

DHAKA CITY CORPORATION
OPERATION MANUAL
Matuail Sanitary Landfill



Bureau of Research, Testing & Consultation
Bangladesh University of Engineering and Technology, Dhaka
and
JICA Expert to Dhaka City Corporation

June, 2008

DHAKA CITY CORPORATION

OPERATION MANUAL

Matuail Sanitary Landfill

Prepared by
Department of Civil Engineering
Bangladesh University of Engineering & Technology,
Dhaka
and
JICA Expert to Dhaka City Corporation

June, 2008

TABLE OF CONTENTS

		Page
CHAPTER 1 : INTRODUCTION		1
1.1	Purpose	1
1.2	Landfill Development Levels	1
1.3	Waste Stabilization Processes	2
1.4	Scope of the Manual	4
1.5	Limitations	4
1.6	Organization of the Manual	5
 CHAPTER 2: ORGANIZATIONAL STRUCTURE		 6
2.1	Organizational Structure	6
2.2	Responsibilities of Permanent Site Staff	7
 CHAPTER 3 : THE LANDFILL FACILITIES		 10
3.1	The Facilities	10
3.2	Purpose/Function and Structure	11
3.2.1	Administrative/Operational Facilities	11
3.2.2	Main Facilities	12
3.2.3	Support Facilities	14
3.3	Inspection and Maintenance of Facilities	15
3.3.1	Introduction	15
3.3.2	Leachate Collection Facilities	16
3.3.3	Rainwater Drainage Facilities	16
3.3.4	Gas Removal Facilities	17
3.3.5	Leachate Ponds	18
3.3.6	Leachate Treatment and Recirculation Facilities	19
3.3.7	Road and Platform Facility	19
3.3.8	Monitoring Facilities	20
3.3.9	Administrative/Operational Facilities	20
3.3.10	Other Related Facilities	21

CHAPTER 4 : LANDFILL OPERATIONS AND MANAGEMENT 23

4.1	Introduction	...	...	...	23
4.2	Vehicle Operations	...	...	...	23
4.2.1	Traffic Flow	...	...	...	23
4.2.2	Weigh Bridge Operation	...	...	...	24
4.2.3	Vehicle Washing	...	...	...	25
4.3	Disposal Operations	...	...	...	26
4.3.1	General	...	...	...	26
4.3.2	Waste unloading	...	...	...	26
4.3.3	Landfill Work	...	...	...	26
4.4	Soil Cover	...	...	...	30
4.4.1	Effectiveness and Necessity	...	...	...	30
4.4.2	Types of Soil Cover	...	...	...	30
4.4.3	Selection of Soil Cover	...	...	...	30
4.4.4	Determination of Thickness	...	...	...	31
4.4.5	Operation and Maintenance	...	...	...	31
4.4.6	Storage Area	...	...	...	32
4.5	Waste Filling and Soil Cover at Side Slopes	...	...	...	35
4.6	Drainage of Working Road	...	...	...	38
4.7	Temporary Drains	...	...	...	39
4.8	Construction and Operation of Working Road	...	...	...	40
4.9	Leachate Pond Aeration	...	...	...	40
4.10	Leachate Recirculation and Sludge Disposal	...	...	...	41
4.11	Gas Vent Extension	...	...	...	41
4.12	Special Waste Handling	...	...	...	41
4.13	Landfill Equipment Maintenance	...	...	...	41

CHAPTER 5 : ENVIRONMENTAL MANAGEMENT 42

5.1	Potential Environmental Impacts	...	...	...	42
5.2	Mitigation of Adverse Impacts	...	...	...	42
5.3	Environmental Monitoring Program	...	...	...	44
5.3.1	Monitoring Requirement	...	...	...	44
5.3.2	Monitoring Plan	...	...	...	46
5.4	Environmental Enhancement	...	...	...	47

CHAPTER 6 :	EMERGENCY MANAGEMENT	48
6.1	Types of Emergencies... ..	48
6.2	Emergency Management and Contingency Plan ...	48
6.3	Emergency Response ...	48
6.3.1	Hazardous, Toxic and Infection Wastes ...	48
6.3.2	Fire	48
6.3.3	Earthquake	49
6.3.4	Severe Wet Weather Conditions ...	49
6.3.5	Access Road Problems ...	49
CHAPTER 7 :	POST CLOSURE PLAN	51
7.1	Introduction	51
7.2	Capping of the Site	51
7.3	Management of Leachate and Gas	51
7.4	Settlement Monitoring and Maintenance of Final Soil Cover	52
7.5	Surface Water Control	52
7.6	Other Facilities	52

Chapter 1

INTRODUCTION

1.1 Purpose

This manual has been developed to provide guidance for smooth operation of Matuail Sanitary landfill. It provides basic information about the landfill facilities, organizational structure, routes of vehicle movement, landfill operations, environmental management and emergency management including post closure plan. This manual is intended for use by the personnel of Dhaka City Corporation (DCC) and contractors involved in the operation and maintenance of the Matuail landfill.

1.2 Landfill Development Levels

Solid waste disposal by landfill should be done in a sanitary manner to protect health and environment. Landfills in developing countries have been categorized into 4 development levels by JICA based on the available facilities of the landfills. The main features of these landfill development levels are presented in Table 1.1.

Table 1.1: Proposed Sanitary Landfill Levels by JICA

Facility	Level 1	Level 2	Level 3	Level 4
Description	Controlled tipping	Sanitary Landfill with bund and daily cover	Sanitary Landfill with leachate re-circulation	Sanitary Landfill with Leachate Treatment facilities
(1) Soil cover	√ (Periodic)	√	√	√
(2) Embankment		√	√	√
(3) Drainage facility		√	√	√
(4) Gas venting		√	√	√
(5) Leachate collection			√	√
(6) Leachate recirculation			√	√
(7) Leachate treatment				√
(8) Liner				√

The Matuail landfill site has the facilities from (1) soil cover to (7) leachate treatment except item (8) liner. Therefore, the sanitary landfill at Matuail may be conservatively considered as level 3 landfill. The landfill is underlain by a 8 to 12 m thick clay layer, which is expected to function as a natural liner. Hence, the Matuail landfill can be categorized as having a level between 3 and 4 i.e. a level 3.5 landfill.

1.3 Waste Stabilization Processes

The organic fraction of solid waste decomposes under aerobic or anaerobic process in a landfill depending on the availability of oxygen. In most sanitary landfills, the available oxygen in the waste is quickly exhausted during decomposition process and the system becomes anaerobic. Anaerobic decomposition of organic matter produces methane, carbon dioxide, water and some odour producing gases. The anaerobic process is slow and the leachate content is higher. On the other hand, under aerobic decomposition organic matter decomposes into carbon dioxide and water and the decomposition is rapid. Aerobic decomposition requires supply of oxygen to be pumped into the landfill. This is a costly system both in terms of construction and operation.

However, decomposition of the organic matter generates heat and increase the temperature to about 50-70°C in the waste layers. The warm air and gases generated in the decomposing landfill tend to rise up and construction of a venting system in the landfill helps supply of air in the system and thus oxygen is supplied at least in the surrounding areas of vent pipes and a semi-aerobic system of solid waste stabilization is established. It involves installation of a pipe network below the solid wastes for collection of leachate produced in the landfill as well as supply of oxygen into the deposited waste. Perforated vertical pipes are connected to the pipe network at definite intervals for supply of oxygen to the surrounding wastes and for gas venting. The relative advantages and disadvantages of the anaerobic and semi-aerobic systems of waste decomposition are presented in Table 1.2.

Table 1.2 : Advantages and disadvantages of anaerobic and semi-aerobic processes.

Anaerobic Process	Semi-aerobic Process
<ul style="list-style-type: none"> ▪ Anaerobic process is very slow and takes years to fully stabilize the waste in the landfill; ▪ The anaerobic process is associated with bad smell and methane gas generated in the landfill may causes fire hazards; ▪ Ground and surface water pollution is caused by highly polluting leachate produced due to long contact between waste and leachate; ▪ Operation of the landfill is easier; ▪ The anaerobic system does not require special attention; ▪ The methane can be collected for use as a fuel. 	<ul style="list-style-type: none"> ▪ The semi-aerobic process is faster than anaerobic process and hence the stabilization process is rapid; ▪ The odour and fire hazards problems are greatly reduced due to venting of gases and circulation of air in the landfill; ▪ Rapid drainage of leachate from landfill reduces possibility of infiltration of leachate in the deeper layers; ▪ The BOD and COD of the leachte produced are significantly reduced; ▪ The surface and ground water pollution potentials are greatly reduced; ▪ Emission of carbon dioxide instead of methane reduces global warming potential.

The semi-aerobic system established in Fukuoka city, Japan is schematically presented in Figure 1.1.

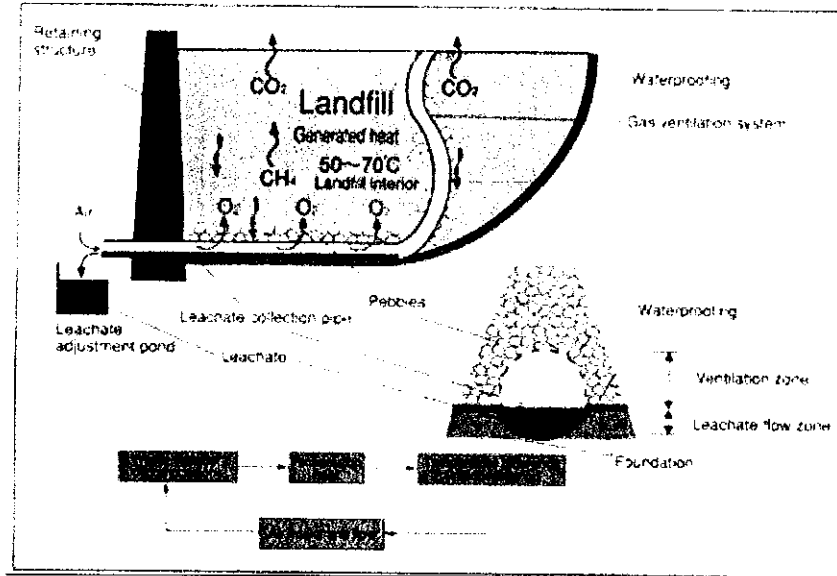


Figure 1.1 Schematic Presentation of Semi-aerobic Landfill System.

Considering the relative advantages, semi-aerobic system of solid waste stabilization has been established at the Matuail landfill site. A perforated pipe network embedded in crushed stone/Brick chips has been installed with vertical perforated ventilation pipes at approximately 50m intervals. A simplified representation of semi-aerobic system established at Matuail site is shown in Figure 1.2.

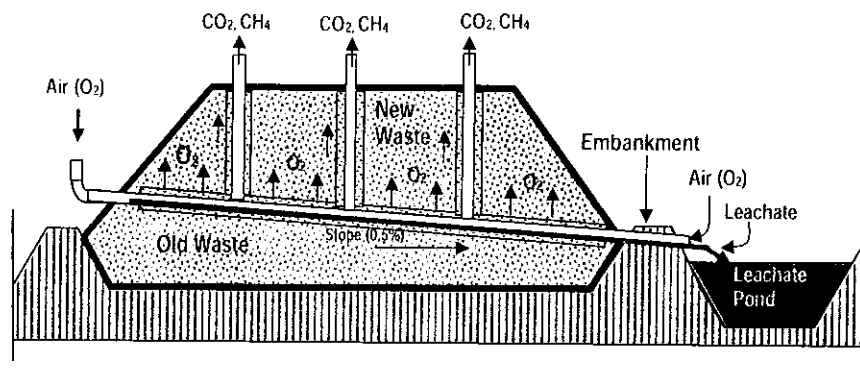


Figure 1.2 : Semi-aerobic system in a landfill

At Matuail landfill site, the leachate leaves the outlet pipe to discharge into a manhole of boundary leachate collection pipe and is finally discharged into the leachate pond. The outlet of the leachate pipe is placed above the leachate level and *not submerged in the leachate*, to allow air to be sucked into the sanitary landfill. The gas removal pipes and the

free ends of the leachate collection pipes are kept open for circulation of air and consequently creating a semi-aerobic system. In a semi-aerobic system, the following processes are observed:

- a. Parts of the landfill in the vicinity of the pipes are under aerobic condition.
- b. The differential temperatures in the landfill create natural ventilation and supply of air to the landfill.
- c. The leachate is quickly discharged and the quality of leachate is improved.

1.4 Scope of the Manual

The scopes of this Operation Manual are as follows:

- 1) Provide guidance on the sharing of responsibilities amongst the various related staff of DCC and contractors;
- 2) Provide information on the basic components of the landfill designed and constructed;
- 3) Familiarize the operator with the general operational phasing and sequencing of waste filling;
- 4) Provide basic information on the type and purpose of the landfill heavy equipment;
- 5) Provide instructions on daily waste filling operations including load inspection procedures, recording, spreading and compaction of waste and application of cover;
- 6) Provide procedures for operating under inclement or wet weather conditions;
- 7) Provide procedures for emergency response and environmental management;
- 8) Familiarize the operator with safety procedures related to landfill operations.

1.5 Limitations

This manual was prepared initially by JICA expert in accordance with basic standard practices in the operation of modern sanitary landfills of this level, specifically practices employed in operation of semi-aerobic landfills in Japan and other developing countries.

The operation of landfills in Japan is strictly regulated and therefore standards applicable there were referred to in this manual. However, some facilities included in landfills operating in Japan for dealing with waste characteristics of Japan were not included at Matuail site. For that reason the practices adopted and followed in developing countries in south-east Asia were also referred to. The BUET consultants updated the manual considering the local context.

The manual does not provide specific procedures in other areas of Solid Waste Management (SWM) such as equipment maintenance and repair, handling of toxic and hazardous waste, detailed safety procedures, and detailed emergency response. It is intended to provide the operator with the basic knowledge and understanding of landfill operation in general.

1.6 Organization of the Manual

The manual has 7 chapters describing all aspects of operations and management of the Matual Sanitary Landfill. Chapter 1 introduces the waste stabilization processes, landfill levels, scope and limitations of the manual. The organizational structure of staff needed for the Matuail landfill is presented in Chapter 2. Chapter 3 describes the landfill facilities and Chapter 4 discusses the operation and management of the Matuail landfill. Environmental management and emergency management are described the Chapter 5 and Chapater 6 respectively. Finally Chapter 7 presents the post closure plan of the landfill.

Chapter 2

ORGANIZATIONAL STRUCTURE

2.1 Organizational Structure

The Dhaka City Corporation (DCC) staff will be required for the management of landfill operations at Matuail site. The proposed organizational structure of the DCC staff is shown in Fig. 2.1. Moreover, contractor will be required for construction works such as supplying of final cover materials, construction and maintenance of temporary roads and platforms, temporary drainage including special operations in the landfill. Security of the landfill site, machineries, equipment and facilities is to be ensured by hired personnel preferably Ansars numbering 20 persons working in three shifts.

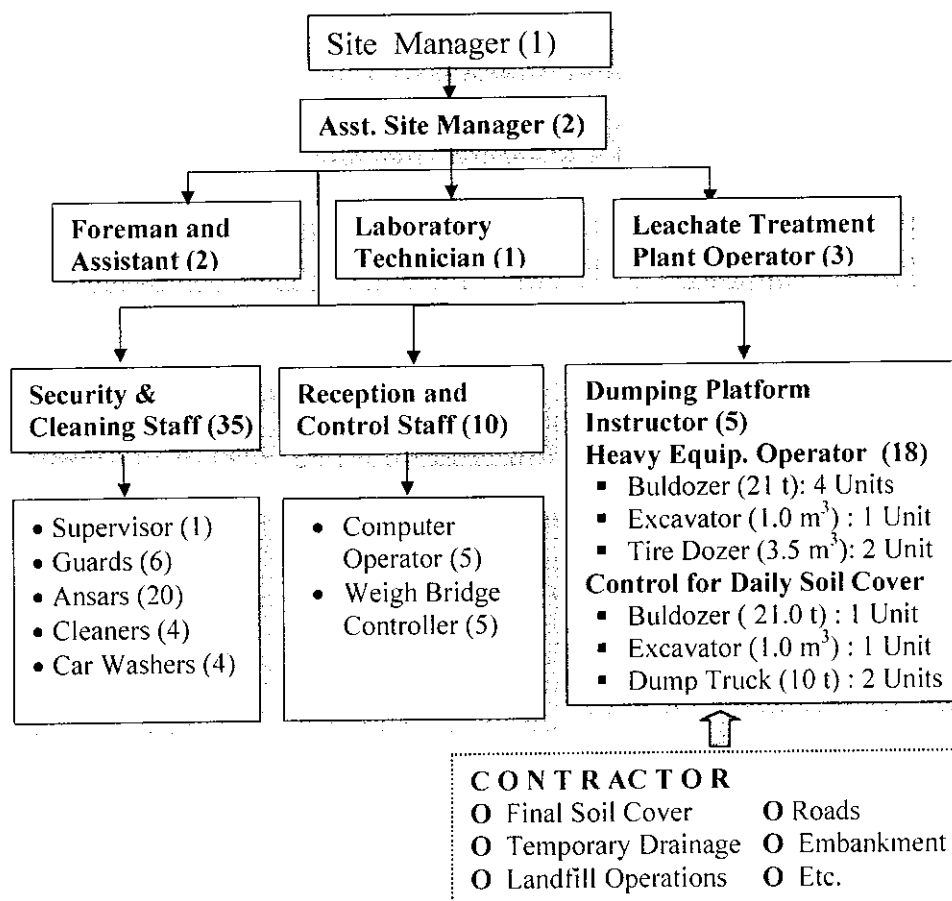


Figure 2.1 : Organizational Structure for Landfill Operation.

3.2 Responsibilities of Permanent Site Staff

Permanent staff engaged by the DCC shall operate the sanitary landfill site. The staff shall operate under the direct instructions of the Site Manager. Two Assistant Site Managers will help the manager to operational activities as instructed by the Site Manager.

The minimum required staffing and their duties and responsibilities are outlined as follows:

- (1) Site Manager (1 person)
 - Manage the landfill staff
 - Prepare the operational plan and supervise its implementation
 - Prepare the budget and review the expenditures
 - Manage the leachate aeration and re-circulation system and leachate pond.
 - Report to Waste Management Division (WMD) of DCC
- (2) Asst. Site Manager (2 shifts x 1 person)
 - Develop the disposal plan and supervise the preparation of waste cells
 - Maintain the operations expenditures accounts
 - Maintain the daily operation records
 - Others as directed by the Site Manager
 - Report to the Site Manager
- (3) Foreman (1 person)
 - Daily inspection of heavy equipment, aerators and pumps and maintain the maintenance records
 - Carry out simple repair and maintenance works
 - Maintain sufficient spare parts on site for simple repairs
 - Maintain records of heavy repairs and maintenance works carried out on equipment
 - Others as directed by the Site Manager or Assistant Site Managers
 - Report to the Asst. Site Manager
 - Ensure stock of consumables for maintenance works
- (4) Assistant to Foreman (1 person)
 - Help the foreman in repairing and maintaining equipment
 - Report to the foreman
- (5) Laboratory Operator (1 person)
 - Maintenance of laboratory equipment
 - Conduct sampling and testing of leachate, surface and ground water and air quality
 - Maintenance of record of all laboratory analysis
 - Report to the Asst. Site Manager

- (6) Leachate Treatment Operator (3 shift x 1 person)
 - Operation of treatment plant as per instruction manual
 - Observe functioning of the plat equipment
 - Report malfunctioning of the equipment to the Asst. Site Manager
 - Carry out simple maintenance and repair works
- (7) Computer Operators (2 shifts x 2persons + 1 shift x 1 person)
 - Collect information regarding trips of dump trucks and trailers and their loads
 - Maintain a daily record of the incoming waste
 - Random check of incoming waste
 - Others as directed by Site Manager or Assistant Site Manager
- (8) Weigh Bridge Operator (2 shifts x 2persons + 1 shift x 1 person)
 - Direct only dump trucks to weigh Bridge
 - Assist computer operators in collecting information regarding the trips of dump trucks and trailers
 - Random check of incoming waste
 - Direct truck and trailers carrying unacceptable toxic, hazardous and infectious wastes
 - Others as directed by Site Manager or Assistant Site Manager
- (9) Dumping Platform Instructor (2 platforms x 2shifts x 1 person + 1 Platform x 1 shift x 1 person)
 - Direct the waste trucks to the disposal cell
 - Manage the heavy equipment operations
 - Direct daily soil cover application
 - Spraying of insecticides and odor suppressants
 - Preparation of new waste disposal cell
 - Others as directed by the Site Manager or Assistant Site Manager
- (10) Heavy Equipment Operators (2 shifts x 7 Operators + 1 shift x 4 Operators)
 - Operation of the heavy equipment under the direction of the Dumping Platform Instructors
 - Daily inspection of heavy equipment
 - Assist in simple repair and maintenance works
 - Others as directed by the Site Manager, Assistant Manager or Dumping Platform Operators.
- (11) Temporary Roads and Platform construction and Maintenance and applying Soil Cover (4 Operators x 1 shift)
 - Construction and maintenance of temporary roads and platform as instructed by Asst Managers and Platform Instructors
 - Operation of heavy equipment for applying daily soil cover
 - Others as directed by Site Manager or Assistant Site Managers and platform Instructors.

- (12) Supervisor (1 shift x 1 Supervisor)
- Supervise the works of the Ansars, Guards, Cleaning Staff and Car Washers.
 - Others as directed by Site Manager or Assistant Site Manager
- (13) Guards (3 shifts x 2persons)
- Landfill access control
 - Protection of landfill facilities and equipment
 - Others as directed by Site Manager or Assistant Manager
- (14) Security and Cleaning Staff (34 persons)
- Ansars (2 shift x 7 persons + 1 shift x 6 persons) to provide security of the whole landfill site, machinery, equipment etc. They will be employed on contract basis.
 - Cleaning staff (1 shift x 4) to clean the roads, drains and leachate collection pipes, manholes etc.
 - Car washers (2 shift x 2) to wash the vehicles leaving the landfill site after duming solid wastes

Chapter 3

THE LANDFILL FACILITIES

3.1 The Facilities

The purpose of this chapter is to acquaint the Operators with the facilities available at the landfill site and their specific functions in the operation of the landfill. The facilities available at the landfill site may be classified into three categories as shown in Table 3.1. Some important landfill facilities at Matuail landfill site are shown in Figure 3.1.

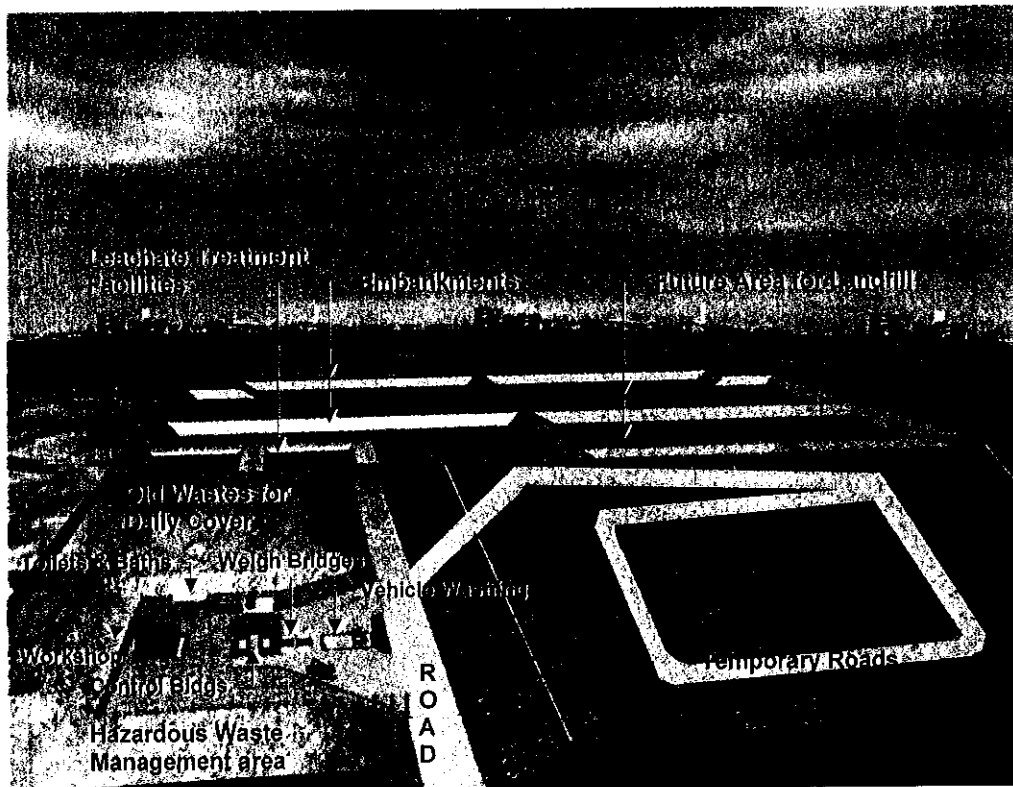


Fig. 3.1 : Some Important Facilities at Matuail Landfill site.

Table 3.1: The facilities installed at Matuail Landfill site

Administrative/operational Facilities	Main Facilities/Structures	Support Facilities
<ul style="list-style-type: none"> ▪ Administrative Building/ Control Office ▪ Truck Scale/ Weigh Bridge ▪ Workshop ▪ Vehicle Washing ▪ Monitoring/ Recording 	<ul style="list-style-type: none"> ▪ Landfill Areas ▪ Working Roads ▪ Embankments ▪ Rainwater Drainage System ▪ Leachate Collection/ Air venting system ▪ Gas Venting System ▪ Leachate Pond and Treatment Facilities ▪ Leachate Recirculation and Effluent Disposal Facilities ▪ Soil Cover 	<ul style="list-style-type: none"> ▪ Water supply & Sanitation ▪ Electrical Sub-station ▪ Lighting System ▪ Gate & Fences ▪ Groundwater Monitoring Wells ▪ Security Barrack

3.2 Purpose/Function and Structures

3.2.1 Administrative/Operational Facilities

The facilities, description of purpose/functions of facilities and structures of administrative/operational facilities are summarized in Table 3.2.

Table 3.2 : Purpose/function of Administrative/Operational facilities

Facilities	Purpose/Function	Structures
Administrative/ Control Office Building	It houses the site offices that control landfill operations. It has rooms for Managers, control staff and guards. A meeting room is also available in the Building.	A building constructed with Polyurethane panels on RCC floor to house the offices and facilities for weighbridge operation including collection and storing of information in computer.
Truck Scale/ Weighing Bridge	Collection of information regarding number of trips & quantity of waste transported.	Weighbridge connected to automatic recording of weight of the dump tracks. Only number of trip is recorded for trailers.
Workshop	Minor repair of all heavy equipment and vehicles.	A building with basic workshop facilities.
Vehicle Washing	Washing of tires and body of vehicles while leaving the landfill after disposing of waste load and a final wash after each day/night of operation.	A car wash pool for washing 4 vehicles at a time with facilities for high pressure washing machine.
Monitoring/Recording	Monitoring the type and quantity of waste transported and accurately recording of information.	Weighbridge, auto-recording in computer side road and provisions for inspection of wastes transported.

3.2.2 Main Facilities

The description of purpose and structures of main facilities of the Matuail Landfill site is summarized in Table 3.3. Some of the main facilities of the Matuail landfill site that are shown in Fig. 3.1. Some additional facilities like boundary drainage and semi-aerobic system consisting of leachate collection and gas venting pipe network underneath the waste dump are shown in Fig. 3.2. The figure also shows temporary roads, permanent roads, Leachate treatment ponds etc.

Table 3.3 : Purpose/function of Main Facilities

Facilities	Function	Structure
Landfill Areas	Disposal of solid wastes for stabilization by semi-aerobic process, leachate collection and gas venting facilities	The landfill areas have been divided into working area, reserve landfill area for future operation, old waste areas for systematic operation of the landfill
Rain Water Drainage Facility	Quick drainage of rainwater after rainfall to prevent drainage congestion of road and to reduce leachate volume by preventing infiltration of rainwater into the waste	Open drains and storm sewerage system constructed around the sides of roads and at the toe of the waste heaps for quick drainage of the water accumulated from road and waste surfaces. Combination of saucer drains and covered pipe drains for drainage of side slopes and top surface when covered by soil.
Leachate Collection Facility	A leachate collection cum ventilation system (Semi-aerobic system) comprising of a network of perforated pipe embeded in gravel pack has been constructed in the landfill. Additional leachate collection facility has been installed at the boundary of the landfill.	Main pipe: Installation of perforated PVC pipes of 400 mm dia. surrounded by gravel. Branch pipe: Installation of perforated PVC pipes of 200mm dia. surrounded by gravel. PVC pipes of varying size with manhole at 30m interval have installed at the periphery of the landfill
Leachate Treatment Facility	The leachate treatment system by aerated lagoon method has been installed for reduction of pollution load of the leachate to acceptable level.	Leachate treatment system is composed of aerated lagoons and sedimentation chamber set in two ponds. The capacity of 1st pond is 5,000m ³ and the capacity of second pond is 7,400 m ³ . Both the ponds have networks of pipes with air difusers.

Leachate and sludge Re-circulation Facility	This facility will re-circulate leachate back to disposal site, when necessary for providing further treatment of leachate under anaerobic conditions. The biological sludge from the sedimentation chambers will also be pumped on the landfill.	Installation of re-circulation pump of capacity 0.5m ³ /min. and portable flexible hose pipes (80mm dia.).
Gas Venting Facility	In order to prevent fire and/or explosion hazards, impact on ecological system, and offensive odor to surrounding areas, gas venting facilities have been installed.	The system consists of perforated PVC pipes of dia. 200mm surrounded by crushed stone and installed vertically at around 50m spacing.
Road and Platform	The roads are constructed for the operation and maintenance of the landfill site. Both permanent and temporary platforms have been constructed for efficient disposal of solid waste in the landfill	7.5 m wide permanent reinforced concrete roads and brick roads have been constructed for movement of vehicles and 12m wide temporary road (working road) made of construction debris (gravel paved) has been constructed on landfill to facilitate disposal of waste. Permanent platforms made of RCC and temporary platforms of construction debris are constructed for solid waste disposal.
Daily and Final Soil Cover	The soil cover prevents spreading of bad odors, scattering of waste, and breeding of vectors and harmful insects. It would also prevent catching and spreading of fires on the site. In addition, it would provide good appearance for the neighborhood. It will prevent rainwater infiltration into the bottom layers of the landfill site and thus make the leachate volume reduced.	<u>Daily cover</u> Material : Inorganic debris and/or old stabilized waste available at the site, Thickness:15-20cm (old waste) 30-50cm (construction debris) <u>Final cover:</u> Material :Natural soil. Thickness: 50cm or more

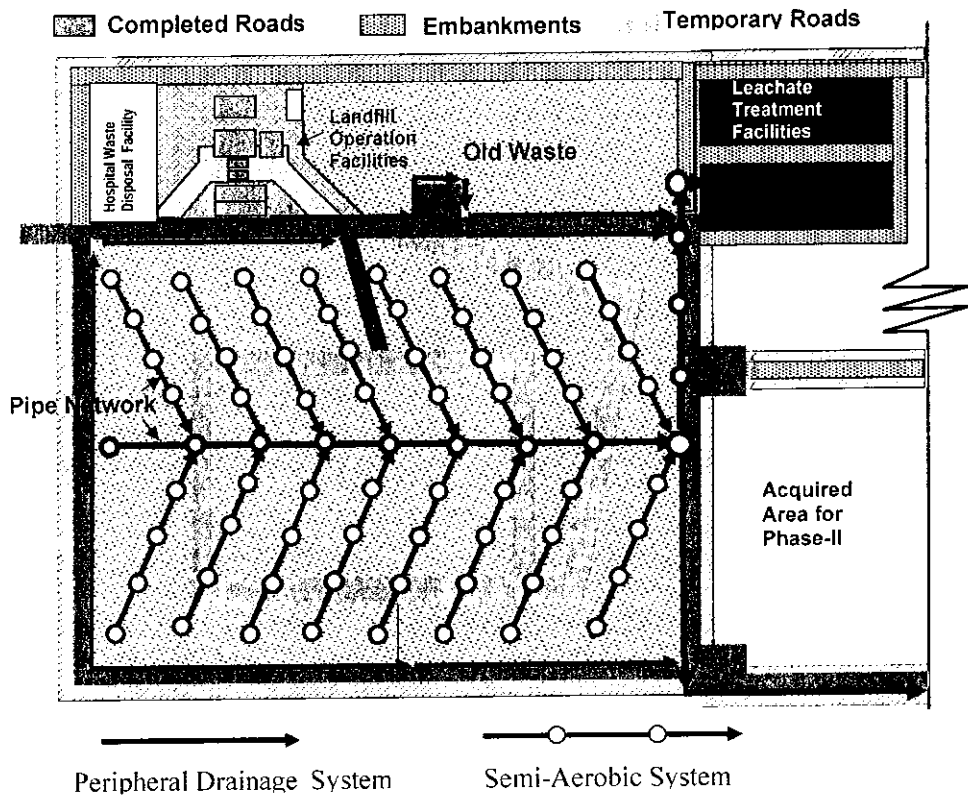


Fig. 3.2 : Boundary Drainage and Semi-aerobic system at Matuali Existing Landfill

3.2.3 Support Facilities

The description of purpose and structures of support facilities of the Matuail Lanfdill site is presented in Table 3.4.

Table 3.4 : Purpose/function of Support facilities

Facilities	Function	Structure
Water Supply and Sanitation	Water supply is provided for drinking, cooking, car washing, bathing and for sanitation facilities for the people working in the landfill areas.	A deep tubewell, an underground water reservoir, roof water tanks, toilets in administrative building and separate toilet units have been constructed.
Electrical Sub-station	The sub-station houses HT switch gear and a stand by 300 kVA 3-phase AC generator	A one-storey building has been constructed adjacent to administrative building to accommodate all electrical components.
Lighting	To facilitate operation of landfill at night	Four light masts have been constructed at four corners of the present operation areas and flood lights are installed on the masts as per requirement.
Gates and Fences	Provide security and prevention of entry of unauthorized persons in the landfill	One gate for the entry in the landfill. Barbed wire fencing around the landfill.
Security	Provide constant vigilance to protect all the facilities installed at Matuail Landfill site and prevent entry of unauthorized persons	Security Barrack has been constructed with kitchen and toilet facilities in the control area. Four sentry boxes have also been installed.

3.3 Inspection and Maintenance of Facilities

3.3.1 Introduction

Inspection and maintenance of all the facilities should be carried out at regular intervals for keeping the facilities functional. If all the facilities function properly, the objectives of environmentally sound solid waste disposal at the final disposal site will be achieved. On the other hand, non-functioning of the facilities will disrupt disposal of solid waste and pose a threat to the surrounding environment. Thus, inspection of the facilities is very important for uninterrupted operation of the landfill site. The facilities that need close inspection, maintenance and supervision include:

- 1) Leachate Collection Facilities
- 2) Rainwater Drainage Facility
- 3) Gas Removal Facility
- 4) Leachate Ponds
- 5) Leachate Treatment Facility
- 6) Road and Platforms
- 7) Monitoring Facilities
- 8) Administrative/Operational Facility
- 9) Other Related Facilities

3.3.2 Leachate Collection Facilities

Leachate collection cum ventilation pipes have been laid under the deposited waste at about 5m above the road level. Leachate collection pipes are also laid around the boundary of the landfill adjacent to the open drains. Inspection and repair of items for leachate collection facility are mentioned below:

- a) There is a possibility of breaking/rupture and settlement of leachate collection pipes if the heavy equipments run directly over them. So, the heavy equipments should move over them only after covering the pipes by wastes of adequate thickness. When the surrounding area of the leachate collection pipes will be filled, land filling work should be done carefully to avoid damage to the pipes.
- b) Functioning of leachate collection pipes should be checked periodically. The extreme ends projected outside the landfill shall remain open for the entry of air. Any obstruction to air flow should be removed.
- c) The discharge end of the pipe network under the landfill shall not be submerged under any condition. There shall always be a free discharge so that air can enter into the pipes through upper empty space of the pipe.
- d) The flow of leachate collection pipe around the landfill should be checked through opening the manhole and any obstruction should be cleaned by rodding.
- e) If any damage of leachate pipes would be found, it should be repaired.

Inspection methods of leachate collection pipe are shown in Table 3.5.

Table 3.5: Inspection method of leachate collection pipe.

Items	Method	Frequency
Leachate Collection Pipes at the Boundary	Inspect through manholes whether there is free flow through the pipes	Once a week
	Condition of system should be observed after heavy rainfall	Just after cessation of the heavy rainfall.
Main Leachate Collection Pipe Network	Inspect visually whether there is any abnormal depression.	Once a month

3.3.3 Rainwater Drainage Facility

Open drains and storm sewerage system have been constructed around the landfill for efficient drainage of rainwater. Inspection and maintenance of items for the rainwater drainage facility are mentioned below:

- a) To prevent blockage and maintain the functioning of the facilities, periodic cleaning of drains is needed. The side openings of the drains are to be kept open all time for entry of surface runoff.

- b) The drains are to be checked for any damage, crack, collapse and settlement and necessary repair and reconstruction works should be carried out without delay.

For proper functioning of the rainwater drainage system, following cleaning activities should be carried out once a week.

- a) Removal of waste and sand deposited in open rectangular drains, collection pit; connecting pit, etc.
- b) Removal of weeds and leveling of the ground around the saucer drains and gutters;
- c) Immediate cleaning of refuge accidentally dropped form loaded vehicle or collapse of side slopes into the drains
- d) The flow of storm water through the sewers should be checked by opening the manholes and any deposition should be removed.

Inspection methods of rainwater drainage facility are shown in Table 3.6

Table 3.6: Inspection of rainwater drainage facility

Items	Method	Frequency
Main Drains	Visual inspection of debris, plastic bags, papers or any litters in the drains	Once in every day
Saucer Drains and Gutters	Conduct visual inspection to check for the presence of damages on U-type gutter, collection pit, etc.	Once a week
Storm Sewers	Inspect through the manholes whether there is free flow through the sewer	Once a week

3.3.4 Gas Removal Facility

The gas vent pipes surrounded by gravel pack are extended above the landfill level at regular intervals. These are subject to damage by random movement of waste moving/spreading and compacting vehicles/equipment. Inspection and maintenance of the items of gas removal facility are mentioned below:

- a) If the heavy equipment hit the gas vent pipes, the gas vent pipes would be damaged. During the land filling works at the surrounding area of the gas vent pipes, land filling work must be done very carefully without hitting the pipes.
- b) Verticality of the gas vent should be ensured for its proper functioning. The landfill heavy equipment either should not operate too close to the vent pipes or operate in such a mode not to apply excessive pressure on one side of the pipes.
- c) Functions of gas vent pipes should be checked periodically and give effort so that open ends of the pipes remain free from obstruction. Dropping of anything through the open end is strictly prohibited.
- d) If any damage of gas vent pipes is found, it should be repaired immediately.

- e) Condition of gravel jacket surrounding the gas vent pipes should be checked after rainfall.

The inspection methods of gas removal facilities are shown in Table 3.7

Table 3.7: Inspection methods of gas removal facilities

Items	Method	Frequency
Active waste disposal cells/ areas surrounding gas removal pipes	Inspect damages of pipes etc. by visual observation.	Once a day
The venting system in the whole land fill site	Inspect damages etc. by watching.	Once a month

3.3.5 Leachate Ponds

Inspection and repair of items of leachate ponds are as mentioned below:

- a) Visually observe the stability of the bottoms and bank slope of the leachate ponds (lagoons).
- b) The damage of the leachate ponds, damage and displacement of concrete slabs on slopes, and the bottom slab should be inspected.
- c) Inspection of cracks and pot holes on embankment.
- d) Any damages found in the leachate pond and leachate treatment facilities should be repaired immediately.

To maintain the functions of the leachate ponds, the bed of the leachate pond should be cleaned up once a year.

Inspection methods of the leachate pond are shown in Table 3.8.

Table 3.8: Inspection methods of leachate pond.

Items	Method	Frequency
Embankments	Cracks, pot holes and subsidence of embankment around the leachate ponds	Once a day
Integrity of the pond	Check the embankment, side slopes and bottom of the pond	Once in a week

3.3.6 Leachate Treatment Facility and Re-circulation Facility

The leachate treatment facilities include aeration of leachate in leachate lagoons, sedimentation of aerated leachate, recirculation of sludge and leachate in the landfill as and when required. The items of inspection of the Leachate Treatment Facility and Re-circulation Facility are described below:

- a) Functioning of the leachate distributors, collectors, air pump, air distribution pipe network, diffusers etc.
- b) Periodical inspection of facilities should be carried out to prevent the possible accident and adverse effect on environment because of the damages of the facilities.
- c) Any damage of the facilities should be repaired immediately.

Inspection methods of the Leachate Treatment Facility and Re-circulation Facility are as shown in Table 3.9.

Table 3.9: Inspection methods of Leachate Treatment Facility and Re-circulation Facility

Items	Method	Frequency
Aeration and Re-circulation Facilities	Check operation condition of the leachate treatment facility (aeration pipe network, diffusers etc.), re-circulation facility (pipes and pump).	Constantly
Mechanical equipment	In case of blower, pump and other mechanical equipment, there shall be daily maintenance checks for oil and lubricants.	Once a day
do	Conduct visual inspection to check for any problems in parts, nut loose, deformation of construction materials, and damages etc.	Once a week

3.3.7 Road and Platform Facility

Items of inspection of the road and platform facility are mentioned below:

- a) To secure safe and smooth transport, as well as to prevent any adverse effect on the surrounding environment, cleaning and maintenance of the roads should be carried out periodically.
- b) To prevent interruption of the waste transportation and disposal caused by road and platform damages, periodic inspection should be carried out for early detection of the trouble.
- c) Inspection of working condition of the temporary road and platform is required at all weather condition for uninterrupted operation of the landfill. Special attention is to be given during the rainy season because of the high vulnerability of these facilities in the wet season.
- d) If any damages are found, it should be repaired immediately.

To ensure the smooth traffic and minimum impact on the surrounding environment, following activities should be carried out.

- a) Cleaning up of the wastes and soil scattered on the road.
- b) Filling up of the depression on temporary roads and platforms caused by movement of vehicles/equipment.

Inspection methods of the roads are shown in Table 3.10.

Table 3.10 : Inspection methods of the roads and platforms.

Items	Methods	Frequency
Permanent roads and platforms	Check by watching for the presence of pot holes, settlement, rut, cracks or sign of damage or deterioration of the permanent roads and platforms	Once a week
Temporary roads and platforms	Depression, damage, water logging, pot holes, sign of deterioration.	Daily

3.3.8 Monitoring Facilities

Periodical inspection of monitoring facilities established in the landfill area should be carried out to find damages by subsidence or human intervention. Inspection methods of ground water observation well and other facilities are mentioned in Table 3.11

Table 3.11: Inspection methods of the ground water observation well

Items	Method	Frequency
Monitoring wells	Check by watching whether there are damages of the well, well head, caps etc of the monitoring well.	Once in two weeks
Others	Periodic inspection of other facilities such as air sampling pump, gas detection equipment, wastewater analysis equipment and kits.	Once in two weeks

3.3.9 Administrative/Operational Facilities

Supervision items of the administrative/operational facilities are mentioned below:

- a) To prevent damages and maintain the functioning of the equipment and facilities, maintenance and improvement of the equipments should be done periodically.
- b) In case of any damage, it should be repaired immediately.

To prevent the damages and maintain the functioning of the facilities, following cleaning activities should be carried out daily.

- a) Cleaning of the areas surrounding the truck scale
- b) Cleaning of the areas surrounding the transport control facility
- c) Cleaning and regular drainage of vehicle wash pool
- d) Cleaning of the administration offices.
- e) Cleaning of the workshop areas

The inspection methods of the truck scale are shown in Table 3.12

Table 3.12: Inspection methods of the truck scale

Items	Method	Frequency
Track Scale/ Weigh Bridge	Check the operation condition of the load cell, computers etc	Once a day
-do-	Conduct visual inspection to check for abnormality of parts, nut loose, deformation/ damage of construction materials, etc.	Once a week

3.3.10 Other Related Facilities

Supervision items of the other relevant facilities are mentioned below:

- a) Periodical inspection of the facilities should be carried out to prevent the possible accident and impact on environment because of damages of the facilities.
- b) Functioning of flood lights mounting on the towers and the light posts.
- c) Fencing around the site
- d) Electrical sub-station
- e) If any damages or non-functional items are found at the site that shall be repaired or replaced.

To prevent from damages and maintain functioning of the facilities, following cleaning activities should be carried.

- a) Discharging of polluted water of the car wash pool daily.
- b) Cleaning mud of the car wash facility once a week
- c) Cleaning of gate, fences, etc. once a week and painting those once in a year.
- d) Cleaning of toilet and bath rooms daily and as and when required.
- e) Cleaning of control areas daily.

Inspection methods of the other relevant facilities are shown in Table 3.13

Table 3.13: Inspection methods of the relevant facilities.

Items	Method	Frequency
All related facilities	Check by watching, whether there is any damage of the facilities.	Once a week

Chapter 4

LANDFILL OPERATIONS AND MANAGEMENT

4.1 Introduction

The main roles of landfill sites are to receive waste, place the waste in systematically arranged cells, protect the environment, and stabilize the waste and return the waste to the soil. Landfill sites should be managed and operated in a sound manner to fulfill these roles. It is, therefore, vital to have intimate knowledge of the available facilities in the landfill sites including their structures, objectives and functions. Knowledge of dumping track control, disposal operations, environmental management, emergency management and post closure operations is also essential for proper management of landfill sites. The major activities of landfill operations and management have been described under the following broad sections:

- (1) Vehicle Operations : Control of incoming and leaving vehicles (Chapter 4)
- (2) Disposal Operations: Control of dumping, compaction and daily cover (Chapter 4)
- (3) Landfill facilities : Operation and maintenance of landfill facilities (Chapter 3)
- (4) Environmental Management : Control of environmental pollution (Chapter 5)
- (5) Emergency Management : Management under adverse conditions (Chapter 6)
- (6) Post-closure Management : Management after closure of the landfill (Chapter 7)

4.2 Vehicle Operations

4.2.1 Traffic Flow

Systematic movement of waste dump trucks, trailers and heavy equipment engaged in disposal operations within the landfill is required for uninterrupted operation of the landfill. The systematic flow of traffic in a definite route is also important for efficient operation of the landfill. The traffic flow in the landfill site is shown in Figure 4.1.

The incoming vehicles will follow the specified route via weighing bridge and discharge the waste load in a definite location demarcated by the platform supervisors. The outgoing vehicles will leave the landfill site via vehicle washing facility and leave the landfill site. The landfill heavy equipment will then push the waste to the final disposal area and compact it. The final cover by soil or stabilized old will be made after a day's work is over.

The site manager may change these conditions in order to improve the operation or meet unforeseen circumstances. In such case the modified information should be made available to all landfill operating staff.

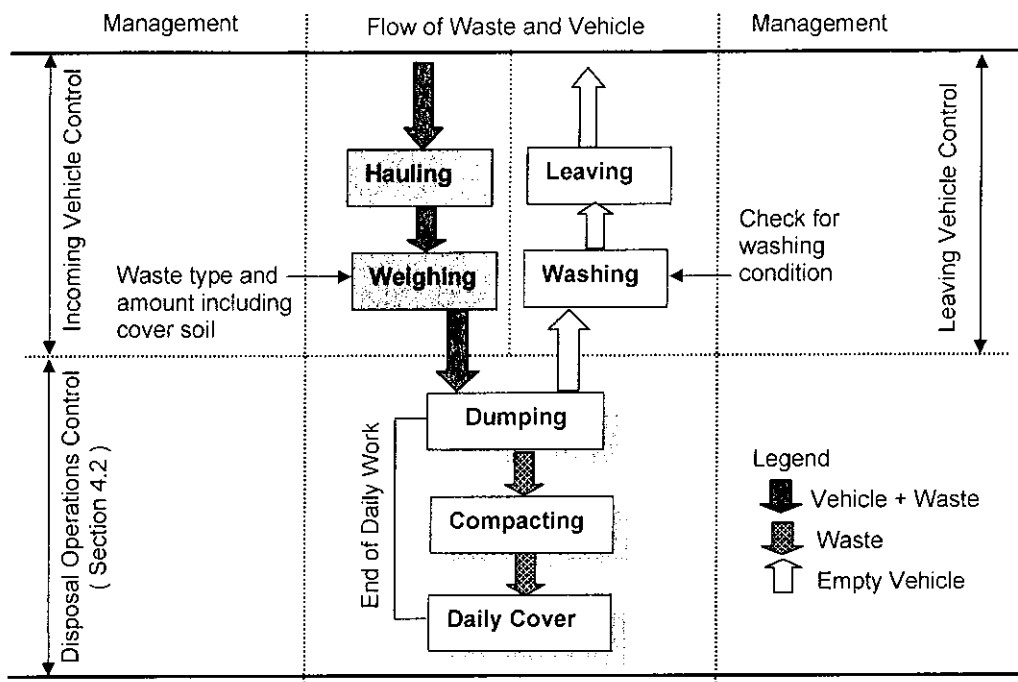


Fig. 4.1 : Traffic Flow in the landfill site

4.2.2 Weigh Bridge Operation

The weigh bridge operation will have two main functions:

- (1) Inspection of the vehicle at the point of entry to assess the suitability of its load for acceptance at the site, and
- (2) Recording of the quantity of waste and particulars of the vehicle and the trip.

Waste Inspection

The Matuail landfill shall accept all types of non-hazardous municipal solid waste types, including domestic and market wastes, road sweepings and sludges from cleaning of sewers. Hazardous waste, toxic wastes, infectious hospital waste, radioactive waste, liquid waste and other waste not considered as municipal waste shall not be accepted at the Matuail landfill site. The inspection of the incoming waste will be as follows:

- a) The weigh bridge operator may demand a visual inspection. In this case, the vehicle will be directed to a separate location for inspection, which may be just visual inspection or detailed inspection by dropping waste at designated location.
- b) Regardless of initial acceptance at the weighbridge, the waste may be rejected during unloading at the active cell, if it contains unacceptable materials. In this case the rejected waste will be reloaded in the vehicle and returned back from the landfill site.

- c) Should a vehicle not permitted to discharge its load at the landfill based on the above inspection, the vehicle number, driver's name, date and time of arrival and reasons for rejection shall be reported to the DCC.

Weigh Bridge Record

- a) A form shall be prepared for the purpose of storing information. It may be revised from time to time based on the requirements.
- b) A coding system shall be prepared for inputting the collected information into the computer
- c) The data to be recorded should be as follows:

Sl. No.	Data for Recording	Provider/ Recorder of data
1	Vehicle number	Weigh Bridge Operator
2	Weight of empty vehicle	Should be retrieved from computer, if recorded once against the vehicle number
3	Arrival time	Weighbridge Operator
4	Weight of the vehicle	Weighbridge Operator (automatically recorded if weighbridge output is connected to computer)
5	Trip origin	Driver (station's name for transfer haul, collection zone for direct haul)
6	Departure time	Weigh Bridge Operator

- d) The recorded data shall be given as input into the computer using the coded format for analysis on daily basis
- e) A computer program may be developed for the analysis of above information as per requirement.

4.2.3 Vehicle Washing

The body and wheels of the vehicles may be contaminated by the waste and leachate from the landfill. To avoid pollution of the roadways by the vehicles, the collection vehicles should be washed before leaving the landfill site. When a vehicle makes several trips during working period, the wheels of the vehicle needs washing while leaving the landfill but the body of the vehicle needs washing only after the final trip. The water used for washing vehicle may be considered as leachate depending on the level of contamination of the wash water. The wash water should pass through a skimming tank to trap oil and grease.

4.3 Disposal Operations

4.3.1 General

Landfills need proper operations to make best use of landfill capacity, stabilize waste, and to ensure sound management of leachate and landfill gases. It is also necessary to record landfill work description so that the data can be utilized as basic information to establish a post closure plan.

It is required to make a landfill plan and to dispose waste systematically according to the plan and record actual amount of haulage and disposal of wastes. Time and place of land filling should also be recorded to grasp the remaining landfill capacity. These data will also be utilized as basic information to determine the cause and measures in an emergency.

This landfill site is planned to be operated by the "cell construction method" as described in the following sections. The un-loaded wastes should be moved and placed by chain dozers and compacted sufficiently by the compacting equipment to form a waste cell. At the close of daily operation, soil/stabilized wastes should be placed over the waste to finish the cell.

4.3.2 Waste Unloading

Landfill staff will direct the vehicle drivers to the active waste disposal areas. The platform operators at the active fill areas will direct the vehicle to the appropriate disposal area along the working face as required. No vehicles will be permitted to un-load their waste at any location other than the area designated by the platform operators.

The operators will maintain control of the waste unloading within the active disposal area in order to minimize the width of the working face, and decrease the unloading and waiting times. The drivers may be instructed to un-load the waste in two or three different waste cells.

4.3.3 Landfill Work

(1) Landfill Method

The landfill method to be adopted shall be cell method. This method, as shown in Figure 4.1, is widely used as the landfill method of sanitary landfill systems now-a-days. This has a cell of solid waste covered with a layer of soil or stabilized waste. The size of each cell is determined by the amount of solid waste filled per day. Since each cell is thought to be an independent landfill area, it acts as a fire-breaker. Each cells with soil cover also prevents the waste from being scattered, the emission of bad odors and breeding of harmful vectors.

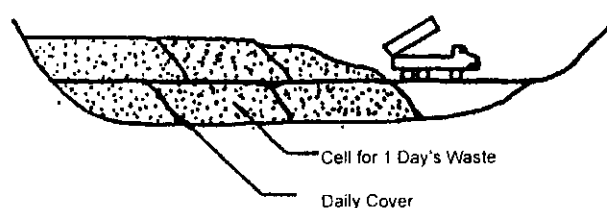


Figure 4.1: Waste Disposal by cell Method

(2) Cell Configuration

A cell shall be prepared to accommodate one day's waste. The cell area should not be too large to limit the leachate production. The cell shall have a height of 3 m and the waste shall be deposited in layers of around 30-50cm to allow for more uniform compaction. The width shall be sufficient to allow for 4-5 vehicles to discharge the waste at the same time (i.e. minimum 15 m).

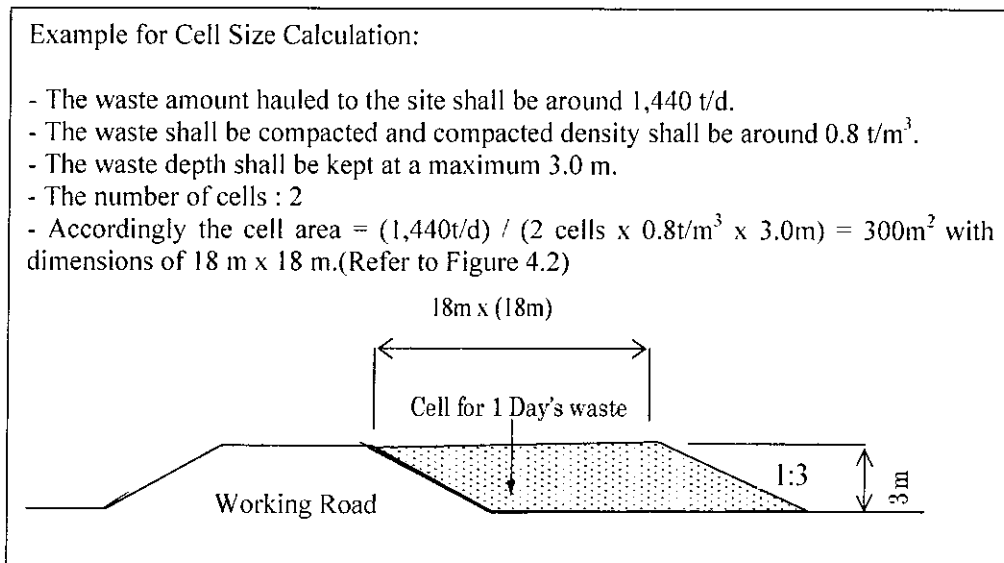


Figure 4.2 : Caulation of Cell Size

(3) Spreading and Compaction

The spreading and compaction of the solid waste dumped from the collection vehicles are done by "Push Down" or "Push Up" methods on a slope by a chain dozer as shown in Figure 4.3.



Figure 4.3 : Spreading/compaction by Push Down and Push Up method.

In the case of pushing the solid waste down the slope, it is difficult to spread the waste into a uniform thickness. The bottom part of the slope tends to be thicker. Mixing and compaction is also difficult. On the other hand, it is easier to make uniform landfill layers when pushed up on the slope. Compaction is easier in “*Push Up*” method.

Therefore, when the compaction has to be done quickly, the “*Push Up*” method is preferable. As the landfill will be soaked with leachate during the rainy season, “*Push up*” method will be difficult at that time. Therefore in the rainy season “*Push Down*” method will get preference over “*Push Up*” method.

The spreading and compaction of the solid waste delivered to the landfill site will influence largely the capacity of the landfill, stabilization of the landfill layer, post-closure land use, and environmental conservation. The method of the spreading and compaction of the solid waste to be adopted is mentioned below:

- In general, the “*Push Down*” method of the spreading and compaction shall be adopted when the platform /temporary road is higher while “*Push Up*” method will be adopted when the platform/temporary road shall be lower than the filling area.
- “*Push Down*” method shall be adopted during rainy season.
- Thickness of layers shall be about 30 to 50 cm.
- At the boundary of the waste cell a side slope of 1(vertical) to 3 (horizontal), about 18.5 degrees is to be maintained.
- The number of passes of the chain dozer shall be 3 to 5 for compaction of spreaded waste layer..

The typical operation of spreading and compaction by “*Push Up*” and “*Push Down*” methods are shown in Figures 4.4 and 4.5 respectively.

In the extended landfill both platform and roads will be used for the disposal of solid wastes. Particularly the dump trucks that can dispose off the waste standing parallel to the edge of the road can comfortably use the roads for disposal of wastes. The Trailers and tipping trucks will use the platforms constructed at the four corners of the new landfill site. The chain dozers will spread and compact the waste by push-down method upto the level of the embankments. Later both push-up and push-down method as appropriate can be adopted. A temporary road network will have to be established for climbing up of the dump trucks on the waste dump as its level becomes higher.

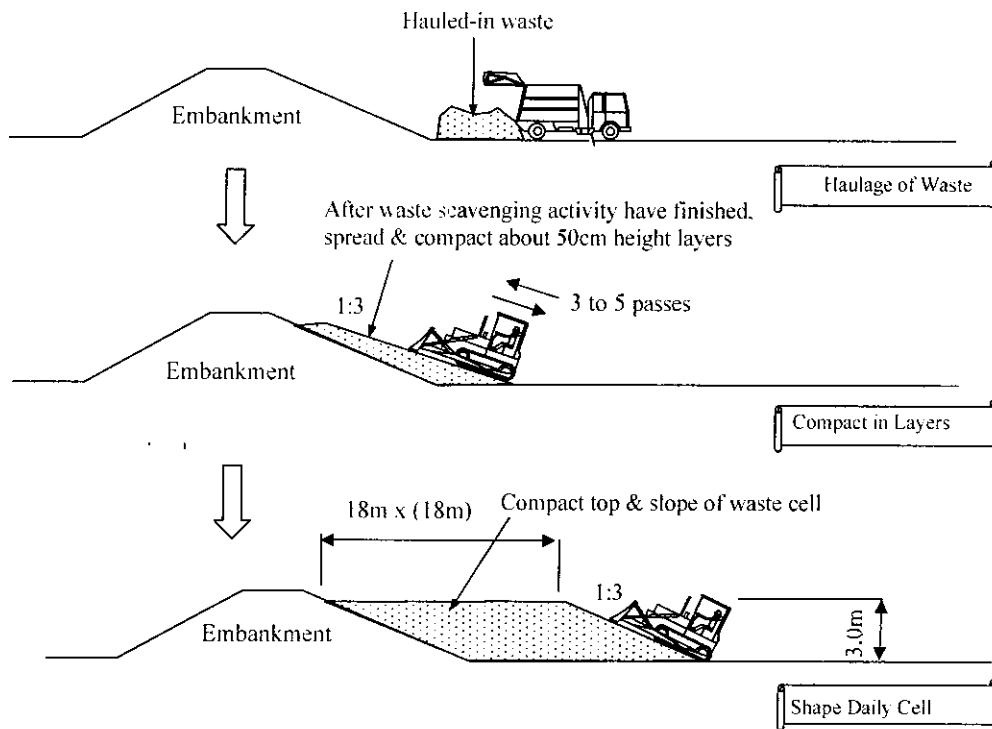


Figure 4.4 : Operation of Spreading and Compaction ("Push Up" Method)

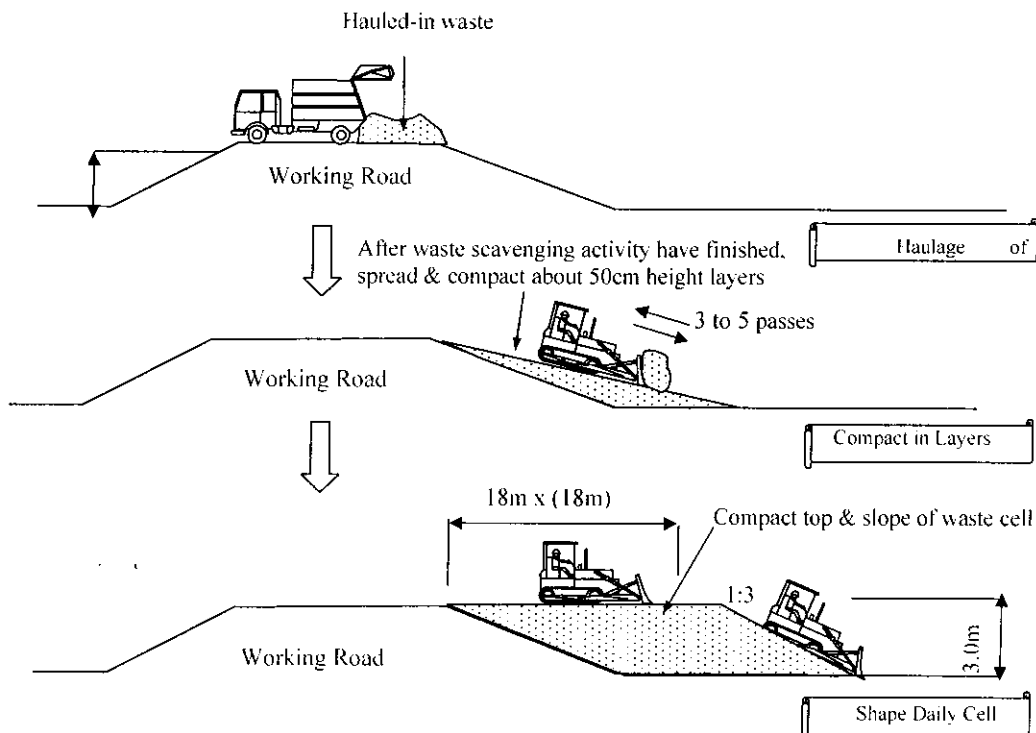


Figure 4.5 : Operation of Spreading and Compaction ("Push Down" Method)

7.4 Cover Soil

7.4.1 Effectiveness and Necessity of Cover Soil

In the sanitary landfill system, cover soil is indispensable for conservation of the surrounding environment. The cover soil would prevent spreading of bad odors, scattering of waste, and breeding of vectors and harmful insects. It would also prevent catching and spreading of fires on the site. In addition, it would provide good appearance for the neighborhood. Further, from an operation and management point of view, it would allow easy solid waste spreading and compaction work, and prevent rainwater from seeping into the inner layers of the landfill site and thus the leachate volume is reduced.

7.4.2 Type of Cover Soil

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

1) Daily Cover Soil

When the landfill layer reaches the thickness as specified in the design document, or when a one-day portion of the landfill work is completed, soil cover should be provided on the layer. The purposes of the daily cover soil are the following:

- To prevent the scattering of waste;
- To control bad odors; and
- To stop the breeding of harmful vectors like flies.

In case of non-availability of soil, old stabilized solid waste, dirt and construction debris can be used as daily cover instead of soil.

2) Final Cover Soil

The landfill has been designed as a multi-stage landfill of about 5m stage height. Final cover should be applied as the side slope of a stage progresses. Eventually, when all the landfill work is finished, final cover soil should be placed on top of the last layer. The purposes of the final cover soil are the following:

- To provide good appearance for the neighborhood;
- To enhance usability of the post-closure land;
- To reduce leachate volume; and
- To promote growth of vegetation on the slope, berm and top surfaces.

7.4.3 Selection of Cover Soil

1) Daily Cover Soil

Construction debris and old stabilized waste in the site are to be used as daily cover soil. Old waste to be used as daily cover soil should be 3 or more years old. Construction debris shall be pieces of brick, broken concrete, plaster and excavated soil from construction site. They should be checked carefully for toxic substances.

2) Final Cover Soil

The final cover soil should be resistant to erosion by rainwater, of low permeability and suitable for plant and vegetation growth. Thus, a loam type of soil, which contains some humus, is recommended. When soil from other construction site are used, they should be checked carefully for toxic substances.

7.4.4 Determination of Thickness

The thickness of cover soil should be determined depending on the purpose of cover soil, composition, type and shape of solid waste to be covered, and the surrounding environmental condition. According to the type of cover soil, the thickness is generally set up as mentioned below.

1) Daily Cover Soil

- Debris : 30 to 50 cm
- Old waste at the site : 15 to 20 cm

2) Final Cover Soil

- Grass or low height plants and bushes are planted : more than 50 cm
- Medium height to tall trees are planted : more than 1.0 m

7.4.5 Operation and Maintenance of the Cover Soil

The cover soil should be spread uniformly and compacted by using appropriate type of landfill equipment, which would depend on the thickness, area and type of the cover soil.

In particular, it would take some time for the final cover soil on a slope to stabilize, and care must be taken to prevent this final layer from being eroded by rainwater. It is, therefore, recommended that the slope gradient should be about 15 degrees.

The typical operation of spreading and compaction is shown in Figures 4.6 and 4.7.

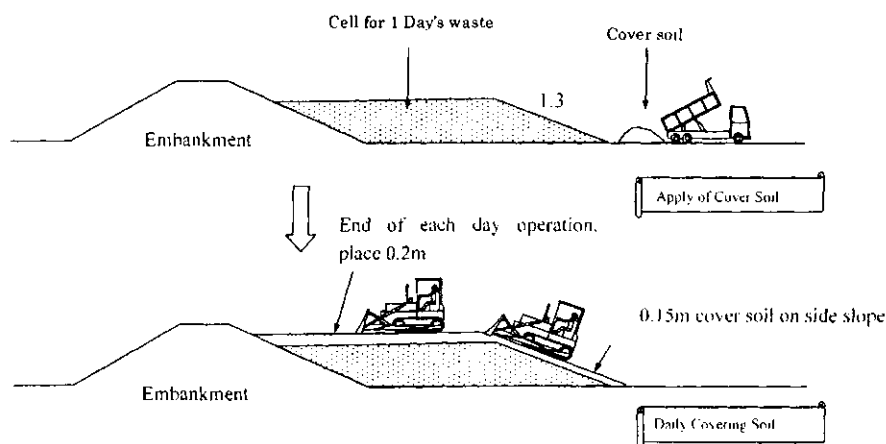


Figure 4.6 : Operation Procedure of daily covering soil (Push-up Method)

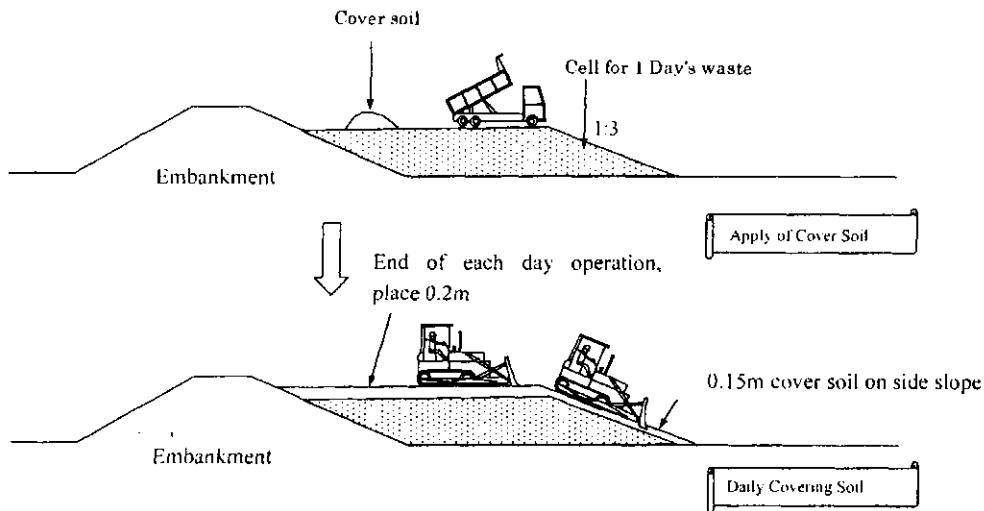


Figure 4.7 : Operation Procedure of daily covering soil (Push-down Method)

Maintenance of the cover soil is an integral part of the maintenance of post-closure landfill, besides leachate and gas treatment. The surface of the final cover soil will sink, crack and form pot holes due to decomposition and consolidation of the filled waste. This may result in percolation of rainwater, water logging, increase of leachate volume, leakage of gas, erosion of the cover soil, land slides and fires. A survey on subsidence of the post-closure landfill gave the following findings:

- The landfill site subsides deeper when combustible waste is disposed and shallower when incombustible waste, refuse such as construction debris, is disposed;
- The deeper the landfill the deeper the site subsides;
- The site subsidence continues for several years;

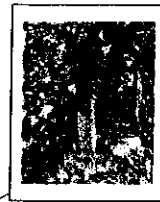
In particular, if the surface of the landfill area depresses or cracks, rainwater will seep into the inner layers via these areas. This will thus result in increasing the amount of estimated leachate volume. Additionally, these areas will also become points for gas release. Therefore, the surface of the final cover soil and condition of plants should be checked and maintained periodically.

7.4.6 Storage Area

Daily cover materials and final covering soil shall be temporarily kept in the brick paved area between the control building area and the hospital waste management facility area. These materials shall be brought to the landfill site as and when necessary. The old waste stocks available in the north-west of landfill shall be used for daily cover.

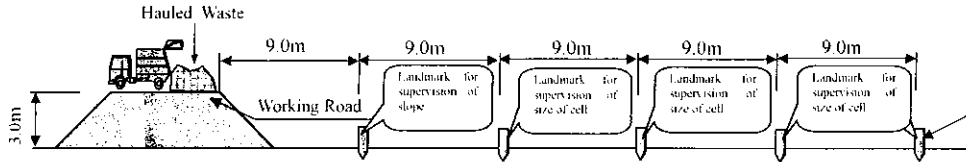
Landfill work and soil cover work shall be conducted by "Push Down" method as shown in Figure 4.8.

As push down method is more effective than push up method in case of land filling of the organic waste, **working road should be 3 meters high (refer to 6.9)**; and waste should be filled by pushing down from the working road. As mentioned earlier, size of each cell should be 18 meters in width, 18 meters in length and 3 meters in height. Waste filling should be done after establishing the landmark of the slope and the cell size as mentioned in the drawing below.



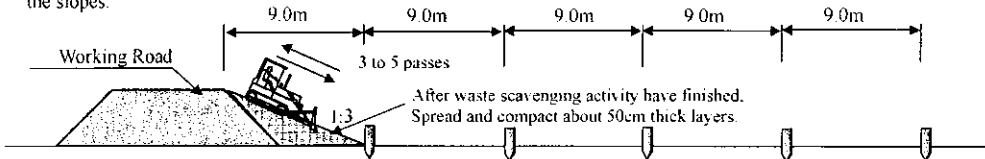
Landmark

1) Haulage of Waste



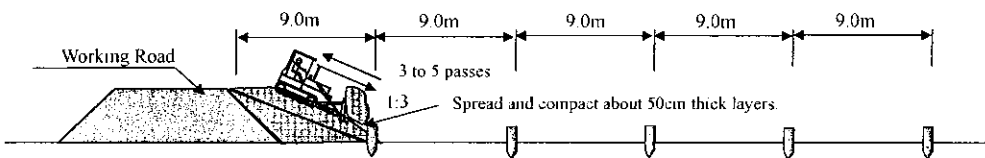
2) Build 1:3 slope for waste filling

Waste filling slope 1:3 would be secured using the landmark that established for the supervision of the waste filling of the slopes.



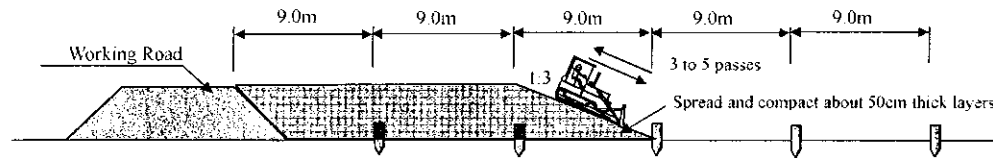
3) Spreading and Compaction of Waste

Waste should be filled maintaining 1:3 slope that build in no 2). For compaction thickness per layer should below 0.5 meter and compaction work should be sufficient.

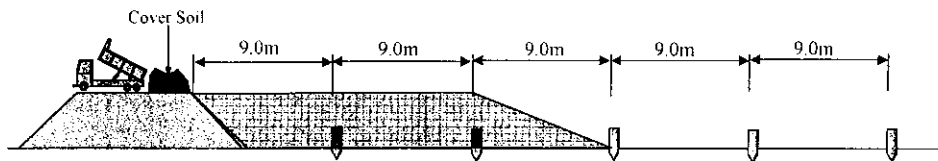


4) Secure the size of Cell

Using the landmark that established for the supervision of the size of the cell and repeating the activities that mentioned in no 3), cell for 1 day should be completed.

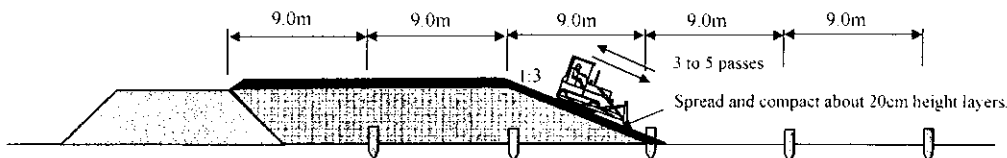


5) Apply of cover Soil

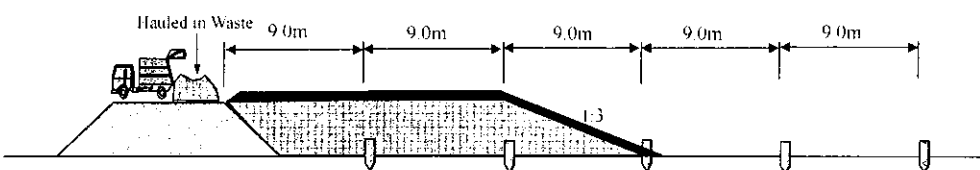


6) Providing Daily Soil Cover

Daily soil covering should be done after the activities that mentioned in no 5). Thickness of compaction of daily soil cover would be minimum 0.2 meter with proper compaction. After that operation for 1 day would be completed.



7) Haulage of Waste

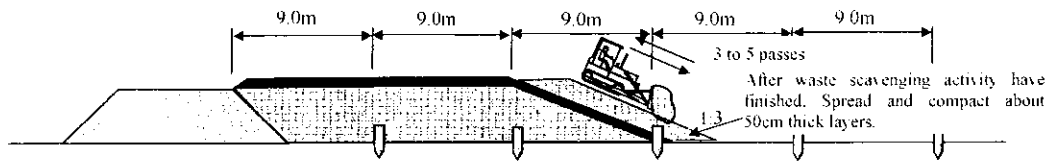


Construction of Cell for 1 Day's waste

Covering soil for 1st Cell

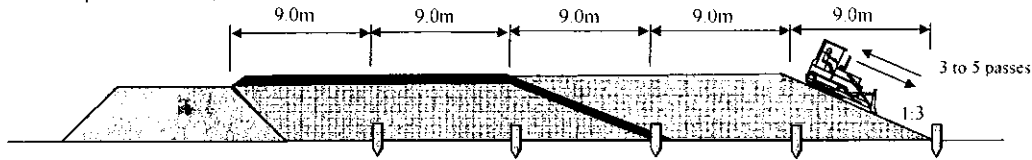
Figure 4.8 Operation Procedure of Controlled Landfill (1/2)

8) Spreading and Compaction of Waste
Same operation as no 3).

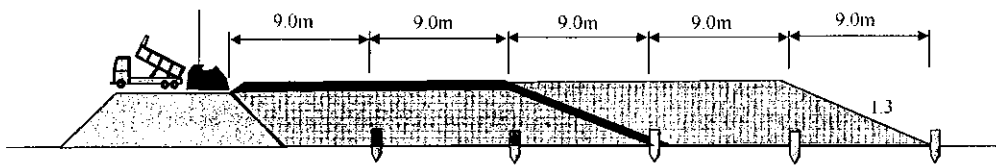


Construction of Cell for 2 Day's waste

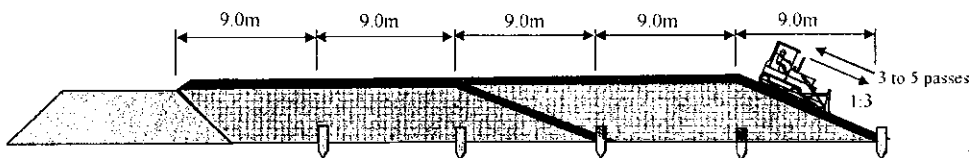
9) Secure the size of the Cell
Same operation as no 4).



10) Application of cover Soil
Cover soil



11) Providing Daily Soil Cover
Same operation as no 6).



Covering soil for 2nd Cell

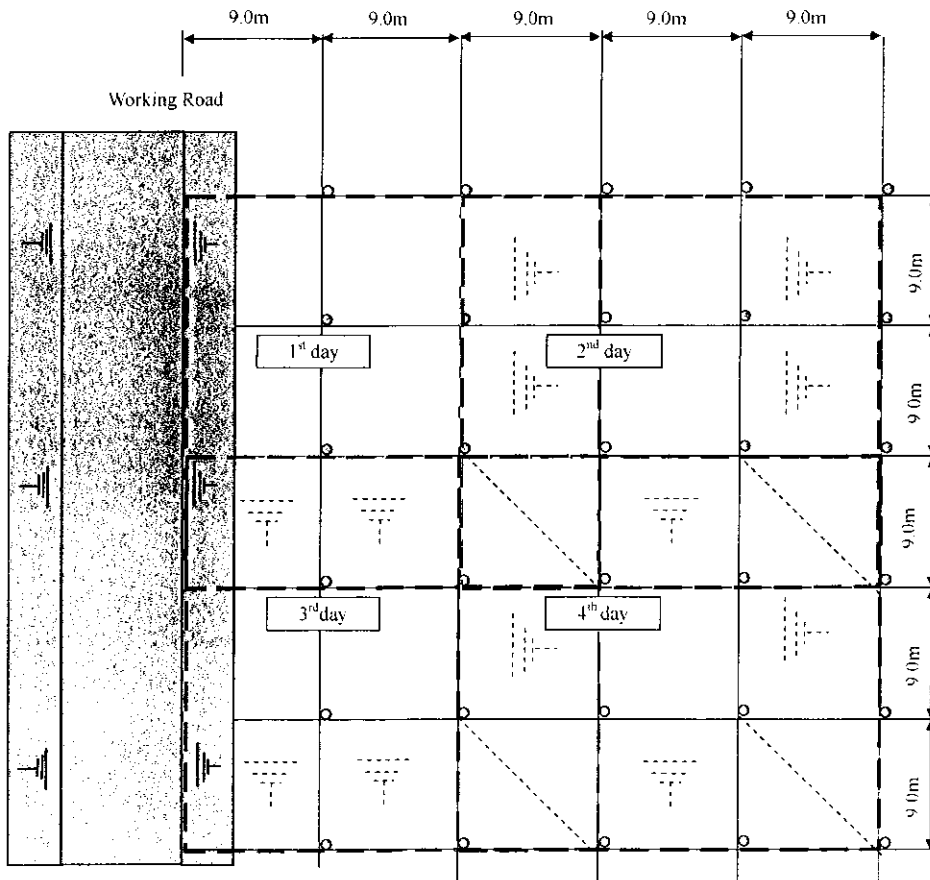


Figure 4.8 Operation Procedure of Controlled Landfill (2/2)

4.5 Waste Filling and Soil Cover at Side Slopes

The establishment of the side slope at the periphery of a landfill is a difficult job. The height of landfill in the periphery and the slope shall be constructed with the help of height poles and rope as shown in Figure 4.9(a), 4.9(b), 4.10(a) and 4.10(b). The supervision of landfilling at the side slope shall be done accordingly. The height of the waste filling per stage is 5m, it should be filled in two layers of 3m and 2m in heights. The steps shall be followed are described below.

Step 1: Demarcation of landfilling height of first 3m height (0 – 3 m)

Two ropes shall be stretched between waste positioning pole and waste height pole as shown in Figure 4.9(a) to demarcate the height of the wastes filling and final soil cover at the slope respectively. Thus the waste filling, thickness of the final soil cover and the landmark of the slope should be fixed (Fig. 4.9 (a)).

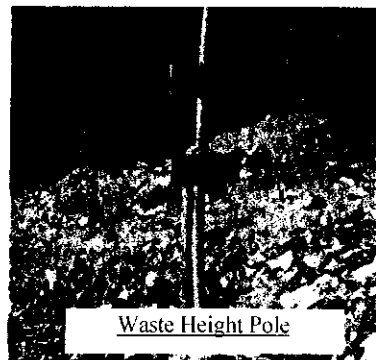
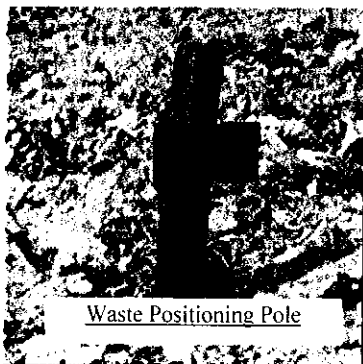
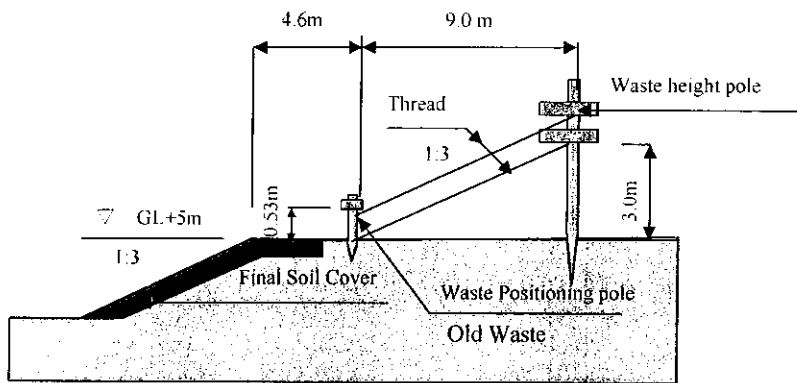


Figure 4.9(a) Landmark of Slope of the first layer landfill

Step 2: Waste Filling at the 1st layer (0 - 3m)

The waste filling and compaction shall done considering the landmark points mentioned in step 1. The finished level of the waste shall just touch the rope indication waste height (Fig. 4.9(b)).

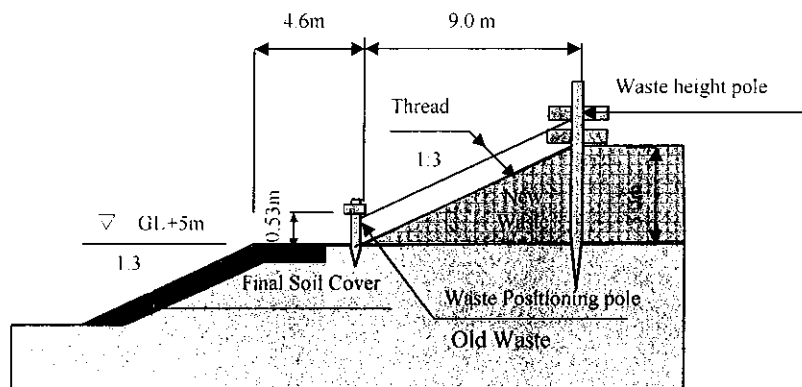


Figure 4.9(b): Waste filling of first layer.

Step 3: Establishment of Final Soil Cover at the 1st layer (0 – 3m)

The final soil cover shall be established following the landmark points mentioned in step 1(Fig. 4.9(c)). The finished soil cover shall be aligned with the rope stretched between the poles to demarcate the alignment of the final soil cover (Fig 4.9(b)).

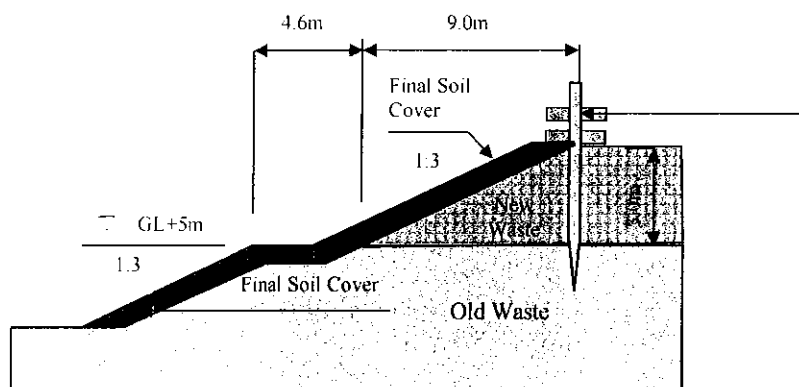


Figure 4.9(c) : Final soil cover of the first layer.

Step 4: Demarcation of the landfill height of 2nd 2 m height (3-5m)

Demarcation of the waste filling and final soil cover heights by poles and ropes as discussed in step 1. and shown in Fig. 4.10(a)

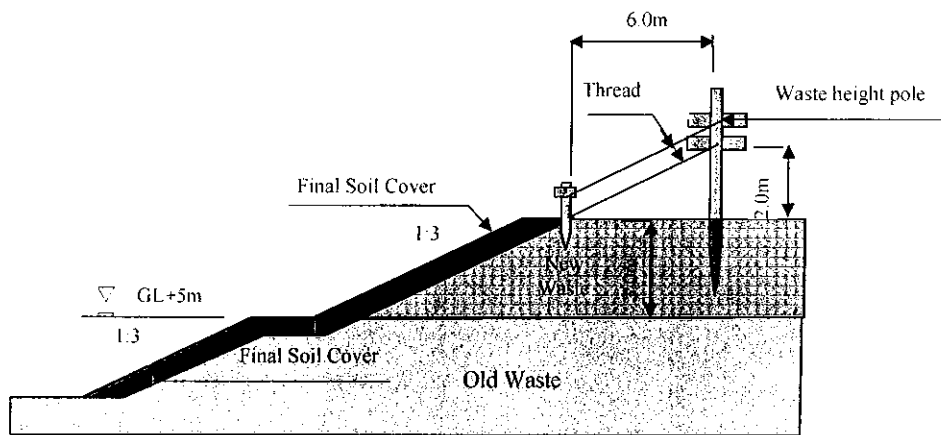


Figure 4.10 (a) Demarcation of second layer of land filling.

Step 5: Waste filling at second Layer (3 – 5m)

The waste filling and compaction shall done considering the landmark points established in step 4. The finished level of the waste shall just touch the rope indication waste height (4.10(b))

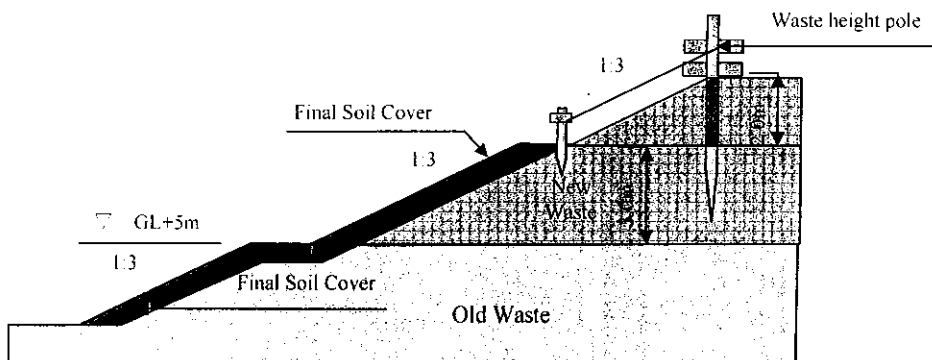


Figure 4.10(b): Waste filling of second layer

Step 6: Establishment of Final Soil Cover at the Second layer (3 – 5m)

The final soil cover of the second layer shall be done considering the landmark mentioned in step 4 and following the alignment established by poles and ropes. The establishment of final soil cover is shown in Figure 4.10(c)

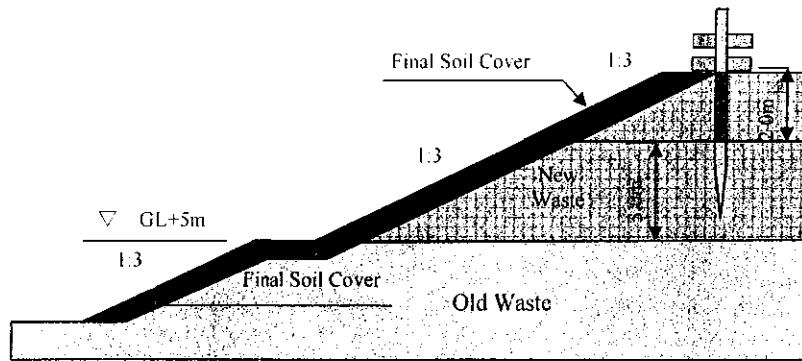


Figure 4.10(c) : Final soil cover of the second layer layer

4.6 Drainage of Working Road

The working road constructed on the waste is used by the waste loaded vehicle to climb up the landfill for disposal of waste at designated areas. Drainage congestion in the working road constructed by construction debris on old waste can make the road unstable and be the cause of failure. Hence proper drainage of the working road and its surrounding area is very important for uninterrupted landfill operations.

It is necessary to make properly sloped drain at the edge of the working road between road and slope of waste with soil cover as shown in Figure 4.11 before the rainy season so that rainwater cannot enter into or under the working road and make it unstable. If there is a possibility of producing leachate by mixing of rain water and waste then the drain is to be connected to the nearby gas vent pipe. Again, if rainwater or leachate accumulation occurs in any location of the landfill, some kind of drain should be constructed and connected to the nearest gas vent pipe. The final soil cover at the periphery of the landfill should be done before the rainy season to minimize the generation of leachate.

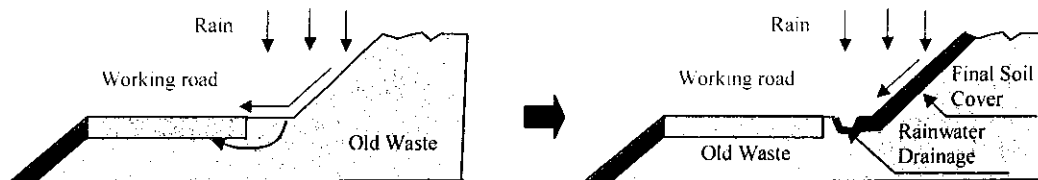


Figure 4.11 : Drainage at the edge of temporary/working road

If rainwater flows over the soil cover at slope, it will make rain cuts on the slope. A part of rain water may also enter into the waste and push the soil cover as shown in Figure 4.12 and make it unstable. In this case, the soil cover will be washed out. To prevent rain cuts and washing out of soil cover, temporary drains as shown in Figure 4.12 should be constructed.

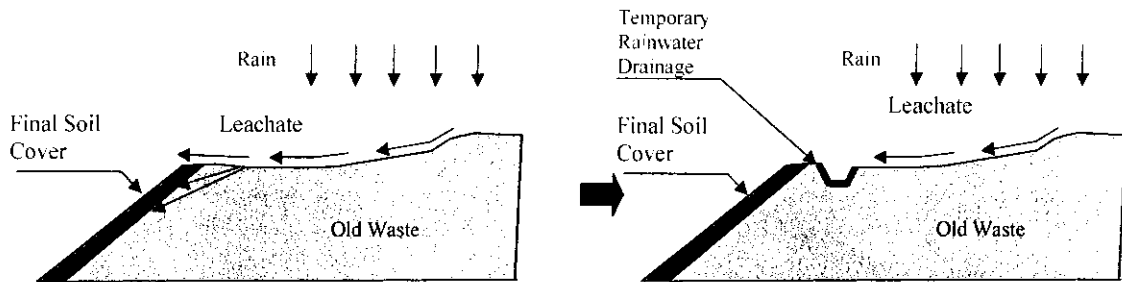


Figure 4.12 : Construction of temporary drains at the slopes

4.7 Temporary Drains

Temporary drains, in combination with earth bunds, may be constructed during the operation period to divert storm water from entering into active waste disposal area. The operators shall ensure that these drains do not convey water outside the site. The water collected in these temporary drains shall ultimately seep into the disposed waste and enter into the leachate collection system to be conveyed to the leachate ponds. Once the temporary drains have served their purpose they should be reclaimed properly. No standing water shall be allowed in any part of the landfill.

Proper drainage of the side slopes shall be ensured in accordance with the progress of landfill through construction of longitudinal and traverse drain as shown in the Figure 4.13 in order to protect the slopes.

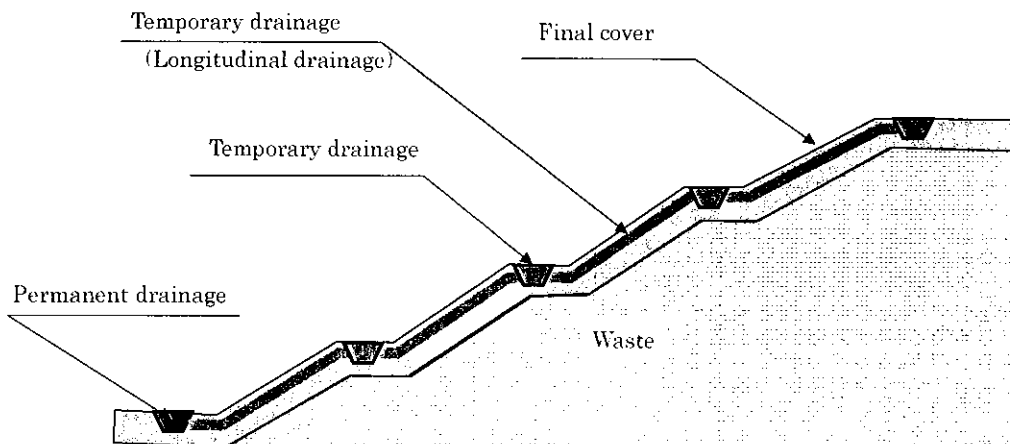


Figure 4.13 : Drainage plan at the slope

4.8 Construction and Operation of Working Road

The construction and operation of working road are of great importance to keep the landfill operational in all seasons. In the rainy season, rainwater and leachate may accumulate on the working road, which will damage the road and make the waste carrying vehicle difficult to operate. It is necessary to raise the working road above the level of waste and land filling is conducted by push-down method from the working road.

Since construction work for raising the level of working road with the increase in the height of landfill is a continuous process, DCC shall ensure availability of enough construction debris at site for use as and when required. For this purpose, DCC shall build storage of construction debris in a suitable area between the control building and the hospital waste management facility. In order to ensure movement of waste carrying vehicle at all times, steel plate may be used in the upper parts of the working road in the rainy season. Steel plate is welded with steel bars to avoid sliding. The width of the working road shall be 12m and built by construction debris by 1m thick layers over compacted old waste. The arrangement of the working roads is shown in Figure 4.14.

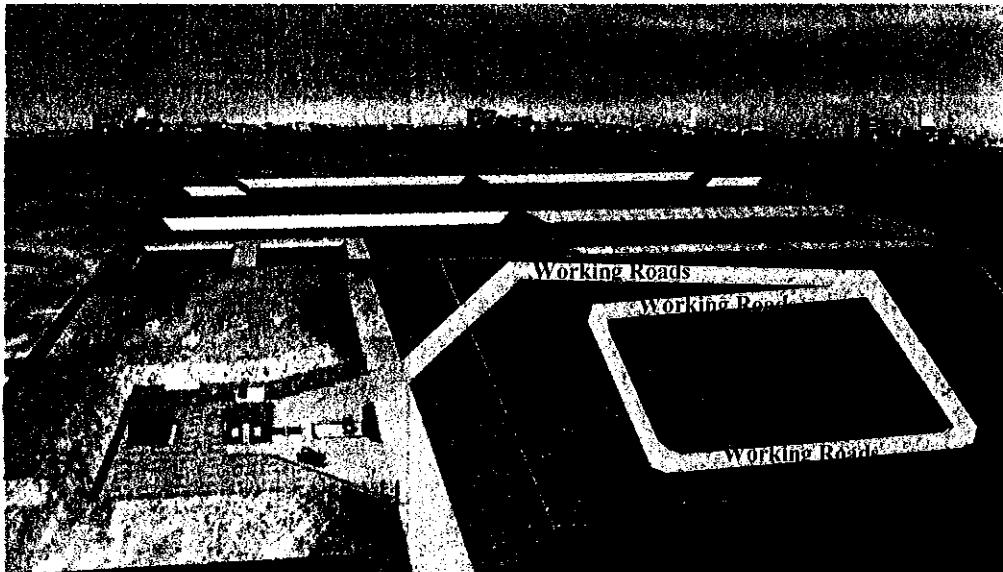


Figure 4.14: Plan of working road at the site

4.9 Leachate Pond Aeration

Aeration of the leachate in the leachate ponds by operation of air blower is important for biological treatment of the leachate. Aeration keeps the leachate aerobic and prevents odor emission from the leachate discharged in the pond. The Operation Manual provided by the aerator manufacturer is to be followed for operation and maintenance issues.

4.10 Leachate Re-circulation and Sludge Disposal

Leachate re-circulation shall be performed to allow for an increased rate of waste decomposition and provide further treatment of the leachate through exposure to anaerobic conditions.

During the dry seasons the leachate re-circulation shall be done on a regular basis so as to reduce cost of operation of the treatment plant and to moisten the disposed waste to hasten the decomposition process. However, during the rainy season the re-circulation shall be done as required to prevent overflow of the leachate pond. Crushed brick or stone bed connected to stone jacket around the gas vent pipes should be installed for receiving re-circulated leachate. Crushed stone or bricks will work as a trickling filter and enhance treatment of leachate.

The accumulated sludge in the sedimentation pond and at the bottom of aeration pond shall be pumped as and when required and deposited over the disposed waste in the landfill.

4.11 Gas Vents Extensions

As the waste height increases it will be necessary to increase the height of the gas vents. This will be necessary in order that the gas vents continue to passively expel the generated landfill gas and introduce air into the disposed waste layers. The Operator shall use perforated PVC vent pipes surrounded by aggregate in a cage built by wire mesh or mesh made of bamboo slices. The landfill staff shall ensure maintaining the vents free of any foreign materials.

4.12 Special Waste Handling

Matuail landfill site is not designed to handle special waste (e.g. liquid waste, chemical waste, hazardous waste, etc.). Should such waste be delivered to the site, the truck hauling these waste shall be refused access, in case of detection at the entrance of the site or control area, or be directed to re-load and remove the waste, should the nature of the waste be detected during the unloading operation.

4.13 Landfill Equipment Maintenance

In principle, simple repairs and daily inspection of the heavy equipment shall be carried out at the site. For this purpose the landfill staff shall include a mechanic with an assistant. The site shall also have some spare parts, and required equipment for the maintenance.

For larger maintenance work the equipment will be transported to DCC central workshop or a qualified workshop in the city. All equipment will have a maintenance record identifying the dates of inspections, repairs, and maintenance. The contents of each input data will be described in detail. For light equipment, such as aerator, pump and generator there shall be daily maintenance checks for oil and lubricants. The Operator stationed at the site should also be capable to provide simple repairs for these equipment.

Chapter 5

ENVIRONMENTAL MANAGEMENT

5.1 Potential Environmental Impacts

The major adverse impacts during the operational phase of the landfill include possible pollution of surface water bodies affecting fisheries and agriculture; groundwater contamination, drainage congestion, leachate flooding, increased air, odour and noise pollution; and occupational health and safety issues for waste pickers and people involved in landfill operation. Leachate generated in the landfill has extremely high potential for the pollution of groundwater and surface water sources in the area. Although, dikes have been constructed around the landfills to confine the waste and its degraded products, oozing out of leachate is common during high rainfall, which can cause severe surface water pollution around the landfill site leading to damages to fishery, agriculture and aquatic environment. The clay layer under the landfill is considered as an adequate barrier against groundwater pollution but short circuiting of leachate through an undetected permeable layer poses a threat to groundwater pollution

Local drainage congestion, filthy environment, breeding of flies and mosquito, obnoxious odour in the surrounding, fire hazards, air and noise pollution are some of the potential adverse environment impacts during construction and operation phases of Matuail landfill. These are common adverse effects of improper design and operation of landfill facilities. Occupational health and safety of the workers at Matuali landfill site including the waste pickers are of great concerns. These vulnerable groups of people are at health risk primarily from increased exposure to hazardous materials, pathogens and unhealthy environment. The DCC and contractor's workforce involved in landfill operation are exposed to higher risk at the landfill site. Obstruction of regional drainage system may also cause environmental problem in the area.

5.2 Mitigation of Adverse Impacts

Collection, treatment and safe disposal of leachate from the landfill site have been given top priority to mitigate possible impacts on the environment. A network of pipe system has been installed within and around the waste in the landfill to convey the leachate into a pond system for treatment. The leachate will be treated by aerated lagoon method in the ponds to reduce the pollution load to acceptable levels and the effluent from the treatment plant will be recirculated to the landfill or discharged with storm drainage while the excess sludge will be put back into the landfill for biodegradation with solid wastes.

The drainage channel of the area is located in the north of the landfill site, which discharges water into a natural khal following by the west side of the newly developed Green Model Town. This natural khal carry water towards the main drainage khal far

away from the site. A 20 ft. wide drainage channel in the north of the landfill site as a tributary to the main khal has been maintained for the local drainage of the area. Separate storm water RCC drains has been constructed around the landfill for efficient drainage of rainwater away from the landfill site.

The peripheral slopes and berms after each stage around the landfill will be covered with thick clay layer. The decomposable fresh wastes in a cell will be covered by stabilized solid wastes from the landfill site to avoid bad smell. The vertical ventilation pipes connected to leachate pipes at certain interval will prevent accumulation of gases in the landfill and keep the system semi-aerobic and free from bad smell.

The activities, potential adverse impact and mitigation measures related to operation of Matuail landfill are presented in Table 5.1

Table 5.1: Summary of adverse impacts and corresponding mitigation measures during Operational phase

Operational Activity	Significant Potential Adverse Impacts	Mitigation Measures
Transportation of solid wastes	Littering of approach roads	It must be made sure that trucks/vehicles carrying solid wastes are covered. Littered solid waste on road, if any shall be removed immediately.
Inadequate cleaning of trucks after disposal of wastes	Bad smell and littering of city roads	Washing of vehicle after disposal of SW in the landfill before leaving the site.
Improper disposal of vehicle wash water	Water pollution; Risk of drainage congestion and groundwater pollution.	The wastewater generated during washing of trucks/vehicles and those generated in the vehicle workshop should be properly disposed into the leachate pond during dry season, and along with storm water during the wet season.
Placement and compaction of solid waste	Air pollution, bad smell, breeding of insects and littering of waste.	Placement of daily cover after placement of solid waste in designated cells; Care should be taken during unloading, placement and compaction of solid waste, so that they do not block the peripheral drainage lines or interfere with the gas venting systems and leachate conveyance network.
Operation of Vehicles	Noise pollution: air pollution	Equipment (excavators, bulldozers, compactors) used at the landfill site should be properly maintained.
People engaged in the operation of landfill.	Occupational health and safety issues	Operators of the equipment producing excessive noise should be encouraged to wear air plugs. DCC workers working at the landfill site must be provided safety accessories, e.g., gloves, boots, helmet, filters etc.. They should also be provided with proper training for working at the landfill site. DCC workers working at the landfill site should undergo regular medical checkup. Efforts should be made to improve occupational health and safety at the site.

Operational Activity	Significant Potential Adverse Impacts	Mitigation Measures
Uncontrolled waste picking	Health and safety of the waste pickers	Ensure safety of the waste pickers. In the short-term, such efforts may include providing waste pickers with safety accessories, e.g., gloves, boots, masks; discouraging underage boys/girls from working at the site. Efforts should be made to ensure easy access of waste pickers to medical treatment and check-up. The DCC may consider working with suitable NGOs in these regards. In the longer-term, efforts may be made to find alternative occupations for the waste-pickers.
Blockage of drainage system	Possible drainage congestion, insect breeding and filthy environment	Peripheral drainage lines should always be properly cleaned and kept in flowing condition to avoid any drainage congestion and stagnation of polluted water.
Interference with free flow of leachate	Leachate flooding, infiltration of leachate to cause groundwater pollution.	Free flow of leachate through collection pipe network shall be ensured to avoid accumulation of excess leachate within the deposited solid waste and possible spill of leachate. The discharge end and upstream open ends of pipe networks shall remain open at all times for entry of air.
Inadequate treatment of leachate	Pollution of surface water by effluent from leachate treatment facilities	Operate the treatment facilities properly. Recirculate excess leachate in the landfill for further treatment.

5.3 Environmental Monitoring Program

5.3.1 Monitoring Requirements

Environmental monitoring is required to assess the actual impact, evaluate the effectiveness of the mitigation measures and adopt additional measure required to control the unpredicted impacts. Much of monitoring activities will form part of the routine inspections of the contractor's work, operational activities and proper functioning of the facilities.

The environmental monitoring during operation of Matual landfill shall primarily focus on addressing the possible negative impacts arising from:

- a) Bad quality of surface run off, wash water, sanitary sewage and leachate;
- b) Pollution of surface water around the landfill site;
- c) Increased risk of groundwater pollution from landfill leachate;
- d) Air (including odor) pollution from construction activities and increased vehicular movement;
- e) Noise pollution from construction activities and increased vehicular movement;

- f) Occupational health and safety problems faced by construction workers, DCC personnel working at the landfill site and waste pickers.

The specific monitoring requirements for each of the environmental issues listed above are presented in Table 5.2. In addition, monitoring plan should also include regular reviews of the impacts that cannot be adequately assessed before the start of the works, or which arise unexpectedly, along with appropriate measures to mitigate any negative impacts and/or enhancing beneficial impacts.

Table 5.2: Monitoring issues/ requirements during operational phase of the project

Environmental Issue	Monitoring Requirements/issues	Monitoring Method
Possible pollution from discharge of surface drainage, wash water, septic tank effluent and leachate	(1) Quality of surface drainage, wash water and leachate generated and effluent from leachate treatment facilities. Functioning of the surface drainage system.	(1) Laboratory analysis as specified in Table 5.3. (2) Visual observation of colour, floating oils, and smell every day
Possible pollution of surface water and land around the landfill	(1) Water quality of the surrounding surface water bodies should be monitored. (2) Possible leakage of leachate and discharge of polluted surface drainage and wash waters. (3) Leachate quality and effluent from leachate treatment system.	(1) Laboratory analysis of the stated parameter as specified in Table 5.3. (2) Visual observation of colour (dark or grey colour indicates pollution), floating foam or bubbles and bad smell (indicates anaerobic condition, low dissolved oxygen and pollution) daily.
Risk of groundwater pollution from landfill leachate	(1) Groundwater quality from observation wells. (2) Accumulation of leachate in the landfill	(1) Laboratory analysis of relevant water quality parameters as specified in Table 5.3. (2) Observation of leachate drainage system specified in Table 5.1.
(1) Air (including odor) pollution at landfill site (2) Noise pollution. (3) Quality of soils	(1) Monitoring air quality (CO, CH ₄ , H ₂ S, and Particulates) at landfill site. (2) Monitor noise level. (3) Monitoring of soil quality	(1) Analysis of the mentioned parameters with the help of portable field kits as specified in Table 5.3. (2) Analysis of parameters as specified in Table 5.3. (3) Analysis of parameters as specified in Table 5.3
Occupational health and safety problems faced by construction workers, DCC personnel and waste pickers working at the landfill site.	(1) Monitor the efforts to improve occupational health and safety. (2) Monitor access of landfill workers, especially the waste pickers, to medical treatment and check up.	Work areas within the landfill.

5. 3.2 Monitoring Plan

The monitoring plan for the environmental parameters stated in Table 5.2 needs repeated measurement of the relevant parameters at definite intervals and analysis of the results to observe variations, trend of variations and compliance with the Environmental Conservation Rules (ECR) of Bangladesh. Table 5.3 shows the monitoring plan for surface water, groundwater, air and soil qualities, noise level and leachate quality. The sampling location except the groundwater monitoring wells, should be decided by the Landfill Management Unit of the DCC, depending on circumstances, especially considering the fact that land-use around the project site is changing rapidly. The monitoring results should also be compared with those reported in the environmental baseline condition reported in the Environmental Impact Assessment (EIA) Report.

Table 5.3 : Plan for monitoring of surface water, groundwater and soil quality at the operational phase of the project.

To be Monitored	Monitoring Parameters	Monitoring Frequency	Tentative Sampling Location
Surface Water	(1) pH, EC, DO, Ammonia, COD (2) pH, Color, Turbidity, EC, Chloride, Sulfate, Ammonia, Nitrate, Phosphate, DO, BOD ₅ , COD, Lead, Chromium, Cadmium	(1) Once a month (2) Twice a year (once during wet season and once during dry season)	Close to storm water discharge points and in water bodies on both sides of the landfill
Groundwater	Water level, Temperature, pH, EC, Ammonia, COD. If contamination is suspected from these measurements, also monitor: Color, Turbidity, Chloride, Sulfate, Hardness, Ammonia, Nitrate, Phosphate, Iron, Lead, Chromium, Nickel, Cadmium, and Faecal Coliform	Once a month	At two monitoring wells located at two different sides of the landfill. Water quality of the production well at the landfill site is to be monitored once in 6 months.
Air quality (landfill gases)	CH ₄ , CO, CO ₂ , H ₂ S, O ₂	Twice a year (once during wet season and once during dry season)	Two locations (north and south sides of the existing landfill site)
Noise	Noise level	Once a week	Close to operating equipment and northern boundary (bordering the housing project)
Leachate	(1) pH, EC, Ammonia, COD (2) pH, Color, Turbidity, EC, Potassium, Ca, Mg, Chloride, Sulfate, Ammonia, Nitrate, Phosphate, BOD ₅ , COD, Lead, Chromium, Nickel, Cadmium	(1) Once a month (2) Twice a year (once during wet season and once during dry season)	(i) Last pit before entrance of leachate into the aeration pond (i.e., leachate sample before treatment), and (ii) treated leachate sample
Soil	Lead, Chromium, Cadmium, Zinc	Once a year	Discharge points of surface drainage and treated leachate

DCC shall establish a laboratory at the landfill site for measurement of common parameters particularly the parameters that can be measured by field kits. A reliable reference laboratory should be used for analysis of water and soil quality parameters that cannot be analyzed in the DCC laboratory. Some 10% test should be repeated in the reference laboratory. Surface water and soil sample collection points may be changed/modified by the DCC Landfill Management Unit, depending on monitoring results. The DCC Landfill Management Unit will be responsible for environmental monitoring of the Matuail landfill.

5.4 Environmental Enhancement

The most important positive impact of the project is significant improvement of overall environmental condition within and around the project site. A network of perforated pipes with gravel pack has been installed in the wastes for ventilation-cum-leachate collection in order to make semi-aerobic condition in the landfill for rapid stabilization of waste with minimum odour. It will reduce the discharge of methane, a highly potent greenhouse gas in the environment. The pipe network will facilitate collection of methane produced in the landfill, if required for generation of electricity during post closure period.

Tree plantation should be carried out in a planned way around the project site which will act as a visual barrier and also a barrier for odor, noise and air pollutants generated within the dump site. An elevated land, 40-50 ft. high and about 100 acre in area, will be available after the landfill is completed, which will be converted into a planted forest. When the waste is fully stabilized, it can finally be developed as a picnic spot, park or any other eco-friendly uses. This area will ultimately contribute toward improvement of the environment of Dhaka city.

Chapter 6

EMERGENCY MANAGEMENT

6.1 Types of Emergencies

Crises at the landfill that require the need for an emergency management and contingency plan include failure of embankment, fires, release of methane or other noxious fumes, chemicals or fuel spills, earthquakes, flooding and heavy rains.

Other emergencies may include blockade of access road to the site by the surrounding residents, collapse of road and vehicle failure, injuries of the operating staff, utilities failure or shortages, unauthorized scavenging and waste picking activities in and around the landfill, etc.

6.2 Emergency Management and Contingency Plan

The intent of this section is to provide a guideline to identify the potential emergencies at the landfill site. A separate Emergency Management and Contingency Plan (EMCP) needs to be prepared and distributed to the staff at the site in order to make them aware and trained on the emergency response procedures.

6.3 Emergency Response

6.3.1 Hazardous, Toxic, and Infectious Waste

In the event of any hazardous, toxic or infectious waste found at the active waste disposal area, site personnel will not attempt to cleanup such materials. The personnel will inform the management and a specialized person/company will be immediately contacted to identify the waste and its clean-up. The following procedure will be followed:

- Immediately cordon off area where suspected materials are found;
- Inform the management about the incident;
- Relocate the working force as required;
- If possible, identify the materials;
- Contact a person/company specializing in hazardous and toxic materials management and assist to identify and remove the suspected materials, as required;
- Prepare full report with supporting documentation for submission to the relevant authorities.

6.3.2 Fire

Fires that may occur in the landfill waste will be controlled by the use of fire extinguishers, covering the burning materials with additional soil. Once the fire is extinguished, the cell containing the burned materials will be excavated, removed and

spread out in an isolated area of the site. Following confirmation that all burning materials have been extinguished, the waste will be covered with a minimum of 15 cm of soil.

The following actions will be taken if a fire occurs in the refuse fill area:

- Burning refuse will be buried immediately with cover soil;
- If the fire is within the reach of the leachate recirculation system, leachate may be pumped on the fire.
- The Fire Department will be summoned if the site personnel and equipment cannot extinguish the fire. The contact information of the closest fire department should be available at the site.
- If the fire occurs at areas outside the active waste disposal areas, maximum effort shall be made to prevent the fire from spreading to the waste areas. One method may be to excavate a fire break between the active waste disposal areas and the oncoming fire.

6.3.3 Earthquake

Should a strong earthquake occur, it is advisable to suspend the landfill operation in order to conduct a damage assessment of the site facilities. These facilities include, but are not limited to the embankment, roads, administration buildings, gas vents, leachate collection and treatment facilities, and utilities supply networks. The damages shall be repaired after assessment.

6.3.4 Severe Wet Weather Conditions

If there is severe rainfall and fear of collapse of the landfill slopes or the disposed waste then it is necessary to suspend operation and take necessary actions such as application of cover materials and compaction of the affected areas, once the storm has abated.

- If the side slopes collapse, urgent repair will be made and side slopes are to be brought into their original shape by excavator. Soil covers are to be provided and properly compacted.
- Drainage congestion, if found in some area, shall be urgently drained out by excavating drainage channel.
- The temporary roads are to be checked and repaired, if required.

6.3.5 Access Road Problems

Should there be any disruption of transport to and from the site due to collapse of access road or parts of the access road, the landfill operator should notify the relevant Department of DCC or the Department of Roads and Highway as appropriate for prompt action.

When the road within the landfill collapse, immediate repair work is to be taken up or by-pass arrangement should be made to keep the landfill operational.

In case of collapse of the temporary road used by the vehicles to climb up on the landfill for disposal of wastes, repair should immediately be started using construction debris.

Adequate quantities of construction debris are to be stored in area of the landfill for this purpose. An alternative temporary arrangement shall be made to store the incoming wastes at the site until the temporary road is made operational. The permanent platforms may be such sites.

Should the access road problem remain un-resolved then it may be necessary to suspend operation at the landfill.

Chapter 7

POST CLOSURE PLAN

7.1 Introduction

The Matuail landfill will be closed when a height of 20 m above the boundary road level is reached. Closure of the site will be accompanied by restoration to prepare the final landform through spreading of the soil and site maintenance during a post closure period. The aftercare will include taking steps during and after restoration to bring the land up to the required standard for after use by cultivating, fertilizing, and draining the land to sustain vegetative growth.

The potential for environmental problems such as groundwater contamination by leachate, waste washout due to flooding, slope failures and landslides, landfill gas migration, odor problems and uncontrolled fires can still exist after site closure. Thus, upon cessation of activities (i.e. waste disposal), necessary measures are to be taken to avoid any pollution risk and to develop the site to a satisfactory state. The activities to be carried out during post-closure period are discussed in the following sections.

7.2 Capping of the Site

The capping system is the final component in the construction of the landform, and it consists of engineering and restoration of surface layers. The restoration layer is layer of earthen material of at least 1.0 meter thick, which will support native plant growth and thus enable the site for its planned use.

The engineered layers of the cap will comprise, as a minimum of the following:

- A barrier layer - may be of compacted clay, geo-membranes or geo-synthetic clay to reduce infiltration of water into the waste and escape of gas from the waste;
- The top surface must be finished on a slope towards the edge of the landfill so that the rainwater quickly flows to the edges gutters to join the drainage system;
- A gas collection layer may be composed of gravel, sand, geo-textiles or geo-nets to transmit gas to collection points;
- If gas collection is planned, the existing gas vents are to be used as wells for gas collection after the closure of the landfill.

7.3 Management of Leachate and Gas

When the final capping is complete, the leachate production will be reduced. The equipment used for leachate collection and gas venting and control are to be maintained in good condition in the post- closure period. Treatment of leachate shall continue as long as leachate is collected through the leachate collection system. DCC may plan to collect methane gas for use as a source of energy if the amount of gas produced in the landfill is

considered sufficient for cost effective power generation

7.4 Settlement Monitoring and Maintenance of Final Soil Cover

During the aftercare period, the site operator shall consider two types of settlement in relation to monitoring:

- Settlement of the wastes due to decomposition and stabilization of the waste in the landfill;
- Settlement associated with stability of the site including slopes and associated structures.

Investigation of the settlement potential and physical stability of the site are to be undertaken using theoretical and practical investigations. The investigation will take account of the composition and density of the waste deposited. Assessment of the magnitude of settlement and settlement trends, and identification and stability assessment of slopes and structures are required.

The soil cover which constitutes the final cap must remain stable and checks must be made to identify cracking of the capping layer. Regular maintenance is required to repair the effects of settlement, subsidence or erosion.

7.5 Surface Run-off Control

In order to maintain effective surface run-off, the integrity of the final cover must be maintained after closures. The cracks, depressions, rain cuts and erosion appear on the capping layer need regular repair and maintenance. The monitoring for surface water is to be continued during the post closure.

The surface drains in the landfill area must remain operational and well maintained for quick and efficient drainage of the whole landfill area. Where pipes or drainage systems have been laid during the construction of the landfill they are to be checked and repaired if necessary. In the event that modifications are necessary in order to maintain effective surface drainage controls such changes are to be undertaken as long as practicable.

7.6 Monitoring of Other Facilities

Roads and other site infrastructure are to be maintained in accordance with the post-closure plan. It will also be necessary to maintain site security and keep the site free from vectors.

