CHAPTER 06

Solid Waste Management

INTRODUCTION

- Solid wastes are all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted.
- Solid waste encompasses the heterogeneous mass of throwaways from residence and commercial activities as well as the more homogeneous accumulation of a single industrial activity.
- The safe disposal of solid wastes of a society was not a serious problem, as long as the population was small and the land available for assimilation of wastes was large.
- The density of Indian refuse is generally higher than that of the developed countries and hence the Indian refuse can be carried efficiently and economically by mechanical transport.
- The calorific value of Indian refuse is much smaller, and its moisture content is high.
- The term 'refuse' is often used interchangeably with term solid wastes.

6.1 Types of Solid Wastes

The general categories of solid waste are as below:

1. Municipal wastes
2. Industrial wastes

6.1.1 Municipal Solid Wastes

- The municipal solid waste (MSW) is a heterogenous mixture of various kinds of solid wastes which are not transported with water as sewage.
- It may include biodegradable (putrescible) food wastes called garbage and the non-putrescible solid wastes like paper, glass, rags, metal items, etc., called rubbish.
- The garbage includes all sorts of putrescible (bio-degradable) organic wastes obtained from kitchens, hotels, restaurants etc.
- The rubbish comprise of material which may either be combustible such as paper, plastic, textile etc or incombustible such as broken glass, crockery, metal, masonry etc.
- Classification of material comprising municipal solid waste as shown in table given below:

Table: 6.1 Classification of materials comprising municipal solid waste

Component	Description
Food wastes	The animal, fruit, or vegetable residues (also called garbage) resulting from the handling, preparation, cooking, and eating of foods. Because food wastes are putrescible, they will decompose rapidly, especially in warm weather.
Rubbish	Combustible and noncombustible solid wastes, excluding food wastes or other putrescible materials. Typically, combustible rubbish consists of materials such as paper, cardboard, plastics, textiles, rubber, leather, wood, furniture, and garden trimmings. Noncombustible rubbish consists of items such as glass, crockery, tin cans, aluminum cans, ferrous and nonferrous metals, dirt, and construction wastes.
Ashes and residues	Materials remaining from the burning of wood, coal, coke, and other combustible wastes. Residues from power plants normally are not included in this category. Ashes and residues are normally composed of fine, powdery materials, cinders, clinkers, and small amounts of burned and partially burned materials.
Demolition and construction wastes	Wastes from razed buildings and other structures are classified as demolition wastes. Wastes from the construction, remodeling, and repairing of residential, commercial, and industrial buildings and similar structures are classified as construction wastes. These wastes may include dirt, stones, concrete, bricks, plaster, lumber, shingles, plumbing, heating and electrical parts.
Special wastes	Wastes such as street sweepings, roadside litter, catch-basin debris, dead animals and abandoned vehicles are classified as special wastes.
Treatment-plant wastes	The solid and semisolid wastes from water, wastewater and industrial-waste treatment facilities are included in this classification.

6.1.2 Industrial Wastes

- Industrial wastes are generated from the industrial activities or manufacturing processes.
- All the three types of wastes, solid, liquid and gaseous are generated
- The solid wastes produced by industries can be broadly divided into following two categories.

I. Non-hazardous solid wastes II. Hazardous solid wastes.

I. Non-hazardous Solid Wastes

The non-hazardous solid wastes generated by various industries can be further subdivided into the following two categories.

(a) Biodegradable Wastes (b) Non-biodegradable Wastes

(a) **Biodegradable Wastes:** The major industries in urban area that generate substantial amounts of biodegradable non-hazardous solid wastes are : fruit processing, cotton mills, paper mills, sugar mills, textile factories etc.

(b) **Non-biodegradable Wastes:** The non-biodegradable non-hazardous solid wastes of industries are usually referred to as the industrial solid waste.

They are usually produced by industries like thermal plants which produce coal ash, integrated iron and steel plant which produce blast furnace slag and steel melting slag, non ferrous industries like aluminium, zinc and copper - which produce red mud and tailings, fertilizers and allied industries - which produces phospho-gypsum.

II. Hazardous Solid Wastes

- Some of the wastes generated by industries are deemed to be hazardous wastes because the certain substances that are toxic to plants, animals and humans are flammable, corrosive, explosive or highly reactive chemically.
- The major industries that produce hazardous wastes include metals, chemicals, drugs and pharmaceuticals, leather, pulp and paper, electroplating, refining, pesticides, dyes, rubber goods, etc.
- A waste is classified as hazardous, if it exhibits any of the following characteristics (i) ignitability, (ii) corrosivity (iii) reactivity (iv) toxicity
- Hazardous wastes was often grouped into the following categories,
  (i) radioactive susbstances (ii) chemicals (iii) biological wastes (iv) flammable (v) explosives
- The principal sources of hazardous biological wastes are hospitals and biological research facilities.

6.1.3 Municipal Solid Waste Composition and Quality of Generated Municipal Solid Wastes

I. Municipal Solid Wastes are Classified as:

(a) Garbages: It includes all sort of putrescible organic wastes, obtained from kitchens, hotels, restaurants etc. All waste food articles, vegetable peelings, fruit peelings, etc. These wastes are organic in nature, and thus, likely to decompose quickly; producing foul odours and health hazards. They may also result in breeding of flies, mosquitoes, insects, etc. Hence, garbage must be disposed of, properly and quickly. When it is scientifically processed and composted then we may obtain some valuable products like grease, fertilizer, etc. from the garbage. The density of garbage usually varies between 450 to 900 kg/m^3.

(b) Rubbish: It can include a variety of materials, which may either be combustible (such as paper, plastic, textile etc.) or incombustible (such as broken glass, crockery, metal, masonry etc.). Most of these types of wastes are discarded on a regular basis from homes, offices and small commercial establishments. The density of rubbish usually varies between 50 to 400 kg/m^3.

(c) Ashes: The incombustible ashes from household heaters (chulhas) called ashes, may also stand included in the MSW, although the quantity is getting reduced in modern urban homes due to increasing use of cooking gas, kerosene oil stoves and lesser use of cooking coal or fire wood. The density of ashes generally varies between 700 to 850 kg/m^3.

Besides the above three important components, the municipal solid waste may be also include the fine dust, silt and sand obtained from street sweepings.

In the addition to the above four usual components of refuse, certain special wastes such as construction debris, abandoned appliances and automobiles etc may also be collected at sporadic intervals from different places.

II. Municipal Solid Wastes Classified on the Bases of Source are as Follows:

Refuse may also be classified, depending on its source, as:

(i) House refuse : "They are residential and commercial wastes."

(ii) Street refuse : "They are also called open areas wastes"

(iii) Trade refuse : "They are generated from treatment plant sites."

III. Quantity of Municipal Solid Waste (MSW) Produced

- The quantity of MSW produced by a society depends upon the living standards of its residents.
- The degree of commercialisation, urbanisation and industrialisation, infact, has resulted in a vast increase in the amount of refuse generated per person.
- With the modernisation and industrialization, new type of solid waste have come in abundance. For example cans, plastic bottles and containers, plastic toys and appliances, tyres, packaging foils and films, cardboard boxes etc. All such factors have increased the MSW by a large extent.
- The quantity of refuse produced in a city not only depends upon the type of the city and on the living standards of the resident, but also depends upon the seasons.
- The average compositions of refuse (by weight) is estimated to be as shown in table below.

Table: 6.2 Average Composition and Other Properties of MSW (Refuse)

Sl. No.	Item / Constituent	App. Av. composition (% age by weight at disposal site)	
		For a typical Indian city	For a typical city of U.S.A.
1.	Garbage	45%	20%
2.	Rubbish	15%	50%
3.	Ashes	15%	15%
4.	Fine dust, silt and sand	25%	15%
	Density Calorific value* in kilo. Joule/kg**	400 to 600 kg/m^3 5000-6600	100 to 250 kg/m^3 15,000

*Heat, which garbage can generate. ** kJ/kg = 0.243 kC/kg.

- The density of Indian refuse is generally higher than that of the developed countries, and hence the Indian refuse can be carried efficiently and economically by mechanical transport (carrying more weight for the same volume) for land fillings.
- But since the calorific value of the Indian refuse is much smaller, and its moisture content is high, it cannot be easily burnt or incinerated, and hence the incineration method of refuse disposal is not so suitable for India.

6.2 Functional Elements of Solid Waste Management

The activities involved with the management of solid wastes from the point of generation to final disposal have been grouped into six functional elements.

1. Waste generation
2. On-site handling, storage and processing
3. Collection
4. Transfer and transport
5. Processing and recovery
6. Disposal

Table : 6.3 Description of the functional elements of a solid waste management system	
Component	Description
Waste generation	Those activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal
On site handing, storage, and processing	Those activities associated with the handling, storage and processing of solid wastes at or near the point of generation.
Collection	Those activities associated with the gathering of solid wastes and the hauling of wastes after collection to the location where the collection vehicle is emptied
Transfer and transport	Those activities associated with (1) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and (2) the subsequent transport of the wastes, usually over long distance, to the disposal site.
Processing and recovery	Those techniques equipment and facilities used to improve the efficiency of the other functional elements and to recover usable materials, conversion products or energy from solid wastes
Disposal	Those activities associated with ultimate disposal of solid wastes, including those wastes collected and transported directly to a landfill site, semisolid wastes (sludge) from wastewater treatment plants, incinerator residue, compost or other substances from the various solid-waste processing plants that are of no further use.

6.2.1 Factors affecting Generation Rates

Factors that influence the quantity of municipal wastes generated include:

1. Geographical location
2. Season of the year
3. Collection frequency (affects amount collected)
4. Use of kitchen wastes grinders
5. Characteristics of popular
6. Extent of salvaging and recycling
7. Public attitudes
8. Legislation

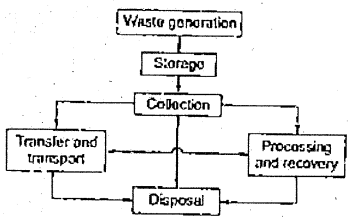

Fig. 6.1 Interrelationship of functional elements comprising a solid-waste management system

6.2.2 On-site Handling, Storage and Processing

The handling, storage and processing of solid wastes at the source before they are collected are the functional elements in a solid-waste management system.

On-site Handling: It refers to the activities associated with the handling of solid wastes until they are placed in the containers used for their storage before collection. Depending on the type of collection service, handling may also be required to move loaded containers to the collection point and to return the empty containers to the point where they are stored between collections.

Domestics wastes accumulated at several location in and around low and medium rise residential dwellings are placed in large storage containers to await removal by the waste-collection agency.

On-site Storage: Factors that must be considered in the on-site storage of solid wastes includes,

(1) The type of container to be used (2) The container location
(3) Public health and aesthetics and (4) The collection methods to be used

On-site Processing Methods: These are used to recover usable materials from solid wastes, to reduce the volume, or to alter the physical form. The most common on-site processing operations include sorting, compaction and incineration.

6.2.3 Collection of Solid Wastes

- Information on collection, one of the most costly functional elements, is presented in four parts dealing with
  1. The types of collection services
  2. The types of collection systems
  3. An analysis of collection systems.
  4. The general methodology involved in setting up collection routes.
- Regular collections and transport of solid waste are most important operations in any efficient solid waste management which costs about 80% of the total cost of solid waste management.
- In India, refuse is generally collected in individual houses in small containers, and from there it is collected by sweepers in small hand driven lorries/carts and than dumped into the community storage bins constructed road sides by muncipalities.
- The capacity of the bins may vary from 100 to 500 litres depending on the quantity of zone wise waste generation.
- On-site storage will be appropriate in case of large quantity of putrescible garbage.

Types of Collection System: Based on their mode of operation, collection systems are classified into two categories:

1. Hauled container system
2. Stationary container systems

1. Hauled Container System (HCS)

- Collection system in which the container used for the storage of wastes are hauled to the processing, transfer to disposed site, emptied and returned to either their original location or some other location are defined as hauled container systems.
- They are two main types of HCS
  (i) Tilt frame container
  (ii) Trash Trailer

2. Stationary Container System (SCS)

- Collection system in which the containers used for the storage of wastes remain at the point of waste generation, except when moved for collection, are defined as stationary container system.
- There are two main types of SCW
  (a) Those in which self-loading compactors are used.
  (b) Those in which manually loaded vehicles are used.

Table: 6.4 Typical data on vehicles and containers used with various collection systems		
Vehicle	**Collection container type**	**Typical range of container capacities, m^3**
Hauled -container system		
Tilt-frame	Open-top, also called debris boxes Used in conjunction with stationary compactor. Equipped with self-contained compaction mechanism.	6 - 40 10 - 30 15 - 30
Trash trailor	Open-top trash-trailers Enclosed trailer-mounted containers Equipped with self-contained compaction mechanism	10 - 30 15 - 30
Stationary-container systems Compactor, mechanically loaded Compactor, manually loaded	Open top and enclosed top and side-loading Small plastic or galvanized metal containers, disposable paper and plastic bags	06 - 8 75 - 200

Points to be taken care of during solid waste management:

- The house sweepers and street scavengers, do not bother much for carrying refuse properly, and they go on scattering it here and there, while carrying it up to the municipal chambers. This should be taken care.
- The street scavengers do not bring lorries and even at the entrance point of the municipal refuse chamber, they just throw the refuse, scattered around in and out of its gate. The street animal, would further scatter it, leading to all around scattering of the refuse, resulting in highly insanitary conditions and health hazard.
- The municipal truck, do not generally clear and clean the refuse chambers properly, and the residual refuse remains dumped for a long time, resulting in its decomposition and evolution of obnoxious gases, and consequently causing health hazard.
- The municipal trucks, while carting refuse, are generally not closed bodied and hence go on throwing refuse on way, and also giving pungent smells.
- The process of refuse collection and its carriage, therefore need vast changes in this country. The refuse should, therefore, infact be collected by municipal trucks directly from the houses.

NOTE: Roadside refuse collection masonry chambers need complete elimination.

- Municipal trucks should be completely closed and should visit home and houses, twice a day, to collect house hold refuse and street sweepings.
- The transporting vehicles should also be of high quality of special design and be properly maintained.
- They should be strong, durable and water tight and be made of stainless steel with smooth interior, having rounded corners and edges, for facility of cleaning.
- They should have a low loading line, say upto 1.5 m, so that minimum time and effort is required in filling them.
- Mechanical devices should be installed in these vehicles, for lifting the body to the sides or back, or for pushing the refuse out, so that they can be quickly and easily emptied.
- An optimum collection route, particularly for large and densely populated area should be selected in order to optimise the collection system.

6.2.4 Transfer and Transport

- The functional element of transfer and transport refers to the means, facilities and appurtenances used to effect the transfer of water from relatively small collection vehicles to larger vehicles and to transport them over extended distances to either processing centers or disposal sites.
- Transfer and transport operation becomes a necessity when haul distances to available disposal sites or processing centers increase to the point that direct hauling is no longer economically feasible.
- Important factors that must be considered in the design to transfer stations include
  (i) Type of transfer operation to be used. (ii) Capacity requirements
  (iii) Equipment and accessory requirements (iv) Environmental requirements
- Depending on the methods used to load the transport vehicles, transfer station may be classified into three types.
  (i) Direct discharge transfer station in which waste from the collection vehicles usually are emptied directly into the vehicles to be used to transport them to a place of final disposition.
  (ii) Storage discharge transfer station, in which wastes are emptied either into a storage pit or onto a platform from which they are loaded into transport vehicles by various types of auxiliary equipment.
  (iii) Combined direct and storage discharge transfer station. There are multipurpose facilities designed to service a broader range of users than a single-purpose facility. In addition to serving a boarder range of user, a multipurpose transfer station can also house a materials salvage operation.
- Whenever possible, transfer station should be located:
  (i) As near as possible, to the weighted centre of the individual solid waste production areas to be served.
  (ii) Within easy access of major arterial highway routes as well as near secondary or supplementary means of transportation.
  (iii) Where there will be a minimum public and environment objection to the transfer operations.
  (iv) Where construction and operation will be most economical.

6.2.5 Processing Techniques

Processing techniques are used in solid wastes managements system to:
(i) improve the efficiency of solid-waste disposal systems
(ii) to recover resources (usable materials)
(iii) to prepare materials for the recovery of conversion product and energy.

Important processing techniques used routinely in municipal solid-waste system include compaction, thermal volume reduction (incineration) and manual separation of waste components.

1. **Mechanical Volume Reduction:** It is the most important factor in the development and operation of solid-waste management systems. Vehicles equipped with compaction mechanisms are used for

the collection of most municipal solid wastes. Wastes are compacted to increase the useful life of landfills.

2. **Thermal Volume Reduction:** The volume of municipal wastes can be reduced by more than 90 percent by incineration. Incineration was quite common in the past, however, with more restrictive air pollution control requirements only a limited number of municipal incinerators are currently in operations.

3. **Manual Component Separation:** The manual separation of solid waste components can be accomplished at the source where solid wastes are generated, at a transfer station, at a centralized processing station, or at the disposal site. Manual sorting at the source of generation is the most positive way to achieve the recovery and reuse of materials. The number and types of components salvaged or sorted (e.g., cardboard and high quality paper, metals and wood) depend on the location, the opportunities for recycling and the resale market.

Table: 6.5 Factors that should be considered in evaluating on-site processing equipment

Factor	Evaluation
Capabilities	What will the device or mechanism do? Will its use be an improvement over conventional practices?
Reliability	Will the equipment perform its designated functions with little attention beyond preventive maintenance? Has the effectiveness of the equipment been demonstrated in use over a reasonable period of time or merely predicted ?
Service	Will servicing capabilities beyond those of the local building maintenance staff be required occasionally? Are properly trained service personnel available through the equipment manufacturer or the local distributor?
Safety of operation	Is the proposed equipment reasonably foolproof so that it may be operated by tenants or building personnel with limited mechanical knowledge or abilities? Does it have adequate safeguards to discourage careless use?
Ease of operation	Is the equipment easy to operate by a tenant or by building personnel? Unless functions and actual operations of equipment can be carried out easily, they may be ignored or "short-circuited" by paid personnel or by tenants.
Efficiency	Does the equipment perform efficiently and with a minimum of attention? Under most conditions, equipment that completes an operational cycle each time it is used should be selected.
Environmental effects	Does the equipment pollute or contaminate the environment? Where possible, equipment should reduce environmental pollution presently associated with conventional functions.
Health hazards	Does the device, mechanism, or equipment create or amplify health hazards?
Aesthetics	Does the equipment and its arrangement offend the senses? Every effort should be made to reduce or eliminate offending sights, odours, and noises.
Economics	What are the economics involved? Both first and annual costs must be considered. Future operation and maintenance costs must be assessed carefully. All factors being equal, equipment produced by well-established companies having a proven history of satisfactory operation, should be given appropriate consideration.

6.3 Disposal of Municipal Solid Wastes (MSW)

- During the time the refuse is discarded and thrown away, and till the time it is loaded in trucks for transportation, a lot of recyclable materials like plastics, papers and glasses are removed by the rag pickers.
- After the wastes are loaded in trucks it is taken for its final disposal.
- Appropriate method of disposal of solid waste should be chosen in order to satisfy the present as well as future requirement.
- It should not create environmental pollution and should result in recovery of material as well as energy.
- Most commonly employed methods for solid waste disposal, practiced all over the world are.
  - (i) Open dumping
  - (ii) Sanitary land filling also called controlled tipping.
  - (iii) Shredding and Pulversiation
  - (iv) Composting including vermicomposting
  - (v) Incineration and Thermal Pyrolysis
  - (vi) Barging it out into the sea

6.3.1 Disposal of Refuse by Open Dumping

- Oldest method of disposing solid wastes
- Very simple method and commonly adopted in our country.
- Solid wastes collected from the city zone is dumped in low lying areas located far off from the city.
- Not an eco-friendly method and thus results in contamination of environment.
- This method is highly unacceptable as it gives unsightly nuisances, obnoxious smell and is a breeding place for flies and mosquitoes.
- The method is still in practice in semi-urban and rural areas.

6.3.2 Disposal of Refuse by Land Filling

- Disposal on or in the earth's mantel is at present the only variable method for the long term handling of:
  1. Solid wastes that are collected and are of no further use
  2. The residual matter remaining after solid wastes have been processed.
  3. The residual matter remaining after the recovery of conversion products and/or energy has been accomplished

Land filling is the method of disposal used most commonly for municipal wastes, land farming and deep well injection have been used for industrial wastes. Although incineration is often considered a disposal method, it is in reality, a processing method.

- Land filling involves the controlled disposal of solid wastes on or in the upper layer of the earths mantle.
- Important aspects in the implementation of sanitary land fills include
  - (a) Site selection
  - (b) Land filling methods and operations.
  - (c) Occurrence of gases and leachate in land fills.
  - (d) Movement and control of land fill gases and leachate.
- In this method of refuse disposal, refuse is carried and dumped into the low lying area (earmarked as land fill site) under an engineered operation, designed and operated in an environmentally sound manners as not to cause any public nuisance or hazards to public health or safety.
- In this method, the refuse is dumped and compacted in layers of about 0.5 m thickness, and after the day work when the depth of filling becomes about 1.5 m, it is covered by good earth of 15 cm thickness. This cover of good earth is called daily cover.

- The refuse is well compacted with bulldozers, trucks rollers etc. and is well covered daily with good earths, it does not cause any public nuisance.
- The filling of refuse is actually done in sanitary land filling by dividing the entire land fill area into smaller portion called cells.
- These cells are initially filled with daily compacted refuse about 1.5 m depth, in turn. After filling all the cells with first lift, the second lift is laid is about 1.5 m height and covered with good earth cover of about 0.15 m depth called intermediate cover.
- The process will continue till the top most lift is piled up, over which the final cover of good earth of about 0.6 m depth shall be laid and well compacted to prevent the rodents from burrowing into the surface.
- A cap system may also be installed over the top of the final cover.
- Insecticides like DDT, creosote etc should be sprayed to prevent mosquito breeding.
- The filled up refuse gets stabilized due to the decomposition of organic matter in due course of time subsequently getting converted into stable compounds.

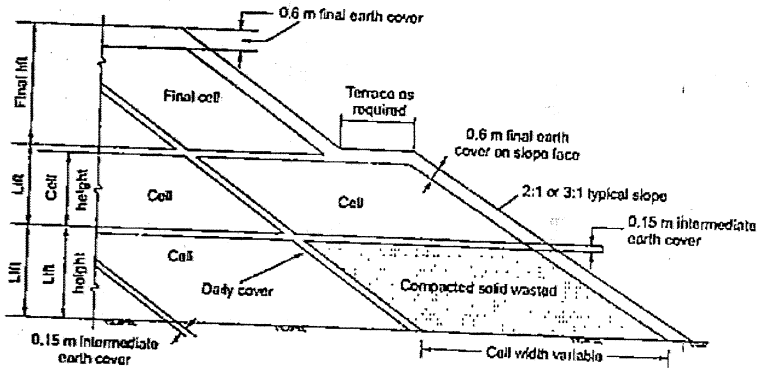

Fig. 6.2 Sectional view of a sanitary land fill

Steps involving Refuse Stabilization:

- With the passage of time, the filled up refuse will get stabilized due to the decomposition of organic matter and subsequent conversion into stable compounds.

NOTE

1. The land filling operation is essentially a biological method of waste treatment, since the waste is stabilized by aerobic as well as anaerobic bacterial processes.
2. Initially, the bacterial decomposition occurs under the aerobic conditions, because a certain amount of air is trapped within the landfill. However, the oxygen in the trapped air is soon exhausted within a few days and the long term decomposition occurs under anaerobic conditions.

- The entire period of refuse stabilization can infact, be divided into five distinct phases.
  - (i) During the first phase of operation, aerobic bacteria and fungi which are dominant, deplete the available oxygen to effect oxidation of organic matter. As a result of aerobic respiration, the temperature in the fill increase.
  - (ii) In the second phase, anaerobic and facultative bacteria develop to decompose the organic matter and H_2 and CO_2 gases are thus evolved through acidogenic activity.
  - (iii) In the third phase, methanogenic bacteria develop to cause evolution of methane gas.
  - (iv) In the fourth phase of decomposition, the methanogenic activity gets stabilised.
  - (v) In the fifth stage, the methanogenic activity subsides representing depletion of the organic matter and ultimately, the system returns to aerobic condition within the land fill.

NOTE

A refuse, in managed land fills, may usually get stabilised generally within a period of 2 to 4 months and settle down by 20-40% of its original height. The filled up land can be used for developing some green land, parks or other recreational spots.

Advantages:

(i) This method is most simple and economical. No costly plant or equipment is required in this method, as is required in other methods of incineration or pulverization.

(ii) Separation of different kinds of refuse, as required in incineration method is also not required in this method.

(iii) There are no residues or by products left out/evolved in this methods and hence no further disposal is required, this being a complete method in itself.

(iv) Low lying waterlogged areas and old quarry pits can be easily reclaimed and put to better use. The mosquito breeding places are thus, eliminated.

Disadvantages:

(i) Low lying depressions or dumping sites may not always be available as they may become scarce or unavailable in future.

(ii) There is a continuous evolution of foul gases near the fill site, especially during the times the refuse is being dumped there. These gases may often be explosive in nature and are produced by the decomposing or evaporating organic matter. These gases known as land fill gases.

(iii) Since the dumped garbage may contain harmful and sometimes carcinogenic non-biodegradable substances such as plastic, unused medicines, paint etc. they may start troubling on a later date, particularly during rainy season, when excess water seeping through the area, may come out of the dump as a coloured liquid called leachate. Leachate is highly poisonous.

Land Filling with Solid Wastes: Land filling involves the controlled disposal of solid wastes on or in the upper layer of the earth's mantle. Important aspects in the implementation of sanitary land fills include.

1. Site selection
2. Land filling methods and operations.
3. Occurrence of gases and leachate in land fills
4. Movement and control of land fill gases and leachate.

Site Selection

- Factors that must be considered in evaluating potential solids waste disposal site are summarized in the table below:

Table: 6.6 Factors that must be considered in evaluating potential landfill sites

Factor	Remarks
Available land area	Site should have a useful life greater than 1 yr (minimum value).
Haul distance	Will have significant impact on operating costs.
Soil conditions and topography	Cover material must be available at or near the site.
Surface water hydrology	Impacts drainage requirements.
Geologic and hydrogeologic conditions	Probably most important factors in establishment of landfill site, especially with respect to site preparation.
Climatologic conditions	Provisions must be made for wet-weather operation.
Local environmental conditions	Noise, odour, dust, vector, and aesthetic factors control requirements
Ultimate use of site	Affects long-term management for site.

- Final selection of a disposal site usually is based on the result of preliminary site survey, results of engineering design and cost studies and an environmental impact assessment.

Land Filling Methods and Operations: The principal methods used for land filling dry areas may be classified as:

(a) Area (b) Trench (c) Depression

(a) Area Method

- It is used when the terrains is unsuitable for the excavation of trenches to place the solid wastes.
- Entire land fill sites is divided into number of sub areas by constructing embankments and roads.
- The subareas are called sub-division cells or simply cells. Rest method is similar to as described earlier.

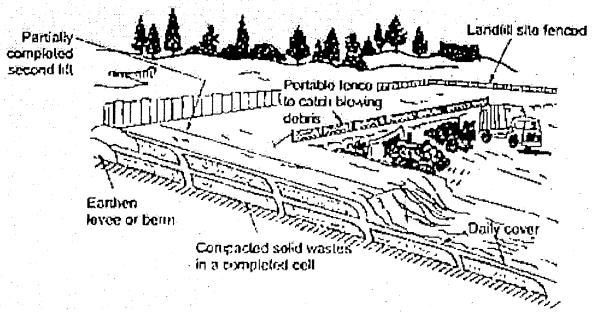

Fig. 6.3 Area method of landfilling solid wastes

(b) The Trench Method

- The trench method of land filling is ideally suited to area where an adequate depth of cover material is available at the site and where the water table is well below the surface.
- In this method, a trench is dug with a bulldozer and the dirt is stockpiled to form an embankment being the first trench.
- Then placed in the trench, spread into thin layers and compacted.
- The operation continuous until the desired height is reached.
- Cover material is obtained by excavating an adjacent trench or continuing the trench that is being filled. .
- In large land fills, a dragline and one or more scrapers are used to excavate a deep rectangular pit.

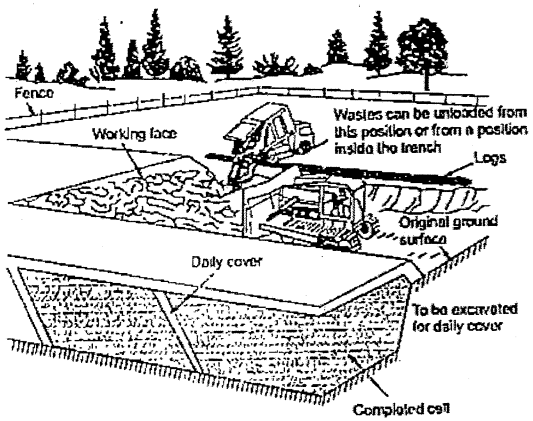

Fig. 6.4 Trench method of landfilling solid wastes for small landfills.

(c) Depression Method

- At locations where natural or artificial depressions exist, it is often possible to use them effectively for landfilling operations
- The techniques to place and compact solid waste in depression landfills vary with the geometry of the site, the characteristics of the cover material, the hydrology and geology of the site and the access to the site.
- In a canyon site, filling starts at the head end of the canyon and ends at the mouth. This practice prevents the accumulation of waste behind the landfill.
- Wastes usually are deposited on the canyon floor and from there it is pushed up against the canyon face at a slope of about 2 to 1. In this way, a high degree of compaction can be achieved.

NOTE

1. Because of the problems associated with contamination of local ground waters, the development of odours and structural stability, landfills in wet areas are seldom used.
2. If wet areas such as swamps and marshes, tidal areas and ponds pit or quarries must be used as landfill sites, special provisions must be made to contain or to eliminate the movement of leachate and gases from completed cells.

Occurrence of Gases and Leachates in Land Fills: The following biological, physical and chemical events occur when solid wastes are placed in a sanitary landfill:

1. Biological decay of organic materials (aerobically/anaerobically) with the evolution of gases and liquids
2. Chemical oxidation of waste materials
3. Escape of gases from the fill
4. Movement of liquids caused by differential heads
5. Dissolving and leaching of organic and inorganic materials by water and leachate moving through the fill;
6. Movement of dissolved material by concentration, gradients and osmosis
7. Uneven settlement caused by consolidation of material into voids.

Gases in Land Fills:

- Gases found in land fills include air, ammonia, carbon dioxide, carbon monoxide, hydrogen, hydrogen sulfide, methane, nitrogen and oxygen.
- Carbon dioxide and methane are the principal gases produced from the anaerobic decomposition of the organic solid waste components.
- The movement of gases in landfills should therefore be controlled with properly designed engineering methods such as by constructing vents and barriers.
- The movements of land fills gases can be controlled by the land fill sealants. Compacted clay is most commonly used as land fill sealants.

Leachate in Land Fills:

- Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials from it
- In most landfills, the liquid portion of the leachate is composed of the liquid produced from the decomposition of the wastes and liquid that has entered the landfill from external sources, such as surface drainage, rainfall, groundwater and water from underground springs.
- Under normal conditions, leachate is found at the bottom of landfills. From there, it moves through the underlying strata (although some lateral movement may also occur) depending on the characteristics of the surrounding material.
- The use of clay lines or synthetic liners like geotextiles has been the most favourable method for reducing and eliminating the percolation of leachate.
- An important method to control the production of leachate is to eliminate the infiltration of surface water from the landfill which is the major contributor to the total volume of the leachate . For this we use an impervious clay layer over the top of the fill at a decent slope , provided with adequate drainage and surface infiltration.

Table: 6.7 Landfill Sealants for the Control of Gas and Leachate Movement

Sealant		Remarks
Classification	Representative types	
Compacted soil		Should contain some clay or fine silt.
Compacted clay	Bentonites, illites, kaolinites	Most commonly used sealant for landfills; layer thickness varies from 0.15 to 1.2 m; layer must be continuous and not allowed to dry out and crack.
Inorganic chemicals	Sodium carbonate, silicate, or pyrophosphate	Use depends on local soil characteristics.
Synthetic chemicals	Polymers, rubber latex	Experimental, use not well established.
Synthetic membrane liners	Polyvinyl chloride, butyl rubber, hypalon, polyethylene, nylon-reinforced liners.	Expensive, may be justified where gas is to be recovered.
Asphalt	Modified asphalt, asphalt-covered poly propylene fabric, asphalt concrete	Layer must be thick enough to maintain continuity under differential settling conditions.
Others	Gunite concrete, soil cement, plastic soil cement.	

Example 6:1 In a sanitary landfill, decomposition and chemical changes within organic content of the solid waste goes on. Consequential changes within landfill can be

1. temperature changes within landfill
2. production of gases like H_2S, CO, CO_2 and CH_4
3. destruction of pathogens
4. production of other gases like SO_2 and NO_2

Which of these statements are correct?

(a) 1, 2, 3 and 4 (b) 1, 2 and 3
(c) 1 and 4 (d) 2 and 3

Ans. (b)

Movement and Control of Landfill Gases and Leachate

Gas Movement and Control:

- Under ideal conditions, the gases generated from a land fill should be either vented to the atmosphere or, in larger landfills, collected for the production of energy.
- In most cases, over 90 percent of the gas volume produced from the decomposition of solid wastes consists of methane and carbon dioxide.
- Although most of the methane escape to the atmosphere, both methane and carbon dioxide have been found in concentration of upto 40 percent at lateral distances of upto 120 m from the edges of landfills.
- Because carbon dioxide is about 1.5 times as dense as air and 2.8 times as dense as methane, it tends to move towards the bottom of the landfill. As result the concentration of carbon dioxide in the lower portions of landfills may be high for year.

NOTE

Because carbon dioxide is readily soluble in water, it usually lowers the pH, which in turn can increase the hardness and mineral content of the ground water through the solubilization of calcium and magnesium carbonates.

- The movement of gases in landfills can be controlled by constructing vents and barrier and by gas recovery.
- The lateral movement of gases produced in a landfill can be controlled by installing vents made of materials that are more permeable than the surrounding soil.
- Control of the downward movement of gases can be accomplished by installing perforated pipes in a gravel layer at the bottom of the landfill.
- The movement of landfill gases through adjacent soil formation can be controlled by constructing barriers of materials that are more impermeable than the soil.
- The movement of gases in landfills can also be controlled by installing gas recovery wells in complete landfills clay and other liners are used where landfill gas is to be recovered.

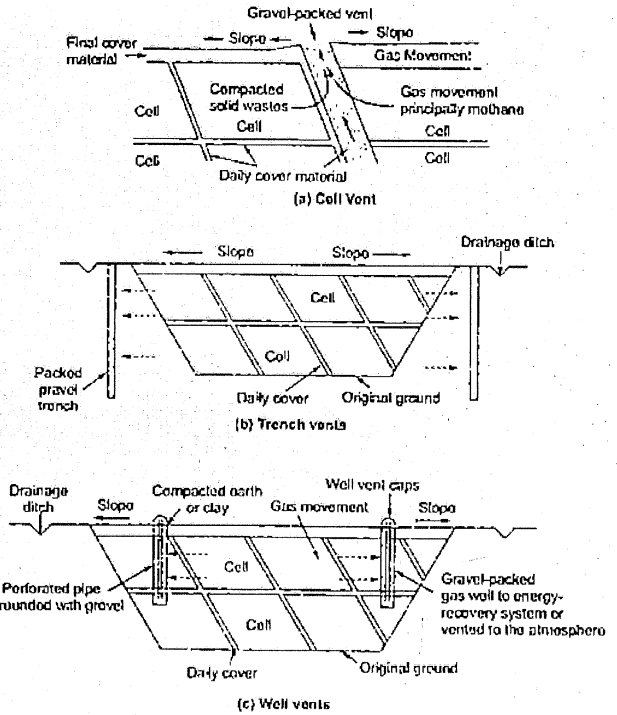

Fig. 6.5 Typical methods for venting landfill gases: (a) cell; (b) trench; (c) well

Leachate Movement and Control:

- Under normal condition, leachate is found in the bottom of landfills. From there, movement is through the underlying strata, although some lateral movement may also occur, depending on the characteristic of the surrounding materials.
- As leachate percolates through the underlying strata, many of the chemical and biological constituents originally contained in it will be removed by the filtering and adsorptive action of the material composing the soils, especially the clay content.
- The use of clay has been the favoured method of reducing or eliminating the percolation of leachate.
- Membrane liners have also been used, but they are expensive and require care so that they will not be damaged during the filling operations.

Factors to be Considered in the Design and Operations of a Sanitary Landfill Site

Important design consideration in the design and operation of landfills include.

(i) Land requirement
(ii) Types of wastes that must be handled
(iii) Evaluation of seepage potential
(iv) Design of drainage and seepage control facilities
(v) Development of a general operation plan
(vi) Design of solid waste filling plan
(vii) Determination of equipment requirement.

6.3.3 Disposal of Refuse by Shredding and Pulverisation

- The size and volume reduction of municipal solid waste (MSW) is accomplished by the physical processes of shredding and pulverisation.
- Shredding refers to the actions of cutting and tearing, whereas, pulverisation refers to the actions of crushing and grinding.
- The shredding and pulverising not only helps in reducing the volume of MSW, but also helps in changing the physical character of the waste, which becomes practically odourless and unattractive to the insects.
- The pulverised refuse, though contains fertilizing element like potash, phosphorus and nitrogenous materials, yet cannot be suitably used as manure. It has, therefore, to be further disposed off either by filling in trenches, or is digested in open windrows or closed digesters.
- The shredding and pulverising may help in reducing the overall volume of the original MSW by as much as 40%.
- The pulverisation of MSW is usually achieved in a hammer mill, where the raw solid waste is cramped with a force, sufficient to crush or tear individual components of the waste.
- In order to further reduce the waste volume and facilitate handling of the pulverised MSW, it is usually compacted to form rectangular blocks and bails. This process is called bailing of MSW.
- The bailing process, thus has significant advantages in decreasing the waste volume, and in providing an easy way for handling waste as blocks rather than as litter, thereby reducing the litter nuisance of scattering, etc.

6.3.4 Disposal of Refuse by Composting

- Composting of refuse is a biological method of decomposing solid wastes.
- This decomposition can be affected either under aerobic conditions or under anaerobic condition or both.
- The final end product is a manure, called the compact or humus.
- If the organic materials, excluding plastics, rubber and leather are separated from municipal solid wastes and are subjected to bacterial decomposition, the end product remaining after dissimilatory and assimilatory bacterial activity is humus or compost. The entire process involving both separation and bacterial conversion of the organic solid wastes is known as composting.
- Decomposition of the organic solid wastes may be accomplished either aerobically or anaerobically depending on the availability of oxygen.
- Basically, composting is considered to be an aerobic process, because it involves piling up of refuse and its regular turning, either manually or by mechanical devices, so as to ensure sufficient supply of air and oxygen during its decomposition by bacteria, fungi and other microorganisms, like antinomycetes.
- Initially, the process starts with the mesophilic bacteria, which oxidises the organic matter (in the refuse) to carbon dioxide and liberate heat. The temperature rise about 45°C and at this point, the thermophilic bacteria take over and continue the decomposition. During this phase, the temperature further rises about 60°C which has to be maintained for at least 3 days in order to destroy pathogenic bacteria. This temperature control is crucial, because optimal decomposition occurs between 55 and 60°C, but if the temperature exceeds 60°C, decomposition slows down.
- Complete stabilisation occurs after the compact is allowed to cure for another 2 to 8 weeks. During the active early decomposition phase, the thermophilic bacteria are more active during the curing stage.
- The entire composting, thus gets completed in about 3-4 months time. Volume reductions of the original organic material of up to 50% are achieved under ideal conditions. The finally produced compost usually, has earthy smell and a dark brown colour.
- Moisture content of the compost mass should, however be controlled to ensure optimum aerobic decomposition, because excessive moisture will make it difficult to maintain aerobic conditions, while deficient moisture inhabits biological life. A moisture content of about 55% should be established, so that aerobic biological activity may proceed at an optimum rate.
- Most composting operation involve three basic steps
  1. Preparation of the solid wastes.
  2. Decomposition of the soil wastes
  3. Product preparation and marketing
- Receiving, sorting, separation, size reduction and moisture and nutrient addition are part of the preparation step. Several techniques have been developed to accomplish the decompostion step Once the solid wastes have been converted to a humus, they are ready for the third step, product preparing and marketing. This step include fine grinding, blending with various additives, granulation, bagging, storage, shipping and in some case direct marketing.
- The principal design consideration associated with the biological decomposition of prepared solid wastes are presented in table below.

Table: 6.8 Important design considerations for aerobic composting processes

Item	Comment
Particle Size	For optimum results the size of solid wastes should be between 25 and 75 mm (1 and 3 in).
Seeding and Mixing	Composting time can be reduced by seeding with partially decomposed solid wastes to the extent of about 1 to 5 percent by weight. Sewage sludge can also be added to prepared solid wastes. Where sludge is added, the final moisture content is the controlling variable.
Mixing or turning	To prevent drying, caking, and air channeling, material in the process of being composted should be mixed or turned on a regular schedule or as required. Frequency of mixing or turning will depend on the type of composting operation.
Air requirements	Air with at least 50 percent of the initial oxygen concentration remaining should reach all parts of the composting material for optimum results, especially in mechanical systems.
Total Oxygen Requirements	The theoretical quantity of oxygen required can be estimated.
Moisture Content	Moisture content should be in the range between 50 and 60 percent during the composting process. The optimum value appears to be about 55 percent.
Temperature	For best results, temperature should be maintained between 323 and 328 K (50 and 55°C) for the first few days and between 328 and 333 K (55 and 60°C) for the remainder of the active composting period. If temperature goes beyond 339 K (66°C), biological activity is reduced significantly.
Carbon-nitrogen Ratio	Initial carbon-nitrogen ratios (by mass) between 30 and 50 are optimum for aerobic composting. At lower ratios, ammonia is given off. Biological activity is also impeded at lower ratios. At higher ratios, nitrogen may be a limiting nutrient.
pH	To minimize the loss of nitrogen in the form of ammonia gas, pH should not rise above about 8.5.
Control of pathogens	If properly conducted, it is possible to kill all the pathogens, weeds and seeds during the composting process. To do this, the temperature must be maintained between 333 and 343 K (60 and 70°C) for 24 h.

Carbon-Nitrogen Ratio

- The C/N of the input material in compost heap is an important factor for the bacterial activity to continue, since the bacteria use nitrogen for building their cell structures (as proteins) and carbon for food (as energy).
- Anaerobic bacteria, developing in this digestion, use up carbon about 30 - 50 times faster than they use up nitrogen. Hence, for proper development of anaerobic digestion, C/N ratio of the digestive material should be between 30 to 50 for optimum digestion.
- If there is too much of carbon i.e. C/N is higher than the optimum, then nitrogen will be used up and carbon left over, thereby leaving the digestion of organic matter incomplete.
- If there is too much of nitrogen, i.e. C/N ratio is lower than the optimum, then the carbon will soon get exhausted and fermentation stop, leaving nitrogen in the digester which will combine with hydrogen to form ammonia (NH_3). This can kill or inhibit the growth of bacteria especially the methane producers.
- The anaerobic digestion will hence require an optimum C/N ratio of about 30 - 50.

NOTE

The initial C-N ratio and moisture content of the compact heap are two important controlling factors in the success of anaerobic digestion, which finally produces a compost, free from pathogens and contains 1% N, 1.1% P(as P_2O_5) and 1.5% K(as K_2O) on dry basis, thus proving to be a valuable nutrient for the soils, along with producing biogas as a by-product.

Indian Method of Composting:

In India, the composting is practised in rural areas on the mixture of night soil and refuse.

Two methods, which are generally adopted here, are :

1. Indore process
2. Bangalore process

1. **Indore Method of Composting:**
   - It uses manual turning of piled up mass (refuse + night soil) for its decomposition under aerobic conditions.
   - In this method, layers of vegetable wastes and night soil are alternatively piled in depths of about 7.5 to 10 cm each, to a total depth of about 1.5 m in a trench or above the ground to form a mound called a windrow.
   - The mixture is kept aerobic by turning regularly for 2 to 3 months.
   - This compost mass is then left for another about 1 to $1\frac{1}{2}$ months without any turning after which, the compost becomes ready for use. The entire process thus takes about 4 months. This method is primarily aerobic in nature.

2. **Bangalore Method:**
   - The Bangalore method of composting, involves anaerobic decomposition of wastes, and does not involve any turning or handling of the mass, and is, hence, cleaner than the Indore method . This method is, therefore, widely adopted by municipal authorities throughout India.
   - The refuse and night soil, in this method, are therefore piled up in layers in an underground earthen trench of about (10 m x 1.5 m x 1.5 m).
   - This mass is covered at its top by layer of earth of about 15 cm depth, and is finally left over for decomposition.
   - Within 2 to 3 days of burial, intensive biological action starts taking place and organic matter begins to be destroyed
   - Considerable heat gets evolved in the process which raises the temperature of the decomposing mass of about 75°C. This heat prevents the breeding of flies by destroying the larvae.
   - After about 4 to 5 months (depending upon the season), the refuse gets fully stabilised and changes into a brown coloured odourless innocuous powdery mass, called humus.
   - This humus is removed from the trenches, sieved on 12.5 mm sieves to remove stones, broken glass, brickbats, etc. and then sold out in the market as manure. The empty trenches can again be used for receiving further batches of refuse.

NOTE

Night soil is defined as human waste, and, as such, it is bacteriologically unsanitory and chemically unstable.

Night soil is a euphemism for human feces collected at night form cesspools, privies, etc. and sometimes used as a fertilizers.

Fully Mechanised Composting Plants:

- It involves mechanised receipt, segregation and pulverization of the refuse, before its digestion in closed digesters.
- Closed digesters are costly and used in developed countries. In developing countries like India, it is carried out in open windrows by turning the compost mass by mechanical devices.
- The procedures adopted for composting in mechanised plants are discussed below.
  (a) Receipt of Refuse. (b) Segregation of Refuse.
  (c) Grinding or Pulverizing of Refuse (d) Digestion or Fermentation of Refuse

Vermi-Composting:

- Vermi-composting uses the natural composting process of decomposition of biodegradable organic matter by the soil bacteria as in ordinary composting technique, but takes the assistance of cultured earthworms.
- These earthworms do help in quicker decomposition of the organic matter.
- The various steps involved in applying the vermi-composting technique at individual domestic level are summarised below:
  (i) Dig a small pit about 0.5 m square and 1 m deep.
  (ii) Line the pit with straw or dried leaves and grass.
  (iii) Organize the disposal of organic domestic waste (such as vegetable wastes) into the pit as and when generated.
  (iv) Introduce a culture of worms that is now produced commercially.
  (v) Cover the pit contents daily, by sprinkling of dried leaves and soil everyday.
  (vi) Water the pit once or twice a week to keep it moist.
  (vii) Turn over the contents of the pit every 15 days.
  (viii) In about 45 days, the waste will be decomposed by the action of the micro organisms.
  (ix) The produced humus (soil) in the pit is fertile and rich in soil nutrients. It can, hence, be used in the garden

Example 6.2 Which one of the following methods of solid waste management conserves energy most efficiently in the form of gas or oil?

(a) Incineration with heat recovery (b) Combusting
(c) Pyrolysis (d) Fluidized bed incineration

Ans. (d)

6.3.5 Disposal of Refuse by Incineration and Thermal Pyrolysis

- Burning of refuse at high temperatures in furnace, called incinerators, is quite a sanitary method of refuse disposal, and is widely adopted in developed countries like USA, where the collected refuse is of high calorific value, and is hence quite suitable to burning.
- Only the combustible matter, such as garbage rubbish and dead animals are burnt, and the incombustible matter like broken glass, chinaware, metal etc. are either left unburnt or are separated out for recycling and refuse, before burning the solid wastes. Prior separation of such materials will reduce the load on the furnance and shall more than compensate the cost of this separation.

- One of the most effective methods of reducing the volume and weight solid wastes by burning it in a well designed furnace.
- When the available land is scarce, disposal requirements are string out and destruction of toxic water is necessary, incineration is the best method for treatment of solid wastes.
- There are mainly two stages involved is the process of incineration first drying and then combustion. Drying and combustion may be accomplished either in separate units or successively in the same unit depending on temperature constraints and control parameter.

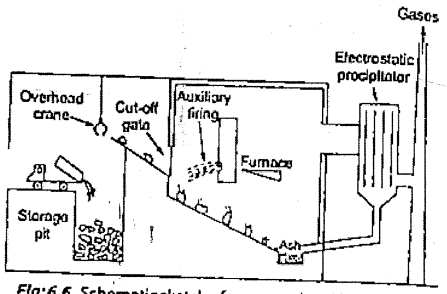

Fig: 6.6 Schematic sketch of a conventional incinerator (travelling grate type), to be used for incinerating municipal solid waste (refuse)

- Estimation of oxygen requirement and heat balance are very vital for efficient functioning of the incineration process.
- Large scale air pollution particularly due to the emissions of dioxins remains a serious problem with the incinerators.
- Large size incinerators are called destructor, and they can burn 100 to 150 tonnes of refuse per hour. A destructor consist of a furnace chamber, combustion chamber, expansion chamber, and a tall chimney. The ancillary work consist of ash-pit, charging apparatus, forced draft apparature, preheating arrangements, steam generating apparatus etc.
- While operating the incinerators, the following points should be carefully observed.
  (a) The charging should be thorough and rapid.
  (b) Each batch of refuse entering the furnace should be well mixed, and the proportion of the fuel in the charge be adjusted to provide complete combustion, and proper temperature.
  (c) The minimum temperature in the combustion chamber should be sufficient (normally larger than 670°C), so as to incinerate all organic matter and oxidise foul smelling gases.

Advantage:

- This is the most sanitary method of refuse disposal and ensures complete destruction of pathogenic bacteria and insects.
- There is no odour trouble or dust nuisances
- Some cost can be recovered by selling the steam power and clinkers.
- The disposal site can be conveniently located within the city near the outskirts, and transportation problems sorted out easily.
- It requires very less space for refuse disposal.

Disadvantage and Limitations:

- It is a very costly method and requires a lot of technical knowledge.
- Solid waste to be burnt should have a high calorific value.
- Smoke odour and ash nuisance may result due to the improper and incompetent operation of the plant, particularly if substances like plastic, giving high calorific value of the wastes, are present in the wastes.

Pyrolysis:

- Upon heating in closed containers in oxygen free atmosphere, most of the organic sustenances of solid waste can be split through a combination of thermal cracking and condensation reactions into gaseous, liquid and solid fractions. This process is known as pyrolysis or thermal pyrolysis.
- This process is also known as destructive distillation.
- When the organic solid waste is pyrolysed, following three type of products are obtained at different stages or temperature.
  (i) a gas stream which contains hydrogen, methane, CO, CO_2.
  (ii) a liquid fraction consisting of a tar and oil stream and is found to contain chemical like acetic acid, acetone and methanol
  (iii) a solid fraction consisting of charcoal like product plus any inert material.
- The respective quantum's of three end products (i.e gas, oil and charcoal) is found to depend upon the temperature of pyrolysis.
- Pyrolysis may be used for reducing the quantities of sludge produced in water or waste water treatment plant, before their ultimate disposal by methods like landfill and land application.

6.3.6 Disposal of Refuse by Barging it out into the Sea

- This method had been used in the past to dispose off refuse by throwing it away into the sea.
- The sea depth at such disposal point should not be less than 30 m or so, and the direction of the currents should be such as not to bring it back towards the shore.
- This method may, however have a limited use and that too only in a few coastal towns.
- This method, however, proves to be quite cheap and simple but possesses the following disadvantages:
  (i) The bulky and lighter parts of the refuse do not settle down remain floating and tend to return to the shores, especially during high tides.
  (ii) This method require ships or barges for taking the refuse into the interior of the sea, the movement of which may be difficult during monsoons and stormy weathers. During such periods the refuse will either have to be collected or disposed of by some other method.
  (iii) Even inspite of the best care and efforts, some refuse in this method, returns to the shores, spoiling their beauty.
  (iv) The dumping of refuse in sea may cause pollution of sea, leading to large scale fish kills, if the refuse happens to contain any toxic material.

Due to such disadvantage and due to general ban imposed on dumping of wastes into the sea, this method has now become obsolete.

6.4 Storage, Transportation and Disposal of Industrial Solid Wastes

- Management of industrial wastes have generally remained some wat neglected in India. Of late, slag from steel industry and fly ash from thermal power plants have been utilised by cement industry However, only 1 - 2% of fly ash and 30 - 60% of blast furnace slag are being utilised by cement industry.

- Some serious draw backs noticed in collection, storage, transport and disposal of industrial solid wastes in India are listed below:
  1. No municipal corporation (or any other public body) is assigned the duty of safe collection, transportation, and disposal of industrial wastes. The responsibility lies totally with the industrial units and is largely neglected.
  2. Wastes are shovelled into storage containers and loaded into lorries manually.
  3. Useful item from the wastes are salvaged by factory workers, who usually handle the wastes without gloves.
  4. Wastes are piled against a or on open grounded is a common sight in factories.
  5. Concrete bays or disused drums are often used for storage.
  6. Wastes are rarely covered.
  7. Wastes are transported in open trucks, which often spill the wastes.
  8. Drivers are not advised about the precaution to be taken.

Table: 6.9 Existing Methods of Waste Disposal in India for Certain Select Industries

S. No	Industry	Disposal of wastes
(i)	Petrochemicals	All sludge and solid wastes from a plant are collected and sent to a disposal site outside the plant.
(ii)	Paints, varnish, lacquers	Solid waste is collected at point of generation in barrels and given to a contractor for disposal. Date expired paints are sold off. Waste treatment sludge is disposed of along with other solid wastes.
(iii)	Dye intermediates (naphthalene-based), H acid, G acid, peracids	Manually collected and dumped in low-lying areas.
(iv)	Ethanolamine	Put in drums and stored under-ground, or incinerated.
(v)	Orthochlorine	Burnt in open pits

- Industrial solid wastes pose a serious threat to the environment in India, because their disposal is largely uncontrolled. The responsibility of their safe disposal lies solely on the industrial units.
- Highly toxic wastes are sometimes destroyed by controlled incineration, but more commonly, small quantities of sludges are burnt along with factory garbage in open pits. Secured land filling of containers of wastes, again is not as common as uncontrolled dumping, which is most common practice. Industrial waste is disposed along with municipal solid waste in industrial agglomerations.

Summary

- Refuse represents dry wastes or solid wastes of the society.
- Gases found in landfills include air, ammonia, carbon dioxide, carbon monoxide, hydrogen, hydrogen sulphide, methane, nitrogen and oxygen.
- Composting of refuse is a biological method of decamping solid wastes.
- C/N of the input material in the compost heap is an important factor for the bacterial activity to continue, since the bacteria use nitrogen for building their cell structures (or proteins) and carbon for food (energy)

Objective Brain Teasers

Q.1 Which one of the following comprehensive classifications is used for different types of solid wastes?
(a) Residential, commercial and treatment plant wastes
(b) Food, demolition and construction wastes
(c) Municipal, industrial and hazardous wastes
(d) Rubbish, special wastes and wastes from open areas

Q.2 The term 'Refuse' generally does not include
(a) putrescible solid waste
(b) excreta
(c) non-putrescible solid waste
(d) ashes

Q.3 Consider the following statements; In solid waste management
1. density separation of solid wastes can be accomplished by air classifiers.
2. iron recovery from solid wastes can be done by magnetic separators.
3. aluminium separation from solid wastes can be accomplished by eddy current separators.

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

Q.4 The daily cover of MSW landfills consists of which one of the following?
(a) Compacted soil (b) Geomemebrane
(c) Geotextile (d) Geocomposite

Q.5 Which one of the following parameters is not included in the routine characterization of solid waste for its physical composition?
(a) Moisture content
(b) Density
(c) Particle size analysis
(d) Energy value

Q.6 Dioxin is released during which one of the following processes?
(a) Composting
(b) Incineration
(c) Sanitary land filling
(d) Bio-fertilization

Q.7 The leachate is an effluent from which of the following?
(a) Septic tanks (b) Sanitary lands fills
(c) Compost plants (d) Aerated lagoons

Q.8 Two biodegradable components of municipal solid waste are
(a) plastics and wood
(b) cardboard and glass
(c) leather and tin cans
(d) food wastes and garden trimmings

Q.9 The typical density in kg/m^3 (in situ) of well-compacted municipal solid waste in landfill is in the range of
(a) 100 to 300 (b) 310 to 500
(c) 550 to 850 (d) 900 to 1100

Q.10 Non-disposal of solid waste may cause the spread of
(a) malaria
(b) rodents related plague
(c) typhoid
(d) dysentery

Q.11 Which one of the following statements explains the term pyrolysis?
(a) Solid waste is heated in closed containers in oxygen-free atmosphere
(b) Solid waste is incinerated in presence of oxygen
(c) Wastewater is treated with oxygen
(d) Dissolved solids from water are removed by glass distillation

Q.12 50 g of CO_2 and 25 g of CH_4 are produced from the decomposition of municipal solid

waste (MSW) with a formula weight of 120 g. What is the average per capita green house gas production in a city of 1 million people with a MSW production rate of 500 ton/day?

(a) 104 g/day (b) 120 g/day
(c) 208 g/day (d) 313 g/day

Q.13 **Statement-I:** Municipal Solid Waste is disposed off in the Transport Safe Disposal Facility (TSDF) to convert it into organic compost.

Statement -II: The organic Municipal Solid Waste is converted into compost by worms; and the process is called 'Vermicomposting'.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Answers

1. (c)	2. (c)	3. (d)	4. (a)	5. (d)
6. (b)	7. (b)	8. (d)	9. (d)	10. (b)
11. (a)	12. (d)	13. (a)		

Hints and Explanations:

Ans.9 (d)

When compacting a broad range of municipal solid wastes, the typical density obtained is about 1100 kg/m^3 irrespective of the starting density and applied pressure.

Ans.11 (a)

Upon heating in an oxygen free atmosphere during pyrolysis, most organic substances can be split through a combination of thermal cracking and condensation reactions in gaseous liquid and solid fractions.

Ans.12 (d)

We know that both CO_2 and CH_4 are green house gases.

∴ Total green house gases produced by 120 gm of MSW

$= 50\ g\ CO_2 + 25\ g\ of\ CH_4$

$= 75\ gm$

500 ton of MSW will produce green house gases

$$= 500 \times 10^6 \times \frac{75}{120}$$

$$= 312.5 \times 10^6\ g/day$$

Per capita average production of green house gases

$$= \frac{312.5 \times 10^6}{1 \times 10^6}\ g/day$$

$$= 312.5\ g/day \approx 313\ g/day$$

■■■■