Waste Management:
Module 1

5th Semester – Dept. of Civil Engineering, VSSUT

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Waste Management:

Solid Waste: Classification, Generation & Storage

5th Semester – Civil Engineering, VSSUT

Disclaimer

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Solid Waste:-

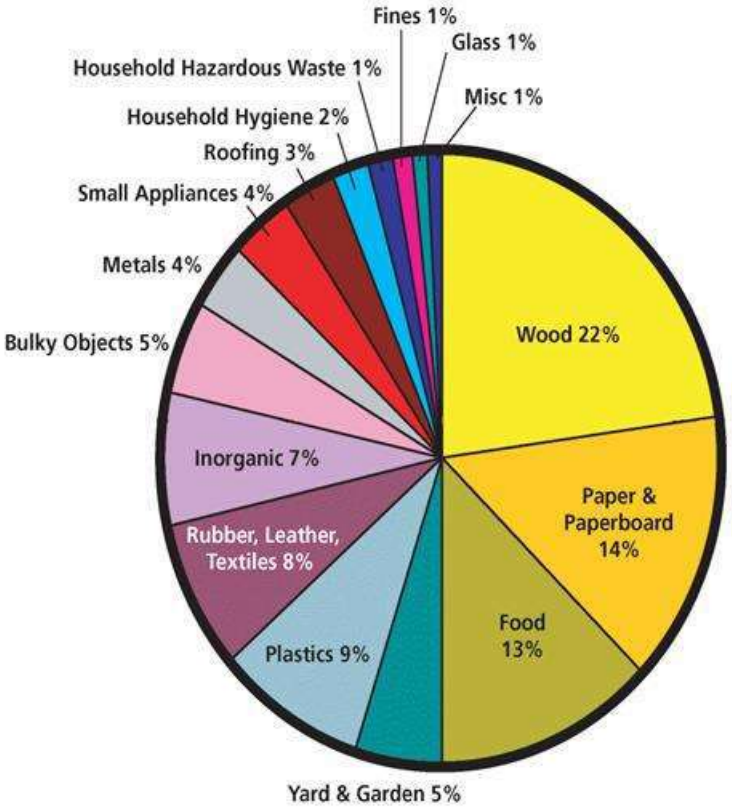
1) Discarded as **useless or unwanted things** or material arising from human & animal activities that are normally solid.

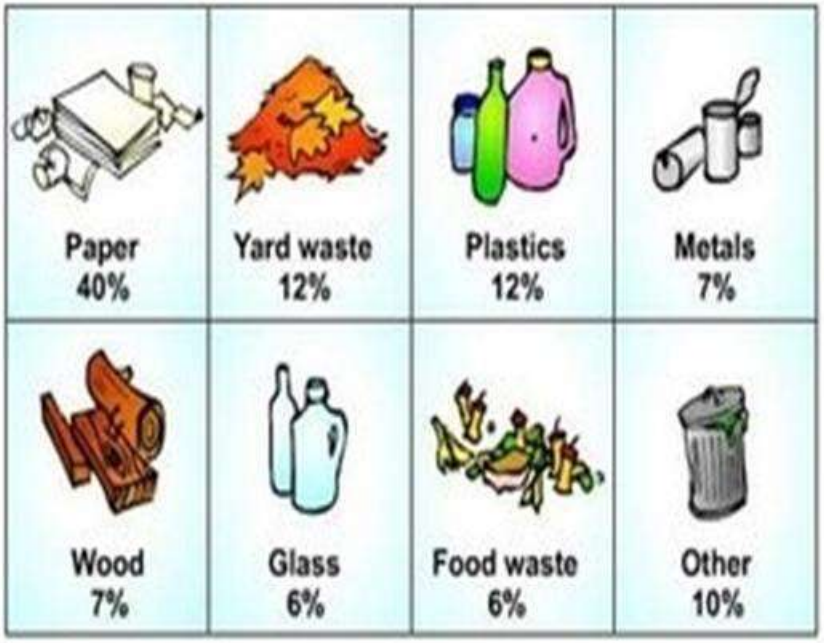
2) Substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the **provisions of the law**.

3) Mismanaged things.

4) United Nations Statistics Division (UNSD):- **Wastes are materials that are not prime products** (prime product - products produced for the market) for which the generator has no further use in terms of his own purposes of production, transformation or consumption, and of which he wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Residuals recycled or reused at the place of generation are excluded.

Solid Waste:-





COMPONENTS OF U.S. MUNICIPAL WASTE

Types of waste

Agricultural wastes

Industrial wastes

- Household wastes

- Hospital waste

Classification of Solid Waste on the source of generation:-

1) **Domestic/ Residential/ House Waste:**
   - Solid waste originates from domestic or residential area.
   - Waste generated as consequences of household activities such as cooking, cleaning, repairing, etc.
2) **Commercial Waste:**
   - Waste originates from offices, stores, hotels, markets, etc.
3) **Institutional Waste:**
   - Waste originates from institutes, schools, universities, colleges, etc.
4) **Municipal Waste:**
   - Waste originates from municipal activities.
   - Includes street waste, commercial waste, & market waste, etc.
   - Term commonly applied in a wider sense to incorporate domestic, institutional & commercial waste.
5) **Street Waste:**
   - Waste that originates from street, walkways, alleys & vacant areas.
   - Includes paper, plastic, leaves & other matter discarded by road users.

6) Construction & Demolition Waste:

- Waste generated by construction, repairing & demolition of building.
- Consist of earth stones, concrete, bricks, & other material.

7) Industrial Waste:

- Waste arising from industrial activities.
- Cover vast range of substances which are unique to each industry.

8) Sewage Waste:

- Waste generated from treatment plant.
- Mostly organic in nature.

9) Hazardous waste:

- Waste that poses great danger to human, animal & Plant b'coz of its toxicity, reactivity, corrosivity & ignitability.
- Requires special handling & good management.

10) Biomedical waste:

- Waste arising from hospital & pathological lab.
- Comes under category of hazardous waste.

11) Garbage:

- Contains putrescible organic matter.
- Decomposes quickly.

12) Rubbish:

- Dry non-putrescible solid waste excluding ash & garbage.

13) Agricultural Waste:

Classification of Wastes according to their Properties

Bio-degradable :

can be degraded (paper, wood, fruits and others)

Non-biodegradable:

cannot be degraded (plastics, bottles, old machines, cans, containers and others)

Classification of Wastes according to their Effects on Human Health and the Environment

Hazardous wastes :

Substances unsafe to use commercially, industrially, agriculturally, or economically and have any of the following properties:-

1) ignitability,
2) corrosivity,
3) reactivity &
4) toxicity.

Non-hazardous :

Substances safe to use commercially, industrially, agriculturally, or economically and do not have any of those properties mentioned above.

Classification of wastes according to their origin and type

1) **Municipal Solid wastes:** Solid wastes that include household garbage, rubbish, construction & demolition debris, sanitation residues, packaging materials, trade refuges etc. are managed by any municipality.

2) **Bio-medical wastes:** Solid wastes including containers, intermediate or end products generated during diagnosis, treatment & research activities of medical sciences.

3) **Industrial wastes:** wastes that are generated by manufacturing & processing units of various industries like chemical, petroleum, coal, metal gas, sanitary & paper etc.

4) **Agricultural wastes:** Wastes generated from farming activities. These substances are mostly biodegradable.

5) **Radioactive wastes:** Waste containing radioactive materials. Usually these are byproducts of nuclear processes. Sometimes industries that are not directly involved in nuclear activities, may also produce some radioactive wastes, e.g. radio-isotopes, chemical sludge etc.

6) **E-wastes:** Electronic wastes generated from any modern establishments. They may be described as discarded electrical or electronic devices. Some electronic scrap components, such as CRTs, may contain contaminants such as Pb, Cd, Be or brominated flame retardants.

Useful Options

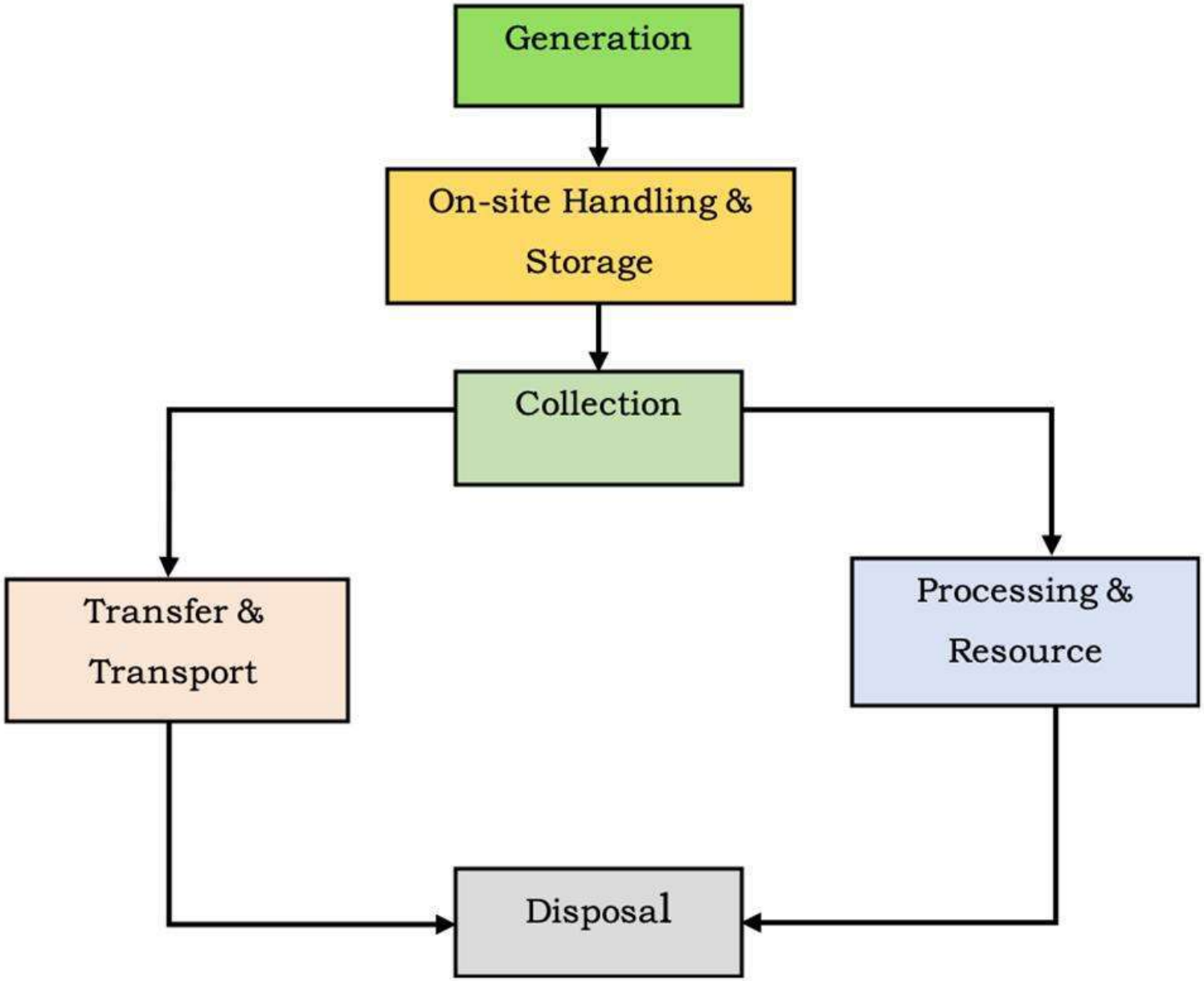
1) Resource recovery
2) Composting
3) Vermi-composting
4) Energy recovery
5) Incineration
6) Pyrolysis
7) Gasification
8) Bio-methanation or anaerobic digestion

- Solid Waste Management should be **environmentally feasible** considering principles of **economy, aesthetics, energy** & other considerations.

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

1) Generation
2) Storage
3) Collection
4) Transport
5) Processing
6) Disposal

Functional Elements of Solid Waste Management System



COLLECTION

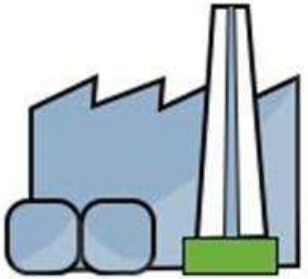
TRANSPORTATION

RECOVERY

PROCESSING

ANAEROBIC DIGESTER

COMPOST



INCINERATION

SANITARY LANDFILL

Functional Elements of Waste Management System

Generation/ source/ quantity/ composition

On-site processing and storage

Primary collection

Communal storage

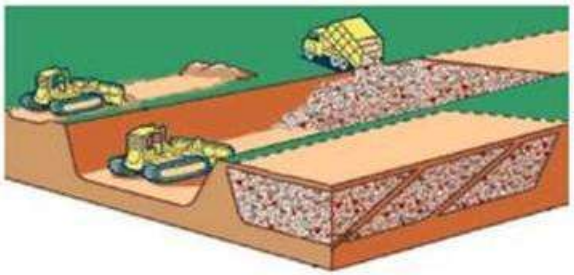
Transfer station

Secondary collection

Intermediate treatment

Final disposal

Reduction/ recycling & reuse/ resource recovery (energy or recyclables)



Six Functional Elements of Solid Waste Management:-

1) **Generation:-**
   - Activities in which materials are generated and identified as useless or unwanted materials.
   - Average generation rate is 0.33 kg/Person/Day. (0.3 to 0.6)

2) **Storage:-**
   - The generated wastes are stored near the point of generation for short period & then transfer to community storage bin.

3) **Collection:-**
   - Gathering of stored solid waste & then transfer to community storage bin.

4) **Transport:-**
   - The material collected in community bin is transferred to the processing or disposal site by transport vehicles.

Six Functional Elements of Solid Waste Management:-

5) Processing:-

- It is the process to reduce its potential nuisance value (strength) and to recover usable material or energy from solid waste before its final disposal.

6) Disposal:-

- It is ultimate disposal of solid waste.
- After transportation or processing solid waste can be disposed on land or water logged areas for reclamation or low laying area or into sea etc.

Impacts of Waste :-

1) Chemical poisoning through chemical inhalation.
2) Cancer.
3) Neurological disease.
4) Nausea and vomiting.
5) Increase in hospitalization of diabetic residents living near hazard waste sites.
6) Mercury toxicity from eating fish with high levels of mercury.
7) Uncollected waste can obstruct the storm water runoff resulting in flood.
8) Low birth weight.
9) Congenital malformations.
10) Increase in mercury level in fish due to disposal of mercury in the rivers.
11) Resulted in high algal population in rivers and sea.

Impacts of waste on Environment

13) Waste breaks down in landfills to form methane, a potent greenhouse gas.

14) Change in climate and destruction of ozone layer due to waste biodegradable.

15) Littering, due to waste pollutions, illegal dumping, Leaching: is a process by which solid waste enter soil and ground water and contaminating them.

1. Generation

Generation:-

1) Rate may vary widely from place to place.
2) In US – 2 Kg/C/Day
3) Japan – 1 Kg/C/Day
4) Canada – 3 Kg/C/ Day
5) **India – 0.3 to 0.5 Kg/C/Day**
6) Data includes refuse from residential, commercial, institutional & industrial sources.
7) Actual generation tare must be carefully determined for management.
8) Generation rate expected to be **double by 2025.**
9) Higher the income level greater will be generation rate.

Factors causing variation

- As we know, wastes cause pollution. While the nature of wastes determines the type and intensity of pollution, it also helps us decide on the appropriate application, engineering design and technology for management.
- For example, the nature of wastes has implications for collection, transport and recycling. For effective SWM, therefore, we not only need information about the present but also the expected future quantity and composition of wastes.
- There are several factors, which affect the present as well as the future waste quantity and composition (Tchobanoglous, et al., 1977), and some of which are listed below:

- **Geographic location:** The influence of geographic location is related **primarily to different climates that can influence both the amount of certain types of solid wastes generated and the collection operation**.
- **Seasons:** Seasons of the year have implications for the **quantities and composition of certain types of solid wastes**. For example, the growing season of vegetables and fruits affect the quantities of food wastes.
- **Collection frequency:** A general observation is that in localities, where there are **ultimate collection services, more wastes are *collected*. Note that this does not mean that more wastes are *generated*.**
- **Population diversity:** The characteristics of the population influence the **quantity and composition of waste generated**. The amount of waste generated is more in low-income areas compared to that in high-income areas. Similarly, the composition differs in terms of paper and other recyclables, which are typically more in high-income areas as against low-income areas

- **Extent of salvaging and recycling:** The existence of salvaging and recycling operation within a community definitely affects the quantity of wastes collected.
- **Public attitude:** Significant reduction in the quantity of solid waste is possible, if and when people are willing to change – on their own volition – their habits and lifestyles to conserve the natural resources and to reduce the economic burden associated with the management of solid wastes.
- **Legislation:** This refers to the existence of local and state regulations concerning the use and disposal of specific materials and is an important factor that influences the composition and generation of certain types of wastes. The Indian legislation dealing with packing and beverage container materials is an example.

Composition of Solid Wastes:-

Composition of Solid Waste in %age by Net Weight for Indian Cities		
SN	**Solid Waste Content**	**Contribution or Composition**
1	Glass	0.3 %
2	Metal	0.3 %
3	Paper	2 - 7 %
4	Plastic	2 – 7 %
5	Ash & Inert	20 – 50 %
6	Total Compostable Matter	30 - 60 %


NEWS
NEWS
PAPER
GLASS
ORGANIC
PLASTIC

Characteristics of Solid Waste:-

Characteristics of Solid Waste in %age by Net Weight for Indian Cities		
SN	**Solid Waste Characteristics**	**Contribution or Content in %**
1	Total Nitrogen	0.5 – 0.9 %
2	Organic Matter	20 - 40 %
3	Moisture Content	20 – 40 %
4	C/N ratio	20 – 40
5	Calorific Value	800 – 1800 kcal/kg
6	Density	300 – 600 kg/m3
7	Phosphorous, Potassium, Carbon, etc.	-------

Phyical characteristics

- **Density: Density of waste, i.e., its mass per unit volume (kg/m3), is a critical factor in the design of a SWM system, e.g., the design of sanitary landfills, storage, types of collection and transport vehicles, etc. To explain, an efficient operation of a landfill demands compaction of wastes to optimum density.**

- **Moisture content: Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total weight of the wet waste. Moisture increases the weight of solid wastes, and thereby, the cost of collection and transport. In addition, moisture content is a critical determinant in the economic feasibility of waste treatment by incineration, because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour.**

- **Size: Measurement of size distribution of particles in waste stream is important because of its significance in the design of mechanical separators and shredders. Generally, the results of size distribution analysis are expressed in the manner used for soil particle analysis.**

Chemical characteristics

- Knowledge of the classification of **chemical compounds and their characteristics is essential for the proper understanding of the behaviour of waste**, as it moves through the waste management system.
- The products of **decomposition and heating values** are two examples of chemical characteristics. If solid wastes are to be used as fuel, or are used for any other purpose, we must know their chemical characteristics, including the following:

(i) Lipids:

- ✓ This class of compounds includes fats, oils and grease, and the principal sources of lipids are garbage, cooking oils and fats. Lipids have high heating values, about 38,000 kJ/kg (kilojoules per kilogram), which makes waste with high lipid content suitable for energy recovery.

- ✓ Since lipids become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition. Though they are biodegradable, the rate of biodegradation is relatively slow because lipids have a low solubility in water.

(ii) **Carbohydrates:**

- ✓ These are found primarily in food and yard wastes, which encompass sugar and polymer of sugars (e.g., starch, cellulose, etc.) with general formula $(CH_2O)_x$.

- ✓ Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane. Decomposing carbohydrates attract flies and rats, and therefore, should not be left exposed for long duration.

(iii) **Proteins:**

- ✓ These are compounds containing carbon, hydrogen, oxygen and nitrogen, and consist of an organic acid with a substituted amine group (NH_2).
- ✓ They are mainly found in food and garden wastes. The partial decomposition of these compounds can result in the production of amines that have unpleasant odours.

(iv) **Natural fibres:**

- ✓ These are found in paper products, food and yard wastes and include the natural compounds, cellulose and lignin, that are resistant to biodegradation. (Note that paper is almost 100% cellulose, cotton over 95% and wood products over 40%.) Because they are a highly combustible solid waste, having a high proportion of paper and wood products, they are suitable for incineration.

(v) **Synthetic organic material (Plastics):**

- ✓ Accounting for 1 – 10%, plastics have become a significant component of solid waste in recent years.

- ✓ They are highly resistant to biodegradation and, therefore, are objectionable and of special concern in SWM.

- ✓ Hence the increasing attention being paid to the recycling of plastics to reduce the proportion of this waste component at disposal sites. Plastics have a high heating value, about 32,000 kJ/kg, which makes them very suitable for incineration. But, you must note that polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas. The latter increases corrosion in the combustion system and is responsible for acid rain.

(vi) **Non-combustibles:**

- ✓ This class includes glass, ceramics, metals, dust and ashes, and accounts for 12 – 25% of dry solids.

(vii) **Heating value:**

- ✓ An evaluation of the potential of waste material for use as fuel for incineration requires a determination of its heating value, expressed as kilojoules per kilogram (kJ/kg).
- ✓ The heating value is determined experimentally using the *Bomb calorimeter test*, in which the heat generated, at a constant temperature of 25C from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water (100C), the combustion water remains in the liquid state. However, during combustion, the temperature of the combustion gases reaches above 100C, and the resultant water is in the vapour form.

Table -1 shows the typical inert residue and heating values for the components of municipal solid waste (Tchobanoglous, et al., 1977):

Typical Heating and Inert Residue Values

Component	Inert Residue %		Heating Value (kJ/kg)	
	Range	Typical	Range	Typical
Food wastes	2-8	5	3500-7000	4500
Paper	4-8	6	11500-18500	16500
Cardboard	3-6	5	14000-17500	16000
Plastics	2-20	10	28000-37000	32500
Textiles	2-4	2.5	15000-20000	17500

Component	Inert Residue %		Heating Value (kJ/kg)	
	Range	Typical	Range	Typical
Rubber	8-20	10	21000-28000	18500
Leather	8-20	10	15000-20000	17500
Garden trimmings	2-6	4.5	2300-18500	6500
Wood	0.6-2	1.5	17500-20000	18500
Glass	96-99	98	120-240	140
Tin cans	96-99	96	-	-
Nonferrous metals	90-99	96	240-1200	700
Ferrous metals	94-99	98	240-1200	700
Dirt, ash, bricks, etc.	60-80	70	2300-11500	7000
Municipal solid waste			9500-13000	10500

(viii) **Ultimate analysis:**

- ✓ This refers to an analysis of waste to determine the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur, and the analysis is done to make mass balance calculation for a chemical or thermal process.

- ✓ Besides, it is necessary to determine ash fraction because of its potentially harmful environmental effects, brought about by the presence of toxic metals such as cadmium, chromium, mercury, nickel, lead, tin and zinc.

- ✓ Note that other metals (e.g., iron, magnesium, etc.) may also be present but they are non-toxic. Table-2 shows the result of ultimate analysis of a typical municipal solid waste:

Municipal Solid Waste: A Typical Ultimate Analysis

Element	Range (%dry weight)
Carbon	25-30
Hydrogen	2.5-6.0
Oxygen	15-30
Nitrogen	0.25-1.2
Sulphur	0.02-0.12
Ash	12-30

(ix) **Proximate analysis:**

- ✓ This is important in evaluating the combustion properties of wastes or a waste or refuse derived fuel. The fractions of interest are:
- ❖ moisture content, which adds weight to the waste without increasing its heating value, and the evaporation of water reduces the heat released from the fuel;
- ❖ ash, which adds weight without generating any heat during combustion;
- ❖ volatile matter, i.e., that portion of the waste that is converted to gases before and during combustion;
- ❖ fixed carbon, which represents the carbon remaining on the surface grates as charcoal. A waste or fuel with a high proportion of fixed carbon requires a longer retention time on the furnace grates to achieve complete combustion than a waste or fuel with a low proportion of fixed carbon.

Proximate analysis for the combustible components of municipal solid waste:

Municipal Solid Waste: A Typical Proximate Analysis

Components	Value, percent	
	Range	Typical
Moisture	15-40	20
Volatile matter	40-60	53
Fixed carbon	5-12	7
Glass, metal, ash	15-30	20

Typical Waste Composition: Low/High Income Population

Characteristics	Low income	High income	Comments
Paper	1 – 4%	20 – 50%	Low paper content indicates low calorific value.
Plastics	1 – 6%	5 – 10%	Plastic is low as compared to high-income areas though the use of plastic has increased in recent years.
Ash and Fines	17 – 62%	3 – 10%	Ash and fines do not contribute to combustion process.
Moisture Content	30 – 40%	15 – 30%	Moisture content depends largely on the nature of the waste, climate and collection frequency. Waste can dry out while awaiting collection.
Bulk Density	300 – 400 kg/ m^3	150 kg/m^3	Heavier waste may cost more to handle and difficult to burn.

Solid Wastes: Typical Composition, Moisture and Density

Components	Mass %		Moisture content %		Density in kg/m	
	Range	Typical	Range	Typical	Range	Typical
Food wastes	6-26	14	50-80	70	120-480	290
Paper	15-45	34	4-10	6	30-130	85
Cardboard	3-15	7	4-8	5	30-80	50
Plastics	2-8	5	1-4	2	30-130	65
Textiles	0-4	2	6-15	10	30-100	65
Rubber	0-1	0.5	1-4	2	90-200	130
Leather	0-2	0.5	8-12	10	90-260	160
Garden Trimming	0-20	12	30-80	60	60-225	105
Wood	1-4	2	15-40	20	120-320	240
Misc. Organic substances	0-5	2	10-60	25	90-360	240
Glass	4-16	8	1-4	2	160-480	195
Tin cans	2-8	6	2-4	3	45-160	90
Non-ferrous metals	0-1	1	2-4	2	60-240	160

Components	Mass %		Moisture content %		Density in kg/m	
	Range	Typical	Range	Typical	Range	Typical
Ferrous metals	1-4	2	2-6	3	120-1200	320
Dirt, ash, bricks, etc.	0-10	4	6-12	8	320-960	480

2. Storage

Storage:-

1) Waste stored in premise must be kept in standardized containers for collection.
2) Depending upon where it is adopted & frequency of waste removal container must be designed.
3) Storage should be compatible for collection.
4) Use of no standardized container increase time for collection, risk of muscular strain or injury to labor.
5) Storage should be of plastic with detachable cover.
6) Precaution should be taken to ensure that the stored waste is not exposed & does not come in contact with moisture & vectors of diseases.
7) Dry & wet solid waste stored separately.
8) Recyclable & hazardous waste stored separately.
9) Wet solid waste should be stored in no corrosive container with lid & should be removed everyday from house..

Household Storage:-

1) This type of storage stores waste in a container or bucket or plastic sack of 5-7 liters capacity which are adequate for an average family.
2) It is desirable to use plastic container with tight fitting lids.
3) Use of standardized storage will improve environmental condition as well as the collection of the waste.

Commercial Waste Storage:-

- In commercial Waste Storage like colleges, offices, hotels markets, etc. large size storage of 50-100 liter capacity can be provided with handled for lifting & wheels for easy movement.

Street Waste Storage:-

1) Litter Bins
2) It is used to store waste from streets.
3) The top part of storage is designed in such a way to prevent entry of rainwater & also to prevent lighter material getting airborne.
4) The spacing of storage will depend upon the quantity of waste generated, importance of the road & frequency of cleaning.

Collection:-

- Removal of waste from individual houses is termed as collection.
- Collection can be carried out by using various methods such as:

    1) **House to House Collection System**
    2) **Community Bin System.**
    3) **Bell Ringing System.**
    4) **Collection of Waste from Street.**

- Expenditure on collection of solid waste is 45 to 75 % of total cost of solid waste management.
- Municipal agencies are responsible for collection of waste from residential & commercial areas while in case of industrial area owners are responsible.

Collection of waste from street:-

1) In this system, workers sweep the roads & collect the material at specific points.
2) In addition to the waste generated in the premises, waste is also generated along the street.
3) Collection from street is deposited in storage bin from where separated vehicle collect and transport to processing or disposal site.

Community Bin System:-

1) This system commonly adopted in India.
2) Community bins are located at street corner and at specific frequencies along the roads.
3) Residents are expected to bring their waste & deposit the same in the community bin.
4) Locations of community bins are fixed according to convenience of local citizens.
5) The capacity of community bins are should be 50% in excess when collection is daily and 100% in excess when collection is weekly.
6) Spacing should be fixed on the basis of per capita quantity & Population contributing the waste.
7) However distance between community bins should not be more than 100m.

Bell Ringing System:-

1) In this system, the collection vehicle is provided with a bell & on reaching specified points it is rung.
2) Residents from adjoining areas come to vehicle & deposit the waste in the vehicle.
3) This system work efficiently, if the movement of the vehicle is appropriately & continuously control & citizens are also cooperative.

House to House Collection System:-

- In this method, generated & stored waste in individual premises is collected by following ways:
    1) **Curb Service.**
    2) **Alley Service.**
    3) **Set out, Set Out Back Service.**
    4) **Set Out Service.**
    5) **Backyard Service.**

A) Set Out Set Back Service:-

- In this system, set out men go to individual houses, collect the container & empty them in the vehicle.
- Another group of persons return them to house owner yard.

B) Set Out Service:-

- In this system, the worker will collect the container from individual houses & empty them in vehicles.
- The house owner is required to take back the empty container.

C) Curb Service:-

- In this system, the house owner is responsible for placing the containers at the curb on the scheduled day.
- Workmen collect & empty the container in the vehicle & place them at the curb.
- The house owner is required to take back the empty containers to his house.

D) Alley Service:-

- In this system, The containers are placed at the alley line from where they are taken by workmen & deposited in the vehicle.

E) Backyard Service:-

- In this system, The worker carry a bin or handcart or sack to the yard and empty the solid waste container in it.
- The handcart or bin or sack is subsequently taken to solid waste collection vehicles where it is emptied.

Tools & Equipments Used in Collection of Solid Waste:-

- Collection & transportation of solid waste involves use of a variety of tools, equipments & facilities.
- It is essential that these are selected with due care so as to ensure optimum performance of the system.
- Most of the tools & equipments that are currently being used have not been specifically designed for solid waste collection work and are often adopted because they are readily available for some other service.
- To improve performance of the system following tools & equipments should be used for storage, collection & transfer of solid waste.

1. Brooms
2. Shovels
3. Mechanical sweepers
4. Handcarts
5. Household Storage
6. Commercial storage
7. Street waste Storage
8. Community Bins (Stationary & Moveable)

Brooms:-

- These are mainly of two types short handled & long handled.

1. Short Handled Brooms:-

- It has wooden handled to which large number of short tufts are bound.
- For dislodging heavy deposit of dirt a large force has to be exerted which leads to the dust getting airborne & its consequent inhalation adversely affects health.
- It also strains the back of worker due to the stooping posture adopted by him for sweeping.

Brooms:-

- These are mainly of two types short handled & long handled.

2. Long Handled Brooms:-

- It consists of a bunch of long flexible fibers attached to a bamboo handled & are used by workers while standing erect.
- The brooms are used with long strokes to sweep the material on the roads.
- It clear most of the light material such as paper, plastic, etc.
- This broom is safer from the health point of view & hence preferred.

Shovels:-

- The collection of solid waste material is carried out by a shovel.
- A straight blade shovel & flat board shovel made of GI sheets are used.

Mechanical Sweepers:-

1) Mechanical road sweepers are used in developed countries.
2) Also used in high income areas of a few Indian cities.
3) Equipment consists of one or more rapidly involving brushes which dislodge the material & direct the deposited material from the road surface to a single point from where it is sucked by a suction mechanism.
4) Engine for forward movement as well as for providing suction is the same in some units while in some units separate engines are provided.
5) Mechanical sweepers are likely to get easily damaged due to the uneven, rough surface & heavy objects.
6) It can be used only in certain situation and have to be supplemented by manual sweeping.
7) It obstructs the traffic due to their slow speed of movement.

Community Bins:-

It can be divided into two categories stationary & moveable bins.

A. Stationary:-

1) Large size stationary storage bins are of two types covered & uncovered enclosure.
2) These bins are often constructed in brick masonry or concrete to various sizes.
3) People are expected to deposit the solid waste inside the enclosure.
4) Sometimes masonry enclosure have roofs on the top and shutter infront.
5) Due to enclosure waste is protected from rain.

B. Moveable:-

1) These are designed to be compatible with the transport vehicle.
2) Two system of large sized wheel-less containers are often used.
3) 8-10 m3 size container are used which when full are taken away to the disposal site after lifting them on vehicle.
4) Due to the large capacity of these containers a workers are often posted at site.

Handcart:-

1) Handcart is used to collect & transport the solid waste to the community bin.
2) Handcarts are singled or doubled or three wheeled type.
3) To transport the same quantity lesser force is required in the 3 wheel handcart than in the 2 wheel handcart.
4) Light tabular frame is recommended for easy loading & unloading & to reduce the weight.
5) Wheels should be large as possible for easy movement.
6) Sometimes handcarts are also provided space for brooms, shovels, etc.

Waste Management:

Solid Waste - Collection, Transfer & Processing

5th Semester – Civil Engineering, VSSUT

3. Collection

Planning of Solid Waste Collection Program.

Routing system of collection

1. Micro-routing is:

—the routing of a vehicle within its assigned collection zone.

—concerned with how to route a truck through a series of one or two way streets so that the total distance traveled is minimized.

—very difficult to design and execute.

2. Macro-routing is:

—large scale routing to the disposal site and the establishment of the individual route boundaries.

Labor requirements for the collection of solid waste depend on both the type of service provided and the collection system used:

a) For hauled container system:

- Collection systems in which the containers used for the storage of wastes are hauled to the processing, transfer or disposal site, emptied and returned to either their original location or some other location are defined as hauled container systems.
- one person, two for safety, and a driver to drive the vehicle load and unload containers and empty the container at the disposal site.

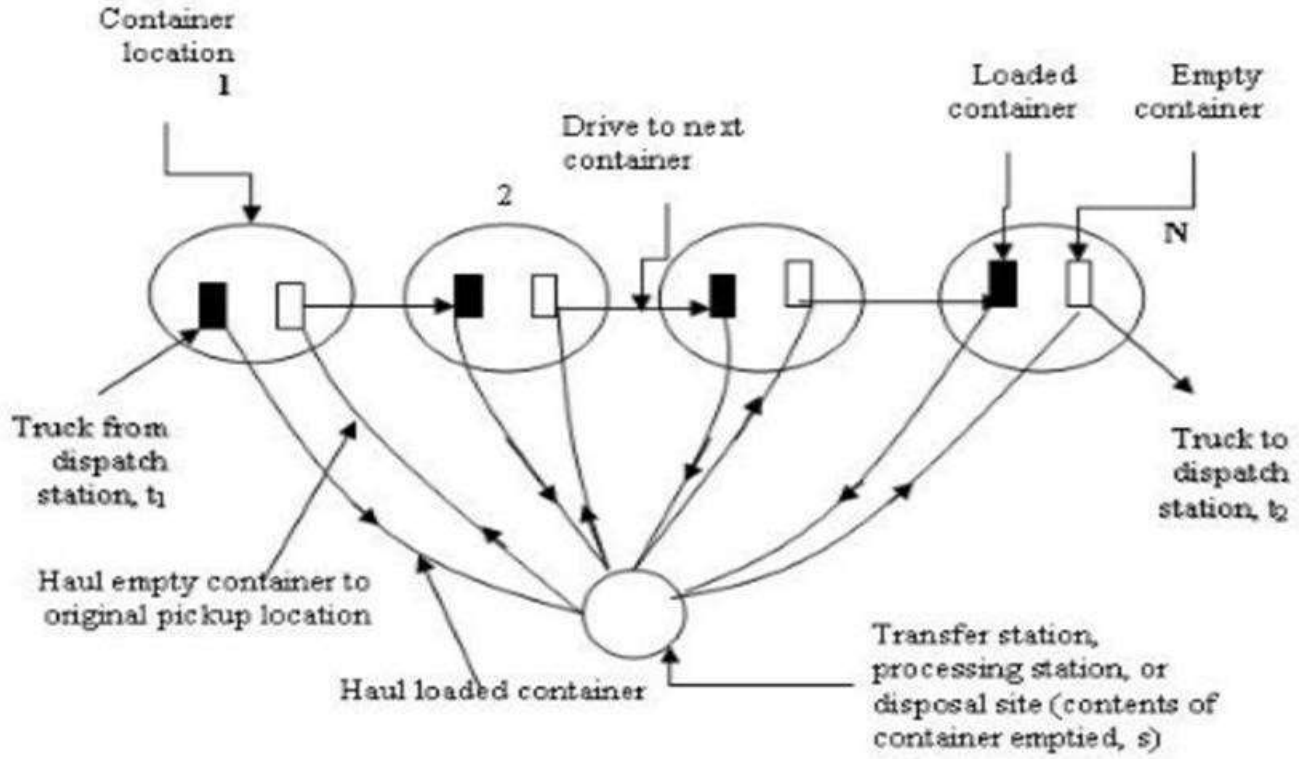
b) For stationary container system :

- Collection systems 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
- the labor requirement for mechanically loaded ones are essentially the same with hauled container system. Occasionally, a driver and two helpers are used.

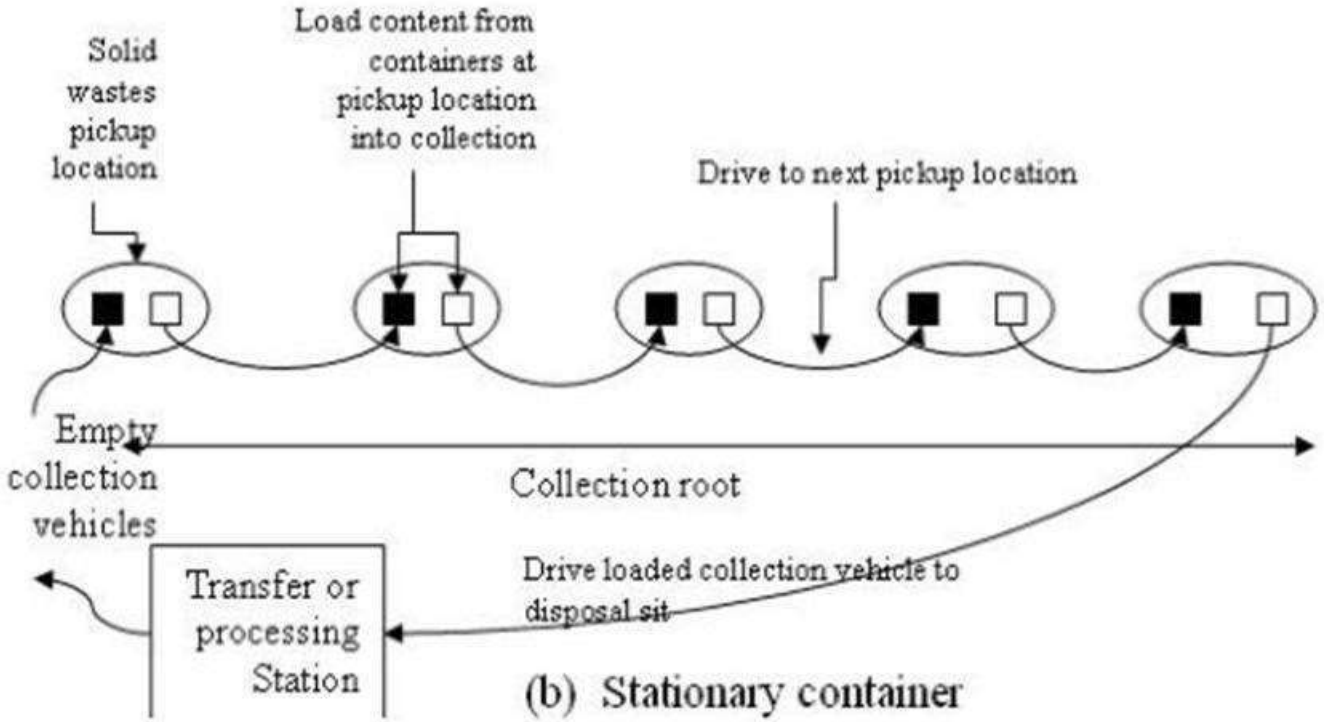
Modes of operation in solid waste collection

Unit operations

1. **Pick-up** - refers to the time spent driving to the next container after an empty container has been deposited.
2. **Haul** - represents the time required to reach the disposal site starting after a container whose contents are to be emptied has been loaded on the truck plus the time spent after leaving the disposal site until the truck arrives at the location where the empty container is to be deposited.
3. **At-site-** refers to the time spent at the disposal site and includes the time spent waiting to unload as well as the time spent in loading.
4. **Off-site** - includes the time spent on activities that are non-productive from the point of view of the overall collection system.



(a) Hauled container.



(b) Stationary container

Frequency of solid waste collection

- The frequency of collection depends on the quantity of solid waste, time of year, socioeconomic status of the area served, and municipal or contractor responsibility. In business districts, refuse, including garbage from hotels and restaurants, should be collected daily except on Sundays.
- **In residential areas, twice-a-week for refuse collection during warm months of the year and once a week at other times should be the maximum permissible interval. Slum areas usually require at least twice-a-week collection.** The receptacle should be either emptied directly into the garbage truck or carted away and replaced with a clean container.
- Refuse transferred from can to can will cause spilling, which results in pollution of the ground and attraction of flies. If other than curb pickup is provided, the cost of collection will be high.
- Some property owners are willing to pay for this extra service. **Bulky wastes should be collected every 3 months.**

- **Garbage - should be collected at least two times weekly in residential sections in summer and winter.** However, most commercial establishments should be accorded daily collection service throughout the year.
- **Rubbish - is generally collected weekly in residential areas and daily in business sections.**
- **Mixed refuse - should be collected twice daily from most commercial concerns.**
- The provision of frequent collection services is important in the prevention of fly breeding in garbage, because irregular collections can contribute to the nuisances and hazards which result under poor storage conditions and in chances the amount greater than the expected requirement from households.

Collection equipment

- **Mechanical collection systems have been developed to reduce collection cost.** The system requires use of a special container, truck container pick-up equipment, and replacement of the container.
- Collection equipment that simplifies the collection of refuse and practically eliminates cause for legitimate complaint is available. **The tight-body open truck with a canvas or metal cover has been replaced in most instances by the automatic loading truck with packer to compact refuse dumped in the truck during collection, except for the collection of bulky items.**
- Compaction-type bodies have twice the capacity of open trucks and a convenient loading height. Low-level closed-body trailers to eliminate the strain of lifting cans are also available.
- The number and size of the collection vehicles and the number of pickups in residential and business areas for communities of different population will vary with location, affluence, and other factors. **The average refuse truck holds 6,000 to 8,000 kilograms.**
- **The solid waste collection vehicle should be covered and able to compact the refuse collected.** It may load from the rear, side, or top. The storage areas in these vehicles should be kept relatively clean and water-tight.

Organization of solid waste collection program

- **Many cities and towns require homeowners to use certain types of receptacles.** In some neighborhoods the collectors pick up the receptacles in the backyard, as the people who live there consider receptacles too bulky to handle and unsightly in front of their dwellings.
- **Haul distance to the disposal facility must be taken into consideration in making a cost analysis. In some highly urbanized areas it is economical to reduce haul distance by providing large, specially designed trailers at transfer stations.**
- **In suburban and rural areas, container stations can be established at central locations.** These stations may include a stationary compactor for ordinary refuse and a bin for tires and bulky items. Separate bins for paper, glass, and aluminum may also be provided.

4. Transfer & Transport

Transport:-

The waste collected in storage containers or community bins are carried to the processing or disposal site by using a variety of vehicles.

I. Vehicles which moves through narrow streets & after travelling a short distance discharge their contents into another vehicle (big) at the transfer station or directly at the processing or disposal site.

II. Vehicles which move through wider roads and after travelling over long distance discharge their contents at the processing or disposal site.

If transportation vehicles are selected properly then transportation cost can be reduced substantially by 20 – 45%

Transport:-

The vehicles should satisfy the following requirements:-

1. The loading height should not exceed 1.5 m.
2. Vehicles should have tipping gear arrangement for fast & efficient unloading.
3. Vehicles should have covered body.
4. When fully loaded, they should be able to climb a gradient of upto 1:10.
5. Sufficient carriage capacity.
6. Reliable & economic.
7. Their bodies should have atleast two coats of anti corrosive paint of distinct color for easy identification.
8. The body should not have sharp corner where material accumulates & should facilitates easy cleansing.
9. Satisfy the prevailing motor vehicle rules.

Transport:-

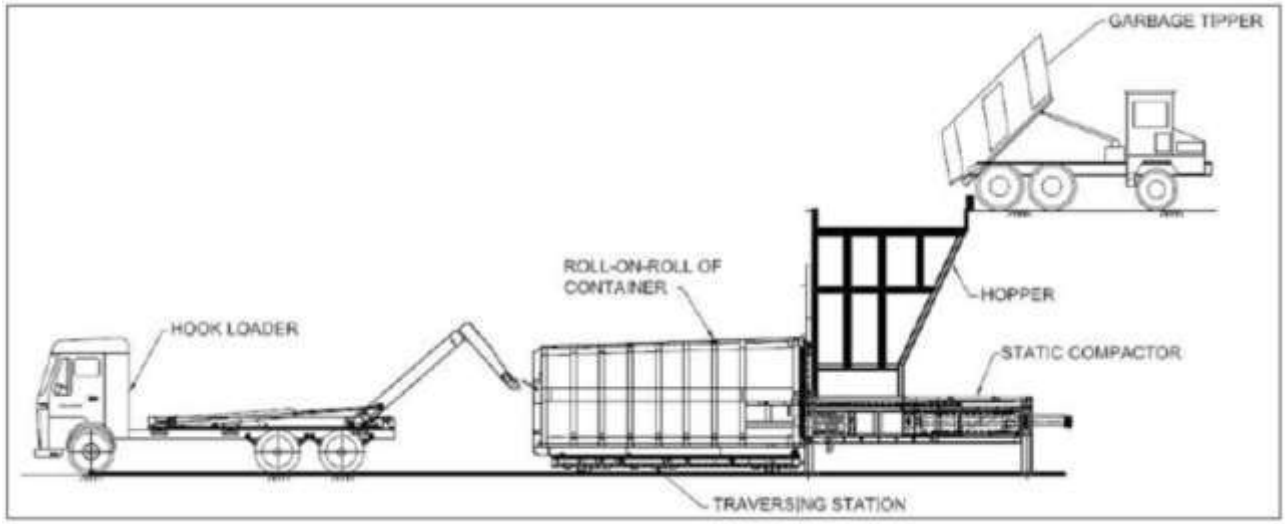
The types of transportation vehicles:-

1. Animal cart
2. Tractor Trailer
3. 3 wheeled Auto Rickshaws
4. Trucks
5. Pedal Tricycle
6. Dumper Placer
7. Container Carriage System
8. Special Municipality Vehicles, etc.

Transfer and Transport

- **Transfer stations are used to collect the refuse at a central location and to reload the wastes into a vehicle** where the cost per kilogram-kilometer ton-mile will be less for the movement of the ultimate waste to the disposal site. **Transfer stations are employed when the disposal site is situated at significant distance from the point of collection.**
- **A transfer station can reduce the cost of transporting refuse by reducing manpower requirement and total kilometers**. When a collection vehicle goes directly to the disposal site, the entire crew, driver plus laborers, are idle. For a transfer vehicle, only one driver is needed. As the distance from the centers of solid waste generation increases, the cost of direct haul to a site increases. Ideally, the transfer station should be located at the center of the collection service area.
- **A transfer station may include stationary compactors, recycling bins, material recovery facility, transfer containers and trailers, transfer packer trailers, or mobile equipment.**

- **A transfer station should be located and designed with drainage of paved areas and adequate water hydrants for maintenance of cleanliness and fire control and other concerns like land scaling, weight scales, traffic, odor, dust, litter, and noise control.**
- Transporting vehicles could be a modern packer truck (trailer), motor-tricycles, animal carts (appropriate for developing countries), hand carts and tractors.
- Transfer and transport station should provide welfare facilities for workers (lockers, toilets, showers); small stores for brooms, shovels, cleaning materials, lubricants, parking facilities for hand trucks, sweepers, refuse collectors, and office and telephone for the district inspector.



Stationary Compactor Transfer Station Design

Typical activities at the Transfer Station

5. Processing

Resource Recovery and Processing

- **Resource recovery is a partial solid waste disposal and reclamation process. It can be expected to achieve about 60% reductions in future landfill volume requirements.** Resource recovery must recognize what is worth recovering and the environmental benefits.
- **Resource recovery and processing is a complex, economical and technical system with social and political implications, all of which require critical analysis and evaluation before a commitment is made**. They demand capital cost, operating cost, market value of reclaimed materials and material quality, potential minimum reliable energy sales, assured quantity of solid wastes, continued need for a sanitary landfill for the disposal of excess and remaining unwanted materials and incinerator residue, a site location close to the center of the generators of solid wastes.

Products That Can Be Recycled

1. **Plastic**
2. **Tires**
3. **Paper**

Obstacles to resource recovery

- ✓ heterogeneity of the waste
- ✓ putrescibility of the waste
- ✓ location of the waste
- ✓ low value of product
- ✓ uncertainty of supply
- ✓ unproven technology
- ✓ administrative and industrial constraints
- ✓ legal restriction
- ✓ uncertain market

Processing of Solid Waste:-

1) Perform a series of mechanical or chemical operations on (something) in **order to change it.**

1) It is the process **to reduce its potential nuisance value** (strength) and **to recover usable material or energy** from solid waste before its final disposal.

2) Solid waste contain various ingredients however these ingredients can be used as a raw material to produce some useful form of material or as **source of energy.**

3) Objective of a processing is **to utilize the recycling potential** of solid waste & simultaneously **reduce the load** on solid waste management system especially on the disposal.

Processing of Solid Waste:-

1) Physical Processing Technology

2) Biological Processing Technology

3) Thermal Processing Technology

- Composition of solid waste varies place to place & country to country. This aspect is important while selecting processing technology for above objectives.

Physical Processing Technology:-

It involves altering the physical characteristics of a solid waste.

These solid waste may be shredded, separated & dried.

1) **Mechanical Separation**

2) **Densification**

3) **Size Reduction**

4) **RDF (Refused Derived Fuel)**

Mechanical Separation:

- It is utilized for removing specific materials from solid waste.
- Mechanical separation is carried out before processing the waste by other methods.

TECHNOLOGY	MATERIALS TARGETED
Screening	Large: film plastics, large paper, cardboard, misc. Mid-sized: recyclables, organics, misc. Fines: organics, metal fragments, misc.
Hand Picking	Recyclables, inerts and chemical contaminants
Magnetic Separation	Ferrous plus contaminants associated with ferrous met
Eddy Current Separation	Non-ferrous metals
Air Classification	Lights: paper, plastic Heavies: metals, glass, organics
Wet Separation	Floats: organics, misc. Sinks: metals, glass, gravel, misc.
Ballistic Separation	Light: plastic, undecomposed paper Medium: compost Heavy: metals, glass, gravel, misc.

Size Reduction:

- Size reduction is required to allow for efficient & easier handling of material.
- In order to reduce the size, mechanical equipment such as shredders is used. This allow for other process to work more efficiently.

Aerobic Composting or Indore Method of Composting:-

1) During aerobic composting aerobic micro-organism oxidize organic compounds to CO2, NO2, & NO3.
2) Carbon from organic compounds is used as source of energy while nitrogen is recycled.
3) Due to exothermic reaction, temp. of the mass rises.
4) Indore Method, conventionally carried out in pits.
5) Initially a layer of coarse solid waste is placed at the bottom of a pit to a depth of 15 to 25 cm & then night soil is put to a thickness of 5cm again layer of solid waste is placed over night soil.
6) In this way, a night soil is sandwiched between two layers of MSW.
7) Solid waste & night soils are place in alternate layers till it rises to a height of 30cm above the pit edge.
8) The final layer of solid waste is atleast 25 to 30 cm thick.
9) The top of deposited material is rounded off to avoid rain water entry into the mass or pit.

Anaerobic Composting or Bangalore Method of Composting:-

1) During anaerobic process, the anaerobic micro-organism, while metabolizing the nutrients break down the organic compounds through a process of reduction.

2) A very small amount of energy is released during the process and the temp. of composting mass does not rise much.

3) The gases evolved are mainly CH_4 & CO_2.

4) Anaerobic process is a reduction process & the final product is subjected to some minor oxidation when applied to the land.

Anaerobic Composting or Bangalore Method of Composting:-

1) In this method, pits are filled similar to Indore method except that it is covered at the top by soil layers to avoid rain water entering the pit.

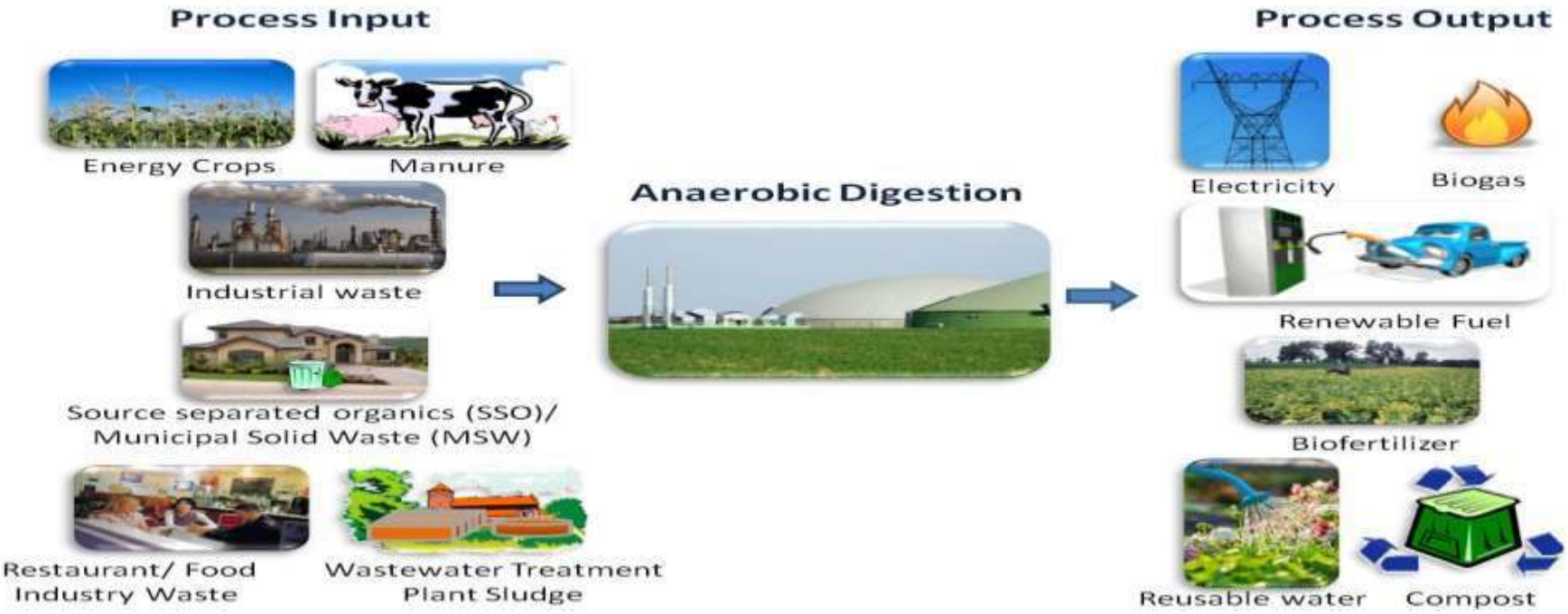
2) Anaerobic condition is maintained in the pit.

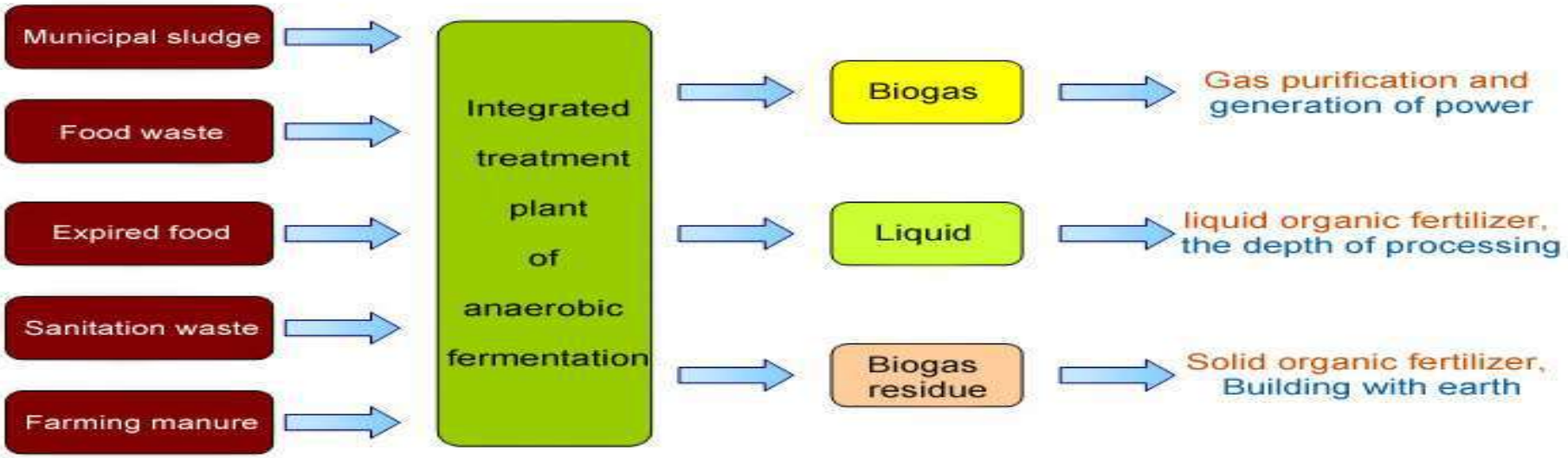
3) After 4 to 6 months, decomposed and stabilized material is taken out and used as compost.

Anaerobic Composting/Anaerobic Digestion: Salient Points

1) It is Composting : absence of oxygen, closed reactor system & high moisture.
2) Organics from MSW are first separated from the inorganic and then after size reduction are digested anaerobically in large size digesters.
3) The generated gas is either directly used as a source of energy or fed to dual fuel engines for generation of electricity.
4) The digested residue is commonly used as a manure.
5) In conventional anaerobic digestion, the solids concentration is kept at about 1%.
6) The pH is continuously monitored & maintained between 6.5 to 7.5.
7) The volatile acid conc. is not normally allowed to exceed 2000 mg/l.
8) The contents of the reactor are continuously stirred and the digested sludge is withdrawn from the bottom and put on drying beds.
9) The drainage liquid from the bottom of drying beds is again added to the plant influent.
10) The digester may have either a fixed dome or a floating dome for the collection of gas.

Anaerobic Digestion Solution





Factors Affecting Composting Process:-

1) **Organism:** different micro-organism are known to play predominant role in the breakdown of solid waste

2) **Use of culture**: the required forms of micro-organisms are indigenous to solid waste

3) **Moisture:** 50-60%

4) **Temperature:** 30-60^{0}c

5) **C/N ratio:** 26 - 31

6) **Aeration:** 1-2 cum/day/kg of volatile solid

7) Addition of sludge or sewage:

8) Types of solid waste or composition of solid waste:

Vermi-composting:-

1) Organic solid waste is converted through earthworm consumption.
2) Decomposition of organic matter in the earthworm occurs in alimentary tract by micro-organism inhabiting the gut.
3) Ingested organic matter is first subjected to size reduction in anterior part of the worms, gut followed by decomposition.
4) These species survive in the temp. range of 20-40^{0}c & moisture range of 40-70.
5) They don't survive in pure organic substrate containing more than 40% fermentable organic substances. Hence, fresh waste is mixed with partially or fully stabilized waste before it can be vermi-composted.
6) Worms are adversely affected by high conce. Of heavy metals such as Cd, Cr, Pb, & Zn.
7) Vermi-compost has high nutrient content.
8) Generally Vermicompost is used for agricultural waste.
9) Houses & colonies often use this method for the organic household waste, however it has not yet been successfully used for MSW.

Thermal Processing Technology:-

a) The various constituents of solid waste give it a good thermal value, when solid waste is completely or partially burnt, heat energy is released.

b) The residue after combustion requires less volume and is hygienic to handle.

c) It is that process which generates energy in the form of electricity, fuel or heat from thermo-chemical process such as combustion or gasification of solid waste.

d) Solid waste Thermal Technology is also referred to as waste to energy transformation.

e) There are following thermal processing technologies:-

1) **Incineration**
2) **Pyrolysis**
3) **Gasification**

Incineration:-

1) It involves controlled combustion of the waste with specific amount of air to ensure that complete combustion occurs in a specific range of temperature is an enclosed space.
2) During the process of incineration the combustible portion is burnt to final residue and ash, which is comparatively less in volume (10-20% of original).
3) Residue can be used for landfilling or some other suitable purpose.
4) Incineration plant requires much less space as compared to other disposal facilities.
5) The plant can be located in the city area itself, so that the cost of transportation is reduced.
6) Large amount of heat can be made available from incineration.
7) Incineration is not commonly used due to various reason mainly due to low calorific value and high operation & maintenance.
8) Types of incineration according to purpose:
   - Domestic (low capacity upto 50 kg/hr)
   - Commercial (capacity between 50 to 500 kg/hr)
   - Municipal (above 500 kg/hr)

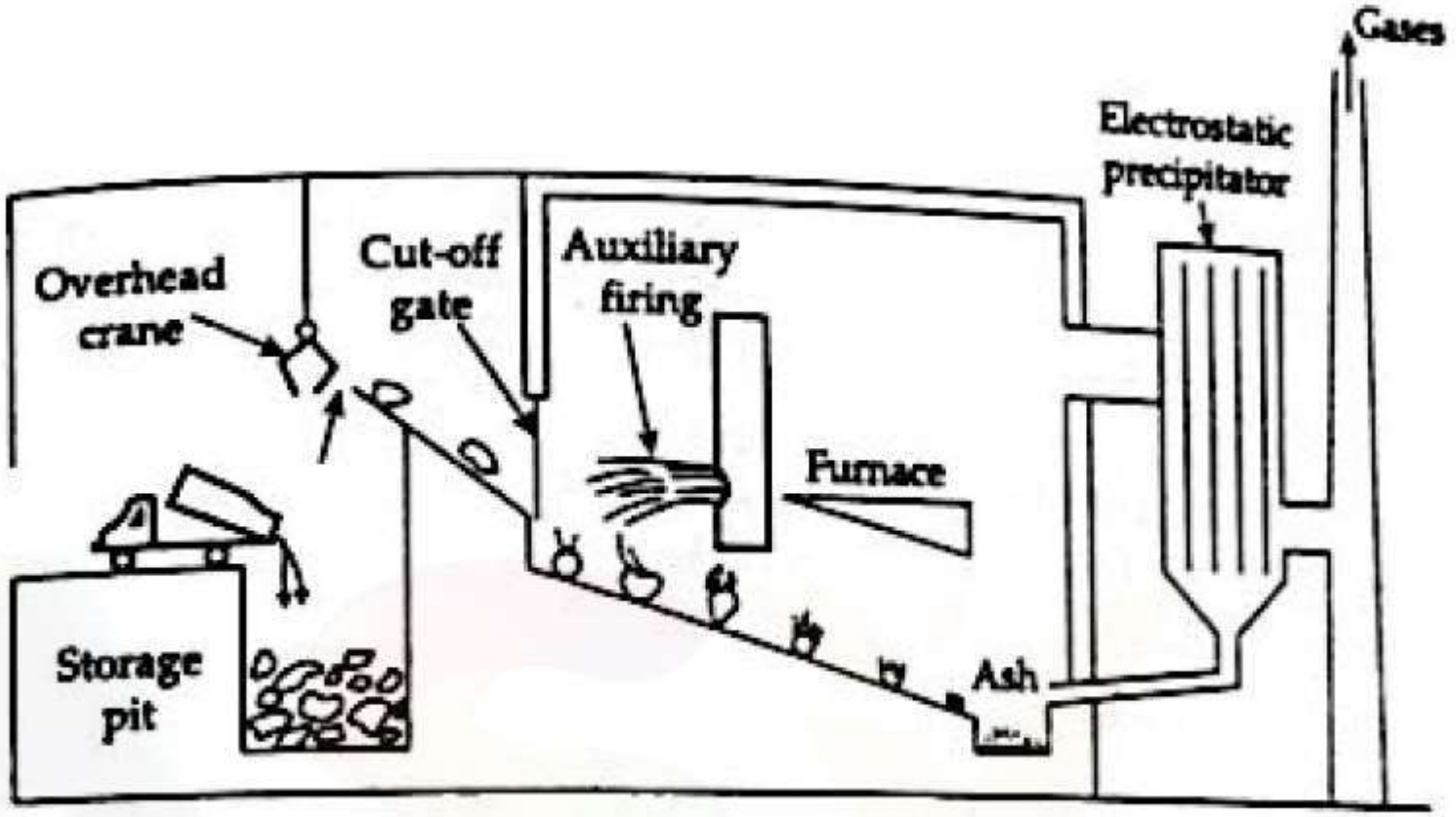


Fig. 14.7. Schematic sketch of a conventional incinerator (travelling grate type), to be used for incinerating municipal solid waste (refuse).

Advantages of incineration

- The volume and weight of the waste are reduced to a fraction of its original size.
- Waste reduction is immediate, does not require long term residence.
- Waste can be incinerated on site without carted to a distant area.
- Air discharge can be effectively controlled for minimal impact on the atmospheric environment.

Advantages of incineration

- The ash residue is usually non putrescible or sterile.
- Technology exists to completely destroy even most hazardous material in a complete effective manner.
- Requires relatively small disposal area compare to land burial. Particularly popular in countries such as Japan where land is a scarce resource.
- By using heat recovery techniques the cost of operation can often be reduced or offset through the use or sale of energy. (resource recovery/ waste to energy facility)

Disadvantages of incineration

- The capital cost is high.
- Skilled operators are required.
- All materials are not incinerable (construction and demolition waste).
- Supplemental fuel is required to initiate and at times to maintain the incineration process.
- The most publicized concerns from environmentalists about the incineration of municipal solid wastes (MSW) involve the fear that it produces significant amounts of dioxin and furan emissions.

Disadvantages of incineration

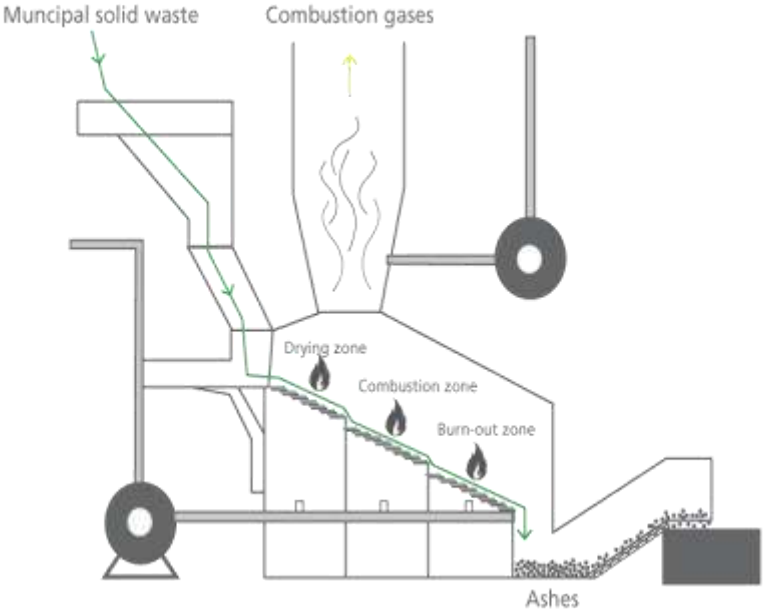
- The solid residue remaining in the furnace after incineration is called as bottom ash which ultimately go for land disposal. The bottom ash may contain metals like lead and cadmium, can be treated prior to disposal.

- Dioxins occur as in the incineration of chlorine-containing substances such as PVC (polyvinyl chloride)

- Health effects such as
  - ✓ Developmental of abnormalities in the enamel of children's teeth.
  - ✓ Central and peripheral nervous system
  - ✓ Thyroid disorders
  - ✓ Damage to the immune systems
  - ✓ Endometriosis
  - ✓ Diabetes

Disadvantages of incineration

- Fly ash is the incinerator ash carried along in the combustion airstream. So air pollution control devices are installed to remove fly ash and potentially harmful gaseous contaminants.
- Thus, Installation of air pollution control equipment make the process expensive.
- These equipments are located after the furnace and before the stack.



Waste to Energy Plant Diagram

Pollution Control System

1. Nitrogen Oxide Removal System
2. Mercury & Dioxin Removal System
3. Acid Gas Removal System
4. Particulate Removal System
5. Pollution Control Test

Water Vapor & Cleaned Flue Gases

14 Megawatt Electricity

Steam

Turbine Generator

Flue Gases

Ash

Tipping Hall

Trash Storage Bunker

Ash Conveyor Belt

Landfill

Pyrolysis:-

1) It is an endothermic reaction and heat must be supplied to the waste to distill off volatile matter.
2) Whereas incineration is an exothermic process wherein the waste is fully burnt and heat is released.
3) Pyrolysis is an irreversible chemical change brought by action of heat in an atmosphere devoid of oxygen.
4) This is also referred to as thermal decomposition or destructive distillation or carbonization.
5) 500 – 900 ^{0}C.
6) Normally pyrolysis is carried out in two ranges: low temp. in which avg. reaction temp. is around 500 ^{0}C & high temp in which the avg. temp. is around 900 ^{0}C.
7) Pyrolysis of solid waste produces three types of products.
    1) Gas
    2) Liquid
    3) Char
8) According to the temp. at which the solid waste are pyrolysed, the % of these products vary.

Pyrolysis:-

- Pyrolysis of solid waste produces three types of products.

  1) **Gas** : mixture of gases such as hydrogen, carbon monoxide, methane, carbon dioxide & other hydrocarbons
  2) **Liquid :** contains tar, pitch, light oil, low organic chemicals like acetic acid, acetone, methanol, etc.
  3) **Char :** consist of elemental carbon along with the inert material in the waste feed.

  All the three component have **high calorific values** & can be used as fuels after making necessary modification in the design of burning equipment.

- **Different Pyrolysis Methods Recently Developed** :

  1) Destrugs system
  2) Garetts Flash Pyrolysis Process
  3) Process Developed by Energy Research Center of Bureau of Mines.

Gasification:-

1) It is a important technology for renewable energy. > 700 ^{0}C
2) Now days, gasification is main technology for solid waste conversion to energy & effective alternative for incineration.
3) It is achieved by reacting the material at high temp.
4) Limited amount of air is introduced to allow some organic waste to be burned to produce energy which drives a second reaction.
5) This process is largely exothermic but some heat may be required to initialize & sustain the gasification process.
6) It is a method for extracting energy from different types of organic materials.
7) The resulting gas mixture is called syngas or producer gas & itself as fuel.
8) Syngas can be valuable commercial product such as transportation fuel, chemicals & fertilizers instead of making just heat & electricity.
9) The main products are CO, CH4, H2, etc.

Waste hierarchy

Waste hierarchy refers to 3 Rs

Reduce, Reuse, Recycle

- The three **R's - reduce, reuse and recycle** - all help to cut down on the amount of waste.

- They conserve natural resources, landfill space and energy.

REDUCE

1) The best way to manage waste is to not produce it. This can be done by shopping carefully and being aware of a few guidelines:
2) Buy products in bulk. Larger, economy-size products or ones in concentrated form use less packaging and usually cost less per ounce.
3) Avoid over-packaged goods, especially ones packed with several materials such as foil, paper, and plastic. They are difficult to recycle, plus you pay more for the package.
4) Avoid disposable goods, such as paper plates, cups, napkins, razors, and lighters. Throwaways contribute to the problem, and cost more because they must be replaced again and again.
5) Buy durable goods - ones that are well-built or that carry good warranties. They will last longer, save money in the long run and save landfill space.
6) At work, make two-sided copies when ever possible.
7) Maintain central files rather than using several files for individuals.
8) Use electronic mail or main bulletin board.
9) Use cloth napkins instead of paper napkins.
10) Use a dish cloth instead of paper towels.

REUSE

It makes economic and environmental sense to reuse products. Sometimes it takes creativity:

1) Reuse products for the same purpose. Save paper and plastic bags, and repair broken appliances, furniture and toys.
2) Reuse products in different ways. Use a coffee can to pack a lunch; use plastic microwave dinner trays as picnic dishes.
3) Sell old clothes, appliances, toys, and furniture in garage sales or ads, or donate them to charities.
4) Use re-sealable containers rather than plastic wrap.
5) Use a ceramic coffee mug instead of paper cups.
6) Reuse grocery bags or bring your own cloth bags to the store. Do not take a bag from the store unless you need one.

RECYCLE

Recycling is a series of steps that takes a used material and processes, remanufactures, and sells it as a new product. Begin recycling at home and at work:

1) Buy products made from recycled material. Look for the recycling symbol or ask store managers or salesmen. The recycling symbol means one of two things - either the product is made of recycled material, or the item can be recycled. For instance, many plastic containers have a recycling symbol with a numbered code the identifies what type of plastic resin it is made from. However, just because the container has this code does not mean it can be easily recycled locally.
2) Check collection centers and curbside pickup services to see what they accept, and begin collecting those materials. These can include metal cans, newspapers, paper products, glass, plastics and oil.
3) Consider purchasing recycled materials at work when purchasing material for office supply, office equipment or manufacturing.
4) Speak to store managers and ask for products and packaging that help cut down on waste, such as recycled products and products that are not over packaged.
5) Buy products made from material that is collected for recycling in your community.
6) Use recycled paper for letterhead, copier paper and newsletters.

TYPICAL QUESTIONS

1) Define solid waste and classify the solid waste with their sources of generation?
2) What are the various sources of generation of SWM?
3) How do you find per capita generation of solid waste?
4) Explain the various factors affecting the per capita generation of solid waste?
5) What are the things to be kept in mind while sampling?
6) Explain physical and chemical characteristics of MSW?
7) Explain various compositions of solid waste by giving its value for Indian refuse?
8) Explain the procedure adopted for finding out the various characteristics of solid waste?
9) What is material balance analysis? How is it performed?
10) What do you understand by SWM? Why is it necessary? Explain?
11) Explain the elements of solid waste management?
12) With a neat flow diagram show the interrelationship between the functional elements of solids waste management system?
13) Write a short note on:- Characteristics of solid waste, Composition of solid waste, Classification of solid waste with their source, Sources of generation of solid waste.

Waste Management: Disposal methods

Open Dumping

(i) **Uncontrolled dumping or non-engineered disposal:** As mentioned, this is the most common method being practised in many parts of the world, and India is no exception. 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.

Sanitary land filling

- An engineered landfill is a controlled method of waste disposal.
- The objective of a landfill facility is to contain the waste in a manner that is protective to human health and the environment.
- Landfills perform by controlling and managing the movements of fluids.
- Landfills are engineered facilities for the disposal of
  - Municipal Solid Waste
  - Hazardous Waste

Relative Merits of Disposal Options

Disposal Option → / ↓Sustainability Indicator	Non-engineered Disposal	Sanitary Landfill	Composting	Incineration
Volume reduction	×	×	×	√
Expensive	×	√	√	√
Long term maintenance	√	√	×	×
By product recovery	×	√	√	√
Adaptability to all wastes	√	√	×	×
Adverse environmental effect	√	√	×	√

Site selection Criteria

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, odor, dust, vector, and aesthetic factors control requirements.
Ultimate use of site	Affects long-term management for site.

Landfill - Types

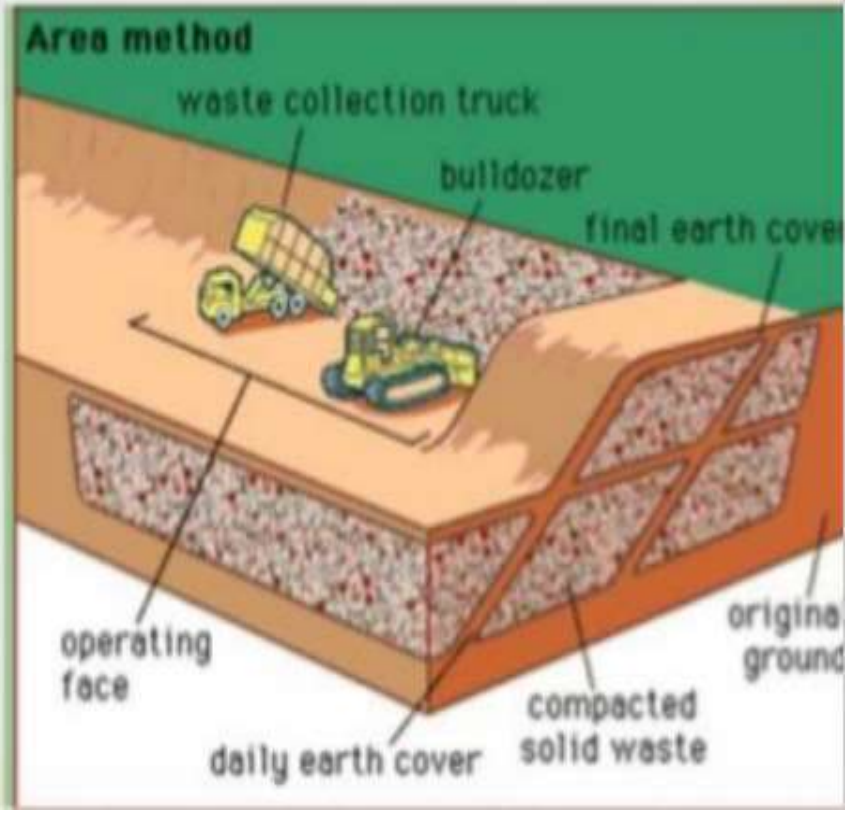
Based on Site Topography and Capacity Requirements:

- Above Ground Landfill (Area Landfill)
- Below Ground Landfill (Trench Landfill)
- Above and Below Ground Landfill
- Slope Landfill
- Valley Landfill (Canyon Landfill)

Area landfill

- Used on flat ground or terrain is unsuitable for the excavation of trenches.
- Before actual land filling, an earthen levee is constructed against which wastes are placed in thin layers and compacted.
- Thickness of layer reaches a height of 200 to 300 cm.
- Cover material of 15 to 30 cm thickness is placed after each layer.
- A completed lift including the cover is called a cell.

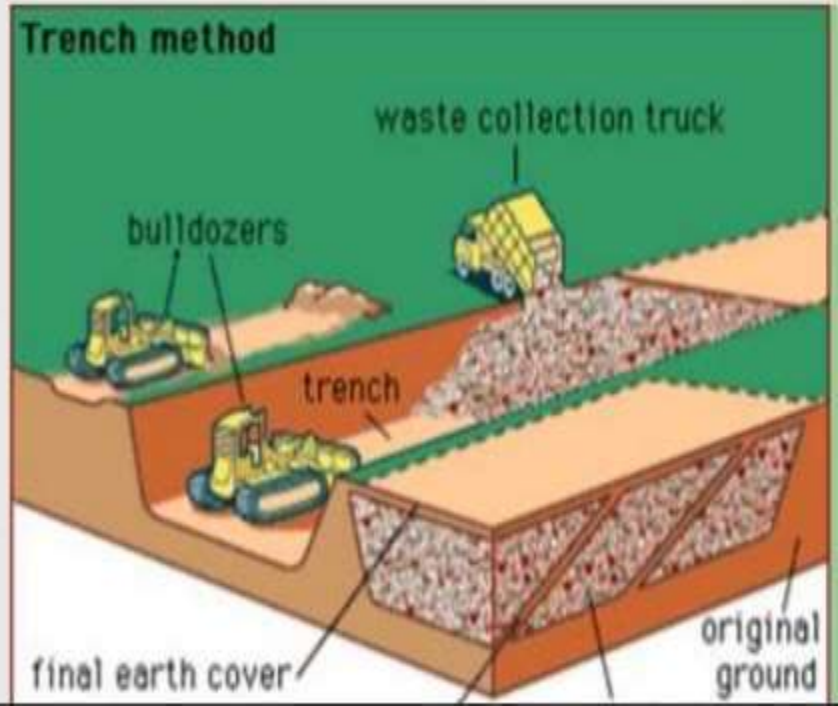
- This method is used to dispose of large amounts of solid waste.



Trench landfill

- Used where adequate cover material is available at site and the water table is well below the surface.
- Waste are placed in trench and compacted in thin layers.
- After layer's compacted height reaches design height, cover material is placed over the compacted layer.
- Same trench is then continued and filled similarly.

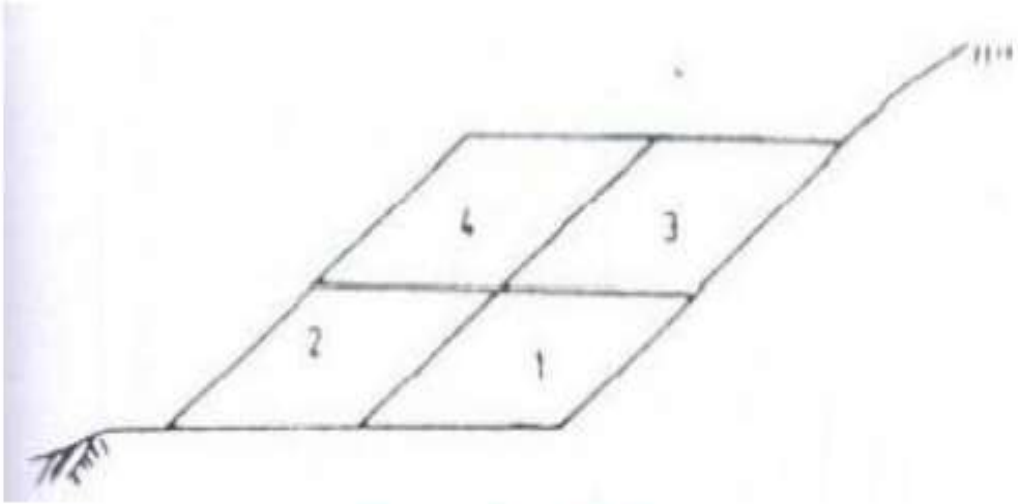
- Good in areas where there is relatively little
- Waste.



Slope landfill

- **Slope landfill:**

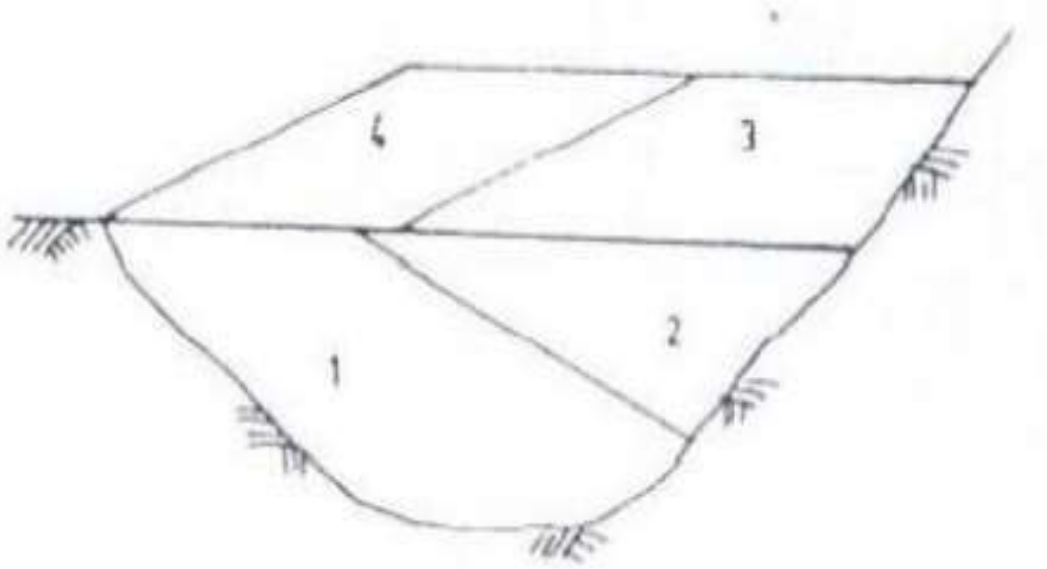
- In some places, it is not possible to find flat ground for landfills. In such cases slope landfills have to be adopted.
- Control of inflowing water from hill slopes is a critical factor in design.



Slope Landfill

Valley landfill

- **Valley landfill / Canyon landfill:**
- Waste is filled between the hills or rolling terrain
- Control of surface drainage is often a critical factor



Valley Landfill

Landfill components

- Bottom and side liner system
- Leachate collection and removal system
- Leak detection system
- Gas collection and removal system
- Top liner system
- Storm water management system
- Environmental monitoring system
- Other infrastructure

Typical Cross-Section of Landfill

Landfill Processes_1

- **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.

- **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.

Landfill Processes_2

- **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 continues until all decomposable organic matter is degraded. The settling rate, however, gradually decreases with the passage of time.

Decomposition Stage

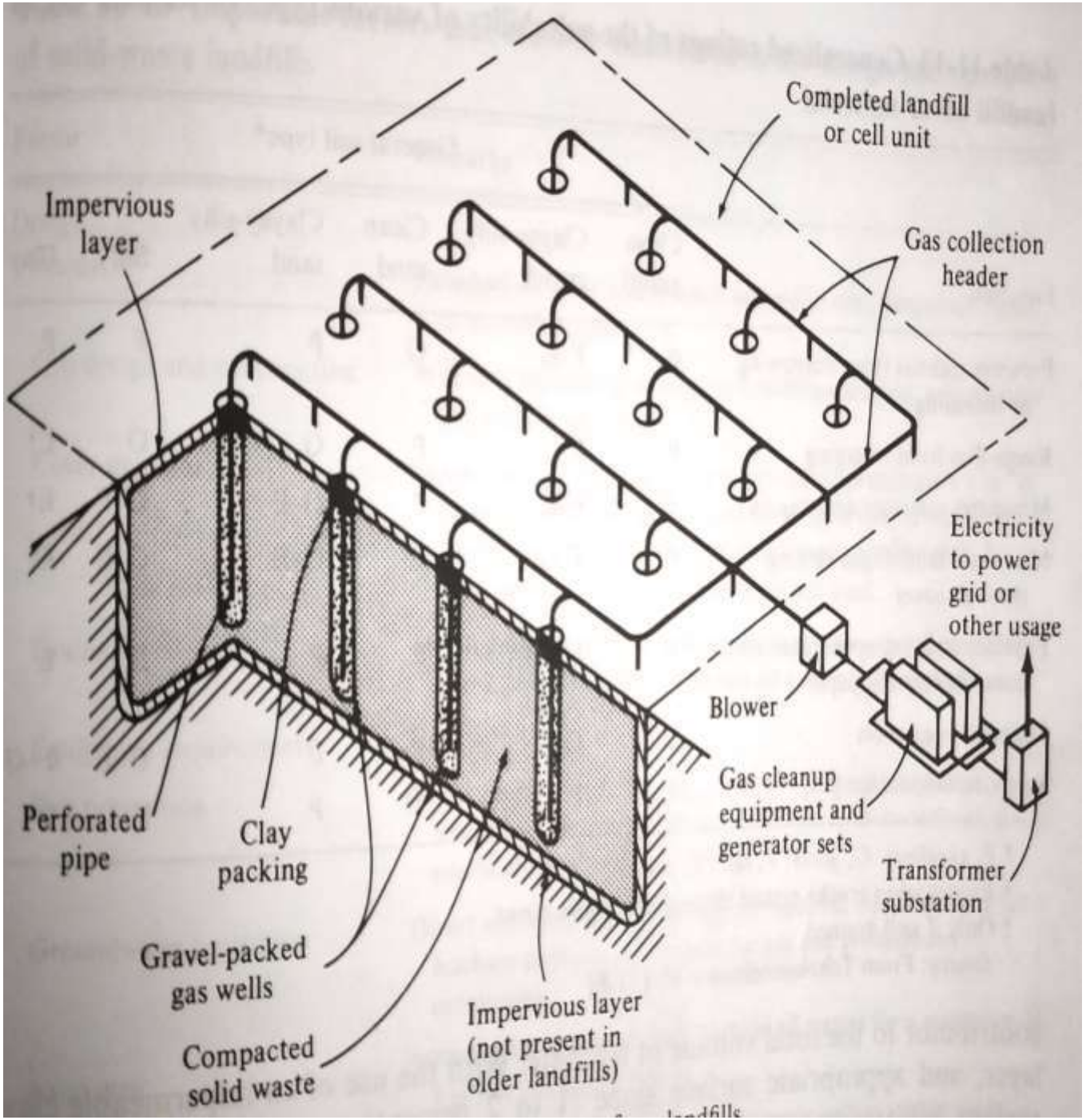
(*i*) During the first phase of operation, aerobic bacteria and fungi, which are dominant, deplete the available oxygen to effect oxidation of organic matter. As a result of aerobic respiration, the temperature in the fill increases. (*ii*) In the second phase, anaerobic and facultative bacteria develop 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 conditions within the land fill.

Landfill Gas Collection

Gas Collection & Removal System:

- Municipal solid waste can generate large quantities of gas during decomposition.
- Two primary constituents : Methane and Carbon dioxide
- System to collect and extract gas from within the landfill
- Landfill gas can either be used to produce energy or flared under controlled conditions

(ii) ***Control of Gas Movement by Gas Recovery.*** In large sized landfills, the gases evolved due to decomposition of refuse may be collected through installing **gas recovery wells**, as shown in Fig. The recovered gas may be used for generation of electric power or may be supplied to nearby houses for domestic use. Although gas recovery systems have been installed in some advance countries in some large municipal landfills, yet the economics of such operations are not well defined. The cost of cleaning of the generated gas and that of the processing equipment may limit the recovery of landfill gases, especially from small landfills.


Completed landfill or cell unit
Impervious layer
Gas collection header
Electricity to power grid or other usage
Blower
Gas cleanup equipment and generator sets
Transformer substation
Perforated pipe
Clay packing
Gravel-packed gas wells
Compacted solid waste
Impervious layer (not present in older landfills)

Leachate & its Control

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

- water availability;
- landfill surface condition;
- refuse state;
- condition of surrounding strata.

Properties and Composition of Leachate

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	-

Leachate & its Control

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

Leachate Collection & Removal System:

- **To collect the leachate produced in a landfill**
- **To prevent the buildup of leachate head on the liner and to drain leachate effectively outside the landfill for treatment**

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

- **Natural liners:** These refer to compacted clay or shale, bitumen or soil sealants, etc., and are generally less permeable, resistant to chemical attack and have good sorption properties. They generally do not act as true containment barriers, because sometimes leachate migrates through them.
- **Synthetic (geo-membrane) liners:** These are typically made up of high or medium density polyethylene and are generally less permeable, easy to install, relatively strong and have good deformation characteristics. They sometimes expand or shrink according to temperature and age.

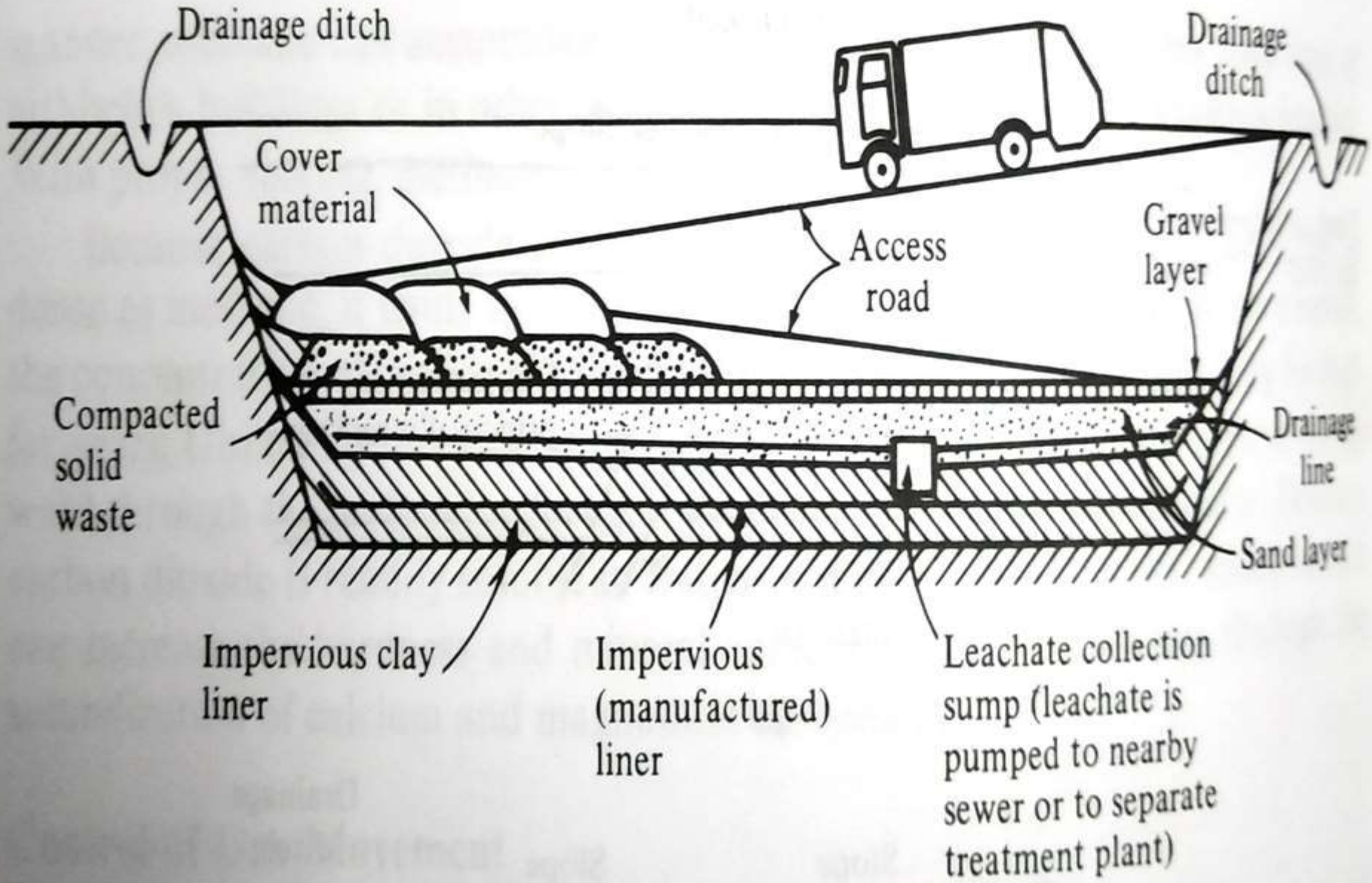


Figure 11-21 Landfill designed to prevent the movement of gases and leachate.

Source

- NPTEL Material
- Lecture note by Dr. M Venkataraman
- Environmental Engg. (Vol.II) – S K Garg
- Environmental Engineering – Peavy, Rowe & Tchobanolgus
- Internet sources

Source

- **NPTEL Material**
- **Environmental Engg. (Vol.II) – S K Garg**
- **Environmental Engineering – Peavy, Rowe & Tchobanolgus**
- **Internet sources**
- **Guidelines on Implementation of E-Waste (Management) Rules, 2016**

Waste Management:
Module 2
Hazardous waste

5th Semester – Dept. of Civil Engineering, VSSUT

Dr. R R Dash

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Definition

Wastes that exhibit measurable properties posing sufficient threats to warrant regulation. For a waste to be deemed a characteristic hazardous waste, **it must cause, or significantly contribute to, an increased mortality or an increase in serious irreversible or incapacitating reversible illness, or pose a substantial hazard or threat of a hazard to human health or the environment**, when it is improperly treated, stored, transported, disposed of, or otherwise mismanaged.

Identification

By using either or both of the following criteria, we can identify as to whether or not a waste is hazardous:

(i) **Characteristics** such as ignitibility, corrosivity, reactivity and toxicity of the substance.

(ii) The **list provided by government agencies** declaring that substance as hazardous.

Characteristics/Properties

(i) Ignitability: A waste is an ignitable hazardous waste, if it has a **flash point of less than 60°C; readily catches fire and burns so vigorously as to create a hazard**; or is an ignitable compressed gas or an oxidiser. Naphtha, lacquer thinner, epoxy resins, adhesives and oil based paints are all examples of ignitable hazardous wastes.

(ii) Corrosivity: A liquid waste which has a **pH of less than or equal to 2 or greater than or equal to 12.5** is considered to be a corrosive hazardous waste. Sodium hydroxide, a caustic solution with a high pH, is often used by many industries to clean or degrease metal parts. Hydrochloric acid, a solution with a low pH, is used by many industries to clean metal parts prior to painting. When these caustic or acid solutions are disposed of, the waste is a corrosive hazardous waste.

Characteristics/Properties

(iii) Reactivity: A material is considered a reactive hazardous waste, if it is **unstable, reacts violently with water, generates toxic gases when exposed to water or corrosive materials**, or if it is capable of detonation or explosion when exposed to heat or a flame. Examples of reactive wastes would be waste gunpowder, sodium metal or wastes containing cyanides or sulphides.

(iv) Toxicity: To determine if a waste is a toxic hazardous waste, a representative sample of the material must be subjected to a test conducted in a certified laboratory. The toxic characteristic identifies **wastes that are likely to leach dangerous concentrations of toxic chemicals into ground water**.

Listed hazardous wastes

A specific list showing certain materials as hazardous wastes minimises the need to test wastes as well as simplifies waste determination. In other words, any waste that fits the definition of a listed waste is considered a hazardous waste.

F-list: The F-list contains hazardous wastes from **non-specific sources**, that is, **various industrial processes that may have generated the waste**. The list consists of solvents commonly used in **degreasing, metal treatment baths and sludges, wastewaters from metal plating operations** and dioxin containing chemicals or their precursors. Examples of solvents that are F-listed hazardous wastes, along with their code numbers, include **benzene** (F005), carbon tetrachloride (F001), cresylic acid (F004), methyl ethyl ketone (F005), methylene chloride (F001), 1,1,1, trichloroethane (F001), **toluene** (F005) and trichloroethylene (F001). Solvent mixtures or blends, which contain greater than 10% of one or more of the solvents listed in F001, F002, F003, F004 and F005 are also considered F-listed wastes.

Listed hazardous wastes

K-list: The K-list contains hazardous wastes generated by **specific industrial processes**. Examples of industries, which generate K-listed wastes include **wood preservation, pigment production, chemical production, petroleum refining, iron and steel production, explosive manufacturing and pesticide production**.

P and U lists: The P and U lists contain **discarded commercial chemical products, off-specification chemicals, container residues and residues from the spillage of materials**. These two lists include commercial pure grades of the chemical, any technical grades of the chemical that are produced or marketed, and all formulations in which the chemical is the sole active ingredient. An example of a P or U listed hazardous waste is a **pesticide**, which is not used during its shelf-life and requires to be disposed in bulk. The primary distinction between the two lists is the quantity at which the chemical is regulated. The P-list consists of **acutely toxic wastes that are regulated when the quantity generated per month, or accumulated at any time, exceeds one kilogram** (2.2 pounds), **while U-listed hazardous wastes are regulated when the quantity generated per month exceeds 25 kilograms** (55 pounds). Examples of businesses that typically generate P or U listed wastes include pesticide applicators, laboratories and chemical formulators.

Classification of hazardous wastes

Radioactive substance: Substances that emit ionising radiation are radioactive. Such substances are hazardous because prolonged exposure to radiation often results in damage to living organisms. Radioactive substances are of special concern because they persist for a long period. The period in which radiation occurs is commonly measured and expressed as *half-life, i.e., the time required for the radioactivity of a given amount of the substance to decay to half its initial value. For example, uranium Municipal Solid Waste Management 390* compounds have half-lives that range from 72 years for U232 to 23,420,000 years for U236. The management of radioactive wastes is highly controlled by national and state regulatory agencies. Disposal sites that are used for the long-term storage of radioactive wastes are not used for the disposal of any other solid waste.

Chemicals: Most hazardous chemical wastes can be classified into four groups: synthetic organics, inorganic metals, salts, acids & bases, and flammables & explosives. Some of the chemicals are hazardous because they are highly toxic to most life forms. When such hazardous compounds are present in a waste stream at levels equal to, or greater than, their threshold levels, the entire waste stream is identified as hazardous.

Classification of hazardous wastes

Biomedical wastes: The principal sources of hazardous biological wastes are hospitals and biological research facilities. The ability to infect other living organisms and the ability to produce toxins are the most significant characteristics of hazardous biological wastes. This group mainly includes malignant tissues discarded during surgical procedures and contaminated materials, such as hypodermic needles, bandages and outdated drugs. This waste can also be generated as a by-product of industrial biological conversion processes.

Flammable wastes: Most flammable wastes are also identified as hazardous chemical wastes. This dual grouping is necessary because of the high potential hazard in storing, collecting and disposing of flammable wastes. These wastes may be liquid, gaseous or solid, but most often they are liquids. Typical examples include organic solvents, oils, plasticisers and organic sludges.

Classification of hazardous wastes

Explosives: Explosive hazardous wastes are mainly ordnance (artillery) materials, i.e., the wastes resulting from ordnance manufacturing and some industrial gases. Similar to flammables, these wastes also have a high potential for hazard in storage, collection and disposal, and therefore, they should be considered separately in addition to being listed as hazardous chemicals. These wastes may exist in solid, liquid or gaseous form.

Household hazardous wastes: Household wastes such as cleaning chemicals, batteries, nail polish etc in MSW constitute hazardous waste. Especially batteries contain mercury which are alkaline which is dangerous enough to kill people. Generic household hazardous material include non chlorinated organic, chlorinated organic, pesticides, latex paint, oil based paints, waste oil, automobile battery and household battery.

Common Hazardous Wastes: Community Source

Waste Category	Sources
Radioactive substances	Biomedical research facilities, colleges and university laboratories, offices, hospitals, nuclear power plants, etc.
Toxic chemicals	Agricultural chemical companies, battery shops, car washes, chemical shops, college and university laboratories, construction companies, electric utilities, hospitals and clinics, industrial cooling towers, newspaper and photographic solutions, nuclear power plants, pest control agencies, photographic processing facilities, plating shops, service stations, etc.
Biological wastes	Biomedical research facilities, drug companies, hospitals, medical clinics, etc.
Flammable wastes	Dry cleaners, petroleum reclamation plants, petroleum refining and processing facilities, service stations, tanker truck cleaning stations, etc.
Explosives	Construction companies, dry cleaners, ammunition production facilities, etc.

Treatment Operations and Processes

Operation/Processes	Functions performed[$]	Types of wastes[*]	Forms of waste[#]
Physical Treatment			
Aeration	Se	1, 2, 3, 4	L
Ammonia stripping	VR, Se	1, 2, 3, 4	L
Carbon sorption	VR, Se	1, 3, 4, 5	L,G
Centrifugation	VR, Se	1, 2, 3, 4, 5	L
Dialysis	VR, Se	1, 2, 3, 4	L
Distillation	VR, Se	1, 2, 3, 4, 5	L
Electro dialysis	VR, Se	1, 2, 3, 4, 6	L
Encapsulation	St	1, 2, 3, 4, 6	L,S
Evaporation	VR, Se	1, 2, 5	L
Filtration	VR, Se	1, 2, 3, 4, 5	L,G
Flocculation/Settling	VR, Se	1, 2, 3, 4, 5	L
Flotation	Se	1, 2, 3, 4	L
Reverse osmosis	VR, Se	1, 2, 4, 6	L
Sedimentation	VR, Se	1, 2, 3, 4, 5	L
Thickening	Se	1, 2, 3, 4	L
Vapour scrubbing	VR, Se	1, 2, 3, 4	L

[$] *Functions: VR= volume reduction; Se = separation; De = detoxification; St = storage;* [*] *Waste types: 1= inorganic chemical without heavy metals; 2 = inorganic chemical with heavy metal; 3 = organic chemical without heavy metal; 4 = organic chemical with heavy metal; 5= radiological; 6 = biological; 7= flammable and 8= explosive;* [#] *Waste forms: S=solid; L= liquid and G= gas*

Treatment Operations and Processes

Operation/Processes	Functions performed[$]	Types of wastes[*]	Forms of waste[#]
Chemical Treatment			
Calcination	VR	1, 2, 5	L
Ion exchange	VR, Se, De	1, 2, 3, 4, 5	L
Neutralisation	De	1, 2, 3, 4	L
Oxidation	De	1, 2, 3, 4	L
Precipitation	VR, Se	1, 2, 3, 4, 5	L
Reduction	De	1, 2	L
Solvent extraction	Se	1, 2, 3, 4, 5	L
Sorption	De	1, 2, 3, 4	L

[$] *Functions: VR= volume reduction; Se = separation; De = detoxification; St = storage;* [*] *Waste types: 1= inorganic chemical without heavy metals; 2 = inorganic chemical with heavy metal; 3 = organic chemical without heavy metal; 4 = organic chemical with heavy metal; 5= radiological; 6 = biological; 7= flammable and 8= explosive;* [#] *Waste forms: S=solid; L= liquid and G= gas*

Treatment Operations and Processes

Operation/Processes	Functions performed[$]	Types of wastes[*]	Forms of waste[#]
Thermal treatment			
Incineration	VR, De	3, 5, 6, 7, 8	S, L, G
Pyrolysis	VR, De	3, 4, 6	S, L, G
Biological Treatment			
Activated sludges	De	3	L
Aerated lagoons	De	3	L
Anaerobic digestion	De	3	L
Anaerobic filters	De	3	L
Trickling filters	De	3	L
Waste stabilisation pond	De	3	L

[$] *Functions: VR= volume reduction; Se = separation; De = detoxification; St = storage;* [*] *Waste types: 1= inorganic chemical without heavy metals; 2 = inorganic chemical with heavy metal; 3 = organic chemical without heavy metal; 4 = organic chemical with heavy metal; 5= radiological; 6 = biological; 7= flammable and 8= explosive;* [#] *Waste forms: S=solid; L= liquid and G= gas*

Thermal Treatment

Incineration: Incineration can be regarded as either a pre-treatment of hazardous waste, prior to final disposal or as a means of valorising waste by recovering energy. It includes both the burning of mixed solid waste or burning of selected parts of the waste stream as a fuel. The concept of treating hazardous waste is similar to that of municipal solid waste.

Mass-burning system/ Rotary kilns

Mass-burning systems are the predominant form of MSW incineration. A mass-burn facility typically consists of a reciprocating grate combustion system and a refractory-lined, water-walled steam generator. Mass-burn systems generally consist of either two or three incineration units ranging in capacity from 50 to 1,000 tonnes per day. That is to say, the facility capacity ranges from about 100 – 150 to 2,000 – 3,000 tonnes per day. These facilities can accept refuse that has undergone little preprocessing other than the removal of oversized items. Although this versatility makes mass-burn facilities convenient and flexible, local programmes to separate household hazardous wastes (e.g., cleaners and pesticides) and recover certain materials (e.g., iron scrap) are necessary to help ensure environmentally viable incineration and resource conservation.

Modular incineration

Modular incinerator units are usually prefabricated units with relatively small capacities between 5 and 120 tonnes of solid waste per day. Typical facilities have between 1 and 4 units with a total plant capacity of about 15 to 400 tonnes per day. The majority of modular units produce steam as the sole energy product. Due to their small capacity, modular incinerators are generally used in small communities or for commercial and industrial operations.

Fluidised-bed incineration

Fluidised-bed incineration of MSW is typically medium scale, with processing capacity from 50 to 150 tonnes per day. In this system, a bed of limestone or sand that can withstand high temperatures, fed by an air distribution system, replaces the grate. The heating of the bed and an increase in the air velocities cause the bed to bubble, which gives rise to the term *fluidised*. There are two types of fluidised-bed technologies, viz., bubbling bed and circulating bed. The differences are reflected in the relationship between air flow and bed material, and have implications for the type of wastes that can be burned, as well as the heat transfer to the energy recovery system.

Thermal Treatment

Pyrolysis: This is defined as the chemical decomposition or change brought about by heating in the absence of oxygen. This is a thermal process for transformation of solid and liquid carbonaceous materials into gaseous components and the solid residue containing fixed carbon and ash. The application of pyrolysis to hazardous waste treatment leads to a two-step process for disposal. In the first step, wastes are heated separating the volatile contents (e.g., combustible gases, water vapour, etc.) from non-volatile char and ash. In the second step volatile components are burned under proper conditions to assure incineration of all hazardous components (Freeman, M. H. et al., 1988).

Regulations

HAZARDOUS WASTES (MANAGEMENT & HANDLING) RULES, 1989.

The Ministry of Environment & Forests, Govt. of India has notified rules, vide Gazette notification no. S.O. 694 (E) DT. 28th July '89, under title Hazardous Wastes (Management & Handling) Rules, 1989 **to deal with various environmental aspects related with hazardous wastes**. The salient features of the rules are as follows:

The occupier generating hazardous wastes shall take all practical steps to ensure **proper handling and disposal of hazardous wastes in environment friendly manner**.

The occupier generating hazardous wastes, subject to the quantity specified in the schedule, shall apply to the State Pollution Control Board, in Form–1 for necessary authorisation.

The State Pollution Control Board, shall grant authorisation having satisfied that the operator of a facility or an occupier, as the case may be, **possesses appropriate facility, technical capabilities and equipment to handle hazardous wastes**.

The Authorisation, unless suspended or cancelled, shall remain in force for a period of two year from the date of issue or from the date of renewal.

Regulations

The occupier shall apply for the renewal of authorisation before its expiry.

The authorisation shall continue to be in force until it is renewed or revoked.

The State PCB may, after giving reasonable opportunity of being heard to the application refuse to grant any authorisation.

The authorised person shall maintain the record of returns in Form-3 and shall communicate it to the SPCB annually in Form -4.

Accident occurred at the facility or on a hazardous wastes site shall be reported to the SPCB in Form 5.

Import of hazardous wastes to be allowed only for processing or re-use as raw material.

The importers of hazardous wastes is required to furnish information country shall communicate in Form 6 to the Central Ministry.

The Central Govt. shall after examining the matter and on being satisfied on various environmental implications, grant permission or may refuse permission to import such hazardous wastes.

The importer is required to maintain the record in specified Form 7.

Source

- NPTEL Material
- Tchobaanoglous, G., Theisen, H., and Samuel A Vigil, 1993. Integrated Solid Waste Management, McGraw-Hill, Inc., New Delhi.
- Environmental Engg. (Vol.II) – S K Garg
- Environmental Engineering – Peavy, Rowe & Tchobanolgus
- Internet sources

Waste Management:
Module 3
Biomedical Waste

5th Semester – Dept. of Civil Engineering, VSSUT

Dr. R R Dash

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Definition

The wastes (solid wastes as well as liquid wastes) produced by hospitals, nursing homes, clinics, research laboratories, diagonostic centres, veternary hospitals, etc., are potential sources of health hazards, and need to be specially treated and disposed of.

BIO-MEDICAL WASTE (MANAGEMENT AND HANDLING) RULES, 1998

Any waste, which is generated during the diagnosis, treatment or immunisation of human beings or animals or in research activities pertaining thereto or in the production or testing of biologicals, and including categories mentioned in Schedule I.

SOURCES

Hospitals • Nursing homes • Clinics • Medical laboratories

Blood banks • Mortuaries • Medical research & training centers

Biotechnology institution/production units • Animal houses etc.

Such a waste can also be generated at home if health care is being provided there to a patient (e.g. injection, dressing material etc.)

SEGREGATION, PACKAGING, TRANSPORTATION AND STORAGE

(1) Bio-medical waste shall **not be mixed** with other wastes.

(2) Bio-medical waste shall be **segregated into containers/bags** at the point of generation in accordance with **Schedule II** prior to its storage, transportation, treatment and disposal. The containers shall be **labeled** according to **Schedule III**.

(3) If a container is transported from the premises where bio-medical waste is generated to any waste treatment facility outside the premises, the container shall, apart from the label prescribed in **Schedule III**, also carry information prescribed in **Schedule IV**.

SEGREGATION, PACKAGING, TRANSPORTATION AND STORAGE

(4) Notwithstanding anything contained in the Motor Vehicles Act, 1988, or rules there under, **untreated bio-medical waste shall be transported only in such vehicle as may be authorised** for the purpose by the competent authority as specified by the Government.

(5) No **untreated bio-medical waste** shall be kept stored beyond a period of **48 hours**.

(6) The Municipal body of the area shall continue to pick up and transport segregated **non bio-medical solid waste** generated in hospitals and nursing homes, as well as duly treated bio-medical wastes for disposal at municipal dump site.

CATEGORIES OF BIO-MEDICAL WASTE (SCHEDULE I)

Waste Category No.	Waste Category	Treatment and Disposal Option
Category No. 1	**Human Anatomical Waste** (human tissues, organs, body parts)	Incineration/ deep burial
Category No. 2	**Animal Waste** (animal tissues, organs, body parts carcasses, bleeding parts, fluid, blood and experimental animals used in research, waste generated by veterinary hospitals, colleges, discharge from hospitals, animal houses)	Incineration/ deep burial
Category No. 3	**Microbiology & Biotechnology Wastes** (Wastes from laboratory cultures, stocks or specimens of micro-organisms live or attenuated vaccines, human and animal cell culture used in research and infectious agents from research and industrial laboratories, wastes from production of bio-logicals, toxins, dishses and devices used for transfer of cultures)	local autoclaving/microwaving/ incineration

CATEGORIES OF BIO-MEDICAL WASTE (SCHEDULE I)

Waste Category No.	Waste Category	Treatment and Disposal Option
Category No. 4	Waste sharps (needles, syringes, scalpels, blades, glass etc. that may cause puncture and cuts. This includes both used and unused sharps)	disinfection (chemical treatment/ auto claving/ microwaving and multilation/ shredding
Category No. 5	Discarded Medicines and Cytotoxic drugs (wastes comprising of outdated, contaminated and discarded medicines)	incineration/destruction and drugs disposal in secured landfills
Category No. 6	Soiled Waste (Items contaminated with blood, and body fluids including cotton, dressings, soiled plaster casts, lines beddings, other material contaminated with blood)	Incineration / autoclaving/ microwaving

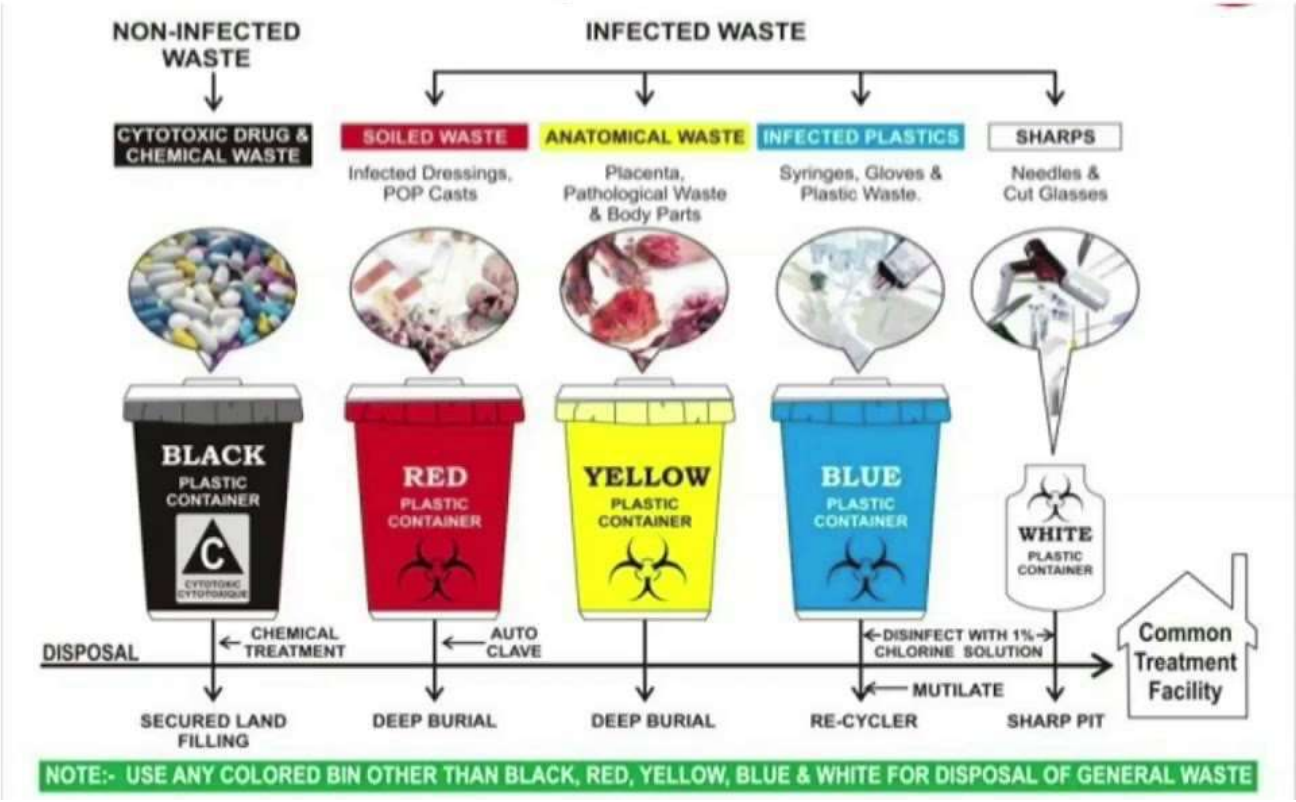
CATEGORIES OF BIO-MEDICAL WASTE (SCHEDULE I)

Category No.	Waste Category	Treatment and Disposal Option
Category No. 7	Solid Waste (wastes generated from disposable items other than the waste sharps such as tubing's, catheters, intravenous sets etc.)	disinfection by chemical Treatment/ autoclaving/ microwaving and mutilation/ shredding
Category No. 8	Liquid Waste (waste generated from laboratory and washing, cleaning, house-keeping and disinfecting activities)	disinfection by chemical Treatment and discharge into drains
Category No. 9	Incineration Ash (ash from incineration of any biomedical waste)	disposal in municipal landfill
Category No. 10	Chemical Waste (Chemicals used in production of biologicals, chemicals used in disinfection, as insecticides etc.)	Chemical treatment and discharge into drains for liquids and secured landfill for solids

COLOUR CODING FOR COLLECTION OF BIO-MEDICAL WASTES (SCHEDULE II)

Color Coding	Type of Container	Waste Category	Treatment options as per Schedule I
Yellow	Plastic bag	Cat.1, Cat. 2, Cat.3, Cat. 6	Incineration/deep burial
Red	Disinfected container/plastic bag	Cat. 3, Cat.6, Cat.7	Autoclaving/Microwaving/ Chemical Treatment
Blue/ White transluce nt	Plastic bag /puncture proof container	Cat.4, Cat.7	Autoclaving/ Microwaving/ Chemical Treatment and destruction/shredding
Black	Plastic bag	Cat.5 and Cat.9 and Cat.10 (Solid)	Disposal in secured landfill

COLOUR CODING FOR COLLECTION OF BIO-MEDICAL WASTES (SCHEDULE II)



LABEL FOR BIO-MEDICAL WASTE CONTAINERS/BAGS (SCHEDULE III)

Cytotoxic hazard symbol

Handle with care

Thermal Treatment

Incineration: Incineration can be regarded as either a pre-treatment of hazardous waste, prior to final disposal or as a means of valorising waste by recovering energy. It includes both the burning of mixed solid waste or burning of selected parts of the waste stream as a fuel. The concept of treating hazardous waste is similar to that of municipal solid waste.

Autoclaving

Autoclaving. Autoclaving (**steam sterilization**) is a ***low heat thermal process****, and is designed to bring steam into direct contact with the wastes, in a controlled manner and for sufficient duration to disinfect the wastes. The three basic types of steam autoclave systems are :

(*i*) *gravity system*

(*ii*) *pre-vacuum system* ; and

(*iii*) *retort system*.

These three types of autoclave systems are briefly indicated below :

(*i*) **Gravity type autoclaves.** They are those in which pressure of steam alone is used to evacuate air from the treatment chamber. They operate with steam temperatures of about 121°C. These systems require a cycle time of approximately 60-90 minutes in order to achieve full steam penetration into the most densely packed waste loads.

Autoclaving

(*ii*) **Pre-vacuum type autoclaves.** They are those which evacuate air from the treatment chamber using vacuum pumps. This enables them to reduce cycle time to about 30-60 minutes, as the time to heat the air within the chamber is eliminated. These systems operate at about 132°C.

(*iii*) **Retort type autoclaves.** They consist of large volume treatment chambers designed for much higher steam temperatures and pressures ; and hence their cycle times can be substantially lower than those of the other systems.

After autoclaving the wastes, they are shredded and disposed of suitably.

Microwaving

In microwave, heating occurs inside the waste material. This process involves pre-shredding the waste, injecting it with steam, and heating it for 25 minutes at 25°C, under a series of microwave units.

Microwave radiation is designated as that portion of the electromagnetic radiation spectrum lying between the frequencies of 3000 MHz to 3,00,000 MHz and the microbial inactivation occurs as a result of thermal effect of radiation, and not from any intrinsic non-thermal property.

Microwaving, however, cannot be used for human organs or tissue wastes. This technique does not reduce the volume of waste, also.

DEEP BURIAL

1. A pit or trench should be dug about 2 metres deep. It should be half filled with waste, then covered with lime within 50 cm of the surface, before filling the rest of the pit with soil.
2. It must be ensured that animals do not have any access to burial sites. Covers of galvanized iron/wire meshes may be used.
3. On each occasion, when wastes are added to the pit, a layer of 10 cm of soil shall be added to cover the wastes.
4. Burial must be performed under close and dedicated supervision.
5. The deep burial site should be relatively impermeable and no shallow well should be close to the site.
6. The pits should be distant from habitation, and sited so as to ensure that no contamination occurs of any surface water or groundwater. The area should not be prone to flooding or erosion.
7. The location of the deep burial site will be authorized by the prescribed authority.
8. The institution shall maintain a record of all pits for deep burial.

BIO-MEDICAL WASTE (MANAGEMENT AND HANDLING) RULES, 1998

https://parivesh.nic.in/writereaddata/ENV/HSM/note26.pdf

Source

- NPTEL Material
- BIO-MEDICAL WASTE (MANAGEMENT AND HANDLING) RULES, 1998
- Environmental Engg. (Vol.II) – S K Garg
- Environmental Engineering – Peavy, Rowe & Tchobanolgus
- Internet sources

Waste Management:
Module 4
Radioactive waste

5th Semester – Dept. of Civil Engineering, VSSUT

Dr. R R Dash

Disclaimer

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Definition

Radioactive waste is a type of hazardous waste that contains radioactive material. Radioactive waste is a by-product of various nuclear technology processes. Radioactive (or nuclear) waste is a by-product from nuclear reactors, fuel processing plants, hospitals and research facilities. Radioactive waste is also generated while decommissioning and dismantling nuclear reactors and other nuclear facilities.

SOURCES

- Nuclear power plants
- Nuclear armament
- Nuclear fuel treatment plants
- Nuclear fuel cycle
- Nuclear weapons reprocessing
- Medical and industrial wastes
- Naturally occurring radioactive materials (NORM) that can be concentrated as a result of the processing or consumption of coal, oil and gas, and some minerals
- Cosmic rays
- Radionuclide present within the bodies of organisms

High-level waste

- High-level waste (HLW) is produced by nuclear reactors. **High-level waste** (**HLW**) is a type of nuclear waste created by the reprocessing of spent nuclear fuel.

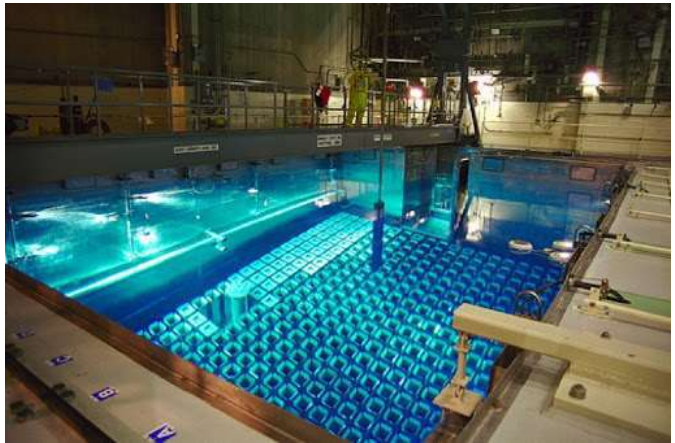
- High-level radioactive waste primarily is uranium fuel that has been used in a nuclear power reactor and is "spent," or no longer efficient in producing electricity. Spent fuel is thermally hot as well as highly radioactive and requires remote handling and shielding.

High-level waste

- High-level wastes are hazardous because they produce fatal radiation doses during short periods of direct exposure. If isotopes from these high-level wastes get into groundwater or rivers, they may enter food chains. The dose produced through this indirect exposure would be much smaller than a direct-exposure dose, but a much larger population could be exposed.
- Reprocessing separates residual uranium and plutonium from the fission products. The uranium and plutonium can be used again as fuel.
- Radioactive isotopes eventually decay, or disintegrate, to harmless materials. Some isotopes decay in hours or even minutes, but others decay very slowly. Strontium-90 and cesium-137 have half-lives of about 30 years (half the radioactivity will decay in 30 years). Plutonium-239 has a half-life of 24,000 years.

High-level waste

- High-level radioactive waste is stored for 10 or 20 years in spent fuel pools, and then can be put in dry cask storage facilities.
- **Spent fuel pools (SFP)** are storage pools for spent fuel from nuclear reactors. They are typically 40 or more feet (12 m) deep, with the bottom 14 feet (4.3 m) equipped with storage racks designed to hold fuel assemblies removed from reactors. A reactor's local pool is specially designed for the reactor in which the fuel was used and is situated at the reactor site. Such pools are used for immediate "cooling" of the fuel rods, which allows short-lived isotopes to decay and thus reduce the ionising radiation emanating from the rods. The water cools the fuel and provides radiological protection shielding from their radiation.



High-level waste

- **Dry cask storage** is a method of storing high-level radioactive waste, such as spent nuclear fuel that has already been cooled in the spent fuel pool for at least one year and often as much as ten years. Casks are typically steel cylinders that are either welded or bolted closed. The fuel rods inside are surrounded by inert gas. Ideally, the steel cylinder provides leak-tight containment of the spent fuel. Each cylinder is surrounded by additional steel, concrete, or other material to provide radiation shielding to workers and members of the public.

Low-level waste

- Low level waste (LLW) is generated from hospitals and industry, as well as the nuclear fuel cycle. Low-level wastes include paper, rags, tools, clothing, filters, and other materials which contain small amounts of mostly **short-lived radioactivity**. Materials that originate from any region of an Active Area are commonly designated as LLW as a precautionary measure even if there is only a remote possibility of being contaminated with radioactive materials. Such LLW typically exhibits no higher radioactivity than one would expect from the same material disposed of in a non-active area, such as a normal office block.
- Low-level waste includes items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. This waste typically consists of contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, equipment and tools, luminous dials, medical tubes, swabs, injection needles, syringes, and laboratory animal carcasses and tissues. The radioactivity can range from just above background levels found in nature to much higher levels in certain cases, such as from parts from inside the reactor vessel in a nuclear power plant.

Low-level waste

- Low-level waste is typically stored on-site by licensees, either until it has decayed away and can be disposed of as ordinary trash, or until amounts are large enough for shipment to a low-level waste disposal site in approved containers.

The low-level radioactive waste-waters are generally treated by the usual waste-water treatment methods, such as *flocculation, precipitation, filtration, ion exchange, and thermal evaporation*. The *precipitation* of radio-nuclides can be achieved by using aluminium salts, iron salts, tannic acid with lime, phosphate with lime, ferrocyanides, and excess lime-soda ash. While the decanted effluent is disposed of in any manner, the radioactive sludge so formed is sent to the special burial sites.

Radiation standard by ICRP

International Commission on Radiological Protection (ICRP)

The Commission aims to make recommendations concerning basic frameworks for radiological protection and protection standards. The Commission consists of the Main Commission and five standing Committees (radiation effects, doses from radiation exposures, protection in medicine, application of the Commission's recommendations, and protection of the environment).

(Reference) Dose limits excerpted from ICRP Recommendations

	1977 Recommendations	1990 Recommendations	2007 Recommendations
Dose limits (occupational exposure)	50 mSv/year	100 mSv/5 years and 50 mSv/year	100 mSv/5 years and 50 mSv/year
Dose limits (public exposure)	5 mSv/year	1 mSv/year	1 mSv/year

mSv: millisieverts

Radiation standard by AERB (*Atomic Energy Regulatory Board*)

DOSE LIMITS

Part of the body	Occupational Exposure	Public Exposure
Whole body (Effective dose)	20 mSv/year averaged over 5 consecutive years; 30 mSv in any single year	1 mSv/y
Lens of eyes (Equivalent dose)	150 mSv in a year	15 mSv/y
Skin (Equivalent dose)	500 mSv in a year	50 mSv/y
Extremities (Hands and Feet) Equivalent dose	500 mSv in a year	-

For pregnant radiation workers, after declaration of pregnancy 1 mSv on the embryo/fetus should not exceed

Source

- NPTEL Material
- Environmental Engg. (Vol.II) – S K Garg
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Waste Management:
Module 5
E- waste &
Soil contamination and site remediation

5th Semester – Dept. of Civil Engineering, VSSUT

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Definition

Electronic waste, popularly known as *E-waste*, can be defined as electronic and electrical equipments/products (including the connecting power plugs and batteries), which have become obsolete due to

(*i*) changes in fashion, style and status ; and

(*ii*) nearing the end of their useful life.

SOURCES

E-waste encompasses ever growing range of obsolete electronic devices, such as computers, servers, main frames, monitors, TVs and display devices, telecommunication devices such as cellular phones and pagers, calculators, audio and video devices, printers, scanners, copiers and fax machines besides refrigerators, air conditioners, washing machines, and microwave ovens. E-waste also covers recording devices such as DVDs, CDs, floppies, tapes, printing cartridges, military electronic waste, automobile catalytic converters, electronic components such as chips, processors, mother boards, printed circuit boards (PCB's), industrial electronics such as sensors, alarms, sirens, security devices, automobile electronic devices, etc.

Waste characteristics & generation

S. No.	Component	E-waste product and operation involved in disposal	Adverse Health Effects
(1)	(2)	(3)	(4)
1.	*Lead*	Mechanical breaking of Cathode Ray Tubes (CRTs) and Removal of solder from microchips, releasing lead as powder and fumes.	A neuro-toxin that affects the kidneys and the reproductive system. High quantities can be fatal. It affects mental development in children.
2.	*Chromium*	Used to protect metal housings and plates in a computer from corrosion.	Inhaling hexavelant chromium or chromium VI can damage liver and kidneys, and cause bronchial maladies, including asthmatic bronchitis and lung cancer.

Waste characteristics & generation

S. No.	Component	E-waste product and operation involved in disposal	Adverse Health Effects
3.	*Beryllium*	Found in switch boards and printed circuit boards.	It is a carcinogen and causes lung diseases.
4.	Mercury	Released while breaking and burning of circuit boards and switches.	Damages brain and kidneys, Impairs foetus growth and harm infants through mother's milk. Mercury in water bodies can form methylated mercury through microbial activity, which is toxic and can enter human food chain through aquatic life forms.

Contd...

Waste characteristics & generation

S. No.	Component	E-waste product and operation involved in disposal	Adverse Health Effects
5.	*Cadmium*	It is released as powder while crushing and milling of plastics, CRTs and circuit boards.	A carcinogen, long term exposure causes itai-itai, which affects kidneys and softens bones. It may be released with dust, entering surface water and groundwater.
6.	*Plastics*	Found in circuit boards, cabinets and cables. Burning PVC a component of plastics also produces dioxins. Even the dust on computer cabinets contains BFR.	They contain carcinogens. *BFRs* or *Brominated Flame Retardants* give out carcinogenic brominated dioxins and furans. Dioxins can harm reproductive and immune systems.
7.	*Acids*	Sulphuric and hydrochloric acids are often used to separate metals from *circuit boards.*	Fumes contain chlorine and sulphur dioxide which cause respiratory problems. They are corrosive to the eye and skin.

Guidelines on Implementation of E-Waste (Management) Rules, 2016

- These rules are applicable to every producer, consumer or bulk consumer, collection centre, dismantler and recycler of e-waste involved in the manufacture, sale, purchase and processing of electrical and electronic equipment or components specified in schedule –I of these Rules.
- Two categories of electrical and electronic equipment namely (i) IT and Telecommunication Equipment and (ii) Consumer Electricals and Electronics such as TVs, Washing Machines, Refrigerators Air Conditioners including fluorescent and other mercury containing lamps are covered under these Rules.
- Stipulate phase wise collection target to producers for the collection of e-waste, either in number or weight, which shall be 30% of the estimated quantity of waste generation during first two year of implementation of rules followed by 40% during third and fourth years, 50% during fifth and sixth years and 70% during seventh year onwards.

Guidelines for Collection and Storage of E-Waste

- After assessing their requirement of collection of e-waste, producers may device a collection mechanism which may include take-back through dealers, collection centres or directly through authorised dismantlers/recyclers.
- Producer may manage a system directly for collection of e-waste by involving relevant stakeholders such as consumer, bulk consumer, informal sector, resident associations, retailers and dealers, etc.
- Producers may also have an arrangement of collection of e-waste from individual consumers and bulk consumers as well.
- The producers may publicize their collection system which may include details of their collection points, bins and collection vans linked to collection centres, take-back system, **deposit refund scheme**, e-waste exchange, retailers/dealers etc.
- Details of authorised dismantlers/recyclers who can take-back e-waste on behalf of the producer if dismantlers/recyclers should be provided.

Guidelines for Collection and Storage of E-Waste

- Every Producer, collection centre, dealer, dismantler, recycler and refurbisher may store the e-waste for a period not exceeding one hundred and eighty (180) days.
- During storage of e-waste care may be taken:(i) To avoid damage to refrigerators and air-conditioner so as to prevent release of refrigerant gases such as CFC, HFS, HCFC etc. and to prevent spillage of oils (mineral or synthetic oil)and other emissions (ii)To avoid damage to Cathode Ray Tube (iii)To avoid damage to fluorescent and other mercury containing lamps (iv)To avoid damage to equipment containing asbestos or ceramic fibres to avoid release of asbestos or ceramic fibres in the environment.
- After collection of fluorescent and other mercury containing lamps, it should be sent only to a recycler or to a TSDF in case no recycler is available.
- Loading, transportation, unloading and storage of E-Waste / end of life products should be carried out in such a way that its end use such as re-use after refurbishing or recycling or recovery is unaffected.

Guidelines for Collection Centre

- Collection centre or collection points are part of E-waste channelisation, and can be established by producers, refurbishers, dismantlers and recyclers.
- Collection Centre may collect and store e-waste, on behalf of producer / dismantler / recycler /refurbisher and transfer the same to authorised dismantlers / recyclers.
- The collection points/bins can be at designated places where e-waste can be collected from residential areas, office complexes, commercial complexes, retail outlets, customer care stores, educational and research institutions, resident welfare associations(RWAs).
- These collection points have to be part of producer's collection and channelisation plan.
- Mobile collection vans can be used for door to door collection of e-waste from institutions/ individuals/small enterprises and such vans shall be linked to collection centres, and if provided by producers, shall be part of their EPR Plan.
- Material from collection centres should be send only to the authorised dismantlers and Recyclers except in case of used Fluorescent and other mercury containing lamps, which can be sent to TSDF in case recyclers are not available.

Guidelines for Transportation of E-Waste

- The sender of E-Waste, that may be a producer, manufacturer, recyclers, dismantler, bulk-consumer, refurbisher and collection centre should identify transporter or make arrangements for a transporting e-waste in such a manner that environmental consequences of hazards associated with its transport could be kept at minimum.
- The responsibility of safe transportation of E-waste shall be with the sender of E-Waste.
- The manufacturers and recyclers while transporting waste generated from manufacturing or recycling destined for final disposal to a treatment, storage and disposal facility will follow the provisions under Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016.

Guidelines for Disposal - Dismantler

- Any person or organisation or registered society or a designated agency or a company or an association can engage in dismantling of e-waste into their components by obtaining authorisation from the respective SPCBs/PCCs. Dismantlers may set up their collection centre, details of which shall be entered in their authorisation. These collection centres shall not require separate authorisation.

- Dismantling operation is essentially manual operation for segregating various components/ parts and sending them to respective users/ recyclers. Directly usable components can be sent only to an authorised refurbisher.

Guidelines for Disposal - Recycler

- As per these rules any person who is engaged in recycling and reprocessing of waste electrical and electronic equipment or assemblies or their component is a recycler.
- Recyclers can obtain raw material such as waste electrical and electronic assemblies or components or used components from producers/e-waste exchange/dismantlers and consumers/bulk consumers.
- The functions of the recyclers include dismantling along with recovery operation.
- The following processes should be employed by recyclers:
  - (i)Manual / semi-automatic/ automatic dismantling operations
  - (ii)Shredding / crushing / fine grinding/wet grinding/ enrichment operations, gravity/ magnetic/density/eddy current separation
  - (iii)Pyrometallurgical operations -Smelting furnace
  - (iv)Hydro metallurgical operations
  - (v)Electro-metallurgical operations
  - (vi)Chemical leaching
  - (vii)CRT/LCD/Plasma processing
  - (viii)Toner cartridge recycling
  - (ix)Melting, casting, moulding operations (for metals and plastics)

Guidelines for Disposal-Refurbisher

- Refurbishment means repairing of used electrical and electronic equipment and it should be carried out in such a way that there should not be any damage to health and environment.
- Any e-waste generated during refurbishment should be collected separately and sent to collection centre /authorised recycler. In case of refurbisher not having own collection centre, the e-waste so generated may be channelized to an authorised recycler.

Soil contamination and site remediation

Soil pollution - Definition

- **Soil pollution** is defined as the presence of toxic chemicals (pollutants or contaminants) in soil, in high enough concentrations to pose a risk to human health and/or the ecosystem.

- In the case of contaminants which occur naturally in soil, even when their levels are not high enough to pose a risk, soil pollution is still said to occur if the levels of the contaminants in soil exceed the levels that should naturally be present.

Soil Pollution

- All soils, whether polluted or unpolluted, contain a variety of compounds (contaminants) which are naturally present.
- Such contaminants include metals, inorganic ions and salts (e.g. phosphates, carbonates, sulfates, nitrates), and many organic compounds (such as lipids, proteins, DNA, fatty acids, hydrocarbons, PAHs, alcohols, etc.).
- These compounds are mainly formed through soil microbial activity and decomposition of organisms (e.g., plants and animals).
- Additionally, various compounds get into the soil from the atmosphere.
- For instance with precipitation water, as well as by wind activity or other types of soil disturbances, and from surface water bodies and shallow groundwater flowing through the soil.

Soil Pollution

- When the amounts of soil contaminants exceed natural levels (what is naturally present in various soils), pollution is generated.
- There are two main causes through which soil pollution is generated: anthropogenic (man-made) causes and natural causes.

Natural Pollutants

- **Natural accumulation** of compounds in soil due to imbalances between atmospheric deposition and leaking away with precipitation water (e.g., concentration and accumulation of perchlorate in soils in arid environments)
- **Natural production** in soil under certain environmental conditions (e.g., natural formation of perchlorate in soil in the presence of a chlorine source, metallic object and using the energy generated by a thunderstorm)

Anthropogenic Pollutants

Anthropogenic (man-made) soil pollution originates in several types of processes, some deliberate (industrial) and some accidental. Human-caused soil pollution can work in conjunction with natural processes to increase the toxic contamination levels in the soil.

- **Accidental spills and leaks** during storage, transport or use of chemicals (e.g. leaks and spills of gasoline and diesel at gas stations);
- **Foundry activities** and manufacturing processes that involve furnaces or other processes resulting in the possible dispersion of contaminants in the environment;
- **Mining activities** involving the crushing and processing of raw materials, for instance, heavy metals, emitting toxic substances;

Anthropogenic Pollutants

- **Construction activities** Construction sites are the most important triggers of soil pollution in urban areas, due to their almost ubiquitous nature. Almost any chemical substance handled at construction sites may pollute the soil. However, the higher risk comes from those chemicals that can travel more easily through the air as fine particulate matter. The chemicals that travel as particulate matter are more resistant to degradation and bioaccumulate in living organisms, such as PAHs.
- **Agricultural activities** involving the diffusion of herbicides, pesticides and/or insecticides and fertilizers;
- **Transportation activities**, releasing toxic vehicle emissions
- **Chemical waste dumping**, whether accidental or deliberate – such as illegal dumping;
- **The storage of waste in landfills**, as the waste products may leak into groundwater or generate polluted vapors
- **Cracked paint chips** falling from building walls, especially lead-based paint.
- **Leaks from sewer lines** into subsurface (e.g., adding chlorine which could generate trihalomethanes such as chloroform).

Types of Soil Pollutants

- Soil pollution consists of pollutants and contaminants. The main pollutants of the soil are the biological agents and some of the human activities. Soil contaminants are all products of soil pollutants that contaminate the soil. Human activities that pollute the soil range from agricultural practices that infest the crops with pesticide chemicals to urban or industrial wastes or radioactive emissions that contaminate the soil with various toxic substances.

- **Biological Agents:** Biological agents work inside the soil to introduce manures and digested sludge (coming from the human, bird and animal excreta) into the soil.

Types of Soil Pollutants

- **Agricultural Practices:** The soil of the crops is polluted to a large extent with pesticides, fertilizers, herbicides, slurry, debris, and manure.
- **Radioactive Pollutants:** Radioactive substances such as Radium, Thorium, Uranium, Nitrogen, etc. can infiltrate the soil and create toxic effects.
- **Urban Waste:** Urban waste consists of garbage and rubbish materials, dried sludge and sewage from domestic and commercial waste.
- **Industrial Waste:** Steel, pesticides, textiles, drugs, glass, cement, petroleum, etc. are produced by paper mills, oil refineries, sugar factories, petroleum industries and others as such.

Examples of Soil Contaminants

- **Lead (Pb)** Potential sources: lead paint, mining, foundry activities, vehicle exhaust, construction activities, agriculture activities
- **Mercury (Hg)** Potential sources: mining, incineration of coal, alkali and metal processing, medical waste, volcanoes and geologic deposits, accumulation in plants & vegetables grown on polluted soils
- **Arsenic (As)** Potential sources: mining, coal-fired power plants, lumber facilities, electronics industry, foundry activities, agriculture, natural accumulation
- **Copper (Cu)** Potential sources: mining, foundry activities; construction activities

Examples of Soil Contaminants

- **Zinc (Zn)** Potential sources: mining; foundry activities; construction activities
- **Nickel (Ni)** Potential sources: mining; foundry activities; construction activities
- **PAHs (polyaromatic hydrocarbons)** Potential sources: coal burning, vehicle emissions, accumulation in plants & vegetables grown on polluted soils; cigarette smoke; wildfires, agricultural burning; wood burning, constructions
- **Herbicides/Insecticides** Potential sources: agricultural activities; gardening

Effect of Soil Pollution

- **Loss of soil fertility & Inferior Crop Quality:** It can decrease the quality of the crop. Regular use of chemical fertilizers, inorganic fertilizers, pesticides will decrease the fertility of the soil at a rapid rate and alter the structure of the soil. This will lead to decrease in soil quality and poor quality of crops. Over the time the soil will become less productive due to the accumulation of toxic chemicals in large quantity.
- **Harmful Effect on Human Health:** It will increase the exposure to toxic and harmful chemicals thus increasing health threats to people living nearby and on the degraded land. Living, working or playing in the contaminated soil can lead to respiratory diseases, skin diseases, and other diseases. Moreover, it can cause other health problems.
- **Climate change:** Deforestation causes a change in the rain cycle and this is a contributing factor to global warming and loss of ecosystems.

Effect of Soil Pollution

- **Water Sources Contamination:** The surface run-off after raining will carry the polluted soil and enter into different water resource. Thus, it can cause underground water contamination thereby causing water pollution. This water after contamination is not fit for human as well as animal use due to the presence of toxic chemicals.
- **Negative Impact on Ecosystem and Biodiversity:** Soil pollution can cause an imbalance of the ecosystem of the soil. The soil is an important habitat and is the house of different type of microorganisms, animals, reptiles, mammals, birds, and insects. Thus, soil pollution can negatively impact the lives of the living organisms and can result in the gradual death of many organisms. It can cause health threats to animals grazing in the contaminated soil or microorganisms residing in the soil.

Site Remediation

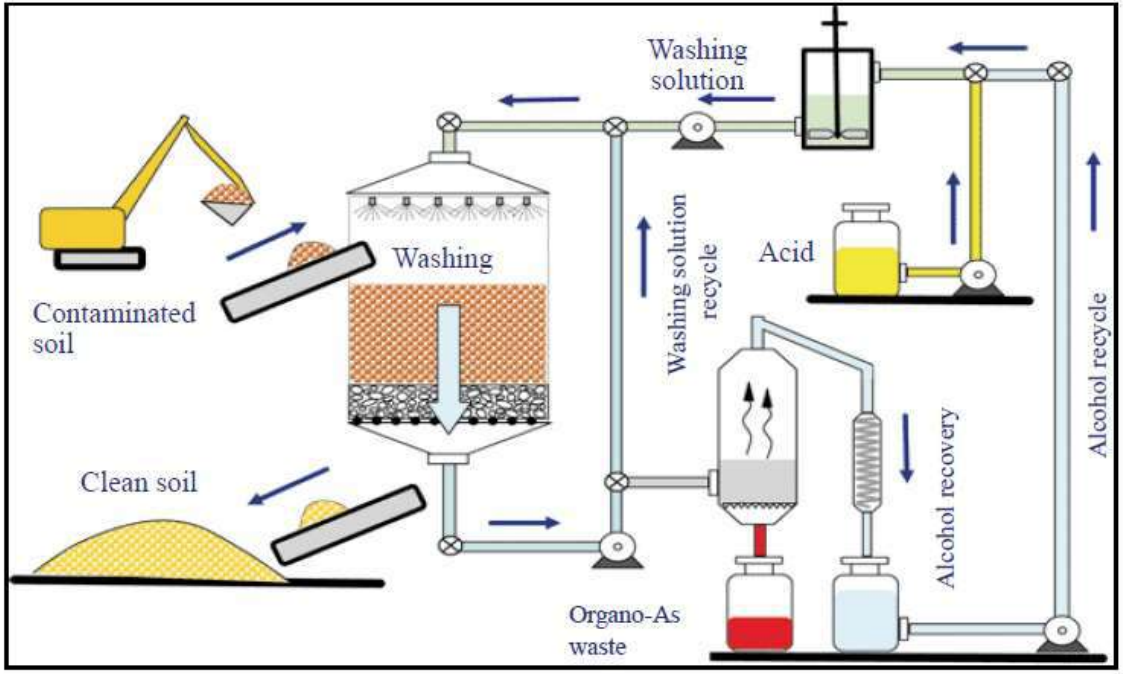
- Based on the toxic level of contaminants and the risk it pose to the environment, a suitable remediation method is selected.
- It must be noted that the remediation does not aim for entire decontamination. The major focus is to bring the contamination level well below the regulatory toxic limit.
- This is done by removing the toxic contaminants and/or immobilizing the contaminant that prevents its movement through subsurface geo-environment. The remediation methods are broadly classified as physico-chemical, biological, electrical, thermal and combination of these methods.

Physico-chemical methods - Removal and replacing of contaminated soil

- One of the simplest physical methods for remediation is by removing the contaminated soil and replacing it with clean soil.
- Essentially it is a dig, dump and replace procedure.
- Such a method is practically possible only if the spatial extent and depth of the contaminated region is small.

Soil washing

- Physical removal of contaminated soil, followed by treatment at a plant or off-site. After the contamination is removed through the treatment process, the soil can be deposited back into the ground.



Soil vapor extraction

- This method is used for soil contamination above the water table. It involves the installation of wells and pipes in the soil, through which soil contaminants are extracted in vapor form.

Solidification and stabilization

- This is the process of immobilizing toxic contaminants so that it does not have any effect temporally and spatially.
- Stabilization-solidification (SS) is performed in single step or in two steps.
- In single step, the polluted soil is mixed with a special binder so that polluted soil is fixed and rendered insoluble.
- In two step process, the polluted soil is first made insoluble and non-reactive and in the second step it is solidified.
- SS process is mostly justified for highly toxic pollutants.
- In-situ SS process is mostly influenced by the transmissivity characteristics of the soil, viscosity and setting time of the binder.
- Well compacted soil, high clay and organic content do not favour in-situ SS.

Chemical decontamination

- This method is mostly applicable for those soils which have high sorbed concentration of inorganic heavy metals (IHM).
- The first process in this method is to understand the nature of bonding between the pollutant and the soil surface.
- A suitable extractant need to be selected for selective sequential extraction (SSE) of IHM from the soil mass.
- The extractants include electrolytes, weak acids, complexing agents, oxidizing and reducing agents, strong acids etc.
- The use of these extractants in single or in combination will depend upon the concentration of IHM and nature of the soil mass.

Electro-kinetic methods

- Electro-kinetic methods are popular field method for decontaminating a particular site by using electrical principles.
- The procedure is more effective for granular type of soils.
- Two metal electrodes are inserted into the soil mass which acts as anode and cathode.
- An electric field is established across these electrodes that produces electronic conduction as well as charge transfer between electrodes and solids in the soil-water system.
- This is achieved by applying a low intensity direct current across electrode pairs which are positioned on each side of the contaminated soil.
- The electric current results in electrosmosis and ion migration resulting in the movement of contaminants from one electrode to the other.
- Contaminants in the soil water or those which are desorbed from the soil surface are transported to the electrodes depending upon their charges.
- Contaminants are then collected by a recovery system or deposited at the electrodes.
- This method is commercially used for the removal of heavy metals such as uranium, mercury etc from the soil.

Thermal methods

- Thermal methods include both high temperature (>500^{o}C) and low temperature (<500^{o}C) methods and are mostly useful for contaminants with high volatilization potential.
- High temperature processes include incineration, electric pyrolysis, and in-situ vitrification.
- Low temperature treatments include low temperature incineration, thermal aeration, infrared furnace treatment, thermal stripping.
- High temperature treatment involves complete destruction of contaminants through oxidation.
- Low temperature treatment increases the rate of phase transfer of contaminants from liquid to gaseous phase there by causing contaminant separation from the soil.

Biological methods - Bioremediation

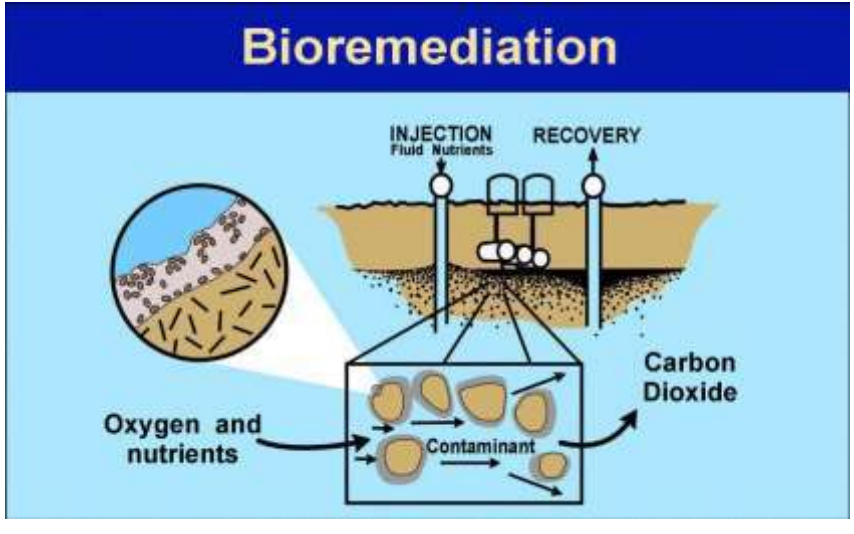
- Remediation by biological treatment is mostly applicable for soil contaminated with organic pollutants and the process is termed as bio remediation.
- In this method, certain soil microorganisms/ plants are used to degrade organic chemical compounds.

Microbial remediation:

- In the process these microorganisms degrade the contaminant.
- If naturally occurring microorganisms such as bacteria, virus or fungi is not capable of producing enzymes required for bioremediation, then genetically engineered microorganisms would be required.
- At the same time, it should be ensured that such microorganisms do not produce any undesirable effect on the geo-environment (such as toxins).

Microbial remediation

- The process of bioremediation is dependent on reactions such as microbial degradation, hydrolysis, aerobic and anaerobic transformation, redox reaction, volatalization etc.
- Utilizes microbes in degrading contaminants into a less toxic form. This technique can be very effective in the treatment of hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs).

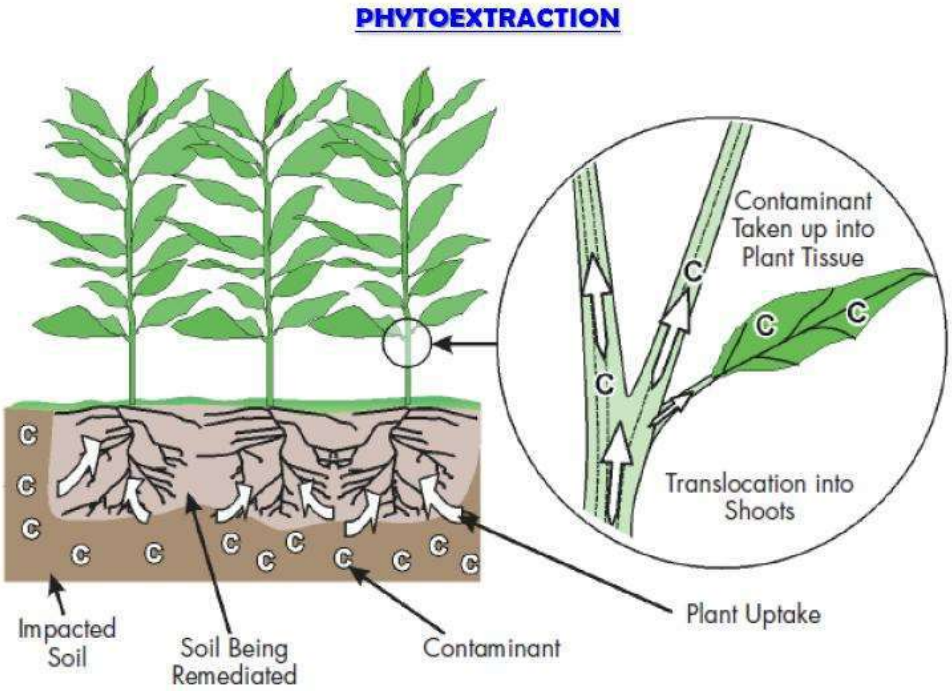


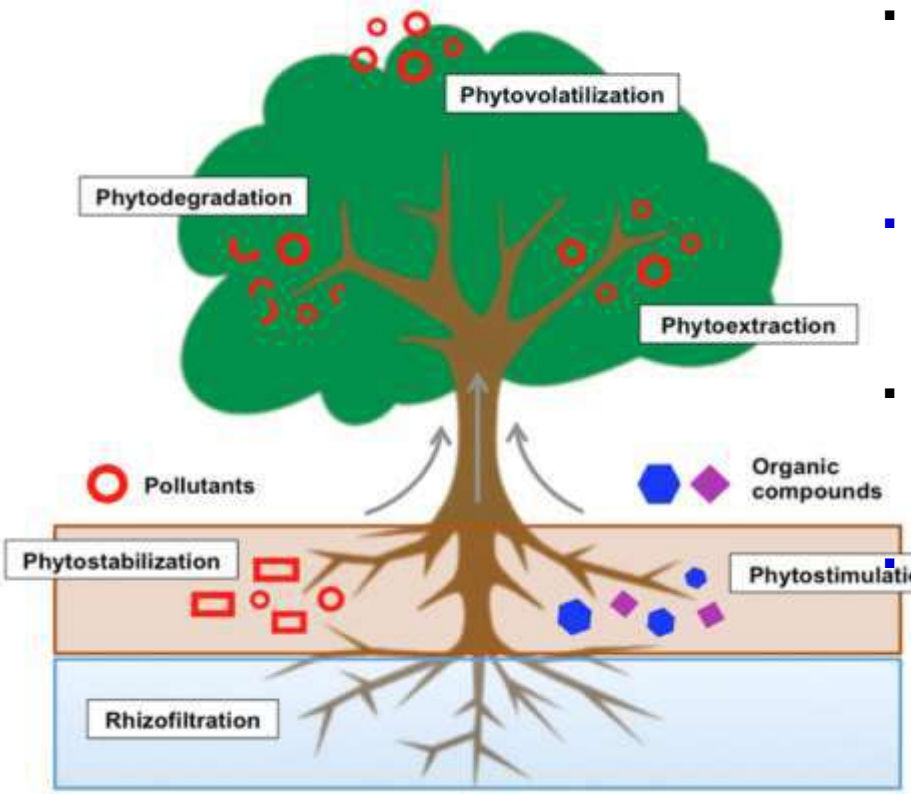
Bioremediation technologies can be generally classified as *in situ* or *ex situ*. *In situ* bioremediation involves treating the contaminated material at the site while *ex situ* involves the removal of the contaminated material to be treated elsewhere. Some examples of bioremediation technologies

- Bioventing is an on site remediation technology that uses microorganisms to biodegrade organic constituents in the groundwater system. Bioventing enhances the activity of indigenous bacteria and archaea and stimulates the natural in situ biodegradation of hydrocarbons by inducing air or oxygen flow into the unsaturated zone and, if necessary, by adding nutrients.
- **Biostimulation** involves the modification of the environment to stimulate existing bacteria capable of bioremediation. This can be done by addition of various forms of rate limiting nutrients and electron acceptors, such as phosphorus, nitrogen, oxygen, or carbon (e.g. in the form of molasses).
- **Biological augmentation** is the addition of archaea or bacterial cultures required to speed up the rate of degradation of a contaminant. Organisms that originate from contaminated areas may already be able to break down waste, but perhaps inefficiently and slowly.
- **Landfarming** is an ex-situ waste treatment process that is performed in the upper soil zone or in biotreatment cells. Contaminated soils, sediments, or sludges are transported to the land farming site, incorporated into the soil surface and periodically turned over (tilled) to aerate the mixture.
- Biosparging is an in situ remediation technology that uses indigenous microorganisms to biodegrade organic constituents in the saturated zone. In biosparging, air (or oxygen) and nutrients (if needed) are injected into the saturated zone to increase the biological activity of the indigenous microorganisms.

Phytoremediation

- A method of planting species that can degrade contaminants around their roots, or species that draw up contaminants from the soil into shoots and leaves, which must then be disposed of.





- Phyto-volatilization is the removal of substances from soil or water with release into the air, sometimes as a result of phyto-transformation to more volatile and/or less polluting substances. In this process, contaminants are taken up by the plant and through transpiration, evaporate into the atmosphere.
- Phyto-degradation uses plants to degrade organic pollutants in the soil or within the body of the plant. The organic compounds are broken down by enzymes that the plant roots secrete and these molecules are then taken up by the plant and released through transpiration.
- Phyto-extraction exploits the ability of plants or algae to remove contaminants from soil or water into harvestable plant biomass. The roots take up substances from the soil or water and concentrate it above ground in the plant biomass`
- Phyto-stabilization reduces the mobility of substances in the environment, for example, by limiting the leaching of substances from the soil. It focuses on the long term stabilization and containment of the pollutant.
- Phytostimulation (or rhizodegradation) is the enhancement of soil microbial activity for the degradation of organic contaminants, typically by organisms that associate with roots.
- Rhizofiltration is a process that filters water through a mass of roots to remove toxic substances or excess nutrients. The pollutants remain absorbed in or adsorbed to the roots. This process is often used to clean up contaminated groundwater through planting directly in the contaminated site or through removing the contaminated water and providing it to these plants in an off-site location.

Monitoring of Disposal Sites

Site characterization or contaminated site assessment (CSA) is important for

a) Determining concentration and spatial distribution of harmful pollutants under consideration.

b) Determining the extent of site remediation (zonation) based on which the suitable remediation technique is selected.

c) For assessing environmental and human health risk due to contamination.

More specifically, CSA is required to answer the following questions:

a) What is the source of contaminants?

b) What is the type and physical form of contaminants

c) Spatial and depth wise extent of contamination

d) Whether the contaminants are stationery or movable?

e) If they are movable, then identify the significant pathways.

f) Identify the potential receptors of contaminants

Data to be collected

Data	Details	Method of acquisition
1) Site history and land use pattern	a) Population density within 3 km from the contaminated site b) Proximity to important geographical features like airport, railways, river etc. c) Ownership of the land d) Extent of contamination	Field
2) Geologic and hydrologic	a) Topography b) Soil profile up to bed rock c) Information on aquifer d) Groundwater depth and flow direction	Field
3) Geotechnical	a) Soil sampling and classification b) Permeability of soil c) Chemical characteristics of soil	Field Field Lab
	d) Soil strength	Lab
4) Waste	a) Water quality b) Identifying the type of contamination c) Concentration of contaminants d) Spatial extent of contamination e) Depth of contamination f) Contaminant retention characteristics g) Contaminant transport characteristics h) Hazard assessment and zonation	Field/ Lab Field/ Lab Lab Field/ Lab Field/ Lab Lab Lab Lab

Source

- NPTEL Material
- Internet sources
- https://www.environmentalpollutioncenters.org/soil