrance.

(ii) Times of exposure

Short:	People spend very limited time at the site like car parking
Controlled:	The hours to stay at the site are controlled like a visitor to the park and/or shop
Full time:	People spend most of the daily hours on the site like a resident

The most risky case will be "Open access" and "Full time exposure"; however, this combination may not be realized. The second risky case will be "Controlled access" and "Full time exposure". This combination will be observed at the residential use of closed site.

b. Engineering work effect (depth of engineering work)

(i) Surface layer use:	Only the surface of top cover of the site is used without excavation
(ii) Middle layer use:	"Surface layer use" and excavation work of cover soil and waste layer
(iii) Bottom layer use:	Bottom of the filled waste layer will be affected.

(2) Examples and Probable Problems

It should be noted that special caution and/or measures shall be taken in case the middle and bottom layer use. The typical problems and/or issues, which may occur from the post-closure land use, are summarized as follows.

a. Agriculture: Limited accessed and little engineering works

   Probable incident is damage of plants caused by the landfill gas

b. Park: Open access and little engineering works

   Probable incidents are accidental fires, unpredictable offensive odour, etc.

c. Motor park/Roads: Open access and some engineering works

   The subsidence will cause the damage on the surface drainage system and casual fires may occur.

   The weight and vibration of the traffic will affect the slope stability.

d. Low Story Houses: Limited person for long time and Medium Engineering Work

   The subsidence will cause the damage on building, pipeline, etc. There might be a possible damage on the human's health via inhalation of landfill gas.

e. Commercial/Industrial Facility: Many persons access for long-time and more engineering works

   There will be many problems as stated above.

Appendix 17

Receptor of Landfill Closure for Social Consideration

(1) Possible Receptors

Possible receptors to be impacted by closures of landfill sites shall be identified by the State/LAs in advance of the closures. The following should be referred for considering of the identification.

- Possible receptors to be impacted by closures of landfills are principally summarized in **Table A17-1**.

Table A17-1 Possible Receptors Impacted by Closures of Landfill Sites

Item	Possible Receptors
At Landfill Sites	- Authorized Workers (Operators of Heavy Equipment, Drivers of Collection Vehicles, Recyclers, Scrap Dealers and so on) - Scavengers
Vicinities of Landfill Sites	- Residential Households

Source: The JICA Study Team

- As for authorized workers, it can be generally considered that they could be appropriately evacuated and re-employed by any legal programs or schemes if authorities close landfills.
- Thus, in this guideline, scavengers working at landfill sites and households located around those sites are assumed as the possible receptors.

(2) Who are the Scavengers?

a. Definition

There is no official definition of scavengers in Malaysia at present. Therefore, in order to make sure who are considered as scavengers, the definition of the scavengers shall be considered and be temporally defined by authorities concerned for the closures in accordance with circumstances of landfills to be closed. The following should be referred for considering of the definition of scavenging and scavengers.*

- Scavenging refers to the informal practice of collecting saleable items from garbage at a waste disposal site and eventual reuse of the materials picked.
- Scavengers devote either part or most of their working time to foraging for saleable materials in the wastes.

* "Waste Recycling in Malaysia: Economics & Environmental Needs", Mohd Nasir Hassan et al. Universiti Putra Malaysia

b. Law and Regulation

According to the following circumstances on law and regulation related, scavenging at landfill sites is prohibited and is regarded as an illegal action in Malaysia.

- "Local Government Act 1976 (Act 171) regulates local government activities in Malaysia.
- In accordance with the act 171, every municipal council respectively enacts a "By Law" by which collection, transportation and disposal of municipal solid waste is regulated.
- Namely municipalities have a responsibility for municipal solid waste management (MSWM) in each administrative boundary.
- Those "By Laws" enacted by municipality councils regulate activities on MSWM, one of which includes prohibition of entering landfill sites without permission.

In spite of the illegal action of scavenging, however, from humanity's point of view, the authorities involved shall appropriately evacuate scavengers from landfills to be closed.

Appendix 18

Questionnaire on the Landfill Condition

Lampiran 1

BORANG RINGKASAN SOAL SELIDIK KAJIAN TAPAK PELUPUSAN DI PIHAK BERKUASA TEMPATAN
(Summary of Qestionnaire on the landfill condition in Local Authorities)

1. Nama PBT/Nama of LA: _____

2. Jumlah tapak pelupusan yang (no. of landfills that):

   a. Telah ditutup (have been closed): _____

   b. Masih beroperasi (in operation): _____

3. Tarikh borang di isi: _____
   (Date the form is filled)

4. Jumlah lawatan yang dibuat oleh pegawani PBT ke tapak pelupusan
   (No. of visit made by the LA personnel to the landfill site)

   a. Tapak yang telah dututup: _____ kali/tahun
   (Closed landfills) (times/year)
   b. Tapak yang sedang beroperasi: _____ kali/tahun
   (Landfils in operation) (times/year)

5. Pegawai yang mengisikan borang (Officer who filled up the questionnaire):

   Nama (Name): _____

   Jawatan (Position): _____

   No Telefon (Tel No.): _____

6. Jumlah Borang Inventori tapak pelupusan yang dikembalikan: _____
   (No. of Questionnaire returned)

7. Pelan lokasi tapak pelupusan disertakan: Ya (Yes) _____ Tidak (No) _____
   (Location plan submitted)

8. Pelan Susunatur tapak pelupusan disertakan: Ya (Yes) _____ Tidak (No) _____
   (Layout plan submitted)

9. Gambar tapak pelupusan disertakan: Ya (Yes) _____ Tidak (No) _____
   (Photos attached)

Nota: Setiap maklumat tapak pelupusan sama ada yang telah tidutup atau pun yang masih beroperasi hendaklah di isi dengan menggunakan Borang Inventori yang berasingan. Bagi setiap maklumat untuk 1 tapak pelupusan di isi dengan menggunakan 1 Borang Inventori.

Note: Separate forms are to be used for every landfill that are either already closed or are still in operation; 1 landfill for 1 inventory form.

INVENTORY TAPAK PELUPUSAN (LANDFILL INVENTORY)

Satu borang untuk satu tapak pelupusan (One form for one landfill)

A. Matlumat Asas *(Basic Information)*

1.Nama Tapak (Name of Site) _____

2. Alamat tapak *(Address of Site)* _____

3. Pelan tapak disertakan *(Layout site attached)* — ya *(yes)* ☐ tidak *(no)* ☐

4. Kategori *(Category)*
Sedang beroperasi *(in operation)* ☐ Telah ditutup *(Closed)* ☐
Sekiranya sedang beroperasi, berapa lama lagikah jangka hayat yang tinggal: _____ tahun
(If still in operational, what is the remaining life span)

5. Diuruskan oleh: *(Managed by)* — PBT *(Local Authority)* ☐ Lain-Lain *(Others)* ☐ Nyatakan(*specify*) _____

6. Pemilik Tanah *(Land ownership)* — Kerajaan *(government)* ☐ Persendirian *(Private)* ☐

7.Adakah tapak digazet *(Is the site gazetted as landfill)* — Ya *(yes)* ☐ Tidak *(no)* ☐

8. Operasi pelupusan *(Disposal Operation)* — Tahun bermula _____ *(Year start)* Tahun berakhir: _____ *(Year end)*

9. Keluasan *(area)* _____hektar

10. Jumlah sisa dilupus sehari _____ ton *(Waste disposed daily)* Total amount of waste disposal of _____ ton

11. Sebab tapak ditutup *(Reason for Closure)*
Telah sampai jangka hayat *(Reach the life span)* ☐
Aduan orang ramai *(Public Complaint)* ☐
Berpindah ke tapak yg lebih baik *(Move to a new improved site)* ☐
Arahan JAS *DOE Directive* ☐
Pembangunan berdekatan *(development at adjacent area)* ☐
Lain-lain sebab, sila nyatakan *(Other reason, pls specify)* ☐

B. Kesan Terhadap Alam sekitar (Environmental Impact Conditions)

Tarikh Kajian *(Date of Survey)*

1. Tahap Tapak Pelupusan *(Landfill Facility Level)*
pelupusan terbuka *(open dumping)* ☐
Tahap 1 *(Level 1)* ☐
Tahap 2 *(level 2)* ☐
Tahap 3 *(level 3)* ☐
Tahap 4 *(level 4)* ☐

2. Keadaan tapak *(Site Condition)*
tanah rata *(flatland)* ☐
berbukit *(hilly)* ☐
tapak kuari *(ex quarry, mines)* ☐
kawasan paya *(swampy area)* ☐
lain-lain, sila nyatakan *(others, please specify)* ☐

3. Sampah ditutup*(Waste Covered)* — Ya *(Yes)* ☐ tidak *(No)* ☐
Jika ya, nyatakan kekerapan sisa ditutup *(If yes, state the frequency of cover material applied)*
setiap hari *(daily)* ☐
seminggu sekali *(weekly)* ☐
sebulan sekali *(monthly)* ☐
setahun sekali *(annually)* ☐
lain-lain, sila nyatakan *(others please specify)* ☐
Catitan *(Remarks)* : _____
(Note: including daily operation)

4. Terdapat tumbuh-tumbuhan *(Vegetation Condition)*
pokok *(Trees)* ☐
an semak-samun*(grasses and bushes)* ☐
tiada tumbuhan *(no vegetation)* ☐
Catitan *(Remarks)*: _____

5.Tanah Runtuh *(Landslide)*
rekahan tanah ketara *(Noticeable)* ☐
rekahan tanah sedikit *(Medium)* ☐
Tiada *(no)* ☐
Catitan *(Remarks)*: _____
Nyatakan tinggi dan kecuraman *(state the height and slope)*

6. Pemendapan Tanah *(Soil Subsidence)*
a. Nampak jelas*(Noticeable)* ☐
b. Nampak sedikit *(medium)* ☐
c. tiada *(not noticeable)* ☐
Catitan *(Remarks)*: _____

7. Vektor dan binatang liar *(Vector and wild animals)*
Nampak jelas*(Noticeable)* ☐
Nampak sedikit *(medium)* ☐
tiada *(not noticeable)* ☐
Catitan *(Remarks)*: _____

8. Bau, gas dan asap *(Odour, landfill gas and smoke)*	Terasa jelas *(noticeable)* ☐ Terasa sedikit *(medium)* ☐ tiada *(not noticeable)* ☐	Catitan *(Remarks)*: _____
9. Kuantiti 'leachate' *(Leachate Quantity)*	jelas kelihatan*(Noticeable)* ☐ sedikit kelihatan *(medium)* ☐ tiada *(not noticeable)* ☐	Catitan *(Remarks)*: _____
10. Lokasi 'intake' air *(Location of water intake)*	di kawasan ulu *(upstream)* ☐ di hilir tapak *(downstream)* ☐ tiada *(No intake point)* ☐	jarak *(distance)* _____km jarak *(distance)* _____km Catitan *(Remarks)*: _____
(Note: No limited stance for down stream within 2km for upstream)		
11. Lokasi perigi untuk air minuman *(Location of Drinking Water Well)*	Kurang dari 500m *(<500m)* ☐ Lebih dari 500m *(>500m)* ☐ Tiada *(no)* ☐	Catitan *(Remarks)*: _____
(Note: within 2km)		
12. Keadaan Geologi *(Geological Condition)*	Batu kapor *(limestones)* ☐ Tanah liat *(alluvial)* ☐ lain-lain (others) ☐	Sila nyatakan *(specify)*: _____
13. Adakah terdapat aduan orang i *(Ae there any Public Complaint)*	Ya *(yes)* ☐	Tidak *(no)* ☐
	Jika ada, nyatakan jumlah aduan dalam setahun : _____ *(If yes, state the no of complaints per year)*	
14. Jarak dari kawasan kediaman *(Distance to the residential area)*	Kurang dari 500m *(<500m)* ☐ Lebih dari 500m *(>500m)* ☐ Tiada *(no)* ☐	Catitan *(Remarks)*: _____

C. PENGGUNAAN TAPAK/PELUPUSAN SELEPAS DITUTUP (Land Utilisation after closure)

1. Kegunaan tanah Sediada *(Existing Land Utilisation)*	kosong *(vacant)* ☐ pertanian*(agriculture)* ☐ industri/perniagaan*(industry/commerce)* ☐	perumahan *(housing)* ☐ rekreasi*(recreation)* ☐ lain-lain *(others)* ☐ nyatakan:_____
2. Kawasan sekeliling *(Surrounding area)*	kosong *(vacant)* ☐ pertanian*(agriculture)* ☐ industri/perniagaan*(industry/commerce)* ☐	perumahan *(housing)* ☐ rekreasi*(recreation)* ☐ lain-lain *(others)* ☐ nyatakan:_____
3.Penggunaan Tapak dimasa hadapan *(Ultimate land use)*	ya *(yes)* ☐	tiada *(no)* ☐
Jika ya. aktiviti yang dirancangkan akan mempunyai penghuni/pengunjung yang: *(If yes, will the proposed activities will be heavily used)*		ramai*(high use)* ☐ sederhana*(medium)* ☐ pengunjung sedikit *(low use)* ☐
4. Adakah tapak ini termasuk dalam Pelan Pembangunan Tempatan *(Is the disposal site is included the Local Development Plan)* Catitan *(Remarks)*: _____		ya *(yes)* ☐ tidak *(no)* ☐ berdekatan *(adjacent)* ☐
5. Adakah tapak ini berkemungkinan akan dibangunkan *(Is the site is to be probably developed)* Catitan (Remarks); _____		Berkemungkinan besar ☐ *(most probably)* Kurang berkemungkinan ☐ *(less probably)*
6. Jarak dari pusat bandar *(distance from town centre)* Catitan (Remarks); _____		kurang dari 5 km ☐ *(less than 5 km)* diantara 5km hingga 10km ☐ *(between 5km to 10km)* lebih dari 10 km ☐ *(more than 10 km)*

* - sila lihat nota *(refer to the notes)*

Appendix 19

List of Landfill Sites Covered by the JICA Study

List of landfill sites covered by the JICA Study is shown in **Table A19-1**. It is noted that the listed landfill sites does not cover all the landfill sites in Malaysia. Remaining landfills which are not listed in the table shall be registered by the concerned authorities and the LACMIS (landfill closure management information system) shall be updated based on the information of remaining landfill sites.

Table A19-1 List of Landfill Sites

ID	State	No.	Name of LA	Name of Site	Landfill Level	Category	Year Start	Year End	Area (ha)	Environ-mental Risk	Value of Land Utilization	The necessity of the safe closure				Group	Closure Level
												C1	C2	C3	C4		
1	Selangor	SL-01	MP Petaling Jaya	Kelana Jaya	Level 1	Closed	1990	1996	8.1	0.28	0.80	0.46				CL-C	C2
2	Selangor	SL-02	MP Klang	Telok Kapas	Level 1	Operation	2000	2003	32.4	0.40	0.28	0.44	0.55	0.43		OP-D	C2
3	Selangor	SL-03	MP Kajang	Sungai Kenbong	Open Dump	Operation	1996	2008	16.2	0.64	0.29	0.76	0.63	1.00		OP-B	C3
4	Selangor	SL-04	MP Selayang	Kundang	Level 1	Operation	1996	2005	32.4	0.34	0.00	0.44	0.48	0.43		OP-D	C2
5	DBKL	DB-01	DB Kuala Lumpur	Taman Beringin	Level 2	Operation	1996	2004	12.0	0.43	0.52	0.54	0.63	0.47		OP-A	C3
6	N.Sembilan	NS-01	MP Nilai	Pajam	Level 1	Operation	1996	2018	27.9	0.23	0.28	0.42				OP-D	C1
7	N.Sembilan	NS-02	MP Nilai	Kuala Sawah	Level 1	Closed	1998	2003	10.1	0.53	0.11	0.58	0.63	1.00		CL-B	C3
8	N.Sembilan	NS-03	MP Seremban	Sikamat	Level 1	Operation	1986	2003	5.3	0.39	0.58	0.68	0.45	0.25		OP-C	C3
9	N.Sembilan	NS-04	MP Port Dickson	Quarters MPPD	Open Dump	Closed	1950	1960	0.4	0.24	0.23	0.22				CL-D	C1
10	N.Sembilan	NS-05	MP Port Dickson	Bukit Palung	Open Dump	Operation	1975	2013	25.0	0.41	0.22	0.78	0.33	0.25		OP-B	C3
11	N.Sembilan	NS-06	MP Port Dickson	Pengkalan Kempas	Open Dump	Closed	1990	2002	1.2	0.28	0.33	0.25		0.21		CL-D	C2
12	N.Sembilan	NS-07	MP Port Dickson	Sua Betong	Open Dump	Operation	1998	2008	3.2	0.47	0.06	0.78	0.52	0.47		OP-B	C3
13	Melaka	ML-01	MD Alor Gajah	Air Molek	Open Dump	Operation	1970	2013	2.4	0.35	0.19	0.78				OP-D	C1
14	Melaka	ML-02	MD Alor Gajah	Pulau Sebang	Open Dump	Closed	1960	2002	0.8	0.45	0.13	0.69	0.63			CL-B	C2
15	Melaka	ML-03	MB Melaka	Krubong	Level 2	Operation	1994	2005	27.7	0.45	0.28	0.78	0.52	0.47		OP-B	C3
16	Melaka	ML-04	MB Melaka	Krubong A	Open Dump	Closed	1974	1994		0.32	0.72	0.34				CL-C	C2
17	Melaka	ML-05	MB Melaka	Kota Laksamana	Open Dump	Closed	1950	1973		0.30	0.71	0.35				CL-C	C2
18	Melaka	ML-06	MD Jasin	Lipat Kajang	Level 1	Closed	1967	2000	3.2	0.43	0.42	0.31		0.57		CL-B	C3
19	Melaka	ML-07	MD Jasin	Batang Melaka	Open Dump	Closed	1970	2001	1.5	0.28	0.42	0.39				CL-D	C1
20	Melaka	ML-08	MD Jasin	Kesang Pajak	Open Dump	Closed	2001	2002	9.2	0.59	0.52	0.40	0.26	0.70	0.43	CL-A	C4
21	Johor	JH-01	MD Tangkak	Chohong	Open Dump	Closed	1970	2000	1.0	0.58	0.38	0.34	0.29	0.57	0.43	CL-B	C4
22	Johor	JH-02	MP Muar	Bakri	Level 1	Operation	1993	2005	14.6	0.32	0.46	0.31	0.37	0.21		OP-C	C3
23	Johor	JH-03	MP JB Tengah	Ulu Tiram	Level 2	Operation	1997	2003	17.4	0.46	0.18	0.95	0.75	0.47		OP-B	C3
24	Johor	JH-04	MP JB Tengah	Lima Kedai	Open Dump	Closed	1992	1997	2.5	0.22	0.14	0.27				CL-D	C1
25	Johor	JH-05	MP JB Tengah	Kempas	Open Dump	Closed	1988	1997	0.9	0.27	0.42	0.34				CL-D	C1
26	Johor	JH-06	MP JB Tengah	Taman Mega Ria	Open Dump	Closed	1988	1997	6.5	0.37	0.45	0.27	0.40	0.47		CL-D	C2
27	Johor	JH-07	MD Kota Tinggi	Batu Empat	Open Dump	Operation	1988	2004	6.0	0.69	0.09	1.00	0.63	1.00		OP-B	C3

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												C1	C2	C3	C4		
28	Johor	JH-08	MD Kota Tinggi	Sungai Rengit	Open Dump	Operation	1998	2008		0.36	0.10	0.95	0.23			OP-D	C2
29	Johor	JH-09	MD Kota Tinggi	Bandar Kota Tinggi	Open Dump	Closed		1988	1.6	0.44	0.68	0.34		0.53		CL-A	C3
30	Johor	JH-10	MD Mersing	Jemaluang	Open Dump	Operation	1993	2013	4.0	0.27	0.07	0.47				OP-D	C1
31	Johor	JH-11	MD Mersing	Endau	Open Dump	Operation	1993	2013	4.9	0.27	0.20	0.47				OP-D	C1
32	Johor	JH-12	MD Mersing	Sri Pantai	Open Dump	Operation	1993	2013	4.0	0.38	0.36	0.86	0.26			OP-D	C2
33	Pahang	PH-01	MD Rompin	Kampong Feri	Level 1	Operation	1983	2020	5.0	0.26	0.50	0.59				OP-C	C2
34	Pahang	PH-02	MD Pekan	Pekan Nenasi	Level 2	Operation	1988	2023	22.7	0.26	0.22	0.49	0.30	0.21		OP-D	C2
35	Pahang	PH-03	MP Kuantan	Taman Bandar	Open Dump	Closed	1983	1986	2.0	0.24	0.58	0.20				CL-C	C2
36	Pahang	PH-04	MP Kuantan	Gambang	Open Dump	Closed	1965	2001	2.0	0.28	0.18	0.53				CL-D	C1
37	Pahang	PH-05	MP Kuantan	Indera Mahkota	Level 1	Closed	1985	1993	50.0	0.26	0.55					CL-C	-
38	Pahang	PH-06	MP Kuantan	Jabor Jerangau	Level 2	Operation	1993	2018	55.0	0.30	0.18	0.36	0.55	0.43		OP-D	C2
39	Terengganu	TR-01	MP Kemaman	Fikri	Open Dump	Closed	1976	1985	2.0	0.26	1.00	0.22				CL-C	C2
40	Terengganu	TR-02	MP Kemaman	Gelugor	Open Dump	Closed	1981	1992	1.2	0.22	0.40	0.22				CL-D	C1
41	Terengganu	TR-03	MP Kemaman	Gelugor	Open Dump	Operation	1993	2006	10.0	0.32	0.50	0.59				OP-C	C2
42	Terengganu	TR-04	MP Kemaman	Mak Cili Paya	Open Dump	Operation	1985	2006	5.0	0.28	0.46	0.54				OP-C	C2
43	Terengganu	TR-05	MP K.Terengganu	Tok Jembal	Open Dump	Closed	1985	1994	8.1	0.28	0.55	0.22				CL-C	C2
44	Terengganu	TR-06	MP K.Terengganu	Wakaf Tok Keh	Open Dump	Closed	1975	1985	4.0	0.29	0.68	0.29				CL-C	C2
45	Terengganu	TR-07	MP K.Terengganu	Kubang Ikan	Open Dump	Operation	1998	2004	13.3	0.53	0.49	1.00	0.63	0.47		OP-A	C3
46	Kelantan	KL-01	MP Kota Baru	Panji	Open Dump	Closed	1961	1987	4.0	0.26	0.80	0.22				CL-C	C2
47	Kelantan	KL-02	MP Kota Baru	Tebing Tinggi	Open Dump	Operation	1987	2003	19.0	0.55	0.20	0.81	0.70	0.47		OP-B	C3
48	Kelantan	KL-03	MD K.Krai Selatan	Sungai Sam	Open Dump	Closed	1984	2000	0.3	0.32	0.00	0.46	0.29			CL-D	C2
49	Kelantan	KL-04	MD K.Krai Selatan	Bukit Tembeling	Open Dump	Operation	2000	2013	4.0	0.39	0.00	0.90	0.34			OP-D	C2
50	Perak	PR-01	MD Kinta Selatan	Sg. Siput Selatan	Level 2	Operation	1990	2028	26.7	0.20	0.46	0.41				OP-C	C2
51	Perak	PR-02	MD Kinta Selatan	Kg. Batu Putih (Kg. Tersusun)	Open Dump	Closed	1980		2.0	0.26	1.00	0.22				CL-C	C2
52	Perak	PR-03	MD Kinta Selatan	Taman Sri Kampar	Open Dump	Closed	1960	1970	4.0	0.49	0.40	0.44	0.40	0.30	0.30	CL-B	C4
53	Perak	PR-04	MB Ipoh	Bercham	Level 1	Operation	1986	2007	50.0	0.49	0.57	0.80	0.63	0.47		OP-A	C3
54	Perak	PR-05	MB Ipoh	Buntong	Open Dump	Closed	1970	1986	20.0	0.28	0.96	0.22				CL-C	C2
55	Perak	PR-06	MB Taiping	Jebong	Open Dump	Operation	2000	2008	20.0	0.70	0.48	0.85	0.75	0.47	0.81	OP-A	C4
56	Perak	PR-07	MB Taiping	Tekkah Jaya	Open Dump	Closed	1980	1999	40.0	0.39	0.67	0.59			0.37	CL-C	C3
57	Perak	PR-08	MD Tapah	Pekan Getah	Level 1	Operation	1985	2004	21.5	0.52	0.62	0.95	0.63	0.47		OP-A	C3
58	Perak	PR-09	MD Tapah	Bidor	Level 1	Operation	1980	2013	2.1	0.60	0.38	0.95	0.86	0.47		OP-B	C3
59	Penang	PP-01	MP Pulau Pinang	Jeti Jelutong	Level 1	Operation	1980	2001	20.0	0.53	0.62	0.73	0.82	0.47		OP-A	C3
60	Penang	PP-02	MP Seberang Perai	Ampang Jajar	Level 3	Operation	1980	2003	17.0	0.32	0.50	0.68	0.60	0.43		OP-C	C3
61	Penang	PP-03	MP Seberang Perai	Pulau Burong	Level 3	Operation	1980	2009	64.0	0.28	0.09	0.44	0.48	0.43		OP-D	C2
62	Kedah	KD-01	MP Kulim Kedah	Padang Cina	Open Dump	Operation	1996	2023	56.0	0.57	0.05	0.88	0.82	0.47		OP-B	C3
63	Kedah	KD-02	MD Baling	Pulai	Level 3	Operation	2001	2018	6.8	0.65	0.09	0.44	0.59	1.00	0.81	OP-B	C4

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												C1	C2	C3	C4		
64	Kedah	KD-03	MD Baling	Kuala Pegang	Open Dump	Closed	1989	2002	11.0	0.35	0.12	0.63				CL-D	C1
65	Kedah	KD-04	MP Sungai Petani	Semeling	Level 1	Operation	1989	2013	51.0	0.45	0.23	0.80	0.63	0.47		OP-B	C3
66	Kedah	KD-05	MP Sungai Petani	Jeniang	Open Dump	Closed	1985	2001	1.5	0.23	0.12	0.22				CL-D	C1
67	Kedah	KD-06	MP Kota Setar	Bukit Tok Bertandok	Level 2	Operation	1983	2009	9.7	0.61	0.35	0.58	0.78	0.96		OP-B	C3
68	Kedah	KD-07	MD Kubang Pasu	Paya Kemunting	Level 2	Operation	1974	2005	5.0	0.41	0.23	0.90	0.60	0.43		OP-B	C3
69	Perlis	PL-01	MP Kangar	Kuala Perlis	Open Dump	Operation	1983	2003	8.0	0.52	0.70	0.95	0.52	0.25		OP-A	C3
70	Kelantan	KL-05	MD K.Krai Selatan	Dabong	Open Dump	Operation	1996	2006	0.2	0.34	0.24	0.49				OP-D	C1
71	Pahang	PH-07	MP Kuantan	Atabara	Open Dump	Closed	1984	1985	20.0	0.26	0.46					CL-D	-
72	Pahang	PH-08	MD Bentong	Sungai Sematut	Level 1	Closed			2.0	0.41	0.30	0.45	0.23	0.36	0.36	CL-B	C4
73	Pahang	PH-09	MD Bentong	Chamang	Open Dump	Operation	1995	2006	3.0	0.46	0.30	0.43	0.23	0.36	0.36	OP-B	C4
74	Pahang	PH-10	MP Temerloh	Ulu Tualang	Level 3	Operation	1998	2006	7.3	0.20	0.54	0.26				OP-C	C2
75	Pahang	PH-11	MD Cameron Highlands	Tapak Pelupusan Sisa Pepejal MDCH (Simpang Pulai)	Open Dump	Operation	2001	2008	0.4	0.40	0.30	0.24	0.26	0.30	0.21	OP-B	C4
76	Pahang	PH-12	MD Cameron Highlands	Tapak Pelupusan Sisa Pepejal MDCH (Cameron Highlands)	Open Dump	Closed	1990	2001	0.4	0.34	0.62	0.51				CL-C	C2
77	Selangor	SL-05	MD Kuala Langat	Tapak Pelupusan Sampah	Open Dump	Operation		2007	6.1	0.47	0.35	0.53		0.64		OP-B	C3
78	Selangor	SL-06	MD Kuala Langat	Tapak Pelupusan Tanjung Sepat	Open Dump	Closed	1985	1995	1.0	0.23	0.41					CL-D	-
79	Selangor	SL-07	MD Kuala Langat	Tapak Pelupusan Banting	Open Dump	Closed	1985	1998	3.0	0.48	0.76	0.47	0.36	0.36	0.32	CL-A	C4
80	Pahang	PH-13	MD Jerantut	Kg.Mat Lilau	Level 2	Operation	1997	2005	4.4	0.68	0.18	0.65	0.94	1.00		OP-B	C3
81	Pahang	PH-14	MD Jerantut	Batu 57	Open Dump	Closed	1984	1996	2.0	0.32	0.76	0.33				CL-C	C2
82	Pahang	PH-15	MD Maran	Tapak Sampah Maran	Level 2	Operation	1988	2013	4.0	0.30	0.24	0.47	0.36	0.26		OP-D	C2
83	Pahang	PH-16	MD Maran	Tapak Sampah Jengka 10	Level 1	Operation	1997	2030	8.0	0.42	0.24		0.22	0.90		OP-B	C3
84	Pahang	PH-17	MD Raub	Sg.Ruan	Level 3	Operation	1997		3.4	0.22	0.40	0.43			0.21	OP-D	C2
85	Pahang	PH-18	MD Raub	Cheroh	Level 3	Operation	1991	2008	4.9	0.30	0.54	0.43	0.31	0.30	0.21	OP-C	C3
86	Perak	PR-10	MD Hilir Perak	MDHP (Teluk Intan)	Open Dump	Operation	1993	2008	20.3	0.35	0.35	0.55				OP-D	C1
87	Perak	PR-11	MD Hilir Perak	Tapak Sampah MDHP (Kaw. Pekan Jenderata)	Open Dump	Operation	1979	2006	0.4	0.35	0.22	0.55				OP-D	C1
88	Perak	PR-12	MD Hilir Perak	Tapak Sampah MDHP (Kaw. Bagan Datoh)	Open Dump	Operation	1979	2006	1.2	0.39	0.32	0.51				OP-D	C1
89	Perak	PR-13	MD Kuala Kangsar	MDKK	Open Dump	Operation	1986	2006	13.4	0.48	0.30	0.57	0.23	0.36	0.36	OP-B	C4
90	Perak	PR-14	MD Lenggong	Air Kala	Open Dump	Operation	1989	2008	1.5	0.34	0.30	0.53				OP-D	C1
91	Perak	PR-15	MD Lenggong	Kuak	Open Dump	Closed	1979	1999	1.2	0.31	0.29	0.33				CL-D	C1
92	Kelantan	KL-06	MD Jeli	MD Jeli (Bato 'O')	Open Dump	Closed	1990	2000	0.4	0.36	0.33	0.57				CL-D	C1
93	Kelantan	KL-07	MD Jeli	MD Jeli (Kg.Sg.Mengkong)	Open Dump	Operation	2000	2015	2.4	0.42	0.05	0.61	0.36	0.26		OP-B	C3
94	Perak	PR-16	MD Pengkalan Hulu	Tapak Pelupusan Sisa Pepejal	Open Dump	Operation	1993	2009	8.4	0.52	0.30	0.45	0.44	0.26	0.61	OP-B	C4
95	Perak	PR-17	MD Selama	Tapak Pelupusan MDS	Open Dump	Operation	1991	2008	4.0	0.44	0.58	0.65	0.22			OP-A	C3
96	Perak	PR-18	MD Tanjong Malim	Panderas	Open Dump	Operation	1980	2010	2.5	0.73	0.60	0.87	0.54	0.69		OP-A	C3
97	Selangor	SL-08	MB Shah Alam	MPSA	Open Dump	Closed		1996	12.0	0.26	0.12					CL-D	-
98	Selangor	SL-09	MP Subang Jaya	Worldwide Landfills Sdn Bhd	Level 4	Operation	1995	2015	43.0	0.35	0.63	0.22	0.48	0.56	0.21	OP-C	C3
99	Selangor	SL-10	MD Kuala Selangor	Kubang Badak B.Berjuntai		Operation	1984		20.0	0.38	0.31	0.65	0.39	0.39		OP-D	C2

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												C1	C2	C3	C4		
100	Selangor	SL-11	MD Sabak Bernam	Jalan Panchang Bedena	Level 3	Operation	1984	2006	4.0	0.18	0.30		0.22	0.26		OP-D	C2
101	Perak	PR-19	MD Kerian	Jalan Dnnistown Parit Buntar	Open Dump	Operation	1979	2003	0.8	0.64	0.60	0.69	0.79	0.56	0.21	OP-A	C4
102	Perak	PR-20	MD Kerian	Pematang Pasir Alor Pongsu (Beriah) Bagan Serai.	Open Dump	Operation	1983	2005	2.4	0.64	0.60	0.69	0.79	0.56	0.21	OP-A	C4
103	Terengganu	TR-08	MD Besut	Landfield (Sistem Tambus)	Open Dump	Operation	1993	2010	4.6	0.32	0.20	0.45				OP-D	C1
104	Terengganu	TR-09	MD Hulu Terengganu	Tapak Pelupusan MDHT	Open Dump	Operation	1982	2013	9.5	0.30	0.52				0.30	OP-C	C3
105	Terengganu	TR-10	MD Marang	MDM	Open Dump	Operation	1986	2004	2.5	0.29	0.04	0.39				OP-D	C1
106	Johor	JH-13	MD Labis	Pusat Membuang Sampah Jalan Temayar	Open Dump	*Operation*		*2005*		*0.40*	*0.35*	*0.67*	*0.30*	*0.26*		*OP-D*	*C2*
107	Johor	JH-14	MD Labis	Pusat Membuang Sampah Jalan Maskil	Open Dump	Operation	2003	2013		0.40	0.35	0.67	0.30	0.26		OP-D	C2
108	Johor	JH-15	MD Pontian	Tapak Pelupusan Jalan Sawah, Pekan Nenas	Open Dump	Operation	1998	2008	12.0	0.40	0.13	0.41	0.30	0.26		OP-D	C2
109	Johor	JH-16	MD Pontian	Tapak Pelupusan Rimba Terjun, Pontian	Open Dump	Operation	1980	2003	12.0	0.45	0.38	0.31	0.65	0.56		OP-B	C3
110	Johor	JH-17	MD Pontian	Tapak Pelupusan Sanglang, Ayer Baloi	Open Dump	Operation	1986	2006	1.2	0.55	0.14	0.55	0.21	0.24	0.51	OP-B	C4
111	Johor	JH-18	MD Segamat	Segamat Baru		Closed		2003	3.3	0.40	0.33	0.35	0.57	0.56	0.21	CL-D	C2
112	Johor	JH-19	MD Segamat	Jementah		Operation	1970	2023	10.0	0.27	0.20	0.41	0.30	0.26		OP-D	C2
113	Johor	JH-20	MD Segamat	Lebuh Raya Segamat / Kuantan		Operation	2003		90.0	0.36	0.29	0.39	0.57	0.56	0.21	OP-D	C2
114	Johor	JH-21	MD Tangkak	Simpang Bekoh	Open Dump	Operation	2000	2023	3.0	0.46	0.10	0.20	0.22	0.79		OP-B	C3
115	Johor	JH-22	MD Tangkak	Batu 16 Sengkang, Bukit Gambir	Open Dump	Operation	1970	2004	7.0	0.43	0.52	0.53	0.26	0.20		OP-A	C3
116	Johor	JH-23	MD Simpang Renggam	Simpang Renggam (Ladang Cep 1)	Open Dump	Operation	1996	2012	6.0	0.39	0.30	0.92	0.28			OP-D	C2
117	Johor	JH-24	MD Simpang Renggam	Machap	Open Dump	Closed	1986	1996	3.0	0.47	0.18	0.53	0.62	0.56		CL-B	C3
118	Johor	JH-25	MD Simpang Renggam	Renggam	Open Dump	Closed	1980	1984	2.0	0.34	0.22	0.33	0.22	0.26		CL-D	C2
119	Johor	JH-26	MD Simpang Renggam	Simpang Renggam (Jln Kulai Cina)	Open Dump	Closed	1990	1995	0.5	0.46	0.60	0.55	0.26	0.30		CL-A	C3
120	Johor	JH-27	MD Yong Peng	MDYP		Operation	1990		0.4	0.49	0.24	0.71	0.65	0.56	0.21	OP-B	C4
121	Kedah	KD-08	MP Langkawi	Tapak Pelupusan Sisa-Sisa Pepejal Majlis	Level 1	Operation	1988	2013	30.0	0.49	0.00	0.44	0.36	0.90		OP-B	C3
122	Kedah	KD-09	MD Padang Terap	MDPT	Open Dump	Operation	1988		2.0	0.53	0.42	0.83	0.57	0.56		OP-A	C3
123	Kelantan	KL-08	MD Bachok	Kg. Sungai Gali, Telong	Open Dump	Operation	1995	2009	10.0	0.40	0.30	0.65	0.27			OP-D	C2
124	Kelantan	KL-09	MD Bachok	Kg. Hujung Repek, Repek	Open Dump	Closed	1985	1995	2.5	0.49	0.52	0.51			0.59	CL-A	C4
125	Perak	PR-21	MD Gerik	MD Gerik (1)	Open Dump	Closed	1976	1997	1.8	0.28	0.10	0.24				CL-D	C1
126	Perak	PR-22	MD Gerik	MD Gerik (2)	Open Dump	Operation	1997	2032	2.0	0.49	0.18	0.47	0.48	0.56		OP-B	C3
127	Kelantan	KL-10	MD Machang	Air Berlaga	Open Dump	Operation	2002	2010	4.0	0.40	0.30	0.53	0.36	0.26		OP-B	C3
128	Kelantan	KL-11	MD Pasir Puteh	Tapak Pelupusan Bukit Gedombak	Open Dump	Operation	1982	2020	2.0	0.38	0.22	0.45	0.22			OP-D	C2
129	Kelantan	KL-12	MD Tumpat	Kok Bedollah	Level 1	Operation	1988		20.0	0.35	0.15	0.44	0.36	0.26		OP-D	C2
130	N.Sembilan	NS-08	MP Port Dickson	Bt.2, Jln Seremban		Closed		1972	2.0	0.22	0.27	0.37				CL-D	C1
131	N.Sembilan	NS-09	MD Jelebu	Pertang	Open Dump	Closed	1997	2002	2.4	0.33	0.17	0.41				CL-D	C1
132	N.Sembilan	NS-10	MD Jelebu	Sg.Muntuh	Open Dump	Operation	2002	2032	6.1	0.33	0.17	0.41				OP-D	C1
133	N.Sembilan	NS-11	MD Jempol	MD Jempol (Rompin)	Open Dump	Operation	1993		5.0	0.39	0.05	0.59				OP-D	C1
134	N.Sembilan	NS-12	MD Jempol	MD Jempol (Bahau)	Open Dump	Closed	1981	1993	1.2	0.26	0.38	0.28				CL-D	C1
135	N.Sembilan	NS-13	MD Rembau	Chembong	Open Dump	Operation	1982	2010	4.0	0.43	0.41	0.51	0.35	0.26		OP-A	C3

ID	State	No.	Name of LA	Name of Site	Landfill Level	Category	Year Start	Year End	Area (ha)	Environ-mental Risk	Value of Land Utilization	The necessity of the safe closure				Group	Closure Level
												C1	C2	C3	C4		
136	Kelantan	KL-13	MD Tanah Merah	KG.Cat Rimau	Open Dump	Closed	1981	1999		0.60	0.32	0.94	0.54	0.30	0.44	CL-B	C4
137	Perak	PR-23	MP Manjung	Sungai Wangi	Level 1	Operation	1980	2003	10.1	0.42	0.09	0.67	0.40	0.30	0.21	OP-B	C4
138	Perak	PR-24	MP Manjung	Tapak Pelupusan Teluk Cempedak	Level 1	Operation	1990	2005	2.0	0.34	0.44	0.47			0.21	OP-C	C3
139	Perak	PR-25	MP Manjung	Pantai Remis	Open Dump	Operation	1970		1.2	0.38	0.12	0.31	0.26	0.30	0.21	OP-D	C2
140	Perak	PR-26	MP Manjung	Beruas	Open Dump	Operation	1970		0.8	0.37	0.09	0.45	0.36	0.26		OP-D	C2
141	Selangor	SL-12		Ampang Jaya	Level 1	Closed	1980	1997	10.0	0.67	0.33	0.47	0.86	1.00		CL-B	C3
142	DBKL	DB-02	DB Kuala Lumpur	Jinjang Utara	Level 2	Operation	1979		10.0	0.52	0.59	0.69	0.76	0.30		OP-A	C3
143	DBKL	DB-03	DB Kuala Lumpur	Sri Petaling	Level 1	Closed	1979	1991	21.0	0.35	0.59	0.26	0.30	0.26		CL-C	C3
144	DBKL	DB-04	DB Kuala Lumpur	Sungai Bersi	Level 2	Closed	1989	1995	14.0	0.36	0.59	0.26	0.44	0.26		CL-C	C3
145	DBKL	DB-05	DB Kuala Lumpur	Paka 2	Level 2	Closed	1989	1994	6.5	0.37	0.59	0.63	0.36	0.26		CL-C	C3
146	DBKL	DB-06	DB Kuala Lumpur	Paka 1	Level 1	Closed	1989	1994	6.5	0.40	0.75	0.63	0.36	0.26		CL-A	C3
147	DBKL	DB-07	DB Kuala Lumpur	Kampung Semarak (Brickfield)	Open Dump	Closed				0.44	0.63	0.63	0.36	0.26		CL-A	C3

Safe closure level shall be determined taking into account the "necessity of the safe closure" described in the above **Table A19-1** and "priority for closure" stated in following **Table A19-2**. Relationship between landfill closure priority and safe closure level is shown below.

Table A19-2 Relationship between Landfill Closure Priority and Safe Closure Level

Group	Priority for closure	Safe closure Level			
		C1	C2	C3	C4
Group A	High			+++	++
Group B	Middle		+	+++	+
Group C	Middle		+++	++	
Group D	Low	++	+++		

Note: +, ++, +++: magnitude of the relation (+: low, ++: medium, +++: high)

Appendix 20

Hazard Experience Caused by the Landfill Sites in Several Countries

Examples of hazardous incidents experiences in other countries are tabulated in **Table A20-1.**

Table A20-1 Hazard Experiences Caused by the Landfill Sites in Several Countries

No	Location	Year	Hazard Types	Outline of the Hazards
1	Kobe, Japan	1977	Gas explosion	2 gas explosions occurred in a school in Kobe. As a result of site investigation, the land was found to be an ex-landfill site. The school was closed for half a year to ensure the area was safe for the pupils to return.
2	Chiba, Japan	n.a.	Gas migration	A carrot farm situated next to the landfill was exposed to the escaping methane gas. The gas and also a rise in temperature caused some damage to the crops.
3	Fukuoka, Japan	1999	Gas breakout	3 workers were killed when they were exposed to a gust of hydrogen sulphide gas whilst carrying out some digging/boring work at the landfill site.
4	Okinawa, Japan	2002	Landfill fire	A fire occurred at a landfill site in Miyako Island which resulted in the release of several types of toxic gases. The local residence experienced and suffered irritations to their eyes and throat.
5	Selangor, Malaysia	1998	Landslide and fire	Landslide occurred at a landfill site in Ampang Jaya, Selangor. It was reported that two people were buried alive. After the incident, the site was immediately closed.
6	Atlanta, USA	1999	Gas explosion	A gas explosion caused an-8-year-old girl to suffer burns on her arms and legs while playing in a playground. The area was later discovered to be an illegal dumping ground many years ago.
7	North California, USA	1994	Gas explosion	A woman was seriously burned by a methane gas explosion while playing soccer in a park that was built over an old landfill site in Charlotte, North Carolina,.
8	Pittsburgh, USA	1987	Gas explosion	Off-site gas migration from the landfill caused an explosion in a housing area in Pittsburgh, Pennsylvania.
9	Ohio, USA	1984	Gas explosion	Off-site gas migration from the landfill caused an explosion and destroyed a house in Akron, Ohio.
10	Cincinnati, USA	1983	Gas explosion	Gas explosion caused by the landfill destroyed a house across the street from the site in Cincinnati, Ohio. Some injuries were reported.
11	Colorado, USA	1975	Gas explosion	In Sheridan, Colorado, a gas explosion occurred near the storm drain laid across the site. The explosive gasses accumulated in the drain pipe ignited when a group of children were playing and lighting candles near the drain. The children all suffered serious injuries.
12	North California, USA	1969	Gas explosion	Methane gas migrated from the adjacent landfill leaked into the basement of an armoury in Winston-Sakem, North Carolina. The gas ignited when a cigarette was lit thus killing three men and seriously injuring five others.

No	Location	Year	Hazard Types	Outline of the Hazards
13	New York, USA	n.a.	Health problem	On the request from the community near the landfill site, an American agency conducted a public health assessment of the area. The assessment report concluded that there is a potential health risk to the community and may of cause respiratory damage due to hydrogen sulphide gas emitting from the sites although Further study is required.
14	Philippine	2000	Landslide	Heavy rainfall triggered an avalanche at a waste dumping site in the suburb of Quezon City. At least 68 people died and 800 were evacuated to emergency shelters.
15	Nantygwyddon, UK	n.a.	Health problem	More than 120 residence living near Nantygwyddon landfill site suffered major health problems. At the court, the residence group won a major compensation claim.
16	Bogota, Colombia	1997	Landslide	It was reported that 80ha of avalanche at a waste dumping site occurred in Bogota.
17	Ghemme, Italy	1992	Gas explosion	Underground gas migration from the closed landfill site caused an explosion at the nearby industrial plant.
18	Carate-Brianza, Italy	1981	Gas migration	Gas migration from operating landfill sites seeping into nearby industrial facility was reported.
19	Casate, Switzerland	1981-	Gas migration	Gas migration from landfill seeping into a home was reported.
20	Sarajevo, Yugoslavia	1977	Landslide and gas explosion	About 200,000 m^3 of avalanche occurred at the landfill site due to stability failure and gas explosions. Horizontal movement was recorded to be over 1 km and a number of nearby houses were burnt.
21	S. Augustin, Germany	1981	Gas migration	Gas migration from nearby landfill site occurred in the subsoil layer resulting in the neighbouring houses had to be evacuated.
22	Biella, Italy	1981	Gas explosion	Gas migrated via the subsoil layer penetrated into the neighbouring house resulting in an explosion that caused the death of the resident.
23	Cavenago, Italy	1996	Gas migration	Landfill gas migrated over a distance of 1 km and caused damage to the vegetation in nearby area.
24	Los Angeles, USA	1982	Landslide	A residential area built on a closed landfill showed cracks on the ground and experienced land movement.
25	Sacramento, USA	2002	Landfill fire	A fire occurred at a landfill site in Sacramento.
26	West Valley, USA	2002	Landfill fire	A fire occurred at a landfill site. It is reported that the fire produced some toxic gases such as carbon monoxide.
27	Vancouver, Canada	2000	Landfill fire	A fire occurred in a landfill site in Vancouver. The total damages and loss by the fire was estimated to be about at $80,000.

Note: The above list is in random order.

Sources: Information retrieved and collected from the "Agency for Toxic Substances and Disease Registry (USA)", CNN, BBC, Encos SA (Switzerland), Fire Department in Sacrament & West Valley (USA), MP Ampang Jaya etc.

Appendix 21

Case Example of Landfill Safe Closure & Post Closure Land Use

(1) CASE EXAMPLE OF THE SAFE CLOSURE OF LANDFILL SITE

a. Outline of the case example of safe closure

For the purpose of surrounding environmental conservation, the seepage control work which surrounds a landfilled waste with the polyethylene sheet was introduced.

b. Outline of the landfill site

Term of landfill works: 1973-1986

Type of landfilled waste: incineration ash and separation residue of non-combustible refuse

Landfill area: 3,000m^2

Amount of waste disposal: 22,000m^3

Remarks: The conservation measures of groundwater contamination, such as seepage control works, are not performed at all.

c. The process which resulted in the safe closure

Since this landfill site was the open dumping landfill site where equipment of seepage control work etc. was not installed and an environmental conservation measure is inadequate, inhabitants at the downstream region were demanding the removal of the landfilled waste by the reason that there is a fear of the ground water pollution.

The cause of the problem was that the seepage control sheet was not installed in this landfill site.

As a result of the environmental investigation performed by specialists whom entrusted by city, the following proposals were made: "It isn't possible to declare that the influence of the pollutant from landfill site does not reach a down-stream region at all. For this reason, it is necessary to take countermeasures so that influence may not arise."

Therefore, it implemented safe closure measure according to the proposal of the professionals.

d. Countermeasure works

Seepage control walls for blocking the flow of the groundwater which flows into landfill was installed, and further, surface liner by cover soil was installed so that rain water might not soak into the landfilled waste from surface of the landfill. The cost of countermeasure works of about 200 million yen in total was paid by the city.

This post-closure landfill site was inherited from the developer by the city with 30,000m^2 including the surrounding area, and is used as a playground of the elementary school in a new urban residential area.

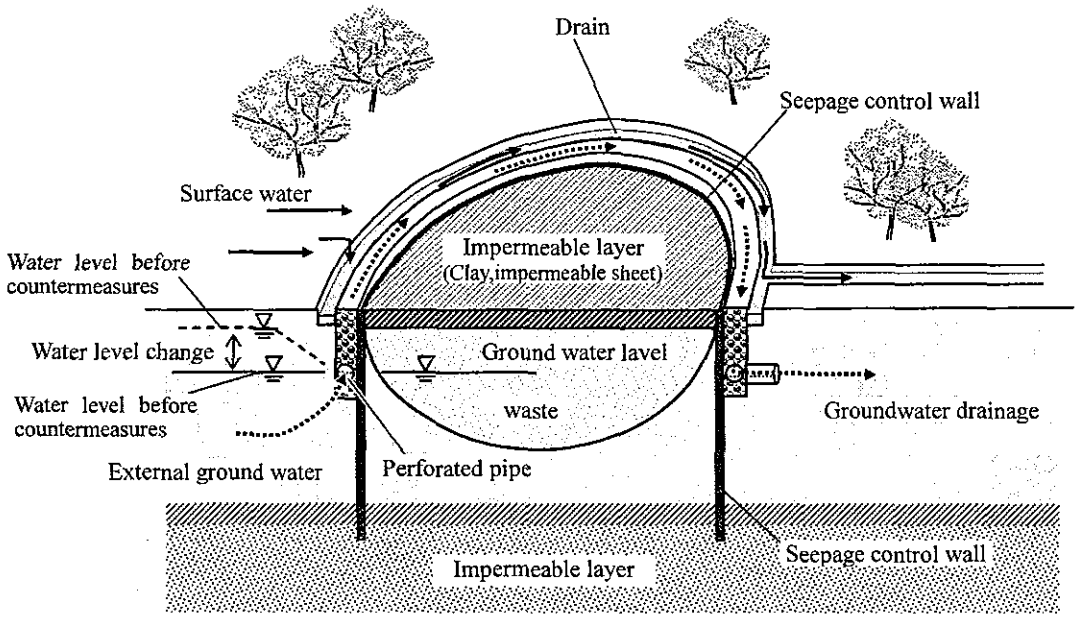

Figure A21-1 Image of the Safe Closure Measurement

(2) CASE EXAMPLE OF THE POST-CLOSURE LAND USE

1) Surface use

Case : Use for golf course

a. Outline of the case example of the post-closure landfill use

A post-closure landfill site for municipal waste of Tokyo metropolitan government was used as the park (Wakasu Sea-side Park) which the golf course is a main use.

Post-closure landfill use is jurisdiction of the bureau of port and harbour, Tokyo metropolitan government. Since it was necessary to make the facilities which the trouble by the sinking of the landfill doesn't occur, a golf course was adopted by the main use of the park.

Countermeasure work was started in 1988 and post-closure landfill use was started from December, 1990.

b. Outline of landfill site

Name of the landfill site: The No.15 site (Tokyo metropolitan government)

Term of landfill works: 1965-1974

Landfill area: 71.2ha

Amount of waste disposal: 10.34 million ton

Thickness of landfill layer: 14-20m

Landfill method: Sea area landfill (the method of dumping waste in the water from the landfill seawall constructed in the sea)

c. Countermeasure works

- Installing of gas ventilation pipes for countermeasure against landfill gas.
- No smoking regulation on the golf course because of generating of methane gas
- Measure which prevents soaking of the rain water for decreasing the quantity of leachate
- Nothing particular measure for subsidence about the play ground of the golf course

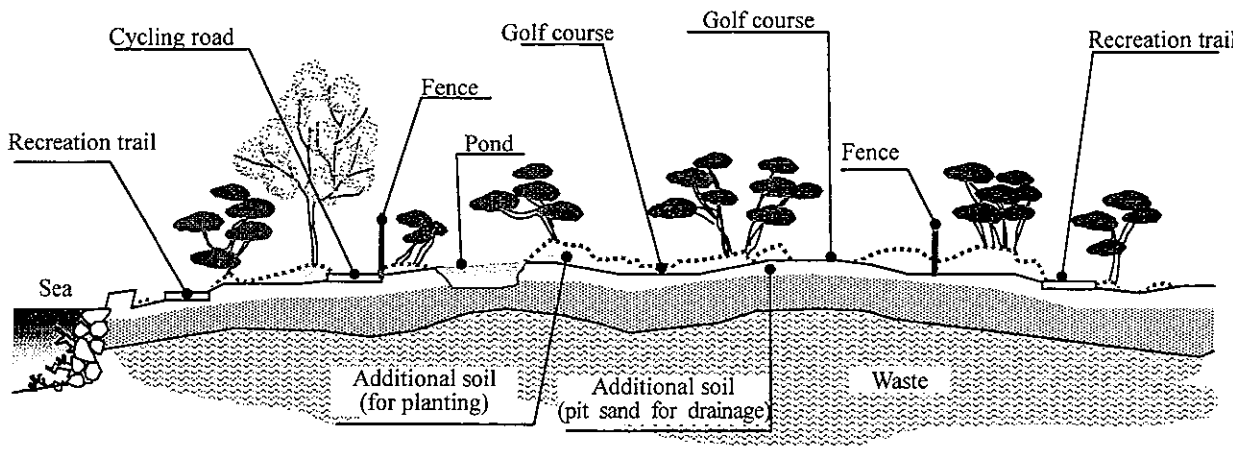

Figure A21-2 Standard Profiles of Wakasu Sea-side Park

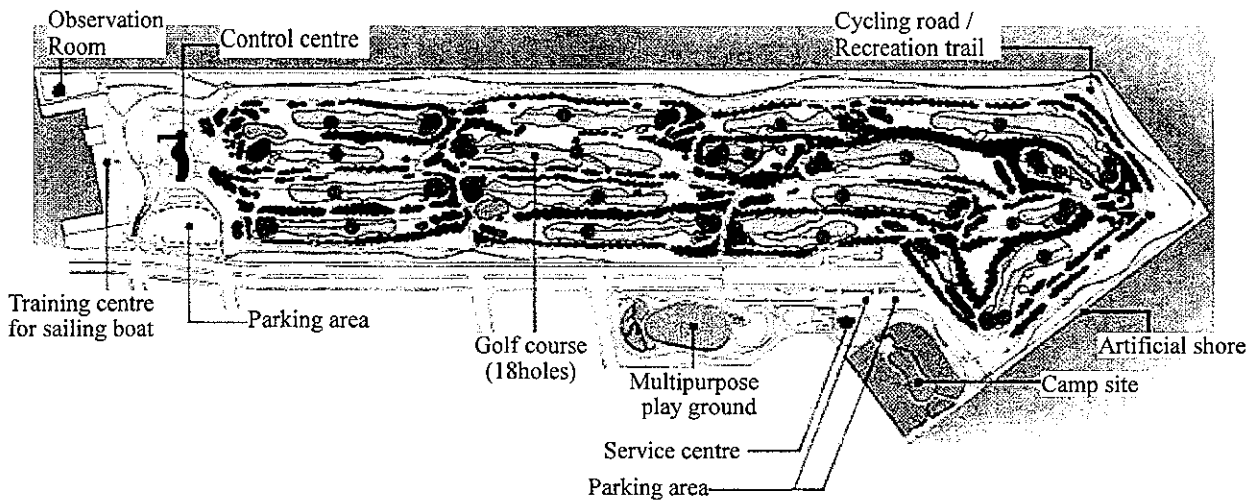

Figure A21-3 Top View of Wakasu Sea-side Park

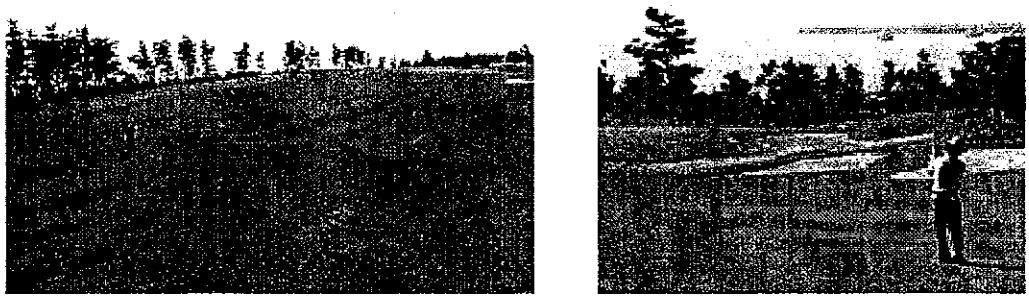

Photo A21-1 Golf Course of Wakasu Sea-side Park

2) Medium layer use

Case: Use for distribution station

a. Outline of the case example of the post-closure landfill use

A post-closure landfill site for municipal waste was used as the distribution station (Fujimae distribution station) and residential district.

b. Outline of landfill site

Type of landfill site: municipal waste landfill site (80% is glass, pottery waste and incineration ashes and others are organic matter.)

Term of landfill works: 1968-1974

Landfill area: approximately 95ha

Amount of waste disposal: estimate 3.3 million ton or more

Thickness of landfill layer: 2-5m

Remarks: Before reclamation, it is the paddy field of 0 m sea level. Seepage control works was not installed.

c. Countermeasure works

- At the area used as common carriers, warehouses and wholesale trades, foundation improvement of the road part was performed by the percussion compaction method for the purpose of the early stability of the subsidence.
- At the other area, foundation improvement was performed by the surcharge method.
- Subsidence was accelerated an average of 1m or more and the amount of residual subsidence was decreased considerably. As for the manhole, the mesh-like hole was processed at the lid for gas ventilation.

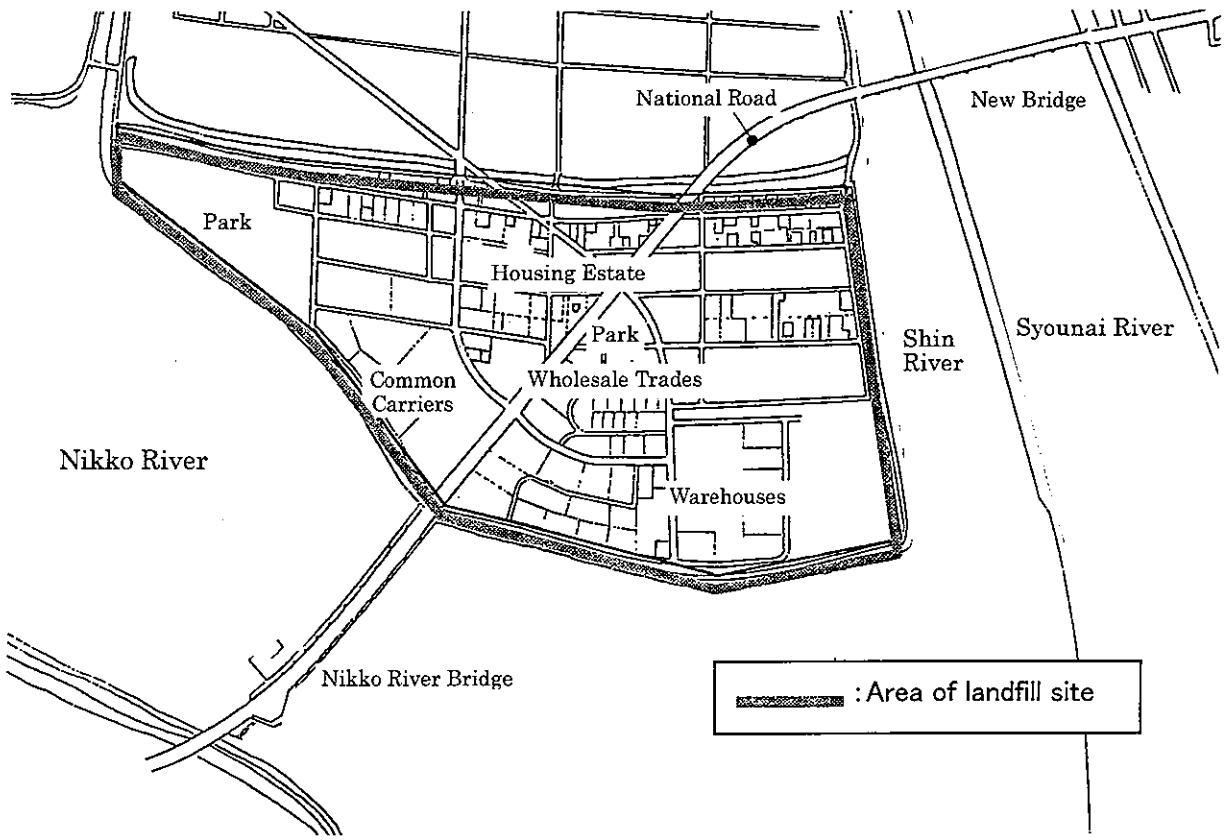

Figure A21-4 Top View of Post-closure Landfill Use

3) Bottom layer use

Case: Bridge pier construction of a highway interchange elevated bridge

a. Outline of the case example of the post-closure landfill use

A post-closure landfill site for industrial waste was used as the highway interchange of the 2nd Meishin super highway (under construction).

The Kuwana interchange is single trumpet type interchange. The highway main road and a ramp part are elevated structures, and seven bridge piers were constructed in the post-closure landfill.

b. Outline of landfill site

Type of landfill site: industrial waste landfill site

Landfill area: approximately 6.4ha

Amount of waste disposal: approximately 42,500 ton (sludge: 200,000m^3, glass and pottery waste: 60,000m^3, slag: 43,000m^3, organic sludge/animal and vegetable residue: 46,000m^3)

Thickness of landfill layer: 14-20m

Remarks: seepage control works by geomembrane lining sheet

Leachate inside the landfill was collected by the leachate collection pipes. It was pumped up and treated by the leachate treatment facility.

The landfill surface was covered by the cover soil of approximately 50cm thickness.

c. Countermeasure works

- Construction of the substructure pile (well foundation, steel pipe sheet pile) to the supporting layer near -45 m of GL
- Substructure construction :

  Displacement of industrial waste within the waste layer to 10m of underground

  Construction of steel pipe sheet pile

  Excavation of industrial waste inside the well curb

- Since the geomembrane lining sheet laid at the landfill bottom is damaged by the construction of steel pipe sheet pile, in order to prevent the outflow of the leachate to the surrounding area, seepage control work (sealing steel sheet pile) was installed to impermeable layer at the circumference of landfill.
- The measure performed with construction is as **Table A21-1**.

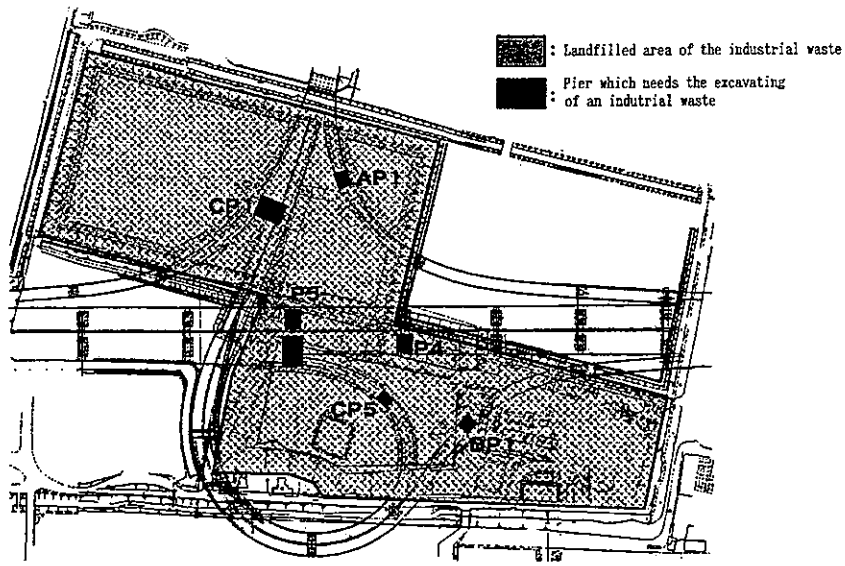

Figure A21-5 Top View of Post-closure Landfill Use at the Kuwana Interchange

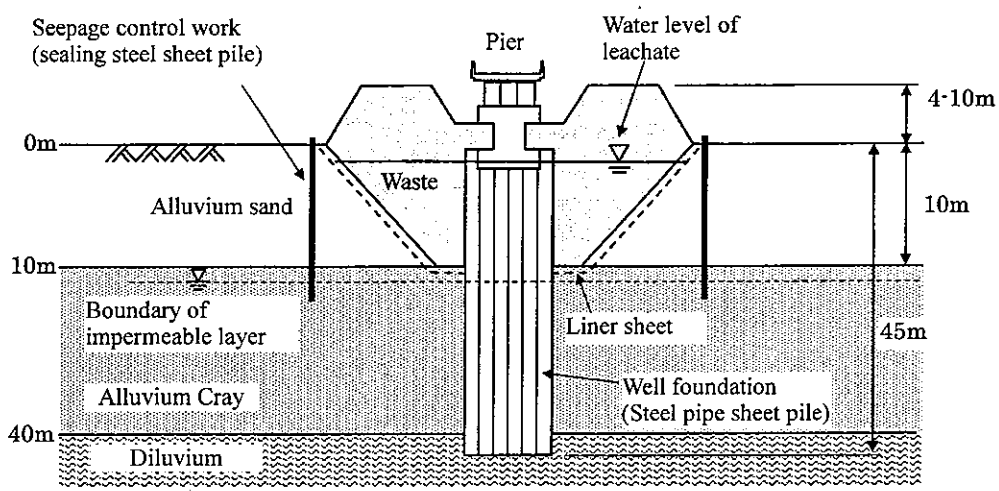

Figure A21-6 Image of Cross Section of the Pier

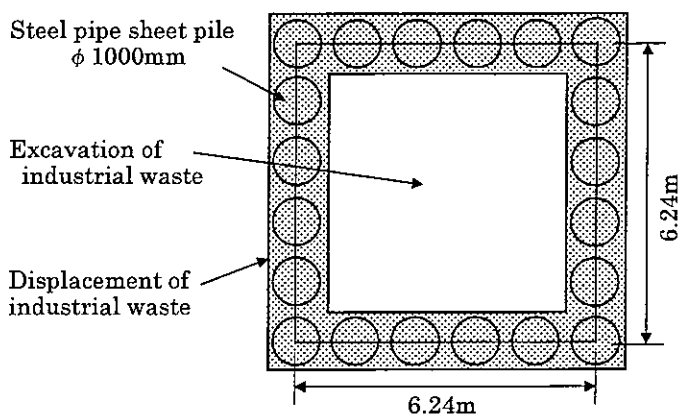

Figure A21-7 Top View of the Pier

Table A21-1 Measure Performed with Construction

Target of measures	Assumed accidents	Countermeasure	Details
Gas	Oxygen depletion Explosion of flammable gas Gas poisoning by hydrogen sulphide Gas poisoning by organic solvent	Gas ventilation in advance	In advance of excavating industrial waste, the retaining gas in the ground was sucked and exhausted compulsorily, and concentration of harmful gas was reduced.
		Automatic gas detecting system	Automatic measurement for every work site Remote central control
		Rescue, lifesaving, and fire-extinguishing equipment	Deployment of breathing apparatus, Emergency escape equipment, special fire extinguisher, etc.
Offensive odour	Odour trouble	Deodorization by soil deodorization equipment	Removal of the offensive odour in closing space
		Spraying of the deodorization material by special atomizer	Automatic spraying by the odour sensor
		Daily cover method	Containment of a odour by the self-hardening foam
Harmful substance (Leachate)	Outflow of pollutants to the surrounding area	Transfer to a neighbouring treatment facility	Installation of a piping system Installation of a leachate controlling facility
		Enclosure of the landfill site	Underground : Installation of sealing steel sheet pile to impermeable layer Ground : Installation of the lining sheet to dykes
		Environmental monitoring	Continuing monitoring of the water quality change etc. at the inside/outside of construction area
	Deterioration of structures	Electrical protection	Process to steel substructure piles etc.
		Corrosion protection of concrete	Surface protection of building frame by the polyurethane membrane
Disease	Infectious disease Contact with chemicals Disorder of respiratory function	Unattended works	Use of a radio-controlled heavy industrial machine in the pit or vertical shaft
		Vaccination Blood test	Prevention of hepatitis and tetanus
		Wear of protective equipment	Use of gas mask, goggle, etc.

Appendix 22

Case Example of Problems Associated with the Post-Closure Landfill Sites

< CASE 1 > EFFECTS OF HEAVY RAIN

1) Overview of the problems

- The landfilled waste was washed out by heavy rain.
- The nearby Cedar forest was damaged by the landfill gas. (refer to Case 4)
- There was an explosion during the construction of the drain pipe at the closed site.

Table A22-1 Basic Description of the Site

Operation start year	early 1970s
Type of waste	Municipal waste
Landfill area	Unknown
Topography	Mountain area
Facility (during operations)	Liner system was not installed. Gas vent pipes, leachate collection facility, and leachate treatment facility was installed.

2) Cause of the problems

- Part of the dyke collapsed by the heavy rain.
- Since the liner system was not installed, the landfill gas escaped to the adjacent land.
- The consideration for post closure development was insufficient.

3) Countermeasures

- The washed out waste was collected and removed back to the landfill and the dyke was repaired.
- Gas venting pipes were installed at the border to the adjacent land in order to prevent further gas migration and vent the collected gas to the air.
- Specific guideline for post-closure land use of the site was prepared.

< CASE 2 > DAMAGE TO THE UTILITY PIPELINES CAUSED BY SUBSIDENCE

1) Overview of the problems

The low-rise apartments constructed at the closed site were provided with precast concrete foundations. There was almost no subsidence to the building but the surrounding grounds of the building experienced heavy subsidence of more than 200mm and thus damaged the connecting pipes. Therefore, in order to avoid further

damage to the utilities such as water, sewage, gas and electricity, etc, special consideration were required.

Table A22-2 Basic Description of the Site

Operation start year	early 1970s
Type of waste	Municipal waste (mainly : incombustible waste)
Landfill area	Unknown
Topography	Mountain area
Facility (during operations)	Liner system, gas vent pipe, etc. were not provided.

2) Cause of the problems

The foundation of the building did not subside, however the surrounding area settled caused the buried pipes to subside and break at the interconnection points to the building. (Refer to **Figure A22-1**)

3) Countermeasures

- Flexible joints were used at the interconnections of the utilities to the building. This increased the flexibility of the pipelines and prevented them from breaking easily.
- In order to determine the future rate of subsidence, investigative study was carried out based on the waste characteristic analysis, the composition analysis and the rate of decomposition.

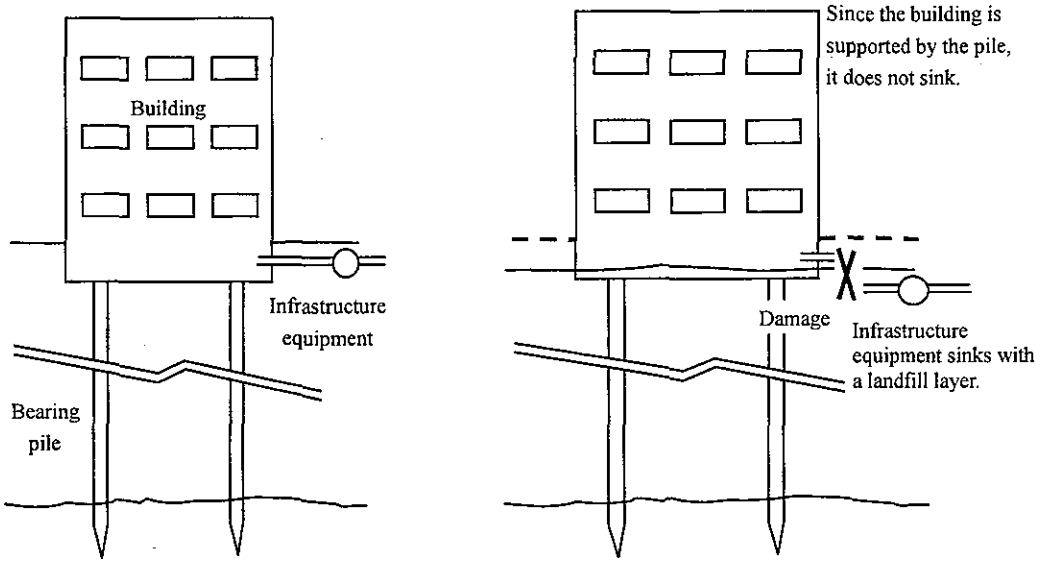

Figure A22-1 Damage Caused by Differential Subsidence

< CASE 3 > DAMAGE TO PADDY FIELD BY INSUFFICIENT LEACHATE TREATMENT

1) Overview of the problems

The rice of a paddy field withered owing to the salt of the leachate from a nearby closed landfill site.

Table A22-3 Basic Description of the Site

Operation start year	early 1970s
Type of waste	Municipal waste (mainly: Incinerator residue)
Landfill area	Unknown
Topography	Unknown
Facility	Unknown

2) Cause of the problems

- The site was mainly filled with the municipal waste the incineration residue. The salts contained in the incinerator residue were dissolved into leachate. The leachate was collected and treated. The effluent from leachate facility was discharged into the small drains. The discharge effluent from the site complied with the standards for the Water Pollution Control Law, however the standard for the salts was not defined.

3) Action against the trouble

- The effluent was diverted and discharged to the wider channel so that some dilution will occur, and the salt will not affect the crops so much.

< CASE 4 > CROP DAMAGED BY LANDFILL GAS

1) Overview of the problems

The crops died at the nearby field due to over exposure to the landfill gas.

Table A22-4 Basic Description of the Site

Operation start year	Unknown (late 1970s)
Type of waste	Inert Waste (mainly : Construction and demolition waste)
Landfill area	Unknown
Topography	Flatland
Facility	Liner system, gas vent pipe, etc. were not provided.

2) Cause of the problems

- At this landfill site, the disposal of only inert waste (i.e. plastics, rubber, metal, glass, ceramic, asphalt concrete and so on) was licensed, but during operations, organic waste was also disposed at the site. Hence, landfill gases were generated by the biodegradation of the organic matter.
- Since the liner system was not installed in this landfill site, the landfill gas migrated and escaped into the adjacent land through the ground. (refer to **Figure A22-2**)
- The landfill gases escaped to the atmosphere not only through the cover soil but also migrated to the adjacent land through the ground.

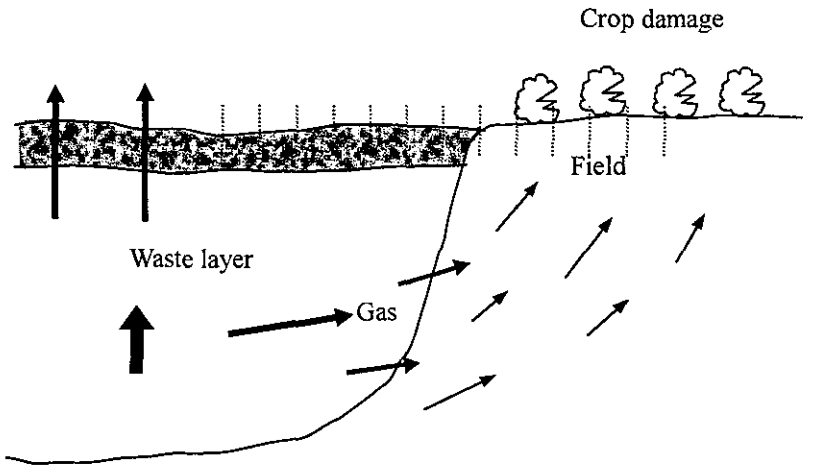

Figure A22-2 Migration of Landfill Gas to the Adjacent Land

3) Countermeasures

- In order to determine the cause of the problem, germination/sprouting tests were carried out.
- In order to prevent the gas migration to the adjacent land, barrier wells (vertical gas vent pipes) were installed at the boundary, as shown in **Figure A22-3**. The gases were intercepted and vented before reaching the crops.

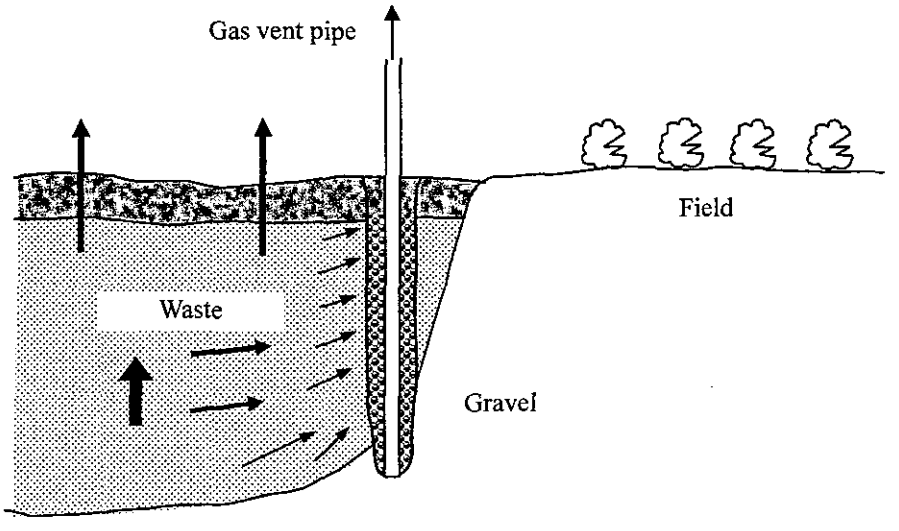

Figure A22-3 Control of Gas Migration by Gas Barrier Wells

< CASE 5 > FIRE CAUSED BY LANDFILL GAS

1) Overview of the problems

- At the residential area developed on the closed site, the residents burned their garden waste in their yard. The fire was extinguished eventually, but in the evenings, bluish flames have been discovered at the garden area. This was due to the landfill gas being burning. The flame of the burning landfill gas is difficult to see in the daylight but is highly visible at night.
- Subsequent investigation determined that the landfill gas was escaping from the ground and was ignited.

Table A22-5 Basic Description of the Site

Operation start year	early 1970s
Type of waste	Municipal waste (Raw garbage, etc.)
Landfill area	Unknown
Topography	Mountain Area
Facility (during operations)	Liner system, gas vent pipe were not provided.

2) Cause of the problem

- The landfill gas, which was generated by biodegradation of raw garbage, escaped into the yard.
- Since the residents were not aware of the presence of the landfill gas, the care for fire hazards and safety was insufficient.
- The housing developers did not give sufficient information or warning concerning the effects of the landfill gas to the residents

3) Countermeasures

- In order to prevent the landfill gas escaping into the yard, the gas collection and vent pipes, i.e. vertical and horizontal pipes, were installed throughout the development, and the gas was collected and vented.
- Gas monitoring, such as composition analysis, was carried out regularly in the outlet of the gas vent pipes.

< CASE 6 > GENERATING OF AMMONIA GAS BY SPREADING OF LIME

1) Overview of the problems

- The spreading of lime on the soil at the closed site was carried out in order to strengthen the bearing capacity of the ground for development purposes. Gaseous ammonia was generated as a result of the unintended chemical reaction between the lime and the chemicals present in the waste. The workers at the development complained about irritation to their eyes and to their respiratory organs.

Table A22-6 Basic Description of the Site

Operation start year	early 1960s
Type of waste	Mainly raw garbage , partly incinerator residue
Landfill area	Unknown
Topography	Flatland
Facility	Unknown

2) Cause of the problems

- Much concentration of ammonium ions were present in the waste layer in the liquid phase which were generated by the decomposition of the waste.
- Since lime, which is a strong alkali, was added to the waste layer, ammonia, "ammonia stripping" reaction will occur and librates the ammonium gas. "Ammonia stripping" is a well-known process to remove the ammonia from waste water into the air by adding the strong alkali.

3) Countermeasures

- The construction of applying lime to the ground was stopped. The post-closure land use plan was revised.
- Composition analysis and a dissolution test for the landfilled waste were carried out.
- The laboratory scale ammonia generating reaction test was carried out.

Appendix 23

Sanitary Landfill System and Levels

1 Integrated Landfill Facilities

A proper sanitary landfill must be provided with all the necessary facilities in order for the system to function effectively. The supporting and ancillary facilities must be integrated with the core facilities to form the Sanitary Landfill System.

A typical sanitary landfill system must be provided with all the necessary facilities as shown in **Figure A23-1**. Generally the sanitary landfill system comprise of the core facilities, such as the waste retaining facility, leachate collection piping facility, gas vents, access roads, drainage system, fencing etc; and the supporting facilities, such as the leachate treatment facility, administrative facility, machineries etc.

The supporting facilities must be able to function independently as individual standalone facilities. However, their functions are generally interdependent and should be operated as integrated facilities, mutually support each other's functions. The design of the individual facilities differs from site to site, depending on the size, the requirements and the design service lifespan. All the facilities must be designed to operate and used throughout the designed target lifespan of the landfill. Some facilities must also be able to function beyond the target lifespan, i.e. to function even after the closure of the site. Such facilities include the gas venting systems, the leachate collection and treatment facilities etc.

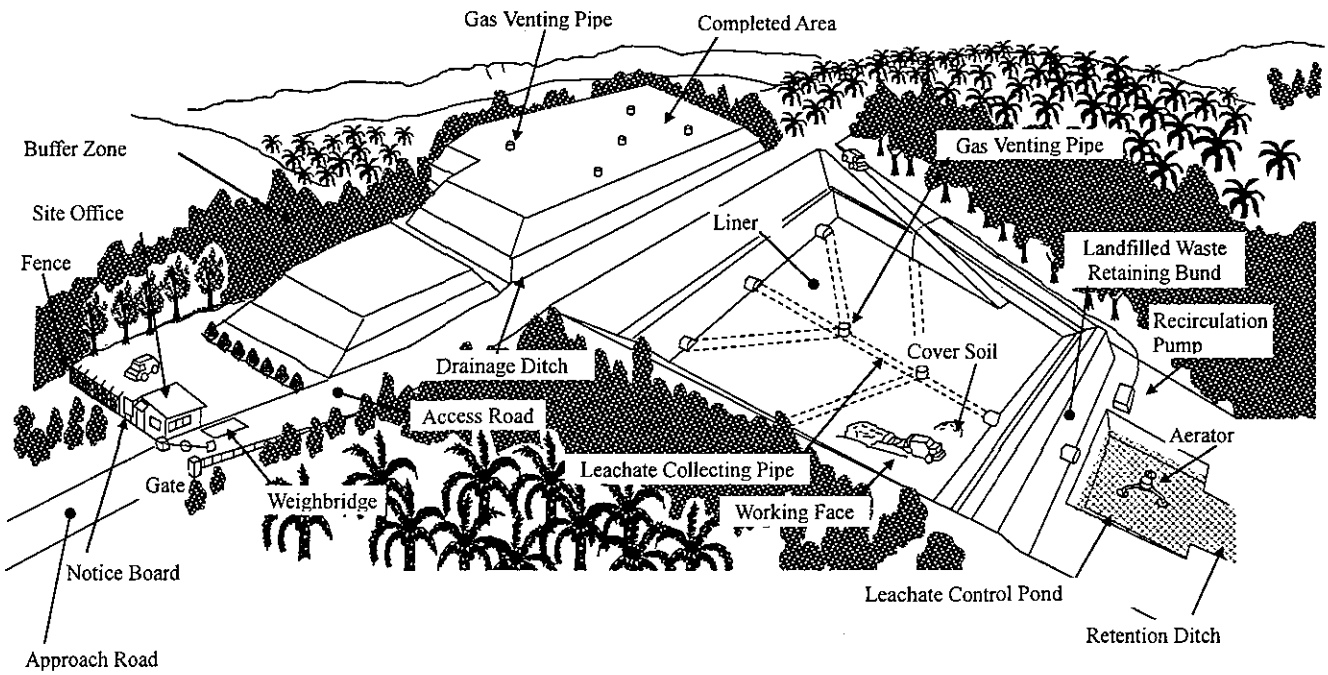

Figure A23-1 Typical Sanitary Landfill System

2. Classification of Sanitary Landfill Levels

The level of improvement of the sanitary landfill system* can be classified into four (4) levels. They are;

Level 1: Controlled tipping

Level 2: Sanitary landfill with a bund and daily cover soil

Level 3: Sanitary landfill with leachate recirculation system

Level 4: Sanitary landfill with leachate treatment facilities

The classification is used to determine the required standard of improvement to be achieved based on considerations to the site conditions, financial constraints, proposed technology, post closure land use, etc.

* "Sanitary Landfill" is defined as follows:
A method of disposing of solid wastes on land without creating nuisances or hazards to public health or the environment. Using the principles of engineering the solid waste is confined to the smallest practical area, reduced to the smallest practical volume, and covered with a layer of earth at the conclusion of each day's operation (daily cover), or at more frequent intervals as may be necessary.

The levels are also used to determine the environmental impact and countermeasure of the landfill. The higher the level will result in lower environmental impact and thus fewer countermeasures will be necessary for closure and subsequent post closure utilisation.

New landfill should be designed to achieve Level 3 or Level 4, whilst for the existing landfill sites, the rehabilitations and improvement targets must achieve Level 3 or below. Landfills that do not meet the minimal standards are considered as open dump sites and should not be encouraged. Such sites must be closed safely and immediately.

The summary of the classification of the levels and the proposed facilities are tabulated *in* **Table A23-1.**

Table A23-1 Level of Sanitary Landfill System

Facilities	Level 1	Level 2	Level 3	Level 4
Soil Cover	+	++	++	++
Embankment		++	++	++
Drainage facility		++	++	++
Gas venting		++	++	++
Leachate collection			++	++
Leachate re-circulation			++	++
Leachate treatment				++
Liners				++
			Semi-aerobic	

Note: + / To be provided periodically.
++ / Level 2, 3 and 4 : To be provided daily.

2.1 Level 1

The level 1 is the lowest level to be adopted. Basically waste is just dumped on the landfill in a controlled manner and levelled. Soil cover should be laid periodically.

(1) Target

- Introduction of controlled tipping. Waste shall be dumped in an orderly manner.

(2) Achievements

- Provision of well maintained access to the site
- Provision of periodic cover material to prevent scattering of wastes, minimise odour and fire
- Provision of basic management systems to inspection, control and daily logs of incoming wastes.

(3) Necessary Improvements to the Next Level

- Establishment of the site boundary
- Provision of environment protection facilities
- Provision of basic staff amenities such as office space, toilets, locker room
- Introduction of semi-aerobic sanitary landfill.

(4) Environmental Issue

- Since only periodic cover materials are provided, the environmental impacts are still present, such as:
- Surface and groundwater pollution by leachate
- Scattering of waste and dusty
- Breeding of insects and rodents
- Unpleasant view of landfill
- Noise pollution
- Unpleasant odour

2.2 Level 2

The level-2 sanitary landfill shall be provided with the solid waste retaining structure, clearly defined cells and surface water drainage. The soil cover shall be provided daily.

(1) Target

- Sanitary landfill with a bund and daily cover soil

(2) Achievements

- Establishment of site boundary to clearly demarcating the disposal site
- Provision of sufficient daily cover soil
- Provision of surrounding bund to contain the waste
- Provision of surface and perimeter drainage system to divert the storm water
- Provision of environment protection facilities such as buffer zone, litter control and gas ventilation facilities
- Introduction of semi-aerobic sanitary landfill by providing gas ventilation facilities
- Provision of basic staff amenities such as office space, toilets, locker room

(3) Necessary Improvements to the Next Level

- Improvement of semi-aerobic sanitary landfill
- Provision of leachate collection system
- Provision of leachate treatment facilities

(4) Environmental Issue

In this level, since disposal site and drainage system are already established, landfill operations can be controlled effectively. With the application of sufficient cover and provision of some environment protection facilities, impacts from landfill operation will be much lower than Level 1. The installation of gas ventilation facilities will result in achieving semi-aerobic conditions. However, leachate is still not under control and an environmental monitoring system should be established.

2.3 Level 3

The level-3 is an improvement to the level 2 sanitary landfill by the provision of leachate collection and recirculation system. The leachate collected trough a series of collection pipes will be recirculated back to the waste layer so that it may be reprocessed and further decompose to improve leachate quality. Recirculation will also promote faster evaporation and thus reducing the quantity of the effluent.

(1) Target

- Sanitary landfill with leachate recirculation system

(2) Achievements

- Establishment of leachate control by the installation of leachate collection, recirculation and monitoring facilities

(3) Necessary Improvements to the Next Level

- Provision of leachate treatment system
- Establishment of semi-aerobic sanitary landfill

(4) Environmental Issue

The leachate accumulated at the bottom layer of landfill will be collected and recirculated thus improving the quality and reducing the odour by the semi-aerobic decomposition process. The installation of leachate collection pipes beneath the waste layers will also promote ventilation and allow oxygen to penetrate into the waste to maintain the landfill site in the semi-aerobic condition, and accelerate the stabilisation of the wastes.

2.4 Level 4

The level-4 is an improvement to the level 3 sanitary landfill by the provision of the leachate treatment facilities and liner system.

The liner system will act as barriers to provide sealing function by preventing the leachate from penetrating deeper into the ground. The leachate will flow to the collection pipes and diverted to the leachate retention pond for further treatment. Aerators or air diffusers will be provided to enhance and hasten the treatment process for the effluent to be discharged.

(1) Target

- Sanitary landfill with leachate treatment facilities

(2) Achievements

- Provision of leachate treatment facilities with the installation of oxidation pond, etc.
- Provision of liners to control the seepage
- Establishment of semi-aerobic sanitary landfill

(3) Environmental Issue

The provision of seepage control facilities and leachate treatment facilities will enhance and promote semi-aerobic decomposition, and thus hasten the waste stabilisation period.

The leachate treatment facilities should be able to treat and improve on the quality of the effluent for discharge to the drains or watercourses. However, if the effluent discharge quality have to adhere to the more stringent requirements of Environmental Quality Regulations 1979, then it is necessary to provide higher level of treatment facilities that are able to treat the effluent to the requirement of Standard A.

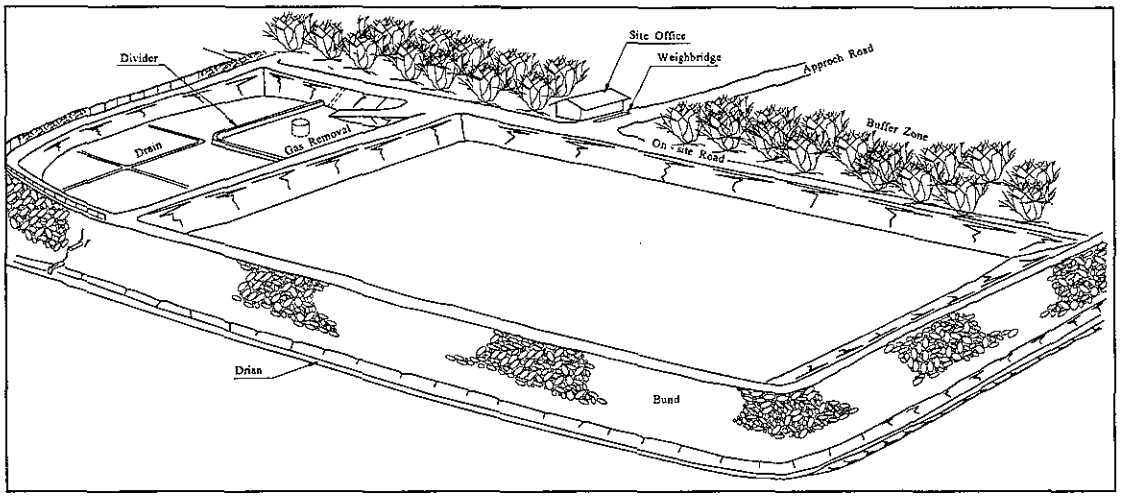

Figure A23-2 (a) Typical Layout for the Level 2 Sanitary Landfill

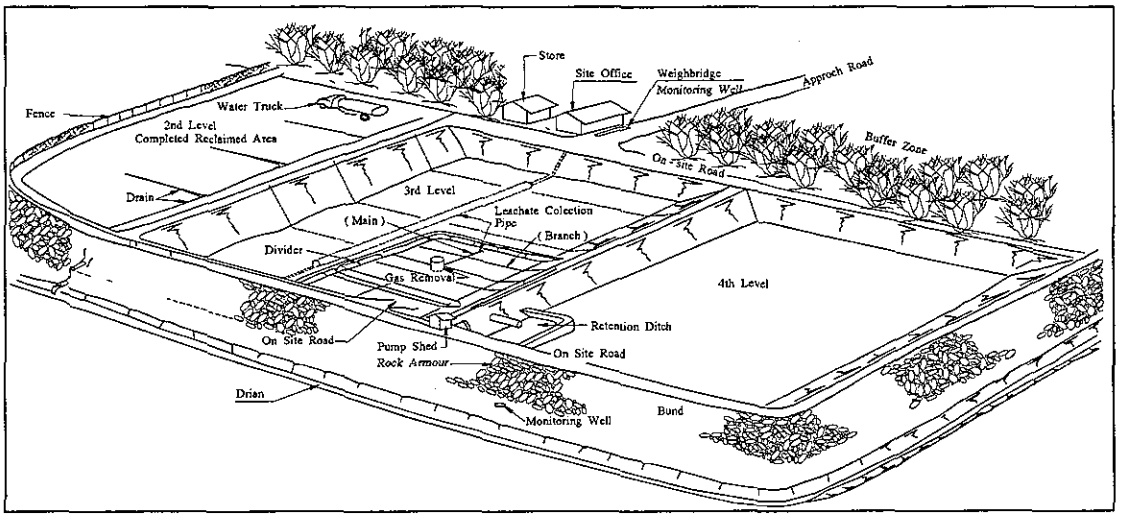

Figure A23-2 (b) Typical Layout for the Level 3 Sanitary Landfill

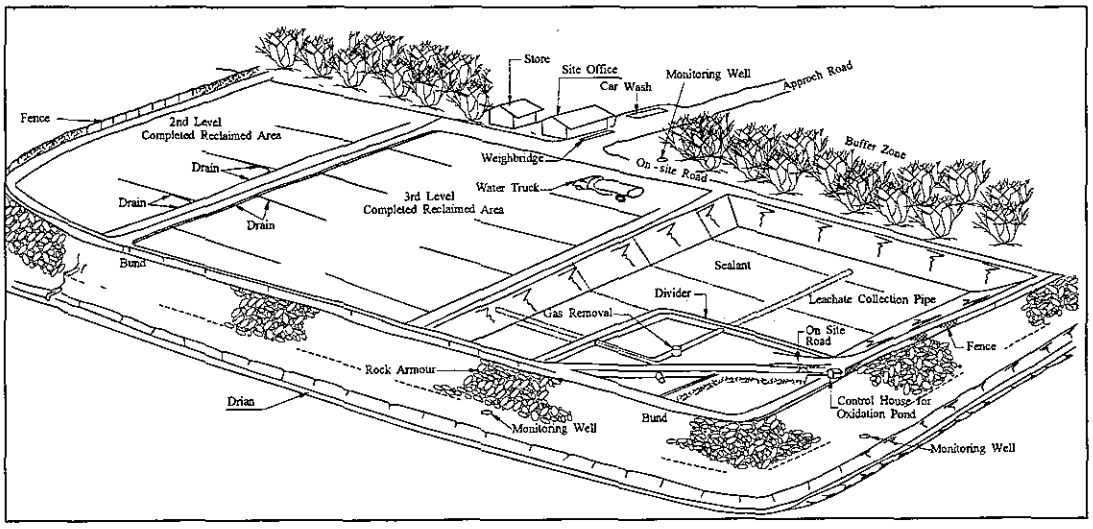

Figure A23-2 (c) Typical Layout for the Level 4 Sanitary Landfill

Appendix 24

Referred Standards/Guidelines

(1) "Plan and Design Guideline of Final Disposal Site", Japan Waste Management Association, 2001

(2) "Guidance for Safety Management at Mining site" :Occupational Safety and Health Act (Japan) 1970

(3) US EPA. (1994) Design, Operation, and Closure of Municipal Solid Waste Landfills. EPA report no. 625/R-94/008. Washington, DC.

(4) COUNCIL DIRECTIVE 1999/31/EC of 26 April 1999 on the Landfill of Waste

(5) UK DOE (1991) Waste Management Paper No 26, 27


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