**Vision of the institute**

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

**Mission of the institute**

To keep pace with advancements in knowledge and make the students competitive and capable at the global level.

To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations to shine as torch bearer of tomorrow’s society.

To strive to attain ever-higher benchmarks of educational excellence.

**Vision of the Department**

The department will be recognised for its value based teaching, associated activities pertaining to research and entrepreneurship.

**Mission of the Department**

* To provide quality education through faculty and state of art infrastructure
* To identify the current problems in society pertaining to Civil Engineering disciplines and to address them effectively and efficiently
* To inculcate the habit of research and entrepreneurship in our graduates to address current infrastructure needs of society

**PEO’s**

**Graduates who complete their UG through our institute will be,**

**PEO 1**- Engaged in professional practices, such as construction, environmental, geotechnical, structural, transportation, water resource engineering by using technical, communication and management skills.

**PEO 2**- Engaged in higher studies and research activities in various civil engineering fields and life time commitment to learn ever changing technologies to satisfy increasing demand of sustainable infrastructural facilities.

**PEO 3**- Serve in a leadership position in any professional or community organization or local or state engineering board

**PEO 4**- Registered as professional engineer or developed a strong ability leading to professional licensure being an entrepreneur.

**PSO’s**

**PSO 1** – To apply science, mathematics and mechanics to solve problems in engineering realm

**PSO 2** – To analyse the techniques, skills and modern engineering tools necessary for engineering practices

**PSO 3** – To develop ability to function as a leader and a team player in multidisciplinary teams

**PSO 4** – To recognize of the need for and an ability to engage in research and life-long learning for developing sustainable construction practices

**PSO 5** – To design and conduct experiments as well as to analyse and interpret data

**Unit – 6**

**Sanitary Land Filling**

**Structure**

6.0 Introduction

6.1 Objectives

6.2 Types of Sanitary Land Filling

6.3 Site selection for sanitary landfill:

6.4 Advantages and disadvantages of the sanitary landfill

6.5 Reactions that take place inside a sanitary landfill

6.6 Leachate formation:

6.7 Landfill gas emission:

6.8 Design and construction

6.9 Geo-synthetic fabrics in sanitary land fill:

6.10 Assignment questions

6.11 Outcomes

6.12 further reading

**6.0 Introduction:**

The sanitary landfill is a technique for the final disposal of solid waste in the ground that causes no nuisance or danger to public health or safety; neither does it harm the environment during its operation or after its closure. This technique uses engineering principles to confine the waste to as small an area as possible, covering it daily with layers of earth and compacting it to reduce its volume. In addition, it anticipates the problems that could be caused by the liquids and gases produced by the decomposition of organic matter.

A modern sanitary landfill can be defined as a facility designed and operated as a basic sanitation project that has sufficiently safe elements of control, and the success of which lies in the selection of the suitable site, its design, and of course, its effective and efficient operation and control.

**6.1 Objectives**

1. Discuss the processes and stages involved in sanitary land filling, and use appropriate sanitary land filling technologies;
2. Identify its advantages and disadvantages
3. Assess the environmental effects of sanitary land filling
4. Develop and operate a sanitary land filling.

**6.2 Types of Sanitary Land Filling**

**Trench method:**

The trench method is used primarily on level ground, although it is also suitable for moderately sloping ground. In this method, trenches are constructed by making a shallow excavation and using the excavated material to form a ramp above the original ground. Solid waste is then methodically placed within the excavated area, compacted, and covered at the end of each day with previously excavated material. Because of the need to install landfill control measures (e.g., liners), a number of trenches are typically excavated at one time. Trenches are made 20 to 25 ft wide and at least twice as wide as any compacting equipment used. The depth of fill is determined by the established finished grade and depth to groundwater or rock. If trenches can be made deeper, more efficient use is made of the available land area.



**Area or Ramp method:**

On fairly flat and rolling terrain, area method can be utilized by using the existing natural slope of the land. The width and length of the fill slope are dependent on the nature of the terrain, the volume of solid waste delivered daily to the site, and the approximate number of trucks that will be unloading at the site at one time. Side slopes are 20 to 30 percent; width of fill strips and surface grades are controlled during operation by means of line poles and grade stakes. The working face should be kept as small as practical to take advantage of truck compaction, restrict dumping to a limited area, and avoid scattering of debris. In the area method, cover material is hauled in from a nearby stockpile or other source. The base of the landfill is established by the previously determined elevation of bedrock, groundwater, and bottom liners and leachate collection and removal systems.



**Valley or Ravine Area or Pit method:**

In valleys and ravines, the ravine method is usually the best method of operation. In those areas where the ravine is deep, the solid waste should be placed in ‘‘lifts’’ from the bottom up with a depth of 8 to 10 ft. Cover material is obtained from the sides of the ravine. It is not always desirable to extend the first lift the entire length of the ravine. It may be desirable to construct the first layer for a relatively short distance from the head of the ravine across its width. The length of this initial lift should be determined so that a one-year settlement can take place before the next lift is placed, although this is not essential if operation can be controlled carefully. Succeeding lifts are constructed by trucking solid waste over the first lift to the head of the ravine. When the final grade has been reached (with allowance for settlement), the lower lift can be extended and the process repeated. The bottom landfill liner and leachate collection and removal system must be designed carefully to ensure that slope stability of the liner system and the waste placed is adequately maintained.



**6.3 Site selection for sanitary landfill:**

The location and characteristics of the site will determine the extent and nature of the impact of a sanitary landfill on public health and the quality of the surrounding water, air, and land resources.

**Useful lifespan and area of site:**

Useful lifespan and area constitute the first of the factors and is determined by the following parameters: depth of the fill; quantity, rate of delivery, and characteristics of the solid waste; and operating practice. The site should be selected such that the useful life of the fill is sufficient to recover the capital investment. It is generally recommended that a landfill be designed for a useful lifespan of at least ten years. Determination of the size of the site must include two elements: gross area and useful fill area. Gross area is the total area within the property boundaries. Useful fill area excludes the area that will be taken up by buffers, access roads, and soil stockpiles. Useful fill area may be about 50% to 80% of the gross area.

**Topography:**

Topographic information is a basic requirement in the development of an adequate facility design and determination of the impact of the facility. A topographic map of the facility should have sufficient contour intervals to clearly indicate surface water flow patterns in the general area and in each operational landfill unit. Topographic maps are available from a number of sources, or they may need to be developed using any of a variety of land surveying methods. Useful information that may be recorded on the topographic map includes:

• The 100-yr flood plain area,

• Surface waters,

• Current land use patterns (nearest households),

• Water use wells,

• Monitoring wells, and

• Drainage or flood control barriers (dikes, levels).

Maps showing site topography before facility construction, during operation, and after closure should be prepared. All maps should be labelled with map scale, date, and orientation.

**Soils:**

The availability of soil of proper characteristics for the construction of bottom liners, of cover systems, or both is usually one of the more important considerations when analysing and selecting a landfill site. Important soil properties are: particle size distribution (gradation or texture); structure; strength; porosity; activity; depth; spatial distribution; quantity; liquefaction potential; relationships between moisture, density, and permeability; and workability.

**Hydrogeology:**

The potential to pollute the groundwater at the landfill depends, to a considerable extent, on the hydro-geological characteristics of the site, such as:

• Depths to groundwater,

• Nature and approximate thickness of water-bearing formations or aquifers near the landfill,

• Quality of the groundwater up gradient of the landfill,

• Site topography and soil type,

• Soil infiltration rates at the site,

• Effects of nearby pumping wells on groundwater beneath the site,

• Hydraulic conductivity and its distribution at and near the site,

• Depth and nature of bedrock,

• Horizontal and vertical components of groundwater gradients, and

• Groundwater velocity and direction.

**Physiographic setting:**

The physiographic setting is a combination of climate, topography, stream density, and geological structures. Climate plays an important role on the design and operation of a landfill because of its impact on the amount of rainwater that may infiltrate through the unsaturated zone and into a groundwater system. Degree of infiltration depends upon the amount of precipitation, volume of surface ponding and runoff, and the rate of evapotranspiration. Ambient temperature and relative humidity also have an impact on infiltration, evaporation, and evapotranspiration.

**Geology and soil characteristics:**

Knowledge of the geological structure and history of an area is needed to predict groundwater behavioural characteristics. If sedimentary units are present or suspected, knowledge of the depositional history of the region may reveal unsuspected discontinuities in apparently uniform units (e.g., permeable channel deposit in a low permeability unit). Permeability of the surrounding rocks and soils is an important factor in evaluating the suitability of an area as a potential site for a landfill. Although the primary permeability of a soil formation generally refers to groundwater inter granular flow (flow along the primary porosity), rate and direction of flow are controlled by the flow along fractures, joints, bedding planes, and solution cavities (secondary porosity). Secondary porosity may prevail when subsurface flow takes place in carbonate terrains, metamorphic and igneous rocks, and folded and faulted sedimentary rocks. Short circuiting may occur in situations in which secondary porosity is prevalent, inasmuch as low permeability (secondary porosity) is less an obstacle to contamination than is high permeability (primary porosity).

**Groundwater recharge:**

The potential for groundwater recharge to significant aquifers is one of the most important considerations in the evaluation of a potential landfill site. Areas of natural recharge must be avoided. Accordingly, the location of a site with respect to a regional groundwater flow system must be defined, particularly if the site is in or close to a primary recharge area.

**Vadose zone:**

The vadose zone is the zone that lies between the surface of the land and the principal water table. Although the vadose zone is generally known as the “unsaturated zone”, saturated regions may be found in some vadose zones. Examples of such regions are perched water tables and tension-saturated zones. Characteristics are less important in vadose zones in humid regions where the water table is shallow or in areas where fractured rock media occur near the ground surface. Among the physical, chemical, and microbiological characteristics of the vadose zone that have a bearing on the mobility, attenuation, or degradation of contaminants in the subsurface are:

• Mineralogy,

• Porosity,

• Organic matter content,

• Particle size distribution,

• Soil horizons and structure,

• Soil water characteristics,

• Temperature,

• Soil pH, and

• Availability of microorganisms.

**Vegetation:**

Vegetation of concern ranges from the native types growing at the site to types planted as a part of site preparation and maintenance. The types of vegetation include small trees, shrubbery, herbaceous annuals, perennials, and groundcovers. Trees and shrubs are planted to serve as a buffer; to reduce dust, noise, door, and visibility problems; and for site beautification. A groundcover reduces or even eliminates wind and rain erosion of the landfill cover, improves aesthetic quality, and enhances moisture removal by way of evapotranspiration. The amount of water removed through evapotranspiration is significant. A groundcover is especially important because of its role in ensuring the long-term stability and performance of the final landfill cover system.

**Site access and transport:**

The cost of transport of waste to a potential site should be an important consideration during the process of identifying a location for a disposal site. If this were the sole consideration, the optimum location would be one located at the centroid of the waste collection area. However, other considerations come into play, some of which may override the hauling cost consideration. One such consideration is the decline in availability of land due to the constantly strengthening competition exerted by other uses. Socio-political considerations and environmental concerns also are important elements of the site selection process. The competing considerations could be such that the siting of the fill may be so distant that a transfer station would be required.

The conditions of the roads leading to the landfill have an impact on the cost of the overall system. Poor access both delays travel and damages vehicles. Thus, access to the site should preferably be over paved roads or all-weather unpaved roads. In the case of the use of trailer trucks to transport the wastes, the roads, bridges, and similar structures should be adequately designed to support the loads.

**Economic considerations in site selection:**

The cost of cover materials depends in large part upon the availability of the materials. The cost would be minimal if the material could be obtained from the site itself. If not, then the purchase price of the material, plus the cost of transporting it to the site, could have a substantial effect on the total costs of disposal. The high cost associated with securing the cover material and transporting it to the site, in many cases, prevents many communities in economically developing countries from covering the wastes on a daily (or relatively frequent) basis. Hauling costs for transporting the wastes from the collection point to the landfill are a major consideration in selecting a landfill location. Obviously, the further the fill is from the centroid of the collection area, the greater the hauling costs. In fact, the distance between the site and the point of generation can be so great that the hauling costs exceed those of land and predevelopment.

**Climate conditions:**

The direction of the prevailing wind is important because of the nuisance caused by the unloading of waste, extraction of soil, and covering; papers and other light material in the waste are blown by the wind, dust is raised, and the wind can also carry noxious odours to neighbouring areas. Thus, the sanitary landfill should be located downwind from the urban area; otherwise, to counteract this nuisance trees and thick vegetation should be planted all around the landfill. The vegetation, in addition, acts as a screen to prevent the neighbours and passers-by from observing the MSW disposal operations and gives a more aesthetic appearance to the site. Rain is another vitally important factor; it is recommended that the records of rainfall and dry periods be obtained, in order to estimate the amount of water that falls on the area under study. National meteorological institutions or water and sewerage service companies can provide this information. Even when rainfall is expressed in mm/year, it is advisable to consult the monthly records of several years for the sizing of the perimeter drains and the leachate collection and disposal system.

**Ownership of the land:**

Work should start on a sanitary landfill project only when certain conditions are in place: when the municipality or town council has in its possession the legal document of land ownership; when the project has been authorized by the pertinent authorities; and also when it has been accepted by the majority of the community members, with awareness of its future use.

**Cost of the land and of the infrastructure works:**

Once the most appropriate sites have been pre-selected for the construction of the sanitary landfill, the priority is to find out who owns the property, whether it is for sale, or whether it can be negotiated, and —most important— the value of the land. It often happens that the owner will want to speculate with its value when he finds out about the municipality’s interest in purchasing the land. The mayor could resort to the legal remedy of “declaration of public purpose,” in which case the land will be valued at the rate recorded in the official land registers. Another aspect for consideration is the cost of the infrastructure for entering and preparing the terrain and making it ready to receive the town’s waste. It is always advisable to calculate the value of the works and compare it with the funds the municipality has at its disposal, to ensure that the project will not be abandoned in the future for lack of funds. If the investment required is too high and it appears to be beyond the reach of the municipality, it is better to look for another site.

**6.4 Advantages and disadvantages of the sanitary landfill**

**Advantages**

1. The initial capital investment is lower than that required to establish incineration plants or composting facilities for waste treatment.

2. It has lower operating and maintenance expenses than treatment methods.

3. A sanitary landfill is a complete and definitive method, given its capacity to receive every kind of MSW.

4. It creates employment for unskilled labour, which is available in abundance in developing countries.

5. Methane gas can be collected in sanitary landfills that receive more than 500 t/day, and this gas can be an alternative source of energy for some cities.

6. Its location can be as close to the urban area as the existence of available sites permits, which reduces hauling costs and facilitates supervision by the community.

7. It allows lands considered unproductive or marginal to be recuperated, making them useful for constructing parks, recreational facilities, green areas, etc.

8. A sanitary landfill can start operating in a short time as a waste elimination method.

9. It is considered flexible because it can receive greater additional quantities of waste with a small increase in personnel.

**Disadvantages**

1. The acquisition of the terrain is often a problem due to local inhabitants’ opposition to the selected site

· Lack of knowledge of the sanitary landfill technique.

· The term sanitary landfill is associated with the open dump.

· Citizens’ evident distrust of local administrations that do not guarantee the quality or the sustainability of the work.

· Legal problems regarding land registration.

2. The rapid process of urban growth that limits the amount of land available and makes it more expensive, the sanitary landfill to be located at a distance from the town.

3. The vulnerability of the quality of operation of the landfill and the high risk of its becoming an open dump, mainly because of a lack of political decision on the part of local governments to invest the necessary funds for its correct operation and maintenance.

4. The finished landfill is not recommended for building homes, schools, etc.

5. The restriction against building heavy infrastructure because of settling and sinking after the landfill is finished.

6. It is necessary to monitor the site after closure of the sanitary landfill, not only to check for negative environmental impacts, but also to prevent undue use of the site by the inhabitants.

7. It can cause a long term environmental impact if the necessary precautions are not taken in the selection of the site and if mitigation measures are not applied. In the case of large sanitary landfills, it is advisable to analyze the effects of vehicular traffic, in particular the trucks carrying the waste on the roads that converge on the site and that produce dust, noise and windblown litter. In the immediate neighbourhood the impact is produced by the liquids, gases and bad odours that can emanate from the landfill.

8. The properties or lands surrounding the sanitary landfill may be devalued.

9. Usually it cannot receive hazardous waste.

**6.5 Reactions that take place inside a sanitary landfill**

**Physical, chemical, and biological changes**

The MSW deposited in a sanitary landfill undergoes a series of physical, chemical, and biological changes that are simultaneous and interrelated. These changes are described below to give an idea of the internal processes that take place when the wastes are confined.

**Physical changes:**

The most important physical changes are those associated with the compacting of the MSW, the movement of gases within and outside the sanitary landfill, the intake of water and the movement of liquids in the interior and toward the substratum, and settling caused by the consolidation and decomposition of the organic matter present in the waste.

The movement of gases is of particular importance for the operational and maintenance control of the system. For example, when biogas is trapped, internal pressure can cause cracking of the cover and fissures. This condition allows rainwater to penetrate inside the sanitary landfill. This water, in turn, causes a greater production of gases and leaching, contributing to differential sinking and settling at the surface and the destabilization of the fill banks due to the greater weight of the mass of wastes.

**Chemical reactions:**

Chemical reactions that occur within the sanitary landfill and also in open garbage dumps include the dissolving and suspension of matter and products of biological conversion in the liquids that filter through the mass of MSW, the evaporation of chemical compounds and water, the adsorption of volatile organic compounds, and decomposition of organic compounds, and the reactions of oxidation-reduction that affect the dissolving of metals and metallic salts. (The significance of the decomposition of organic products is that these materials can be transported out of the sanitary landfill or out of the garbage dump with the leachates).

**Biological reactions:**

The most important biological reactions that occur in sanitary landfills are carried out by aerobic and anaerobic microorganisms, and are associated with the organic part of the MSW, which produces gases and leachates. The process of decomposition starts with the presence of oxygen (aerobic phase); once the waste is covered, the oxygen starts to be consumed by biological activity. During this phase the principal product is carbon dioxide. Once the oxygen is consumed, decomposition takes place without it (anaerobic phase): at this stage the organic matter is transformed into carbon dioxide, methane, and traces of ammonia and hydrogen sulphide.

**6.6 Leachate formation:**

Leachate can pollute both groundwater and surface water supplies. The degree of pollution will depend on local geology and hydrogeology, nature of waste and the proximity of susceptible receptors. Once groundwater is contaminated, it is very costly to clean it up. Landfills, therefore, undergo siting, design and construction procedures that control leachate migration.

**Composition and properties:**

Leachate comprises soluble components of waste and its degradation products enter water, as it percolates through the landfill. The amount of leachate generated depends on:

* Water availability;
* Landfill surface condition;
* Refuse state;
* Condition of surrounding strata.

The major factor, i.e., water availability, is affected by precipitation, surface runoff, waste decomposition and liquid waste disposal. The water balance equation for landfill requires negative or zero (“Lo”) so that no excess leachate is produced. This is calculated using the following formula:

Lo = I – E – a W

Where

Lo = free leachate retained at site;

I = total liquid input;

E = evapotranspiration losses;

a = absorption capacity of waste;

W = weight of waste disposed.

Common toxic components in leachate are ammonia and heavy metals, which can be hazardous even at low level, if they accumulate in the food chain. The presence of ammoniacal nitrogen means that leachate often has to be treated off-site before being discharged to a sewer, since there is no natural bio-chemical path for its removal. Leachate composition varies with time and location.

**Leachate migration**

It is generally difficult to predict the movement of escaped leachate accurately. The main controlling factors are the surrounding geology and hydrogeology. Escape to surface water may be relatively easy to control, but if it escapes to groundwater sources, it can be very difficult both to control and clean up. The degree of groundwater contamination is affected by physical, chemical and biological actions. The relative importance of each process may change, however, if the leachate moves from the landfill to the sub-surface region.

**Control**

The best way to control leachate is through prevention, which should be integral to the site design. In most cases, it is necessary to control liquid access, collection and treatment, all of which can be done using the following landfill liners:

**Natural liners:** These refer to compacted clay or shale, bitumen or soil sealants, etc., and are generally less permeable, resistant to chemical attack and have good sorption properties. They generally do not act as true containment barriers, because sometimes leachate migrates through them.

**Synthetic (geo-membrane) liners:** These are typically made up of high or medium density polyethylene and are generally less permeable, easy to install, relatively strong and have good deformation characteristics. They sometimes expand or shrink according to temperature and age.

**Treatment**

Concentrations of various substances occurring in leachate are too high to be discharged to surface water or into a sewer system. These concentrations, therefore, have to be reduced by removal, treatment or both. The various treatments of leachate include:

**Leachate recirculation**: It is one of the simplest forms of treatment. Recirculation of leachate reduces the hazardous nature of leachate and helps wet the waste, increasing its potential for biological degradation.

**Biological treatment:** This removes BOD, ammonia and suspended solids. Leachate from land filled waste can be readily degraded by biological means, due to high content of volatile fatty acids (VFAs). The common methods are aerated lagoons (i.e., special devices which enhance the aerobic processes of degradation of organic substances over the entire depth of the tank) and activated sludge process, which differs from aerated lagoons in that discharged sludge, is re-circulated and is often used for BOD and ammonia removal. While under conditions of low COD, rotating biological contactors (i.e., biomass is brought into contact with circular blades fixed to a common axle which is rotated) are very effective in removing ammonia. In an anaerobic treatment system, complex organic molecules are fermented in filter. The common types are anaerobic filters, anaerobic lagoon and digesters.

**Physicochemical treatment:** After biological degradation, effluents still contain significant concentrations of different substances. Physicochemical treatment processes could be installed to improve the leachate effluent quality. Some of these processes are flocculation-precipitation. Separation of the floc from water takes place by sedimentation, adsorption and reverse osmosis.

**6.7 Landfill gas emission:**

Landfill gas contains a high percentage of methane due to the anaerobic decomposition of organic matter, which can be utilised as a source of energy.

**Composition and properties:**

We can predict the amount and composition of the gas generated for different substrates, depending on the general anaerobic decomposition of wastes added. Climatic and environmental conditions also influence gas composition. Due to the heterogeneous nature of the landfill, some acid-phase anaerobic decomposition occurs along with the methanogenic decomposition. Since aerobic and acid-phase degradation give rise to carbon dioxide and not methane, there may be a higher carbon dioxide content in the gas generated than what would otherwise be expected. Furthermore, depending on the moisture distribution, some carbon dioxide goes into solution. This may appear to increase (artificially) the methane content of the gas measured in the landfill. A typical landfill gas contains a number of components such as the following, which tend to occur within a characteristic range:

**Methane:** This is a colourless, odourless and flammable gas with a density lighter than air, typically making up 50 – 60% of the landfill gas.

**Carbon dioxide:** This is a colourless, odourless and non-inflammable gas that is denser than air, typically accounting for 30 – 40%.

**Oxygen:** The flammability of methane depends on the percentage of oxygen. It is, therefore, important to control oxygen levels, where gas abstraction is undertaken.

**Nitrogen:** This is essentially inert and will have little effect, except to modify the explosive range of methane.

**Hazards**

Landfill gas consists of a mixture of flammable, asphyxiating and noxious gases and may be hazardous to health and safety, and hence the need for precautions. Some of the major hazards are listed below:

**Explosion and fire:** Methane is flammable in air within the range of 5 – 15% by volume, while hydrogen is flammable within the range of 4.1 – 7.5% (in the presence of oxygen) and potentially explosive. Fire, occurring within the waste, can be difficult to extinguish and can lead to unpredictable and uncontrolled subsidence as well as production of smoke and toxic fumes.

**Trace components:** These comprise mostly alkanes and alkenes, and their oxidation products such as aldehydes, alcohols and esters. Many of them are recognised as toxicants, when present in air at concentrations above occupational exposure standards.

**Global warming:** Known also as greenhouse effect, it is the warming of the earth’s atmosphere by the accumulation of gases (methane, carbon dioxide and chlorofluorocarbons) that absorbs reflected solar radiation.

**Migration**

During landfill development, most of the gas produced is vented to the atmosphere, provided the permeable intermediate cover has been used. While biological and chemical processes affect gas composition through methane oxidation, which converts methane to carbon dioxide, physical factors affect gas migration. The physical factors that affect gas migration include:

**Environmental conditions:** These affect the rate of degradation and gas pressure build up.

**Geophysical conditions:** These affect migration pathways. In the presence of fractured geological strata or a mineshaft, the gas may travel large distances, unless restricted by the water table.

**Climatic conditions:** Falling atmospheric pressure, rainfall and water infiltration rate affect landfill gas migration.

The proportion of void space in the ground, rather than permeability, determines the variability of gas emission. If the escape of landfill gas is controlled and proper extraction system is designed, this gas can be utilised as a source of energy. If landfill gas is not utilised, it should be burnt by means of flaring. However, landfill gas utilisation can save on the use of fossil fuels since its heating value is approximately 6 kWh/m3 and can be utilised in internal combustion engines for production of electricity and heat.

**Control:**

To control gas emission, it is necessary to control the following:

* Waste inputs (i.e., restrict the amount of organic waste).
* Processes within the waste (i.e., minimise moisture content to limit gas production).
* Migration process (i.e., provide physical barriers or vents to remove the gas from the site and reduce gas pressure). Note that since gas migration cannot be easily prevented, removal is often the preferred option. This is done by using vents (extraction wells) within the waste or stone filled vents, which are often placed around the periphery of the landfill site. Some of the gas collection systems include impermeable cap, granular material, collection pipes and treatment systems.

**Use of collected gas:**

Energy must be recovered from the collected landfill gas. If a landfill operator considers that landfill gas cannot be used at the landfill then they must demonstrate to the competent authority that, at that individual landfill, there are site-specific reasons why utilisation is not feasible.

Landfill operators should recover the maximum amount of energy from the landfill gas over the whole lifecycle of the landfill. The best available techniques should be applied. The following utilisation techniques have been applied successfully:

* Introduction of the treated methane into the gas mains
* Combined heat and power utilisation
* Direct use of the gas as a fuel
* Electricity generation

The most common form of recovering energy from landfill gas is to generate electricity by burning the gas in an engine. Whether the gas can be utilised in this manner will depend on the economics of energy market within individual Member States and the costs of exporting the electricity to the supply grid.

**Landfill operation issues:**

Once a potential site has been identified, an assessment of design aspects, including costs for civil works, begins. Important issues to be looked into in this regard are land requirements, types of wastes that are handled, evaluation of seepage potential, design of drainage and seepage control facilities, development of a general operation plan, design of solid waste filling plan and determination of equipment requirements.

**6.8 Design and construction**

The design and construction process involves site infrastructure, i.e., the position of the buildings, roads and facilities that are necessary to the efficient running of the site and site engineering, i.e., the basic engineering works needed to shape the site for the reception of wastes and to meet the technical requirements of the working plan. At the outset, however, the potential operator and the licensing authority should agree upon a working plan for the landfill. The disposal license includes the design, earthworks and procedures in the working plan.

**Processes involved in design and construction**

(i) **Site infrastructure:** The size, type and number of buildings required at a landfill depend on factors such as the level of waste input, the expected life of the site and environmental factors. Depending on the size and complexity of the landfill, buildings range from single portable cabins to big complexes. However, certain aspects such as the following are common:

* Need to comply with planning, building, fire, health and safety regulations and controls;
* Security and resistance to vandalism;
* Durability of service and the possible need to relocate accommodation during the lifetime of the site operations;
* Ease of cleaning and maintenance;
* Availability of services such as electricity, water, drainage and telecommunication.

Paying some attention to the appearance of the site entrance is necessary, as it influences the perception of the public about the landfill site. All landfill sites need to control and keep records of vehicles entering and leaving the site, and have a weighbridge to record waste input data, which can be analysed by a site control office. Note that at small sites, the site control office can be accommodated at the site itself.

(ii) **Earthworks:** Various features of landfill operations may require substantial earthworks, and therefore, the working plan must include earthworks to be carried out before wastes can be deposited. Details about earthworks gain significance, if artificial liners are to be installed, which involves grading the base and sides of the site (including construction of 25 slopes to drain leachate to the collection areas) and the formation of embankments. Material may also have to be placed in stockpiles for later use at the site. The cell method of operation requires the construction of cell walls. At some sites, it may be necessary to construct earth banks around the site perimeter to screen the landfill operations from the public. Trees or shrubs may then be planted on the banks to enhance the screening effect. The construction of roads leading to disposal sites also involves earthworks.

(iii) **Lining landfill sites:** Where the use of a liner is envisaged, the suitability of a site for lining should be evaluated at the site investigation stage. However, they should not be installed, until the site has been properly prepared. The area to be lined should be free of objects likely to cause physical damage to the liner, such as vegetation and hard rocks. If synthetic liner materials are used, a binding layer of suitable fine-grained material should be laid to support the liner. However, if the supporting layer consists of low permeable material (e.g., clay), the synthetic liner must be placed on top of this layer. A layer of similar fine-grained material with the thickness of 25 – 30 cm should also be laid above the liner to protect it from subsequent mechanical and environmental damage. During the early phase of operation, particular care should be taken to ensure that the traffic does not damage the liner. Monitoring the quality of groundwater close to the site is necessary to get the feedback on the performance of a liner.

(iv) **Leachate and landfill gas management:** The basic elements of the leachate collection system (i.e., drain pipes, drainage layers, collection pipes, sumps, etc.) must be installed immediately above the liner, before any waste is deposited. Particular care must also be taken to prevent the drain and collection pipes from settling. During landfill operations, waste cells are covered with soil to avoid additional contact between waste and the environment. The soil layers have to be sufficiently permeable to allow downward leachate transport. Landfill gas is not extracted before completion, which includes construction of final cover, of the waste body. Extraction wells (diameter 0.3 to 1.0 m) may be constructed during or after operation.

(v) **Landfill capping:** Capping is required to control and minimise leachate generation (by minimising water ingress into the landfill) and facilitate landfill gas control or collection (by installing a low permeability cap over the whole site). A cap may consist of natural (e.g., clay) or synthetic (e.g., poly-ethylene) material with thickness of at least 1 m. An uneven settlement of the waste may be a major cause of cap failure. Designs for capping should, therefore, include consideration of leachate and landfill gas collection wells or vents. For the cap to remain effective, it must be protected from agricultural machinery, drying and cracking, plant root penetration, burrowing animals and erosion.

**6.9 Geo-synthetic fabrics in sanitary land fill:**

A geo-membrane can be defined as a thin, flexible, continuous, fluid-impermeable synthetic or bituminous based product (GLR, 1993). Geo-membranes have been used extensively as effective lining system in several engineering-assignments like: heap leach pads ans tailings dams (mining engineering), leaking tanks (oil and chemical industry), aquaculture lining systems and sanitary landfills.

The main purpose of geo-membranes in a landfill lining system is to act as a fluid and gas barrier. In addition the geo-membrane for landfill capping systems should be capable of withstanding local differential settlement.

Two types of manufactured geo-membranes are: - synthetic geo-membrane, plastomeric (e. g. PVC-P, HDPE) or elastomeric (e. g. EPDM - bituminous geo-membranes, with oxidised tumens or bitumen modified by the introduction of polymers such as EVA or SBS.

**Composite liners**

As already mentioned, individual compacted clay liners and geo-membranes are rarely used. Instead composite geo-membrane/clay liners are used.

Composite liners may consist of a single or double composite liner. In either case the geo-membrane is nearly always placed above the clay, although other arrangements are also possible.

Calculated flow rates through the composite liner are typically at least 100 times less than through the geo-membrane or clay liner alone

**Geosynthetic clay liners**

A geosynthetic clay liner consists of a thin layer of clay (typically bentonite) sandwiched between two geotextiles or attached to a geo-membrane. The primary purpose of the geosynthetic component or components is to hold the bentonite together in a uniform layer and permit transportation and installation of the material without losing bentonite or altering the thickness of the bentonite.

The reason for the use of geosynthetic clay liners in capping systems is the existence of several deficiencies which make the long-term performance of a compacted clay liner questionable.

These problems can be summarizing as follows:

- Difficulties in compaction on a soft foundation (i. e. waste),

- Tendency to desiccation and cracking without adequate protection,

- Vulnerability to damage from freezing and compulsory protection from freezing by suitably thick layer of cover soil,

- Differential settlement of underlying compressible waste will cause cracking in compacted clay if tensile strains become excessive,

- Compacted clay liners are difficult to repair if they are damaged.

**6.10 Recommended Questions**

1. Explain the various factors to be considered in the selection of a site for a sanitary land fill
2. Explain area method and trench method of land filling techniques
3. Determine the landfill area required for municipality, with population 50000. Given that

1. Solid waste generation = 450g/p/d

2. Compacted density of landfill = 504 kg/m3

3. Average depth of compacted solid waste = 5m

**6.11 Outcomes**

1. Design of sanitary landfill plant
2. Explain methods of sanitary landfills

**6.12 Further Reading**

1. http://moud.gov.in/upload/uploadfiles/files/chap17(1).pdf
2. http://cpcb.nic.in/upload/NewItems/NewItem\_133\_MSW-REPORT.pdf
3. http://nptel.ac.in/courses/120108005/module4/lecture4.pdf