DIFFERENT METHODS OF DISPOSAL AND MANAGEMENT OF SOLID WASTES

Disposal is the final element in the SWM system. It is the ultimate fate of all solid wastes. It is, therefore, imperative to have a proper plan in place for safe disposal of solid wastes, which involves appropriate handling of residual matter after solid wastes have been processed and the recovery of conversion products/energy has been achieved. It follows that an efficient SWM system must provide an environmentally sound disposal option for waste that cannot be reduced, recycled, composted, combusted, or processed further.

DISPOSAL METHODS

A. Uncontrolled Dumping or Non-Engineered Disposal

This is the most common method being practised in many parts of the world, including India. In this method, wastes are dumped at a designated site without any environmental control. They tend to remain there for a long period of time, pose health risks and cause environmental degradation. Due to the adverse health and environmental impact associated with it, the non-engineered disposal is not considered a viable and safe option.

B. Sanitary Land Filing

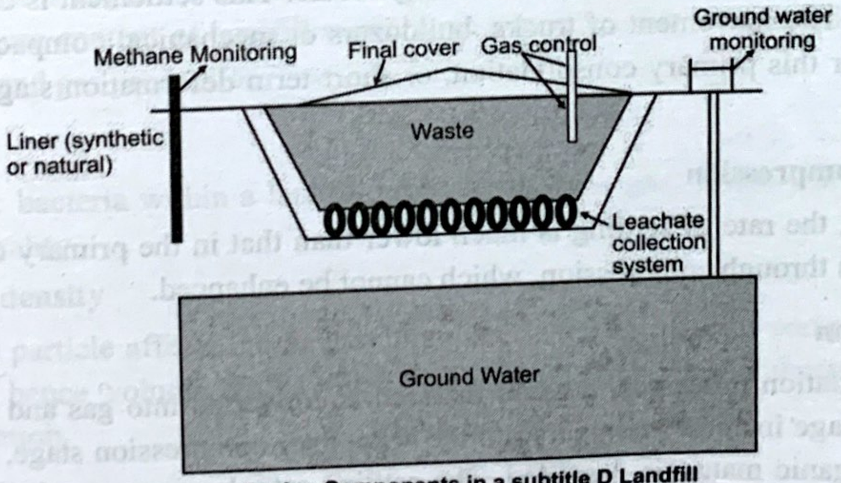
Land filling is the most common and economic method of solid waste disposal in many countries. Disposing solid wastes into "town dump" generally used to be in a low-ling area near a watercourse. This unsanitary dumping of the waste used to result in water pollution, bad odours, blowing papers, fires, flies, rats, etc. These problems are mostly reduced by burial of the waste. Further improvement was achieved by compacting the waste in layers and covering it with earth at the end of the disposal of the waste every day. In order to distinguish from the earlier practice of unsanitary "open dump", this method is called "sanitary landfill". Although compacting and covering still continue to be the basic operations today, several further improvements in the process have taken place during recent years. These include careful and scientific site selection, controlled deposition, better method of compaction, reduced cover, leachate collection to avoid water pollution and site monitoring to ensure environmental protection.

The four minimum requirements you need to consider for a sanitary landfill are:

- Full or partial hydrological isolation;
- Formal engineering preparation;
- Permanent control;
- Planned waste emplacement and covering.

Principle

The purpose of land filling is to bury or alter the chemical composition of the wastes so that they do not pose any threat to the environment or public health. Landfills are not homogeneous and are usually made up of cells in which a discrete volume of waste is kept isolated from adjacent waste cells by a suitable barrier. The barriers between cells generally consist of a layer of natural soil (*i.e.*, clay), which restricts downward or lateral escape of the waste constituents or leachate.



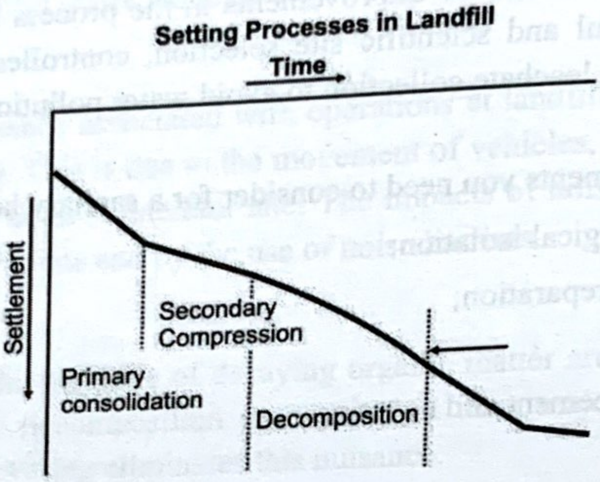
Design Components in a subtitle D Landfill

Land filling relies on containment rather than treatment (for control) of wastes. If properly executed, it is a safer and cheaper method than incineration. An environmentally sound sanitary landfill comprises appropriate liners for protection of the groundwater (from contaminated leachate), run-off controls, leachate collection and treatment, monitoring wells and appropriate final cover design (Phelps, 1995). Figure below gives a schematic layout of sanitary landfill along with its various components:

Landfill processes

1. Site selection process and considerations

This requires the development of a working plan, outlining the development and descriptions of site location, operation, engineering and site restoration. Considerations for site include public opinion, traffic patterns and congestion, climate, zoning requirements, availability of cover material and liner as well, high trees or buffer in the site perimeter, historic buildings, and endangered species, wetlands, and site land environmental factors, speed limits, under pass limitations, load limits on roadways, bridge capacities, and proximity of major roadways, haul distance, hydrology and detours.


Setting Processes in Landfill

2. Settling process

The waste body of a landfill undergoes different stages of settling or deformation. Figure below illustrates three stages:

(i) Primary consolidation

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

(ii) Secondary compression

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

(iii) Decomposition

During the degradation processes, organic material is converted into gas and leachate. The settling rate during this stage increases compared to the secondary compression stage, and continue until all decomposable organic matter is degraded. The settling rate, however, gradually decreases with the passage of time.

3. Microbial degradation process

The microbial degradation process is the most important biological process occurring in a landfill. These processes induce changes in the chemical and physical environment within the waste body, which determine the quality of leachate and both the quality and quantity of landfill gas. Assuming that landfills mostly receive organic wastes, microbial processes will dominate the stabilisation of the waste and therefore govern landfill gas generation and leachate composition. Soon after disposal, the predominant part of the wastes becomes anaerobic, and the bacteria will start degrading the solid organic carbon, eventually to produce carbon dioxide and methane. The anaerobic degradation process undergoes the following stages:

(i) Solid and complex dissolved organic compounds are hydrolysed and fermented by the fermenters primarily to volatile fatty acids, alcohols, hydrogen and carbon dioxide.

(ii) An acidogenic group of bacteria converts the products of the first stage to acetic acid, hydrogen and carbon dioxide.

(iii) Methanogenic bacteria convert acetic acid to methane and carbon dioxide and hydrogenophilic bacteria convert hydrogen and carbon dioxide to methane.

(iv) The biotic factors that affect methane formation in the landfill are pH, alkalinity, nutrients, temperature, oxygen and moisture content.

Landfill gas and leachate

Leachate and landfill gas comprise the major hazards associated with a landfill. While leachate may contaminate the surrounding land and water, landfill gas can be toxic and lead to global warming and explosion leading to human catastrophe. The factors, which affect the production of leachate and landfill gas, are the following:

1. **Nature of waste**

   The deposition of waste containing biodegradable matter invariably leads to the production of gas and leachate, and the amount depends on the content of biodegradable material in the waste.

2. **Moisture content**

   Most micro-organisms require a minimum of approximately 12% (by weight) moisture for growth, and thus the moisture content of landfill waste is an important factor in determining the amount and extent of leachate and gas production.

3. **pH**

   The methanogenic bacteria within a landfill produce methane gas, which will grow only at low pH range around neutrality.

4. **Particle size and density**

   The size of waste particle affects the density that can be achieved upon compaction and affects the surface area and hence volume. Both affect moisture absorption and therefore are potential for biological degradation.

5. **Temperature**

   An increase in temperature tends to increase gas production. The temperature affects the microbial activity to the extent that it is possible to segregate bacteria, according to their optimum temperature operating conditions.

Landfill gas composition

A typical landfill gas contains a number of components such as the following, which tend to occur within a characteristic range:

1. **Methane:** This is a colourless, odourless and flammable gas with a density lighter than air, typically making up 50- 60% of the landfill gas.
2. **Carbon dioxide:** This is a colourless, odourless and non-inflammable gas that is denser than air, typically accounting for 30-40%.
3. **Oxygen:** The flammability of methane depends on the percentage of oxygen. It is, therefore, important to control oxygen levels, where gas abstraction is undertaken.
4. **Nitrogen:** This is essentially inert and will have little effect, except to modify the explosive range of methane.

Leachate composition

Leachate composition varies with time and location. Following table shows a typical leachate properties and composition at various stages of waste decomposition:

Properties and Composition of Leachate at Various Stages of Decomposition (mg/l except pH)

Components	Fresh Wastes	Aged Wastes	Wastes with high moisture
pH	6.2	7.5	8.0
COD	23800	1160	1500
BOD	11900	260	500
TOC	8000	465	450
Volatile acid (as C)	5688	5	12
NH_3-N	790	370	1000
NO_3-N	3	1	1.0
Ortho-P	0.73	1.4	1.0
Cl	1315	2080	1390
Na	9601	300	1900
Mg	252	185	186
K	780	590	570
Ca	1820	250	158
Mn	27	2.1	0.05
Fe	540	23	2.0
Cu	0.12	0.03	-
Zn	21.5	0.4	0.5
Pb	0.40	0.14	-

Control of leachate

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.

a) **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.

b) **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.

Note that natural and geo-membrane liners are often combined to enhance the overall efficiency of the containment system. Some of the leachate collection systems include impermeable liner, granular material, collection piping, leachate storage tank; leachate is trucked to a wastewater treatment facility.

Treatment of leachate

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:

1. **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.

2. **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 recirculated 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.

3. **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. (Note that addition of chemicals to the water attracts the metal by floc formation). Separation of the floc from water takes place by sedimentation, adsorption and reverse osmosis.

ENVIRONMENTAL EFFECTS OF LANDFILL

Some of the major environmental effects are

(i) Wind-blown litter and dust are continuous problems of the ongoing landfill operation and a nuisance to the neighbourhood. Covering the waste cells with soil and spraying water on dirt roads and waste in dry periods, in combination with fencing and movable screens, may minimise the problem of wind-blown litter and dust. However, note that the problem will remain at the tipping front of the landfill.

(ii) Movement of waste collection vehicles, emptying of wastes from them, compactors, earthmoving equipment, etc., produce noise. Improving the technical capability of the equipment, surrounding the fill area with soil embankments and plantations, limiting the working hours and appropriately training the workforce will help minimise noise pollution.

(iii) Birds (e.g., scavengers), vermin, insects and animals are attracted to the landfill for feeding and breeding. Since many of these may act as disease vectors, their presence is a potential health problem.

(iv) Surface run-off, which has been in contact with the land filled waste, may be a problem in areas of intense rainfall. If not controlled, heavily polluted run-off may enter directly into creeks and streams. Careful design and maintenance of surface drains and ditches, together with a final soil cover on completed landfill sections, can help eliminate this problem.

(v) An operating landfill, where equipment and waste are exposed, appears inaesthetic. This problem may be reduced by careful design of screening soil embankments, plantings, rapid covering and re-vegetation of filled sections.

(vi) Gas released, as a result of degradation or volatilisation of waste components, causes odour, flammability, health problems and damage of the vegetation (due to oxygen depletion in the root zone). The measures to control this include liners, soil covers, passive venting or active extraction of gas for treatment before discharge into the atmosphere.

(vii) Polluted leachate appears shortly after disposal of the waste. This may cause groundwater pollution and pollution of streams through sub-surface migration. Liners, drainage collection, treatment of leachate, and groundwater and downstream water quality monitoring are necessary to control this problem.

4. Composting

Composting is the aerobic and thermophillic decomposition of organic matter present in the refuse by microorganisms, primarily bacteria and fungi. The organic matter is transformed into stable humus like substance during this process. The reactions taking please during composting generate heat and hence the compost temperature rises during the process. Depending upon the composition and nature of the waste, the volume is reduced by about 30 to 60%.

For an optimum composting operation, the following control parameters are usually adhered to:

Temperature	40 to 50 °C (If the temperature goes beyond 66 °C, biological activity will be reduced)
pH	4.5 to 9.5 (It is better to maintain pH below 8.5 to minimize the loss of nitrogen in the form of ammonia as gas).
Moisture	40 to 70% (The optimum value is about 55%).
Particle size	0.63 to 2.54 cm
Air	0.5 to 0.8 m^3 /day/kg of volatile compost solids
Carbon to Nitrogen Ratio	(35 to 50) : 1
Carbon to Phosphorus ratio	100 : 1

Composting may be carried out naturally under controlled condition or in mechanized composting plants. In natural systems the garbage (which is ground after removing glass and metallic materials) is mixed with a nutrient source (e.g., wood chips or ground corn cobs) which permits, is kept in windrows having a width of about 2.5m. The mixture is turned over twice a week. Within about 4 to 6 weeks, the temperature falls, the colour darkens and a musty odour develops. This indicates completion of the process. The filler may then be removed and the remaining humus-like material is used as soil conditioner. With mechanical systems, the composting time is reducing to half of that required in natural systems, because of continuous aeration and mixing. The composting process usually consists of the following three steps:

a) **Waste preparation**

The solid waste is placed on slow moving conveyor belt. Materials like corrugated paper are hand is hand-picked and then the ferrous materials are removed by magnetic separation. The waste is then ground in hammer mills or wet pulpers to the desires size range separation. The waste is then ground in hammer mills or wet pulpers to the desires size range (0.6 to 2.5 cm). Then it is mixed with nutrient source, filler and water (to provide 50 % moisture).

b) **Digestion**

The mixture is placed in the windrows for 6 weeks, while turning it once or twice a week. The waste is decomposed by thermophillic micro-organisms during this period. The material is then allowed to stabilize for another 2 to 5 weeks.

c) **Product up gradation**

In order to ensure quick and better marketing prospects, the product is sometimes upgraded by operations such as curing, grinding, and screening, palletising and bagging.

In Western Europe, Japan, Israel and Third-World countries which are committed to land reclamation, many successful composting plants have been operating for several years. India has made considerable progress in organizing compost plants in cities like Bombay, Baroda Calcutta, Nagpur, Delhi, Bangalore and Ahmadabad, Mechanical Compost plants are encouraged by the government in our country as a national programme. The national Research Development Corporation is now I a position to offer the India know-how to other countries. The agricultural research institutes of our country are developing the technology to produce blue green algae coated granulated compost.

C. Thermal processes

The important thermal processes used in solid waste treatment are incineration and pyrolysis.

a) Incineration

In this process, the solid organic wastes are subjected to controlled combustion so as to convert them into incombustible and gaseous products. Incineration process is considered when suitable site for land filling is not within economic haul distance from the sources of solid wastes.

Advantages of Incineration

- The volume of the waste s reduced to more manageable levels thereby reducing the transportation costs to the ultimate disposal site.
- Waste from a bigger community of people can be accommodated for a given acreage available for a landfill. Incineration reduces the land requirement to one-third of that required if the refuse is to land filled.
- The residue after incineration. If properly carried out. Is free from any degradable materials and hence is no longer a source of pollution moreover, the stabilized residue thus produced, minimizes or even eliminates the need to transport the cover material to the landfill site.

Disadvantages of Incineration

- High capital and operation costs.
- The possibility of air pollution if not carried out properly.
- Ordinary incinerators cannot be used for radioactive wastes.

Successful incineration process involves the following steps:

- Handling and feeding the wasted to the incinerator.
- Combustion of the waste within the incinerator.
- Removal of the gaseous and gas-borne residues.

The design of the waste to an incinerator should be based on the following considerations:

(i) The quantity of the waste to be handled, its composition and characteristics.

(ii) Measure to endure that there will not be any pollution of air, water or land resulting from the operation of the incinerator.

On economic considerations, the size of the incinerator is determined of the basis of the weekly quantity of the waste to be incinerated. For unsorted wasted, two types of incinerators are used:

1. The batch type incinerator

It is manually stoked and has a relatively small rated capacity. These plants have several disadvantages,

- Owing to the intermittent operation, the burning temperature cannot be maintained in a uniform manner. This many result in an inadequate and irregular combustion of the waste.

- The output of particulate matter is more.
- The volume reduction of the waste is lesser than the optimal value expected.
- This may end up with an unstable residue still containing some putrescible matter, thus, it may still possess some pollution potential.
- The intermittent incinerator plants are unsuitable for large urban centres.

2. The continuous type of incinerators

These are equipped with large storage bins, automatic feed hoppers, varied types of moving grates and ash discharging systems. These units are capable of maintaining uniform temperatures for combustion and can be equipped with pollution control devices such as scrubbers and electrostatic precipitators. These units are capable of yielding a stable residue which is non-polluting the capital and operating costs are very high, these units, which provide controlled furnace temperatures of 760-980°C, can remove odours and also bring about a substantial reduction in waste volume, in an environmentally acceptable form. Since the final residue is stable, the cost of cover material required to ultimately dispose it in the landfill will be substantially minimized or even eliminated in some cases.

High temperature incineration is a recent innovation where temperatures of the order of 1650 °C are attained using supplementary fuels. In this process, non-combustible fractions of the refuse (e.g., metal and glass) are melted in a bed of high – temperature coke in the refractory lined incinerator and are drained of as molten slag. This technique can achieve volume reduction of the refuse by 97%. In spite of the fact that the first high temperature incinerator was installed on a pilot plant scale as early as in 1966. Application to full-scale commercial units was not followed up enthusiastically for a long time due to the high costs involved.

The Volkswagen Works in Germany reportedly operated the s called melt zit slag-tap process. In this process, the glass in the soil waste is liquefied at about 980°C and the ash is melted at about 1300°C. The resultant magma is either moulded into large blocks or run into water to produce a coarse type of sand useful for preparing road or concrete aggregate.

a) Pyrolysis

The chemical constituents and chemical energy of some organic wastes can be recovered by destructive distillation (or pyrolysis) of the solid waste. In this process the combustible constituents of the solid waste are heated in a special retort like chamber known as a pyrolysis reactor at 600-1000°C in a low-oxygen or an oxygen-free environment. This is an endothermic process and thus differs from the conventional incineration.

Pyrolysis of the solid wastes yields the following components:

1. Tar or oil phase containing methanol, acetone, acetic acid, etc.
2. Gaseous phase containing H_2, CH_2, CO, CO_2, etc
3. Solid phase containing pure carbon char and inert materials like glass, rock metal, etc.

Advantages of the pyrolysis

- Volume reduction by about 90%
- Possibility of handling potentially hazardous plastic e.g., PVC in a safe way
- Absence of pollution problems