

Solid Waste

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Sources of Solid Wastes

- **Agricultural Waste** : Waste arising from agricultural practice.
- **Mining Waste**: Mainly inert material from mineral extracting industries.
- **Energy Production Waste**: Waste from energy production units including ash from coal burning.
- **Industrial Waste**: Wastes generated by various industries.

- **Dredging Waste:** Organic and mineral wastes from dredging operations.
- **Construction and Demolition Waste:** Bricks, brick bats, concrete, asphaltic material, pipes etc.
- **Treatment Plant Waste:** Solids from grit chambers, sedimentation tank, sludge digesters of waste water treatment plant.
- **Residential Waste:** Garbage including food waste, paper, crockery and ashes from fires, furniture.

- **Commercial Waste:** Similar to residential wastes produced from offices, shops, restaurants etc.
- **Institutional Waste:** Similar to residential wastes plus hazardous, explosive, pathological and other wastes which are institution specific (hospital, research institute etc.)

Municipal Solid Wastes

What is Municipal Solid Waste (MSW) ?

The MSW refers to all wastes collected by local authority or municipality and is the most diverse category of waste.

MSW comprises all wastes except agricultural, mining, energy production and dredging wastes.

Waste Quantities

Quantity of solid waste generated (million tons per year)

Country	Agricultural	Mining	C&D	Sewage sludge	Energy Production	Industry	MSW
UK	260	240	35	27	13	62	110
USA	-	1400	31.5	8.4	63	430	133
INDIA	-	700-900	7.2	-	60	-	24

Quantities of MSW generated in some Indian Cities

City	Tons/day
Mumbai	5000
Kolkatta	3500
Delhi	6000
Chennai	3500

Quantities of MSW generated in different countries

Country	Kg/person/day
India	0.25 to 0.33
Srilanka	0.40
Singapore	0.85
UK	0.95 to 1.0
Japan	1.12
USA	1.25 to 2.25

Projected Municipal, Energy and Mine Waste Generation in India (Million Tons/year)

Year	MSW	Energy Waste(ash)	Mine waste
1980	-	-	430
1990	24	46	830
2000	39	92	1220
2010	56	113	-

Major Constituents of MSW Generated in UK, USA and India

Constituent	UK	USA	India
Paper	35	40	5
Plastic	11	8	1
Metals	8	8.5	1
Glass	9	7	0.5
Inert Material	-	-	39
Compostable Matter	19	25	37.5
Others	18	11.5	16

Characteristics of Solid Waste

- Solid waste generated by a society may be inert, biologically active or chemically active.
- Agricultural waste is primarily biologically active. It is generated in large quantities and remains uniformly dispersed on land surface area.
- Mining waste is primarily inert and is also generated in large volumes. However it accumulates continuously at mining sites.

- **Industrial wastes** are generated in industrial area and are highly industry specific. They usually comprise of chemicals and allied products, rubber, plastic, metals, petroleum and coal products etc.
- **MSW** is generated at densely populated urban centres and are most **heterogenous**. The predominant constituents of MSW are paper, food, wastes, plastics, glass , metals and inert material. In developing country like india, **40%** waste is compostable, **40%** inert material where as in developed countries, paper forms a major part of MSW followed by compostable matter. The inert material content is low.

Management of Solid waste

- There are two fundamental objectives of solid waste management.
- To minimize the waste.
- To manage the waste still produced.

Various Activities Associated With Solid Waste

- Waste Generation
- Processing at Source
- Collection
- Processing at a Central Facility
- Transportation and final disposal on land

For all types of waste generated, an integrated solid waste management follow the following options in order of **Hierarchy**

- Waste Reduction at Source
- Resource Recovery Through Separation and Recycling
- Resource Recovery Through Waste Processing
- Waste Transformation
- Waste Disposal on Land

Waste Reduction at Source

- Source reduction is the most effective way to minimize waste.
- Waste reduction may occur through proper design, manufacture and packing of products with minimum toxicity, minimum volume of material and longer useful life.

Resource Recovery Through Separation and Recycling

Recycling involves

- Separation of waste materials
- Preparation of separated fractions for reuse
- Reprocessing and remanufacturing
- Reuse of prepared material

Materials in MSW which can be separated and recycled

- Paper
- Glass
- Plastic
- Ferrous metals
- Aluminium cans

Recycling is a good process as it reduces the volume of waste to be disposed off on land.

Resource Recovery Through Waste Processing

Waste processing involves the physical, chemical or biological alterations of wastes to recover products for reuse. The various techniques used for this are

- **Biological Treatment**
 - Composting
 - Anaerobic digestion/Biogasification
- **Thermal Treatment**
 - Incineration
 - Refuse Derived Fuel Burning
- **Physical Treatment**
 - Making building blocks/bricks from inert waste
- **Chemical Treatment**
 - To recover compounds such as glucose, synthetic oil and cellulose acetate etc.

Waste Transformation

After recovery of various resources from a waste, the residual material may be subjected to a variety of processes to reduce the volume of waste requiring disposal. Treatment process may involve

- Shredding
- Size separation (screening)
- Volume Reduction by thermal treatment or compaction
- Encapsulation (to reduce toxicity)

These processes help in reducing the final land areas required for waste disposal

Waste Disposal on Land

Despite all efforts to minimize waste, the following requirement for storage/disposal of the following types of waste will continue to remain.

- The solid waste that cannot be recycled.
- The residual waste after all types of processing has been undertaken

Changes Occurring in a Waste Dump

Biological Changes

During the aerobic decomposition, **carbondioxide** is the principal gas produced.

Once the available oxygen has been consumed, the decomposition becomes anaerobic and the organic matter is converted to

- Carbondioxide
- Methane
- Trace amounts of ammonia
- Hydrogen sulfide

Many other chemical reactions are also biologically initiated therefore it is difficult to define the condition that will exist in any waste dump at any stated time.

Chemical Changes

The chemical reactions that occurs in a waste dump are

- Dissolution
- Suspension of waste materials
- Biological conversion products in the liquid percolating through the waste
- Evaporation and vaporization of chemical compounds
- Sorption of volatile and semi volatile organic compounds into the waste material
- Decomposition of organic compounds
- Oxidation-reduction reactions affecting metals and the solubility of metal salts.

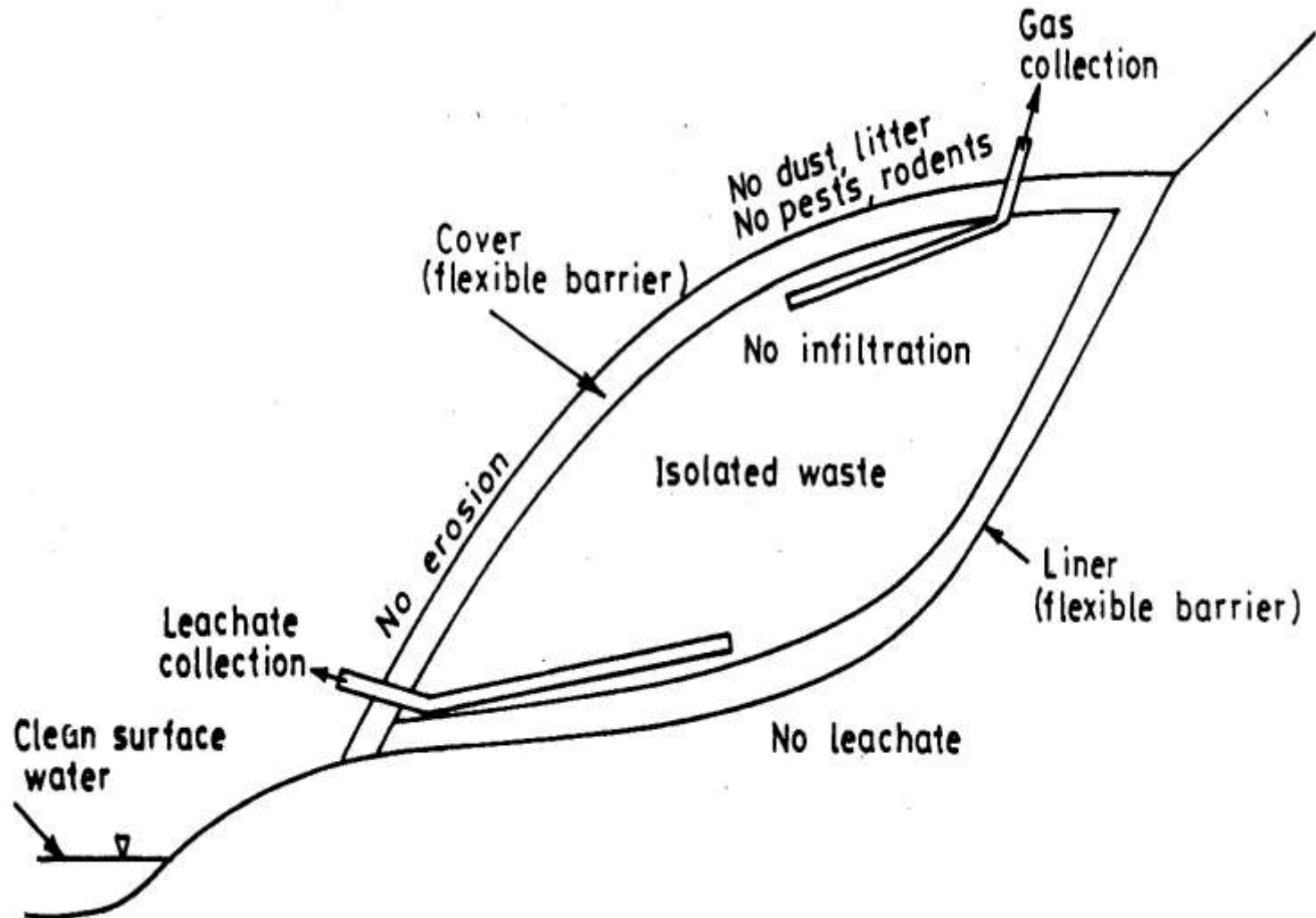
The dissolution of biological conversion into the leachate is of special importance because these materials can be transported out of the waste dump with the leachate.

Physical Changes

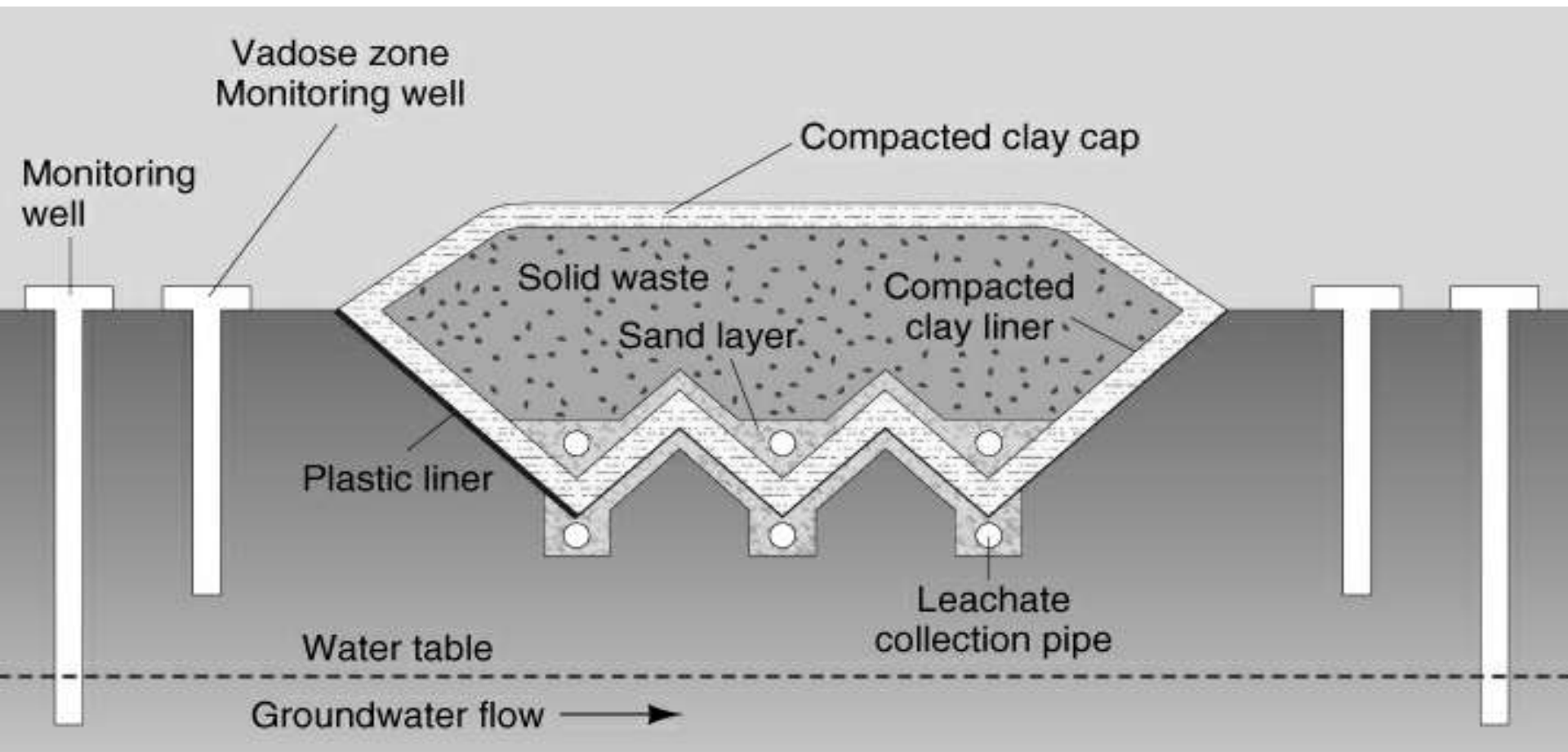
The important physical changes in waste dumps are

- Lateral movement of gases in the waste
- Emission of gases to the surrounding environment
- Movement of leachate within the waste and into underlying soils
- Settlement caused by consolidation and decomposition of the waste.

Concept of Landfilling



Engineered Landfills



The components of the engineered landfill are

- Liner system
- Leachate collection and treatment facility
- Gas collection and treatment facility
- Final cover system
- Surface water drainage system
- An environmental monitoring system
- A closure and post closure plan

Types of Landfills

Landfills can be classified as

- Conventional MSW landfills
- Landfills for processed and shredded solid wastes
- Monofills for individual waste constituents (used for industrial waste)
- Other types of Landfills (For gas generation to generate electricity)

Implications of Disposal Above, On and Below Ground Surface

Above Ground Landfills

Advantage

- ◆ Drainage of leachate is by gravity.
- ◆ Thickness of unsaturated zone below the landfill is large.
- ◆ Landfill is conspicuous and thus cannot be ignored.
- ◆ Poor surface drainage due to settlement of final landfill surface can be avoided.
- ◆ Inspection of the entire facility i.e. final cover, leachate collection system and gas collection system is easier.

Disadvantage

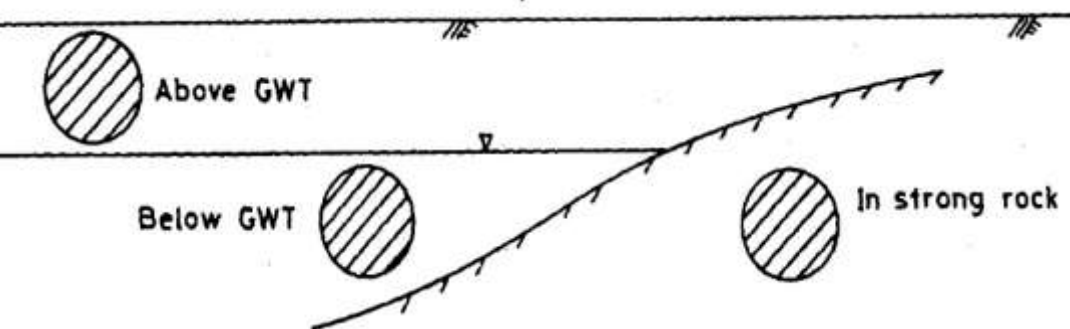
- ◆ They alter the land use pattern of the area.
- ◆ They have more surface area exposed to elements of nature such as wind, rain and require significant erosion control measures.



Landfills Deep Beneath the Earth's Surface

Wastes can also be dumped in underground openings, tunnels or caverns, however the cost of construction in such cases is extremely high. If the disposal is in soil where water table is high, the waste would always be surrounded by ground water and, irrespective of the multiple barriers used for waste isolation, the potential of ground water contamination would always be high. On the other hand,

If waste is disposed in strong competent rock, the very low permeability of the rock mass coupled with multiple barriers layers ensures long term containment of the waste. Such disposal techniques are adopted for extremely hazardous waste where cost considerations are outweighed by the need for fail proof environment protection measures. Waste disposal deep beneath the ground surface has the least impact on the land use pattern.



Characterization of Waste

Liquid Waste Characterization

The basic characterization parameters are

- Source Information for the individual points
 - Waste components
 - Rate of discharge during production run
 - Periodic discharges due to batch operations
 - Duration and frequency of production run
 - Susceptibility to emerging discharges or spills

Chemical Composition

- Organic and inorganic components by compounds or classes
- COD, Total organic carbon, BOD
- Specific problem ions(As, Bo, Cd, Cr etc.)
- Specific problem organic e.g. phenol, certain pesticides, benzidine etc.
- Total dissolved salts
- pH, acidity, alkanity
- Nitrogen, Phosphorous
- Oils and greases
- Oxidizing or reducing agents
- Surfactants
- Chlorine demand

Biological Effects

- Biochemical oxygen demand
- Toxicity
- Pathogenic bacteria

- **Physical Properties**

- Temperature range and distribution
- Insoluble components
- Colour
- Odour
- Foamability
- Corrosiveness
- Radioactivity

- **Flow data for total discharge**

- Avg. daily flow rate
- Duration and level of minimum flow rate
- Maximum rate of change of flow rate

Meaningful characterization information can only be obtained through proper analysis of representative samples or through the use of online water quality monitoring instrumentation.

Solid waste Characterization

Physical and chemical composition of solid wastes vary depending on sources and types of solid wastes. The nature of the deposited waste in a landfill will affect gas and leachate production and composition by virtue of relative proportions of degradable and non-degradable components, the moisture content and the specific nature of the bio-degradable element. The waste composition will effect both gases and the trace components

The important parameters to characterize the waste are

- Waste composition
- Moisture content
- Waste particle size
- Waste density
- Temperature and pH

These parameters affect the extent and rate of degradation of waste. The typical approximate analysis for MSW are show below.

- | | |
|------------------------|-----|
| • Moisture | 20% |
| • Volatile matter | 53% |
| • Fixed carbon | 7% |
| • Glass, metal and ash | 20% |

Geotechnical Properties of Solid Wastes

Unit Weight :- Insitu density- 1.2 to 2.1 t/m³ with extremes of 0.94 t/m³ for poor compaction and 2.8 t/m³ for best compaction.

Permeability :- The reported range of permeability of refuse is 10⁻¹ to 10⁻⁵ cm/sec.

Strength parameters :- Friction Angle - - 30⁰ to 35⁰
Cohesion 1 to 2.5 t/m²

Compressibility :- For one dimensional consolidation test on waste of density 600 kg/m³, the compression index is 0.55 and secondary compression coefficient varying from 0.0036 to 0.005 for a municipal dump in Madras City.

Hazardous Waste Characterization

The waste which can

- Contribute to increase in mortality
- Can cause irreversible illness
- Can pose potential hazard to human health is called **hazardous waste**

Hazardous waste can be classified as

- Radioactive substances
- Chemicals
- Biological Wastes
- Flammable waste
- Explosives

Characteristics of Hazardous Waste

There are four characteristics which make the waste hazardous category

- Ignitability
- Corrosivity if $\text{pH} \leq 2$ or ≥ 12.5
- Reactivity:- A waste exhibits the characteristics of reactivity if a representative sample of the waste has the following properties
 - Reacts violently with water
 - Forms explosive mixture with water
 - When mixed with water, generates toxic gases, fumes or vapours
 - Reacts at a standard temperature or pressure

- **Toxicity**:- The limits for a waste to be toxic for different contaminants are shown in the table.

If the concentration of a particular constituent into the ground water as a result of improper management exceeds the above limits, then it is called as toxic.

Contaminant	Max. Concentration (mg/l)
Arsenic	5.0
Barium	100.0
Benzene	0.5
Cadmium	1.0
Lead	5.0
Mercury	0.2
Vinyl chloride	0.2

Planning and Design Consideration

The landfill planning and design process consists of

- Planning
- Main Design
- Construction operation Design

Planning Phase

The planning phase includes

- ◆ Site Selection
- ◆ Site Investigation
- ◆ Landfill layout and section
- ◆ Evaluation of landfill capacity
- ◆ Phased Operation

Main Design Phase

The main design phase includes

- Design of liner, leachate collection and Treatment
- Gas Collection and Treatment
- Cover System
- Landfill Stability
- Surface Water Drainage
- Environmental Monitoring

Construction Operation Design Process

- Site Development
- Construction Schedule
- Material and Equipment Requirement
- Environmental Control During Operation
- Closure and Post Closure Programme

Waste Acceptance

- Authorized waste only.
- No liquid waste or slurry type waste
- No recyclable waste
- No compostable waste
- No waste from which energy recovery is feasible through thermal/ biological process.
- Incompatible wastes in separate landfill units
- No non-hazardous or municipal waste in HW landfills and no hazardous waste in MSW landfills
- Extremely hazardous wastes should be stabilized before land filling or disposed in specially designed waste disposal units.

Site Selection

Site for development of landfill to be located preferably in areas having

- low population density
- low alternate land use value
- low GW contamination potential
- having clay content in the sub-soil

Factors to be Considered in Site Selection

Receptor Related Attributes

- Population within 500 m
- Distance to nearest drinking well
- Use of site by nearby residents
- Distance to nearest office building
- Land use
- Critical Environment

Pathway Related Attributes

- Distance to nearest surface water
- Depth to ground water
- Type of contamination
- Precipitation
- Soil permeability
- Bed Rock Permeability
- Depth to bed rock
- Susceptability to erosion and runoff
- Climatic factors relating to air pollution
- Susceptibility to seismic activity

Waste Related Attributes

- Toxicity
- Radioactivity
- Ignitability
- Reactivity
- Corrosivity
- Solubility
- Volatility

Waste Management Related Attributes

- Physical state
- Waste quantity
- Waste compatibility
- Use of liners
- Gas Treatment
- Leachate Treatment
- Site security
- Safety measures

Locational Criteria

(for lined landfills)

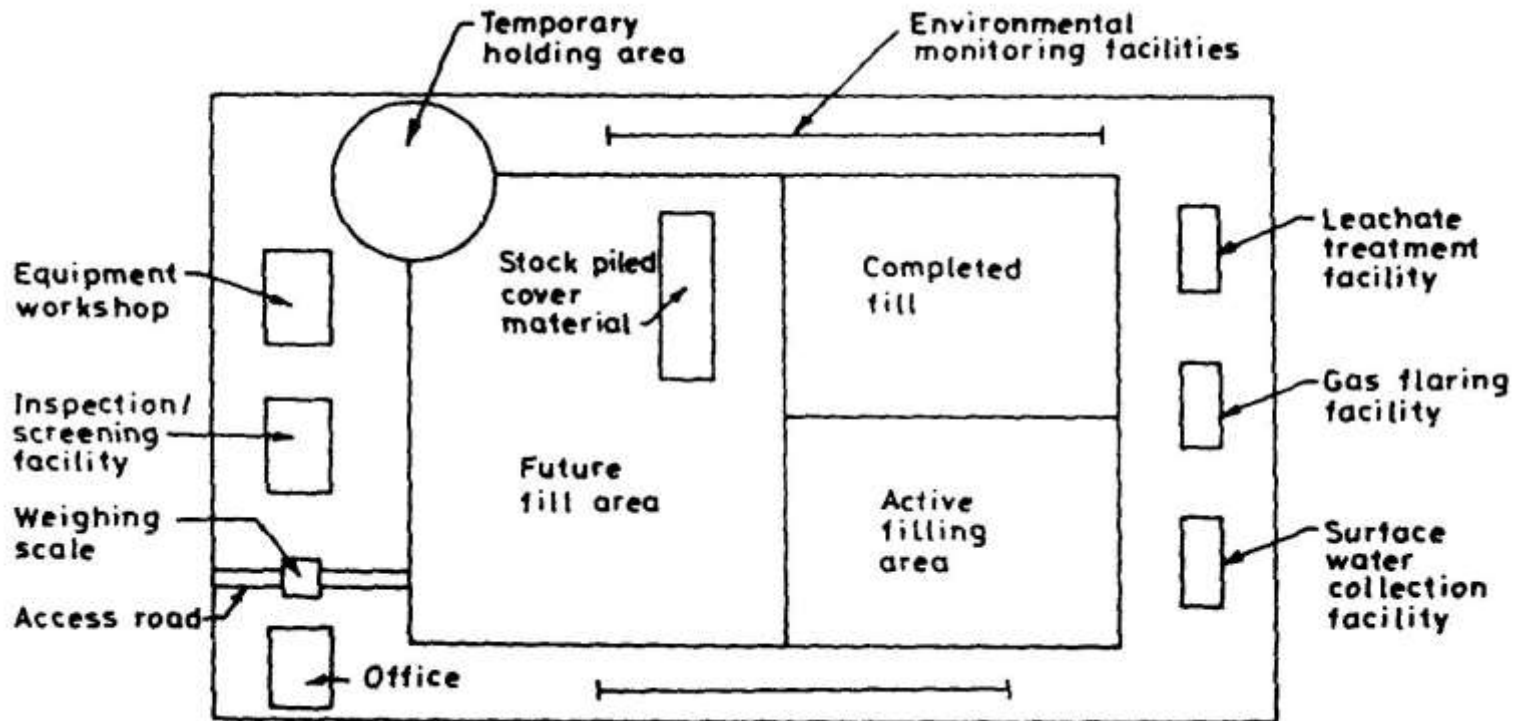
Lake/pond	>200 m
River	>100 m
Embankment	protective embankment
Highway	> 500 m
Habitation	> 500 m
Public park	> 500 m
Critical habitat	No
Wetland	No
Coastal regulation zone	No
Airport	> 3000 m to 20km
Water supply well	> 500 m
Ground water table level	2 m below base of land fill
Others	local needs

Site investigation criteria

- **Sub Soil Investigation:** type of soil, depth of GWT and bedrock, permeability of various strata, strength parameters, extent of availability of liner materials
- **Ground Water / Hydro geological Investigation:** Depth of GWT, GW flow direction, Baseline GW quality parameters
- **Topographical Investigation:** To compute the earth work quantities precisely
- **Hydrological Investigation:** To estimate the quantities of runoff for appropriate design of drainage facilities
- **Geological Investigation and Seismic Investigation:** to delineate the bedrock profile beneath the landfill base

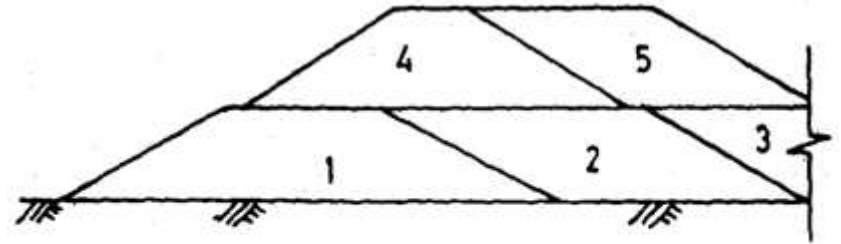
Landfill Layout

A landfill site will comprise of the area in which the waste will be filled as well as additional area for support facilities. Within the area to be filled, work may proceed in phases with only a part of the area under active operation.

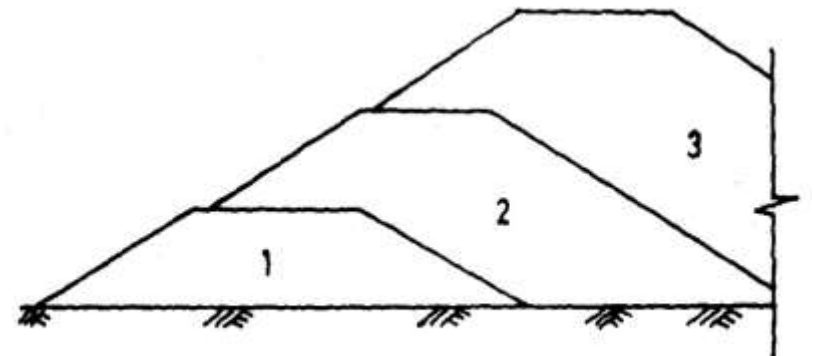


Landfill Section

Landfills may have different types of sections depending on the topography of the area, the depth of ground water table and availability of suitable daily cover material. The landfill may take the following forms



Above ground landfills are used in those areas where GWT is high.



Above ground landfill

Trenches of landfills vary from

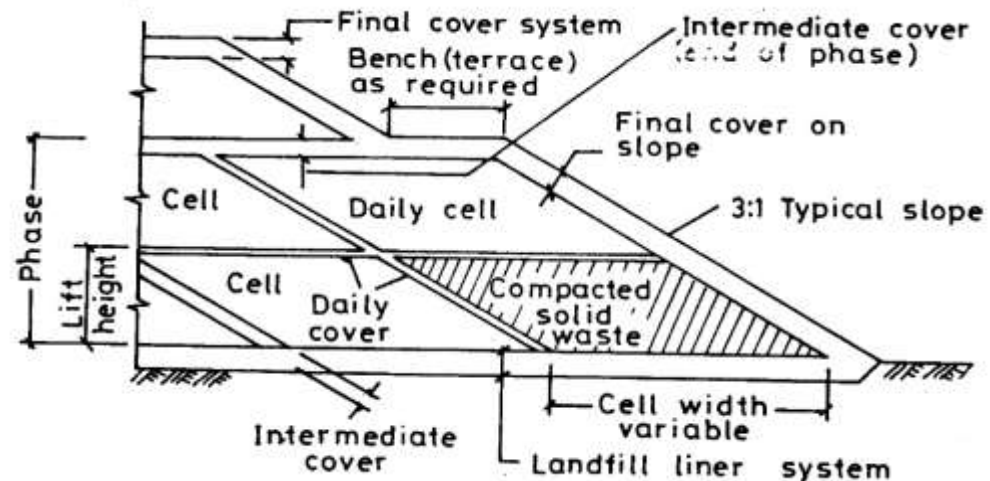
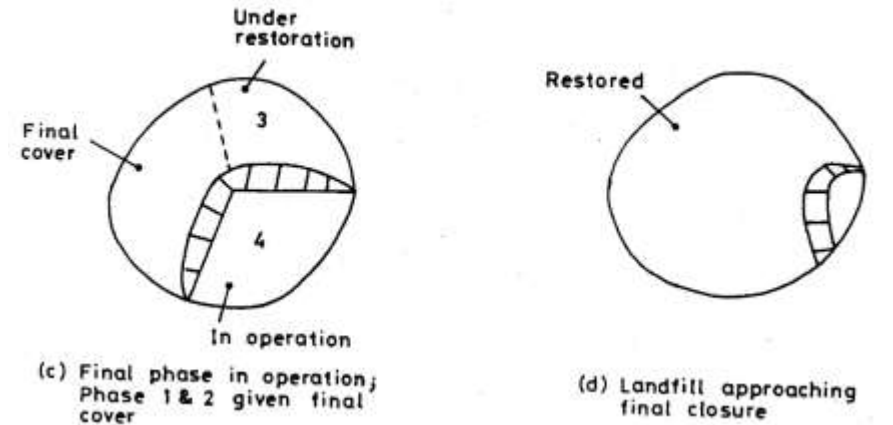
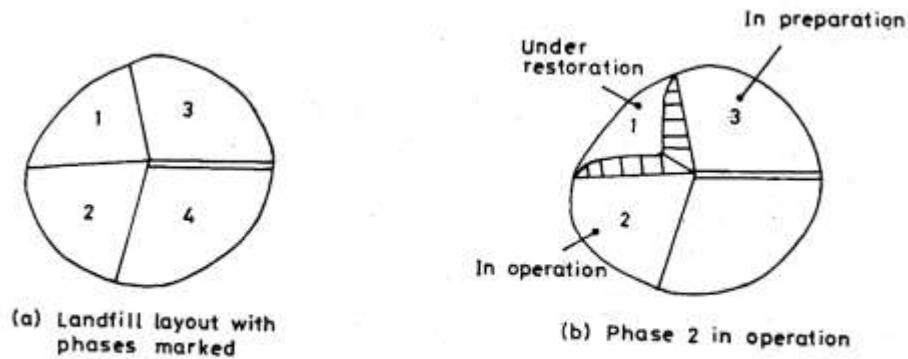
- 100 to 300 m in length
- 1 to 3 m in depth
- 5 to 15 m in width with side slopes of 2:1

Planning of Phased Operation

- Progressive use of the landfill area such that at any given instant of time a part of the site may have a final cover, a part being actively filled, a part being prepared to receive waste and a part in an undisturbed state
- Progressive excavation of on-site fill materials and minimization of double handling
- Minimizes the area required for landfill operations and concentrates waste disposal activities within prepared areas
- Reduces leachate generation by keeping areas receiving waste to a minimum
- Enables progressive installation of leachate and gas control
- Allows clean surface water runoff to be collected separately

Phase:- It is the sub area of the landfill. A phase consists of cells, lifts, daily cover, intermediate cover, liner and leachate collection facility, gas control facility and final cover over the sub-area. Each phase is typically designed for a period of 12 to 18 months.

Cell:- It is used to describe the volume of material placed in a landfill during one operating period usually one day.



Daily cover:- It consists of 15 to 30 cm of native soil that is applied to the working faces. The purpose of this cover is

- To control the blowing of waste materials
- To prevent rats, flies and other disease vectors from entering or exiting the landfill
- To control the entry of water into the landfill during operation

Lift:- It is a complete layer of cells over the active area of the landfill. Typically each landfill phase is comprised of a series of lifts. Intermediate covers are placed at the end of each phase; these are thicker than daily covers and remain exposed till the next phase is placed over it.

Bench:- A bench is a terrace which is used when the height of the landfill exceeds 15 to 20 m. The final lift includes the cover layer.

Landfill Capacity

Factors

- Quantity of waste and its compacted density
- Volume of waste
- Volume occupied by liner and cover
- Volume reduction due to settlement
- Biodegradable waste/municipal waste may have density of 0.6 to 1.2t/cum
- Inorganic waste may have density of 1.2 to 1.6 t/cum
- Inorganic compacted waste:-5% in few years
- Municipal biodegradable waste:-20% in 30 years

Estimation of Landfill Capacity

(Volume/height/area)

1. Waste generation rate = W tons per year
2. Active life of landfill = n years
3. Total waste in n years (T) = $W \times n$ tons
4. Volume of waste(V) = $T/\text{density cum}$
5. Volume for daily cover = $0.1 V$
6. Volume for liner and final cover = $0.2V$ to $0.3V$
7. Total volume(Landfill capacity) = $V+0.1V+0.25V$
8. Total area available = A sqm
9. Area for infrastructure = $0.15 A$ to $0.25A$
10. Area of land filling = $A-0.2A=0.8A$
11. Height (+depth) of landfill = $1.35V/0.8A$

Landfill Liner, Leachate Collection and Treatment

Liner system is provided to prevent migration of leachate generated inside a landfill from reaching the soil and ground water beneath the landfill. The function of leachate collection facility is to

- Remove leachate contained with in the landfill by the liner system for treatment and disposal.
- Control and minimize leachate heads with in the landfill.
- Avoid damage to the liner system.

Landfill liner comprise of

- Compacted clays
- Geomembranes
- Geosynthetic clay liner
- Combinations

