Sometimes, it is difficult to find soil of low permeability and the required compaction in the local area; in that case, demolition waste, compost produced from MSW, or old rugs can also be used for landfill cover.

Landfills for shredded waste: In this method the solid waste before sending to the land fill, the size of the waste is reduced by the shredding or milling process. The main advantage of shredding or milling process of waste is that the waste can be 35% compacted to greater density than normal municipal solid waste. This results in saving the area of the landfill in the localities where the cost of land is high. This method is generally adopted in developed countries such as the United States.

Monofills for specialized waste: The waste which cannot be combined with the mixed waste landfills for degradation, the monofills are used. The individual specialized waste can be such as ash from incineration plants, electronic waste etc. Sulphate odour is produced by the use of incinerator ash monofills for which a gas recovery system is required to control the emissions.

SAQ 1

a) What is the difference between dumping and landfill?

b) What are the types of landfills? Discuss each briefly?

Figure 12.2: Secured Landfill

12.3 SITE SELECTION

Landfill planning, siting and design are complex processes transferring understanding of the environmental issues of landfills and their technical features into a full-scale facility meeting the actual regional demands for landfill volume for a range of years. Landfills are usually planned and designed for a long period, often 10–30 years, in order to distribute the costs on a large volume of waste and to reduce the troublesome and politically sensitive process of siting a new landfill. A landfill usually is seen as an undesirable construction by the neighbouring community and often difficult to get approved. Proper planning, siting and design, including adequate consideration of the use of the area after closing of the landfill, are mandatory in obtaining public acceptance of a landfill.

Planning of a landfill involves:

Capacity needs: Define types and estimate quantity of waste to be land filled for the considered planning period.

Political framework: National and regional legislation defining classes of landfills and their minimum requirements.

Siting of a landfill involves

- Geographical and geological considerations: Identifying areas not suitable for landfills because of physical instability, flooding risks and the presence of protected ecological habitat.
- Physical planning: Paying attention to conflicting physical planning and zoning and to accessibility.
- Hydrogeological considerations: Assessing hydrological barriers and vulnerability to local surface water bodies and groundwater.
- Landscaping and capacity estimates: A preliminary landscaping of the landfill in order to make a first estimate of actual capacity of the site for landfilling.
- Selection of preferred site: Establish selection criteria and identify best option.
- Public involvement.
- Acquisition of land.

12.3.1 Landfill Planning

Landfill planning means to determine the need for landfill volume and to identify the main criteria to be used in siting and designing of landfills. This planning may take place on a national level focusing on the more strategic and political aspects of landfilling or on a regional level leading to the actual construction of a landfill. Modern landfills are engineered constructions with substantial investment cost, operational costs and long-term environmental and maintenance costs. Thus, it is desirable to distribute these costs on a large volume of waste and also preferably over a long period of years. Most modern landfills have a total capacity of 1–50 million m^3, with a few exceptions larger than 100 million m^3. Technical facilities may have lifetimes of 10 to 30 years suggesting that landfills from a technical–economical point of view should be designed for such long periods as well. This indicates that landfills preferably should receive annually in the range of 50,000 to 50, 00,000 m^3 of waste, which again suggest how big a region the landfill can serve. In contrast, in rural areas with simple landfill facilities and only few neighbours to the landfill, the annual amount of land filled waste may be low, governed by practicality rather than by engineering considerations. The need of landfill capacity is determined by the waste management system and how large a population that it serves. The amount of waste generated and the treatment and recycling schemes introduced determine the amount of waste that has to go to landfill. This includes wastes that go directly to landfill, wastes treated prior to landfilling and residues from other treatments. The latter could include ashes from incineration plants or sewage sludge from wastewater treatment plants. Since landfills are planned for long periods, the estimation of needed landfill capacity also must pay attention to current national and local waste management plans as well as possible future developments. This suggests that time phasing may provide vital flexibility.

12.3.2 Capacity Needs

The estimation of needed landfill capacity is based on:

- Number of waste generation units, e.g. population, industrial activity and the expected development over the planning period.
- Unit generation rates of all waste types and their development over time.
- Mass flows in the waste management system identifying the types and amounts of waste going to landfill.

- Conversion of mass of waste to be land filled to landfill volume needed.

Estimating the amount of waste going to landfill must be related to waste type at least in the early stages of the planning. In a modern landfill all waste types may not be land filled in the same landfill section. For example hazardous wastes, homogeneous industrial wastes and incineration ashes may be land filled separately or eventually routed to another landfill. When the decision has been made as to which types of landfills will be available at the actual site, the appropriate waste types provide the basis for estimating needed landfill capacity.

12.3.3 Political Framework

The facts that landfills historically have a bad reputation and that the cost of remediation of old uncontrolled dumps have been very high, have fostered much political focus on landfill permitting, which also affects the planning process. In several countries landfills have been categorized into classes defined by the waste they can receive and the technical and environmental requirements that they have to meet. There may be more that one class of a landfill on a specific site. In general the more complex or hazardous the waste is, the more restrictions are introduced in the siting and design of the landfill. Usually this also means that it is more difficult to obtain public acceptance. This suggests that the need for landfill capacity is determined paying attention to the classification introduced by legislation. While landfills traditionally have accepted a wide range of waste types, the landfill classification and the associated quality criteria introduced in many countries are changing the focus in the direction that the waste has to satisfy certain criteria in order to be land filled. The landfill no longer accepts anything that cannot be handled otherwise. The landfill sets certain criteria that the waste must meet to be land filled. This again may introduce additional treatment of the waste prior to landfilling, which in addition also may make other disposal schemes attractive. Through this process the landfill becomes an integrated part of the waste management system.

12.3.4 Landfill Siting

Landfill siting is a very complex process, which may involve a large number of factors and parties. Furthermore, conflicts can occur among criteria and among involved parties. Therefore, landfill siting needs articulated criteria, use of decision support tools and a multidisciplinary approach in order to consider the interests of all stakeholders. Main issues of this articulated procedure are

- Regulatory aspects on site selection.
- Identification and assessment of siting criteria.
- Establishment of site selection procedure and methodologies.
- Public participation strategies.

The procedure is usually a stepwise one often involving five steps

i. Identification of feasible locations of a landfill.
ii. Selection of the most promising candidate locations according to established criteria.
iii. Supplementary data collection on the candidate locations.
iv. Final selection of the preferred location.
v. Acquisition and legal approval of site.

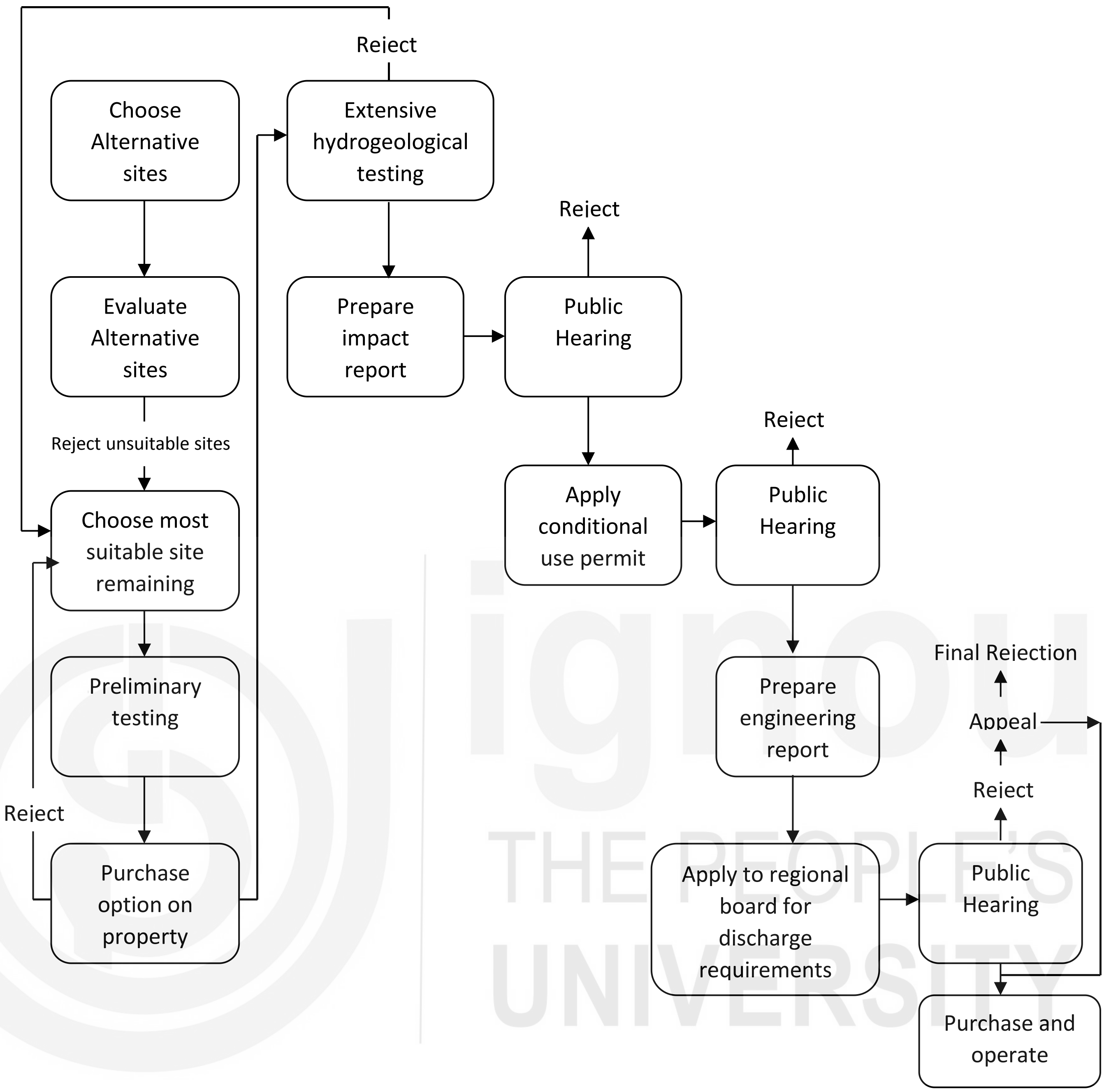


Figure 12.3: Steps required in the development of a sanitary landfill from site selection to final approval

The process may be iterative if no ideal candidates can be identified and criteria used early in the screening process may be modified to develop more alternative locations. In densely populated areas, however, the process may be very complicated because no site is close to ideal and many locations are politically infeasible.

The landfill siting is further discussed with respect to

i. Geographical and geological considerations.
ii. Physical planning.
iii. Hydrogeological considerations.
iv. Landscaping and capacity estimates.
v. Selection procedures.
vi. Public involvement.

12.3.5 Geographical and Geological Considerations

The locations of a landfill must allow the landfill to maintain its physical integrity until the waste is so stable that it can be considered of little harm to the environment. The location should have little vulnerability to any accidental migration of pollutants, and the construction and operation of the landfill should have no irreversible effects on land features outside the landfill boundaries. Therefore landfills should not be located in landscapes subjects to Landslides, Avalanches, Seismic activity, Flooding, Geotechnical instability, Habitats for protected or endangered species.

12.3.6 Physical Planning

As population densities grow, the pressure on the land resource increases and siting of a landfill must pay attention to this, including speculations on future development since the landfill will constitute a feature in the landscape for a century or maybe even longer. Considerations that often restrict the siting

- Distance to urban areas, in particular residential areas.
- Distance to recreational areas, nature reserves.
- Distance to historical sites.
- Distance to airports.
- Sensitive surface water bodies and wetlands.
- Sensitive drinking water infiltration areas.

The siting of landfill, however, would benefit from,

- Proximity to where the waste is generated.
- Proximity to transport facilities, usually roads but potentially also railroads and waterways.
- Proximity to supply lines for water and power as well as sewers.

12.3.7 Hydrogeological Considerations

The hydrogeological condition of a site is a main feature of the protection of the environment. The hydrogeology is also referred to as an important barrier between the landfill and the environment. The hydrogeological evaluation of a site aims at assessing water flows to the site and the potential migration of any leachate that may escape the leachate collection system. These evaluations can be based on existing geological data, borehole information on sediment type, water level and geophysical logs, geophysical surface-based mapping methods and local reconnaissance. The presence of a substantial unsaturated zone (>30 m between landfill bottom and the groundwater table) is considered important in providing attenuation capacity in case of leachate leakage. The hydrogeological conditions should be assessed in the first screening phase in order to rule out the most vulnerable locations. When the selection has been narrowed down to a few alternatives a more thorough evaluation may be advisable, likely including fieldwork on the site. Hydrogeological evaluations are always associated with significant uncertainty unless the data behind the evaluation comprise a dense grid of observations surrounding the actual site. The hydrogeological assessment of the top candidate sites should be performed by experts experienced with the local conditions.

12.3.8 Landscaping and Volume Estimation

The construction of a landfill will change the topography of the site for centuries. Shaping the final contours of the landfill will determine the future landscape. In densely populated areas this will be an important feature of the landfill and an attractive landscape, which even may add value to the community, may improve the public acceptance of the landfill. Active landscaping, involving recreational areas, golf courses and the like have been reported. Landscaping of the completed landfill should also reflect the future use of the land and fit with the features of the surrounding landscape.

Having established the preliminary contours of the completed landfill and assessed the volume obtainable by excavating or levelling off the bottom of the landfill, the overall volume of the site can be estimated. However, a coarse estimate of the volume of the site should be done at the screening stage, while a more detailed estimate must be done before final selection. This should include consideration of actual area to be filled, slope contours and volume of landscaping soil.

12.3.9 Selection Procedure

The selection procedure can be based on graphical representation of the region or on numerical schemes ranking potential sites. The two approaches address the same criteria and combinations of them can be applied.

Graphical procedures

Graphical procedures are based on illustration of the main features and criteria on a map of the region. This may be geographical and geological features as well as human-activity related features such as urban areas, recreational areas and roads. Probably, the first and most famous of these approaches is the land suitability analysis developed by Ian L. McHarg in 1969. He used overlay maps technique, where each feature is plotted on a map of the region by means of colours, different colour intensities across the map denote variation in fulfilling the criterion. So it is possible to identify the most suitable areas for landfilling and those that should be avoided, by superimposing all the thematic maps. The geographic information system (GIS), originating directly from the overlay maps, is widely used in computer aided decision support tool for site selection. These tools combine large amounts of geo-referenced data with other statistical information to assist in evaluating siting locations. Basically, complex sources of information, such as national survey maps, aerial or satellite images are dismantled into files of homogeneous elements that could be easily classified and stored in a database. Classification can relate to land cover, land use, topography, population density, waste generation, etc. Querying the database can generate thematic maps. These maps are then combined by means of Boolean functions that add or subtract these thematic features, or search for particular patterns. Again, the main output of this procedure is an image of region in digitized map, showing areas that are suitable for landfill siting and those unsuited.

Ranking procedures

Ranking procedures basically use similar criteria as the graphical procedures, but are most often used on a limited number of alternative siting locations subject to many criteria. Multi-criteria ranking procedures are based on the simple idea that complex problems can be divided into more manageable parts to be analysed and then reassembled into the final result. The most important advantages of these models are

- The decision maker does not need specific theoretical knowledge about the procedure.
- The procedure is direct and transparent and does not require sophisticated computer facilities.

- The results are particularly clear and simple making them suitable for communication with the public.

The procedure involves a two-dimensional matrix, named the performance matrix. The rows represent the alternatives and the columns are the factors by which the alternatives are judged. The elements of the matrix represent a standardized measurement of the decision maker's satisfaction with each alternative, in relation to the criteria. The relative priority of each criteria is also determined by means of weights that are associated to every factor. The most common approaches are based on direct assignation of weights, these weights multiply the satisfaction values of a specific alternative with respect to every criterion. Data are then aggregated by using simple calculation. As most of these models are based upon the utility theory, if the criteria have positive value, the more the score, the most suitable is the site.

Thus, site selection is performed by

- Assessing the relative importance of each regulatory constraint and that of each siting criterion.
- Assessing the performance of each area with respect to every regulatory constraint and site criterion.
- Combining all these values in final suitability scores.
- Ranking the sites with respect to these scores.

SAQ 2

a) What the stages for the selection of landfill site and write the steps involved in each stage?

b) What is selection procedure? What are different types of selection procedures involved?

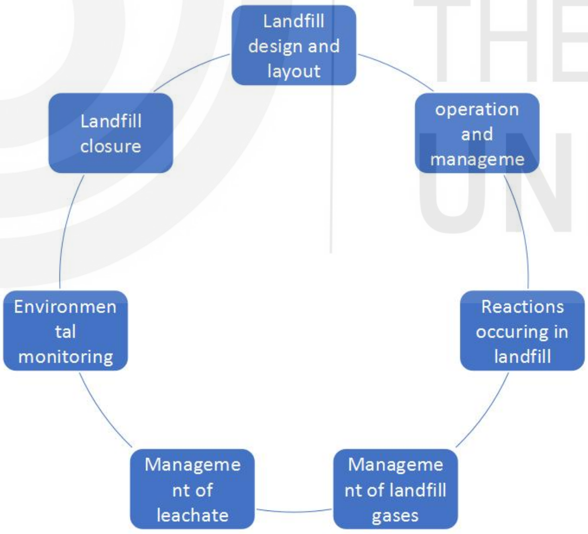


Figure 12.4: Principle elements of landfill planning, design, and operation.

12.4 DESIGN AND OPERATION OF LANDFILL

Design of a landfill involves

- Defining landfill classes and waste acceptance criteria.
- Landfill technology.
- Landscaping and final use.
- Layout of landfill and facilities.

- Capacity sectionizing (which types of waste to which section) and time-phasing.
- Earth works and soil balancing.
- Permits and authorization.

12.4.1 Defining Landfill Classes and Waste Acceptance Criteria

The first step in designing a landfill is to categorize the various waste types as to their landfilling compatibility, i.e. which waste goes to which class of landfill. It may not be practical to have many different landfill classes on a single site, because each class of landfill should have reasonable capacity to be practical to construct and to operate. Each class should also have separate leachate control systems and potentially also be different as to the landfill technology introduced. The classes of landfills on a site could include

- A landfill classified for inert waste and constructed and operated with a minimum of engineering.
- A landfill classified for inorganic waste and constructed and operated with engineering measures focused on control of leachate. This section could contain waste as for example inorganic industrial waste and incineration bottom ashes, but could also contain stabilized hazardous waste.
- A landfill classified for waste containing degradable organic matter and constructed and operated with engineering measures focused on gas as well as leachate control.
- A landfill classified for certain hazardous waste and with highly engineered control measures.
- A landfill classified for special wastes that according to regulations cannot be handled otherwise than by landfilling. This could be asbestos, impregnated wood or PVC waste.

Many countries have their own classification of landfills, while others only distinguish between municipal landfills receiving a mix of nonhazardous waste and hazardous waste landfills. Acceptance criteria must be developed for each of the landfill classes in order to ensure that only waste compatible with the landfill class are accepted. The criteria may, in addition to the distinguishing between hazardous and nonhazardous waste, include total contents of critical pollutants, content of organic carbon, methane potential, respiration potential, and leachability of selected substances. The relevant criteria will depend on national regulation. Acceptance of waste may also be based on positive lists of waste from specific sources.

12.4.2 Landfill Technology

The landfill technology must be defined for each of the classes of landfills at the site. National regulation often determines the minimum level of landfill technology in terms of liners, leachate collection, leachate treatment, gas collection and utilization and final cover.

For most of the landfill classes the range of technical options is limited although the actual solutions may vary. Two issues must in any case be assessed

i. The deeper the landfill, the slower the leaching: for a given water infiltration, a deep landfill will within a certain time period, e.g. 30 years, reach a lower liquid to solid ration than a shallow landfill, which means that the deep landfill has leached less of the leachable fraction of the waste at the end of the period. This may be an important aspects in determining the amount water to enter the landfill (landfill top covers that limit water infiltration or addition of water to enhance leaching) and in defining the life expectancy of the bottom line and leachate collection system.

ii. Landfills receiving organic waste may employ various technologies for enhancing methane generation, carbon degradation and removal of ammonia. These technologies include the bioreactor landfill, the flushing bioreactor and the semi-aerobic landfill.

Earthen Embankment (Soil bunds)

Purpose:

- Permanent bunds for Landfill base lining system
- Temporary bunds for landfill waste controlling system.

Machinery Required	Excavator or crawler tractor
Materials Required	Soil Water
Material Source	Local (Existing / Borrowed)
Tests Required	In-Situ moisture-density Atterberg Limits Grain-size distribution Laboratory moisture-density relationship Permeability Test reports

Figure 12.5: Landfill bund formation

The design & construction of an embankment needs to be built to ensure that an excess amount of surface runoff water doesn't enter the landfill site.

12.4.3 Landscaping and Final Use

An early step in landfill design is to define what the landfill most likely will be used for after its closure. Although the landfill may be active for 20–30 years the final use should receive some considerations, because the final use may define acceptable slopes, acceptable settlements and top cover quality for vegetation. Important issues are

Final slopes: The slopes most likely vary over the area, but should be planned so that surface runoff is easy and any local ponding of storm water is reduced to a minimum. Very steep slopes may limit the use of the site after closure, may be vulnerable to soil erosion and may cause instability for the vegetation.

Deep landfills which are filled fast will have the largest absolute settlements, which may be detrimental to constructions etc.

The final landscaping of the landfill should be designed to blend in with the countryside. The landscaped landfill surface constitutes the upper boundary of the landfill body and hence is an important parameter in calculating the landfill volume available at the site.

12.4.4 Layout of Landfill and Facilities

The physical layout of the landfill must be defined considering the area available and the final landscape. Only part of the area is used as actual fill area, the rest being occupied by facilities, such as buildings for offices, maintenance garage, leachate treatment facility, gas management facilities etc. The landfill may include also a public access area where private cars may deliver waste to the landfill. The infrastructure as well as the fill areas must be planned. In order to optimize investment costs the actual fill area is divided in sectors and the preparation of each sector is carried out at the moment the same sector is needed for waste deposition.

12.4.5 Capacity Sectioning and Time-phasing

For landfills with life times beyond 5 years it is often recommendable to divide each landfill class into sections providing volume for 2–5 years of landfilling and to develop the fill area and install bottom liners and leachate collection system as the sections are filled. This has potentially several benefits

- The investment costs are distributed in time, putting less pressure on the investment needs and on the cash flow.
- Avoid maintaining fill areas not in use and avoid collecting runoff from lined but not yet filled areas.
- Provides flexibility as to future needs for landfill volume.
- Provides flexibility if landfill technology develops or the official technical prescriptions change.

The area of each section should not be so small that instalment costs become too high or the landfilling operation become impractical. Depending on the design of the landfill it may not be possible to finish one section completely before starting to fill another section. This could be the case if access to one section passes over another section or if slopes and geotechnical stability require that adjacent sections rise sequentially. Therefore landfilling of a section may be subject to time-phasing. For example, the lower lifts of waste are put in over a period of maybe some months where after a temporary cover is established and vegetated until landfilling is continued on the same section, maybe two years later. Also the final cover and the final vegetation may be established in stages in order to improve the appearance of the landfill and stabilize slopes (vegetated slopes are less vulnerable to soil erosion than bare slopes).

12.4.6 Earth Works and Soil Balancing

The amount of soil necessary for daily and final cover must be accounted for in the design of the landfill. The refuse to soil ratio usually used in landfill for daily cover ranges from 2:1 to 5:1 on a volumetric basis. In general, refuse to soil ratio of 3:1 is used in planning for most of the site operations. Depending on the phasing requirements or final requirements and special cover requirements, these ratios can be modified.

Figure 12.6: Clay laying at base

The volume of the final cover can be estimated considering a minimum depth of 0.6 m and a maximum depth of 1.5 m. It is here important to remember that the soil takes up some of the landfill capacity. In addition the need for soil for embankment and for noise barriers must be estimated. Estimation of the volume required by the land fill and the soil volume is done after acquiring the basic data, and then the soil balance should be calculated. To optimize the design a series of trials and adjustments will be necessary. It is better to have material in excess quantity because import of soil and gravel may be very costly.

Anchor Trenches

Purpose: Anchoring of liners for Landfill Base and capping system

Machinery Required	Excavator Truck / Crawler Tractor
Materials Required	Soil
Material Sources	Local (Existing /Borrowed)

Figure 12.7: Anchor trench opening

Before start up the laying this task should be performed prior to the geo-membrane deployment the edges where the geo-membrane enters the trench should be free of irregularities, protrusions, etc. to avoid potential damage to the material. Backfilling of another trench shall be in accordance with specifications. Backfilling should occur when the Geo-membrane material is at its avoiding damaging the geo-synthetic during backfilling.

12.4.7 Permits and Authorization

The siting and operation of landfills are subject to legal restrictions and permitting procedures. The regulations are chiefly based on the concern for possible adverse impact of the landfills on human health and environment. The form this regulation takes is different in different regions of the world and also varies with the wastes to be land filled. For example there may be different rules for industrial waste and municipal waste. The generic permitting procedures include environmental impact assessments and the subsequent formulation of accepted impacts. The permit may also prescribe measures to be taken in order to limit emissions and impact on human health, including aftercare and monitoring. Permits or licences may also include contingency plans and provisions for future damages in the form of financial guarantees.

12.4.8 Landfill operation

The operation of landfill generally involves

- Moving equipments
- Waste filling sequences and placement methods
- Waste compaction
- Daily cover placement

In addition to this, aspects like safety and security, temporary road placement, storm water management and waste input control are taken into consideration. The effectiveness of the operation of landfill by placing the waste is followed by environmental procedures of controlling odours, noise, dust, litter, fire etc at the site.

The equipments that are used at the landfills are scrapers, excavators, crawler tractors, compactors, and motorgraders. Among these equipments the versatile one is the crawler tractor which is used to cover the soil and spread the waste simultaneously. It is also used for excavation where it is necessary where the cover soil is to be excavated from the location nearby or the source is a borrow pit. The tractors are also use to build the temporary roads after the preparation of landfill site and also used to compact the waste as well as the cover soil. The most used equipment globally is the compactors which are equipped with knobbed steel wheels and are aimed at compacting the waste in large amounts. The only drawback of using the compactors is, they are poor at hauling and excavating materials. So if the cover soil is to be excavated from the nearby location or from the borrow pits in the site, another equipment is required in addition. The type of equipment required and the number of the equipments required depends on the landfill requirements. The method of operation at the landfill also shows the requirements of the equipments. Budget constraints, climatic conditions etc are some factors that describe the requirement of the equipments of an individual landfill.

Figure 12.8: Drag line

Figure 12.9 Motor Grader

Figure 12.10: Landfill compactor

The following are the steps to be followed for effective landfill operation

- Isolate the fully constructed (ready to operate) portion of landfill from un-completed part of landfill by placing a temporary bund and anchor the High Dense Polyethylene (HDPE) liners of constructed portion of landfill in the bund.
- Prepare a ramp from the ground to the bed of landfill from uncompleted part of landfill.
- Approach the waste carrying vehicles near the temporary bund which is placed to isolate the fully built landfill with the un-completed one
- Drive the vehicle on top of the temporary bund and at least 1m away from the anchored HDPE liner.
- Unload the waste into the built landfill from the temporary bund and form a layer of atleast 1.5 to 2 m thick. Do not walk on the liner.
- Level the dumped waste using dozers maintaining the required thickness and compact the waste with dozer / roller to prepare a rigid pathway to approach into the landfill.
- Level the dumped waste using dozers maintaining the required thickness and compact the waste with dozer / roller to prepare a rigid pathway to approach into the landfill.
- Lead the vehicles into the landfill through the prepared pathway and continue dumping the waste to a thickness of 1.5 m.
- Place the soil cover every day after levelling and compacting.
- Mark the pegs all around the landfill at 10m intervals and mark capital alphabets on East – West bunds and small alphabets on North – South bund and consider 1.2 m as 1 layer.
- Consider 1.2 m thick and 10 m x 10 m area as 1 grid.
- Collect the lab advice from the truck driver and direct the vehicle to the desired point in the landfill for unloading.
- Record the grid no. and all other details.
- Doze/Level the material into the 0.3 to 0.5 m layer approximately and record the timings of machinery worked.
- Observe for any abnormalities like smoke or fumes.
- Place the daily cover in 10 to 15 cm layer over the waste at the end of the day.
- Compact the waste after daily cover using rollers, and record the timings of machinery worked.
- Cover completely with proper over laps during the monsoon season or when there is a forecast for rain.
- Observe vehicle movement in landfill area for avoiding accidents. (Ex. Excavators, dozers, waste carrying vehicles, tippers etc.)

- Restrict the entry of unauthorized into the Landfill operation area.

SAQ 3

a) What are the design parameters to be considered while planning the landfill?

b) What are the operational principles involved in landfills?

c) Draw the flow chart of design and operation of landfill in detail?

12.5 LEACHATE MANAGEMENT

Leachate is a specific wastewater with relatively variable composition. Leachate composition depends in principle on the composition of the land filled waste, but in practice the influence of landfill technology and more complex physical, chemical and biological processes. As a result, it may sometimes be difficult to predict leachate composition precisely. The rate of flow of leachate depends on the landfill conditions such as storage, infiltration and the climatic conditions such as evaporation, precipitation etc. During the filling period leachate production is highly variable and depends on the geometry of the landfill and the filling strategy. Therefore, accurate prediction of the leachate volume is only possible for completed sections of the landfill over longer periods of time like one year. Until 1990 the most important feature of leachate treatment was the reduction of biologically degradable components, such as biodegradable COD and nitrogen, using the simplest possible technologies. Gradually non-biodegradable organic substances such as the remaining COD and organic halogens became increasingly important. With the use of physical and chemical processes, treatment systems have changed in many cases to more sophisticated and technical systems. The continuing development of leachate treatment has not taken place in a logical manner, thus no single treatment process can be described universally as the best available technology, and instead, preferred processes in individual countries reflect the different approach that regulators have taken. This chapter describes the specific issues about leachate treatment and provides an introduction to the major treatment processes available for leachate treatment.

12.5.1 Leachate Treatment

Landfill leachate is a wastewater with complex characteristics. However, in most situations a few specific parameters are of most importance for the treatment processes. Other parameters are often only of limited importance for the environment or their concentrations are lower than required effluent discharge standards. Landfill leachate from the solid waste of municipalities is polluted mainly by nitrogen and organic materials. So to describe organic substances, in most cases the summarised parameter chemical oxygen demand (COD) is used. Many investigations to characterise organic substances in detail have been unsuccessful, because they comprise a very complex mixture. For many wastewaters the summarised parameter biochemical oxygen demand (BOD) is used to provide an indication of the biologically degradable portion of the COD. For leachate this is only useful if the relationship of BOD to COD is greater than 0.4. Then the degradable organic substances are in the region of 1.7–1.9 multiplies by the 5 day BOD value. At lower values of this relationship the biodegradable part of COD is greater than twice the BOD_5 value. In most instances the residual COD after biological treatment is relatively high, and can only be further reduced by chemical or physical treatment steps. In countries such as Germany, organic halogens comprise only a small specific proportion of overall organic substances, but may be an important parameter for leachate treatment. These components are often measured using the surrogate parameter of adsorbable organic halogens (AOX), although there is very little, if any, evidence to demonstrate any relationship between AOX values which is measured in mg/l and concentrations of hazardous organic compounds which is measured in µg/l. In most of the cases the environmental risk is due to nitrogen although the values of chemical oxygen demand are very high. Most of the nitrogen comprises ammonia (NH_3) and ammonium (NH_4^+) nitrogen and in many cases only this parameter is measured. Nevertheless, in some instances, significant concentrations of organic nitrogen can be measured, which have potential to be converted to ammonium in a biologically active environment. Heavy metal concentrations in most municipal solid waste landfill leachate are much lower than values found in household sewage, and rarely exceed specified discharge values, primarily because at these sites a high proportion of the metals are immobilised by the organic matter in the landfill. However, at landfills which receive increased proportions of inorganic wastes, such as incinerator ashes, heavy metals can become more important parameters. Similarly, organic micro pollutants, often defined as priority pollutants, are rarely of great importance for leachate treatment.

Figure 12.11: Leachate collection pipes (header 200mm + lateral 160mm)

However, with the reduction of organic waste in future landfills, they may become more important, because of less degradation and attenuation capacity when less organic waste is present in the landfill. Micro pollutants in terms of dioxins are considered a major problem in leachate from incineration slag and ash landfills. Leachate from incineration slag and ash landfills may contain high concentrations of chloride and sulphate. In most cases, other substances in such leachate are present at relatively low concentrations, and do not require specific treatment systems. However, at higher COD or nitrogen concentrations, their treatment often becomes a more serious problem. One solution may involve membrane separation, with additional evaporation or direct evaporation. Co-disposal of the concentrate from the process with municipal solid waste can result in serious problems as inorganic salts in leachate increase in concentration, where they can hinder treatment processes. Both parameters could become more important in the future, with the reduction of organic fractions in municipal solid wastes being land filled. Sulphur compounds are readily reduced to sulphide, and although this is readily removed from leachate in the presence of ferrous iron, where iron is lacking, free sulphide can be emitted to produce noxious odours and extremely toxic hydrogen sulphide concentrations. Sulphide concentrations in leachate can reach concentrations that are toxic to biological treatment processes. Leachate alkalinity is an important parameter for biological treatment processes, particularly for the buffering of acidity produced during the biological nitrification of ammoniacal-N. Changes in pH values and/or calcium–carbonic acid equilibrium can affect many treatment processes. The leachate flow depends on climatic conditions, the situation of the landfill, the surrounding strata, the type of waste, the water storage capacity of waste, landfilling techniques, the landfill operational conditions etc. For new landfills it is extremely difficult to estimate future leachate flow rates accurately. Only at existing landfills with flow measurements over a number of years can future leachate flow rates be estimated accurately, but often then only as an average value over a year or a season. For leachate treatment the daily flow rate is an important parameter, but can often only be estimated with a large element of uncertainty. As a consequence, the provision of raw leachate storage capacity, and the consideration of appropriate treatment process capacity are very important points.

12.5.2 Specific Problems in Leachate Treatment

Unlike the problems in the treatment of sewage, the treatment of leachate has three problems. They are

i. Change in the composition over time.
ii. Large flow variations.
iii. Potential changes with new landfill section because of changes in waste management.

12.5.3 Flow Variations

The large variations in the rate of flow of leachate depend on the uneven distribution of rainfall, climatic conditions and some other factors. So in order to control the influence of such variations, and to balance flow rates requiring to be treated, storage capacity for untreated leachate is required. The difficulties of flow rate estimation such as the long-term risk of treatment plants being overloaded or under loaded is great. If landfills receive an engineered capping layer after closure, then leachate flow generally decreases, depending on the type and quality of the liner system, and possible short or long term liner failures. Measurements at different closed landfills have shown that clay covers of up to 60 cm thickness, or normal soil cover up to more than 1 m, may not necessarily reduce leachate flow rates. But such cover systems can often produce more uniform leachate flow rates, although it is difficult to estimate the impact they do have.

12.5.3.1 Changes in Composition over Time

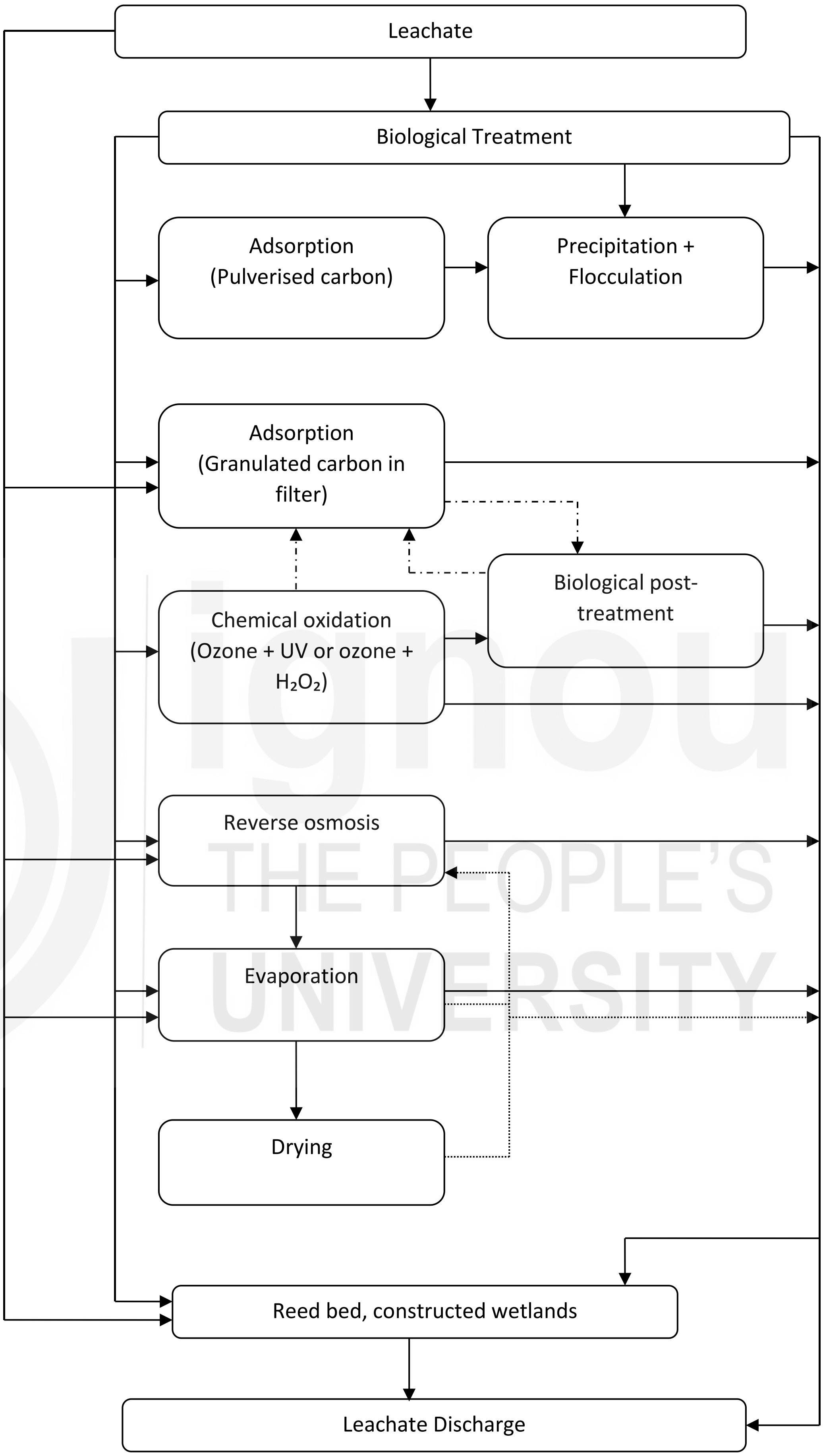
Unlike most other wastewaters, leachate quality changes over time at each landfill site. In the long term, over decades and centuries a slow but significant reduction of most components occurs. The reduction rate varies between parameters, and it may require 200–400 years before a direct discharge of leachate being produced can be accepted without a requirement for treatment. Critical parameters for most landfills are COD and ammoniacal-N. Additionally, the organic components of leachate change after some years of landfill operation, with a change in biological conditions within the waste body, from the more acidic phase to a more methanogenic phase. During this transition the concentration of COD decreases, but simultaneously the proportion of biodegradable organic substances decreases substantially. The resulting effect is a decrease in concentrations of organic substances, but an increase in the proportion of these that are not readily biodegradable. The rate and extent of this change depends on the landfill operational regime and inputs, and on the intensity of the initial acidic phase of decomposition.

12.5.3.2 Changes in Composition for New Landfill Sections

A number of changes in waste composition, and in landfill operation, can have significant effects on leachate quality. The composition of wastes being deposited not only has initial influences on leachate quality but also, together with the extent of compaction of wastes, affect the rates of flow of liquids through the landfill. Often the biological, chemical and physical processes are also affected, which will all influence leachate quality. The recycling of specific waste fractions such as paper, plastic, glass, metals, compostable organic substances, demolition wastes etc. will increasingly result in new types of landfill. But each of these new landfills will be the result of specific regional waste management conditions, and the influence of waste types remaining to be land filled will become more and more important. In the past, the total mixture of all types of waste in a landfill produced more uniform landfill types, with less variation in leachate quality between different sites. In future, landfills will change to become more specific, with very different leachate qualities and flow rates. With increasing separation, removal and pre-treatment of organic waste fractions from waste streams, in the future such effects will inevitably increase. As a result, inorganic leachate parameters will become more important, as problems for the existing treatment processes or in meeting required discharge limits. For example, heavy metals may not be immobilised by organic waste components, allowing concentrations to increase in the leachate. Another parameter likely to increase might be sulphide in leachate from such sites.

12.5.4 Leachate Treatment Processes

Until now leachate treatment development has responded to the major pollutants in leachate from municipal landfills, and to increases in environmental protection during recent decades. In the recent days the treatment of leachate has become complex due to the high restriction on the effluent standards.



-.-.-.- rare flow paths of adsorption and chemical oxidation processes

.... Possible routes of vapour sludge and other wastes, and the type of treatment process.

Figure 12.12: Flow chart of possible leachate treatment systems

12.5.4.1 On Site Leachate Treatment

To select an optimum on site leachate treatment system, not only treatment results and costs must be considered. Other important factors are production of Different leachate treatment processes consume different amounts of energy. Some processes require additional materials with associated variations in consumption of resources. All issues must be considered when choosing a leachate treatment process. For the removal of organic leachate contaminants, an important factor is the means by which these are removed. For oxidation processes such as biological or chemical oxidation, the organic compounds are oxidised to CO_2 . Other processes such as membrane separation or flocculation only separate the organic substances, and do not actually provide any breakdown of them. A third group of processes is represented by activated carbon, which is also primarily only a separation process, but has the benefit that during thermal reactivation of the carbon, the separated organic substances are also oxidised. These differences can be an important point to consider for the philosophy of leachate treatment. The first stage of any leachate treatment plant should be an adequate flow balancing system for raw leachate, which in some circumstances might involve temporary storage of leachate within the landfill itself. Experience has shown that very large volumes of external storage may be necessary, in order to adequately balance normal leachate flow variations over the course of a year, if the landfill cannot be used. Under the climatic conditions of central Europe, long periods of external storage, for example in open lagoons, during winter months, can rapidly cool leachate resulting in problems for subsequent biological treatment. As a consequence of the need to achieve specific discharge limits, the composition of effluents at most treatment plants is often determined in detail. But for the solution of leachate treatment problems it is also important to analyse raw leachate in detail. This is also necessary for parameters which are not affected by the treatment process, or which are not regulated by discharge consents. Such parameters include alkalinity, calcium, phosphorus, chloride, sulphate, etc.

12.5.4.2 Treatment Combined with Sewage Treatment

In the past, a very widespread option for leachate treatment has been co-treatment with domestic sewage in a biological treatment plant. With co-treatment, biologically degradable organic substances and nitrogen can generally be removed to the same extent as in an on-site biological leachate treatment plant. Normally, the quantity of leachate is not a problem for the sewage treatment plant but the overall load of contaminants, for example, kg/day ammoniacal-N, can be. Because of the very high concentrations of ammoniacal-N found in leachate, the addition of just a little leachate into a domestic sewer can result in a doubling or greater of the overall loading to the treatment plant. Flow balancing of leachate flows may be very important, and where possible, pumping of leachate during the night, when flows of sewage reduce, may be beneficial. After co-treatment there also remains the problem of non-biodegradable components. Remaining COD and AOX values may be reduced and low, but this is primarily as a result of dilution by the high sewage flow rate. Secondary treatment of the combined effluent to reduce COD and AOX is less effective and very expensive, as a consequence of the large dilution. However, co-treatment can provide a solution able to handle high leachate flow rates which could not be treated efficiently by an on-site plant, in circumstances where the sewage treatment works has adequate spare capacity. Potentially also the combination of some on-site treatment of leachate followed by discharge to a municipal sewage treatment facility could be attractive, but this would in most cases suggest that a significant fraction of nitrogen is removed on site prior to discharge to the sewage treatment plant.

12.5.5 Biogas Recovery from Landfill

Landfill gas is produced by the decomposition of biodegradable wastes present inside landfill sites. Based on the type of waste and the time that is exposed after discharge, the gas composition varies accordingly. The composition and quantity of the landfill gas emitted from a landfill are variable over both the short and long term. The typical composition of landfill gas is 35% carbon dioxide and 65% methane by volume. It consists of trace quantities of vapours and organic gases that are harmful to animals and humans. As a result, there are concerns about its unconstrained release and migration. At present the focus is towards burning the landfill gas for heating and generation of power since it has high calorific value. The aim of burning landfill gas is to alter the adverse environmental impacts, odour nuisance, health hazard and safe disposal of the flammable constituents. Proper attention should be given to achieve the effective destruction of harmful gases while flaring; this will reduce the environmental impacts and health risks associated with combustion products. Landfills are a potential source of greenhouse gases and contribute about 22% of methane emissions worldwide, depending on the period considered. In any period, all phases of degradation can be found in a landfill due to the continuous accumulation of solid waste landfill. The rate of the decomposition process depends on local conditions such as climate, temperature, and waste composition. Anaerobic activities inhibit decomposition due to the presence of air inside the landfill; this results in the combustion of waste present inside the landfill and affects the proportion and landfill gas generation. Also, variations in atmospheric pressure also influence the air content inside the landfill. The profile of landfill gas varies from place to place, around 50–200 components are found at trace-level concentration. Approximately 350 minor constituents are estimated in landfill gas, most of them are organic in nature. Inorganic constituents include hydrogen sulphide in significant levels and volatile metallic compounds, ammonia mercury in trace amounts.

SAQ 4

a) What are the objectives of leachate management?

b) Write the problems involved in treating the leachate?

c) How the biogas can be extracted from the landfills? Explain any two solutions to manage the biogas obtained from landfills without effecting the environment?

12. 6 SUMMARY

In this unit the discussion was on the types of landfills, Landfill planning, siting and design. i.e. various steps involved in the planning and selection of the landfill site. Principle elements in the landfill design and various equipment used at the landfill site are also discussed. Subsequently, the operation of landfill and the leachate management from the landfill i.e. on site leachate treatment techniques were discussed.

12.7 KEYWORDS AND DISCTRIPTION

Keywords	Meaning / Definition
Refused derived fuel (RDF)	Fuel is produced from various types of solid waste.
Hydrogeology	Area that deals with the distribution and movement of groundwater.
Leachate	Contaminated liquid that drains from a landfill.

12.8 REFERENCES AND FURTHER READINGS

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SMART CITIES: SAFE WATER, SANITATION AND SUSTAINABILITY

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Unit 1 : Clean and Safe Drinking Water
Unit 2 : Water Management for Smart Cities
Unit 3 : Smart Monitoring of Water Supply in Smart Cities
Unit 4 : Water Treatment for Smart Cities

BLOCK 2 : *SANITATION, SEWERAGE SYSTEMS FOR SMART CITIES*

Unit 5 : Physical Infrastructure for Sewerage Systems
Unit 6 : Sources and Flow Rates of Sewage
Unit 7 : Design Considerations for Sewerage Systems
Unit 8 : Waste Water Treatment

BLOCK 3 : *SOLID WASTE MANAGEMENT IN SMART CITIES*

Unit 9 : Solid Waste in Smart Cities
Unit 10 : Physical Infrastructure for Solid Waste Management
Unit 11 : Solid Waste Management and Waste to Energy
Unit 12 : Engineering Disposal

BLOCK 4 : *VALUE ADDED PRODUCTS: A ROAD TO SUSTAINABLE SMARTCITIES*

Unit 13 : Value Added Products
Unit 14 : Various Emerging Value Added Products
Unit 15 : Value Added Products from Organic Residues

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