j

UNIT 2 SANITARY LANDFILL AND TYPES

Structure

2.1 INTRODUCTION

A sanitary landfill is an engineered facility on land designed for the final disposal of solid waste in a manner that minimizes the harm to the environment. Sanitary landfills are engineered operations, designed and operated according to acceptable standards as opposed to open dumps which are simply places to deposit waste. The sanitary landfilling operation involves numerous stages, including siting, design, operation, and closing. The biological, chemical and physical processes that occur within a dumpsite/landfill cause decomposition of waste, producing landfill gas (LFG). Typically, the constituents of LFG are methane (45–60% by volume), carbon dioxide (40–60%), nitrogen (2–5%) and traces of oxygen, ammonia and non-methane volatile organic carbon compounds (NMVOCs). Rainwater entering into the waste, along with water produced during these processes and the inherent moisture content of waste, is emanated from the bottom of landfill in the form of a contaminated effluent leachate. In case of an open, unmanaged dumpsite, the gases are emitted into the atmosphere and leachate enters groundwater, thus polluting air, water and soil. The situation aggravates in case of fires when combustible gases and solids burn. Waste is encapsulated in a sanitary landfill by daily cover on the top and liner system at the bottom. This isolation is accomplished with the use of a bottom liner and daily covering of soil. A landfill continues to subside after closure, so that permanent structures cannot be built onsite without special foundations.

Objectives

After studying this unit, you should be able to:

- Purpose and detailed working mechanism of sanitary landfills
- Classification and importance of sanitary landfills
- Do the economic analysis of sanitary landfills.

j

2.2 DIFFERENCE BETWEEN LANDFILL AND SANITARY LANDFILL

Landfills have been known to be as deep as hundreds of feet and can take years before they are fully filled after compaction. In case a sanitary landfill gets filled, landfill capping is done. This is the process of capping or topping the landfill with synthetic plastic or clay, just as the bottom of the landfill. The aim of this is to prevent methane gas from escaping to the atmosphere as well as bad odours. Further, this layer is reinforced with a layer of topsoil, about 2-3 feet, and vegetation is planted. When all this is completed, the land is reclaimed and can be used for other purposes. Despite all these processes, due to the toxicity of the waste buried deep down, there is still a chance of contamination, either through the waterways or the soil, which affects plants, some of which are edible to both man and animals. There are following differences between landfill and sanitary landfills are listed as in table 2.1 (refer Figure 2.1).

Table 2.1: Difference between sanitary landfill and landfills

Sanitary landfills	Open dumping/Landfills
Sanitary landfills are only set up by the authority of the local government or the state. It is not a personal or individualized decision but a societal one. The religious leaders, the non-governmental organizations and the public must all be consulted before it is set up.	This waste disposal method is not processed officially by the relevant authority. Instead, people set up their own open dumping sites outside their houses or a common dumping site that is left open for the small organisms such as rats and flies to make their habitat. These open dumping sites can be found anywhere in people's compounds, market places, and even public places like schools and churches.
Soil is a major component of sanitary landfills, given that it is applied daily or on a regular basis to keep bad odors and pests off the land surface. This ensures that the land near the landfill can be used by others without pollution of the air or infestation by pests.	For open dumping sites, however, there is no soil applied. Open dumps are just holes dug to accumulate waste, and no amount of operational activity such as application of compact soil is done. Hence, they pose a greater danger to the environment in terms of bad odors containing harmful contaminants such as methane.
Monitoring is a key part of any sanitary landfill. With the application of the compressed clay in the bottom layer, engineers are able to monitor whether there is any water seeping from the ground up to the landfill or the landfill down to the ground since this would cause a health hazard to the underground water. In the second layer, the engineers monitor the	For open dumps, there is no monitoring at all. Once a pit has been dug, there is absolutely no monitoring of what is disposed of and in what manner. It is for this reason that large open pits have led to contamination of the land and water supply. Moreover, open dumps do not have treatment plants for the treatment of liquids or gases from the dumpsite.

i

drainage of all liquids accumulated in the landfill. Proper drainage is essential to ascertain there is no water seeping to the bottom layer and subsequently to the underground water.	
Open dumps are small in size and are mostly used as domestic waste disposals. Open dumps are relatively shallow, going to a few feet deep. Due to this, they are more in number compared to sanitary landfills. Approximately every household has an open dump in most countries.	On the other hand, sanitary landfills are big. One of the biggest ones is in California and is about 500 feet deep. It is home to over 40% of the state's waste management system. Landfills take a long time to dig up as opposed to open dumps and involve a lot more than human labor. For example, heavy machinery is needed to get to the deep depths. So, the landfills serve communities and states rather than a few individuals.

Figure 2.1: (a) Dumping and (b) Sanitary Landfills

2.2.1 Effects of Landfilling

A major disadvantage of a landfill is the release of harmful gases. One tonne of biodegradable waste can produce about 400–500 cubic meters of landfill gas that contains methane and carbon dioxide as the major constituents and traces of other gases. Methane is a greenhouse gas that is 25 times more hazardous than carbon dioxide. Thus, this increases the implications of global warming and climate change. The people living near landfills or having prolonged exposure may suffer from cancer, respiratory disorders, and developmental defects in children. Even short-term exposures to ammonia and hydrogen sulfide releasing in the air can cause eye, nose, and throat irritation as well as asthma. Other reported health complaints include sleeping difficulties, weight loss, and chest pain. Methane and carbon dioxide that release in the landfill can affect the availability of oxygen to tissues causing coordination issues, fatigue, nausea, vomiting, and unconsciousness. Methane build up is also a concern which exposes the lives of nearby residence due to the risk of methane explosion. In an enclosed space with poor ventilation, it lights up quite

i
easily, and the entire landfill site can be on fire in a blink. A similar case occurred recently in Bangalore's Bellandur Lake. Sprawling over 900 acres, the lake caught fire owing to the production of methane gas. Landfill sites often become vulnerable to collapses of abrupt landfill settlement due to rain, spontaneous combustion of gases or materials, or excessive waste accumulation causing damages that are deep and almost irreversible. The death toll was 113 when a massive landfill outside Ethiopia's capital, Addis Ababa, collapsed in March 2017. Just a month later, Sri Lanka's Meethotamulla landfill site suffered a massive collapse, destroying 140 houses and taking 30 lives. In February 2020, two workers lost their lives when the Zaldívar landfill site in Spain collapsed.

2.3 PURPOSE OF SANITARY LANDFILLS

The main purpose of sanitary landfills is to ensure the safe decomposition of the waste which otherwise may pollute all the periphery of the dumping site. The alternative layering of garbage and soil aids in hastening decomposition. Because methane, a toxic gas is produced from decomposition, it is collected in the landfill to generate electricity instead of being released into the atmosphere. The sanitary landfill also uses a clay liner to isolate the trash from the environment. Besides, it involves well-designed engineering methods to protect the Environment from contamination by solid or liquid wastes. When the sanitary landfill is full, impervious clay is used to seal it, and if deemed safe, that area can be used for other purposes. The main function of sanitary land filling is:

a) Designed to bury waste in layers of soil
b) Compacting the layers to reduce volume
c) Slowdown of waste decomposition with minimal amounts of oxygen and moisture.
d) Finally covering them with soil each day so as to minimize human health and environmental problems.
e) And for careful filling, monitoring and maintenance while they are active and for up to 30 years after they are closed.

2.3.1 Landfill Liner Layers

There are different levels of layering of waste to facilitate the decomposition of the materials as well as trap toxic gases released from the process. The layers are made in such a way that the bottom part has the smallest volume, with the top part taking the bigger volume to avoid collapsing of the land.

The first layer: This is the lowest layer and the first one used in laying a foundation for the sanitary landfill. The process entails the application of compact and well dense clay to prevent the seeping in or out of liquids. It is for this reason that this clay is completely impervious. This modernized type of sanitary landfill is also fitted with high-density plastic which is applied on top of the clay for reinforcement. This engineering design is to make certain there is no room for the penetration of liquids, thus preventing contamination of the underground water.

The second layer: The second layer is the drainage system. The drainage system takes care of the liquid produced from the decomposition of some waste materials. Due to the toxicity of this liquid, it should not seep past the liner layer. The drainage layer aids in draining away this liquid to avoid it from getting close to the liner

i
system. Moreover, rainfall and snow may also seep from the top surface to the landfill and also needs to be drained away. These liquids may contain contaminants from the waste materials that can corrode the liner system and contaminate the soil and water below the landfill. In reducing this risk, the sanitary landfill is fitted with perforated pipes on top of the liner layer to collect all the liquids that find their way to the bottom of the landfill through leaching, thus the name leachate. The plumbing system then directs the leachate to treatment plants to undergo treatment for reuse.

The third layer: The third layer is the gas collection system. In the same way that liquids are produced, methane gases are also released through natural processes. There are, therefore, extraction pipes in this layer that traps methane gas and transport it to treatment plants to treat the gas and thereafter, use it to produce electricity and to power various processes.

The fourth layer: The fourth layer contains the thrash itself. This is the largest layer and is also the topmost. Periodically, trash from various sources is brought in by the various garbage collection companies and dumped in this layer. To avoid taking too much space, the garbage disposed of is compacted on a daily basis. Once this has been done, a layer of compacted soil is applied to the surface of the sanitary landfill. Soil does a good job of containing bad smells and the growth of harmful microorganisms such as pests and flies. Also, the compact soil keeps away windblown debris.

2.4 Settling Processes in Landfill

The consolidation of landfilling is illustrated in Fig. 2.3 . The three stages shown in the figure above are described below:

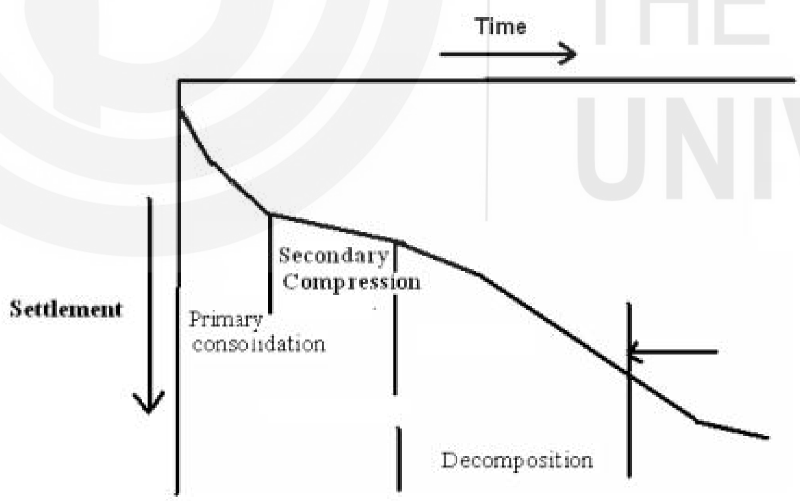

Fig. 2.3: Consolidation of landfills with time

Primary consolidation: During this stage, a substantial amount of settling occurs. This settlement is caused by the weight of the waste layers. The movement of trucks, bulldozers or mechanical compactors will also enhance this process. After this primary consolidation, or short-term deformation stage, aerobic degradation processes occur.

i

Secondary compression: During this stage, the rate of settling is much lower than that in the primary consolidation stage, as the settling occurs through compression, which cannot be enhanced.

Decomposition: During the degradation processes, organic material is converted into gas and leachate. The settling rate during this stage increases compared to the secondary compression stage, and continue until all decomposable organic matter is degraded. The settling rate, however, gradually decreases with the passage of time. The microbial degradation process is the most important biological process occurring in a landfill. These processes induce changes in the chemical and physical environment within the waste body, which determine the quality of leachate and both the quality and quantity of landfill gas. Assuming that landfills mostly receive organic wastes, microbial processes will dominate the stabilisation of the waste and therefore govern landfill gas generation and leachate composition. Soon after disposal, the predominant part of the wastes becomes anaerobic, and the bacteria will start degrading the solid organic carbon, eventually to produce carbon dioxide and methane. The anaerobic degradation process undergoes the following stages:

- ✓ Solid and complex dissolved organic compounds are hydrolysed and fermented by the fermenters primarily to volatile fatty acids, alcohols, hydrogen and carbon dioxide.
- ✓ An acidogenic group of bacteria converts the products of the first stage to acetic acid, hydrogen and carbon dioxide.
- ✓ Methanogenic bacteria convert acetic acid to methane and carbon dioxide and hydrogenophilic bacteria convert hydrogen and carbon dioxide to methane. The biotic factors that affect methane formation in the landfill are pH, alkalinity, nutrients, temperature, oxygen and moisture content.

Enhancement of degradation: Enhancement of the degradation processes in landfills will result in a faster stabilisation of the waste in the landfill, which enhances gas production, and we can achieve this by adding partly composted waste. As the readily degradable organic matter has already been decomposed aerobically, the rapid acid production phase is overcome, and the balance of acid and methane production bacteria can develop earlier and the consequent dilution effect lowers the organic acid concentration. Also, recirculating leachate may have positive effects since a slow increase in moisture will cause a long period of gas production. During warmer periods, recirculated leachate will evaporate, resulting in lower amounts of excess leachate.

2.5 CLASSIFICATION OF SANITARY LANDFILLS

The term landfill generally refers to an engineered deposit of wastes either in pits/trenches or on the surface. And, a sanitary landfill is essentially a landfill, where proper mechanisms are available to control the environmental risks associated with the disposal of wastes and to make available the land, subsequent to disposal, for other purposes. However, you must note that a landfill need not necessarily be an engineered site, when the waste is largely inert at final disposal, as in rural areas, where wastes contain a large proportion of soil and dirt. This practice is generally designated as non-engineered disposal method. When compared to uncontrolled

i
dumping, engineered landfills are more likely to have pre-planned installations, environmental monitoring, and organised and trained workforce. Sanitary landfill implementation, therefore, requires careful site selection, preparation and management. The four minimum requirements you need to consider for a sanitary landfill are:

a) full or partial hydrological isolation;

b) formal engineering preparation;

c) permanent control;

d) planned waste emplacement and covering.

Landfills may be classified in various ways. One of the classifications is based on source of waste. The classification is shown in Table 2.2.

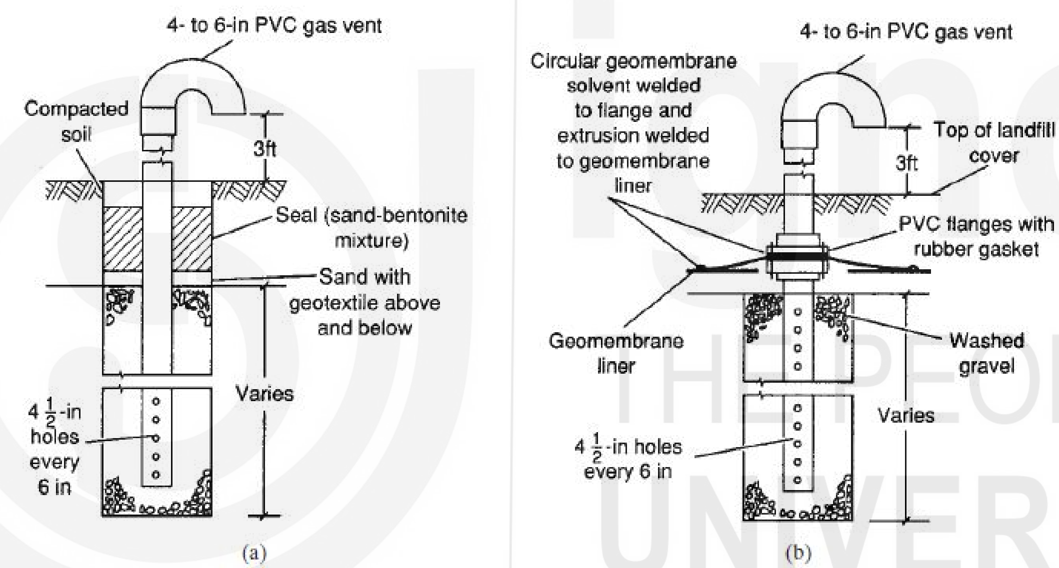

Figure 2.2: Typical gas vents used in the surface of a landfill for the passive control of landfill gas:

(*a*) gas vent for landfill with a cover that does not contain a geo-membrane liner;

(*b*) gas vent for a landfill with a cover that contains a synthetic membrane liner

Second classification of landfills may be based on cover of landfill liners. The potential threat posed by the waste determines the type of liner system required for each type of landfill. Liners may be described as single (also referred to as simple), composite, or double liners. Single-Liner Systems Box 1) consist of a clay liner, a geosynthetic clay liner, or a geomembrane (specialized plastic sheeting) (Figure 2.3). Single liners are sometimes used in landfills designed to hold construction and demolition debris (C&DD). Construction and demolition debris results from building and demolition activities and includes concrete, asphalt, shingles, wood, bricks, and glass. These landfills are not constructed to contain paint, liquid tar, municipal garbage, or treated lumber; consequently, single-liner systems are usually adequate to protect the environment. It is cheaper to dispose of construction materials in a C&DD landfill than in a municipal solid waste landfill because C&DD landfills use only a

j
single liner and are therefore cheaper to build and maintain than other landfills. Composite-Liner Systems consists of a geomembrane in combination with a clay liner. Composite-liner systems (Figure 2.4) are more effective at limiting leachate migration into the subsoil than either a clay liner or a single geomembrane layer. Composite liners are required in municipal solid waste (MSW) landfills. Municipal solid waste landfills contain waste collected from residential, commercial, and industrial sources. These landfills may also accept C&DD debris, but not hazardous waste. The minimum requirement for MSW landfills is a composite liner. Frequently, landfill designers and operators will install a double liner system in MSW landfills to provide additional monitoring capabilities for the environment and the community. A double liner consists of either two single liners, two composite liners, or a single and a composite liner (Figure 2.4). The upper (primary) liner usually functions to collect the leachate, while the lower (secondary) liner acts as a leak-detection system and backup to the primary liner. Double-liner systems are used in some municipal solid waste landfills and in all hazardous waste landfills. Hazardous waste landfills (also referred to as secure landfills) are constructed for the disposal of wastes that once were ignitable, corrosive, reactive, toxic, or are designated as hazardous by the U.S. Environmental Protection Agency (U.S. EPA). These wastes can have an adverse effect on human health and the environment, if improperly managed. Hazardous wastes must be disposed of in hazardous waste landfills. Hazardous waste landfills must have a double liner system with a leachate collection system above the primary composite liner and a leak detection system above the secondary composite liner

Table 2.2: Types of landfills based on sources of waste

Municipal solid waste landfills	Landfills that accept household waste as well as other wastes.
Managed landfills	Landfills composed mainly of clean fill, but also construction and demolition waste with light contaminants.
Construction and demolition landfills	Landfills where construction and demolition materials such as wood products, asphalt, plasterboard, insulation and others are disposed to land.
Clean fills	Clean fill material is material that when buried will have no adverse effect on people or the environment. It includes virgin natural materials such as clay, soil and rock, and other inert materials such as concrete or brick that are free of: • combustible, putrescible, degradable or leachable components • hazardous substances • products or materials derived from hazardous waste treatment, hazardous waste stabilisation or hazardous waste disposal practices • materials that may present a risk to human or animal health such as medical and veterinary waste, asbestos or radioactive substances

i

	• liquid waste.
Industrial landfills	Landfills that accept specified industrial wastes. In most cases industrial waste landfills are mono fills associated with a specific industry or facility.

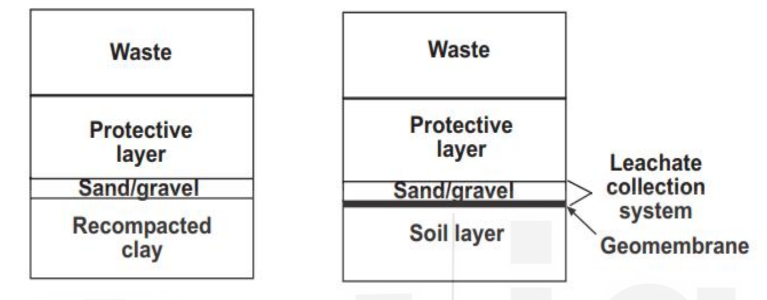

Figure 2.3: Single liner system

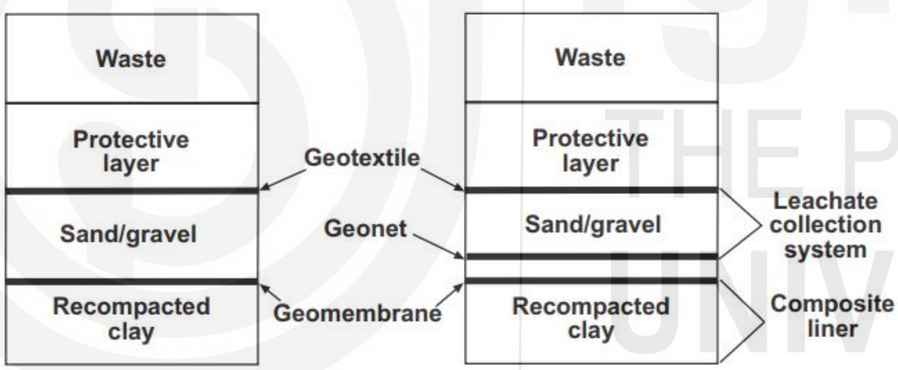

Figure 2.5: Composite liner system

2.6 CLASSIFICATION BASED ON CONSTRUCTION OF SANITARY LANDFILLS

The principal methods used for the landfilling of MSW may be classified as

(1) Excavated cell/trench Method

(2) area Method

(3) Canyon Method

j

2.6.1 Excavated Cell/Trench Method

The cell/trench method of landfilling (see Figure 2.6a) is ideally suited to areas where an adequate depth of cover material is available at the site and where the water table is not near the surface. Typically, solid wastes are placed in cells or trenches excavated in the soil. The soil excavated from the site is used for daily and final cover. The excavated cells or trenches are lined with synthetic membrane liners, low permeability clay, or a combination of the two to limit the movement of both landfill gases and leachate. Excavated cells are typically square, up to 1000 ft in width and length, with side slopes of 2:1 to 3:1.Trenches vary from 200 to 1000 ft in length, 3 to 10 ft in depth, and 15 to 50ft in width. A variation of this method is the artesian or zone of saturation landfill. These landfills are constructed below the naturally occurring groundwater table surface. Drainage systems control the entry of groundwater into the landfill cell. Both lined and unlined sites have been constructed using this method.

2.6.2 Area Method

The area method is used when the terrain is unsuitable for the excavation of cells or trenches in which to place the solid wastes (see Figure 2.6b). High groundwater conditions necessitate the use of area-type landfills. Site preparation includes the installation of a liner and leachate management system. Cover material must be hauled in by truck or earthmoving equipment from adjacent land or from borrow-pit areas. As noted, in locations with limited material that can be used as cover, compost produced from yard wastes and MSW, foundry sand, and auto Shredder fluff have been used successfully as intermediate cover material. Other techniques include the use of movable temporary cover materials such as soil and geosynthetics. Soil and geosynthetic blankets, placed temporarily over a completed cell, can be removed before the next lift is begun.

2.6.3 Canyon/Depression Method

Canyons, ravines, dry borrow pits, and quarries have been used for landfills (see Figure 2.6c). The techniques to place and compact solid wastes in canyon/depression landfills vary with the geometry of the site, the characteristics of the available cover material, the hydrology and geology of the site, the type of leachate and gas control facilities to be used, and the access to the site. Control of surface drainage often is a critical factor in the development of canyon/depression sites. Typically, filling starts at the head end of the canyon and ends at the mouth, so as to prevent the accumulation of water behind the landfill. Canyon/depression sites are filled in multiple lifts, and the method of operation is essentially the same as previously described. If a canyon floor is reasonably flat, the initial landfilling may be carried out using the excavated cell/trench method discussed previously.

j

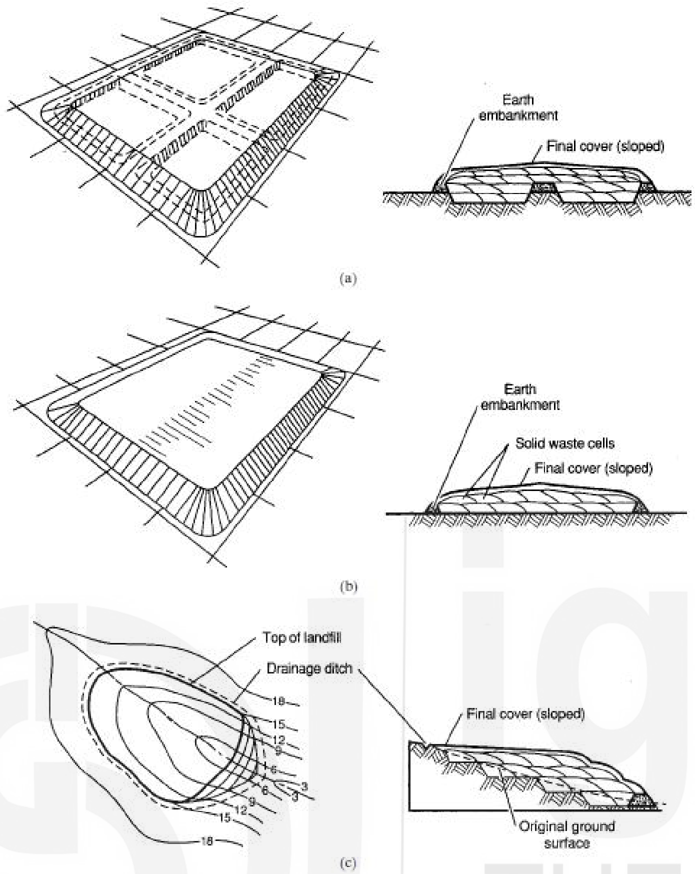

Figure 2.6: Commonly used landfilling methods:

(*a*) Excavated cell/trench (*b*) Area (*c*) Canyon/depression

2.7 OTHER TYPES OF LANDFILLS

Various other configurations of landfills are constructed to meet specialized objectives. These include construction and demolition waste landfills that receive only materials that are the result of tearing down buildings and removing roadways. Other specialized landfills are those associated with receiving high volumes of industrial waste such as that from paper mills, foundries, power plants, and mines. Each of these landfills has unique design considerations. The landfills may or may not contain all of the conventional design elements, depending upon the particular specialized nature of the waste. For example, a power plant ash landfill would not have a gas recovery system since no decomposition of waste is expected, given the fact that all organic matter had been removed during the combustion process. An emerging technology for more quickly stabilizing waste in conventional landfills is the bioreactor (Figure 2.7).

i

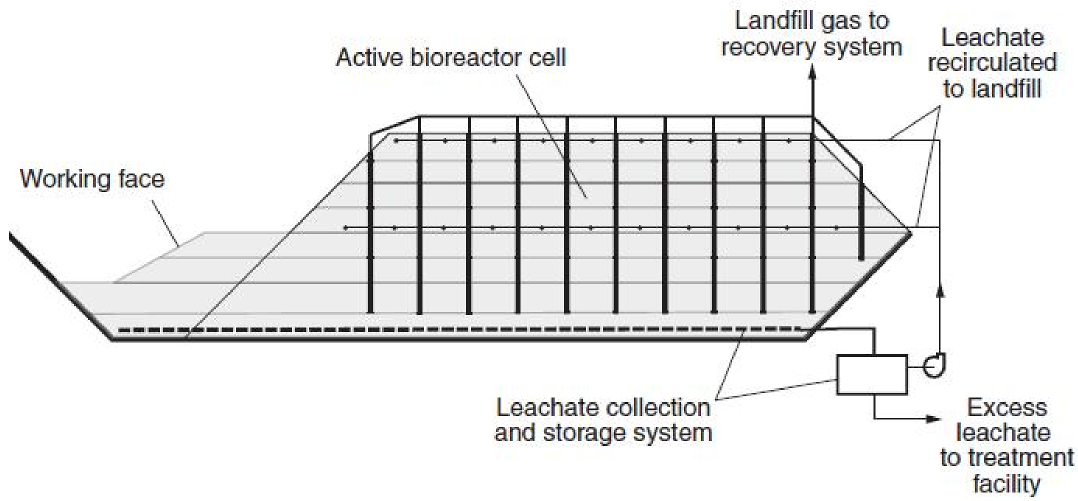

Figure 2.7: Bioreactor landfill with leachate recirculation and landfill gas recovery (Solid and Hazardous Waste Education Center, University of Wisconsin-Madison, 2000)

A bioreactor landfill is constructed and operated in a manner that will enhance the decomposition rate of the organic material within municipal solid waste. Operating procedures are adjusted from those used at conventional landfills to quickly initiate the decomposition of the waste. Gas collection facilities are installed immediately upon the construction of the landfill cell so that methane gas can be recovered. To accelerate the decomposition rate, the leachate withdrawn from the base of the landfill is recycled and, in addition, other sources of moisture, such as sewage sludge, may be added to the waste profile. Bioreactor landfills are being viewed as an option that will reduce the long-term care period of landfills after they are closed by quickly stabilizing the waste. In addition, some designs have as their goal reducing the waste volume to the maximum extent possible and in the shortest period of time so that more waste material can be disposed of on the original landfill site. The methods for lining and covering bioreactor landfills are still under consideration. Design issues that are currently being evaluated are those associated with slope stability, landfill liner leakage, methods for collecting landfill gas in a partially opened cell, and constructing leachate recirculation systems that will be effective in inclement weather and will minimize odor).

2.8 ECONOMIC ANALYSIS OF LANDFILLING

Five different components contribute to the landfilling cost- transportation of waste, land acquisition, landfill construction and operations, leachate management (collection and treatment) system and landfill gas (LFG) flaring system.

a) **Transportation of waste**: Only the cost associated with transport of waste to the landfill/dumpsite from different localities is considered. Operating and maintenance expenses constitute expenses on diesel, salaries and maintenance of trucks and are calculated annually. Each truck requires one driver and one helper.

j

b) **Land acquisition**: Land acquired cost should be calculated by multiplying total area and cost.

c) **Landfilling construction and operations**: Landfilling constitutes five components: site development, construction, facility operations and maintenance, facility closure and facility post-closure costs.

d) **Leachate management (collection and treatment):** Leachate contains organic matter, ammonia-nitrogen, heavy metals and chlorinated organic and inorganic salts and therefore, leachate management is important. Leachate system construction costs, which largely constitute liner costs, needs to be calculated.

e) **LFG flaring system**: It is assumed that the LFG is collected and flared. The economic analysis of such a flaring system is based on a pre-feasibility report of LFG recovery and flaring system.

SAQ

1 Explain the importance of sanitary landfill over landfill.

2 Explain the classification of sanitary landfilling based on sources of Solid waste.

3 Discuss the land fill liners and its classification.

2.9 SUMMARY

A sanitary landfill is an engineered facility on land designed for the final disposal of solid waste in a manner that minimizes the harm to the environment. Sanitary landfills are engineered operations, designed and operated according to acceptable standards as opposed to open dumps which are simply places to deposit waste. The sanitary landfilling operation involves numerous stages, including siting, design, operation, and closing. The biological, chemical and physical processes that occur within a dumpsite/landfill cause decomposition of waste.

2.10 KEY WORDS

Liner: Low permeable barrier, which is laid down under, engineered landfill sites.

Trench: A long narrow hole dug in the ground for water to flow along.

Canyon: A deep valley with very steep sides

Degradation: Act of lowering something or someone to a less respected state.

Remediation: Act of correcting something that has been corrupted or that is deficient.

2.11 ANSWERS TO SAQs

a) Refer Section 2.2

b) Refer Section 2.5

c) Refer Section 2.3.1

j