GUIDEBOOK FOR SAFECLOSURE OF DISPOSAL SITES

NATIONAL SOLID WASTE MANAGEMENT COMMISSION
JAPAN INTERNATIONAL COOPERATION AGENCY
Guidebook

for

Safe Closure of Disposal Sites

Second Edition 2010

by

National Solid Waste Management Commission
(NSWMC)
Japan International Cooperation Agency
(JICA)
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<td>OD</td>
<td>Open Dump</td>
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<tr>
<td>ORP</td>
<td>Oxidation Reduction Potential</td>
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<td>PC</td>
<td>Physical Closure</td>
</tr>
<tr>
<td>PCM</td>
<td>Post-closure Management</td>
</tr>
<tr>
<td>PD</td>
<td>Project Description</td>
</tr>
<tr>
<td>PVC</td>
<td>Poly Vinyl Chloride</td>
</tr>
<tr>
<td>QC/QA</td>
<td>Quality Control/Quality Assurance</td>
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<tr>
<td>RA</td>
<td>Republic Act</td>
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<tr>
<td>SC</td>
<td>Safe Closure</td>
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<tr>
<td>SS</td>
<td>Suspended Solids</td>
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<tr>
<td>SWM</td>
<td>Solid Waste Management</td>
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<td>TOC</td>
<td>Total Organic Carbon</td>
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Part I GENERAL

I-1 Purpose of the Guide Book

The Guide Book for Safe Closure of Disposal Sites was prepared for the following purpose:

a) To provide a manual in the safe closure and rehabilitation of disposal facilities;

b) To avoid the negative environmental impact and risks attributed to continuous operation of open dumpsites and controlled dumpsites and/or its abandonment;

c) To ensure that the public health and the environment are protected by instituting safe and appropriate measures in the proper closure of open, controlled dumpsites and sanitary disposal sites.

Municipal solid waste disposal sites cause environmental pollution and hazards long after this ceases in operation. Degradation of the waste layers takes a long time even as these continue to generate leachate and methane gases. It is necessary to manage the dumpsite properly after the operations and to manage the post closure land use in order to protect the public health and preserve the environment. These problems are further aggravated by the fact that majority of disposal sites in the Philippines are not being managed and closed properly. In order to prevent any negative environmental impact and risks from mismanagement of closed disposal sites, it is imperative that appropriate engineering measures shall be instituted from the initial/planning stage on the design and development of disposal site sites and throughout its operation.

*While this Guidebook highlights the systems necessary for the safe closure of open dumpsites and controlled dump facilities, it also provides appropriate engineering measures on the post closure management and other recommendations on the post closure land use of all disposal types.*

It should be noted that for disposal sites with proper facilities and operation, the burden on safe closure will be significantly reduced. Thus, the reduced risks of pollution and hazards will significantly reduce the cost for safe closure. *Figure I-1* shows the flowchart on the disposal facility management activities.

I-2 Closure Stages of Disposal Sites Covered by the Guide Book

This Guide Book mainly covers the following closure stages of disposal sites.

a) Physical closure (PC)

b) Post-closure management (PCM), and

c) Post-closure land use.

To highlight the immediate requirement for the safe closure of open and controlled dumpsites, the guide book focuses mainly on the safe physical closure process.
This Guide Book shall cover the disposal sites that accept municipal solid waste categorized as follows:

a. Open Dump Sites
b. Controlled Dump Facilities
c. Sanitary Landfill Facilities

The closure of open dumpsites and controlled dumpsites shall be taken as a priority concern in view of the deadline set for the operation of open dumpsites and controlled dumps. To come up with an integrated approach in the implementation of the SWM plan, the program covering the closure and rehabilitation of dumpsites should go hand in hand with the development of sanitary disposal sites.
Recently, the National Solid Waste Management Commission approved the guidelines for the closure and rehabilitation of open and controlled dumpsites and the guidelines for the categorized final disposal facilities. These guidelines are aimed at supporting the local government units’ planning and implementation strategies on ecological solid waste management. Given the current financial and technical capacities of LGUs, the categorized disposal facilities will enable LGUs to satisfy in a more practical and sustainable basis the requirements of RA 9003 with respect to waste disposal. All disposal categories have been developed and designed to meet environmental standards.

I-4 Definitions of Terms

Open dumpsites are operated and used with the least consideration to environmental protection. In terms of safety, the deposited area may have such uncontrolled settlement due to the on-going decomposition of wastes.

Controlled Dump is a progression from open dumping as stipulated in Section 37, RA 9003. Controlled Dump Facilities shall only be allowed to operate for a period of five (5) years, inclusive of the 3-year conversion period. In doing so, there is no significant investment required in the capital cost or equipment purchases, but rather its enhancement will concentrate primarily on improvements of the facility to mitigate the hazards to health, public safety and to the environment as a whole.

Sanitary Landfill is where municipal wastes are disposed off by land filling. Such sites should be provided with adequate disposal site facilities. As approved, the following categories of sanitary disposal site may be used:

Category 1
Shall apply to LGUs or cluster of LGUs generating residual waste of \( \leq 15 \) tpd

Category 2
Shall apply to LGUs or cluster of LGUs generating residual waste of \( >15 \) tpd but \( \geq 75 \) tpd

Category 3
Shall apply to LGUs or cluster of LGUs generating residual waste of \( >75 \) tpd but \( \leq 200 \) tpd

Category 4
Shall apply to LGUs or cluster of LGUs generating residual waste of \( >200 \) tpd

Safe closure (SC): Safe closure consists of the activities of Physical closure (PC) and Post-closure management (PCM).

Physical closure (PC): The action by which the necessary measures for safe closure has been applied to the entire disposal area.

Post-closure management (PCM): The management activities necessary to maintain and monitor the disposal site facilities such as the leachate treatment, disposal site gas treatment, cover soil etc. The activities also include the environmental monitoring, disposal site stabilization monitoring and management of information/records of the closed disposal sites.

Post-closure land use: The re-utilization of closed disposal sites for purposes other than for waste filling. The PCM activities should be continued through out the post-closure land use.
1-5 Review of Laws and Regulations Related to Solid Waste Management

The related laws, regulations and guidelines on the disposal site are as follows.

P.D. 1152 - Philippine Environment Code  Comprehensive Program on Environment protection and management by establishing specific environmental management policies and prescribing environmental quality standards in the Philippine Environment Code.

P.D. 984 - Pollution Control Law  Provides the specific guidelines and implementing rules and regulations on liquid waste disposal after physical or chemical treatment in accordance with existing rules and regulations

Commonwealth Act No. 383  An Act to punish the dumping into any river of refuse matter or substances of any kind whatsoever that may bring about the rise or filling in of river beds or cause artificial alluvial formation

P.D. 825 - Penalty for Improper Garbage Disposal  Providing penalty for the improper disposal of garbage and other forms of uncleanliness and for other purposes.

P.D. 856 - Code of Sanitation  Provides the rules on disposal of refuse in food establishments, and for construction of markets and abattoirs. Prescribes the sanitary facilities with potable water, sewage treatment works, septic tanks, and disposal of septic tank effluent drainage.

Provides for special precaution of human waste from hospitalized patients given high dose of radioactive isotopes. However, the provision merely provides for separate facilities and flushing at least 3 times after its use. The special treatment and methods of disposal are provided for health care wastes in the Joint DENR-DOH Administrative Order No. 2 Series of 2005.

DENR Administrative Order 98-49  Technical Guidelines for the disposal of municipal solid waste and operates on the premise of eventual phase-out of all open dumps in the country.


The above laws belong to the earliest legislations of which provisions particularly addresses solid waste management practices, environment impacts, technologies, pollution control and prevention, and penalties for violations thereat.

While some policies in these laws have been superseded with the enactment of the Ecological Solid Waste Management Act and other laws, they still contain relevant provisions that contribute to planning and implementation.

RA 6957 amended by RA 7718 (Build-Operate-Transfer Law)  Providing that infrastructure and development projects normally financed and operated by the public sector, that solid waste management may be wholly or partially implemented by the private sector
Republic Act 7160  Local Government Code of the Philippines, devolving certain powers to the local government units, including that on enforcement of laws on cleanliness and sanitation, preparation of their respective solid waste management programs, and other environmental matters.

Presidential Decree 1586  Philippine Environmental Impact Statement or EIS System carry-out the policy of the State to “attain and maintain a rational and orderly balance between socio-economic growth and environmental protection.”

DENR Administrative Order 2000-28  Implementing Guidelines on Engineering geological and Geohazard Assessment as Additional Requirement for ECC Applications covering Subdivision, Housing and other Land Development and Infrastructure Projects

Republic Act 8749  An Act Providing for a Comprehensive Air Pollution Control Policy and for other purposes (Philippine Clean Air Act)

In order to promote the framework of sustainable development, this law aims to formulate a holistic national program on air pollution management, encourage cooperation and awareness among citizens and industry, focus on pollution prevention rather than control and enforce a system of accountability of a certain project in causing adverse impact to the environment.

Section 20- Ban on Incineration  Prohibited the use of incinerators for municipal, bio-medical and hazardous wastes, which process emits toxic and poisonous flames. However, hospital incinerators are given 3 years at the interim to look for alternative technologies. Such units shall be limited to the burning of pathological and infectious wastes, and subject to close monitoring by the Department.

DENR Administrative Order No. 34  Revised Water Usage and Classification

DENR Administrative Order No. 35  Revised Effluent Regulations of 1990


Republic Act 9003  Ecological Solid Waste Management Act of 2000, an Act providing for environmentally-sound techniques of waste recovery, waste utilization, processing and disposal.

DENR Administrative Order No. 01-34  Implementing Rules and Regulations of RA 9003, with the enactment of RA 9003, all laws, decrees, issuances, rules and regulations, or parts thereof that are inconsistent with the provisions of the Act are hereby repealed or modified accordingly.

RA 9003 is a primary legislation on solid waste management providing a comprehensive, systematic and ecologically viable program that would:

- ensure public health and protect the environment
- employ environmentally-sound methods to encourage resource conservation & recovery and promote national research & development programs
• encourage greater private sector participation while retaining the primary enforcement & responsibility of Solid Waste Management with local government units
• Integrate the Ecological SWM and research conservation & recovery topics into the academic curricula of formal & non-formal education

To promote environmental means of disposing wastes, the DENR is enforcing specific technical guidelines in the Implementing Rules and Regulations (DENR Administrative Order 01-34) in order to direct the local government units towards an environmentally sound, technically feasible and economically sustainable solid waste management program.

**National Solid Waste Management Commission Resolution No. 1, Series of 2002**
Delegation of Certain Functions of the NSWMC Chairman to the DENR Regional Executive Directors and Prescribing Appropriate Permits and Clearances for Solid Waste Management Facilities.

**Memorandum Circular No.1**
Approved during the NSWMC Commission, it provides for the clarification on the effectivity date of RA 9003 and the filing of appropriate cases.

**DENR Administrative Order No 9 Series of 2006**
General Guidelines in the Closure and rehabilitation of Open and Controlled Waste Disposal Facilities

**DENR Administrative Order No. 10 Series of 2006**
Guidelines on Categorized Disposal Facilities (Sanitary Disposal sites)

**Joint DENR-DOH Administrative Order No. 02, Series of 2005**
Policies and Guidelines on effective and proper handling, collection, transport, treatment, storage and disposal of health care wastes.

**NSWMC Resolution No. 26, series of 2009:**
Resolution Adopting Eco-Park as an Option to Sanitary Landfill

**I-6 Overview of the Closure Program**

**I-6.1 Basic Concepts of Safe Closure**

**Closure of Disposal Facilities.** A municipal dumping site where waste-filling activities have been completed shall be closed properly for the safe storage of waste and prevention of pollution to the surrounding environment.

**Measures to take in closed disposal sites.** When a dumpsite is being closed, appropriate measures shall be undertaken to prevent environmental pollution caused by leachate or methane gas resulting from the decomposition and degradation of the waste.

**Preceding and precautionary approach.** When a dumpsite ceases in operation and is closed, it is necessary to formulate a safe closure plan which comprises of the physical closure (PC) and the post-closure management (PCM). This also applies to the abandoned sites.
Closure Levels. The extent of closure program may vary depending on present and existing condition of the dumpsite. Considerations include but are not limited to the site condition, amount of waste disposed, types of wastes dumped, etc., where pre-closure assessment should be undertaken on these disposal sites.

Site-specific approach. In order to determine the safe closure requirements, the conditions of each individual site shall be investigated. Their risks to environmental pollution/hazards and potential for post-closure land use should be evaluated based on the site-specific conditions.

Even after dumpsite has been closed, proper maintenance or post-closure management should be carried out continuously to monitor the environmental condition within and throughout the surroundings of the dumpsite. Subsequently, when the potential hazards of the dumpsite have past, the applicable post closure land-use could then be implemented.

Parameters that indicate the stability of the disposal site may lead to the termination of the post-closure management are described below.

I-6.2 Disposal Site Stability Indicators

1.6.2.1 Physical Conditions

(1) Rate of subsidence

The rate of subsidence on a disposal site would normally depend on the qualitative and quantitative analyses of the waste deposited. The rate of subsidence for the stabilized disposal site and other disposal sites should be less than 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 soil. The minimum recommended number of benchmarks is two (2), or one (1) for each hectare of the site. The subsidence should be monitored and observed for more than two years. Other stability procedures and indicators include ground attenuation, compaction rate, liquefaction, etc.

(2) 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 should be at least 600mm and should be well compacted. The top cover should be planted with shrubs, vegetation or grass that are indigenous to the area are recommended to prevent dust and soil erosion.

1.6.2.2 Chemical Conditions

(1) Quality of the raw leachate

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

(2) Quality of disposal site gas

The concentrations of disposal site gas should satisfy the following conditions.

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

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

(3) Quality of groundwater around the site

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

(4) 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.

I-6.3 Post-closure Land Use

(1) The type of post-closure land use of closed disposal sites should be carefully considered based on the clear understanding of the disposal conditions during operations, closure, and together with impacts it may have had on the surroundings. The post-closure land use should also take into consideration the aspects pertaining to environmental protection and the health and safety of the users and the public.

(2) The “Post-closure land use plan” (including the land use plan, safe measures and post-closure management) will have to be formulated and submitted to the relevant authorities for approval. Once approval has been obtained, only then, the new land use for the closed disposal site can be implemented.

(3) Operation and maintenance of the disposal site facilities and other disposal sites should be continued throughout the post closure land use redevelopment. Those facilities that may have been affected by the redevelopment works, such as the gas ventilation pipes and surface drainage, must be re-installed at suitable locations in order to preserve their functions.
(4) The stabilization period of landfill site or other disposal sites after waste filling has completed is expected to be a minimum of 10 years. Therefore, post-closure land use shall be considered and can proceed after this period. This is to minimize the effects of land subsidence and disposal site gas generation on the development site. (refer to Appendix 1)

However, for the disposal sites 5 years after which waste filling was completed, provisional land-use might be applied under the following conditions.

a) Utilization of only surface layers of the closed disposal site and access of the people to the site shall be very limited; such as green space, parking etc.

b) Prior to the utilization, monitoring of environment and disposal site stabilization shall be carried out and then the site’s condition shall be clarified.

I-6.4 Legal Process of Safe Closure of Disposal Sites

In order to implement and manage the sustainable safe closure of disposal sites efficiently and effectively, institutional and legal systems will have been set up in accordance with the following principles.

To ensure better enforcement of the required measures and long-term operation and maintenance of the closed disposal sites in accordance with the appropriate safe closure measures, entities (both public and private) abide with the guidelines on safe closure of disposal facilities.

I-6.5 Roles of Stakeholders

The roles of the main stakeholders are as follows:

(1) National Solid Waste Management Commission (NSWMC)

The NSWMC will provide technical advice and assistance to the operators of disposal facilities for the safe closure and post-closure land use of disposal facilities.

Specifically, the NSWMC will be responsible for the following major tasks:

a) To provide the guidelines for safe closure of disposal sites

b) To provide technical assistance to the Local Government Units.

c) To monitor and verify the re-development plan for the closed site with regards to the technical issues and to assist the operators when required.

(2) Operators of Disposal Facilities (PRIVATE/LGU)

Private or LGU operators should construct and operate the disposal site in accordance with good practices as set out in the “Technical Guide book on Solid Waste Disposal, Design and Operation”. When the waste filling activities have been completed, safe closure plans should be implemented. In addition, operators of disposal facilities shall carry out the duties and activities on safe closure of said facilities. Operators should prepare and
implement a Closure plan for the existing open dumpsites and/or controlled dump facilities. The said Program should be viewed as an integral part of the overall implementation of the LGU Solid Waste Management Plan.

The operators of disposal facilities should be responsible for the following:

a) To undertake the preliminary closure assessment and a complete list of all possible data that need to be covered to come up with a comprehensive assessment in their respective sites in order to clarify the environmental pollution potential and land-use potential.

b) To document and manage the information and appropriate records of their disposal site properly (i.e. the geological survey report, EIA report, construction records, operation and monitoring records, etc). For OD/CDF (cadastral maps, TCT, free patent, available logbook for disposal records) and for SLF (should be based on the conditions of the ECC);

c) To operate the site properly and to keep daily records of the operations (i.e. the tonnage of waste accepted, cover soil work, leachate treatment, etc.) and to manage/control the PC and PCM for the abandoned sites

d) To inform the NSWMC, DENR and Provincial Government on the schedule of final waste acceptance

e) To prepare the SC plan (PC and PCM) and the Post closure Land Use Plan with the cooperation of relevant parties for submission to LGU and/or NSWMC/DENR for approval, and;

f) To implement the approved SC plan and Post-closure Land Use Plan to the disposal facility as soon as the proper permits and Authority to Close (ATC) for Open Dump and Controlled Dump Facility has been issued. For the post closure of the Sanitary Landfill, it is included in the Environmental Management Plan of IEE or EIS report.

(3) Department of Environment and Natural Resources (DENR)

The DENR and EMB shall guide the LGUs or the operators in the formulation of the closure plan, issue the necessary permits for implementation and impose on appropriate sanctions in accordance with pertinent provisions of RA 9003, DAO 01-34(IRR) and PD 984.

The DENR and/or the EMB Regional Offices shall refer to the DAO No. 9 regarding the implementation of the guidelines on the closure and rehabilitation of disposal facilities and be responsible for the following:

a) To review and/or approve the closure plan submitted by the LGU.

b) To issue an Authority to Close (ATC) within 15 days upon receipt of the request if closure plan is found adequate, while those who have implemented closure will be required to submit closure plan to the Department.
c) To conduct a regular inspection and monitoring of the dumpsite during the actual closure activities and thereafter to ensure that the site is not utilized as an open dump.

d) To issue sanctions covered by the provisions of RA 9003 and PD 984 if closed site is re-used as an open dump.
Part II TECHNICAL REQUIREMENTS

II-1 Technical Requirements for Safe Closure of Disposal Sites

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

(1) Different types of disposal sites should be closed safely and the post-closure management should be carried out properly.

(2) Objectives for the safe closure of different disposal sites.

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

(3) Objectives for the post-closure management of different disposal sites.

a) To implement appropriate maintenance activities of disposal sites such as providing or application of the sufficient final soil cover. The provision of minimum 0.60m final soil cover at closure, and post closure maintenance of cover, drainage and vegetation; post closure maintenance shall be for a period of ten (10) years (Rule 13, Sec. 2 i of the IRR of RA 9003)
b) To continuously maintain the facilities in the disposal site such as the operation of the leachate treatment plant/facility and continuous flaring of installed gas collection system.
c) To continue with the environmental monitoring work such as water quality including leachate generation from surface water and groundwater, disposal site gases and air quality of these disposal sites
d) To continue with the waste stabilization monitoring such as the prevailing topography and slope stability of the completed filled areas.
e) To continue to maintain the good access road surface of these disposal sites.
f) To continue to maintain the drainage system of the disposal sites.
g) To continue to maintain the vegetative layer of the final cover of the disposal sites using indigenous plants (refer to Annex 2 for a more detailed Requirements of Post Closure Management).

(4) Appropriate measures and activities required to achieve safe closure should be determined based on the conditions of the site including operation level, existing facilities, surrounding environment and post closure land use.
II-2 Establishment of Safe Closure System

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

(1) Site assessment survey should be carried out in order to determine the general conditions, environmental conditions and land use conditions of the site. From the results of the survey, the environmental pollution potential and land use potential can be evaluated. For further information, refer to Annex 3 for the sample evaluation /assessment form for Disposal Sites.

(2) From the evaluation, the closure priority of the disposal site and applied closure system should be setup.

(3) The proper safe closure plan should then be formulated and the physical closure works and the post closure management activities should be carried out.

II-2.1 Safe Closure System Applied for Disposal Sites

The appropriate closure system should be assigned and applied to prevent environmental pollution and hazards. The closure levels of the disposal sites are classified into 4 systems; i.e. Closure Level 1, 2, 3 and 4. The category is shown in Table II-2-1.

**Table II-2-1 Safe Closure Level and Required Facility**

<table>
<thead>
<tr>
<th>Site Clearing</th>
<th>Closure Level 1 (≤54,000 tons of filled waste or less than 1 hectare in disposal area)</th>
<th>Closure Level 2 (≥54,000 tons to 274,000 tons or more than 1 hectare but less than 5 hectares in disposal area)</th>
<th>Closure Level 3 (≥274,000 tons to 730,000 tons or more than 5 hectares but less than 15 hectares in disposal area)</th>
<th>Closure Level 4 (≥730,000 tons or more than 15 hectares in disposal area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilization of Critical Slopes</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Final Cover</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Drainage Facility</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Embankment</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Gas Vent</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Leachate Collection System</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Leachate Pond</td>
<td>✓ recommended</td>
<td>✓ recommended</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Leachate re-circulation</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Leachate Treatment</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Signages</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Perimeter Fences/Security</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
*Note: The computation of filled waste and area for Closure level 1-4, (assuming 10 years life span of disposal site). Example: 15tpd waste disposed x 365 days/yr x 10 yrs = 54,750 tons or rounding to 54,000 tons

While Figure II-2-1 shows the facilities necessary to be provided for each of the closure level of the disposal sites.

**Figure II-2-1  Schematic Diagram of Safe Closure Levels of Disposal Sites**

Note: For SCL3 & SCL4, aerobic area of existing disposal site will be expanded by safe closure measures.
II-2.2 Steps for the Safe Closure of Dumpsite leading to Eco-Park

These steps were developed for LGUs in order to simplify the closure of open and controlled dumpsites and for the site to still be useful after its closure. It would take some time for LGUs to develop new site/s for their waste management system/s and likewise some LGUs still do not have feasible sites, especially for final disposal. This concept of Eco-Park is already being undertaken by some LGUs such as Malolos City, Bulacan, Municipality of Los Banos, Laguna, Bacolod City, Negros Occidental, Municipality of Sto. Tomas, Davao del Norte and Municipality of Hinatuan, Agusan del Sur.

1. Site grading and stabilization of critical slopes
   *(pag-sasaayos sa tamang taas ng tambak)*

2. Application and maintenance of soil cover
   and putting of vent pipes and other provisions
   *(Pagtatabon ng lupa at pagalagay ng pasingawan)*
3. Provision of drainage control system
(Paglalagay ng kanal)

4. Leachate Pond
(Sahuran ng katas ng basura).

5. Putting up fencing and security
(Paglalagay ng bakod)
6. Establishment of MRF/storage for recyclables
(paglalagay ng hiwalay na lugar para sa mga recyclables)

7. Organization of waste pickers into Eco Soldiers and provision of working schedule for retrieval of recyclables.
(Pag-organisa at paglalagay ng iskedyul sa mga mambubulas o mangangalahig)

8. Prohibits Open Burning
(Bawal magsunog ng basura)
II-2.3 Site Survey for Evaluation and Design

All disposal sites should be evaluated properly based on the site survey or investigation. The following items will be required in order to evaluate the disposal sites and to provide the proper measures for safe closure. Refer to Table II-2.2 on the survey items for the site assessment and Annex 3 for the other items of the Questionnaire or Survey Form.
Table II-2.2 Survey Items for the Site Assessment

<table>
<thead>
<tr>
<th>Items Proposed Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Topographic and Geological survey</td>
</tr>
<tr>
<td>(2) Structures and facilities of the disposal site</td>
</tr>
<tr>
<td>(3) Shape and stability of filled waste</td>
</tr>
<tr>
<td>(4) Total amount of disposed waste</td>
</tr>
<tr>
<td>(5) Degradation of the filled waste</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>(6) State of the surrounding environment</td>
</tr>
<tr>
<td>(7) Surrounding land use</td>
</tr>
<tr>
<td>(8) Type of Waste Disposed</td>
</tr>
</tbody>
</table>

II-3 Requirements of Safe Closure

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

(1) The Physical Closure (PC) consists of the measures or facilities necessary for the safe storage of waste, prevention of environmental pollution and early stabilization of the waste at the dump site.

(2) The Post Closure Management (PCM) consists of the operation of disposal facilities such as leachate treatment plant (not necessarily required for disposal sites safe closure levels (1) and (2), the maintenance of the facilities including soil cover, fence, drainage
canal, embankment and the monitoring of environmental pollution and stabilization of waste.

**II-3.1 Physical Closure**

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

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

The exposed waste should be compacted. The shape or slope of the filled waste should be modified if they are deemed to be unstable and/or when the waste has been overfilled. The gradient of the slopes should be less than 1:3 or slopes ranging from 2 to 4% to facilitate drainage and prevent ponding and soil erosions.

The waste storage bank, suitable retaining wall or embankment structures should be constructed if the shape of the filled waste is not stable, and if the boundary of the site is limited. Whereas, the side slopes can be generally set at the ration of 1 vertical to 3 horizontal or gentler depending in the nature of waste and actual site conditions. Step or terraces should be provided where necessary at 5m intervals at the slopes, whereas the terrace width should be about 2m to 3m as shown in Figure II-3.1. In addition, the slopes and terraces should be provided with topsoil suitable for turfings and plantings to protect from erosion and as aesthetic landscape. The proposed modification and improvement works should be described in detail in the safe closure plan.

2) Final Soil Cover and Vegetation

The final cover should be the cover soil laid on top of the final waste layer, after the disposal site has been completed. The purpose of final cover is to provide improvement to the sanitary conditions, the landscape, post-closure land use, the reduction of the leachate quantity as shown in Figure II-3.2, reduction of offensive odor, prevention of outbreak of fire, reduce the breeding of vectors, minimize leachate generation, serve as vegetation layer, etc. The final soil cover should be at least 60 cm which include 15 cm topsoil and 45 cm compacted soil (DAO No. 2001-34).

Suitable vegetation for planting on top of closed disposal sites include vegetative covers, the most effective of which is Vetiver grass. Another type of vegetation is known as “living filters” or those plants that minimize the amount of toxic gases. These are suitable for planting in areas surrounding closed disposal sites or buffer areas. For post-closure land use (as a park, for example) these may also be planted on top of the closed site. For planting trees and shrubs, the final soil cover should be more than 150cm. (For further details of the living filters, please refer to Annex 7)
Figure II-3.1 Slope Improvement

Figure II-3.2 Purpose of Soil Cover
The topsoil, which is usually not compacted, will serve as protection layer as well as support for the plant growth. In areas where trees and scrubs are to be planted, the thickness should be increased to be more than 150cm. Regular maintenance of the cover soil will be necessary. The soil material should possess permeability not less than $1 \times 10^{-6}$ cm/sec, resistance to erosion and suitable for vegetation growth and with an inclined slope of about 2 to 5% gradient as shown in Figure II-3.3. However, the soil’s final thickness is dependent on the post-closure land use plan of the disposal site.

![Figure II-3.3 Specification of Final Cover](image)

(3) Drainage Facility

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

(4) Gas Vents

The waste decomposition process will generate a large amount of gasses such as methane and carbon dioxide, which rises and escapes through the surface. The gas vents should be provided and installed at 50m intervals to allow the gasses to escape and vented to the atmosphere and thus preventing gas explosion. These vents will also supply air deep into the waste layers to promote the decomposition process and to accelerate the stabilization of the disposal sites. These vents may be made up of local materials such as bamboo or PVC pipes or perforated polyethylene pipe or perforated PVC covered by gravel or crushed rock with a diameter of 7.5 to 30cm. as shown in Figure II-3.4
Figure II-3.4 Typical Vertical Gas Venting Pipe Detail

(5) Leachate Collection Pipes and Leachate Re-circulation Facility

The leachate collection/drainage pipes are installed as much as possible in the bottom of disposal sites to accelerate the stabilization of the disposed waste by gas vent and to supply inside the disposal site to create a semi-aerobic condition. The pipe lies down with a gentle slope so that it can drain by the natural flow as shown in Figure II-3.5. The pipes are made of perforated hume pipe or perforated synthetic resin conduit and with cover materials composed of cobble stone or crushed rocks which prevents clogging.

In case of installing the leachate collection/drain pipe will be installed at the closure stage of the disposal sites, the waste is excavated with heavy industrial machines, such as excavator with hoe equipment, then leachate collection/drainage pipe is installed where the depth of a leachate pipe is restricted to the depth the machines can excavate, approximately 5m from the surface. On the other hand, when using existing leachate collection drainage pipe, or when installing a pipe at the position where the construction height of a pipe is higher than water level of retaining of leachate, it is scarcely effective for drainage of leachate. Another effective way to drain the leachate is by installing a leachate drainage pipe by horizontal boring though the disposal site condition cannot become semi-aerobic by using this method.

The leachate collection pipes and leachate re-circulation facilities should be installed in order to provide semi-aerobic conditions to the waste layers of the disposal sites. The re-circulation equipment pumps out leachate from the collection pond and draws back to the surface of the facility as shown in Figures II-3.6 and II-3.7. These facilities minimize the groundwater contamination by removing leachate accumulated in the waste layers; by 1) improving leachate quality through contact with air and aeration; 2) accelerating waste decomposition process and 3) reducing the generation of methane gas.
(6) Leachate Treatment Facility

The leachate treatment facility should be installed to treat the leachate in order to comply with the DENR-DAO 35 Effluent Standards prior to discharging the effluent into the public water bodies via the drainage system. The purpose of the facility is to prevent contamination of the public waterways and the groundwater sources.

(7) Groundwater Protection Facility (liner)

If a groundwater protection facility is necessary, such as vertical artificial liner systems, it should be installed in order to prevent leachate from seeping into the groundwater sources and contaminating the groundwater. There are other methods that may prevent groundwater pollution such as injection method, diaphragm wall method, and driving method.
Figure II-3.6 Typical Image of Leachate Re-circulation

Figure II-3.7 Type of Infiltration Equipment
II-3.2 Procedures for Closure of Disposal Facility

Section 6 of DENR Administrative Order No. 09 states that the following guidelines shall provide the LGUs with the appropriate closure procedure and the extent of subsequent work needed to undertake the full closure program on Municipal Solid Waste (MSW) disposal sites.

II-3.2.1 Pre-Closure Assessment

The activities covered by the pre-closure assessment shall include the following:

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

II-3.2.2 Assessment Parameters

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

II-3.3 Safe Closure Plan

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

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

b. Closure level

- Closure level depends on the Table II.2-1.

c. Physical Closure Plan

- Stable shape/slope and elevation plan
- Covering soil and other facilities (gas ventilation, leachate, wastewater, etc)
- Final Soil Cover and Vegetation Cover
- Drainage Facility and Drainage Plan
- Gas Ventilation/Gas Management Facility
- Leachate Collection and Treatment Facility
- Perimeter fence, signages and access road

d. Post closure management plan

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

e. Implementation plan and schedule of safe closure

f. Costs estimation for safe closure

- Physical closure
- Post closure management (PCM)

The Post closure management includes establishment of an Ecological Park (ECO-PARK)

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


<table>
<thead>
<tr>
<th>Waste Management Facilities</th>
<th>Project Parameter</th>
<th>EIA Report Type for Corresponding Project</th>
<th>Size/Decision document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost/fertilizer making</td>
<td>Daily production rate</td>
<td>EIS</td>
<td>IEER or IEE Checklist/ECC</td>
</tr>
<tr>
<td>Materials Recovery Facilities</td>
<td>Kind of Activity</td>
<td>With composting facilities (see category of composting above)</td>
<td>Materials segregation only</td>
</tr>
<tr>
<td>Receiving facilities, paper, plastic, and other materials recycling</td>
<td>Quantity of waste to be treated annually</td>
<td>300,000 MT</td>
<td>&lt;300,000 MT or involving the use of chemical</td>
</tr>
<tr>
<td>Sanitary landfill for domestic wastes only</td>
<td>&gt;1,000 MT</td>
<td>1,000 MT</td>
<td></td>
</tr>
</tbody>
</table>

DENR Administrative Order No. 10- Guidelines for Categorized Sanitary Landfill

<table>
<thead>
<tr>
<th>Category Level (SLF)</th>
<th>Required decision document prior issuance of ECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1 &amp; 2</td>
<td>IEE Checklist</td>
</tr>
<tr>
<td>Category 3 &amp; 4</td>
<td>IEE Report</td>
</tr>
</tbody>
</table>

Proposed Financial Estimation for Safe Closure Plan

Expenses for Rehabilitation and Closure of Disposal Facilities will depend on the condition of the site thus site assessment or survey is required. Based on Table II 2.1, there are listed required facilities depending on the Safe Closure System identified that will correspond to the investigated disposal site. The following are listed to guide or to provide possible option to the LGU or operators.

**Final Cover:** (area x 60cm x price/sq.m of soil) Indigenous materials (crashed stone, bentonite or other clay) may be used as mixture to the soil as final cover. However, it is important that in the final cover layer, the permeability should not be more than 1x10^-6 cm/sec. *Usual price of soil range from Php200 to 500 per cu.m.

**Drainage Facility:** storm water drainage such as peripheral canals and/or ditches is required to channel rainwater/runoff from the specific disposal site. For estimation, an 80 linear meter concrete ditch or storm water drainage is 700 pesos/lm. That includes
cement, CHB, RSB, gravel, sand and labor. While the following specs may be used that includes (multiply this with the quantity of the specs):

- Excavation 170 pesos/m3
- Fill 300 pesos/m3
- Canal concrete liner 900 pesos/m2
- Pipe crossing structures 25,000 pesos/unit
- Flushing point 10,000 pesos each

Gas Ventilation System: As required to be provided and installed at 50m intervals to prevent gas explosion. It can be estimated at approximately 100 pesos per square meter. These include perforated pipes, pvc pipe, pvc elbow, gravel, gas vent cap, solvent cement, excavation and labor cost. Other option includes bamboos as pipes.

Leachate Collection System (estimated price)
- Gravel 500 pesos/cum
- Sand 450 pesos/cum
- Perforated PE Pipes 1,000 pesos/meter
- Flushing point 10,000 pesos per unit

Leachate Recirculation (estimated price)
- Excavation 170 pesos/m3
- Fill 300 pesos/m3
- Soil liner 350 pesos/m3
- HDPE liner 400 pesos per m2
- Leachate distribution pipelines 800 pesos per meter
- Pumps 50,000 pesos per set

Perimeter and Fence: Any indigenous materials can be used, just make sure that the purpose is met. An amount of 800 pesos per meter is estimated. Guard house with an approximate of 12,000 pesos per m2.

Signages:

Equipment rental: ranges from 800 pesos per hour or 1,500 pesos per hour
- Backhoe 2.5M pesos per unit
- Bulldozer 2.3 M pesos per unit
- Compactor 2M pesos per unit
- Track loader 2M pesos per unit
- Dumper 1.5M pesos per unit

**NOTE: Estimation cost of materials varies subject to current price or location.**
Annex 1
Stabilization Process of Disposal Site (Old sites in Japan)

(1) SUMMARY OF SITE INVESTIGATION

Investigation of the disposal site in Tokyo harbor 15 and the inner central-breakwater disposal site. In these sites, an observation base is installed. The list of disposal sites for investigation is as follows.

Table A1-1 Outline of Investigation Site

<table>
<thead>
<tr>
<th>Term of disposal site works</th>
<th>Disposal site area</th>
<th>Amount of waste disposal</th>
<th>Thickness of disposal site layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>The No. 8 site</td>
<td>1927 – 1962</td>
<td>36.4 ha</td>
<td>3,710,000 t</td>
</tr>
<tr>
<td>The No. 14 site</td>
<td>1957 – 1967</td>
<td>45 ha</td>
<td>10,340,000 t</td>
</tr>
<tr>
<td>The No. 15 site</td>
<td>1965 – 1974</td>
<td>71.2 ha</td>
<td>18,440,000 t</td>
</tr>
<tr>
<td>The Inner central-breakwater disposal site</td>
<td>1973 – 1987</td>
<td>78 ha</td>
<td>12,300,000 t</td>
</tr>
</tbody>
</table>

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 DISPOSAL SITE

In the case of the inner central-breakwater disposal site, the amount of subsidence has occurred about 40mm per year in early stages of the disposal site when the decomposition of waste is active. The amount of subsidence decreases slowly over time. After 20-25 years pass after disposal was completed, the amount of annual subsidence per 10m of waste layers is about 10mm or less. The result of the observation which was analyzed by regression analysis shows the amount of subsidence of a disposal site tends to become small in time according to the hyperbola.

Fig. A1-1 Change of Annual Subsidence
(3) CHANGE OF TEMPERATURE INSIDE DISPOSAL SITE

The distribution of temperature inside disposal site changes as decomposition of disposed waste.
In early stages of the disposal site, 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 disposal site layer.

![Fig. A1-2 Change of Temperature Inside disposal site](image)

(4) CHANGE OF GAS GENERATION

In early stages of disposal siting (prime of decomposition), the amount of gas generation is 70-90 L/min. The amount of gas generation changes as decomposition of disposed waste, it becomes almost 0 L/min in last stage of decomposition.
As for the concentration of the various gas components which constitute disposal site gas, methane and carbon dioxide occupy the great portion of generating gas in early stages of disposal siting. In last stage of decomposition, the concentration of methane becomes about 5% and the concentration of carbon dioxide becomes about 10%.

![Fig. A1-3 Change of Gas Generation Rate](image)
Fig. A1-4 Change of Methane Gas Concentration

Fig. A1-5 Change of Carbon Dioxide Gas Concentration
Annex 2

Requirement of Post Closure Management

The facilities installed for safe storage of waste, prevention of environmental pollution and accelerating early stabilization should be operated and maintained properly, up until the closed disposal site has stabilized. The monitoring of the environmental pollution and stabilization of waste should be carried out continuously. The result of the monitoring and record of the operation and maintenance should be reported to relevant authority periodically.

(1) Operation and Maintenance of Disposal Facilities

a) **Top cover.** Major subsidence may occur during the first two years after completion of waste filling works, therefore, special care for disposal facilities shall be considered. After a period of time, major subsidence may not occur, but risk of minor subsidence and damage to the top cover will still remain. It is necessary to maintain the top cover to prevent the percolation of rainwater into the waste layers and to protect the disposal site.

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

c) **Gas ventilation.** The disposal site gas ventilation system should be operated for a long time to prevent the build up of toxic gases and to prevent fire/explosion hazards. The gas ventilation pipes will also act as air pipes and provide air (oxygen) to the waste layers and accelerate the waste degradation process. Therefore, the gas ventilation pipes should be maintained over the long term and new ventilation pipes should be installed where necessary.

d) **Leachate treatment.** The proper operation and maintenance of the leachate treatment facility is very important to prevent any further environmental pollution that may occur after the physical closure. The concentration and the amount of the leachate will eventually decrease and improved gradually with time, and it may take a long time to do so. When the concentration of leachate has improved and comply with the relevant environmental effluent discharge standards and will not cause serious damage to the surroundings, then the leachate treatment process could be changed or even terminated. However, it should be noted that the Nitrogen levels in the leachate could remain at high concentration for a long time.

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

f) **Other supporting facilities.** Other supporting facilities like the access road and the vegetation growth on the top/slopes should be maintained where necessary for
a long period of time. The typical example of the items of the disposal facilities, method and scale/frequency are shown in Table A-2.1.

### Table A-2.1 Summary of Maintenance Items

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

(For further information, refer to **Annex 4**.)

(2) Monitoring of Environmental Pollution and Early Stabilization

**The monitoring of the environment and the waste stabilization process should be carried out periodically.**

a) Items and Frequency of Monitoring. The typical examples of the monitoring items, parameters and frequency of monitoring are shown in Table A-2.2.
### Table A-2.2 Summary of Monitoring Items

<table>
<thead>
<tr>
<th>Monitoring media/parameters</th>
<th>Item and parameters</th>
<th>Frequency</th>
<th>Location</th>
</tr>
</thead>
</table>
| Preliminary site inspection | 1) The surrounding environment  
2) The condition of the facility  
3) Nuisance condition | Once (before monitoring) | - |
| Leachate                    | • pH  
• BOD  
• COD  
• Nitrogen (Ammonia, Nitrate, Nitrite)  
• ORP  
• EC (Electric Conductivity)  
• TOC | 4 times per year | 1 point per leachate pond |
| Disposal site gas           | • Oxygen (O₂)  
• Nitrogen (N₂)  
• Methane (CH₄)  
• Carbonic anhydride (CO₂)  
• Hydrogen sulphide (H₂S)  
• Temperature | 2 times per year | 2 points per site |
| Soil subsidence             | Topographic level at the top of the disposal site | Once a year | 1 point per disposal site block |
| Groundwater                 | Groundwater benchmark parameters | Once a year | 3 points per site |
| Surface water               | Effluent standard parameters | Once a year | 2 points per stream |

b) Period. The duration of the monitoring period depends on the bio-degradation and stabilization of the filled waste layers. In practice, the monitoring should be continued a long term after the PC. However, the monitoring items and frequency may vary depending on the conditions of the filled waste layers.

c) Recording and reporting. The data and records of the monitoring activities should be submitted to the relevant authorities in the LGU and DENR periodically and should be documented and kept. (For further information, refer to *Annex 4*)
Annex 3
Evaluation/Assessment Form of the Disposal Site Conditions

1. Name of Local Government Unit: ________________________________

2. No. of disposal sites that:
   a. Have been closed: ________________________________
   b. In operation: ________________________________

3. Date the form is filled: ________________________________

4. No. of visit made by the Local Government Unit personnel to the disposal site:
   a. Closed disposal site _______ (times/year), type of facility/ies __________
   b. Disposal site in operation _______ (times/year), type of facility/ies __________

5. Officer who filled up the questionnaire:
   Name: ________________________________
   Position: ________________________________
   Telephone No: ________________________________

6. No. of Questionnaire returned _________________

7. Location plan submitted: Yes _____  No _____

8. Layout plan submitted: Yes _____  No _____

9. Photos attached: Yes _____  No _____

Note: Separate forms are to be used for every disposal facility/site that are either already
closed or are still in operation; 1 disposal site or 1 inventory form.
## DISPOSAL SITE INVENTORY
*(One form for one site)*

### A. Basic Information

1. Name of Site: ____________________________________________
2. Address of Site: ____________________________________________
3. Layout site attached: Yes ☐ No ☐
4. Category: In operation ☐ Closed ☐
   If still in operational, what is the remaining life span: _________________
5. Managed by: Local Government ☐ Others ☐ pls. specify _________
7. Disposal Operation: Year Start __________ Year End __________
8. Area: __________ hectare
9. Waste disposed daily: __________ ton
   Total amount of waste disposal of __________ ton
10. Types of Wastes disposed:
   - mixed ☐
   - hospital ☐
   - hazardous ☐
   - special waste ☐
   - etc. Pls specify __________
11. Reason for Closure: Reach the life span ☐ DENR Directive ☐
   - Public Complaint ☐
   - Development at adjacent area ☐
   - Move to a new improved site ☐ Other reason, pls. specify
### B. Environmental Impact Conditions

#### Date of Survey

1. Disposal site Facility Level
   - Open dumping
   - Level 1
   - Level 2
   - Level 3
   - Level 4
   - Controlled Disposal Facility
   - Abandoned disposal site

2. Site Condition
   - Flat land
   - Swampy area
   - Hilly
   - Others, pls. specify
   - Ex quarry, mines

Prior Land use Condition
   - Agricultural
   - Residential
   - Etc. pls specify

3. Waste Covered
   - Yes
   - No
   - If yes, state the frequency of cover material applied
     - Daily
     - Weekly
     - Monthly
     - Annually
   - Remarks
   - (Note: Including daily operation)

4. Vegetation Condition
   - Trees
   - Grasses and Bushe
   - Remarks
   - No vegetation

5. Land slide
   - Noticeable
   - Medium
   - No
   - Remarks: _________________________
   - (state the height and slope)

6. Soil Subsidence
   - Noticeable
   - Medium
   - Not noticeable
   - Remarks: _____________

7. Vector and Wild animals
   - Noticeable
   - Medium
   - Not noticeable
   - Remarks: _____________

8. Odour, disposal site gas and smoke
   - Noticeable
   - Medium
   - Not noticeable
   - Remarks: _____________

---

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<table>
<thead>
<tr>
<th>Section</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Leachate Quantity</td>
<td>Noticeable [ ] Medium [ ] Not noticeable [ ] Remarks: ____________</td>
</tr>
<tr>
<td>10. Location of Water intake</td>
<td>Upstream [ ] distance _________ km Downstream [ ] distance _________ km No intake point [ ] Remarks: _________</td>
</tr>
<tr>
<td>11. Location of Drinking Water Well</td>
<td>&lt;500 m [ ] &gt;500 m [ ] No [ ] Remarks: _________</td>
</tr>
<tr>
<td>13. Are there any Public Complaint</td>
<td>Yes [ ] No [ ] If yes, state the no. of complaints per year: _________</td>
</tr>
<tr>
<td>14. Distance to the residential area</td>
<td>&lt;500 m [ ] &gt;500 m [ ] No [ ] Remarks: _________</td>
</tr>
</tbody>
</table>

### C. Land Utilization before/ after closure

1. Prior to land use condition
   - Agricultural [ ] Residential [ ] Industrial [ ] A&D [ ] Etc. pls specify _________

2. Existing Land Utilization
   - Vacant [ ] Housing [ ] Recreation [ ] Industry/Commerce [ ] Others [ ] Specify _________

3. Surrounding Area
   - Vacant [ ] Housing [ ] Recreation [ ] Industry/Commerce [ ] Others [ ] Specify _________

4. Ultimate Land Use
   - Yes [ ] No [ ]
   - If yes, will the proposed activities will be heavily used
     - High use [ ]
     - Medium [ ]
     - Low use [ ]

5. Is the disposal site is included the Local Development Plan
   - Yes [ ] No [ ]
   - adjacent [ ] Remarks: _________
6. Is the site is to be properly developed
   most probably ☐
   less probably ☐
   Remarks: ________________________________

7. Distance from town center
   Less than 5 km ☐
   Between 5 to 10 km ☐
   More than 10 km ☐
   Remarks: ________________________________

D. Existing Environment

1. is there any structures/settlement established?
   Yes ☐
   No ☐
   Others ☐
   If yes, pls. specify __________

2. What are the health problems encountered, please specify health hazards/problems by the constituents___________

3. othr problems encountered __________

* - refer to the notes
Annex 4
Maintenance of 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 odor or vectors
- Disaster which has direct influences in the life of the person such as the collapse of the disposed 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 disposed layer

Visual inspection to the portion which has appeared on the ground shall be performed after the inspection of top cover and dykes. Frequency of regular inspection shall be decided in view of the condition of these facilities. In addition, special 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 damage is confirmed, repair shall be performed. If a crack and corrosion are left, corrosion will be accelerated by rain thus 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 disposal site which is caused by the stabilization of the 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 the layer.

As the inspection of the surface drainage, visual inspection shall be performed to 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 caused the increase of the leachate quantity by the soaking of the rain water into deposited layer.

As the inspection of the cut-off drainage, visual inspection shall be performed to 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, special 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 disposal site which is caused by the stabilization of the deposited 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 disposal site gas properly and becomes the factor which discourages stabilization of disposal site.

About gas ventilation pipes exposed from the surface, its transformation and damage shall be checked by visual inspection.

It is difficult to perform the visual inspection for the gas ventilation in pipes located below the disposal sites surface, thus, the following items should be considered:

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

(5) LEACHATE COLLECTION PIPES

It becomes difficult to manage and treat the leachate when damage or clog of leachate collecting drainage pipes occurs. Moreover since the groundwater level inside the disposal site 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.
With regards to 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 of the leachate collection/drainage pipes are buried underground, it shall be judged synthetically from the following:

- Leachate quantity at the end of leachate collection/drainage pipe
- Groundwater level inside the disposal site
- Crack and subsidence of the disposal site surface
- Clogging of the pipes (Check inside the pipe from end of pipe)

(6) LEACHATE TREATMENT FACILITY

When the leachate treatment facilities does not functioning appropriately, it is difficult to treat leachate that satisfies designed treated water quality thus it causes water pollution at the downstream region.

The following items shall be performed in the inspection of leachate treatment facilities:

- 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 the disposal sites or influence to the surrounding environment, thus it tends to cause the misjudgments about maintenance of these disposal sites.

For the inspection of the groundwater monitoring well, the following items shall be performed:

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

The following items shall be performed the inspection of the monitoring facilities:

- Existence of damage or failure of equipments
- Calibration of equipments
- Existence of damage or failure of sensing element/Replacement of sensing element
Annex 5
Environmental Monitoring
(GENERAL OBJECTIVE AND METHODOLOGY OF ENVIRONMENTAL MONITORING)

1. Role of Monitoring

Role of monitoring for disposal sites can be categorized based on the purposes. While environmental impact monitoring is the primary objective, monitoring for safety of the site at operational phase and monitoring of the 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 the environmental impact monitoring as well as for the stabilization process monitoring. Figure A5-1 shows the concept of role of monitoring.

Table A5-1 is the summary of each monitoring parameter related purposes.

Table A5-1 Summary of Each Monitoring Parameter related to Purpose

<table>
<thead>
<tr>
<th>Monitoring media/parameters</th>
<th>Environmental impact</th>
<th>Safety</th>
<th>Stabilization process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Site inspection</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Leachate</td>
<td>++</td>
<td></td>
<td>++</td>
</tr>
<tr>
<td>Disposal site gas</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Soil subsidence</td>
<td></td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Groundwater</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsurface water</td>
<td></td>
<td></td>
<td>++</td>
</tr>
</tbody>
</table>

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

2. Monitoring Parameters and Frequency

The following tables summarize recommended monitoring parameters and frequency for the noted media.
### Table A5-2 Recommended Monitoring Parameters and Frequency for Medias

<table>
<thead>
<tr>
<th>Monitoring media/parameters</th>
<th>Items and parameters</th>
<th>Frequency</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Site Inspection</td>
<td>Surrounded environment Facility condition Nuisance condition</td>
<td>Once before monitoring</td>
<td>-</td>
</tr>
<tr>
<td>Leachate</td>
<td>• pH  • BOD  • COD  • Nitrogen (Ammonia, Nitrate, Nitrite)  • ORP  • EC  • TOC</td>
<td>4 times / year</td>
<td>1 point / leachate pond</td>
</tr>
<tr>
<td>Disposal site gas</td>
<td>• Oxygen (O₂)  • Nitrogen (N₂)  • Methane (CH₄)  • Carbon Dioxide (CO₂)  • Temperature</td>
<td>2 times / year</td>
<td>2 points / site</td>
</tr>
<tr>
<td>Land subsidence</td>
<td>Topographic height of the top of disposal site</td>
<td>Once / year</td>
<td>1 point / disposal site block</td>
</tr>
<tr>
<td>Groundwater</td>
<td>Groundwater benchmark parameters</td>
<td>Once / year</td>
<td>3 points / site</td>
</tr>
<tr>
<td>Surface water</td>
<td>Effluent standard parameters</td>
<td>Once / year</td>
<td>2 points / stream</td>
</tr>
</tbody>
</table>

Groundwater benchmark and Effluent standard parameters are shown in Tables A5-3 and A5-4.
### Table A5-3  National Guideline for Drinking Water Quality applied for Groundwater

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

### Table A5-4  Parameter Limits of Effluent of Standard A and B

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

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3. Preliminary Site Inspection

Prior to the preparation of the monitoring plan, site visit inspections to the following are recommended:

(1) Surrounding Environment
Site’s specific condition around the disposal site shall be clarified firsthand as specified:

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

- Topography and geology (near-surface soil profile)
- Residence and community nearby (how close and how many?)
- Workers for disposal site 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 disposal site facilities had 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 disposal site slope will provide base to evaluate the risk of waste collapse and outflow of the waste to outside. In view of this, the 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
- Disposal site slope and band structure

(3) Nuisance Condition

Apart from facility condition, nuisance condition as follows shall be checked.

- Odor
- 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 A5-2).

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.

![Fig. A5-2 Schematic Diagram of Monitoring Plan](image-url)
4. Leachate

(1) Objective

Rainwater penetrated into the disposal site is contaminated with the leaching substances from the waste materials and then effuses from the pore of the disposal site. Therefore such contaminated water shall be treated before discharging into the public water body to prevent environmental contamination. Water quality of leachate varies by the nature of waste materials, structure of the disposal site, metrological condition as well as the period elapsed after disposal site. For example, at the disposal site on land, leachate quality in the early stage is high in concentration due to contamination, while in the later stage is of less concentration. Therefore leachate shall be monitored not only for environmental impact but also during 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 (NH3-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

The important parameters and reasons for the monitoring area as follows:

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) NH3-N
Ammonia is generated from the decomposition of the waste. It can be used to evaluate the decomposition stage of the disposal site waste, since Ammonia is high in concentration at early stage, but gradually decreased in the later part of the process.
5) ORP (Oxidation Reduction Potential)
ORP provide indication if the inside of the disposal 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 disposal site.

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

5. Disposal site Gas

(1) Objectives

Organic decomposition at the disposal site generates carbon dioxide under aerobic condition and methane under anaerobic condition. Trace of hydrogen sulphide and ammonium are also generated. The volume of the gas generation will decrease while decomposition proceeds and the remaining organic decreases. Therefore disposal site gas measurement can provide qualitative indication of the stabilization of disposal site 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 sulfide is also hazardous and gives offensive odor 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 collected 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 sulfide and ammonium. Also gas volume can be estimated by measuring pressure. Twice a year monitoring is recommended. More disposal site gas emitted from the boundary section of the disposal site 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 disposal site shall be monitored. Subsidence is caused by the compaction due to the weight and by the waste decomposition as shown in the following figure.

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

![Fig.A5-4 General Pattern of Land subsidence at Disposal Sites](image)

Above figure illustrates the general pattern of land subsidence at the disposal site sites. Two line indicates the different disposal site 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 disposal site has potential to contaminate the river and/or pond water. Therefore surface water has to be monitored for such potential contamination by the disposal sites.
(2) Methodology
DENR 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 the primary importance to evaluate the impact of the contamination. DENR has separate effluents standard if water intake is at the downstream.

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 disposal 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 disposal site 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 cannot 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 Mines and Geo-Sciences Bureau 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 disposal 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:
In order to use submersible pump during the sampling work, casing pipe diameter shall be larger than 2 inch or 50mm at minimum case, and better still 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 cannot 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. In many cases, this is quite hard work if one has to do only with bailer. Therefore submersible 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 flows, 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 straightforward, if hydraulic gradient and conductivity are taken at the field monitoring. For example, if hydraulic gradient is 1/100 (=1 m 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%)

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

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;

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

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 disposal sites. Figure A5-5
summarizes the waste decomposition and stabilization process.

Fig A5-5 Waste Decomposition and Stabilization Process
Annex 6

Post-closure Land Use

The closed disposal sites could be used for other purpose if proper counter-measures have been taken in order to develop the site. The post closure management (PCM) activities should be continued after the post-closure land use.

(1) Required Counter Measures

When the closed site has been earmarked for the redevelopment, the appropriate counter-measures should be carried out. These counter-measures can be categorized into four functions as follows.

(a) Succession and/or Improvement of Disposal site Facilities

The disposal site facilities and/or safe closure facilities should be properly operated and maintained at all times even if no major problems are apparent in the closed site. Existing facilities like the gas ventilation and the surface drainage systems that may be affected by the development works should be moved and reinstalled at the appropriate new locations.

(b) Safety Measures for Development and Land Use

The safe control items of the post closure land use are shown below in Table A6-1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Landslide / collapse</td>
<td>The stabilization of the slopes should be designed and checked regularly. Be sure that the facility could handle the dynamic load exerted from the weight of the equipments and should be monitored properly.</td>
</tr>
<tr>
<td>b. Fires / Explosion</td>
<td>Disposal site gas contains highly flammable and explosive mixture of gases. Methane gas is highly explosive and volatile when the concentration in air is between the ranges of 5% to 15% (by volume). The concentration of the methane gas in the disposal site gas mixture will have to be monitored regularly. It is also necessary to control the migration paths of disposal site gas to prevent it from accumulation in dangerous quantities. As precautionary measures, fire protection and prevention facilities should be installed near the gas discharge points.</td>
</tr>
<tr>
<td>c. Damage to the plant life and vegetation at the sites</td>
<td>Disposal site gas and certain waste may damage the plant life and vegetation. The top cover soil layer should be sufficiently thick to support and promote secondary growth plants and the roots not exposed to the filled waste. Certain type of plants or vegetation are susceptible to various compounds found in the disposal site gas, i.e. H2S, NH4, Ethylene, etc. Therefore, the selection of suitable plants for planting at the closed disposal site sites should be considered carefully.</td>
</tr>
<tr>
<td>d. Damage to the equipments</td>
<td>Disposal site gas mixtures contain various corrosive gases such as H2S and NH4, that may corrode and damage metallic objects and concrete</td>
</tr>
</tbody>
</table>
and facilities structures installed at the site. Therefore, the selection of construction materials for the equipment and facilities must be carried out diligently. Possible ground subsidence may also damage foundations and infrastructures such as pipelines, drains and the access roads.

e. Chemical reactions

The decomposing waste layers contain large amount of hazardous chemical compounds such as ammonium (NH4+). The ammonium will react with the alkaline compounds in the cement and limestone present in the discarded construction waste. The resulting unintended chemical reaction will produce ammonia gas (NH3), which is extremely toxic. This process of de-nitrification is also known as “Ammonia Stripping”.

(3) Measures to Control and/or Prevent the Environmental Pollution and Hazards

The development work at the closed disposal site will definitely cause some environmental pollution and hazards. The excavation work will expose the waste layers and resulting in dust pollution and emission of offensive odor. Road surface paving works may prevent the disposal site gas migration to the surface and trapped the gases in pockets that may cause the gas explosion. Appropriate counter-measures must be provided to ensure such occurrences are prevented. Development works of post closure land use at the closed disposal site may affect/destroy the existing environment pollution control measures. Some of the possible effects are as follows:

**Table A6-2 Environmental Control Items**

<table>
<thead>
<tr>
<th>Items</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Disposal site gas migration</td>
<td>The developer may have constructed floors or road surfaces that are impervious and prevents the gas from escaping through the surface. This will cause the gas to migrate and seep into the neighboring grounds and into the houses where the gas accumulates and may cause damage or explosions.</td>
</tr>
<tr>
<td>b. Leakage of leachate</td>
<td>Development works may damage the existing disposal site facilities such as the leachate collection and treatment system and the soil cover. Care must be taken when preparing such works at the site.</td>
</tr>
<tr>
<td>c. Groundwater pollution</td>
<td>Development works may puncture and damage the impermeable layer of the bottom soil liner. Preventive measures must be taken to ensure the layer is not damaged and regular groundwater monitoring should be carried out during and after the development works.</td>
</tr>
<tr>
<td>d. Excavated waste</td>
<td>The excavated waste during development works should be disposed of in a safe and proper manner and should not be left exposed on the site.</td>
</tr>
<tr>
<td>f. Liner</td>
<td>Development works that require extensive excavation or piling should not be permitted on closed sites that have been previously provided with artificial bottom liner system. The construction works may puncture and damage the liners. Such work should only be allowed when alternative counter-measures to the liner have been installed around the site. Such measures may include providing sheet piles to acts as vertical liners to contain the flow of leachate etc.</td>
</tr>
</tbody>
</table>
(4) Facilities to Minimize Effects to the Public

If the post closure land use resulted in the increase in the population and human traffic to the developed site, then the future land use plan must include appropriate counter-measures to protect and minimize the harmful effects that may occur. Such measures may include the installation of gas collection system around the buildings to control gas migration. (refer to Annex 8 Indicators For Risk of Post-Closure Land Use)
Annex 7

Tree and Other Plant Species Recommended for Planting on Closed and Rehabilitated Disposal Sites

Suitable vegetation for planting on top of closed disposal sites include vegetative covers, the most effective of which is Vetiver grass. Another type of vegetation is known as “living filters” or those plants that minimize the amount of toxic gases. A series of laboratory and field tests were conducted by the Environmental Management Bureau (EMB) to determine the varying degrees of resistance of the various tree and other plant species exposed to heavy pollution and solely to sulfur dioxide (SO2) and nitrogen dioxide (NO2) contents. Plants classified as resistant were those that showed zero to twenty percent injury per plant for at least 66% of all plants of the same species in three test sites.

Air Pollution-Resistant Tree and Other Plant Species - ERDS-NCR (1999)

Plants considered sensitive were those that exhibited greater than 50% injury per plant for at least 66% of all plants of same species in three sites. The results of such experiments identified the following:

The highly resistant tree and other plant species are:

<table>
<thead>
<tr>
<th>Adelfa</th>
<th>Bunga</th>
</tr>
</thead>
<tbody>
<tr>
<td>African tulip</td>
<td>Caballero</td>
</tr>
<tr>
<td>Antsoan dilau</td>
<td>Campanilla</td>
</tr>
<tr>
<td>Bandera de Espanola</td>
<td>Chichirica</td>
</tr>
<tr>
<td>Bougainvilia</td>
<td>Creeping daisy</td>
</tr>
<tr>
<td>Ipil-ipil</td>
<td>Picara</td>
</tr>
<tr>
<td>Lumbang</td>
<td>San Francisco</td>
</tr>
<tr>
<td>Mayana</td>
<td>Yellow bell</td>
</tr>
<tr>
<td>Molave</td>
<td>Yemane</td>
</tr>
<tr>
<td>Mollucan sau</td>
<td>Zigzag plant</td>
</tr>
</tbody>
</table>

The moderately resistant tree and other plant species are:

<table>
<thead>
<tr>
<th>Acacia</th>
<th>Narra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balitbitan</td>
<td>Palawan cherry</td>
</tr>
<tr>
<td>Baston de Jose</td>
<td>Palo Maria</td>
</tr>
<tr>
<td>Copper leaf</td>
<td>Palo santo</td>
</tr>
<tr>
<td>Guyabano</td>
<td>Poinsettia</td>
</tr>
<tr>
<td>Mabolo</td>
<td>Rubber tree</td>
</tr>
<tr>
<td>McArthur Palm</td>
<td>Shanghai beauty</td>
</tr>
<tr>
<td>Maluko</td>
<td></td>
</tr>
</tbody>
</table>

Tree and Other Plant Species that Absorb Sulfur Dioxide (SO2) and Nitrogen Dioxide (NO2)

There were also experiments to determine the specific tree and other plant species that specifically absorb sulfur dioxide (SO2) and nitrogen dioxide (NO2). The following are sulfur dioxide and nitrogen dioxide absorbent tree and other plant species that are recommended for planting:
The relation between the Depth of final cover soil and Vegetation

The purpose of final cover is to provide improvement to the sanitary conditions, the landscape, post-closure land use, the reduction of the leachate quantity, reduction of offensive odor, prevention of outbreak of fire, reduce the breeding of vectors, minimize leachate generation, serve as vegetation layer, etc. The final soil cover should be at least 60 cm which include 15 cm topsoil and 45 cm compacted soil (DAO No. 2001-34). The topsoil, which is usually not compacted, will serve as protection layer as well as support for the plant growth. In areas where trees and scrubs are to be planted, the thickness should be increased to be more than 150 cm. General standard is shown in Table A7-1 and Fig.A7-1.

Table A-7.1 General Standard of Top Soil

<table>
<thead>
<tr>
<th>Area</th>
<th>The depth of final cover soil</th>
<th>Compacted soil</th>
<th>Top soil</th>
<th>Total</th>
<th>General standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare area</td>
<td></td>
<td>45 cm</td>
<td>15 cm</td>
<td>60 cm</td>
<td>60 cm</td>
</tr>
<tr>
<td>Flower and grass area</td>
<td></td>
<td>45 cm</td>
<td>50 cm</td>
<td>95 cm</td>
<td>100 cm</td>
</tr>
<tr>
<td>Small tree area</td>
<td></td>
<td>45 cm</td>
<td>100 cm</td>
<td>145 cm</td>
<td>150 cm</td>
</tr>
<tr>
<td>Tree area</td>
<td></td>
<td>45 cm</td>
<td>150 cm</td>
<td>195 cm</td>
<td>200 cm</td>
</tr>
</tbody>
</table>

Fig.7-1 The relation between the Depth of final cover soil and Vegetation
Annex 8

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 disposal site 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 disposal site 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 following:

(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 disposal site.

If the effluent water at the border of disposal 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 disposal site gas contains the explosive and combustible matter; i.e. methane (CH4), hydrosulphide (H2S), hydrogen (H2), 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, burning shall be strictly prohibited.
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 disposal site 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 disposal site gas collection and ventilation system shall be installed under the building.

Therefore, the developer/owner should certify the followings:

(a) Quality of disposal site gas will not cause the explosion and fire
(b) Quality of disposal site 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 disposal 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 disposal site gas and soil contamination.

The disposal site gas contains some hazardous matters: methane, ethylene, acetylene, hydrosulfide, 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 disposal site 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 Sulfide (H2S) is well known for their corrosiveness on cement and steel.

The building materials faced the disposal site gas, waste, and leachate may have a risk of corrosion. Acidity and H2S 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 disposal 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 use for the development works of the disposal site 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 disposal 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 disposal site 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.
Annex 9

Case Studies for Safety Closure of Disposal Sites located beside a river, coastal area and cliff side.

It is very difficult and expensive to do safety closure work of disposal sites located beside a river, coastal area and cliff side. The selection of landfill site is one of the most important issue in consideration of final disposal. New landfill site shall be selected by post closure land-use and closure method.

However the existing disposal sites located in the conditions above mentioned, safety closure work shall be considered following process.

1. Disposal site located beside a River and Coastal area

Assessment of existing disposal site shall be carried out as follows:

- Field survey of topographic conditions
  - to identify the existing dumping area and surrounding topographic conditions, especially relation between a dumping site and an area of water
- Hydrological investigation
  - To study on water activity (flood from river water and high tide of sea water), movement of water level, flood area by river water and sea water occurred in typhoon.

Design and construction shall be carried out as follows;

- Decision of new site area
  - To identify the new disposal area, this can be avoided from the flood.
- Construction of Embankment
  - To protect dumped waste washed away by the flood.

Existing waste dumped in the flood area shall be removed to new site. After removing of waste, the safety closure shall be carried out as a rule. The idea of safety closure of flood area is shown in Fig. A9-1.

If all area of existing dump site is included in flood area, all waste shall be removed to new site.

![Safety Closure Method of Disposal Site located beside a River and Coastal area](image-url)
2. Disposal site located cliff side

Case 1. Non-sharpness Slope
Embankment shall be constructed to protect the falling of the waste at existing dump site located at non-sharpness slope. Slope shall be formed 1:2, and surface will be covered by cover soil more than 60 cm (24 inches).

![Fig.A9-2 Safety Closure Method of Disposal Site located cliff side A](image)

Case 2. Steep Slope
If it is difficult to construct the embankment along steep slope, the embankment shall be constructed acrossing the creek. Safety closure system of Case 2 requires access road, embankment and drainage ditch. If the cliff has huge catchment area, the drainage pipes should be large enough to drain the storm water from the upstream side.

![Fig.A9-3 Safety Closure Method of Disposal site located cliff side B](image)
Annex 10

Post Closure Land Use Plan

The developer should prepare the post closure land use plan and submitted to the Department and/or National Solid Waste Management Commission for review and approval. The content of the plan should include the following.

(1) General information/condition of disposal site and its surroundings

(2) Status of stabilization of the filled waste

(3) Post-closure land utilization

(4) Alteration plan of disposal facilities

(5) Safe control measures
   - Construction and development
   - Land utilization

(6) Environmental pollution control measures

(7) Post closure management (PCM) plan
   - Operation and maintenance of facilities
   - Monitoring of environment and stabilization

(8) Implementation schedule of the above items

(For further information, refer to Appendix 11.)
Annex 11

Type of Development for Post Closure Land Use

There are several patterns of development of closed disposal site 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 disposal site gas
b. Park: Open access and little engineering works
   Probable incidents are accidental fires, unpredictable offensive odor, 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 disposal site gas.

 e. Commercial/Industrial Facility: Many persons access for long-time and more engineering works
   There will be many problems as stated above.
Annex 12
Social Considerations on Closure of Disposal Sites

There are many reasons for closing a disposal site and the main reason is usually due the inherent negative social impacts it has on the surrounding population. The main health risk and impact are on those working at the disposal sites, i.e. the operators and waste pickers, and the residents living around the sites. The social considerations on the closures should be implemented at each stage as follows.

(1) Social Consideration for the Waste Pickers

Waste pickers are part of the informal waste sector and this sector is defined as individuals, families, groups or small enterprises engaged in the recovery or waste materials with revenue generation as the motivation either on a full-time or part-time basis. According to laws and regulations related to solid waste, waste picking or scavenging at disposal sites is prohibited and is regarded as an illegal action in the Philippines. In spite of the illegal action of scavenging, however, from a humanitarian point of view, the authorities involved shall appropriately evacuate waste pickers from disposal sites to be closed.

Various studies have shown that informal waste sector contribute positively to our overall solid waste management. They reduce the volume of waste at little or no cost to the local governments or taxpayers. The volume they handle directly results to the extension of the life of sanitary landfills.

The closure of disposal sites are viewed negatively by waste pickers since it will mean loss of their livelihood. Not only that, it also means displacement from their homes as the waste pickers usually settle near or at disposal sites. Closure plans should be made to include the informal waste sector and considerations given to integrate or include them in the new solid waste management system that shall be implemented with the disposal site closure. The reason for this is to address waste their need for long term, sustainable livelihood and to upgrade their working conditions from an unsafe, unsanitary and inhumane one to a more decent, humane, healthy and safe one.

The proposed interventions for the informal sector in the UNEP study entitled “The Preparation of a National Framework Plan for the Informal Sector in Solid Waste Management” are as follows:

1. Supporting waste pickers to enter new service roles and niches in separate collection and recycling. Waste pickers shall be recognized as LGU partners in carrying out various waste recovery and recycling projects. The goal is to change waste pickers’ source of livelihood from disposal sites to MRF’s, junk shops, composting facilities or other environmentally sound waste management facilities pursuant to RA 9003.
2. Assuring waste pickers access to sorting space in MRF’s, transfer stations and Eco Park.
3. Supporting better market leverage and/or diversification of activities by waste pickers thru cooperatives and associations. Chapter II Section 13 of RA 9003 provides for the Establishment of Multi-purpose Environment Cooperatives or Associations in Every LGU. These cooperatives or associations shall be opened to the involvement and participation of waste picker.
a-1. Carry out a survey on the informal waste sector and their activities

a-2. Preparation of relevant information on the closure of disposal sites

a-3. Preparation of the waste pickers relocation plan from the disposal facility

a-4. Conduct consultation with waste pickers regarding the closure of the disposal site and the proposed interventions. If necessary, employ the services of a social worker. It must be clear to the waste pickers that the closure of the disposal site must not be viewed negatively and consideration shall be given in order for them to be integrated in the new ecological solid waste management system to be implemented.

a-5. Set up an information desk on the closure of disposal site

b. After disposal site closure

b-1. Preparation of signboards to prohibit trespassing within closed disposal sites

b-2. Construction of fences and/or barbed wire structures at disposal sites

b-3. Carry out regular patrols to check for illegal entries into the disposal sites

(2) Social Consideration for Surrounding Community

It is in the best interest of the community surrounding the disposal site that this be closed. It is proper that they should be considered and involved in the closure plan. The community thru various organizations, can play a role in the information campaign before closure of disposal site and conduct monitoring to the site after closure. Partnerships with community organizations are useful for this end.

a. Before disposal site closure

a-1. Carry out a survey on the surrounding households or community

a-2. Preparation of relevant information on the disposal site closure

a-3. Preparation of information on environmental health issues

a-4. Organize and conduct public consultation on the closure of disposal site for possible health impacts from the continuing emissions and other environmental effects. Present methods or engineering interventions when the LGUs’ disposal site operator will use in addressing emissions and other environmental effects in order to protect the health of the surrounding community.

a-5. Setting up of an information desk on the closure of disposal site

b. After disposal site closure

b-1. Preparation of signboards to prohibit entering at disposal site sites or any disposal sites
b-2. Construction of fences at disposal site sites or any disposal sites

b-3. Carry out regular patrol/monitoring teams composed of representatives from the disposal sites operator, LGU representatives and volunteer community members to check for illegal entries into the closed disposal site. Patrol/monitoring teams may also be used for monitoring the closed disposal site to prevent accidents such as collapsing and other possible untoward incidents.

b-4. Carry out public hearing to gather public opinions and reactions to the utilization of closed disposal site sites/ or closed disposal sites
Annex 13

Receptor of Disposal site Closure for Social Consideration

(1) Possible Receptors

Possible receptors to be affected by closure of disposal sites shall be identified by Local Government Units in advance of the closure. The following should be referred for considering the identification.

- Possible receptors to be affected by closure of disposal sites are principally summarized in Table A13-1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Possible Receptors</th>
</tr>
</thead>
</table>
| At Disposal Sites                 | - Authorized Workers Operators of Heavy Equipment, Drivers of Collection Vehicles, Recyclers, Scrap Dealers and so on)  
|                                   | - Waste pickers                                                                    |
| Vicinities of Disposal site Sites | - Residential Households                                                            |

- As for authorized workers, it can be generally considered that they should be properly relocated and re-employed by any legal programs or schemes, if authorities close the disposal sites.

- In this guideline, waste pickers working at disposal sites and households located around those sites are assumed as the possible receptors.

(2) Who are the Waste Pickers?

a. Definition

There is no official definition of waste pickers in Philippines at present. Therefore, in order to make sure who are considered as waste pickers, the definition of the waste pickers shall be considered and be temporally defined by authorities concerned for the closures in accordance with circumstances of disposal sites to be closed. The following should be referred to when considering the definition of waste picking and waste pickers.

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

b. Law and Regulation

According to the following circumstances on law and regulation related, waste picking at disposal sites is prohibited and is regarded as an illegal action in the Philippines.

Despite of the illegal action of waste picking, however, from humanity’s point of view, the
authorities involved shall appropriately relocate waste pickers from disposal sites to be closed.

Additional Information

A. Hazard Experience Caused by the Disposal Sites in Several Countries

B. Case Example of Disposal site Safe Closure & Post Closure Land Use

C. Case Example of Problems Associated with the Post-Closure Disposal site Sites

D. Referred Standards/Guidelines
A. Hazard Experience Caused by the Disposal site Sites in Several Countries

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

Table A-1 Hazard Experiences caused by the Disposal site Sites in Several Countries

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Year</th>
<th>Hazard Types</th>
<th>Outline of the Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kobe, Japan</td>
<td>1977</td>
<td>Gas explosion</td>
<td>A gas explosion 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 attend.</td>
</tr>
<tr>
<td>2</td>
<td>Chiba, Japan</td>
<td>n.a.</td>
<td>Gas migration</td>
<td>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 farm. The local residence experienced and suffered irritations to their eyes and throat.</td>
</tr>
<tr>
<td>3</td>
<td>Fukuoka, Japan</td>
<td>1999</td>
<td>Gas breakout</td>
<td>2 workers were killed when they were blown away by a gust of hydrogen sulphide gas whilst carrying out some digging/boring work at the landfill site.</td>
</tr>
<tr>
<td>4</td>
<td>Okinawa, Japan</td>
<td>2002</td>
<td>Landfill fire</td>
<td>A fire occurred at a landfill site in Okinawa when hydrocarbons were inhaled which resulted in the release of several types of toxic gases. The local residence experienced and suffered irritations to their eyes and throat.</td>
</tr>
<tr>
<td>5</td>
<td>Selangor, Malaysia</td>
<td>1998</td>
<td>Landslide and fire</td>
<td>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 excavated and 3 workers were killed when they were exposed to a very high concentration of hydrogen sulphide gas whilst carrying out some digging/boring work at the landfill site.</td>
</tr>
<tr>
<td>6</td>
<td>Atlanta, USA</td>
<td>1999</td>
<td>Gas explosion</td>
<td>A gas explosion occurred in a school in Atlanta. The school was closed for half a year to ensure the area was safe for the pupils to attend.</td>
</tr>
<tr>
<td>7</td>
<td>North California, USA</td>
<td>1994</td>
<td>Gas explosion</td>
<td>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.</td>
</tr>
<tr>
<td>8</td>
<td>Pittsburgh, USA</td>
<td>1987</td>
<td>Gas explosion</td>
<td>Off-site gas migration from the landfill caused an explosion in a housing area in Pittsburgh.</td>
</tr>
<tr>
<td>9</td>
<td>Ohio, USA</td>
<td>1984</td>
<td>Gas explosion</td>
<td>Off-site gas migration from the landfill caused an explosion and destroyed a house in Akron, Ohio.</td>
</tr>
<tr>
<td>10</td>
<td>Cincinnati, USA</td>
<td>1983</td>
<td>Gas explosion</td>
<td>Gas explosion caused by the landfill destroyed a house across the site from the city in Cincinnati, Ohio. Some injuries were reported.</td>
</tr>
<tr>
<td>11</td>
<td>Colorado, USA</td>
<td>1975</td>
<td>Gas explosion</td>
<td>In another incident, a gas explosion occurred near the storm drain laid across the site. The explosive gases accumulated in the drain pipe ignited when a group of children were playing and lighting candles near the drain. The children all suffered serious burns on their arms and legs while playing in a playground.</td>
</tr>
<tr>
<td>12</td>
<td>North California, USA</td>
<td>1969</td>
<td>Gas explosion</td>
<td>Methane gas migrated from the adjacent landfill site and leaked into the basement of an armoury in Winston-Salem, North Carolina. The gas ignited when a cigarette was lit thus killing three men and seriously injuring another.</td>
</tr>
<tr>
<td>13</td>
<td>New York, USA</td>
<td>n.a.</td>
<td>Health problem</td>
<td>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.</td>
</tr>
<tr>
<td>14</td>
<td>Philippines</td>
<td>2000</td>
<td>Landslide</td>
<td>Heavy rains triggered an avalanche at a waste dumping site in the suburb of Quezon City. At least 280 people died and 800 were evacuated to avoid the threat of a worst-case scenario.</td>
</tr>
<tr>
<td>15</td>
<td>Nantygwyddon, UK</td>
<td>n.a.</td>
<td>Health problem</td>
<td>About 200,000 m² of avalanche occurred at a waste dumping site in the suburb of Quezon City. At least 280 people died and 800 were evacuated to avoid the threat of a worst-case scenario.</td>
</tr>
<tr>
<td>16</td>
<td>Bogota, Cambodia</td>
<td>1997</td>
<td>Landslide</td>
<td>It was reported that 800,000 m² of avalanche occurred at a waste dumping site in Bogota.</td>
</tr>
<tr>
<td>17</td>
<td>Ghenme, Italy</td>
<td>1992</td>
<td>Gas explosion</td>
<td>Underground gas migration from the closed landfill site caused an explosion at the nearby industrial area.</td>
</tr>
<tr>
<td>18</td>
<td>Carale-Brienza, Italy</td>
<td>1981</td>
<td>Gas migration</td>
<td>Gas migration from operating landfill sites seeping into nearby industrial facility was reported.</td>
</tr>
<tr>
<td>19</td>
<td>Casate, Switzerland</td>
<td>1981</td>
<td>Gas migration</td>
<td>Gas migration from landfill seeping into a home was reported.</td>
</tr>
<tr>
<td>20</td>
<td>Sarajevo, Yugoslavia</td>
<td>1977</td>
<td>Landslide and gas explosion</td>
<td>About 200,000 m² 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 buried alive.</td>
</tr>
<tr>
<td>21</td>
<td>S. Augustin, Germany</td>
<td>1981</td>
<td>Gas migration</td>
<td>Gas migration from nearby landfill site occurred in the subsoil layer resulting in the neighboring houses had to be evacuated.</td>
</tr>
<tr>
<td>22</td>
<td>Biella, Italy</td>
<td>1996</td>
<td>Gas explosion</td>
<td>Gas migrated via the subsoil layer penetrated into the neighboring house resulting in an explosion that caused the death of the resident.</td>
</tr>
<tr>
<td>23</td>
<td>Cavenago, Italy</td>
<td>1981</td>
<td>Gas explosion</td>
<td>Landfill gas migrated over a distance of 1 km and caused damage to the vegetation in nearby area.</td>
</tr>
<tr>
<td>24</td>
<td>Los Angeles, USA</td>
<td>1982</td>
<td>Landslide</td>
<td>A residential area built on a closed landfill showed cracks on the ground and experienced land subsidence.</td>
</tr>
<tr>
<td>25</td>
<td>Sacramento, USA</td>
<td>2002</td>
<td>Landfill fire</td>
<td>A fire occurred at a landfill site in Sacramento.</td>
</tr>
<tr>
<td>26</td>
<td>West Valley, USA</td>
<td>2002</td>
<td>Landfill fire</td>
<td>A fire occurred at a landfill site. It is reported that the fire produced some toxic gases such as carbon monoxide.</td>
</tr>
<tr>
<td>27</td>
<td>Vancouver, Canada</td>
<td>2000</td>
<td>Landfill fire</td>
<td>A fire occurred in a landfill site in Vancouver. The total damages and loss by the fire was estimated to be about $80,000.</td>
</tr>
</tbody>
</table>

Note: The above list is in random order.  
Sources: Information retrieved and collected from the “Agency for Toxic Substances and Disease Registry (USDA)”. CNN, BBC, Encos SA (Switzerland). Fire Department in Sacramento & West Valley (USA), MP Ampang Jaya, etc.
B. Case Example of Disposal site Safe Closure & Post Closure Land Use

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

a. Outline of the case example of safe closure
For the purpose of surrounding environmental conservation, the seepage control work which surrounds a disposed waste with the polyethylene sheet was introduced.

b. Outline of the disposal site
Term of disposal site works: 1973-1986
Type of disposed waste: incineration ash and separation residue of non-combustible refuse
Disposal site area: 3,000m²
Amount of waste disposal: 22,000m³
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 disposal site was the open dumping disposal 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 disposed 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 disposal 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 disposal 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 disposal site was installed, and further, surface liner by cover soil was installed so that rain water might not soak into the disposed waste from surface of the disposal site. The cost of countermeasure works of about 200 million yen in total was paid by the city.
This post-closure disposal site was inherited from the developer by the city with 30,000m² including the surrounding area, and is used as a playground of the elementary school in a new urban residential area.
(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 disposal site use
A post-closure disposal 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 disposal site use the jurisdiction of the bureau of port and harbor, Tokyo metropolitan government. Since it was necessary to make the facilities to ensure that there will be no trouble or sinking of the disposal site, a golf course was adopted as the main use of the park. Countermeasure work was started in 1988 and post-closure disposal site was used started from December, 1990.

b. Outline of disposal site
Name of the disposal site: The No.15 site (Tokyo metropolitan government)
Term of disposal site works: 1965-1974
Disposal site area: 71.2ha
Amount of waste disposal: 10.34 million ton
Thickness of disposal site layer: 14-20m
Disposal site method: Sea area disposal site (the method of dumping waste in the water from the disposal site seawall constructed in the sea)

c. Countermeasure works
- Installing of gas ventilation pipes for countermeasure against disposal site 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 playground of the golf course

**Fig. B-2 Standard Profiles of Wakasu Sea-side Park**

**Fig. B-3 Top View of Wakasa Sea-side Park**

**Fig. B-4 Golf Course of Wakasa Sea-Side Park**
2) **Medium layer use**
Case: Use for distribution station

a. **Outline of the case example of the post-closure disposal site use**
A post-closure disposal site for municipal waste was used as the distribution station (Fujimae distribution station) and residential district.

b. **Outline of disposal site**
Type of disposal site: municipal waste disposal site (80% is glass, pottery waste and incineration ashes and others are organic matter.)
Term of disposal site works: 1968-1974
Disposal site area: approximately 95ha
Amount of waste disposal: estimate 3.3 million ton or more
Thickness of disposal site 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.

![Fig. B-5 Top View of post-closure Disposal site Use](image-url)
3) Bottom layer use  
Case: Bridge pier construction of a highway interchange elevated bridge  

a. Outline of the case example of the post-closure disposal site use  
A post-closure disposal 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 disposal site.  

b. Outline of disposal site  
Type of disposal site: industrial waste disposal site  
Disposal site area: approximately 6.4ha  
Amount of waste disposal: approximately 42,500 ton (sludge: 200,000m3, glass and pottery waste: 60,000m3, slag: 43,000m3, organic sludge/animal and vegetable residue: 46,000m3)  
Thickness of disposal site layer: 14-20m  
Remarks: seepage control works by geomembrane lining sheet  

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

The disposal site 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 disposal site 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 disposal site.  
- The measure performed with construction is as Table B-1.
Fig. B-6 Top View of Post-closure landfill use at the kuwana Interchange

Fig. B-7 Image of Cross Section of the Pier

Fig. B-8 Top View of the Pier
### Table B-1  Measure Performed with Construction

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

< CASE 1 > EFFECTS OF HEAVY RAIN

1) Overview of the problems

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

<table>
<thead>
<tr>
<th>Table C-1 Basic Description of the Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation start year</td>
</tr>
<tr>
<td>Type of waste</td>
</tr>
<tr>
<td>Disposal site Area</td>
</tr>
<tr>
<td>Topography</td>
</tr>
<tr>
<td>Facility (during operations)</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

2) Cause of the problems

- Part of the dyke collapsed by the heavy rain.
- Since the liner system was not installed, the disposal site 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 disposal site 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>
<thead>
<tr>
<th>Table C-2 Basic Description of the Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation start year</td>
</tr>
<tr>
<td>Type of waste</td>
</tr>
<tr>
<td>Disposal site Area</td>
</tr>
<tr>
<td>Topography</td>
</tr>
<tr>
<td>Facility (during operations)</td>
</tr>
</tbody>
</table>
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.

![Fig. C-1 Damage Caused by Differential Subsidence](image)

< 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 disposal site.

<table>
<thead>
<tr>
<th>Table C-3 Basic Description of the Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation start year</td>
</tr>
<tr>
<td>Type of waste</td>
</tr>
<tr>
<td>Disposal site Area</td>
</tr>
<tr>
<td>Topography</td>
</tr>
<tr>
<td>Facility</td>
</tr>
</tbody>
</table>

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 DISPOSAL SITE GAS

1) Overview of the problems
The crops died at the nearby field due to over exposure to the disposal site gas.

<table>
<thead>
<tr>
<th>Table C-4</th>
<th>Basic Description of the Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation start year</td>
<td>Unknown (late 1970s)</td>
</tr>
<tr>
<td>Type of waste</td>
<td>Inert Waste: (mainly: Construction and demolition waste)</td>
</tr>
<tr>
<td>Disposal site Area</td>
<td>Unknown</td>
</tr>
<tr>
<td>Topography</td>
<td>Flatland</td>
</tr>
<tr>
<td>Facility</td>
<td>Liner system, gas vent pipes, etc. were not provided</td>
</tr>
</tbody>
</table>

2) Cause of the problems
• At this disposal site, the disposal of only inert waste (i.e. plastics, rubber, metal, glass, ceramics, asphalt concrete and so on) was licensed, but during operations, organic waste was also disposed at the site. Hence, disposal site gases were generated by the biodegradation of the organic matter.

• Since the liner system was not installed in this disposal site, the disposal site gas migrated and escaped into the adjacent land through the ground. (refer to Figure C-2)

• The disposal site gases escaped to the atmosphere not only through the cover soil but also migrated to the adjacent land through the ground.
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 C-3. The gases were intercepted and vented before reaching the crops.
< CASE 5 >  FIRE CAUSED BY DISPOSAL SITE 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 disposal site gas being burning. The flame of the burning disposal site gas is difficult to see in the daylight but is highly visible at night.
- Subsequent investigation determined that the disposal site gas was escaping from the ground and was ignited.

<table>
<thead>
<tr>
<th>Table C-5</th>
<th>Basic Description of the Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation start year</td>
<td>early 1970s</td>
</tr>
<tr>
<td>Type of waste</td>
<td>Municipal waste (Raw garbage, etc.)</td>
</tr>
<tr>
<td>Disposal site Area</td>
<td>Unknown</td>
</tr>
<tr>
<td>Topography</td>
<td>Mountain Area</td>
</tr>
<tr>
<td>Facility (during operations)</td>
<td>Liner system, gas vent pipes, etc. were not provided</td>
</tr>
</tbody>
</table>

2) Cause of the problem
- The disposal site gas, which was generated by biodegradation of raw garbage, escaped into the yard.
- Since the residents were not aware of the presence of the disposal site 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 disposal site gas to the residents

3) Countermeasures
- In order to prevent the disposal site 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>
<thead>
<tr>
<th>Table C-6</th>
<th>Basic Description of the Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation start year</td>
<td>early 1960s</td>
</tr>
<tr>
<td>Type of waste</td>
<td>Municipal raw garbage, partly incinerator residue</td>
</tr>
<tr>
<td>Disposal site Area</td>
<td>Unknown</td>
</tr>
</tbody>
</table>
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 liberates 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 disposed waste were carried out.
- The laboratory scale ammonia generating reaction test was carried out.

D. Referred Standards/Guidelines

(1) “The Study on the Safe Closure and Rehabilitation of Disposal Sites In Malaysia”, JICA Study Team 2004
(2) “Technical Guidebook on Solid Waste Disposal Design and Operation”, NSWMC and JICA 2005
(4) “Guidance for Safety Management at Mining Site:” Occupational Safety and Health Act (Japan) 1970
(7) Safe Closure of Disposal Site, NSWMC and JICA 2006
(8) “Technical Guidebook on Solid Waste Disposal Design and Operation”, NSWMC and JICA 2010