Municipal Solid Waste Management
(Elective)

MODULE 1

Syllabus

Wastes-Sources and characteristics - Categories of wastes-Municipal, Industrial, Medical, Universal, Construction and demolition debris, Radioactive, Mining, e wastes, Agricultural waste.

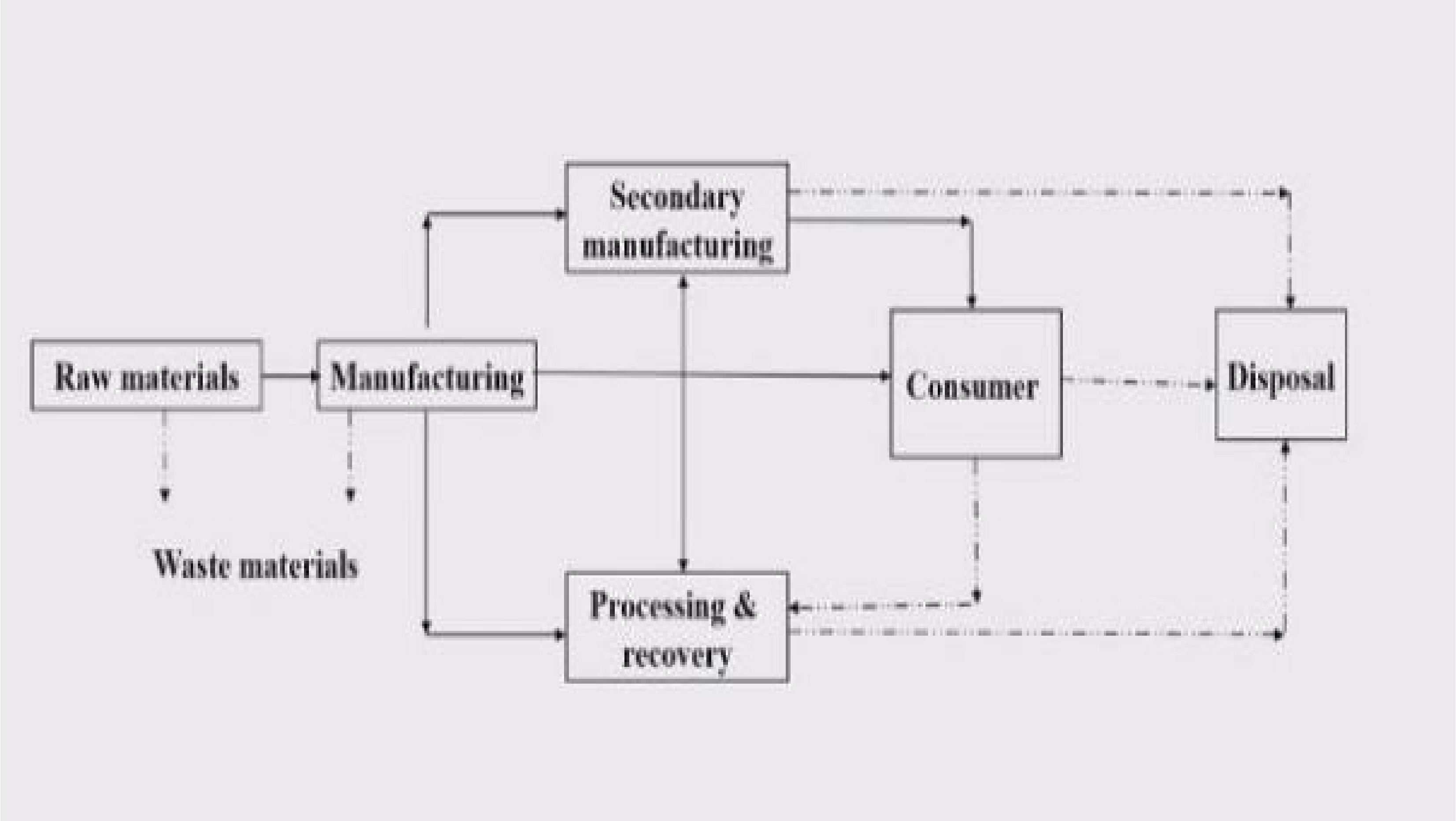
WHAT IS SOLID WASTE ?

- Solid waste comprises all the waste arising from the human, animal activities that typically useless or unwanted.
- It is all inclusive of the **heterogeneous** mass from the urban community as well as more **homogenous** accumulation from agriculture and industrial waste.

Some of the commonly used synonyms for solid wastes are:

- Refuse- more appropriate term for solid waste as most waste can be utilized as a raw material for some other purpose.
- Garbage- It consist of kitchen /wet waste
- Rubbish- those wastes with high ash contents
- Scarp- wastes with high metal content
- Debris- Bulky wastes such as construction wastes

MATERIAL FLOW AND WASTE GENERATION



CLASSIFICATION OF SOLID WASTE

Solid wastes are classified on the basis of type of waste and source of generation .

1. TYPE BASE CLASSIFICATION

Classification of wastes based on types, i.e., physical, chemical, and biological characteristics of wastes:

i. Garbage:

- Resulting from the handling, sale, storage, preparation, cooking and serving of food(animal and vegetable wastes).
- Wastes contains putrescible (rotting) organic matter, which produces an intolerable odour and attracts rats and other vermin
- Requires special attention in storage, handling and disposal.

ii. Ashes and residues:

- Residual of burning of wood, coal, charcoal, coke and other combustible materials for cooking and heating in houses, institutions and small industrial establishments.
- Fine powdery residue, cinders and clinker mixed with small pieces of metal and glass- entirely inorganic - valuable in landfills.
- When produced in large quantities, as in power-generation plants and factories- becomes industrial wastes.

TYPE-BASED CLASSIFICATION Cont..

(iii) Combustible and non-combustible wastes:

- Wastes generated from households, institutions, commercial activities, etc., excluding food wastes and other highly putrescible material.
- Combustible material consists of paper, cardboard, textile, rubber, garden trimmings etc.
- Non-combustible material consists of glass, crockery, tin and aluminium cans, ferrous and non-ferrous material and dirt.

(iv) Bulky wastes:

- Large household appliances such as refrigerators, washing machines, furniture, crates, vehicle parts, tyres, wood, trees and branches.
- Cannot be accommodated in normal storage containers- require a special collection mechanism.

TYPE-BASED CLASSIFICATION Cont..

(v) Street wastes:

- Wastes that are collected from streets, walkways, alleys, parks and vacant plots, and include paper, cardboard, plastics, dirt, leaves and other vegetable matter.
- Littering in public places is a widespread and acute problem in many countries including India.

(vi) Dead animals:

- Die naturally or are accidentally killed on the road.
- Does not include carcasses and animal parts from slaughter-houses, which are regarded as industrial wastes.
- Dead animals are divided into two groups – large and small.
- Large animals -horses, cows, goats, sheep, pigs, etc., and among the small ones are dogs, cats, rabbits, rats, etc.
- Large animals require special equipment for lifting and handling when they are removed.
- If not collected promptly, dead animals pose a threat to public health since they attract flies and other vermin as they decay- offensive from the aesthetic view

TYPE-BASED CLASSIFICATION Cont..

(vii) Biodegradable and non-biodegradable wastes:

-Biodegradable wastes - substances consisting of organic matter such as leftover food, vegetable and fruit peels, paper, textile, wood, etc., generated from various household and industrial activities.

-micro-organisms- degrade complex to simpler compounds.

-Non-biodegradable wastes - inorganic and recyclable materials such as plastic, glass, cans, metals, etc.

Biodegradable and Non-Biodegradable Wastes: Degeneration Time

Category	Type of waste	Approximate time taken to degenerate
Biodegradable	Organic waste such as vegetable and fruit peels, leftover foodstuff, etc.	A week or two.
	Paper	10–30 days
	Cotton cloth	2–5 months
	Woollen items	1 year
	Wood	10–15 years
Non-biodegradable	Tin, aluminium, and other metal items such as cans	100–500 years
	Plastic bags	One million years
	Glass bottles	Undetermined

TYPE-BASED CLASSIFICATION Cont..

(viii) Abandoned vehicles:

- Includes automobiles, trucks and trailers that are abandoned on streets and other public places.
- Have significant scrap value for their metal- value to collectors is highly variable.

(ix) Construction and demolition wastes:

- Generated as a result of construction, refurbishment, repair and demolition of houses, commercial buildings and other structures.
- Consist mainly of earth, stones, concrete, bricks, lumber, roofing and plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream.

(x) Farm wastes:

- Wastes result from diverse agricultural activities such as planting, harvesting, production of milk, rearing of animals for slaughter and the operation of feedlots.
- In many areas, the disposal of animal waste has become a critical problem, especially from feedlots, poultry farms and dairies.

(xi) Hazardous wastes:

- Wastes of industrial, institutional or consumer origin that are potentially dangerous either immediately or over a period of time to human beings and the environment.
- Physical, chemical and biological or radioactive characteristics like ignitability, corrosivity, reactivity and toxicity.
- The active agents, paints and pesticides may be liquid or gaseous hazardous wastes(confined in solid containers).
- Empty containers of solvents, paints and pesticides, which are frequently mixed with municipal wastes and become part of the urban waste stream.
- Certain hazardous wastes may cause explosions in incinerators and fires at landfill sites.
- Others such as pathological wastes from hospitals and radioactive wastes also require special handling.
- Effective management practices should ensure that hazardous wastes are stored, collected, transported and disposed of separately, preferably after suitable treatment to render them harmless.

xii) Sewage wastes:

-solid byproducts of sewage treatment are classified as sewage wastes.

-mostly organic and derived from the treatment of organic sludge separated from both raw and treated sewages.

-inorganic fraction of raw sewage such as grit and eggshells is separated at the preliminary stage of treatment, as it may entrain putrescible organic matter with pathogens and must be buried without delay.

-bulk of treated, dewatered sludge is useful as a soil conditioner but is invariably uneconomical.

-Solid sludge enters the stream of municipal wastes, unless special arrangements are made for its disposal.

Solid Wastes	Type	Description	Sources
	Garbage	Food waste: wastes from the preparation, cooking and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meat.	Households, institutions and commercial concerns such as hotels, stores, restaurants, markets, etc.
	Combustible and non–combustible	Combustible (primary organic) paper, cardboard, cartons, wood, boxes, plastic, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings, etc.	
		Non-combustible (primary inorganic) metals, tin, cans, glass bottles, crockery, stones, etc.	
	Ashes	Residue from fires used for cooking and for heating building cinders	
	Bulky wastes	Large auto parts, tyres, stoves, refrigerators other large appliances, furniture, large crates, trees, branches, stumps, etc.	Streets, sidewalks, alleys, vacant lots, etc.
	Street wastes	Street sweepings, dirt, leaves, etc.	
	Dead animals	Dogs, cats, rats, donkeys, etc.	
	Abandoned vehicles	Automobiles and spare parts	
	Construction and demolition wastes	Roofing, and sheathing scraps, rubble, broken concrete, plaster, conduit pipe, wire, insulation, etc.	Construction and demolition sites.
	Industrial wastes	Solid wastes resulting from industry processes and manufacturing operations, such as, food processing wastes, boiler house cinders, wood, plastic and metal scraps, shavings, etc	Factories, power plants, etc.
	Hazardous wastes	Pathological wastes, explosives, radioactive materials, etc.	Households, hospitals, institutions, stores, industry, etc.
	Animal and agricultural wastes	Manure, crop residues, etc.	Livestock, farms, feedlots and agriculture
	Sewage treatment residue	Coarse screening grit, septic tank sludge, dewatered sludge.	Sewage treatment plants and septic tanks.

CLASSIFICATION OF SOLID WASTE

2. Source-based classification

(i) Residential:

-Wastes from dwellings, apartments, etc

-consists of leftover food, vegetable peels, plastic, clothes, ashes, etc.

(ii) Commercial:

-generated from stores, restaurants, markets, offices, hotels, motels, auto-repair shops, medical facilities, etc.

-Wastes consisting of food wastes, glasses, metals, ashes, demolition and construction wastes etc.

(iii) Institutional:

-generated from educational, administrative and public buildings such as schools, colleges, offices, prisons, etc.

-Waste consists of paper, plastic, glasses, etc

CLASSIFICATION OF SOLID WASTE-Cont..

(iv) Municipal:

-generated from various municipal activities like construction and demolition, street cleaning, landscaping etc.

-includes dust, leafy matter, building debris, treatment plant residual sludge etc.

(v) Industrial:

- due to industrial activities.

- consists of process wastes, ashes, demolition and construction wastes, hazardous wastes, treatment plant residual sludge etc.

(Vi) Construction and demolition waste :

- generated by construction, refurbishment, repair and demolition of houses, commercial building and other structures.

- mainly consist of wood, steel, concrete dirt etc.

(vi) Agricultural:

-generated from fields, orchards, vineyards, farms etc.

-consists of spoiled food grains and vegetables, agricultural remains, litter etc.,

(vii) Open areas:

-wastes from areas such as Streets, parks, vacant plots, playgrounds, beaches, highways, recreational areas etc.

Different categories of solid wastes

1. Industrial wastes

- Waste generated as a byproduct from manufacturing & other process.
- Low toxicity and large quantities will generate
- Eg- coal combustion solids including bottom ash, fly ash, and flue gas due to desulfurization of sludge etc
- Industrial waste is usually not classified directly by federal or state laws as either municipal waste or hazardous waste
- Industrial waste- hazardous-waste should be shipped to licensed treatment, storage and disposal facility
- Non hazardous waste are placed in land fills or land application units or incinerated
- A large proportion of industrial waste is composed of wastewater – stores and treated under surface impoundments thereby discharged into surface waters

2. Medical Wastes

- The institution generating medical waste include hospitals, physicians, dentists, veterinarians, long term health facilities, clinics, laboratories, blood bans and funeral homes.- hospitals are predominant
- Although not all waste generated by above sources is considered as infectious, many facilities choose to handle most or all of their medical waste streams as potentially infectious.

Medical Wastes Cont..

- Specific classes of regulated medical waste include:

1. Cultures and stocks of infectious agents: Cultures from medical, pathological, research and industrial labs

2. Pathological waste: Tissues, organs, body parts, body fluids etc

3. Waste human blood and blood products

4. Sharps: sharps for animal or human patient care in medical, research or industrial labs, which contains used and unused needles, syringes, scalpel blades etc

5. Animal waste : Contaminated carcass, body parts, and the bedding of animals exposed to infectious agents

6. Isolation Wastes: Discarded materials contaminated with fluids from humans who were isolated to protect others from highly communicable diseases.

3. Universal Wastes

- Under the Resource Conservation Recovery Act (RCRA), the environmental Protection Agency(EPA) regulates facilities that generate hazardous wastes
- These regulation provide the framework for how hazardous wastes need to be stored and handled they are onsite, transported and treated or disposed
- Among the regulation are special exemptions or streamlined requirement some types of wastes that don't present high levels of hazards when they are properly managed, including waste that :
- Are often generated by facilities other than industry and manufacturing
- Are generated by members of the community, making it difficult for regulatory agencies to govern them
- May be present in high volumes in non hazardous waste management systems

Five types of wastes can be managed under EPA’s universal waste management rules

1. Batteries such as nickel cadmium and lead acid batteries found in electronic equipment mobile phones laptops etc
2. Agricultural pesticides that have been recalled or banned from use
3. Thermostats that contain liquid mercury
4. Lamps that contain mercury or lead
5. Aerosol Cans- sprays containing paints, solvents, food and personal care products etc

4. Construction And Demolition Debris

- Waste generated as a result of construction, renovation, refurbishment, repair and demolition of houses, commercial buildings ad other structures
- Structures also include residential and non residential building as well as roads and bridges
- Components of C&D debris include – earth, stones, concrete, asphalt, wood , metals, gypsum wall boards, roofing and plumbing materials heating systems and electrical wires and parts of the general municipal waste stream
- Land clearing debris such as tree stumps, rocks, and soil are also included in C&D

5. MINING WASTES

- Includes soil or overburden rock generated during physical removal of desired resource from the subsurface.
- It also includes the tailing or spoils that are produced during the processing of minerals such as smelting operations.
- Heap waste were also produced when precious metals such as gold, silver, copper recovered from piles of low grade rock or tailing by spraying with acid or cyanide solutions.
- As per federal and state mining laws, mine operator are required to return the affected site to its previous contours and use, must post a sufficient bond until all operation completed.

6. EWASTES

- Any broken or unwanted electrical or electronic appliances
- E waste includes computer, consumer electronics, phones, medical equipments toys and other items have been discarded by their original users
- E waste also includes waste which is generated during manufacturing or assembling of such equipments
- It contains hazardous and toxic materials should not be dumped with other wastes
- China and India were the imported of e waste from developed countries like US,UK an Japan
- In India 90% of mobile equipments are imported
- The rate of e waste generation is increasing by 10% by every year
- 3.08 million ton is contributed by India over 40million ton produced globally

- Generally e-wastes are not hazardous however, if hazardous constituents present in it then it should properly dismantled and processed.
- Many substance in are toxic and carcinogenic
- Material were very complex and difficult to recycle in an environmentally sustainable manner
- The impacts fond to be worse in developing countries like India where people engaged in recycling- mostly in unorganised sector, living in close proximity to dump or landfills of untreated e wastes and working without any protection or safe guards

Toxic constituents in e-waste

COMPONENTS	CONSTITUENTS
➢ Printed circuit boards	Lead & cadmium
➢ Cathode ray tubes (CRTs)	Lead oxide & Cadmium
➢ Switches & flat screen monitors	Mercury
➢ Computer batteries	Cadmium
➢ Capacitors and transformers	Poly Chlorinated Bi-phenyls (PCB)
➢ Printed circuit boards, plastic	Brominated Flame Retardant casings cable
➢ Cable insulation/coating	Poly Vinyl Chloride (PVC)

7.AGRICULTURAL WASTES

- Mainly includes animal manures and crop residues, pesticide containers and packing etc
- The sources are diffuse and waste are generated in areas of low population density
- In small scale agricultural operations, animal and plant waste can be recycled directly into the soil.
- In large no of animals are concentrated in small area management of waste become a acute concern
- Manures need to be moved off site for disposal cost and feasibility issues become significant
- Problem related to odour, pathogen content, salt concentration and ammonia production were also present

8.MUNCIPAL SOLID WASTE

- Also know as domestic waste or sometimes household waste generated within a community for several sources and not simply by the individual consumer or household
- Originates from residential, commercial, institutional, industrial and municipal sources
- Includes dust, leafy matter, building debris, treatment plant residual sludge etc generated from various municipal activities like construction and demolition , street cleaning, landscaping etc
- MSW divide in to two categories- garbage and rubbish

Characteristics of solid waste generated from urban areas in India :

Composition of Municipal Solid Wastes

Compostable / Bio-degradable matter = 30% - 55% (can be converted into manure)

Inert material = 40% - 45% (to go to landfill)

Recyclable materials = 5% - 10% (Recycling)

These percentages vary from city to city depending on food habits

Properties of Solid Waste

- Physical
- Chemical
- Biological

Physical Characteristics

- Specific Weight (Density)
- Moisture Content
- Particle Size and Distribution
- Field Capacity
- Permeability of Compacted Waste

Specific Weight

- Specific weight is defined as the weight of a material per unit volume (e.g. kg/m3, lb/ft3)

- Usually it refers to uncompacted waste.

- It varies with geographic location, season of the year, and length of time in storage.

Bulk densities of residential waste for various countries

Country	Bulk density, kg/ m^3
Industrialised country	
United Kingdom	150
USA	100
Middle-income country	
Singapore	175
Tunisia	175
Hong Kong	233
Egypt	330
Low-income country	
Bangladesh	600
Burma	400
China	476
India	300-560
Indonesia	250-400
Nepal	350-600
Pakistan	210-500
Sri Lanka	400
Thailand	290-390

Typical Specific Weight Values

Components	Density (kg/m^3)	
	Range	Typical
Food wastes	130-480	290
Paper	40-130	89
Plastics	40-130	64
Yard Wastes	65-225	100
Glass	160-480	194
Tin cans	50-160	89
Aluminum	65-240	160

Moisture Content

- The moisture in a sample is expressed as percentage of the wet weight of the MSW material

- The wet-weight method is most commonly used in the field of solid waste management.
- Wet- weight Moisture content is expressed as follows:

$$M = \left(\frac{w - d}{w} \right) x100$$

- Where, M= wet-weight moisture content, %
- w= initial mass of sample as delivered, kg (or lb)
- d= mass of sample after drying at 77°C, kg (or lb)

Typical Moisture Content Values

	Type of Waste	Moisture Content, %	
		Range	Typical
Resindential	Food wastes (mixed)	50 - 80	70
	Paper	4 - 10	6
	Plastics	1 - 4	2
	Yard Wastes	30 - 80	60
	Glass	1 - 4	2
Commercial	Food wastes	50 - 80	70
	Rubbish (mixed)	10 - 25	15
Construction & Demolition	Mixed demolition combustibles	4 - 15	8
	Mixed construction combustibles	4 - 15	8
Industrial	Chemical sludge (wet)	75 - 99	80
	Sawdust	10 - 40	20
	Wood (mixed)	30 - 60	35
Agricultural	Mixed Agricultural waste	40 - 80	50
	Manure (wet)	75 - 96	94

Particle Size and Distribution

The size and distribution of the components of wastes are important for the recovery of materials, especially when mechanical means are used, such as trommel screens and magnetic separators.

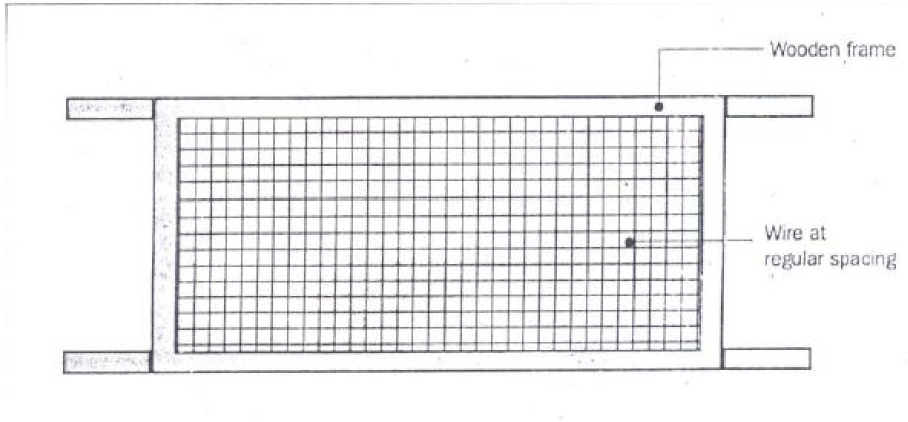


Figure 2.1. A typical screen for determining size distribution

Particle Size and Distribution

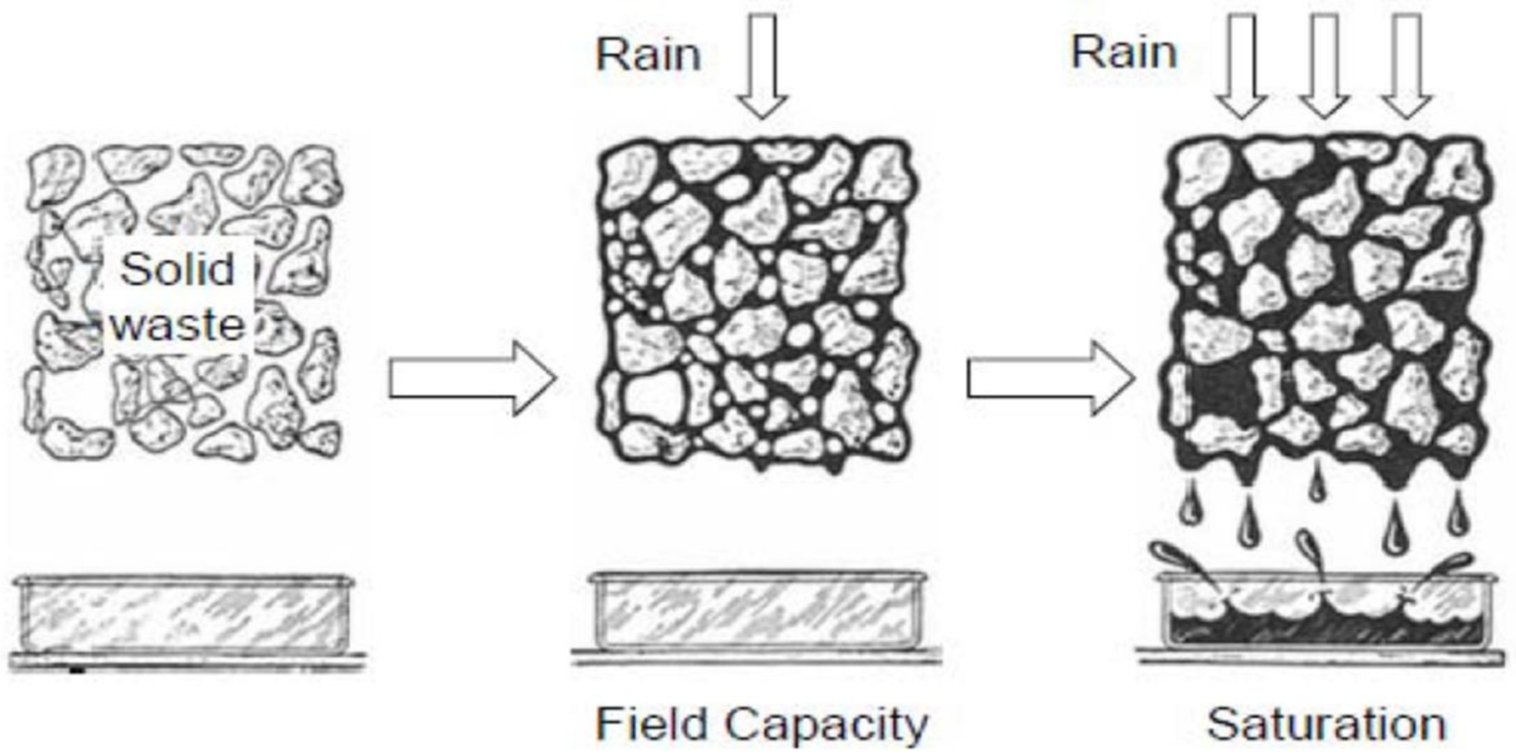
- The size of waste components can be determined using the following equations:

- $S_c = L$
- $S_c = (L+w)/2$
- $S_c = (L+w+h)/3$

- *S_c : size of component, mm*
- *L : length, mm*
- *W : width, mm*
- *h : height, mm*

Field Capacity

- The total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity



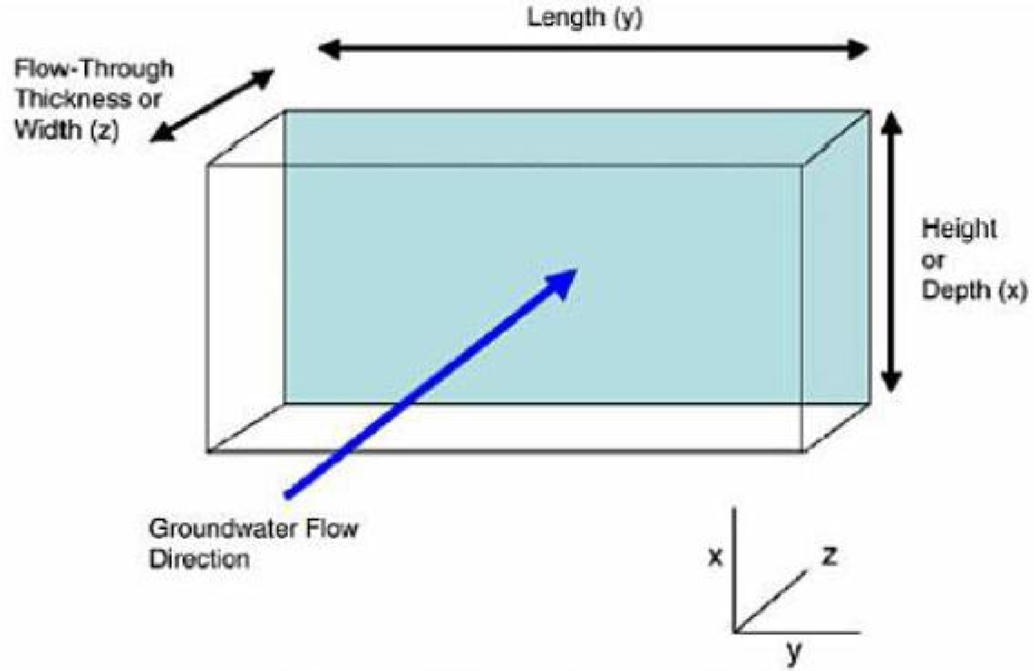
Field Capacity

- Field capacity is critically important in determining the formation of leachate in landfills
- It varies with the degree of applied pressure and the state of decomposition of wastes, but typical values for uncompacted commingled wastes from residential and commercial sources are in the range of 50 - 60%.

Permeability of Compacted Waste

- The permeability (hydraulic conductivity) of compacted solid waste is an important physical property because it governs the movement of liquids & gases in a landfill.

- Permeability depends on:
  - Pore size distribution
  - Surface area
  - Porosity



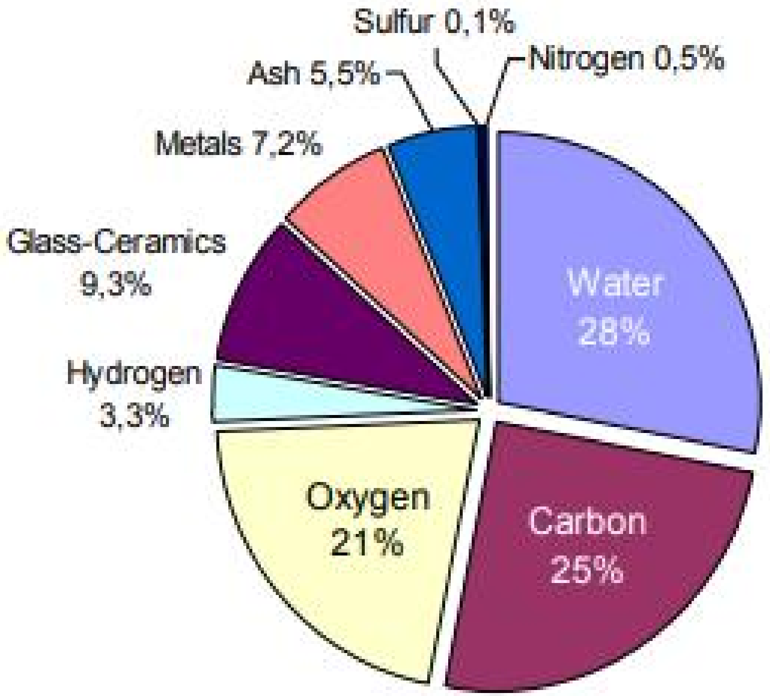
Chemical characteristics:

- proper understanding of the behaviour of waste, as it moves through the waste management system.
  - (i) Improving leachate properties and groundwater contamination;
  - (ii) Evaluating alternative solid waste processing and recovery options;
  - (iii) Information about trace element composition;
  - (iv) Assessing the feasibility of MSW combustion directly affected by chemical composition.
- Products of decomposition and heating values are two examples of chemical characteristics.

Chemical Properties:

- **Ultimate analysis:**
  - total elemental analysis to determine the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur.
  - determine the ash fraction because of its potentially harmful environmental effects due to the presence of toxic metals such as cadmium, chromium, mercury, nickel, lead, tin and zinc.
  - Oxygen value calculated by subtracting all other components (including ash and moisture)
  - Used to characterize the chemical composition of organic fraction of waste.
  - Used to define the proper mix of waste materials to achieve suitable C/N ratios for biological conversion processes.

Chemical composition of typical MSW



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

Proximate analysis of MSW

- More specific compared to ultimate analysis.
- Includes the determination of:
  - Moisture (loss of moisture when heated to 105° C for 1 hr)
  - Ash content (the non-combustible components, ie the weight of residue after combustion in an open crucible)
  - Volatile combustible matter (additional loss of weight on ignition at 950 ° C in a covered crucible)
  - Fixed carbon content (combustible residue left after volatile matter is removed, good indicators of combustion capacity of MSW).
- Assess capability of MSW as fuel.
- Does not provide the indication of possible pollutants arised during the combustion - limitation

	Proximate analysis (% by wt)			
Waste Type	**Moisture**	**Volatiles**	**Fixed Carbon**	**Noncombustable (ash)**
Food mixed	70.0	21	3.6	5.0
Paper mixed	10.2	76	8.4	5.4
Newspapers	6.0	81	11.5	1.4
Cardboard	5.2	77	12.3	5.0
Plastics mixed	0.2	96	2	2
Polyethylene	0.2	98	<0.1	1.2
Polystyrene	0.2	99	0.7	0.5
PVC	0.2	87	10.8	2.1
Textiles	10	66	17.5	6.5
Yard wastes	60	30	9.5	0.5
Wood mixed	20	68	11.3	0.6
Glass	2			96–99
Metals	2.5			94–99
Domestic MSW	10–40	30–60	3–15	10–30

Source: Kiely, G., *Environmental Engineering*, McGraw-Hill, New York, 1997. Reproduced with kind permission of the McGraw-Hill Companies.

Typical proximate analysis of MSW and MSW components

Source: Waste Management Practices: Municipal, Hazardous and Industrial. *John Pichtel*. [Google Books]

Fusion Point of Ash

- It is the temperature at which the ash (from the combustion of waste) forms a solid (clinker) by fusion and agglomeration, which provides information about softening and melting conditions.
- Typical fusing temperatures for the formation of clinker from solid waste range from 1100 to 1200° C.

Heating value of waste

- Heat value of waste is energy released when waste is burned.
- Heat value directly proportional to carbon content of waste; inversely proportional to ash and moisture content.
- 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).
- Heat value calculated using:
  - Dulong formula (HV is the heating value; C, H, O, S are the compositions on dry basis.

$$HV\left(\frac{kJ}{kg}\right) = 33801[C] + 144158[H] - 0.125[O] + 9413[S]$$

  - Modified Dulong formula (C, H2, O2, S, and N are % by weight of each component)

$$HV\left(\frac{kJ}{kg}\right) = 337[C] + 1419[H_2 - 0.125O_2] + 93[S] + 23[N]$$

  - Khan equation(E=energy content; F=percentage weight of food in the waste; CP=percentages of cardboard and paper; and PLR=percentage of plastic, leather and rubber)

$$E\left(\frac{MJ}{kg}\right) = 0.051[F + 3.6(CP)] + 0.352(PLR)$$

- Heat of combustion: Estimated by combusting samples in a boiler and measuring heat output/ using lab scale bomb calorimeter/ ultimate analysis.

- Low heat value is the net heat available for combustion of the MSW, while high heat value includes the latent heat of vaporization also. These are estimated based on the chemical composition of the waste materials.

$$HHV\left(\frac{MJ}{kg}\right) = 0.339[C] + 1.44[H] - 0.139[O] + 0.105[S]$$

$$LHV\left(\frac{MJ}{kg}\right) = HHV - 0.0244 * (W + 9H)$$

Where W is percent mass of water and H is the percent of H in the waste.

Energy Content of Solid Waste Components:

- The energy content of the organic components in MSW can be determined

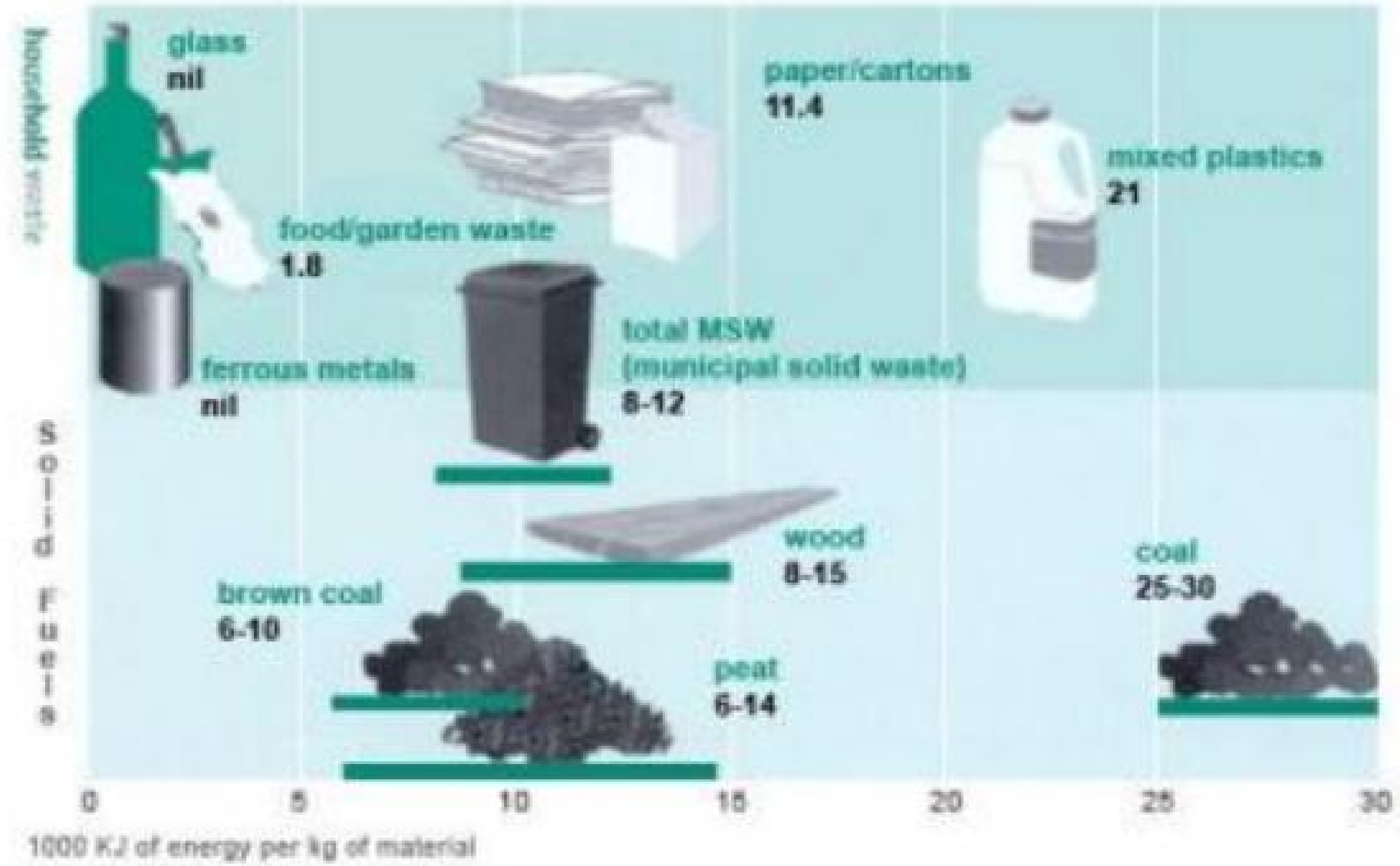
  (1) by using a full scale boiler as a calorimeter

  (2) by using a laboratory bomb calorimeter

  (3) by calculation, if the elemental composition is known.

- Because of the difficulty in instrumenting a full-scale boiler, most of the data on the energy content of the organic components of MSW are based on the results of bomb calorimeter tests.

Energy content of MSW components



Lipids:

- The principal sources of lipids are garbage, cooking oils and fats.
- This class of compounds includes fats, oils and grease.
- 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.

Carbohydrates:

- These are found 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.

Proteins:

- These are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH2).
- 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.

Natural fibre:

- These are found in paper products, food and yard wastes
- 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%.)
- highly combustible solid waste- have high proportion of paper and wood products- suitable for incineration.
- Calorific values of oven-dried paper products are in the range of 12,000 -18,000 kJ/kg and of wood about 20,000 kJ/kg, i.e., about half that for fuel oil, which is 44,200 kJ/kg.

Plastics:

- Highly resistant to biodegradation – needs special concern in SWM.
- 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 synthetic plastic polymer like polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas-increases corrosion in the combustion system – also responsible for acid rain.

Non-combustibles:

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

Characteristics of Municipal Solid Waste in Indian Urban Centres

Chemical Characteristics of Municipal Solid Wastes in Indian Cities

Population range (in million)	No. of Cities surveyed	Moisture %	Organic matter %	Nitrogen as Total Nitrogen %	Phosphorous as P_2O_5 %	Potassium as K_2O %	C/N Ratio	Calorific value* in kcal/kg
0.1-0.5	12	25.81	37.09	0.71	0.63	0.83	30.94	1009.89
0.5-1.0	15	19.52	25.14	0.66	0.56	0.69	21.13	900.61
1.0-2.0	9	26.98	26.89	0.64	0.82	0.72	23.68	980.05
2.0-5.0	3	21.03	25.60	0.56	0.69	0.78	22.45	907.18
> 5.0	4	38.72	39.07	0.56	0.52	0.52	30.11	800.70

All values, except moisture, are on dry weight basis.
*Calorific value on dry weight basis

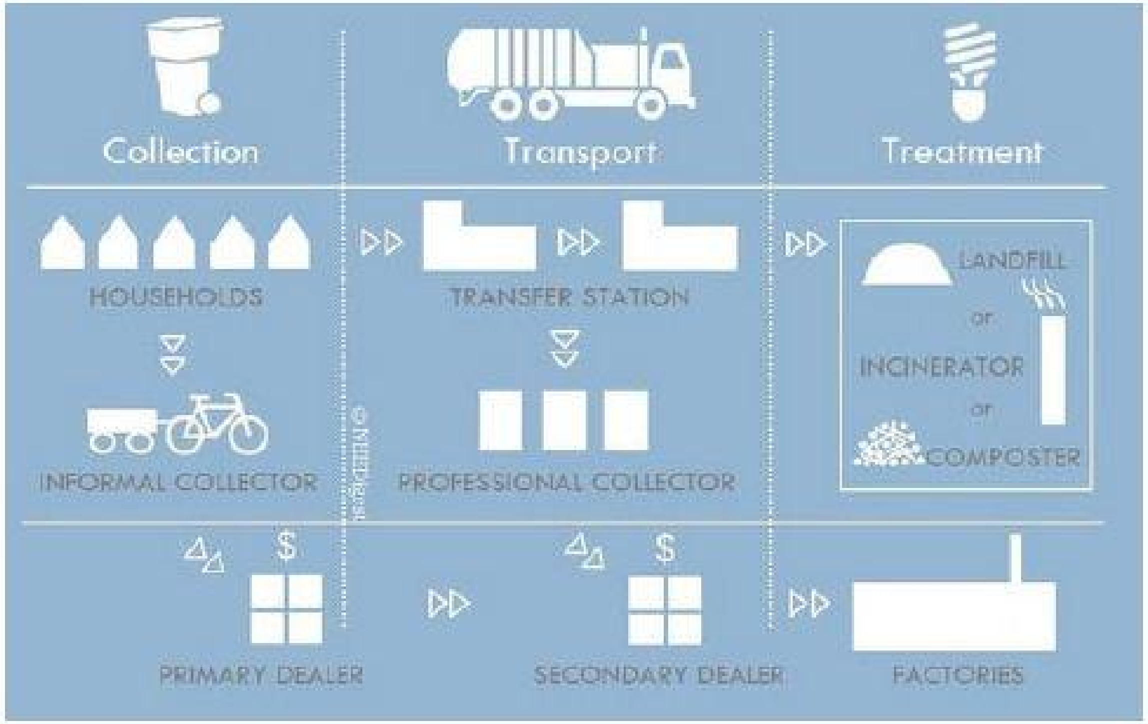
Source : Background material for Manual on SWM, NEERI, 1996.

Biological Characteristics

- **Assignment**

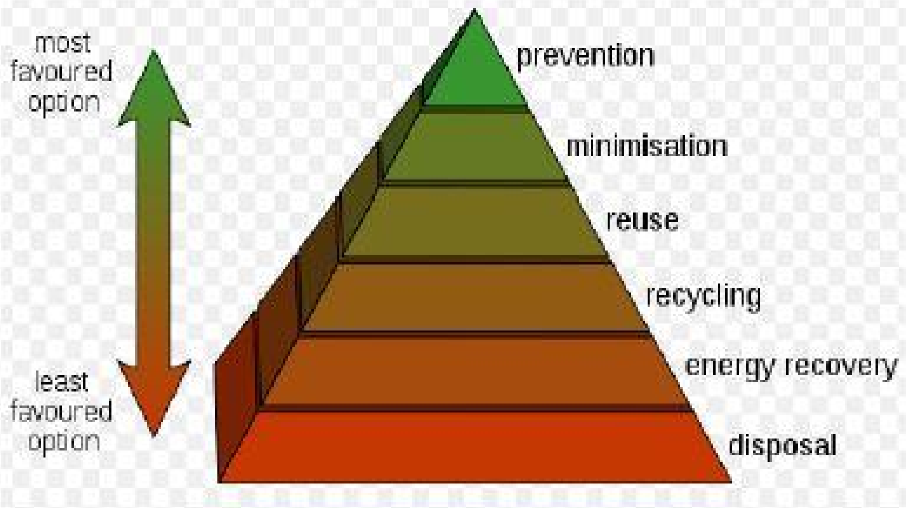
MUNICIPAL SOLID WASTE MANAGEMENT

Steps in management of solid waste



Source: Municipal Solid Waste Management in China – An infographic
www.needigest.com

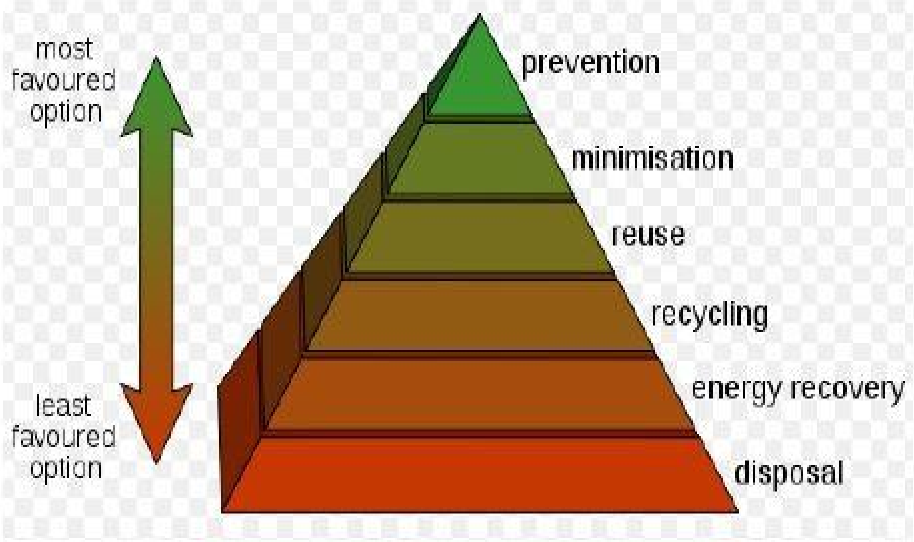
Waste management hierarchy



Source: Wikipedia (Waste hierarchy)
http://en.wikipedia.org/wiki/Waste_hierarchy

MSWM.....

- Principal objective is to collect and dispose solid wastes of the municipality at minimal cost while preserving public health and ensuring negligible adverse impact on the environment.
- Management strategies should be economically viable, technically feasible and socially acceptable to perform the following functions:
    - Promotion of environmental quality.
    - Supporting the efficiency and productivity of the economy.
    - Generation of employment and income.



Waste management hierarchy

MSWM.....

- MSWM processes differ depending on factors such as economic status (e.g., the ratio of wealth created by the production of primary products to that derived from manufactured goods, per capita income, etc.), degree of industrialisation, social development (e.g., education, literacy, healthcare, etc.) and quality of life of a location.
- Influenced by regional, seasonal and economic difference.

FUNCTIONAL ELEMENTS OF MSWM

(i) Waste generation:

- Generated at the start of any process- at every stage as raw materials are converted into goods for consumption.
- Waste generation encompasses activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal.
- The source of waste generation determines quantity, composition and waste characteristics.
- Identification of waste.
- Wastes are generated from households, commercial areas, industries, institutions, street cleaning and other municipal services.

(ii) Waste storage:

- Collection of wastes never takes place at the source or at the time of their generation.
- Waste handling and separation, storage and processing at the source**.** Handling - movement of loaded containers to the point of collection. Separation of waste components - at the source.
- The heterogeneous wastes generated in residential areas must be removed within 8 days due to shortage of storage space and presence of biodegradable material.
- Onsite storage is of primary importance due to aesthetic consideration, public health and economics involved.
- Storage - plastic containers, conventional dustbins (households), used oil drums, large storage bins (for institutions and commercial areas or servicing depots), etc.

(iii) Waste collection:

- Gathering of wastes and hauling them to the location- collection vehicle is emptied – to a transfer station (i.e., intermediate station where wastes from smaller vehicles are transferred to larger ones and segregated), a processing plant or a landfill disposal site.
- Collection depends on the number of containers, frequency of collection, types of collection services and routes.
- For instance, vehicles used for long distance hauling may not be suitable or particularly economic for house-to-house collection.
- Every MSWM system requires an individual solution to its waste collection problem .

(iv) Transfer and transport:

- transfer of wastes from smaller collection vehicles, where necessary to overcome the problem of narrow access lanes, to larger ones at transfer stations
- transport of the wastes, usually over long distances, to disposal sites.
- The factors that contribute to the designing of a transfer station include the type of transfer operation, capacity, equipment, accessories and environmental requirements.

(v) Processing:

- to alter the physical and chemical characteristics of wastes for energy and resource recovery and recycling.
- processing techniques include compaction, thermal volume reduction, manual separation of waste components, incineration and composting.

(vi) Recovery and recycling:

- includes various techniques, equipment and facilities used to improve both the efficiency of disposal system and recovery of usable material and energy.
- Recovery involves the separation of valuable resources from the mixed solid wastes, delivered at transfer stations or processing plants.
- It also involves size reduction and density separation by air classifier, magnetic device for iron and screens for glass.
- The selection of any recovery process is a function of economics, i.e., costs of separation versus the recovered-material products. Certain recovered materials like glass, plastics, paper, etc., can be recycled as they have economic value.

(vii) Waste disposal:

- Disposal is the ultimate fate of all solid wastes, be they residential wastes, semi-solid wastes from municipal and industrial treatment plants, incinerator residues, composts or other substances that have no further use to the society.
- land use planning becomes a primary determinant in the selection, design and operation of landfill operations.
- sanitary landfill is a method of disposing solid waste without creating a nuisance and hazard to public health.
- engineering principles are followed to confine the wastes to the smallest possible area, reduce them to the lowest particle volume by compaction at the site and cover them after each day's operation to reduce exposure to vermin.
- One of the most important functional elements of SWM, therefore, relates to the final use of the reclaimed land.

8. RADIOACTIVE WASTE

- Specialized category of industrial waste
- Main generators- electricity producing nuclear plant, nuclear waste reprocessing facilities and nuclear weapon facilities.
- Also produced by research and medical procedures
- Radioactive waste- unstable, contain atoms with nuclei that undergo radioactive decay
- Energy is naturally released from the nucleus to convert it into some stable form
- Energy can be emitted as particles or electromagnetic waves
- Particles – alpha particles composed of two protons and two neutrons and beta particles essentially identical to electrons

(iv) Bulky wastes:

-large household appliances such as refrigerators, washing machines, furniture, crates, vehicle parts, tyres, wood, trees and branches.

-cannot be accommodated in normal storage containers- require a special collection mechanism.

(v) Street wastes:

-wastes that are collected from streets, walkways, alleys, parks and vacant plots, and include paper, cardboard, plastics, dirt, leaves and other vegetable matter.

-Littering in public places is a widespread and acute problem in many countries including India.

TYPES OF SOLID WASTES

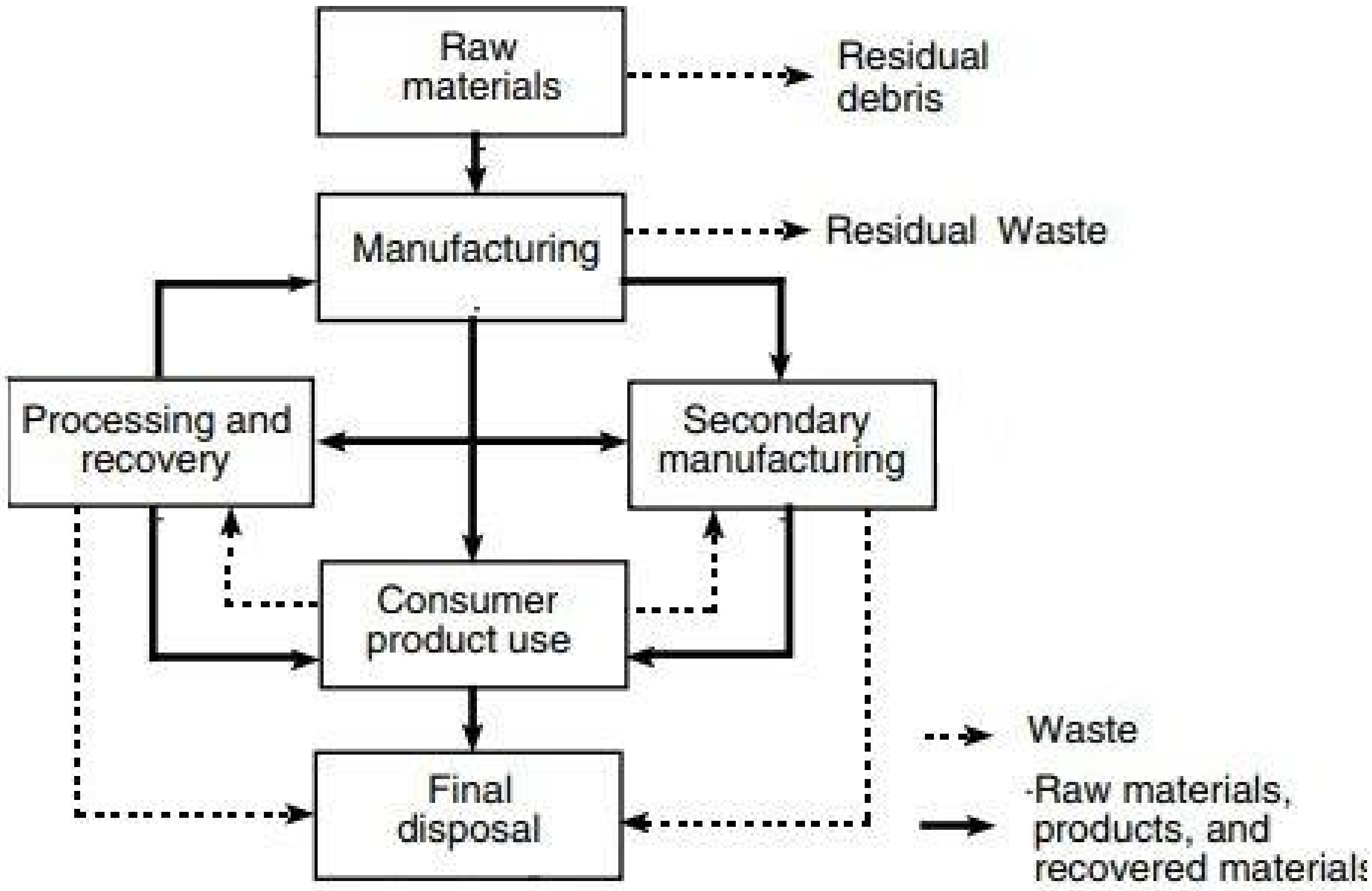
- **Municipal wastes** which include the garbage or food waste ,ashes and residues, construction and demolition wastes, treatment plant wastes, special wastes
- **Industrial wastes** which include all types if liquid and waste generated from different types of industries
- **Hazardous wastes** are waste (liquid, solid, gaseous or sludge) that us dangerous or potentially harmful to our health or environment. They can be discarded commercial products, by-products from industries, or from households

MUNICIPAL SOLID WASTE MANAGEMENT

MODULE 2

II	Waste generation-Methods of estimation of Generation rate-Measure of quantities, Composition- Physical and chemical (simple problems). Storage of solid waste

- Waste generation includes the activities in which waste (solid or semi-solid material) no longer has sufficient economic value for its possessor to retain it.
- Processing of raw materials – waste generation
- Waste generation continues at every step in the process as raw materials are converted into final products for consumption.
- Generation refers to the amount of materials and products in MSW as they enter the waste stream before any materials recovery, composting, or combustion take place.



Flow of material and solid waste generation

Generation Rates

- Waste generation rate is defined as rate of change of quantity of solid waste generation with respect to stipulated time.
- The reason for measuring generation rate to obtain data that can be used to determine the total amount of waste to be managed.
- In any solid waste management study, extreme care is exercised in estimation of generation rates.

Need for analysis of waste composition, characteristics and quantity include the following :

(i) It provides the basic data for the planning, designing and operation of the management systems.

(ii) An ongoing analysis of the data helps detect changes in composition, characteristics and quantities of wastes, and the rates at which these changes take place, which facilitates effective implementation of management systems.

(iii) It quantifies the amount and type of materials suitable for processing, recovery and recycling.

(iv) It provides information that helps in deciding appropriate technologies and equipment.

(v) The forecast trends assist designers and manufacturers in the production of collection vehicles and equipment suitable for future needs.

Importance of Waste Generation Rates

Total waste generated according to the effective management options applied

can be:

- **Disposed/ Collected Waste**: Solid waste materials ultimately taken to the disposal (Landfill)
- **Diverted Waste**: Solid waste materials generated but not processed through the normal waste management channels (recycled, composted etc.).

$$Generated\ Waste = Disposed\ (Collected)\ Waste + Diverted\ Waste$$

Waste generation rates should be in compliance with:

- State diversion requirements
- Equipment selection
- Collection and management decisions
- Design of facilities

Typical per capita solid-waste generation rates in the United States

	Unit rate, kg/capita · d	
Source	Range	Typical
Municipal*	0.75–2.50	1.6
Industrial	0.4–1.60	0.9
Demolition	0.05–0.4	0.3
Other municipal	0.05–0.3	0.2
		3.0

* Includes residential and commercial.

Typical commercial and industrial unit waste-generation rates

Source	Unit	Range
Office buildings	kg/employee · d	0.5–1.1
Restaurants	kg/customer · d	0.2–0.8
Canned and frozen foods	tonnes/tonne of raw product	0.04–0.06
Printing and publishing	tonnes/tonne of raw paper	0.08–0.10
Automotive	tonnes/vehicle produced	0.6–0.8
Petroleum refining	tonnes/employee · d	0.04–0.05
Rubber	tonnes/tonne of raw rubber	0.01–0.3

Waste composition

- composition varies with the socio-economic status within a particular community, for example:-income determines life style, composition pattern and cultural behaviour.

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

Characteristics	Low income	High income	Comments
			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.

- Waste composition also depends on the moisture content, density and relative distribution of municipal wastes.

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
Ferrous metals	1-4	2	2-6	3	120-1200	320
Dirt, ash, bricks, etc.	0-10	4	6-12	8	320-960	480

MEASURES OF QUANTITIES

Both volume and weight are used for the measurement of solid waste quantities. Unfortunately, the use of volume as a measure of quantity can be extremely misleading. For example, a cubic meter of loose wastes represents a different quantity than a cubic meter of waste that have been compacted in a truck and each of these is different from a cubic meter of waste that have been compacted further in a landfill. If volume measurements are to be used the measured volume must be related to the degree of compaction of wastes.

To avoid confusion, solid waste quantities should be expressed in terms of weight. Weight is the only accurate basis for records because the tonnage can be measured directly, regardless of the degree of compaction. The use of weight records ia also important in the transport of solid wastes because the quantity that can be hauled usually is restricted by highway weight limits rather than volume.

Statistical Analysis of generation rates

- It is necessary to determine the statistical characteristics of solid waste generation
- It would be impractical to provide container capacity to handle the largest conceivable quantity of solid waste to be generated in a given day,
- The container capacity to be provided must be based on a statistical analysis of the generation rates and characteristics of collection system
- Statistical measures include the mean, mode ,median, standard deviation and coefficient of variation

Expression of unit generation rates

- In addition to knowing the sources and composition if the solid waste that must be managed,
- it is equally important to be able to develop meaningful unit expression for the quantities generated-
- Different unit of expressions include:

1. **Residential**
   - Relatively stable nature of residential waste in given location- most common unit expression used is –pounds per capita per day
   - When waste composition varies significantly from the typical municipal wastes – use of pounds per capita per day may be misleading especially when quantities are being compared

2.Commercial

- In the past commercial waste generation rates have been expressed in pounds per capita per day
- But this practise adds little useful information about the nature of solid waste generation at commercial sources
- A more meaningful approach is to relate the quantities generated to the number of customers

3. Industrial

- Waste generated from industrial activites should be expressed on the basis of some repeatable measure of production.
- Eg- pounds per automobile for an automobile assembly plant

- When if such data are developed , it is possible to make meaningful comparison between similar industrial activities throughout the country.

4. Agricultural

- Expressed in terms of some repeatable measure of production.

Eg- pounds of waste per ton of raw product

- The quantification of the solid waste generated from the agricultural activites associated with field and row crops is difficult because little useful information has been gathered in past

Method used to determine Generation rates

- Method to assess the per capita generation of solid waste are

1. Load Count analysis

- In this method, the number of individual loads and the corresponding waste characteristics are noted over a specified time period
- If scales are available, weight data are also recorded

2. Weight- Volume analysis

- The use of detailed weight-volume data obtained by weighing and measuring each load will certainly provide better information on the specific weight of the various forms of solid waste at a given location

3.Material balance analysis

- In this method the mass solid waste is analysed in a system boundary or controlled volume
- Mass of solid waste entering into the system should be equal to mass of solid waste leaving the system

Factors causing variation generation rates

- **Geographic location:**

  -different climates that can influence both the amount of certain types of solid wastes generated and the collection operation.

  -substantial variations in the amount of yard and garden wastes generated in various parts of India are related to the climate.

  -In warmer southern areas, the growing season is considerably longer compared to the northern areas and so, yard wastes are collected in considerably larger quantities and over a longer period of time.

- **Seasons:**
  - Seasons of the year have implications for the quantities and composition of certain types of solid wastes.
  - the growing season of vegetables and fruits affect the quantities of food wastes.

Factors causing variation ….

- **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 decision – their habits and lifestyles to conserve the natural resources and to reduce the economic burden associated with the management of solid wastes.
- **Legislation**:
  - the existence of local and state regulations concerning the use and disposal of specific materials
  - an important factor that influences the composition and generation of certain types of wastes.

Factors causing variation ....

- Collection frequency:
  - In localities, where there are ultimate collection services, more wastes are collected.
- 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
  - the composition differs in terms of paper and other recyclables, which are typically more in high-income areas as against low-income areas.

Physical characteristics

- Includes the determination of percent contents of various ingredients of the solid waste.
- Information and data on the physical characteristics of solid wastes are important for the selection and operation of equipment and for the analysis and design of disposal facilities.
- Used in volume calculation.
- Function of location, season, storage time, equipment used, processing (compaction, shredding, etc.)

- (i) 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.
  - a waste collection vehicle can haul four times the weight of waste in its compacted state than when it is uncompacted.
  - changes in density occur as the waste moves from source to disposal, due to storage methods, salvaging activities, handling, wetting and drying by the weather, vibration in the collection vehicle and decomposition.
  - dry density decreases at higher moisture levels

Bulk densities of residential waste for various countries

Country	Bulk density, kg/ m³
Industrialised country	
United Kingdom	150
USA	100
Middle-income country	
Singapore	175
Tunisia	175
Hong Kong	233
Egypt	330
Low-income country	
Bangladesh	600
Burma	400
China	476
India	300-560
Indonesia	250-400
Nepal	350-600
Pakistan	210-500
Sri Lanka	400
Thailand	290-390

Source: Jindal et al. (1998), Muttamara et al. (1994), Habitat

Components	Density (kg/m^3)	
	Range	Typical
Food wastes	130-480	290
Paper	40-130	89
Plastics	40-130	64
Yard Wastes	65-225	100
Glass	160-480	194
Tin cans	50-160	89
Aluminum	65-240	160

Typical density values

Condition	Density (kg/m^3)
Loose MSW, no processing or compaction	90-150
In compaction truck	355-530
Baled MSW	710-825
MSW in a compacted landfill (without cover)	440-740

Physical characteristics …………

Moisture content:

$$\text{Moisture content (\%)} = \left[\frac{\text{Wet weight - Dry weight}}{\text{Wet weight}} \times 100 \right]$$

-Moisture content of solid waste is the weight loss (expressed in percent) when a sample of solid waste is dried to a constant weight at a temperature of 100 to 105 ° C

-increase in the weight of solid wastes - increases cost of collection and transport.

-depends on organic matter, weather, type of source etc.

-great influence on the heat of combustion ,biological processes of organic matter.

-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.

Typical Moisture Content Values

Type of Waste		Moisture Content, %	
		Range	Typical
Resindential	Food wastes (mixed)	50 - 80	70
	Paper	4 - 10	6
	Plastics	1 - 4	2
	Yard Wastes	30 - 80	60
	Glass	1 - 4	2
Commercial	Food wastes	50 - 80	70
	Rubbish (mixed)	10 - 25	15
Construction & Demolition	Mixed demolition combustibles	4 - 15	8
	Mixed construction combustibles	4 - 15	8
Industrial	Chemical sludge (wet)	75 - 99	80
	Sawdust	10 - 40	20
	Wood (mixed)	30 - 60	35
Agricultural	Mixed Agricultural waste	40 - 80	50
	Manure (wet)	75 - 96	94

Field capacity

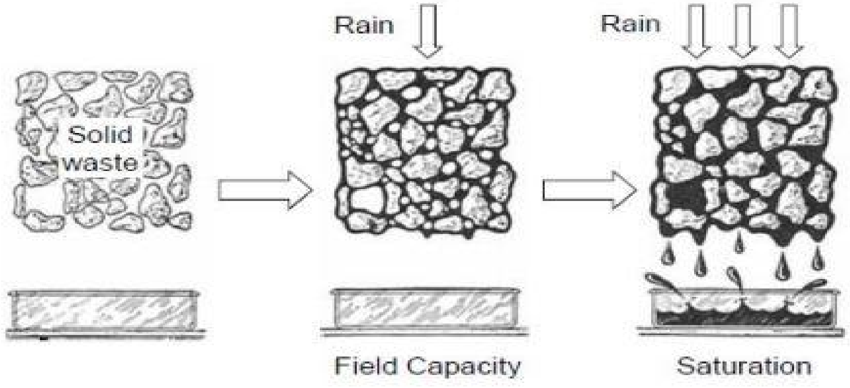
- It is the moisture content retained by the mixed solid waste sample subject to the downward pull of gravity.
- Important in determining the formation of leachate in landfills(leachate-liquid that has seeped through a landfill or a compost pile and has accumulated bacteria and other harmful dissolved or suspended materials).
- It varies with the degree of applied pressure and state of decomposition of the waste ,eg: for un-compacted wastes from residential to commercial areas is in the range from 50 to 60%.

Field cap

$$Field\ Capacity, FC = 0.6 - \left[0.55 * \left(\frac{W}{4500 + W}\right)\right]$$

W - over

at the mid-height of the waste in lift (kg).



Particle size and distribution:

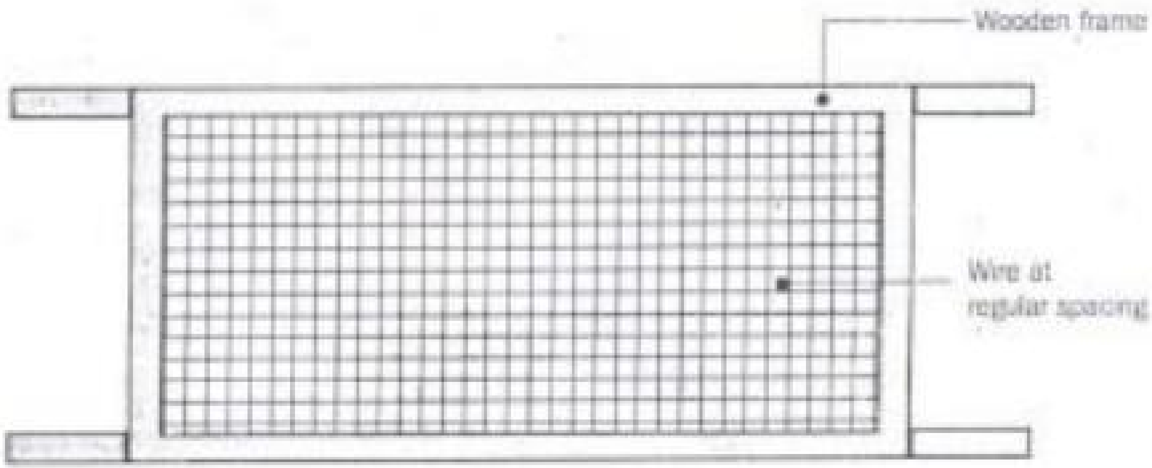
- Difficult to characterize because of waste heterogeneity
- Important in the recovery of materials,especially with mechanical means such as shredders and magnetic seperators.
- The size of waste components can be determined using the following equations:
  - $Sc = L$
  - $Sc = (L+w)/2$
  - $Sc = (L+w+h)/3$

Sc : size of component mm

L : length, mm

W : width, mm

h : height, mm



A typical screen for determining size distribution

Permeability of compacted waste

- Hydraulic conductivity of compacted wastes is an important physical property.
- Governs the movement of liquids and gases in a landfill.
- $K = C d^2 \frac{\gamma}{\mu}$

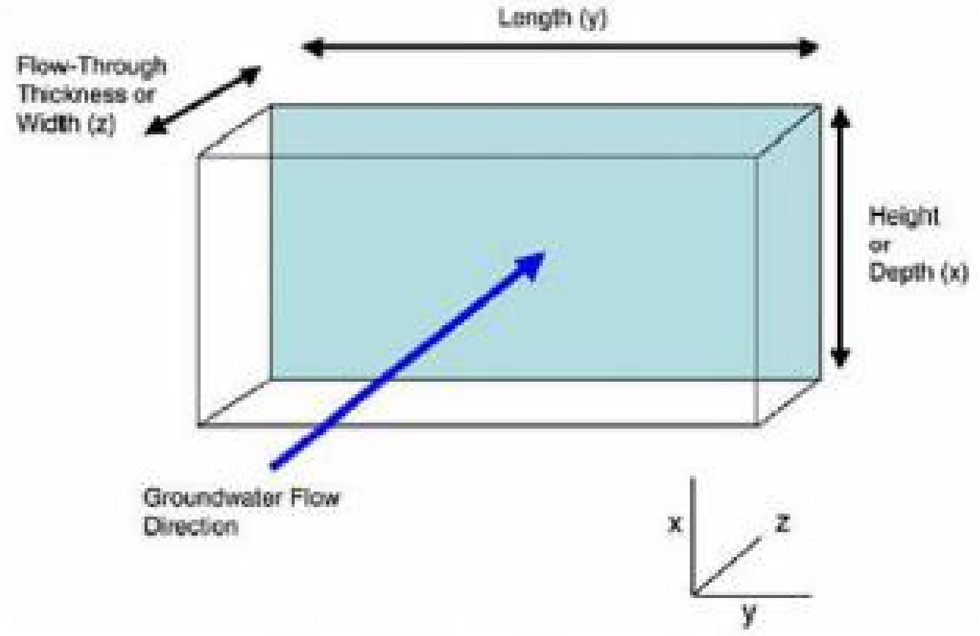
K – coefficient of permeability

C-dimensionless constant or shape factor

d-average size of pores

γ- Specific weight of water

μ- dynamic viscosity of water



- Permeability depends on:
  - Pore size distribution
  - Surface area
  - Porosity
- Porosity:
  - It represents the amount of voids per unit overall volume of material.
  - The porosity of MSW varies typically from 0.40 to 0.67 depending on the compaction and composition of the waste.

Porosity of solid waste, $n = e/(1+e)$

e - void ratio of solid waste

Compressibility of MSW:

- Degree of physical changes of the suspended solids or filter cake when subjected to pressure.

$\Delta H_T = \Delta H_i + \Delta H_c + \Delta H_\alpha$

ΔH_T = total settlement;

ΔH_i = immediate settlement;

ΔH_c = consolidation settlement;

ΔH_α = secondary compression or creep.

1. Estimate the moisture content of a solid waste sample with the following composition

Component	Percent by mass	Moisture content, %	Dry mass*, kg
Food waste	15	70	4.5
Paper	45	6	42.3
Cardboard	10	5	9.5
Plastics	10	2	9.8
Garden trimmings	10	60	4.0
Wood	5	20	4.0
Tin cans	5	3	4.9
Total			79.0

** Based on 100-kg sample of waste*

2. Estimate the density of a solid waste sample with the following composition.

Component	Percent by mass	Typical density, kg/m^3	Volume,* m^3
Food waste	15	290	0.52
Paper	45	85	5.29
Cardboard	10	50	2.00
Plastics	10	65	1.54
Garden trimmings	10	105	0.95
Wood	5	240	0.21
Tin cans	5	90	0.56
			11.07

* Based on a 1000-kg sample of waste

Characteristics of Municipal Solid Waste in Indian Urban Centres

National Environmental Engineering Research Institute (NEERI) has carried out extensive studies on characterisation of solid waste from 43 cities during 1970-1994.

Physical Characteristics of Municipal Solid Wastes in Indian Cities

Population Range (in million)	Number Of Cities Surveyed	Paper	Rubber, Leather And Synthetics	Glass	Metals	Total compostable matter	Inert
0.1 to 0.5	12	2.91	0.78	0.56	0.33	44.57	43.59
0.5 to 1.0	15	2.95	0.73	0.35	0.32	40.04	48.38
1.0 to 2.0	9	4.71	0.71	0.46	0.49	38.95	44.73
2.0 to 5.0	3	3.18	0.48	0.48	0.59	56.67	49.07
> 5	4	6.43	0.28	0.94	0.80	30.84	53.90

All values in table are in percent, and are calculated on net weight basis

Source : Background material for Manual on SWM, NEERI, 1996

Chemical characteristics:

- proper understanding of the behaviour of waste, as it moves through the waste management system.
  - (i) Improving leachate properties and groundwater contamination;
  - (ii) Evaluating alternative solid waste processing and recovery options;
  - (iii) Information about trace element composition;
  - (iv) Assessing the feasibility of MSW combustion directly affected by chemical composition.
- Products of decomposition and heating values are two examples of chemical characteristics.

Chemical Properties:

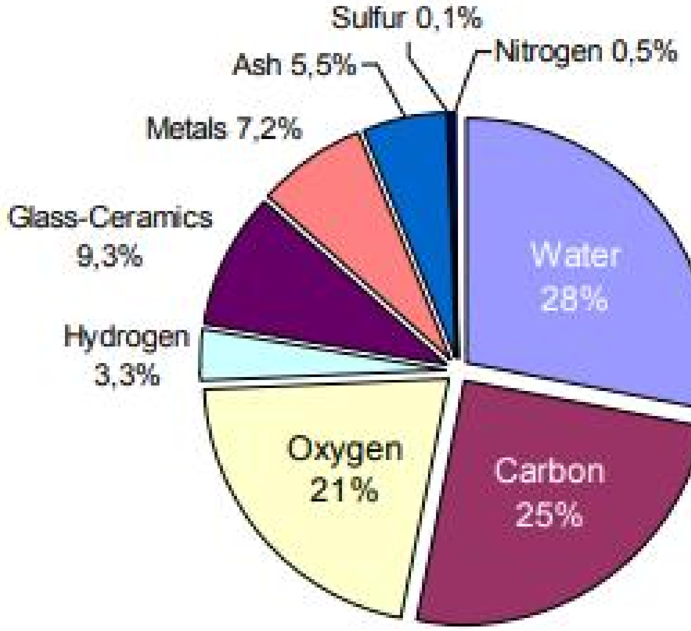
1.Ultimate analysis:

- total elemental analysis to determine the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur.
- determine the ash fraction because of its potentially harmful environmental effects due to the presence of toxic metals such as cadmium, chromium, mercury, nickel, lead, tin and zinc.
- Oxygen value calculated by subtracting all other components (including ash and moisture)
- Used to characterize the chemical composition of organic fraction of waste.
- Determination is essential for assessing the suitability of waste as a fuel and predicting emission from combustion.
- Used to define the proper mix of waste materials to achieve suitable C/N ratios for biological conversion processes.

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

Chemical composition of typical MSW



2. Proximate analysis of MSW

- More specific compared to ultimate analysis.
- Includes the determination of:
  - Moisture (loss of moisture when heated to 105° C for 1 hr)
  - Ash content (the non-combustible components, ie the weight of residue after combustion in an open crucible)
  - Volatile combustible matter (additional loss of weight on ignition at 950 ° C in a covered crucible)
  - Fixed carbon content (combustible residue left after volatile matter is removed, good indicators of combustion capacity of MSW).
- Assess capability of MSW as fuel.
- Limitation – proximate analysis does not provide an indication of possible pollutants emitted during combustion

Waste Type	Proximate analysis (% by wt)			
	Moisture	Volatiles	Fixed Carbon	Noncombustable (ash)
Food mixed	70.0	21	3.6	5.0
Paper mixed	10.2	76	8.4	5.4
Newspapers	6.0	81	11.5	1.4
Cardboard	5.2	77	12.3	5.0
Plastics mixed	0.2	96	2	2
Polyethylene	0.2	98	<0.1	1.2
Polystyrene	0.2	99	0.7	0.5
PVC	0.2	87	10.8	2.1
Textiles	10	66	17.5	6.5
Yard wastes	60	30	9.5	0.5
Wood mixed	20	68	11.3	0.6
Glass	2			96–99
Metals	2.5			94–99
Domestic MSW	10–40	30–60	3–15	10–30

Source: Kiely, G., *Environmental Engineering*, McGraw-Hill, New York, 1997. Reproduced with kind permission of the McGraw-Hill Companies.

Typical proximate analysis of MSW and MSW components

Source: Waste Management Practices: Municipal, Hazardous and Industrial. *John Pichtel.* [Google Books]

3. Fusion Point of Ash

- It is the temperature at which the ash (from the combustion of waste) forms a solid (clinker) by fusion and agglomeration, which provides information about softening and melting conditions.
- Typical fusing temperatures for the formation of clinker from solid waste range from 1100 to 1200° C.

4.Heating value of waste

- Heat value of waste is energy released when waste is burned.
- Heat value directly proportional to carbon content of waste; inversely proportional to ash and moisture content.
- 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).
- Heat value calculated using:
  - Dulong formula (HV is the heating value; C, H, O, S are the compositions on dry basis.

$$HV\left(\frac{kJ}{kg}\right) = 33801[C] + 144158[H] - 0.125[O] + 9413[S]$$

  - M each component)

$$HV\left(\frac{kJ}{kg}\right) = 337[C] + 1419[H_2 - 0.125O_2] + 93[S] + 23[N]$$

  - Kha ght of food in the waste; CP= tage of plastic, leather and rubber)

- Heat of comb boiler and measuring heat output/ using

$$E\left(\frac{MJ}{kg}\right) = 0.051[F + 3.6(CP)] + 0.352(PLR)$$

- Low heat value is the net heat available for combustion of the MSW, while high heat value includes the latent heat of vaporization also. These are estimated based on the chemical composition of the waste materials.

$$HHV\left(\frac{MJ}{kg}\right) = 0.339[C] + 1.44[H] - 0.139[O] + 0.105[S]$$

$$LHV\ \left(\frac{MJ}{kg}\right) = HHV - 0.0244 * (W + 9H)$$

Where W is percent mass of water and H is the percent of H in the waste.

Energy Content of Solid Waste Components:

- The energy content of the organic components in MSW can be determined

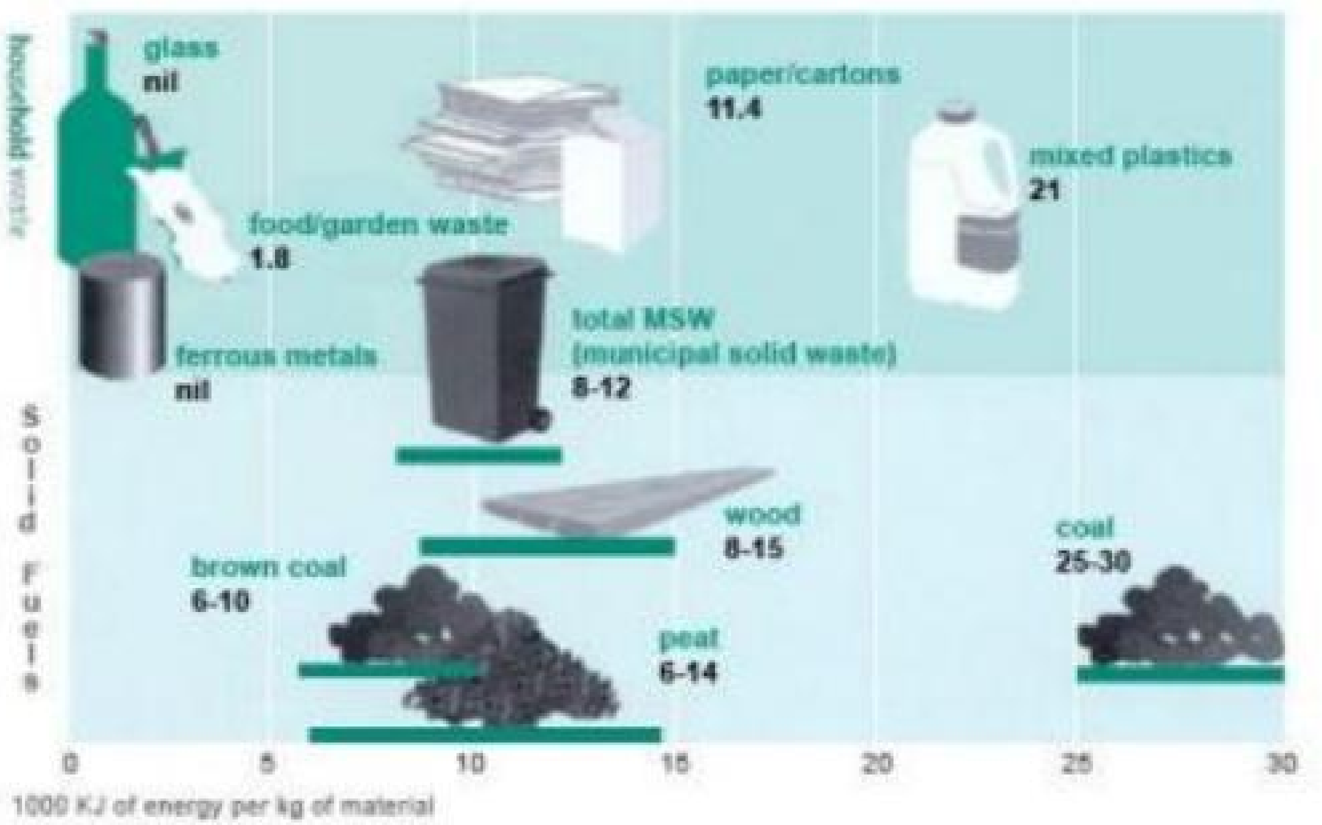
  (1) by using a full scale boiler as a calorimeter

  (2) by using a laboratory bomb calorimeter

  (3) by calculation, if the elemental composition is known.

- Because of the difficulty in instrumenting a full-scale boiler, most of the data on the energy content of the organic components of MSW are based on the results of bomb calorimeter tests.

Energy content of MSW components



Organic Fractions of MSW
Lipids:

- The principal sources of lipids are garbage, cooking oils and fats.
- This class of compounds includes fats, oils and grease.
- 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.

Carbohydrates:

- These are found 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.

Proteins:

- These are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH2).
- 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.

Natural fibres:

- These are found in paper products, food and yard wastes
- 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%.)
- highly combustible solid waste- have high proportion of paper and wood products- suitable for incineration.
- Calorific values of oven-dried paper products are in the range of 12,000 -18,000 kJ/kg and of wood about 20,000 kJ/kg, i.e., about half that for fuel oil, which is 44,200 kJ/kg.

Plastics:

- Highly resistant to biodegradation – needs special concern in SWM.
- 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 synthetic plastic polymer like polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas-increases corrosion in the combustion system – also responsible for acid rain.

Non-combustibles:

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

Characteristics of Municipal Solid Waste in Indian Urban Centres

Chemical Characteristics of Municipal Solid Wastes in Indian Cities

Population range (in million)	No. of Cities surveyed	Moisture %	Organic matter %	Nitrogen as Total Nitrogen %	Phosphorous as P_2O_5 %	Potassium as K_2O %	C/N Ratio	Calorific value* in kcal/kg
0.1-0.5	12	25.81	37.09	0.71	0.63	0.83	30.94	1009.89
0.5-1.0	15	19.52	25.14	0.66	0.56	0.69	21.13	900.61
1.0-2.0	9	26.98	26.89	0.64	0.82	0.72	23.68	980.05
2.0-5.0	3	21.03	25.60	0.56	0.69	0.78	22.45	907.18
> 5.0	4	38.72	39.07	0.56	0.52	0.52	30.11	800.70

All values, except moisture, are on dry weight basis.
*Calorific value on dry weight basis

Source : Background material for Manual on SWM, NEERI, 1996.

Estimate the energy content using Khan Equation, for MSW having the following properties:

Component	% by weight
Paper products	23
Plastics	13
Glass	12
Metals	3
Food waste	19
Textiles	16
Misc.	14
Total	100

$$E = 0.051[F + 3.6(CP)] + 0.352(PLR) = 0.051[19 + 3.6 * 23] + 0.352 * 13 = 9.77\frac{MJ}{kg}$$

STORAGE OF SOLID WASTE

- The waste cannot be tolerated for long on individual premises because of their biodegradability
- It must be moved within a reasonable time usually less than 8 days
- The cost of providing storage for solid waste normally falls to householders or apartment owners or by the management of commercial and industrial properties
- Factors considered in the onsite storage of solid waste:
  - The type of container to be used
  - The container location
  - Public health and aesthetics
  - The collection methods used

STORAGE CONTAINERS

Container type	Typical applications	Limitations
Small		
Container, plastic or galvanized metal	Very low-volume waste sources, such as individual homes, walkways in parks and small isolated commercial establishments, low-rise residential areas with setout collection services	Containers are damaged over time and degraded in appearance and capacity, containers add extra weight that must be lifted during collection operations, and containers are not large enough to hold bulky wastes.
Disposable paper bags	Individual homes with packout collection service, can be used alone or as a liner inside a household container, low and medium rise residential areas	Bag storage is more costly, if bags are set out on streets or curbside, dogs or other animals tear them and spread their contents, paper bags themselves add to the waste load
Medium		
Container	Medium volume waste sources that might also have bulky wastes, location should be selected for direct-collection truck access, high density residential areas, commercial areas, industrial areas	Snow inside the containers forms ice and lowers capacity while increasing weight, containers are difficult to get to after heavy snows
Large		
Container, open top	High volume commercial areas, bulky wastes in industrial arears, low density rural residential areas, location should be within a covered area but with direct collection truck access	Initial cost high, snow inside containers lowers capacity
Container, used with stationary compactor	Very high volume commercial areas, location should be outside buildings with direct collection truck access	Initial cost is high, if container is compacted too much, it is difficult to unload it at the disposal site.

i. Low-rise dwellings

Because solid wastes are collected manually from most residential low-rise detached dwellings, the containers should be light enough to be handled easily by one collector when full. Injuries to collectors have resulted from handling containers that were loaded too heavily. The galvanized metal or plastic container has proved to be the least expensive means of storage for low-rise dwellings.

Galvanized metal containers tend to be noisy when being emptied and in time can be damaged so that a proper lid seal cannot be achieved. Although less noisy in handling, some containers constructed of plastic materials tend to crack under exposure to the ultraviolet rays of the sun and to freezing temperatures but the more expensive plastic containers apparently do not present theses problems.

Temporary and disposable containers are commonly used when curb service is provided and the home owner is responsible for placing accumulated wastes on the curb for collection. Paper bags, cardboard boxes, plastic containers and bags, wooden boxes are used as temporary disposable containers. Under normal circumstances, temporary containers are removed along with the wastes. The principle problem in the use of temporary containers is the difficulty involving in loading them. Paper and cardboard containers tend to disintegrate because of the leakage of liquids. In extremely warm areas where disposable plastic bags are used for lawn trimmings, plastic containers frequently stretch or break when the collector lifts the loaded bag. Such breakage is potentially hazardous and may lead to injuries to the collectors because of the presence of glass and sharp or otherwise dangerous items in the wastes.

ii. Medium and high rise apartments

Where solid chutes are available, separate storage containers are not used. In some older medium and high rise apartments without chutes, wastes are stored in containers on the premises between collections. The most common storage includes:

- Large open top containers
- Enclosed storage containers or disposable bags
- Containers equipped with a self-contained compaction mechanism
- Special containers used in conjunction with processing equipment.

iii. Commercial

Storage techniques used in commercial facilities depend to a large extend on the internal methods used for collecting the wastes produced at various locations within the facility and available space. Typically large open top containers are used. Containers equipped with compaction mechanism and onsite processing equipments are also used.

Importance of MSW Quantities

-the data of quantities are used for designing and implementing effective solid waste management programs.

-extreme care must be made in deciding and allocating funds for data collection.

-quantities are estimated on the basis of data gathered by conducting waste characterization study ,using previous waste generation data or some combination of two approaches.

Problem Statement:

From the following date, estimate the unit waste disposal rate per week for a residential area consisting of 1200 homes. The average occupancy is 3.5 persons per home. The observation location is a local transfer station that receives all of the wastes collected for disposal. The observation period was one week.

Data:

- Number of compactor truck loads = 9
- Average size of compactor truck = 20 yd^3
- Number of flatbed loads = 7
- Average flatbed volume = 2 yd^3
- Number of loads from individual residents' private cars and trucks = 20
- Estimated average volume per domestic vehicle = 8 ft^3

Solution:

<u>Step 1:</u> Setup a computation table to estimate the total weight of waste disposed during this week.

Solution:

Step 1: Setup a computation table to estimate the total weight of waste disposed during this week.

Waste Source	Number of Loads	Average Volume, yd^3	Specific Weight, lb/yd^3 †	Total Weight, lb
Compactor Truck	9	20	500	90,000
Flatbed Truck	7	2	225	3,150
Private Vehicle	20	0.3	150	900
			Total, lb/week =	**94,050**

† based on estimates of average vehicle volume and weight

Step 2: Determine the unit waste disposal rate.

$$\text{Unit or Per Capita Disposal Rate} = \frac{94{,}050 \text{ lb/wk}}{(200 \text{ homes})(.5 \text{ persons/home})(\text{ days/wk})}$$

$$\boxed{\text{Unit or Per Capita Disposal Rate} = 3.2 \frac{\text{lb}}{\text{capita} \cdot \text{day}}}$$

MUNICIPAL SOLID WASTE MANAGEMENT

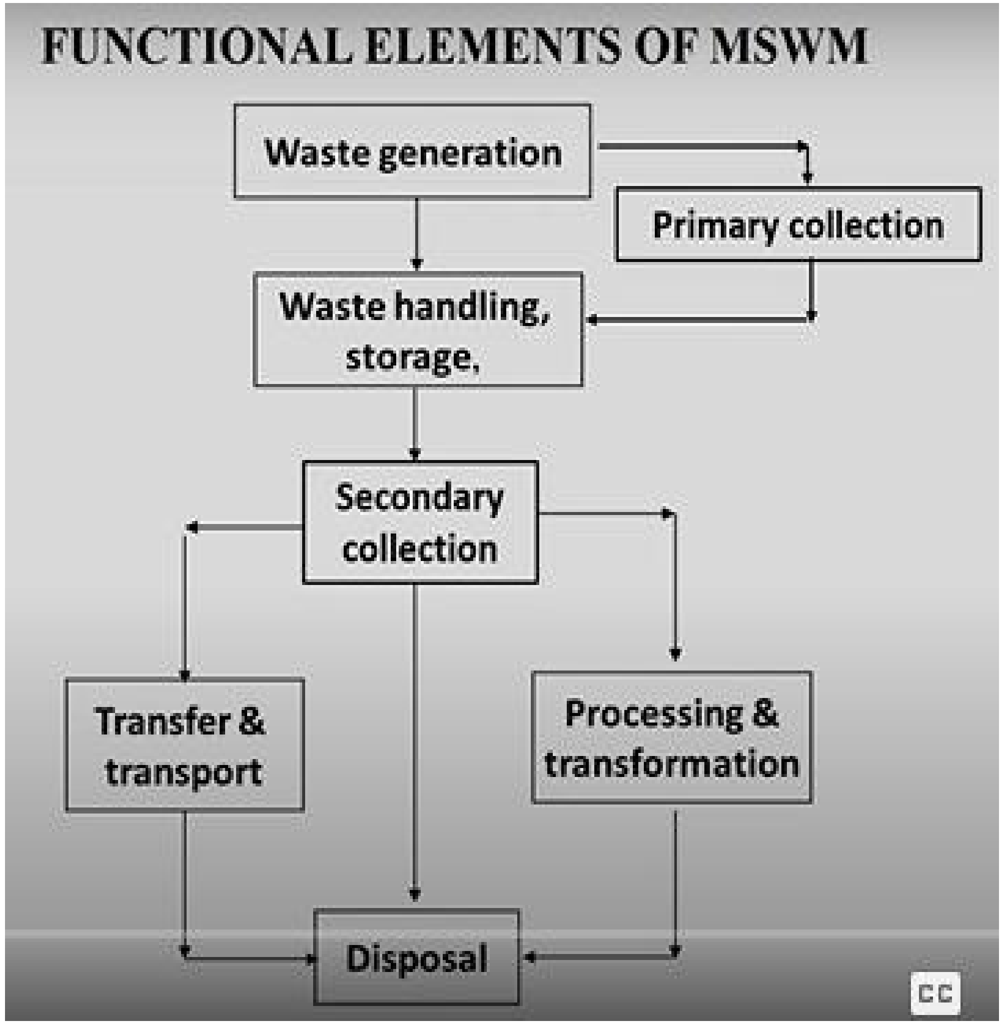
Module 3 -Waste Collection

III	**Collection** – collection services- collection systems, collection routes-Need for transfer operation. Resource conservation and recovery.	6	15

- Collection of solid waste includes gathering of waste, picking up from various sources and hauling of wastes to transfer stations or disposal sites.
- The unloading of collection waste is also considered as apart of collection operation
- The gathering or picking up of solid waste will vary with the characteristics of the facilitates, activities of localities where wastes generated and the methods used for the onsite storage of accumulated wastes between the collections
- Collection is an expensive part of waste management and a proper collection system design and management can reduce the cost significantly.

Two types of collections

- Primary Collection- Collection Services
- Secondary collection- Collection system



Primary Collection/ Collection Services

- Collection of solid waste from the source of generation
- The collection points can be located outside individual household or communal containers that serve a no of households/apartments
- Depending upon the collection vehicle and distance to the disposal site /waste treatment the waste may taken to the disposal or to transfer stations

Collection Services

- Collection of unseparated waste
  - Low rise detached dwellings
  - Medium rise apartments
  - High rise apartments
  - Commercial/industrial facilities
- Collection of separated waste
  - Residential
  - Commercial

Low rise detached dwellings

- Curb
- Curb(mechanised)
- Alley
- Setout- Setback
- Setout
- Backyard carry

Different Collection Services

- **For low rise detached apartments**

Curb Services

- Homeowner/ resident is responsible for placing the containers to emptied at the curb on the collection day
- Homeowner/ resident is also responsible for returning the empty containers to their storage locations until the next collection

Advs

- crew can move quickly
- Crew does not entire the private property, so fewer accidents and trespassing complaints
- This method is less costly than backyard collection because it generally requires less time ad fewer crew members
- Adaptable to automated and semi automated collection equipment

Different Collection Services-Low Rise Detached Apartments

Disadvs

- On collection days waste containers are visible from the streets
- Collections days must be scheduled
- Residents are responsible for placing containers at the proper collection points

Different Collection Services-Low Rise Detached Apartments

Alley Services

- This is preferred where alleys are apart of the layout of the city
- Storage of containers is done in the alleys
- The collection is similar to curb services

Advs. & Disadvs. similar to Curb Services

Different Collection Services-Low Rise Detached Apartments

Set out-Set back

- Containers are set out from house owners property and set back after being emptied by additional crews that work in conjunction with the collection crew responsible for loading the collection vehicle

Advs.

- Collection days need not be scheduled
- Waste containers are not usually visible from the streets
- Use of additional crew members reduces loading times as compared to backyard collection method

Different Collection Services-Low Rise Detached Apartments

Disadvs.

- Crews enter the private property more injures and trespassing complaints are likely
- This method is time consuming
- Residents are not involved and more crew member than for curb side and alley collection are required
- This is more costly than curb side and alley collection because additional crew are required

Setout

- Set out services essentially the same as setout-setback service, expect that the homeowner is responsible for returning the container to their storage locations.

Backyard carry

- Collection is responsible for entering the home owners property and removing the waste from their storage locations

Advs.

- Collection days need not be scheduled
- Waste containers are not usually visible from the street
- Residents are not involved with container setout or movement
- This method requires fewer crew member than setout/setback methods

Considerations	Type of service					
	Curb	Curb (mechanized)	Alley	Setout-setback	Setout	Backyard carry
Requires homeowner cooperation						
To move full containers	Yes	Yes	Optional	No	No	No
To move empty containers	Yes	Yes	Optional	Yes	Yes	No
Requires scheduled service for homeowner cooperation	Yes	Yes	No	No	Yes	No
Aesthetics						
Spillage and litter problem	High	Moderate	High	Low	High	Low
Containers visible	Yes	Yes	No	No	Yes	No
Attractive to scavengers	Yes	Yes	Yes	No	No	No
Prone to upsets	Yes	Yes	Yes	No	Yes	No
Number of persons in crew						
Typical	1	1	1	3	3	3
Range	1–3	1–2	1–3	3–7	1–5	3–5
Crew time	Low	Low	Low	High	Medium	Medium
Collector injury rate due to lifting and carrying	Low	Low	Low	High	Medium	High
Trespassing complaints	Low	Low	Low	High	High	High
Special considerations			Requires alleys and vehicles that can maneuver in them, less prone to block traffic, high vehicle and container depreciation rate			Requires wheeled caddy to roll filled containers or the use of burlap carry cloths or hand-carry bin, works best with driveway
Cost due to crew size and time requirements	Low	Low	Low	High	Medium	Medium

LOADING

- Manual methods commonly used for the collection of residential wastes include the following:
- The direct lifting and carrying of loaded containers to the collection vehicle for emptying
- The rolling of loaded containers on their rims to the collection vehicle for emptying
- The rolling of loaded containers equipped with wheels to the collection vehicle for mechanically assisted emptying
- The use of small lifts for rolling loaded containers to the collection vehicle.

- For manual curb collection, where collection vehicles with low loading heights are used,wastes are transferred directly from the containers in which they are stored or carried to the collection vehicle by the collection crew

- In other cases, collection vehicles are equipped with auxiliary containers into which the wastes are emptied. The auxiliary containers are emptied into the collection vehicle by mechanical means.

- Still another variant involves the use of small satellite vehicles. Wastes are emptied into a large container carried by a satellite vehicle. When loaded, the satellite vehicle is driven to the collection vehicle, where the container is emptied into the truck by mechanical means.

- Where mechanized self-loading collection vehicles are used, the container used for the onsite storage of waste must be brought to the curb or other suitable location for collection, the containers may be brought to the curb and returned to their normal location by the homeowner or by collection agency personnel.

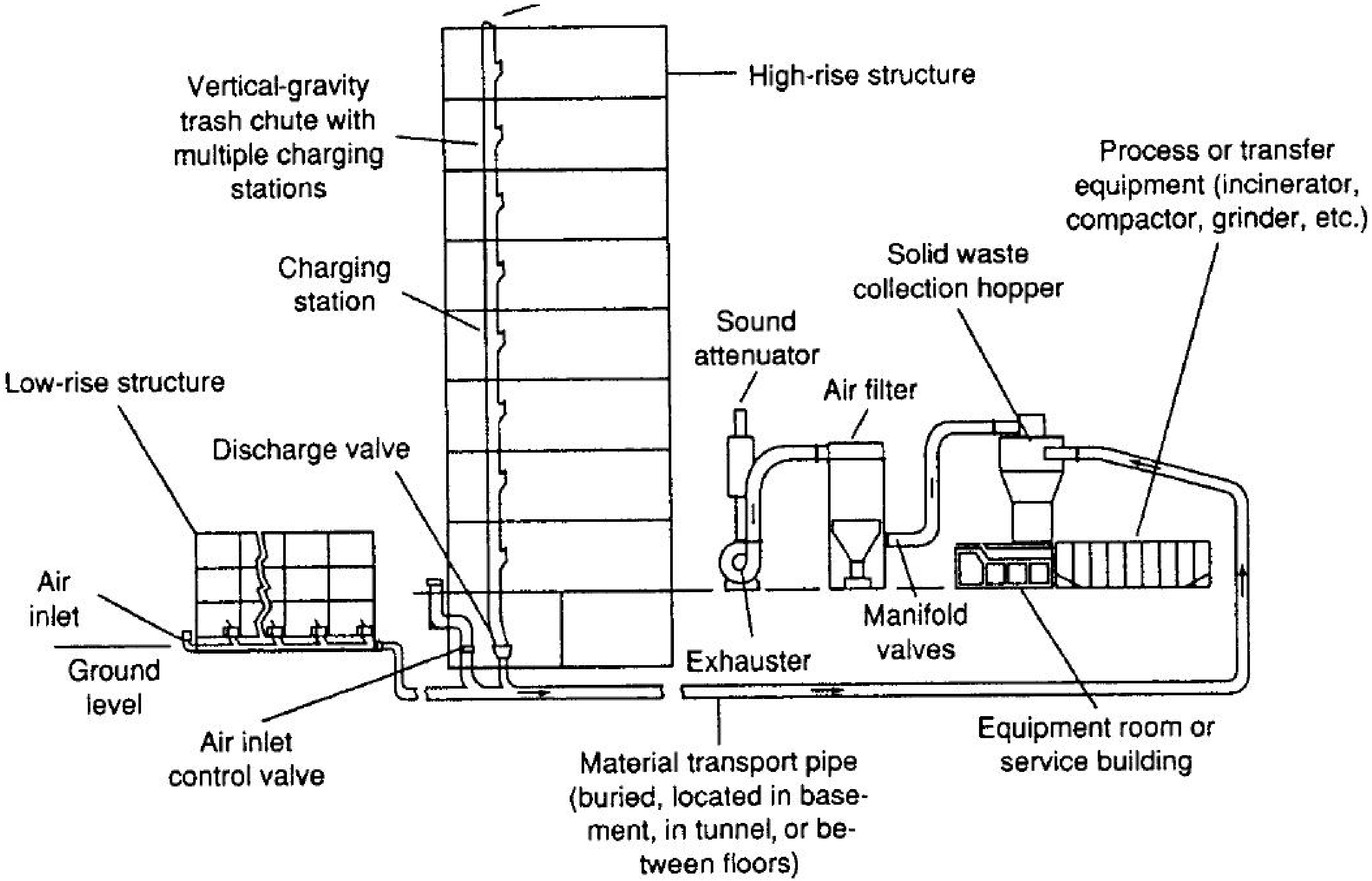
For low and medium rise apartments

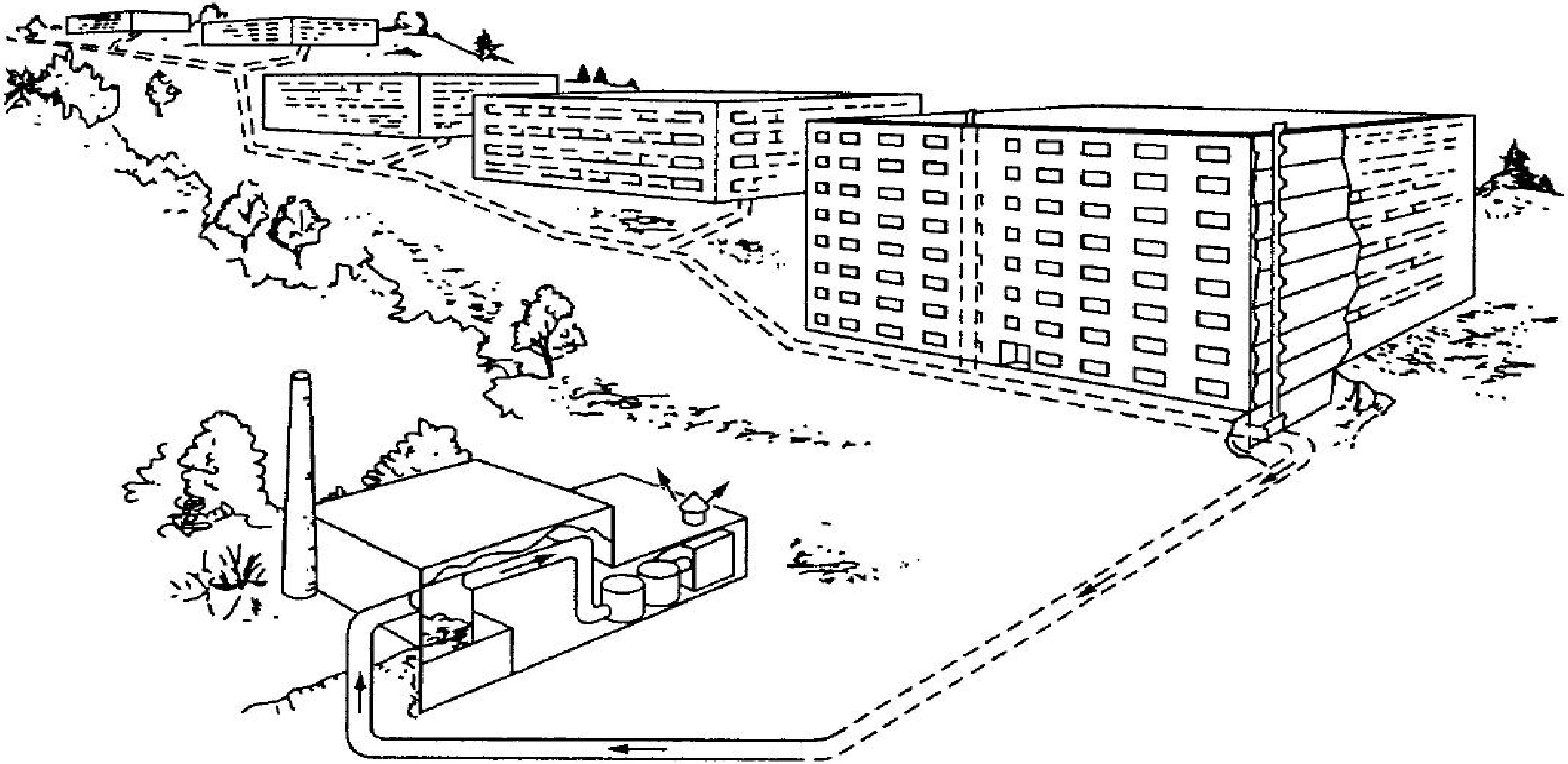
- Curbside collection service is common for most low- and medium-rise apartments the maintenance staff is responsible for transporting the containers to the street for curbside collection by manual or mechanical means.
- In many communities, the collector is responsible for transporting containers from a storage location to the collection vehicle
- Where large containers are used, the contents of the containers are emptied mechanically using collection vehicles equipped with unloading mechanisms.

For High-Rise Apartments

In high-rise apartment buildings (higher than seven stories), the most common methods of handling commingled wastes involve one or more of the following:

- Wastes are picked up by building maintenance personnel from the various floors and taken to the basement or service area.
- Wastes are taken to the basement or service area by tenants.
- Wastes, usually bagged, are placed by the tenants in a waste chute system, which is used for the collection of commingled waste at a centralized service location


High-rise structure
Vertical-gravity trash chute with multiple charging stations
Charging station
Low-rise structure
Discharge valve
Air inlet
Ground level
Air inlet control valve
Process or transfer equipment (incinerator, compactor, grinder, etc.)
Solid waste collection hopper
Sound attenuator
Air filter
Manifold valves
Exhauster
Equipment room or service building
Material transport pipe (buried, located in basement, in tunnel, or between floors)
(a)



(b)

FIGURE 7.4 Schematic of a trash chute system for the collection of wastes from high-rise apartments. (*a*) For an individual apartment, the chute system will normally terminate in the basement. (*b*) In a large apartment complex, composed of a number of buildings, the wastes from the individual apartment building are transported using an underground pneumatic system to a centralized processing facility.

For Commercial-Industrial Facilities

- Both manual and mechanical collection are used
- Because many large cities have extreme traffic congestion during the day, solid wastes from commercial establishments are collected in the late evening and early morning hours.
- Where manual collection is used during the evening hours, wastes from commercial establishments are put into plastic bags, cardboard boxes, and other disposable containers, which are placed on the curb for collection.
- Waste collection is usually accomplished with a three- or, in some cases, four-person crew, consisting of a driver and two or three collectors who load the wastes from the curbside into the collection vehicle. In most evening collection operations, the driver remains with the collection vehicle for reasons of safety.
- Mechanized collection is also accomplished during the evening hours with a driver and helper.

(a)

(b)

FIGURE 7.5 Mechanically loading collection vehicles. (*a*) Front-loading vehicle equipped with internal compactor. (*b*) Collection vehicle, with collection mechanism mounted on truck chassis, that can be used to collect two types of waste at the same time (e.g., a mixture of source-separated recyclable wastes and commingled waste). Such collection vehicles are used to collect wastes from large containers used in apartment complexes and commercial establishments.

(a)

(b)

FIGURE 7.6 Typical examples of large containers used for the collection of wastes from commercial establishments (a) at rear of large department store in a shopping mall, and (b) in downtown location.

Collection of Wastes Separated at the Source

- wastes separated at the source are separated for recovery and reuse (recycled).
- The three principal methods now used for the collection of recyclable materials from residential sources include:

1. Curbside collection using conventional and specially designed collection vehicles

2. Incidental curbside collection by charitable organizations

3. Delivery by residents to drop-off and buyback centers

From Low-Rise Detached Dwellings.

- In a curbside system, source-separated recyclables are collected separately from commingled waste at the curbside in the alley, or at commercial facilities.
- Because residents and businesses do not have to transport the recyclables any further than the curb, participation in curbside programs is typically much higher than for drop-off programs.

(a) (b)

FIGURE 7.8 Typical examples of source-separated materials placed at the curbside for collection. (*a*) From a residential area. (*b*) Recyclable wastes along with commingled waste from commercial establishments placed on sidewalk in New York City to be collected in the evening or early morning hours.

From Low- and Medium-Rise Apartments.

- The two principal methods now used for the collection of source-separated materials from low- and medium-rise apartments include:

1. Curb side collection using conventional and specially designed mechanized collection vehicles
2. Collection from designated storage areas with mechanized collection vehicles

- In many low- and medium-rise apartments, large waste storage containers for recyclable materials are located outdoors in special enclosures
- In some apartment buildings, the waste storage containers are located in the basement.
- Residents carry their waste and recyclable materials to the storage area and deposit them in the appropriate containers
- the containers used for recyclables are located next to or near the containers used for commingled waste.
- Large containers are emptied mechanically using collection vehicles equipped with unloading mechanisms

From Commercial Facilities.

- Source-separated materials from commercial establishments are usually collected by private haulers. In many cases, the haulers have contracts with the facility for the separated material.
- The wastes to be recycled are stored in separate containers.
- In some cities, cardboard is often bundled and left at curbside, where it is collected separately.
- In large commercial facilities, baling equipment is often used for paper and cardboard, and can crushers are used for aluminum cans.

From High-Rise Apartments.

In high-rise apartment buildings, the most common methods of handling commingled and source-separated wastes involve one or more of the following:

- Recyclable and commingled wastes are picked up by building maintenance personnel from the various floors and taken to the basement or service area and placed in separate containers.
- Recyclable and commingled wastes are taken to the basement or service area by tenants and placed in separate containers.
- Recyclable wastes are taken to the basement or service area by tenants or building maintenance personnel and placed in separate containers, and, where available, other commingled waste is placed by the tenants in specially designed waste chutes, as described previously for commingled collection.

➢ Source-separated wastes are collected in large containers, which are emptied mechanically.

TABLE 7.3 Characteristics of Vehicles Used for the Collection of Wastes Separated at the Source

Item	Comment
Standard packer trucks	Packer trucks used for waste collection can also be used for collection of recyclables. Many communities use packer trucks in their recycling programs. Rear-loading packers have been used for newspaper, cardboard, and magazines with trailers attached to them for cans and glass. Front-end loaders have been used to service large containers containing newspaper recovered from apartment buildings. Some cities use side- and rear-loading packer trucks to pick up newspaper one week and glass and cans the following week. When collecting glass and cans, the compacting mechanism is not used because glass is highly abrasive and would damage the packer plate. Also, by not compacting, the majority of the glass remains unbroken and is, therefore, easier to sort into different colors at the processing site.
Closed-body recycling truck	This truck consists of an enclosed steel body installed on a lowered truck chassis, and a low-entry walk-in cab with dual left- and right-hand driving controls (allowing one-person operation). Adjustable hinged dividers on the body can be used to create from two to four compartments for different materials. One or both sides are opened for manual loading. Removable aluminum side panels are used to contain the load as the level of material rises. The overall capacity of the truck can range from 27 to 31 yd^3, although operational capacity when manually loading is 20 to 25 yd^3. The truck is equipped with a front-mounted telescopic hoist and rear body hinge for dumping. Each compartment is discharged separately by opening the rear door, unlocking the appropriate divider, and tipping the body.
Mobile container system	The mobile container system is essentially a steel frame with sets of hydraulic forks that can be used to transport large bins. The number of bins on a trailer range from three to six, and have a low-pull or gooseneck (fifth-wheel) style. To load the trailer, the forklifts are lowered to the ground and the bins are wheeled over them so that the forks slide into channels on the underside of the bins. The bins are then hydraulically raised and secured to the trailer frame. An empty set of bins can be left to replace the full ones. A pickup truck is used to pull the trailer.
Modified flatbed truck	Some curbside programs use a standard flatbed truck with a hydraulic dumping box mounted on the truck bed. The box is usually divided into three or four compartments and has a standard capacity of approximately 15 yd^3.
Open-bin recycling truck	The open-bin recycling truck is a specially designed vehicle with two or three open-top, self-dumping bins. Source-separated wastes are emptied into low-mounted troughs, which are emptied mechanically into the open bins. The front bins are typically 6 to 8 yd^3 and can be specified to unload right or left. The back bin, which dumps to the rear, has a capacity of 10 to 12 yd^3. The cab can be designed for right-hand stand-up drive to allow the loading function to be performed by the driver.

Systems for solid waste collection(Secondary collection)

Secondary collection is the collection of waste from communal bins, storage points or transfer station and transportation to the final disposal site

- **Hauled container system**
- **Stationary container system**

Systems for solid waste collection

- Hauled container system

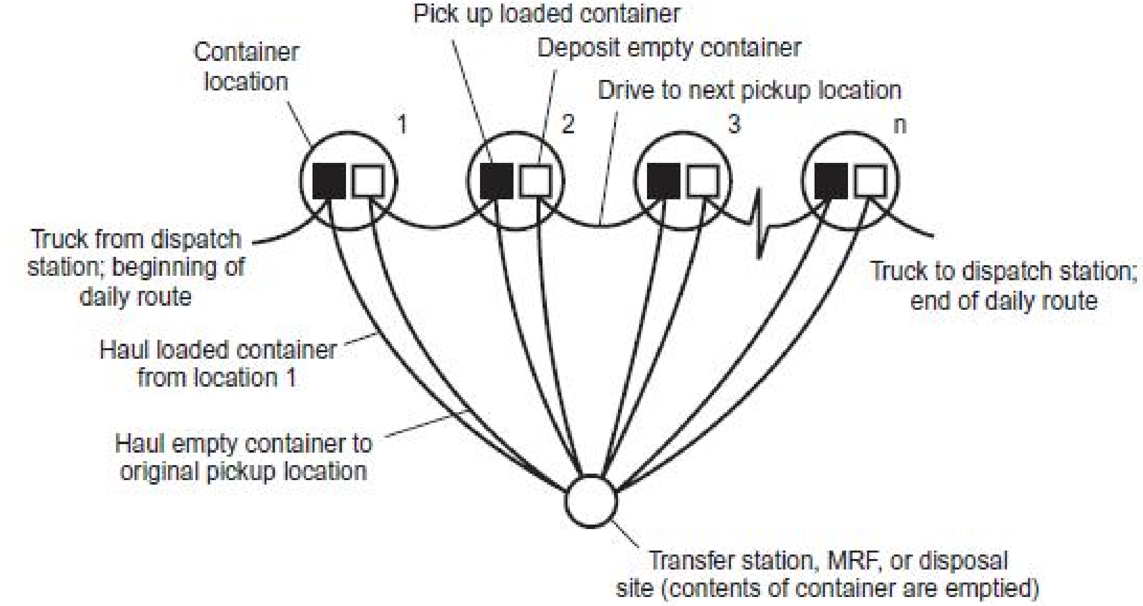
Equipment and Personnel Requirements for Hauled Container System (HCS).

- collection systems in which the containers used for the storage of wastes are hauled to a materials recovery facility (MRF), transfer station, or disposal site, emptied, and returned to either their original location or some other location.
- Hauled container systems are ideally suited for the removal of wastes from sources where the rate of generation is high because relatively large containers are used (The use of large containers eliminates handling time as well as the unsightly accumulations and unsanitary conditions associated with the use of numerous smaller containers.
- Another advantage of HCSs is their flexibility: Containers of many different sizes and shapes are available for the collection of all types of wastes.
- So here it is possible that this entire hauling could be planned in on highways or bigger roads so that the traffic issues and the time required to reach the disposal site or treatment facility isn't very high.

After Jawaharlal Nehru National Urban Renewal Mission (JnNURM) was launched in 2005

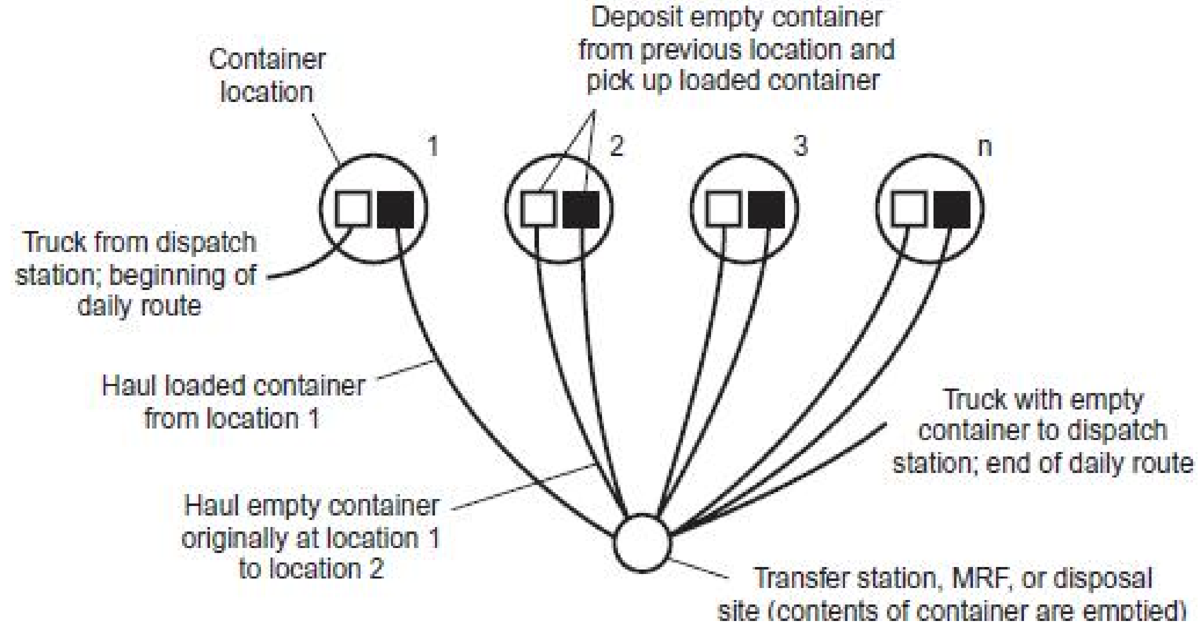
Collected in haul container vehicles to processing/ treatment/ disposal sites

(a) Hauled container system (conventional mode)



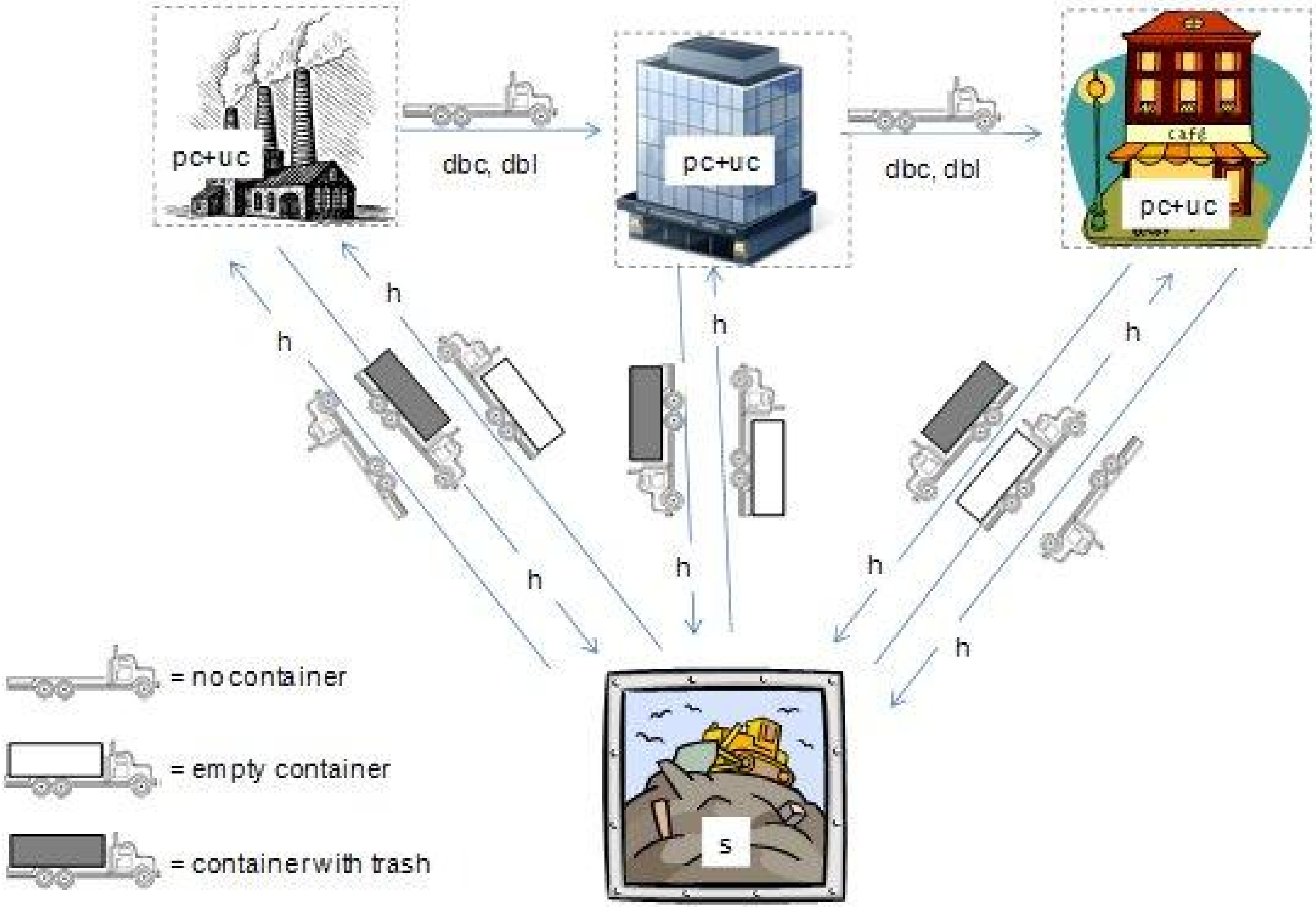
Containers used for the storage of wastes are hauled to an MRF, transfer station, or disposal site, emptied, and returned to their original location.

(b) Hauled container system (exchange container mode)



Containers used for the storage of wastes are hauled to an MRF, transfer station, or disposal site, emptied, and returned to a different location in the exchange mode of operation. The exchange mode works best when the containers are of a similar size. In the exchange mode, the driver must begin the collection route with an empty container on the vehicle to be deposited at the first collection site.

Conventional System, No Dispatch



Collection Truck

MSW COLLECTION SYSTEMS

1) HAUL CONTAINER SYSTEM (HCS)

Hoist Truck

Tilt Frame

Trash Trailer

Collection Truck

- **Three main Types**

1. Hoist Truck System

- In the past, hoist truck were used at military installations.
- The application of mechanically loaded collection vehicles with large capacity is limited for the areas where a considerable amount of waste is generate.
- It is used for the collection of bulky items and industrial rubbish not suitable for the collection with the compaction vehicle

2. Tilt frame container system

- Used to haul large volume of solid waste.
- Also called drop or debris boxes
- Ideally suited for all types of solid waste and rubbish the generation rate warrants use of large containers
- Usually used at apartments complexes, commercial services and transfer stations
- Due to its large hauling capacity they are popular among private collectors serving commercial accounts

Collection Truck

3. Trash trailer

- Similar to that for tilt frame container system.
- These are better for the collection of heavy rubbish, such as sand, timber and metal scrap and used for collection of demolition wastes

Advs. of haul Container System

- Useful when the generation rate is high as the containers are large
- The use of large containers eliminates hauling time as well as the unsightly accumulation and unsanitary condition associated with use of numerous smaller containers
- Another advantage of hauled container system is their flexibility : containers of many different sizes and shapes are available for the collection of all types of wastes
- It requires only one truck and driver to accomplish the collection cycle

Disadvs. of haul Container System

- If the containers are not filled, results low utilization rate

STATIONARY CONTAINER SYSTEM (SCS)

- These are collection system in which the containers used for the storage of wastes remain at the point of generation, except when they are moved to the curb or other location to be emptied .
- Used for collection of all types of wastes
- The system vary according to the type and quantity of wastes to be handled, as well as the number of generation.
- Two main types:-

a) <u>System in which mechanically loaded collection vehicles</u>

In this type, the container size and utilization are not important as the solid waste is collected after compaction

- Trips to disposal site or transfer station or processing station are made after the contents have been collected and compacted and collection vehicle is full

b) <u>System in which manually loaded vehicles</u>

- The major application is the collection of residential source separated and commingled wastes and litters
- It preferred in residential areas because of the quantity picked up at each location is small and loading time is short
- The manual methods are used for residential collection because many individual pickup points are inaccessible to the collection vehicles

MANUALLY LOADED TRUCK

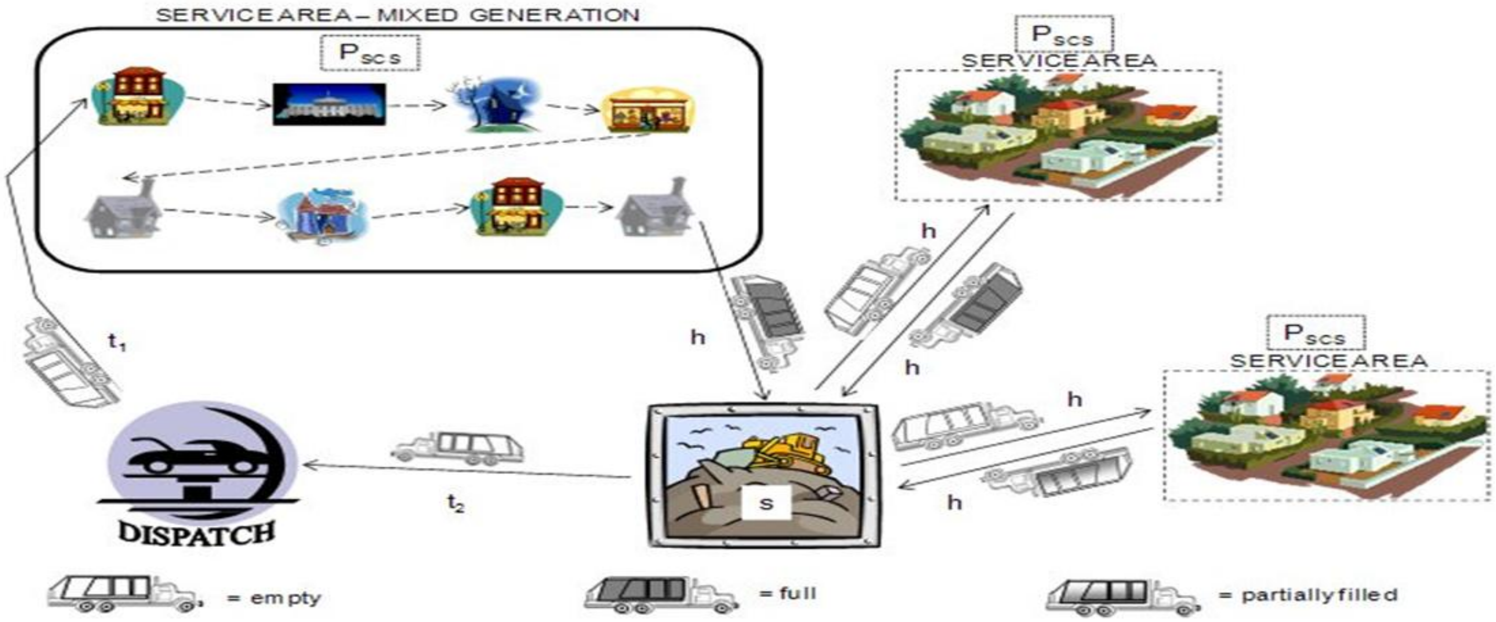
Side-loaded right-hand standup drive collection vehicle for commingled solid waste

MECHANICALLY LOADED TRUCK

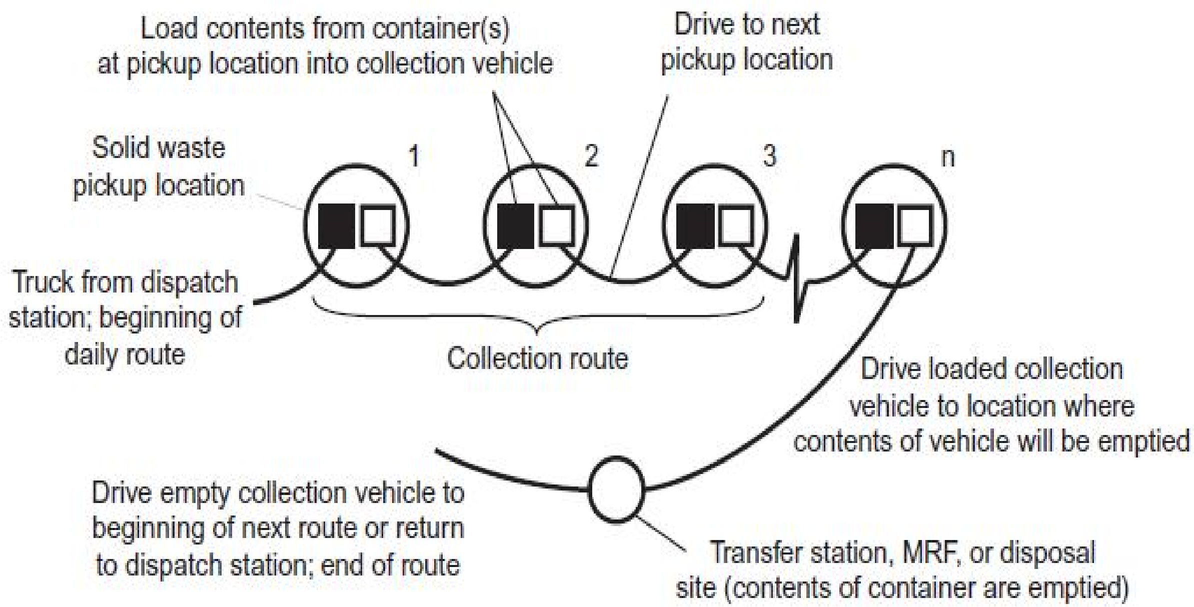
Rear-loading vehicle used for collection of source-separated materials

MECHANICALLY LOADED TRUCK

Stationary Container System, with Dispatch



(c) Stationary container system



Containers used for the storage of wastes remain at the point of generation, except when they are moved to the curb or other location to be emptied. The collection vehicle is driven from pickup location to pickup location until it is loaded fully.

Advs. Of Stationary Container System (SCS)

- The vehicle doesn't travel to the disposal area until it is full, resulting in higher utilization rate

Disadvs. Of Stationary Container System (SCS)

- Not suited for heavy industrial wastes and bulk rubbish as it may damage the relatively delicate mechanism of trucks
- Difficult to service in locations where high volume of rubbish are produced because of the space requirements for the large number of containers
- In manual systems, the manpower required is more
- Special attention should be given to the design of collection vehicle for the use of single collector drivers

ANALYSIS OF COLLECTION SYSTEM

- To establish vehicle and labour requirement for the collection system and methods, the unit time required to perform each task must be determined
- By separating the collection activities into unit operation it is possible to-

- Develop design data and relationship that can be used universally
- To evaluate both the variables associated with collection activities and variables related to or controlled by the particular location.

Definition of unit operations

The activates involved in the collection of solid waste can be resolved into four unit operations

1. Pick up

2. Haul

3.At site

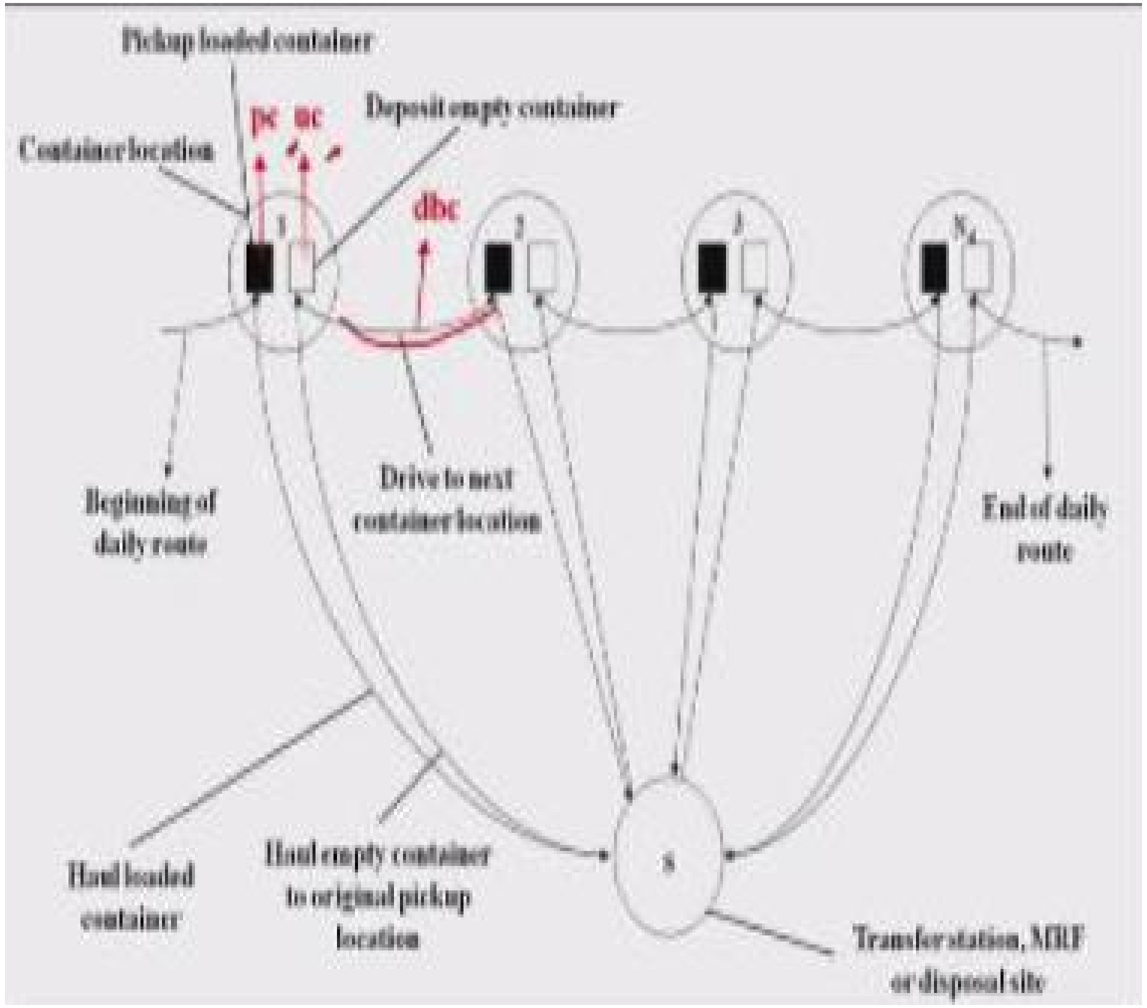
4. Off route

HAUL CONTAINER SYSTEM

Pickup(P_{hcs})

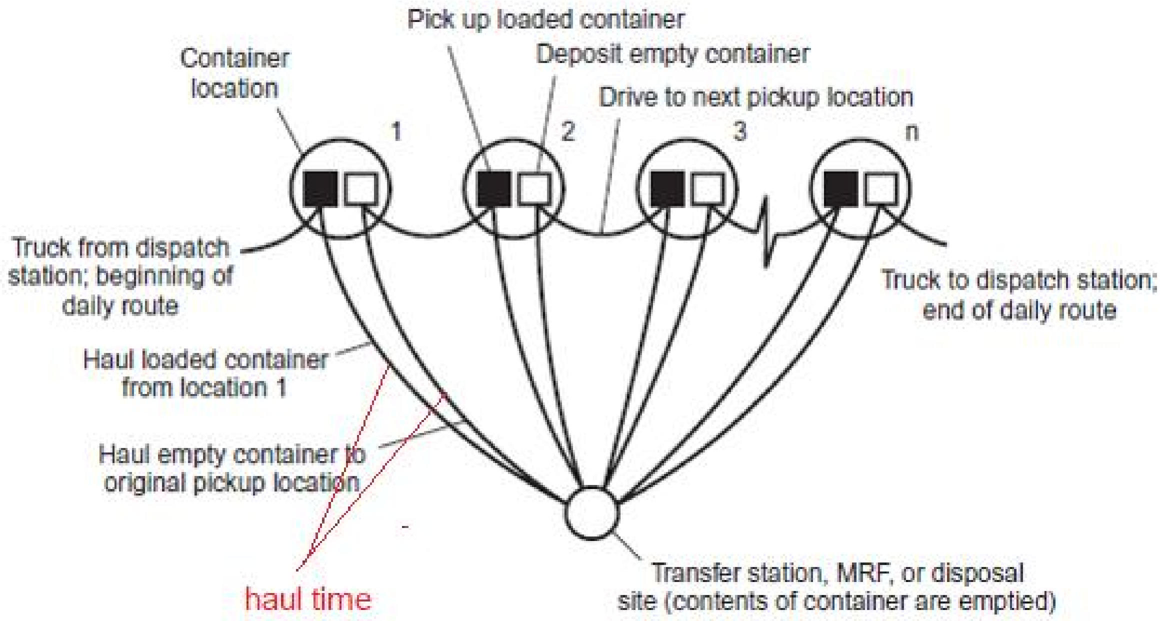
It refers to the time spent in-

- Picking up the loaded container (pc)
- Re-desposition of the container after it has been emptied(uc)
- Driving to the next container after an empty container has been deposited (dbc)



Haul (h_{hcs})

The time required to reach the location where the waste will be emptied, starting when the container has been loaded on the truck and continuing through unloading until the truck arrives at the location where the empty container is to be re-deoposited



At Site (s)

- The time spent at the site (landfill, MRF, Transfer station)where the waste to be unloaded
- It also includes the time spent waiting to unload as well as the time spent unloading the wastes from the container (HCS) or(SCS)

Offroute (w)

- The unit operation off route (W) includes all time spent on activities that are non productive from the point of view of the overall collection operations. **Typically 15%**
- Off route time divided into two

1. **Necessary off route**

Includes-time spending checking in and out in the morning at the end of the day

- Time spent driving to the first pickup point and from location of last pickup point to the dispatch station at the need of the day
- Time lost due to unavoidable congestion
- Time spent on equipment repairs and maintenance

2. **Unnecessary off route**

Time spent for lunch

Time spent on taking unauthorized coffee breaks, talking to friends

EQUATIONS FOR DESIGN OF HAUL CONATINER SYSTEM

- **Time per trip**

$$T_{hcs}\ (h/trip) = P_{hcs} + s + h$$

P_{hcs}= pickup time , P_{hcs} = pc+uc+dbc

s = time at site

h = haul time

- **The haul time (h/trip)**

Generally haul time depends on the haul speed and distance.

The haul time (h/trip) mat be expressed as a function of the distance travelled

$$h = a + bx$$

a= empirical haul-time constant (h/trip)
b= empirical haul-time constant (h/trip)
x =average round trip haul distance (m/trip)

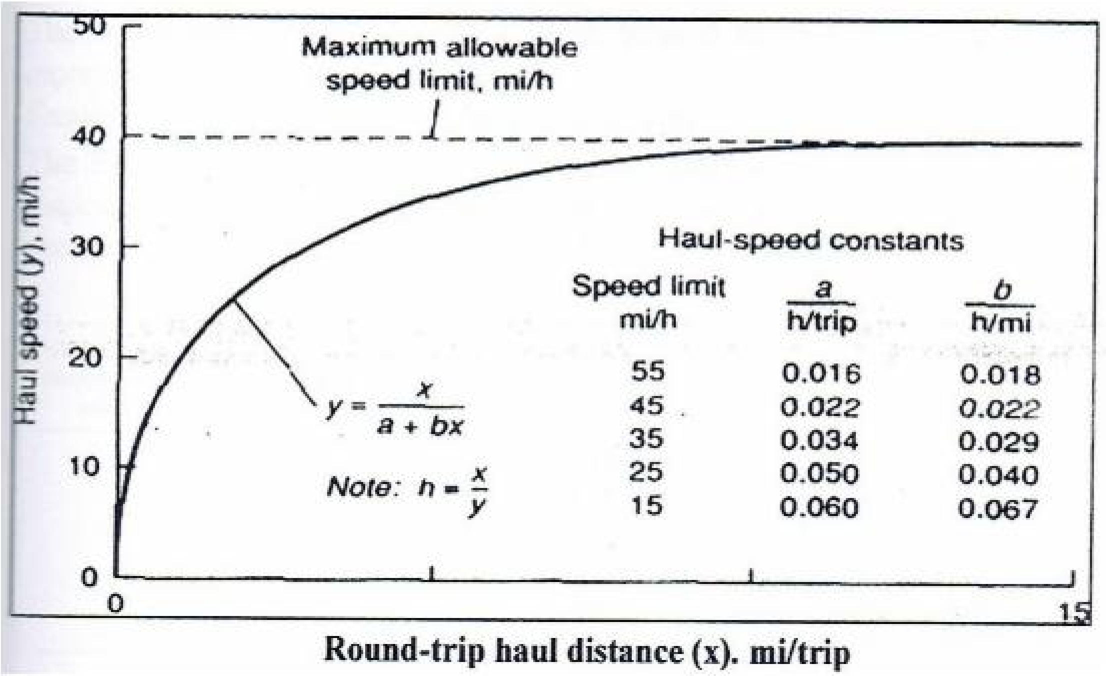


Fig6.8: Correlation between average haul speed and round-trip haul distance for waste collection vehicles.

EQUATIONS FOR DESIGN OF HAUL CONATINER SYSTEM cont.

- **Number of trips** $N_d = [H(1-w)-(t_1+t_2)]/T_{hcs}$

N_d = No of trips per day (trips/d)

H = length of work day (h/d)

w= off route factor, expressed as a fraction

t_1 = time to drive between dispatch station to first container location to be services for the day(h)

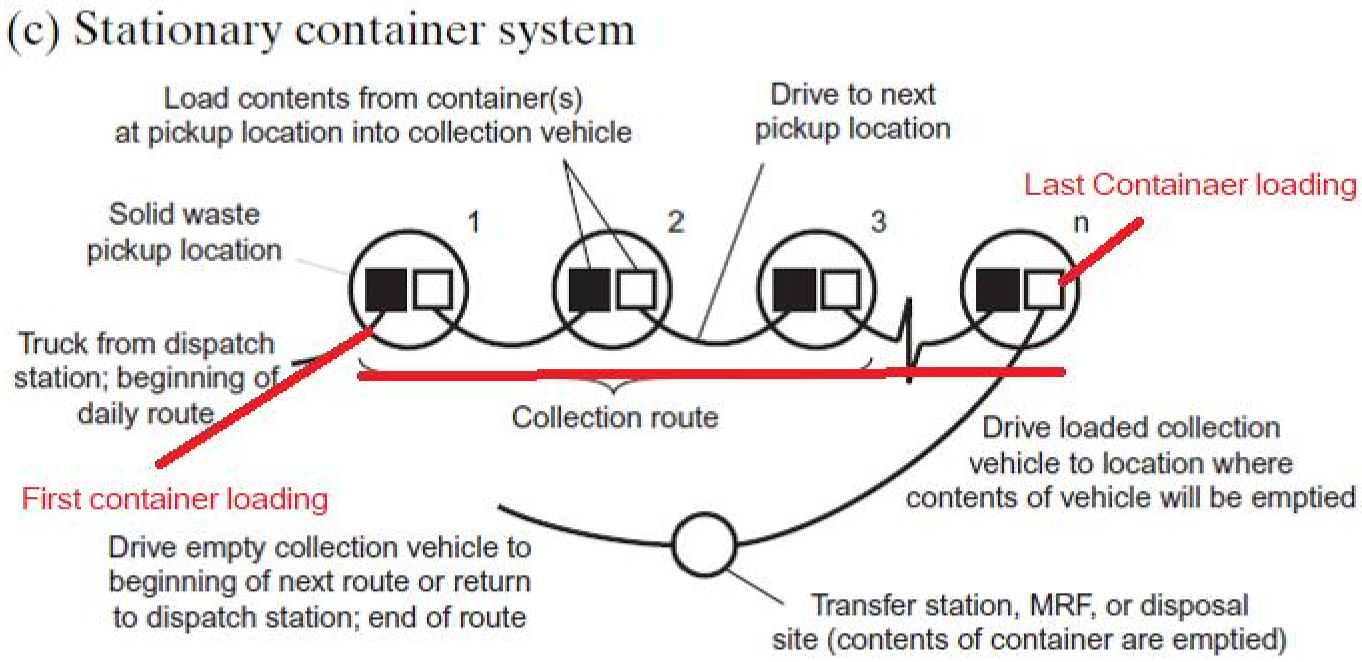
t_2 = time to drive between last container location to be serviced for the day to the dispatch station(garage) (h)

T_{hcs} = pickup time per trip (h/trip)

STATIONARY CONATINER SYSTEM

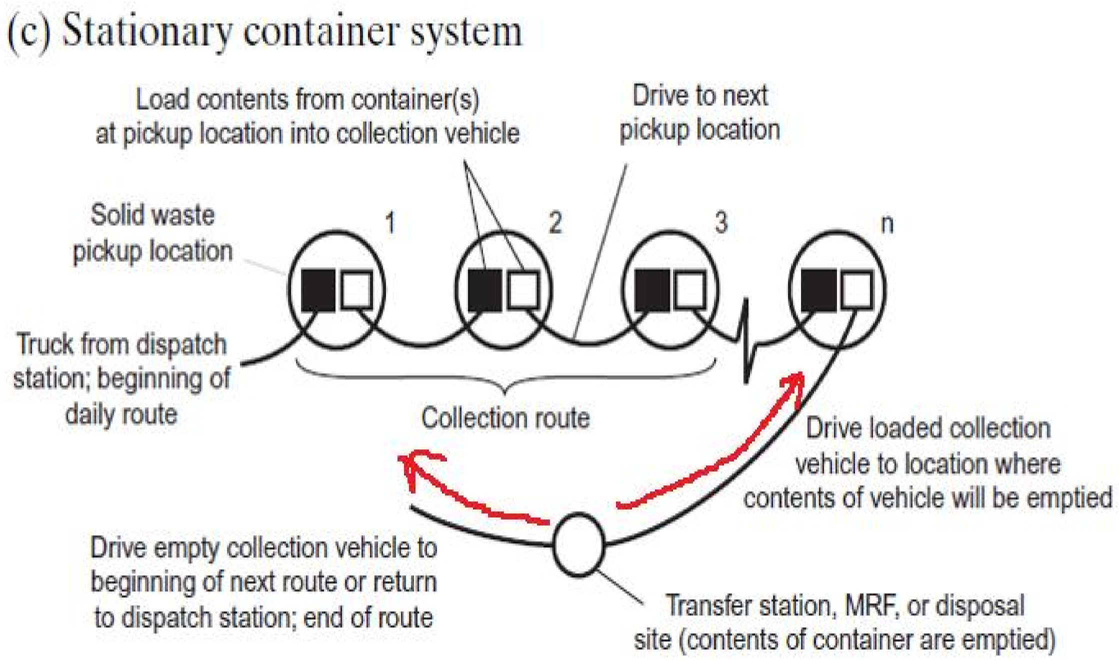
Pickup(P_{hcs})

- It refers to the time spent in loading the vehicle, beginning with the stop to load the first container and ending when the last container has been loaded



Haul (h_{scs})

- The time required to reach the location where full vehicle will be emptied and continuing until the truck arrives at the location where the first container will be emptied for the next route
- It neither include actual picking up of loading container or re deposition if the empty container nor time spent at the location where the waste is unloaded
- **At site (s)**
- **Off Route (w)**



EQUATIONS FOR DESIGN OF STATIONARY CONATINER SYSTEM

Mechanically Loaded vehicles

$$T_{scs}\ (h/trip) = P_{scs} + s + a + bx$$

T_{scs} = time per trip (h/trip)

P_{scs}= pickup time per trip (h/trip)

s = at site per trip (h/trip)

a , b = empirical constant (h/trip)

x = average round trip haul distance(mi/trip)

Pickup Time per trip (h/trip)

$$P_{scs} = C_t\ (uc) + (N_p - 1)(dbc)$$

C_t = no of container emptied per day(container /trip)

uc = avg unloading time per stationary container (h/container)

Np = no of container pickup location per trip(location/ trip)

dbc= time required to drive between container location(h/location)

The pickup time depends upon the number of containers multiplies by the unit loading time plus the number of location times the driving time between the locations

EQUATIONS FOR DESIGN OF STATIONARY CONATINER SYSTEM Cont.

- **No of trips per day**

$$N_d = V_d / vr$$

N_d = no of collection trips required per day (trips/d)

V_d = avg daily quantity of waste collected (yd3/d)

v = volume of collection vehicles (yd3/trip)

r = compaction ratio

- **Time required per day**

$$H = [(t_1 + t_2) + N_d \, T_{scs}] / (1 - W)$$

t_1 = time to drive between dispatch station to first container location to be picked up on the first route of the day, h

t_2 = time to drive from the approximate location of the last container pickup on last route of the day to the dispatch station, h

EQUATIONS FOR DESIGN OF STATIONARY CONATINER SYSTEM Cont.

Manually Loaded collection vehicles

$$N_p = 60nP_{scs}/t_p$$

N_p =no of pickup locations per trip

60 = conversion factor from hour to minutes

P_{scs} = pickup time per trip(h/trip)

n = no of collectors(labours)

t_p = pickup time per pickup locations

The pick up location (tp) per location depends on the time required to drive between container locations, the number of containers per pickups locations and the percent of rear of house pickup locations

$$t_p = dbc + k_1 + C_n + k_2(PRH)$$

T_p = avg pickup time per pickup locations(collector –min/location)

dbc = avg time spent driving b/w container locations(h/locations)

K_1= constant related to the pickup time per container (min/container)

C_n= avg no of container at each pickup locations

K_2= constant related to the time required to collect waste from the backyard of residence (min/PRH)

PRH= rear of house pickup locations(percent)

Collection Route

- In either private or public operations, it is important to set labor and equipment requirements for each type of service.
- Once the equipment and labor requirements have been determined, collection routes must be laid out so that both the collectors and equipment are used effectively.
- In general, the layout of collection routes involves a series of trials
- There is no universal set of rules that can be applied to all situations.
- Thus, collection vehicle routing remains today a heuristic (common-sense) process.

Guidelines for laying collection routes

- Existing policies and regulations related to such items as the point of collection and frequency

of collection must be identified.

- Existing systems, such as crew size and vehicle types, must be coordinated.

- Wherever possible, routes should be laid out so that they begin and end near arterial

streets, using topographical and physical barriers as route boundaries.

- In hilly areas, routes should start at the top of the grade and proceed downhill as the vehicle

becomes loaded.

- Routes should be laid out so that the last container to be collected on the route is located

- Wastes generated at traffic-congested locations should be collected as early in the day as possible.
- Sources at which extremely large quantities of wastes are generated should be serviced during the first part of the day.
- Scattered pickup points where small quantities of solid waste are generated that receive the same collection frequency should, if possible, be serviced during one trip or on the same day.

Layout of Collection Routes

The four general steps involved in establishing collection routes include:

1. Preparation of location maps showing pertinent data and information concerning the waste generation sources

The map should show collection service garage locations, disposal or transfer sites, one-way streets, natural barriers, and areas of heavy traffic flow, number of containers, collection frequency.

2. Data analysis and, as required, preparation of information summary tables

For HCS, Summarize the number of pickup locations and determine the number of containers to be collected each day.

For SCS, estimate the quantity of wastes collected from pickup locations.

3. Preliminary layout of routes

Lay out preliminary collection routes starting from the dispatch station. A route should be laid by considering all the factors.

Thorough collection routes and schedules must be developed for the proposed collection program. Efficient routing and rerouting of collection vehicles decrease costs by reducing the labor expended for collection.

Routing procedures usually comprise two separate components:

- microrouting and
- macrorouting.

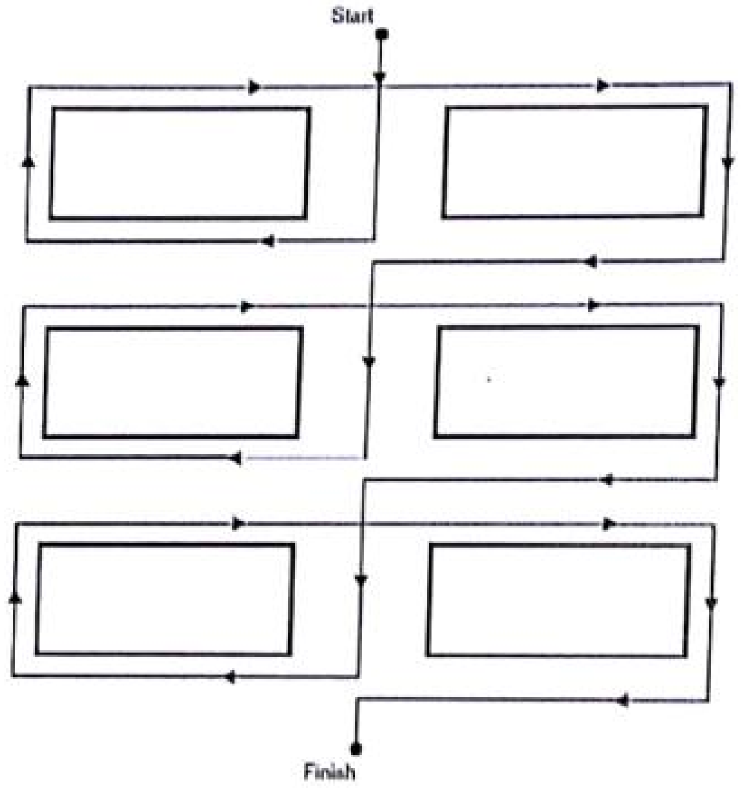
Macrorouting consists of dividing the total collection area into routes of a size sufficient for a 1 day collection for a single crew. The size of a route is a function of the amount of waste collected per stop, distance between stops, loading time, and traffic conditions. Barriers such as railroad embankments, rivers, and roads with heavy competing traffic can be used to divide route areas. For large areas, macrorouting is best accomplished by first dividing the entire community into districts. Each district is subsequently divided into routes for individual crews.

Using the results of the macrorouting analysis, microrouting will designate the specific path that each crew and collection vehicle will take on a given day. Results of microrouting analyses can then be used to readjust macrorouting decisions. Microrouting analyses and planning can accomplish the following:

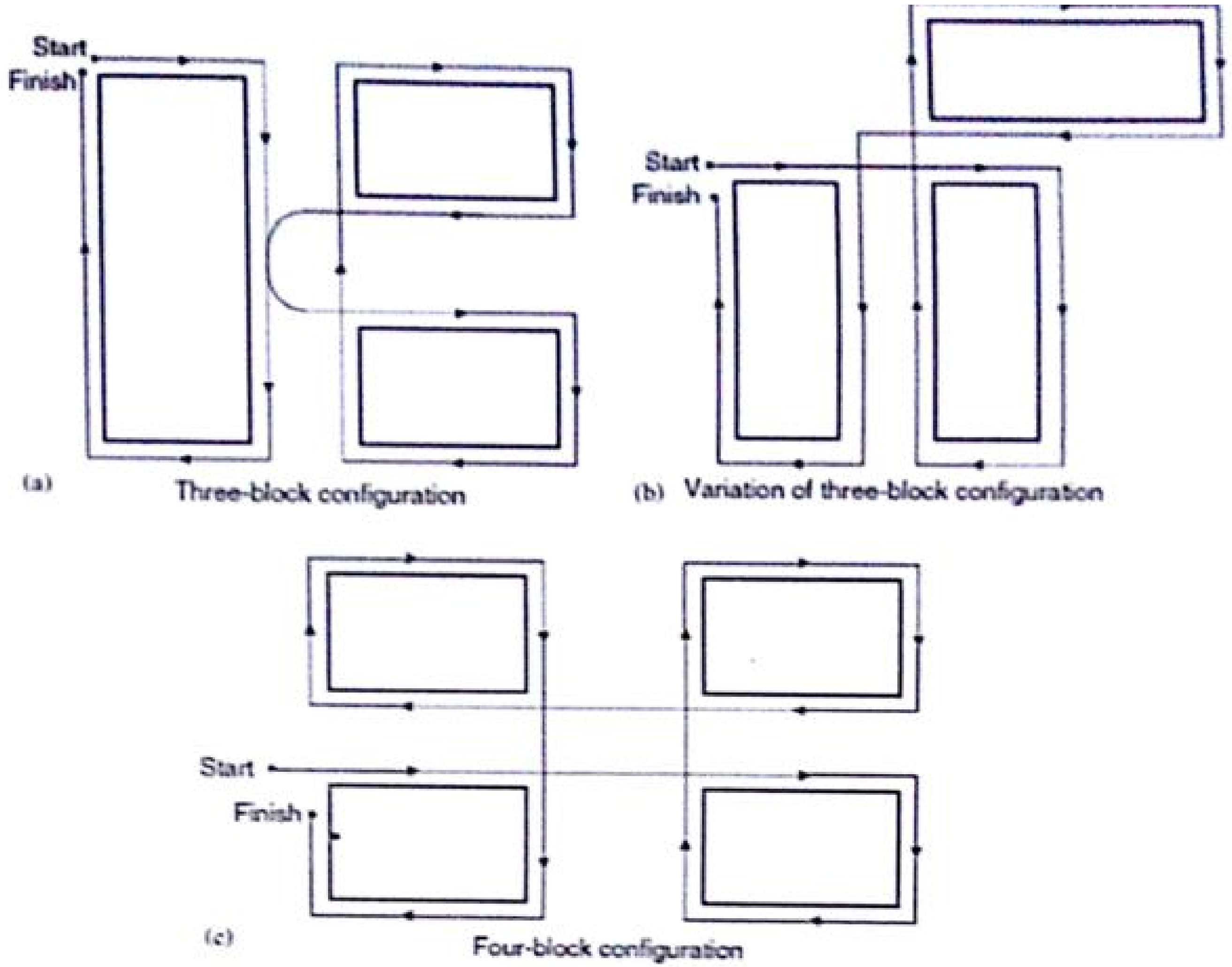
- Increase the likelihood that all streets will be serviced equally and consistently.
- Help supervisors locate crews quickly because they know the specific routes that will be taken.

4. Evaluation of the preliminary routes and the development of balanced routes by successive trials

Develop balanced routes. After the preliminary collection routes have been laid out, the haul distance for each route should be determined. In some cases it may be necessary to readjust the collection routes to balance the work load and the distance traveled. After the balance, routes have been established they should be drawn on the master map.



Routing patterns for one-way street collection



Routing patterns for three- and four-block configurations

Components of Waste collection system:

1)Collection points:

- These affect collection system components such as crew size and storage, which ultimately control the cost of collection.
- Collection points depend on locality and may be residential, commercial or industrial.

2)Collection frequency:

- Climatic conditions ,requirements of a locality and containers and costs determine the collection frequency.
- In hot and humid climates, for example, solid wastes must be collected at least twice a week, as the decomposing solid wastes produce bad odour and leachate.
- Residential wastes contain food wastes and other putrescible (rotting) material, so frequent collection is desirable for health and aesthetic reasons.
- Quality of solid waste containers on site determines the collection frequency. For instance, while sealed or closed containers allow collection frequency up to three days, open and unsealed containers may require daily collection.
- Collection efficiency largely depends on the demography of the area (such as income groups, community, etc.), where collection takes place.

Advantages and Disadvantages of Different Collection Frequencies

Alternative	Potential Advantages	Potential Disadvantages	Favoring Conditions
Once per week or less	Less expensive, Requires less fuel	Improperly stored waste can create odor and vector problems	Cold to moderate climate
Twice per week	Reduces litter, Reduces storage requirements	More expensive, Requires more fuel	Warm climate
More than twice per week	Reduces litter, Reduces storage requirements	More expensive, Requires more fuel	Dense population

The following factors must be considered while deciding collection frequency:

- Cost

  -optimal collection frequency reduces the cost as it involves fewer trucks, employees and reduction in total route distance

- Storage space

  -less frequent collection may require more storage space in the locality

- Sanitation

  -frequent collection reduces concerns about health, safety and nuisance associated with stored refuse.

3)Storage containers:

- Proper container selection can save collection energy, increase the speed of collection and reduce crew size.
- Most importantly, containers should be functional for the amount and type of materials and collection vehicles used.
- Containers should also be durable, easy to handle, and economical, as well as resistant to corrosion, weather and animals.
- In residential areas, where refuse is collected manually, standardised metal or plastic containers are typically required for waste storage.
- The residential waste containers must serve the following:
  - Efficiency – the containers should help maximise the overall collection efficiency.
  - Convenience –the containers must be easily manageable both for residents and collection crew.
  - Compatibility – the containers must be compatible with collection equipment.
  - Public health and safety – the containers should be securely covered and stored.
  - Ownership –the municipal ownership must guarantee compatibility with collection

4)Collection crew

- The optimum crew size for a community depends on labour and equipment costs, collection methods and route characteristics.
- The size of the collection crew also depends on the size and type of collection vehicle used, space between the houses, waste generation rate and collection frequency.
- The collection vehicle could be a motorised vehicle, a pushcart or a trailer towed by a suitable prime mover (tractor, etc.).
- An effective collection crew size and proper workforce management can influence the productivity of the collection system.
- With increase in collection costs, there will be:
  - decrease in the frequency of collection;
  - increase in the dependence on residents to sort waste materials;
  - increase in the degree of automation used in collection.

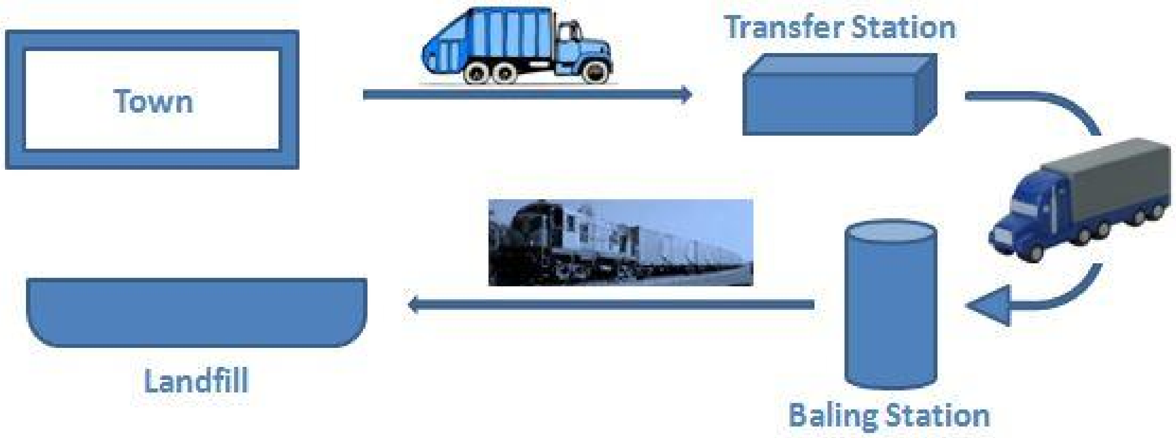
5)Collection route

- The collection programme must consider the route that is efficient for collection.
- An efficient routing of collection vehicles helps decrease costs by reducing the labour expended for collection.
- Proper planning of collection route also helps conserve energy and minimise working hours and vehicle fuel consumption.
- It is necessary therefore to develop detailed route configurations and collection schedules for the selected collection system.
- The size of each route, however, depends on the amount of waste collected per stop, distance between stops, loading time and traffic conditions.
- Barriers, such as railroad, embankments, rivers and roads with heavy traffic, can be considered to divide route territories.

- Routing (network) analyses and planning can:
  - increase the likelihood of all streets being serviced equally and consistently;
  - help supervisors locate or track crews quickly;
  - provide optimal routes that can be tested against driver judgement and experience.

6)Transfer station:

- A typical system includes several stations, located at various points in a city, to which collection trucks bring the refuse.
- The drive to each transfer station is relatively short. This is to increase collection efficiency.
- At the transfer station, bulldozers pack the refuse into large containers that are trucked to the landfill or other disposal facility.
- Alterr



al.

Transfer station

- The following factors that affect the selection of a transfer station:
  - Types of waste received.
  - Processes required in recovering material from wastes.
  - Required capacity and amount of waste storage desired.
  - Types of collection vehicles using the facility.
  - Types of transfer vehicles that can be accommodated at the disposal facilities.
  - Site topography and access.

Need for a transfer station is indicated by the following

- Presence of illegal dumps and litter
- Remote disposal sites (> 10 miles)
- Small capacity collection vehicles (< 20 yd^3)
- Low density residential areas
- Widespread use of medium sized commercial containers

Types of Transfer Stations

- Direct discharge
- Storage discharge
- Combined direct & storage discharge

Checklist of Variables Affecting Collection System

Components	Factors to Consider	
Crew size	• labour cost • distance between containers • size and types of containers • loading accessories available in the truck • collection vehicle used	
Container type	• solid wastes generation rate • density of waste generation • street width • traffic volume • collection crew configuration • standard of living	
Collection accessory	• labour cost • protection of worker's health	
Vehicle size/type	• street width, traffic volume • solid waste generation rates • crew size • viability of a transfer station	
Collection route	• street width, traffic volume • direction of traffic flow • solid waste generation rates • spatial distribution of wastes • local topography	
Transfer station	• distance between disposal site and collection area • hauling cost for small and large trucks • cost of transferring the solid wastes from small to large trucks	

Source: Phelps, et al., 1995

Collection Options

1. City-Run Collection

- More control over collection
- City owns and operates all equipment
- City manages personnel
- Funded from property tax, user fees, or utility bill

- Advantages
  - Non-profit
  - Centralized operation
  - City maintains complete control over waste
- Disadvantages
  - Municipalities tend to be less efficient than private companies
  - Capital expenditures can be difficult.
  - May require bond
  - Tendency to minimize short-term spending without considering long-term implications

2. Private Collection

City gives contract to firm(s) as a set fee based on bidding process, users are billed directly:

Non-Exclusive Franchises

- Multiple contractors competing for service in community

Exclusive Franchises

- One contractor is responsible for a given area

Advantages

- No capital expenditure for city
- Long-term lower costs
- Impose order on collection (exclusive franchise)
- Regular pickup schedules (exclusive franchise)
- Trash cans/trucks on street one or two days per week (exclusive franchise)
- Lower costs due to improved routing and technology (exclusive franchise)

Disadvantages

- Difficult to compete with large haulers
- Leads to domination by a few haulers (exclusive franchise)
- Citizens provide a profit to waste hauler
- City can become overly dependent

MSWM - MODULE IV

Processing

IV	Processing techniques- Mechanical volume and size reduction, chemical volume reduction, component separation, Drying (simple problems)	6

Purpose of processing

(i) Improving efficiency of SWM system

Various processing techniques are available to improve the efficiency of SWM system

- Baled wastes - reduce the haul costs at disposal site.
- compacted solid wastes – effective usage of available land.
- If solid wastes are to be transported hydraulically and pneumatically, shredding is required to improve the efficiency of the

Purpos e.......

(ii)Recovering material for <u>reuse</u>:

- Materials that can be recovered from solid wastes include paper, cardboard, plastic, glass, ferrous metal, aluminium and other residual metals.

(iii)Recovering conversion <u>products and energy</u>:

- Combustible organic materials can be converted to intermediate products and ultimately to usable energy.
- Process like incineration, pyrolysis, composting or bio- digestion.
- Separation of combustible organic matter from the other solid waste components - processing like shredding and drying - used for power generation.

MECHANICAL VOLUME REDUCTION

Reduce the volume (amount)of waste, as compared to its original form, and produce waste of uniform size.

Volume reduction or compaction –Densifying wastes to reduce their volume.

Advantages

i. Reduction in the quantity of materials to be handled at the disposal site;
ii. Improved efficiency of collection and disposal of wastes;
iii. Increased life of landfills;
iv. Economically viable waste management system.
v. More volume of solid waste can be hauled in less no. of trips

Disadvantages :

i. Poor quality of recyclable materials sorted out of compaction vehicle;
ii. Difficulty in segregation or sorting (since the various recyclable materials are mixed and compressed in lumps)i
iii. Bio-degradable materials (e.g., leftover food, fruits and vegetables) destroy the value of paper and plastic material.

Wastes are compressed- reduced volume

$$\text{Volume Reduction}(\%) = \frac{V_i - V_f}{V_f} \times 100$$

$$\text{Compaction ratio} = \frac{V_i}{V_f}$$

where V_i = volume of waste before compaction, m^3

V_f = volume of waste after compaction, m^3

Selection of compaction equipment

i. Characteristics such as size, composition, moisture content, and bulk density of the waste to be compacted.

ii. Method of transferring and feeding wastes to the compactor and handling.

iii. Potential uses of compacted waste materials.

iv. Design characteristics such as the size of loading chamber, compaction pressure, compaction ratio, etc.

v. Operational characteristics such as energy requirements, routine and specialized maintenance requirement, simplicity of operation, reliability, noise output, and air and water pollution control requirement.

Equipments for Volume reduction (or) Compaction:

Stationary Compactors:

- This represents the equipment in which wastes are brought to and loaded into container either manually or mechanically.
- Collection vehicle is equipped with compaction mechanism
- Suited at Residential,Industrial and commercial areas.

According to their application they are:-

- Light duty
- Commercial or light industrial
- Heavy industrial
- Transfer station compactors

Compactors used at transfer stations further be divided according to compaction pressure:

Low Pressure (< 7 kg / cm^2) Compactors:

- These compactors are used at apartments, commercial establishments.
- Example: Baling equipment – For waste papers & card boards

Stationary compactors – For transfer station

High Pressure (> 7Kg / cm 2)Compactors:

-Compact systems with a capacity up to 351.5 Kg / cm^2.

-specialized compaction equipment are used to compress solid wastes in to blocks (or) bales of various sizes

Movable Compactors:

- This represents the wheeled and tracked equipment used to place and compact solid wastes.
- Front end loaders(conveyor belt) and forklifts(bales) are commonly used units.

Equipment used for compactions

Types of Compaction Equipment

Location or Operation	Type of Compactor Stationary/residential	Remarks
Solid waste generation points	Vertical	Vertical compaction ram may be used; may be mechanically or hydraulically operated, usually hand-fed; wastes compacted into corrugated box containers, or paper or plastic bags; used in medium and high-rise apartments.
	Rotary	Ram mechanism used to compact waste into paper or plastic bags on rotating platform, platform rotates as containers are filled; used in medium and high-rise apartments.
	Bag or extruder	Compactor can be chute fed; either vertical or horizontal rams; single or continuous multi-bags; single bag must be replaced and continuous bags must be tied off and replaced; used in medium and high-rise apartments.

Location or Operation	Type of Compactor Stationary/residential	Remarks
	Under counter	Small compactors used in individual residences and apartment units; wastes compacted into special paper bags; after wastes are dropped through a panel door into a bag and door is closed, they are sprayed for odour control; button is pushed to activate compaction mechanism.
	Stationary/commercial	Compactor with vertical and horizontal ram; wastes compressed into steel containers; compressed wastes are manually tied and removed; used in low, medium and high-rise apartments, commercial and industrial facilities.

Collection	Stationary/packers	Collection vehicles equipped with compaction mechanism.
Transfer and/or processing station	Stationary/transfer trailer	Transfer trailer, usually enclosed, equipped with self-contained compaction mechanism.
	Stationary low pressure	Wastes are compacted into large containers.
	Stationary high pressure	Wastes are compacted into dense bales or other forms.
Disposal site	Movable wheeled or tracted equipment	Specially designed equipment to achieve maximum compaction of wastes.
	Stationary/track mounted	High-pressure movable stationary compactors used for volume reduction at a disposal site.

Source: Tchobanoglous, et al., (1993)

Size reduction or shredding

-Process of cutting or shredding thereby reducing the particle size to a finer state.

-Reduces bulky items to particles so that the size becomes compatible with the processing equipment.

-But note that size reduction does not necessarily imply volume reduction, and this must be factored into the des and operation of SWM systems as well as in the recovery of materials for reuse and conversion to energy.

Purpose

- Provide homogeneity- in land filling.
- Less cover material and less frequent covering than that without shredding.
- Increase the surface area of the reacting species in a chemical reaction, improves biological activities of organic materials.
- Recovering materials from the waste stream for recycling.
- Baling the wastes –long distance transport of solid wastes – to achieve a greater density.
- Make the waste a better fuel for incineration waste energy recovery facilities.

Advantages of size reduction:

i. Particle uniformity
ii. Uniform flow
iii. Effective drying
iv. Uniform mixing and drying
v. Increase surface area or viscosity
vi. Increase rate of absorption

Solid matter---Cracking, Crushing, Grinding—Smaller particles

Size reduction mechanisms:

i. Impact---eg:hammer
ii. Compression--particle disintegration
iii. Shear-- between 2 hard edges
iv. Attrition --collision against each other

Selection of size reduction equipment:

i. Operational characteristics

ii. Land availability

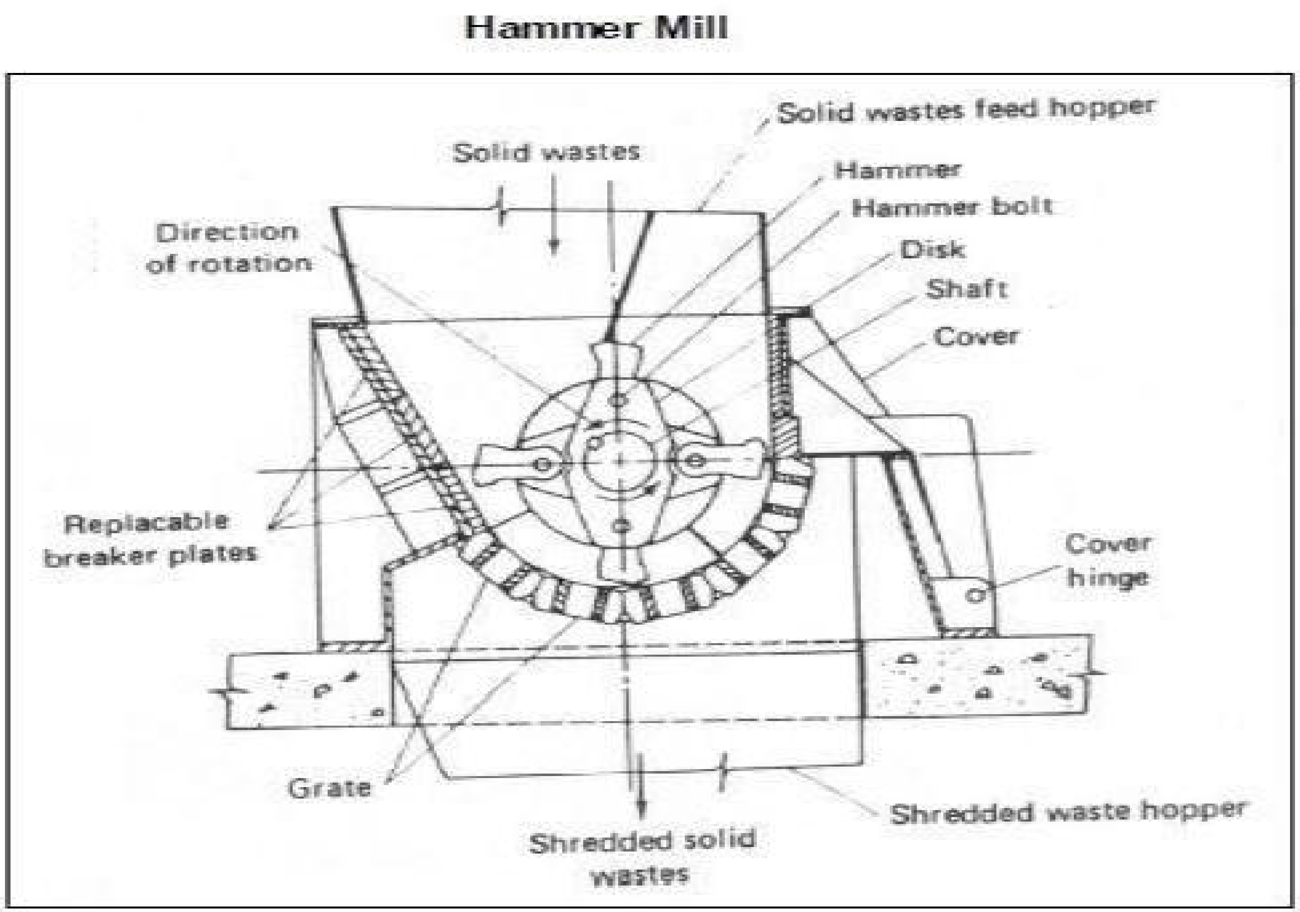
iii. Safety issues

Size Reduction Equipment

Type	Mode of action	Application
Small grinders	Grinding, mashing	Organic residential solid wastes
Chippers	Cutting, slicing	Paper, cardboard, tree trimmings, yard waste, wood, plastics
Large grinders	Grinding, mashing	Brittle and friable materials, used mostly in industrial operation
Jaw crushers	Crushing, breaking	Large solids
Rasp mills	Shredding, tearing	Moistened solid wastes
Shredders	Shearing, tearing	All types of municipal wastes
Cutters, Clippers	Shearing, tearing	All types of municipal wastes
Hammer mills	Breaking, tearing, cutting, crushing	All types of municipal wastes, most commonly used equipment for reducing size and homogenizing composition of wastes
Hydropulper	Shearing, tearing	Ideally suited for use with pulpable wastes, including paper, wood chips. Used primarily in the papermaking industry. Also used to destroy paper records

Hammer mill

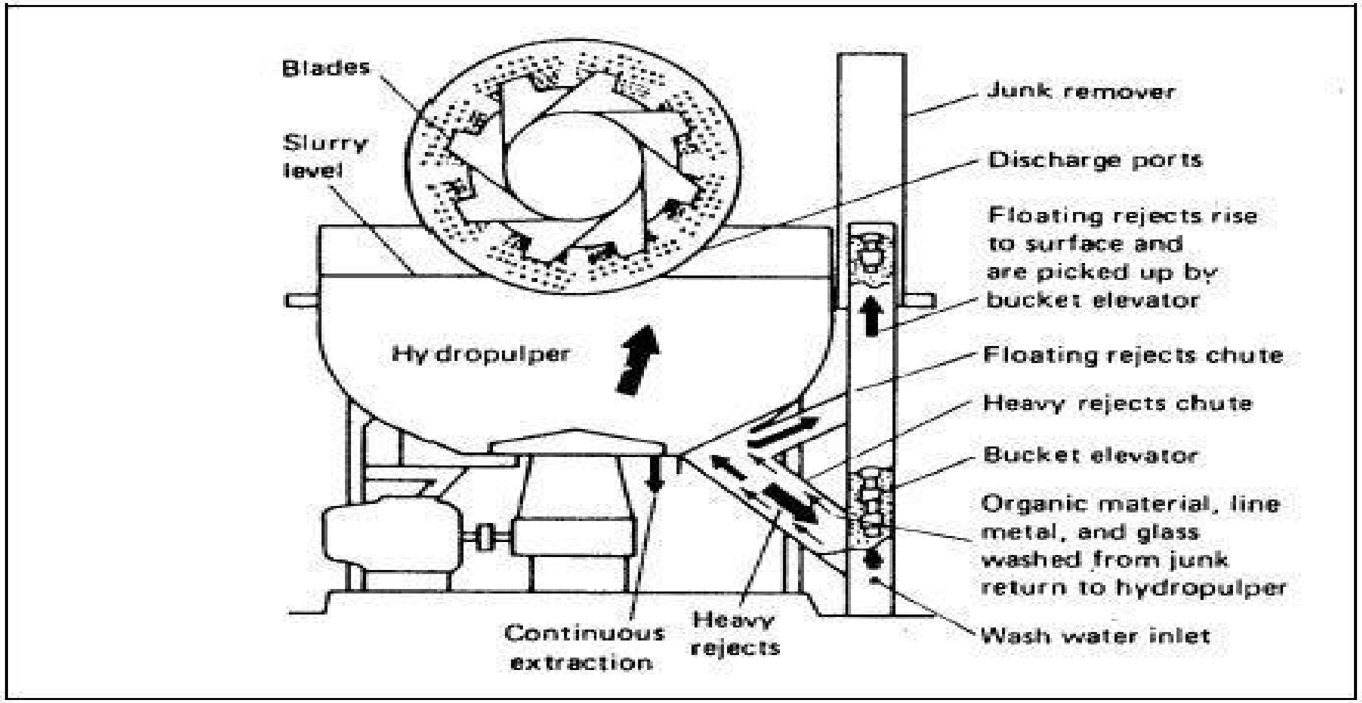
- Solid wastes are hit by sufficient force – crush or tear them with a velocity so that they do not adhere to the hammers.
- Wastes are reduced in size by being struck between breaker plates and/or cutting bars fixed around the periphery of the inner chamber.
- On ... he bottom of ...



Hydropulper

- Solid wastes and recycled water are added to the hydropulper.
- High-speed cutting blades- mounted on a rotor –slurry (2.5 to 3.5% solid content)
- Metal, tins, cans and hard (non-pulpable or non-friable) materials are rejected
  from the hydropulper tank.
- Rejected material passes down a chute , solid slurry passes out through the

Hydropulper: An Illustration

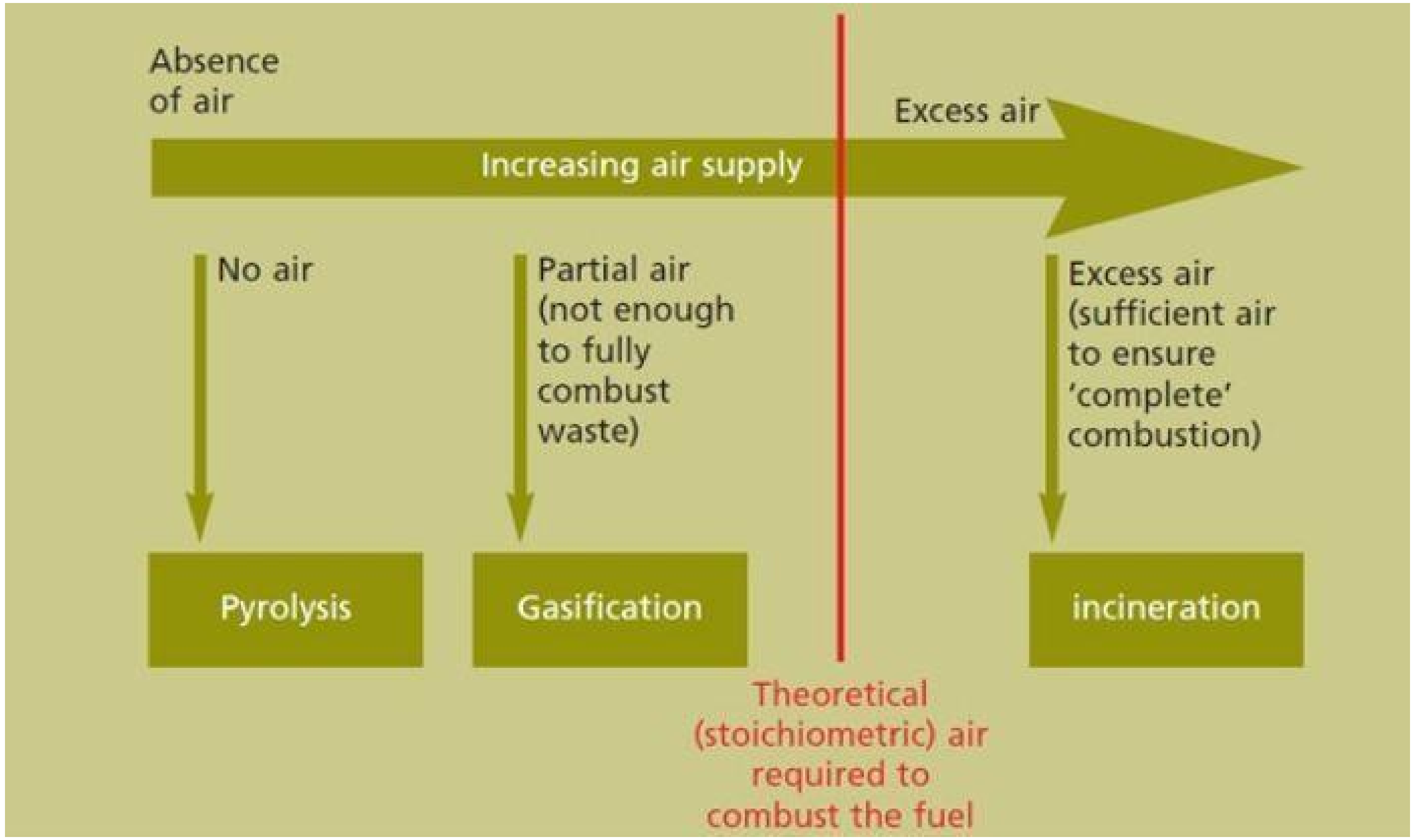


Chemical volume reduction:

- Chemical volume reduction is a method, wherein volume reduction occurs through chemical changes brought within the waste either through as addition of chemicals or changes in temperature
- Incineration is the most common method used to reduce the volume of waste chemically and is used both for volume reduction and power production
- These other chemical methods used to reduce volume chemically include pyrolysis, hydrolysis and chemical conversions

Chemical volume reduction:

Incineration, Pyrolysis, Gasification.



INCINERATION PROCESS

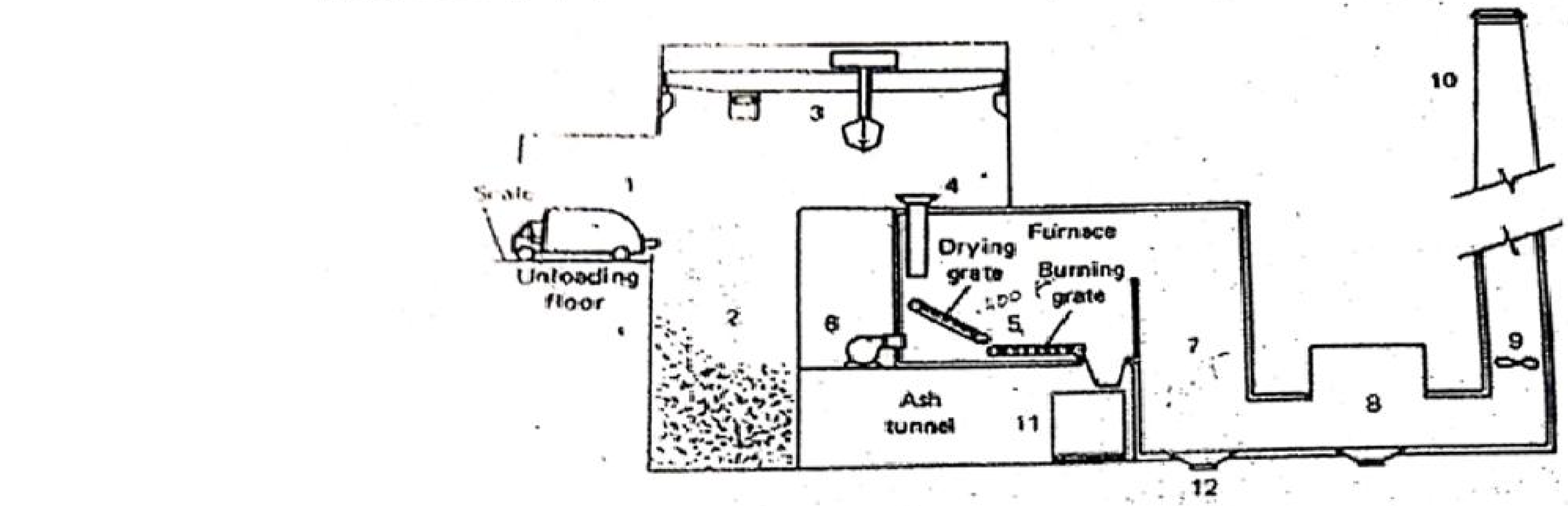
Description of incineration process

The operation begins with the unloading of solid wastes from collection trucks (1) into storage bin (2). The length of the unloading platform and storage bin is a function of the number of trucks that must unload simultaneously. The depth and width of the storage bin are determined by both the rate at which waste loads are received and the rate of burning. Storage capacity usually averages about the volume of 1 day. The overhead crane (3) is used to batch load wastes into the charging hopper (4). The crane operator can select the mix of wastes to achieve fairly even moisture content in the charge. Large or incombustible items are also removed from the wastes. Solid wastes from the charging hopper fall onto the stokers (5) where they are commonly used.

Air may introduce from the bottom of the grates by means of a forced-draft fan (6) or above the grates to control burning grates and furnace temperature. The hottest part of the fire is above the burning grates. The heated air rises over the incoming high-moisture wastes at the top of the drying grate and thus drives off the moisture to permit burning as the wastes travel down the grate. Because most organic wastes are thermally unstable, various gases are driven off in the combustion process taking place in the furnace, where the temperature is about 1400°F. These gases and small organic particles pass into a secondary chamber, commonly called combustion chamber (7). And burn at temperatures in excess of 1600°F. odor-producing compounds usually are destroyed at temperature above about 1400 to 1600 °F.

Some fly ash and other particulates may be carried through the combustion chamber. To meet local air pollution control regulations, space must be provided for air – cleaning equipment (8). To secure adequate air flows to provide for head losses through air cleaning equipment as well as to supply air to the incinerator itself, an induced fan (9) may be needed. Ti may also be done with forced draft fan.

The end products of incineration are the cleaned gases that are discharged to the stack (10). Ashes and unburned materials from the grates fall into a residue hopper (11) located below the grates where they are quenched with water. Fly ash which settles in the combustion chamber is removed by means of a fly ash sluiceway (12). Residue from the storage hopper may be taken to a sanitary landfill or to a resource recovery plant. Fly ash from the sluiceway and wastes from the air-cleaning equipments are taken to a sanitary landfill.



1. Collection truck
2. Storage bin
3. Overhead crane
4. Charging hopper
5. Traveling grate stokers
7. Combustion chamber
8. Gas cleaning equipment
9. Induced draft fan
10. Stack
11. Residue hopper
12. Flyash sluiceway

Pyrolysis process:

- Pyrolysis is a process of thermochemical organic materials at elevated temperatures in the absence of oxygen. The decomposition of organic components in the waste stream starts at 350°C–550°C and goes up to 700°C–800°C in the absence of air/oxygen.
- Unlike incineration is an endothermic reaction and hear must be applied to waste to distil volatile components
- Elevated temperature causes the organic solids (waste input) to breakdown via physical and chemical processes into three products;
  - solid residue (char)-**20-50% by weight**
  - biofuel (bio oil or pyrolysis oil)-tar, oil, water, organic acids, phenols, PAHs and alcohols)-30-50% **by weight**
  - high calorific value gas (synthetic gas or syngas) (H_2, CH_4,CO_2)- 20-50% by weight of the input

MSW pyrolysis will yield mainly:

i) Solid residues(Char) at low temperatures(< 450°C), when the heating rate is quite slow.

Constituents-combination of non-combustible materials and carbon.

Uses-Char is almost pure carbon and can be used in the manufacture of activated carbon filtration media (for water treatment applications) or as an agricultural soil amendment.

ii) Gases at high temperatures(> 800°C), with rapid heating rates which can easily be converted to electricity. This gas is highly combustable.

Constituents-Syngas is a mixture of energy-rich gases (combustible constituents include carbon monoxide, hydrogen, methane).

Uses-Syngas - combusted to generate electricity.

-

iii) liquid fuel (bio oil) at an intermediate temperature and under relatively high heating rates.

Constituents–Bio oil is a dark brown liquid – upgraded to either engine fuel or through gasification processes to a syngas –then to biodiesel.

Uses

-liquid fuel for diesel engines and gas turbines to generate electricity

-Bio oil is particularly attractive for co-firing because it can be relatively easy to handle and burn than solid fuel and is cheaper to transport and store.

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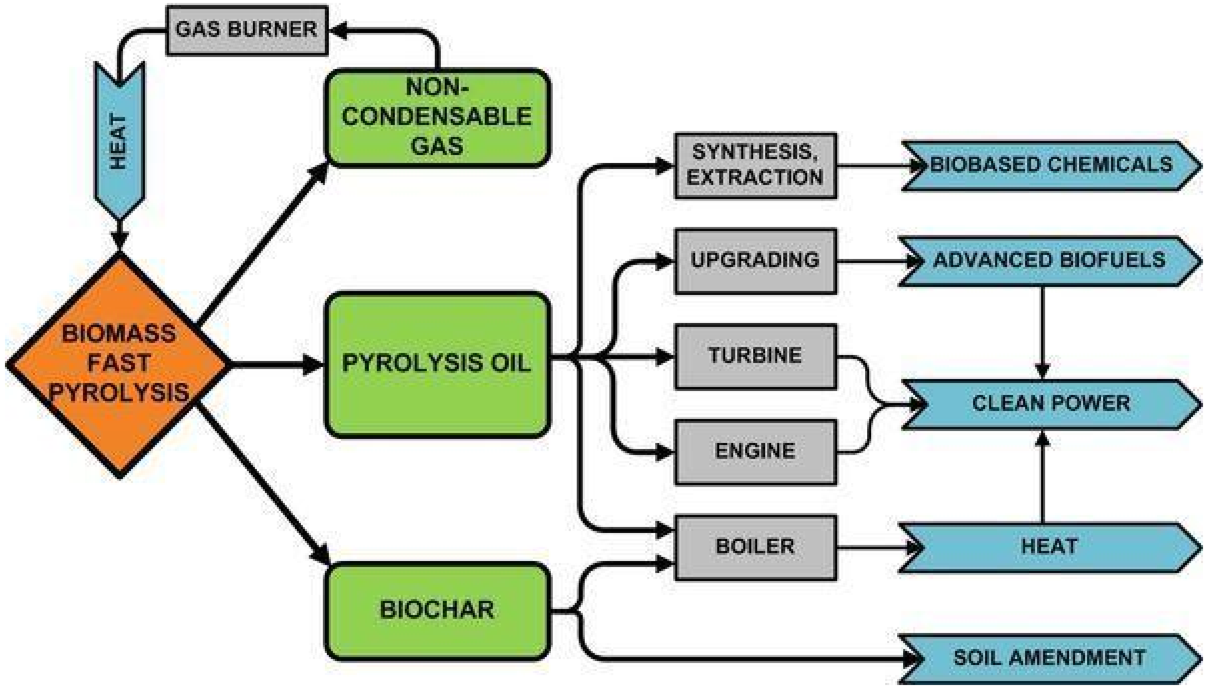
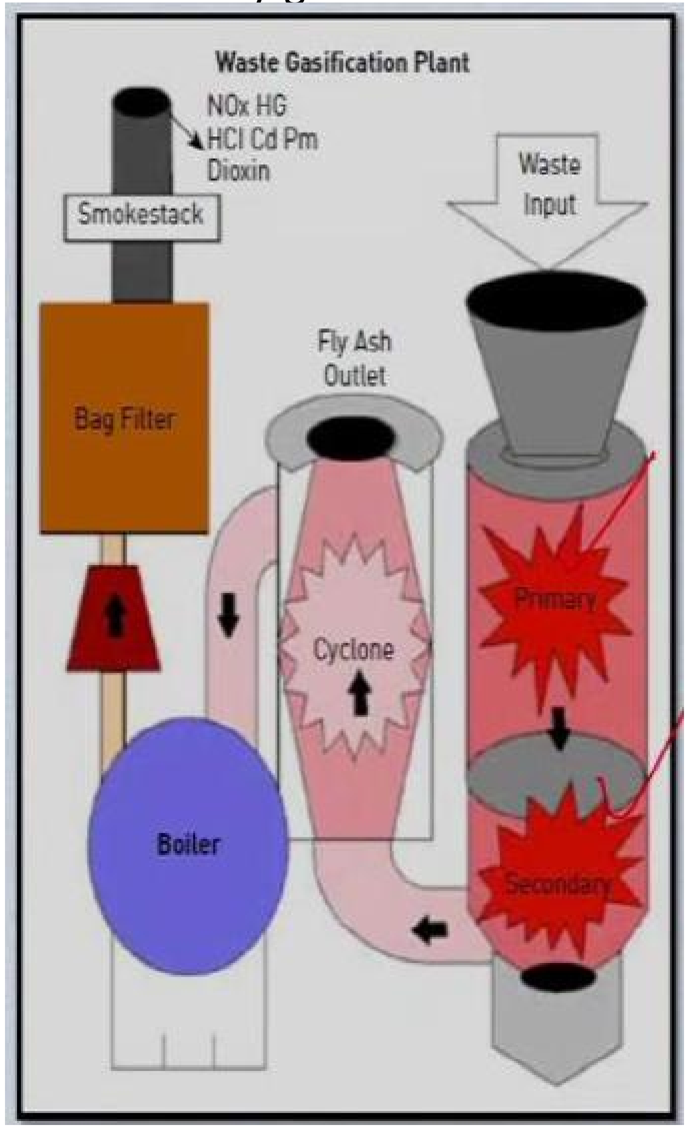


• GASIFICATION

- Gasification is thermal and chemical conversion (800-1500 ^oC) of carbon based material into a mainly gaseous output by partial oxidation with a gasification agent typically air, steam or oxygen



Products if gasification in general:

- Gas-(similar to pyrolysis gas but higher CO_2- 30-60% by weight
- Liquid (tar and oil)- 10-20% by weight of the input
- Solid (ashes)-30-50% by weight of the input

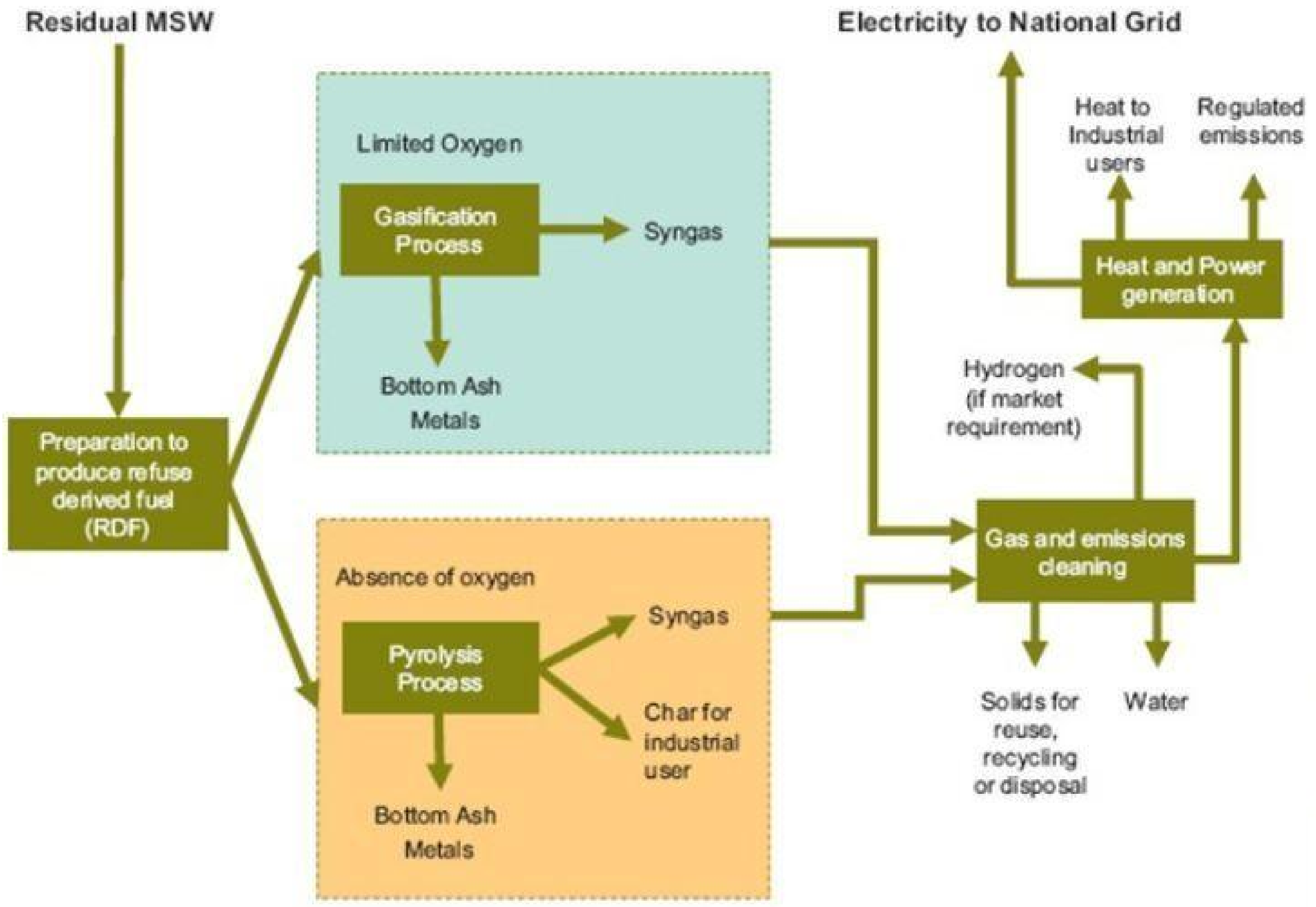
Gasification of MSW is accomplished in two chambers

Primary chamber

- Operated below the stoichiometric air requirement
- Waste is semi pyrolyzed releasing moisture and volatile component
- Heat is provided by the controlled combustion of fixed carbon within the waste

Secondary Chamber

- Operated under excess air conditions
- Syngas is driven odd contains a high calorific value and can act as a feedstock
- Combustion air is then added to the syngas making it highly combustible and prone to self ignition
- Equipped with burner to maintain operating temperature at all times


Residual MSW
Electricity to National Grid
Limited Oxygen
Gasification Process
Syngas
Bottom Ash
Metals
Heat to Industrial users
Regulated emissions
Heat and Power generation
Hydrogen (if market requirement)
Preparation to produce refuse derived fuel (RDF)
Gas and emissions cleaning
Absence of oxygen
Pyrolysis Process
Syngas
Char for industrial user
Bottom Ash
Metals
Solids for reuse, recycling or disposal
Water

Component Separation

-components are identified and sorted either manually or mechanically to aid further processing.

<u>Need:</u>

- recovery of valuable materials for recycling;
- preparation of solid wastes by removing certain components prior to incineration,
- energy recovery, composting and biogas production.

Mechanical techniques :

Air separation, magnetic separation

Other methods:

Hand separation, inertial separation, flotation, Optical sorting

Air separation

-primarily used to separate lighter materials (usually organic) from heavier (usually inorganic) one from dry mixtures

-lighter material may include plastics, paper and paper products and other organic materials- used as fuel for incinerators or as compost material.

-cyclone separator -separate the light fraction of organic material from the conveying air streams.

-heavy fraction is removed from the air classifier (i.e., equipment used for air separation) to the recycling stage or to land disposal.

This method mostly preferred in industries to separate the different component form the dry mixture

Factors that are to be considered for selection of air separation equipment:

- Characteristics of the material produced by shredding equipment including particle size, shape, moisture content and fibre content.
- Material specification for light fraction.
- Methods of transferring wastes from the shredders to the air separation units and feeding wastes into the air separator.
- Characteristics of separator design including solids-to-air ratio, fluidising velocities, unit capacity, total airflow and pressure drop.
- Operational characteristics including energy requirement, maintenance requirement, simplicity of operation, proved performance and reliability, noise output, and air and water pollution control requirements.
- Site considerations including space and height access, noise and environmental limitations.

Conventional chute type:

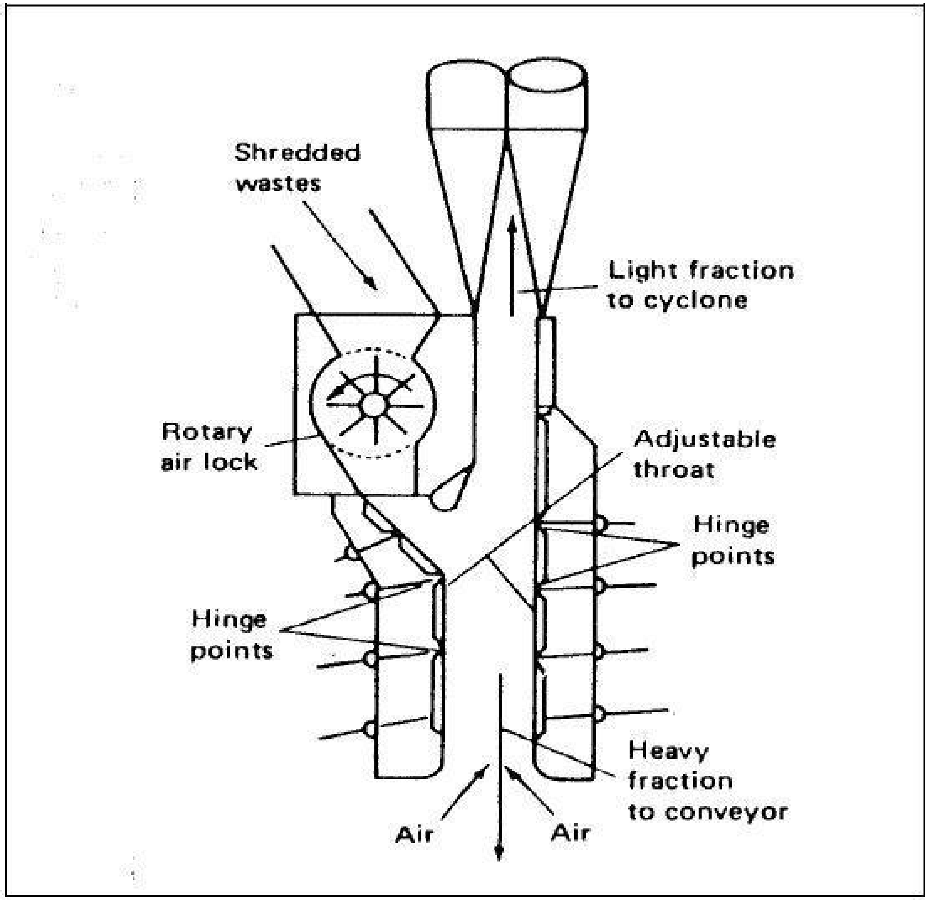
-simplest type

-processed solid wastes are dropped into the vertical chute.

-lighter material is carried by the airflow to the top while the heavier materials fall to the bottom of the chute.

-The control of the percentage split between the light and heavy fraction is accomplished by varying the waste loading rate, airflow rate and the cross section of chute.

-A rotary air lock feed mechanism is required to introduce the shredded wastes into the classifier.



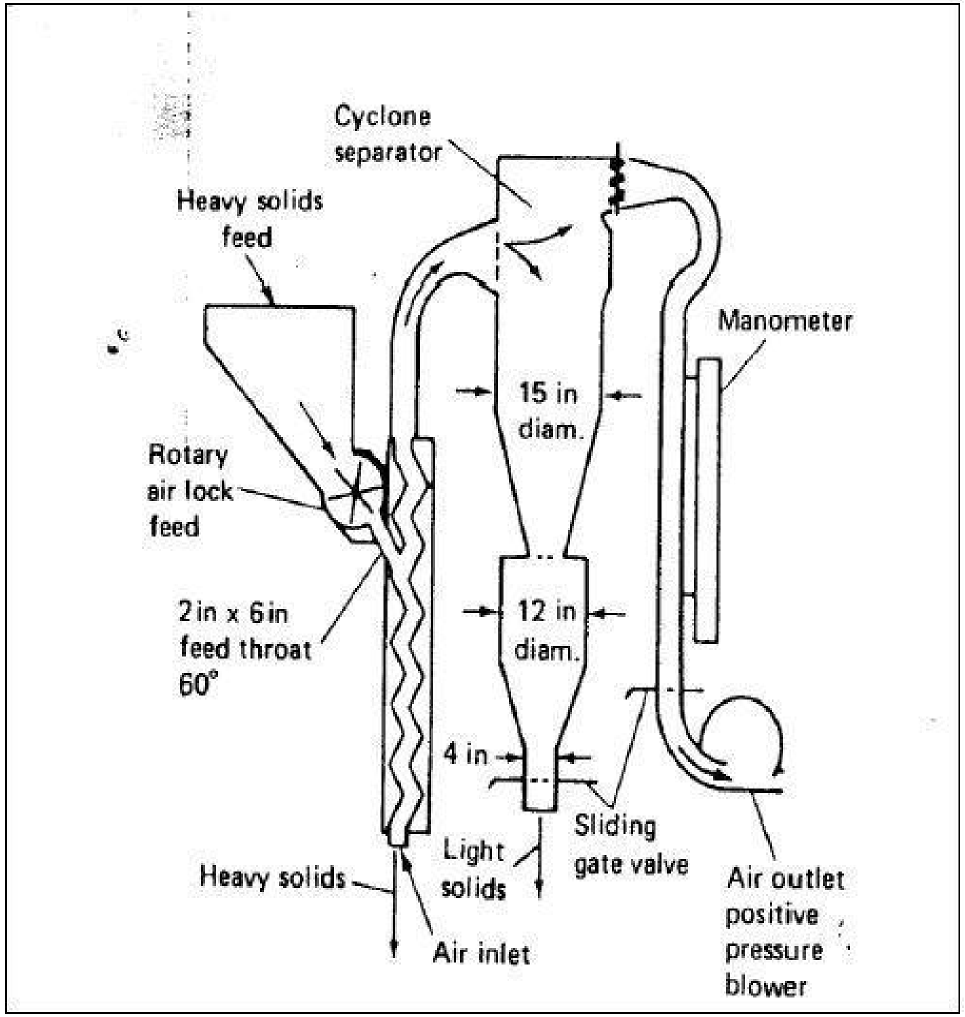
Zigzag air classifier:

-Consist of a continuous vertical column with internal zigzag deflectors through which air is drawn at a high rate

-Shredded wastes are introduced at the top of the column at a controlled rate and air is introduced at the bottom of the column.

-lighter fraction is fluidised and moves upward and out of column, while the heavy fraction falls to the bottom.

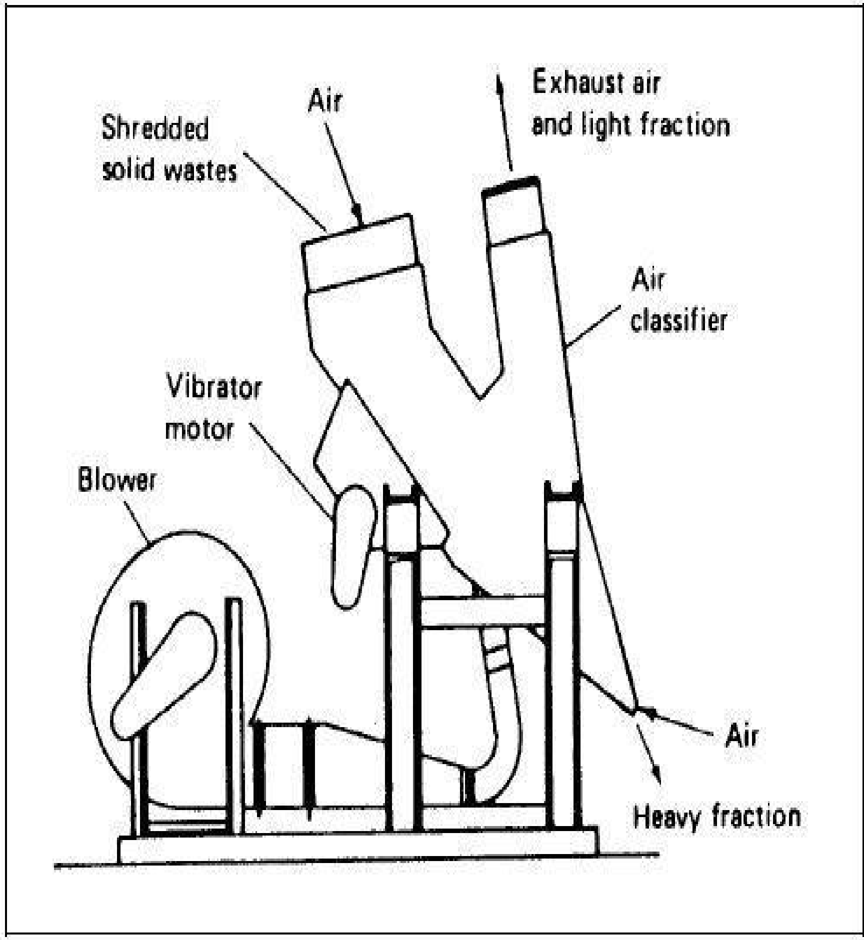
-best separation can be achieved through proper design of the separation chamber, air flow and influent feed rate



Open inlet vibrator type:

The separation is accomplished by a combing the following actions:

- Vibration: stratify the material fed to the separator into heavy and lighter components.
- Due to the agitation, the heavier particles tend to settle at the bottom as the shredded waste is conveyed down the length of the separator.
- Inertial force: Air pulled in through the feed inlet imparts an initial acceleration to the lighter particle, while the wastes travel down the separator as they are being agitated.
- Air pressure: Injection of fluidising air in two or more high velocity and low mass flow curtains across the bed.
- -Advantages of this classifier is that an air lock feed mechanism is not required and wastes are fed by gravity directly into separator inlet



Magnetic separation

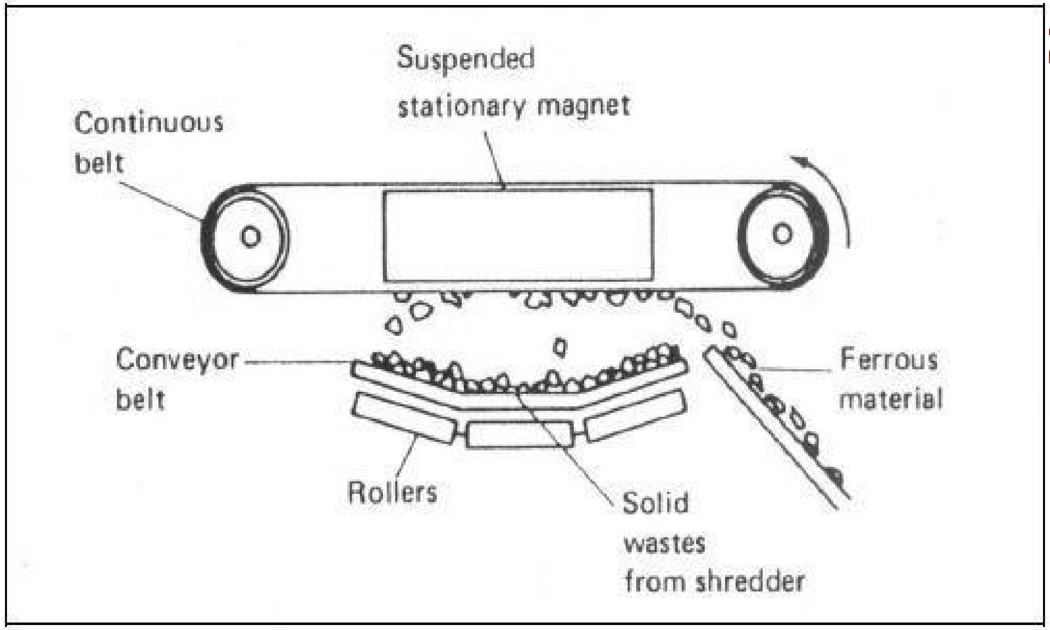
-recovering ferrous scrap from shredded solid wastes

Equipment used for magnetic separation:

Suspended magnet:

- Permanent magnet is used to attract the ferrous metal from the waste stream.
- When the attracted metal reaches the area, where

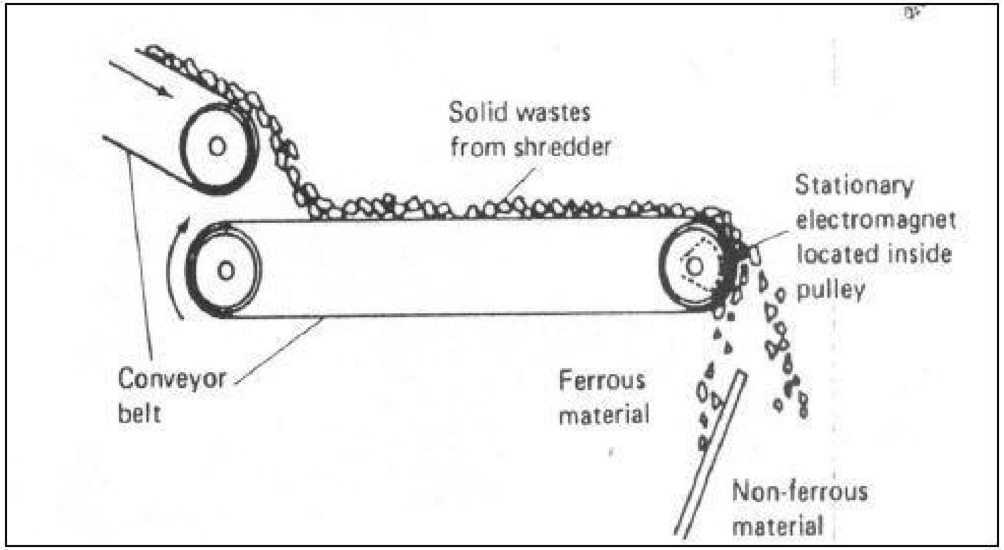
there is



freely.

Magnetic pulley:

- This consists of a drum type device containing permanent magnets or electromagnets over which a conveyor or a similar transfer mechanism carries the waste stream.
- The conveyor belt conforms to the rounded shape of the magnetic drum and the magnetic force pulls the ferrous material away from the falling stream of solid waste.



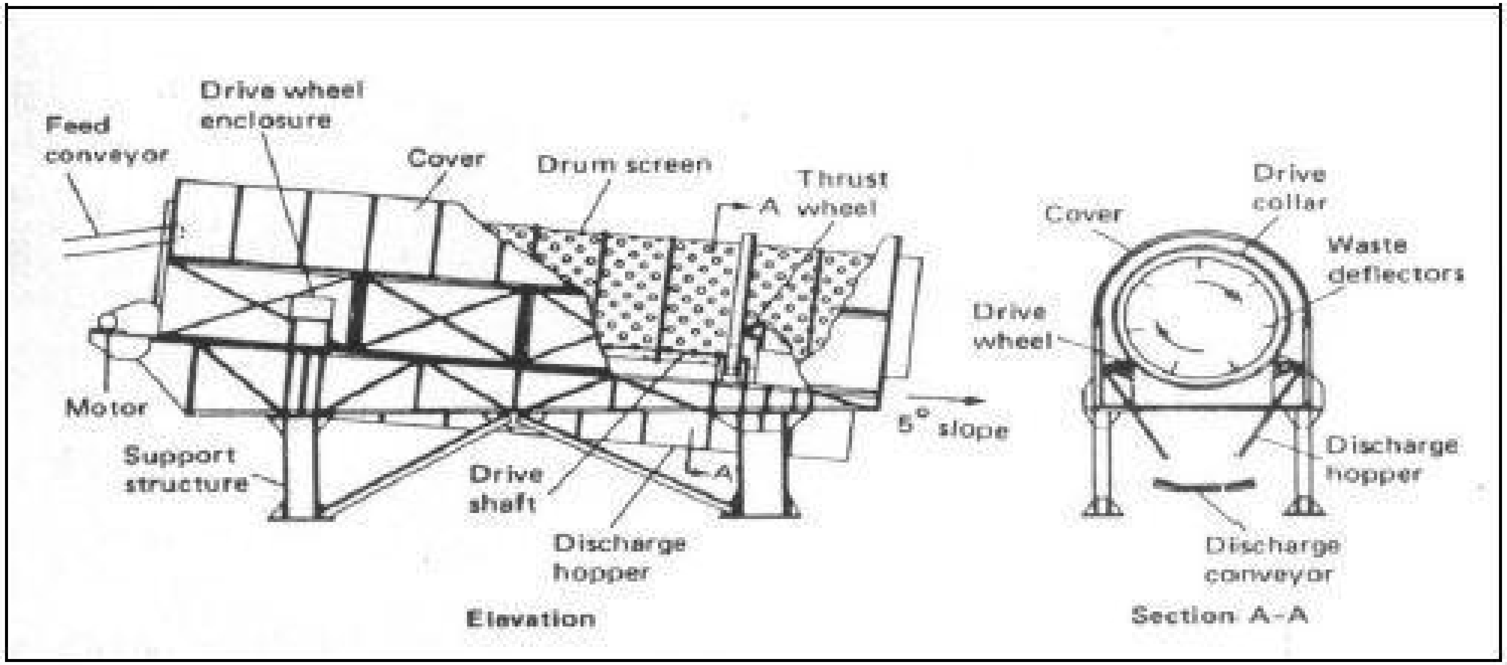
Selection of magnetic separation equipment:

- Characteristics of waste from which ferrous materials are to be separated
- Equipment used for feeding wastes to separator and removing the separated waste streams.
- Characteristics of the separator system engineering design, including loading rate, magnet strength, conveyor speed, material of construction, etc.
- Operational characteristics, including energy requirements, routine and specialised maintenance requirements, simplicity of operation, reliability, noise output, and air and water pollution control requirements.
- Locations, where the ferrous materials are to be recovered from solid wastes.
- Site consideration, including space and height, access, noise and environmental limitations.

Screening

-separating solid wastes, depending on their **size** by the use of one or more screening surfaces.

-Screens can be used before or after shredding and after air separation of wastes in various applications dealing with both light and heavy fraction materials.



Selection of screening equipment :

- Material specification for screened component.
- Location where screening is to be applied and characteristics of waste material to be screened, including particle size, shape, bulk density and moisture content.
- Separation and overall efficiency.
- Characteristics screen design, including materials of construction, size of screen openings, total surface screening area, oscillating rate for vibrating screens, speed for rotary drum screens, loading rates and length.
- Operational characteristics, including energy requirements, maintenance requirements, simplicity of operation, reliability, noise output and air and water pollution control requirements.
- Site considerations such as space and height access, noise and related environmental limitations.

ods

Other separation techniques

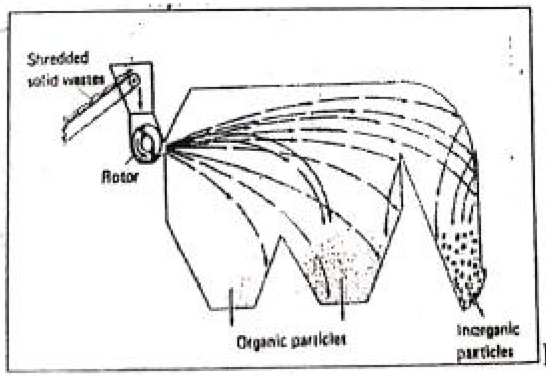
Besides the mechanical techniques we studied earlier for segregating wastes, there are others. A description of some of these other separation techniques is given below:

(i) **Hand-sorting or previewing:**

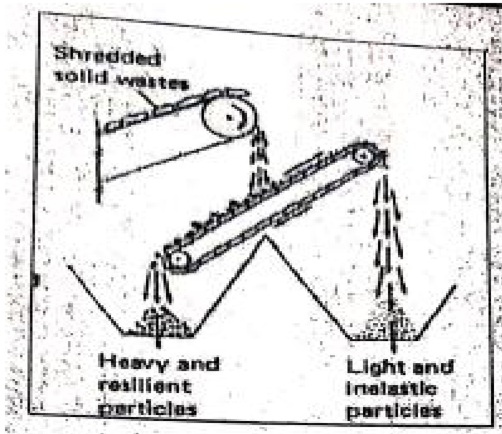
Previewing of the waste stream and manual removal of large sized materials is necessary, prior to most types of separation or size reduction techniques. This is done to prevent damage or stoppage of equipment such as shredders or screens, due to items such as rugs, pillows, mattresses, large metallic or plastic objects, wood or other construction materials, paint cans, etc.

(ii) **Inertial separation:**

Inertial methods rely on ballistic or gravity separation principles to separate shredded solid wastes into light (i.e., organic) and heavy (i.e., inorganic) particles.



Ballistic



Inclined conveyor

(iii) **Flotation:**

In the flotation process, glass-rich feedstock, which is produced by screening the heavy fraction of the air-classified wastes after ferrous metal separation, is immersed in water in a soluble tank. Glass chips, rocks, bricks, bones and dense plastic materials that sink to the bottom are removed with belt scrappers for further processing. Light organic and other materials that float are skimmed from the surface. These materials are taken to landfill sites or to incinerators for energy recovery. Chemical adhesives (flocculants) are also used to improve the capture of light organic and fine inorganic materials.

(iv) **Optical sorting:**

Optical sorting is used mostly to separate glass from the waste stream, and this can be accomplished by identification of the transparent properties of glass to sort it from opaque materials (e.g., stones, ceramics, bottle caps, corks, etc.) in the waste stream. Optical sorting involves a compressed air blast that removes or separates the glasses – plain or coloured. An optical sorting machinery is, however, complex and expensive.

DRYING AND DEWATERING

-remove moisture from wastes and thereby make it a better fuel.

-used primarily for incineration systems, with or without energy recovery systems.

-used for drying of sludges in wastewater treatment plants.

-Sometimes, the light fraction is pelletised after drying to make the fuel easier to transport and store.

Drying

Three methods are used to apply the heat required for drying the wastes:

(i) **Convection drying:** In this method, hot air is in direct contact with the wet solid waste stream.

(ii) **Conduction drying:** In this method, the wet solid waste stream is in contact with a heated surface.

(iii) **Radiation drying:** In this method, heat is transmitted directly to the wet solid waste stream by radiation from the heated body.

Selection of a drying equipment :

- Properties of material to be dried.
- Drying characteristics of the materials, including moisture content maximum material temperature and anticipated drying time.
- Specification of final product, including moisture content.
- Nature of operation, whether continuous or intermittent.
- Operational characteristics, including energy requirements, maintenance requirements, simplicity of operation, reliability, noise output and air and water pollution control requirements.
- Site considerations such as space and height access, noise and environmental limitations.

TYPE OF DRYER	Method of Operations
Rotary tray	Materials to be dried is spread on the top of a series of stacked trays and raked to lower trays as it dries
Endless belt	Material to be dried is spread at the fed end of the dryer on a continues perforated wire mesh belt or conveyor bands which are used to move the material through the dryer
Rotary drum	Slow rotating cylindrical shell, slightly inclined from the horizontal provide with means for continuously feeding material to be dried
Fluid bed	Material to be dried is maintained in fluidised condition . Fluid bed dryers are usually in form of vertical cylindrical columns
Spray	Material to be dried is sprayed into a drying chamber . Movement of feedstock and the drying medium can be concurrent , counter current or combination of both
Flash	Material to be dried is entrained in the drying medium and is conveyed in the process of drying

Dewatering :

-applicable for sludge disposal from wastewater treatment plants, sewage treatment of industrial or municipal wastewater, from water treatment, on-site sanitation systems.

-When drying beds, lagoons or spreading on land are not feasible, other mechanical means of dewatering are used.

-Once dewatered, the sludge can be mixed with other solid waste, and the resulting mixture can be:

- incinerated to reduce volume;
- used for the production of recoverable by-products;
- used for production of compost;
- buried in a landfill.

Methods for the dewatering of sludge:

i)Centrifugation-technique which involves the application of centrifugal force to separate particles from a solution according to their size, shape, density, viscosity of the medium and rotor speed.

ii)Filtration- mechanical, physical or biological operations that separate solids from fluids (liquids or gases) by adding a medium through which only the fluid can pass.

-Sludges with solid content of a few percent can be thickened to about 10–15% in centrifugation and about 20 –30% in pressure filtration or vacuum filtration.

MODULE V

WASTE DISPOSAL

V	Disposal of solid waste; Sanitary land fill- area method, trench method-advantages and disadvantages, Incineration- types of incinerators -parts of an incinerator-incinerator effluent gas composition	8	20

Disposal

- It is the ultimate fate of all solid wastes, like residential wastes (collected and transported directly to a landfill site), semi-solid waste (sludge)(from municipal and industrial treatment plants), incinerator residue, compost or other substances(from various solid waste processing plants) that are of no further use to society.
- Prepare proper plan for safe disposal of solid wastes
- involves appropriate handling of residual matter after solid wastes have been processed and the recovery of conversion products/energy has been achieved.

Problems that arises due to improper disposal:

- Health hazards (e.g: residents in the vicinity of wastes inhale dust and smoke when the wastes are burnt; workers and pickers come into direct contact with wastes, etc.)
- Pollution due to smoke
- Pollution from waste leachate and gas
- Blockage of open drains and sewers

Disposal methods:

(i) Uncontrolled dumping or non-engineered disposal:

- Wastes are dumped at a designated site without any environmental control.
- Remain for a long period of time-- pose health risks and environmental degradation.
- Not a viable and safe option.

(ii) Sanitary landfill:

- This is a fully engineered disposal option
- Operators of sanitary landfills can minimise the effects of leachate and gas production through proper site selection, preparation and management.
- Suitable when the land is available at an affordable price and adequate workforce and technical resources are available to operate and manage the site.

(iii) Composting:

- Biological process of decomposition in which organisms, under controlled conditions of ventilation, temperature and moisture, convert the organic portion of solid waste into humus-like material.
- final product is a stable, odour-free soil conditioner.
- composting is considered when a considerable amount of biodegradable waste is available in the waste stream and there is use or market for composts.
- Composting can be either centralised or small-scale.
- Centralised composting plants -skilled workforce and equipments are available. Small-scale composting practices -household level

(iv) Incineration:

- Controlled burning of wastes, at a high temperature (roughly 1200 – 1500°C), which sterilises and stabilises the waste thereby reducing its volume.
- Combustible materials (i.e., self-sustaining combustible matter, which saves the energy needed to maintain the combustion) such as paper or plastics get converted into carbon dioxide and ash.
- Incineration may be used as a disposal option, when land filling is not possible and the waste composition is highly combustible.

(v) Gasification:

- Partial combustion of carbonaceous material (through combustion) at high temperature (roughly 1000C) forming a gas, comprising mainly carbon dioxide, carbon monoxide, nitrogen, hydrogen, water vapour and methane, which can be used as fuel.

(vi) Refuse-derived fuel (RDF):

- This is the combustible part of raw waste, separated for burning as fuel.
- Various physical processes such as screening, size reduction, magnetic separation, etc., are used to separate the combustibles .

(vii) Pyrolysis:

- This is the thermal degradation of carbonaceous material to gaseous, liquid and solid fraction in the absence of oxygen. This occurs at a temperature between 200 and 900˚C.
- The product of pyrolysis is a gas of relatively high calorific value of 20,000 joules per gram with oils, tars and solid burned residue.

Sanitary landfill:

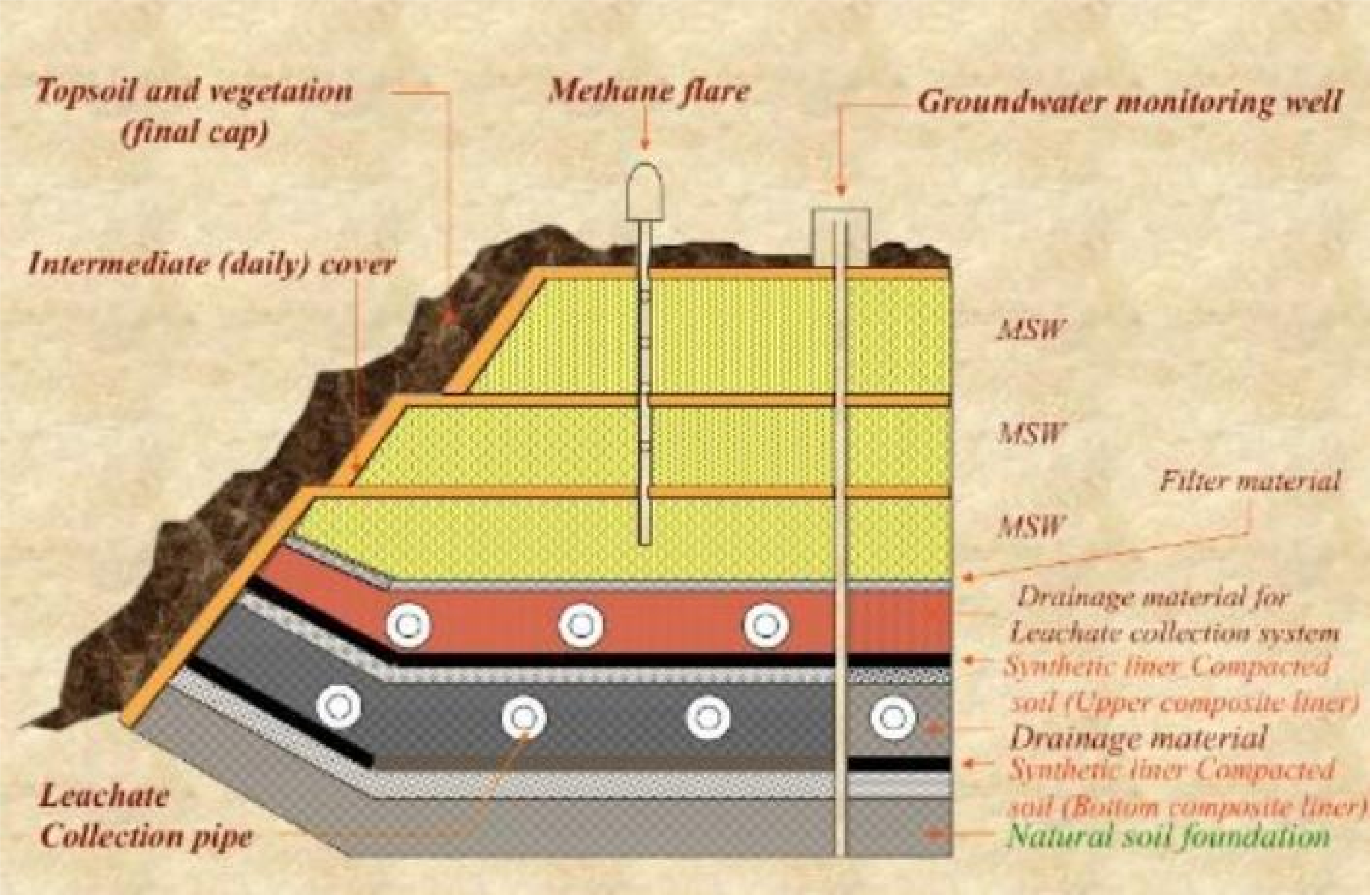
- Engineered deposit of wastes either in pits/trenches or on the surface.
- Proper mechanisms are available to control the environmental risks associated with the disposal of wastes and to make available the land, subsequent to disposal, for other purposes.

Principle

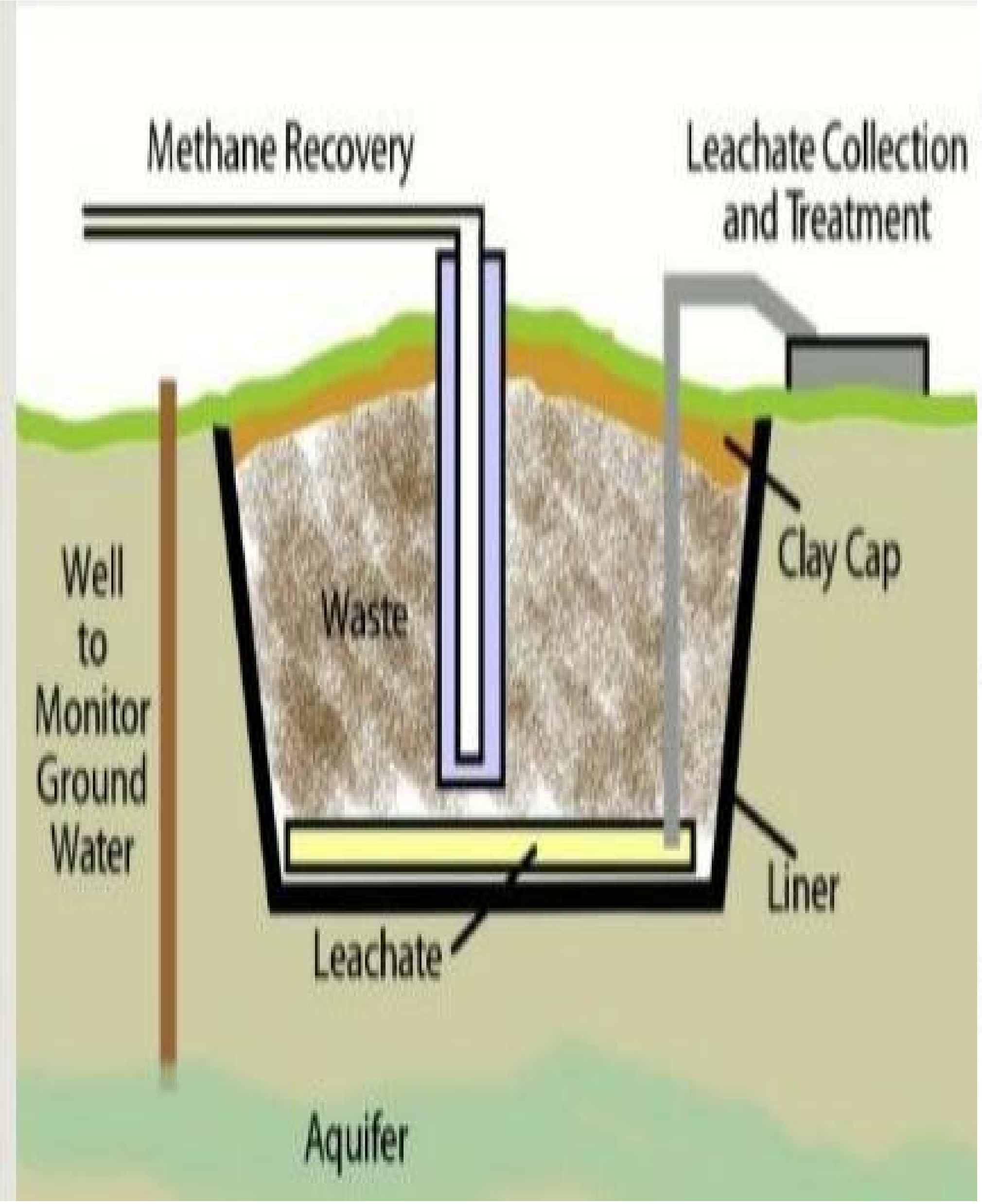
- Bury or alter the chemical composition of the wastes so that they do not pose any threat to the environment or public health.
- Landfills are not homogeneous and are usually made up of cells in which a discrete volume of waste is kept isolated from adjacent waste cells by a suitable barrier.
- The barriers between cells generally consist of a layer of natural soil (i.e., clay), which restricts downward or lateral escape of the waste constituents or leachate.
- Land filling relies on containment rather than treatment (for control) of wastes.
- If properly executed, it is a safer and cheaper method than incineration .
- An environmentally sound sanitary landfill comprises appropriate liners for protection of the groundwater (from contaminated leachate), run-off controls, leachate collection and treatment, monitoring wells and appropriate final cover design.

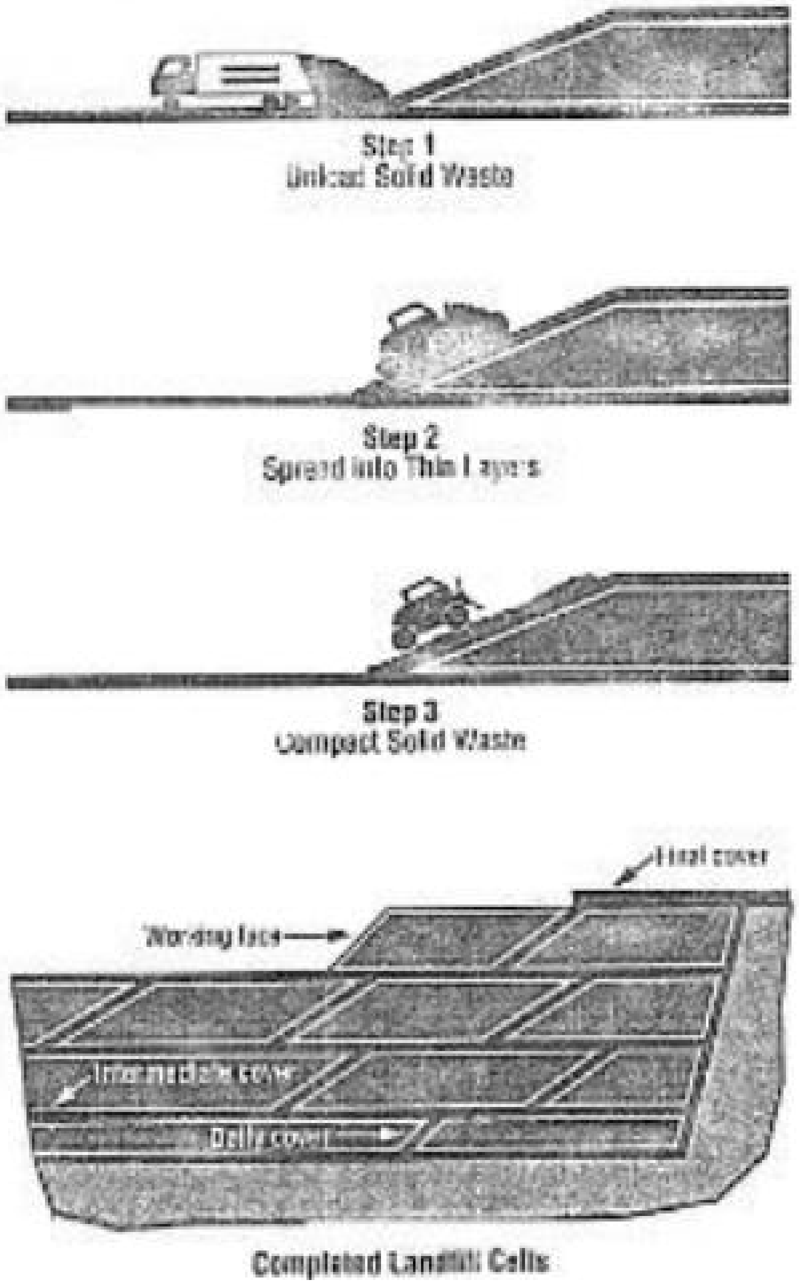
Life cycle of a landfill

1. Planning phase: This typically involves preliminary hydro-geological and geo-technical site investigations as a basis for actual design.
2. Construction phase: This involves earthworks, road and facility construction and preparation (liners and drains) of the fill area.
3. Operation phase (5 – 20 years): This phase has a high intensity of traffic, work at the front of the fill, operation of environmental installations and completion of finished sections.
4. Completed phase (20 – 100 years): This phase involves the termination of the actual filling to the time when the environmental installations need no longer be operated. The emissions may have by then decreased to a level where they do not need any further treatment and can be discharged freely into the surroundings.
5. Final storage phase: In this phase, the landfill is integrated into the surroundings for other purposes, and no longer needs special attention.



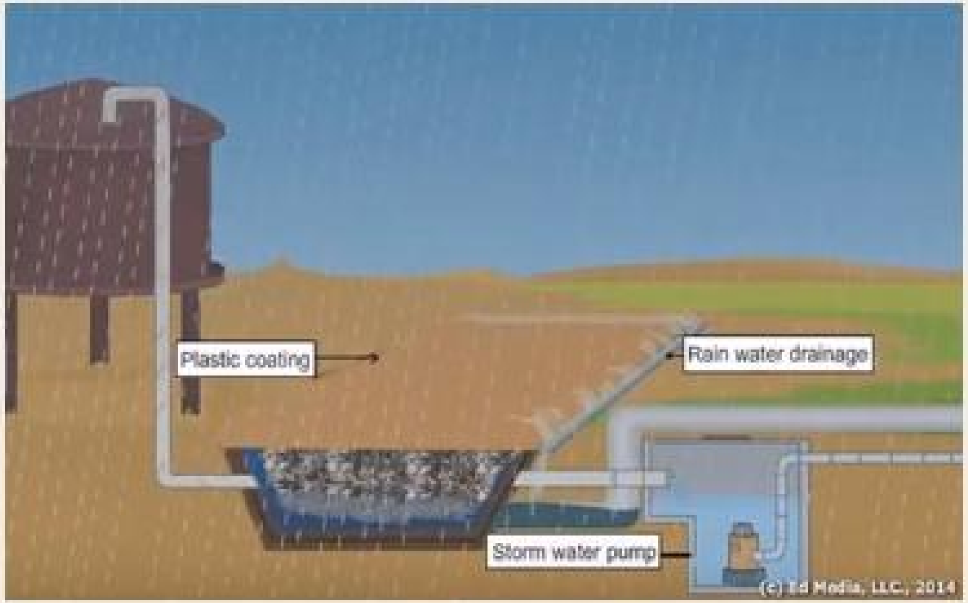
Topsoil and vegetation
(final cap)
Methane flare
Groundwater monitoring well
Intermediate (daily) cover
MSW
MSW
Filter material
MSW
Drainage material for
Leachate collection system
Synthetic liner Compacted
soil (Upper composite liner)
Drainage material
Synthetic liner Compacted
soil (Bottom composite liner)
Natural soil foundation
Leachate
Collection pipe


Methane Recovery
Leachate Collection
and Treatment
Clay Cap
Well
to
Monitor
Ground
Water
Waste
Liner
Leachate
Aquifer


Step 1
Step 2
Step 3
Compact Solid Waste

Sanitary Landfill

- ❑Sites where waste is isolated from the environment until it is safe
- ❑Landfills include any site which is used for more than a year for the temporary storage of waste



Components

- ❑ A **liner system** at the base and sides of the landfill which prevent the migration of leachate or liquid to the surrounding soil
- ❑ **Leachate collection and removal system-** collect liquid or leachate from base of landfill, treat
- ❑ **Gas collection and control facility-** collect gas from top of landfill, treat it and use for energy recovery
- ❑ Final **cover system** at top of landfill usually soil
- ❑ **Surface water drainage system** collect and remove surface runoff from landfill site
- ❑ An **environmental monitoring system**
- ❑ A **closure and post closure plan**

Landfill

Advantages

1. Land available- Most economical solution of municipal solid waste disposal
2. Initial investment low compared to other disposal method
3. Complete or final disposal method
4. Can receive all types of solid waste
5. Flexible
6. Sub-marginal land-reclaimed for use as parking lot, play ground etc

Disdvantages

1. Availability of suitable land
2. Special design and construction required for building construted on completed landfill
3. Gases like methane- hazard/nuisance
4. In residential area-public opposition
5. Proper maintenance

Landfill processes

The feasibility of land disposal of solid wastes depends on factors such as the type, quantity and characteristics of wastes, the prevailing laws and regulations and soil and site characteristics.

(i) Site selection process:

-Development of a working plan – a series of plans outlining the development and descriptions of site location, operation, engineering and site restoration.

- Factors to be considered while selecting landfill site:
  - Groundwater
  - Flood plains
  - Surface water
  - Air quality
  - Operation safety
  - Disease transmission
  - Impact on food chain and cropland
  - Endangered species
  - Topography and hydrography
  - Geotechnical factors

- Groundwater

  - GW quality –by leachate leakage from landfill

  - quality of nearby underlying aquifers

- Flood plains

  -Located outside historic floodplains

  -Map overlays can be used for site selection to eliminate flood plains from consideration.

- Surface water

  -Site must offer capability of collecting and controlling the surface water and storm water runoff .

  -Series of dikes, ponds and other impoundments may be necessary to protect adjacent property.

- Air quality

  -Air quality in the vicinity of landfill must be monitored and controlled to ensure compliance with the air quality standards and to minimize objectionable odours near the site.

  -gas recovery systems-conserve energy and minimize emission of odours.

- Operation safety

  -proper safeguards for working environment.

  -Materials must be handled an dsegregated so as to minimize adverse working conditions.

  -Occupational safety regulations, managerial philosophy in regard to health and safety.

- Disease transmission

  -Infectious medical and biological wastes must be properly characterized and treated prior to entering the landfill so as to minimize their volume and potential for contamination with other hazardous wastes.

- Impact on food chain and cropland

  -Biodegradation of hydrocarbon wastes –used by petroleum industries

  -Halogenated hydrocarbons-difficult to biodegradate, contaminate the land farming operations by toxicity metals that require specialized treatment techniques.

  -Testing and monitoring –crop farming

- Endangered species

- Topography and hydrography

  -base of landfill should be above the saturated zone .

  -Sites should be in climates of low rainfall and high surface evaporation rates.

  -lacted away from water supply wells.

  -Limestone and crystalline rock are not desirable as alluvial bedrock or sedimentary formations.

  -Slope restrictions are necessary to ensure physical integrity-slopes of more than 1% and less than 10%.

- Geotechnical factors

  -Permeability of soil-major factor that affect the rate of contaminant transport through the soil.

  -Soil texture plays an important role in permeability characteristics.

  -Fine grained soil like clay-larger surface area per unit weight-lower leachate penetration.

  -Ideal permeability-1x 10^{-7} cm/s

  -Solubility of metals is inversely proportional to the soil acidity while soils absorb organics in direct proportion to their acidity.

  -soil-pH 7-8- for balance reduction

Site Restrictions:

Place	Distance Parameters
Lake or pond	• Max distance 200 m • Water monitoring system should be installed if a landfill is sited less than 200 m of a lake or pond. • Sites falling within wetlands are avoided.
River	• Max distance 100 m • The distance may be reduced in some instance for non-meandering rivers but a minimum of 30 m should be maintained.
Flood plain	• No landfill should be constructed within a 100 year-flood plain.
Highway	• Max distance 200 m
Habitation	• Max distance 200 m of a notified habituated area. • Sites falling within forest areas and national parks are avoided • A distance of 100 m must maintained from the residential areas.
Public parks	• Max distance 200 m
Ground water table	• No landfill should be constructed in areas where water table is less than 2 m below ground surface.
Airport	• A distance of 20 km from nearby airport must be maintained. • Can set up between 10 km – 20 km by obtaining NOC from the civil aviation authority/ Air force

Place	Distance Parameters
Water Supply Well	• Max Distance 200 m • Locational restriction be abided by at least for down gradient wells. • Permission from the regulatory agency may be needed if a landfill is to be sited within the restricted area
Coastal Regulation Zone:	• A landfill should not be sited in a coastal regulation zone
Unstable Zone	• A landfill should not be located in potentially unstable zones such as landslide prone areas, fault zone etc

Source : *Solid Waste Management Rules, 2016*
Published In the Gazette of India, Part-II, Section-3, Sub-section (i)
Ministry of Environment, Forest and Climate Change
New Delhi, the 8th April, 2016

(ii) Settling process:

The waste body of a landfill undergoes different stages of settling or deformation.

1. Primary consolidation
2. Secondary compression
3. Decomposition

Primary consolidation:

-substantial amount of settling occurs.

-settlement is caused by the weight of the waste layers.

-movement of trucks, bulldozers or mechanical compactors enhance the settlement.

-After primary consolidation or short-term deformation stage, aerobic degradation processes *occur.*

Secondary compression:

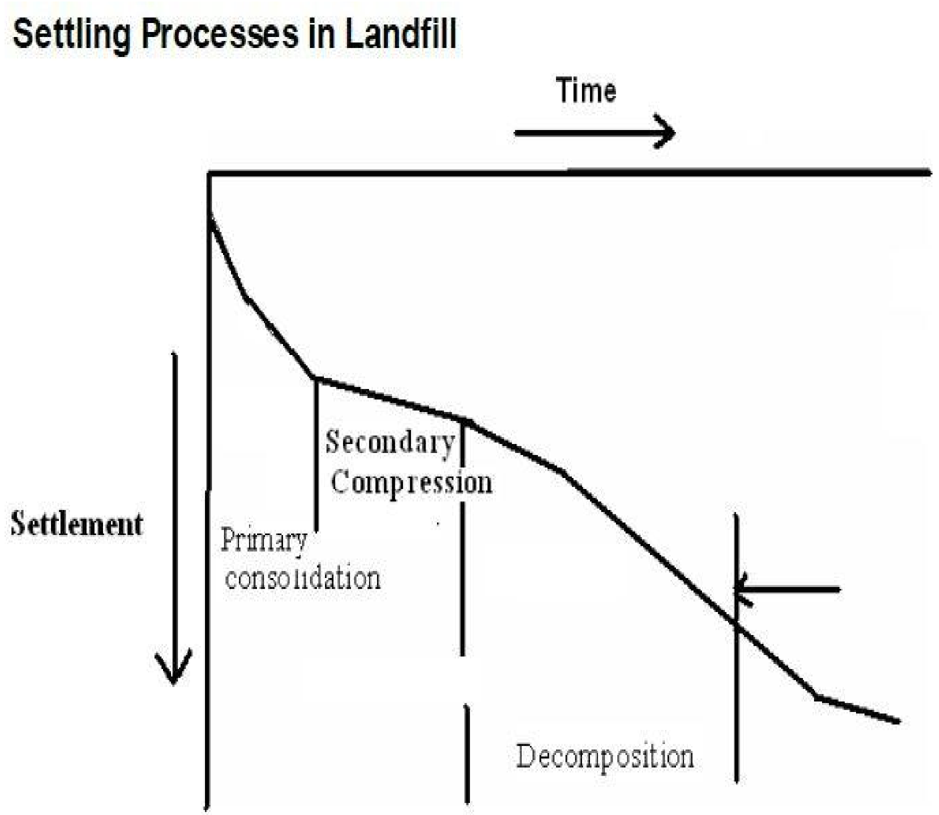
the rate of settling is much lower than that in the primary consolidation stage, as the settling occurs through compression, which cannot be enhanced.

Decomposition:

-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 gradually decreases with the passage of time.



iii)Microbial degradation process:

Solid waste landfill – similar to biochemical reactor

Solid waste+water(Input)-----Landfill gas+leachate(Output)

Generation of landfill gases:

The generation of principal landfill gases occur in five sequential Phases:

Phase I: Initial adjustment:

- Organic biodegradable components in MSW begin to undergo bacterial decomposition soon after they are placed in a landfill.
- Biological decomposition occurs under aerobic conditions because a certain amount of air is trapped within the landfill.

Phase II: Transition Phase:

•Oxygen is depleted and anaerobic conditions begin to develop.

Phase III. Acid Phase:

- Bacterial activity initiated in phase II is accelerated with the production of significant amounts of organic acids and lesser amounts of hydrogen gas.
- 3 step process:

i)Enzyme-mediated transformation (hydrolysis) of higher molecular mass compounds (e.g., lipids, organic polymers, and proteins) into compounds suitable for use by microorganisms as a source of energy and cell carbon.

ii)Acidogenesis- Bacterial conversion of the compounds resulting from the first step into lower molecular weight intermediate compounds, as typified by acetic acid (CH_3COOH) and small concentrations of fulvic and other more complex organic acids. Carbon dioxide (CO_2) is the principal gas generated during phase III.

iii)Methanogenisis-Production of methane gas(discussed in next phase)

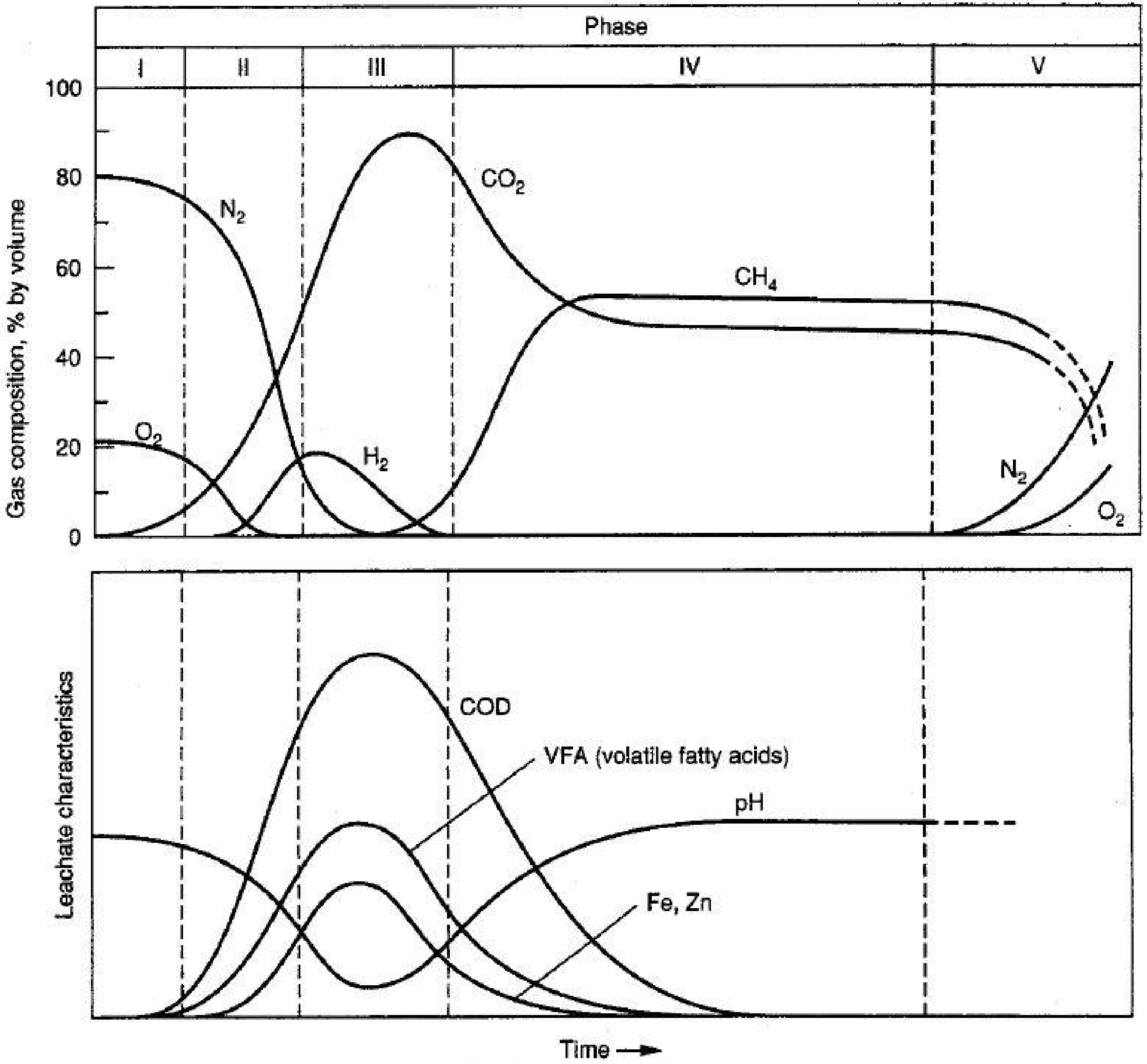
Phase IV. Methane Fermentation Phase:

- Microorganisms convert the acetic acid and hydrogen gas formed by the acid formers in the acid phase to methane (CH4) and CO2.
- Because the acids and the hydrogen gas produced by the acid formers have been converted to CH4 and CO2 in phase IV, the pH within the landfill will rise to more neutral values in the range of 6.8 to 8.

Phase V. Maturation Phase:

- As moisture continues to migrate through the waste, portions of the biodegradable material that were previously unavailable will be converted.
- The rate of landfill gas generation diminishes significantly because most of the nutrients were removed with leachate during previous phases.
- Landfill gases evolved are CH4 and CO2 and traces of nitrogen and oxygen.

$$\underset{\text{(Carbohydrate)}}{C_6H_{12}O_6} \xrightarrow{\text{(Bacteria)}} \underset{\text{(Methane)}}{CH_4} + \underset{\text{(Carbon dioxide)}}{CO_2} + \text{Biomass} + \text{Heat}$$

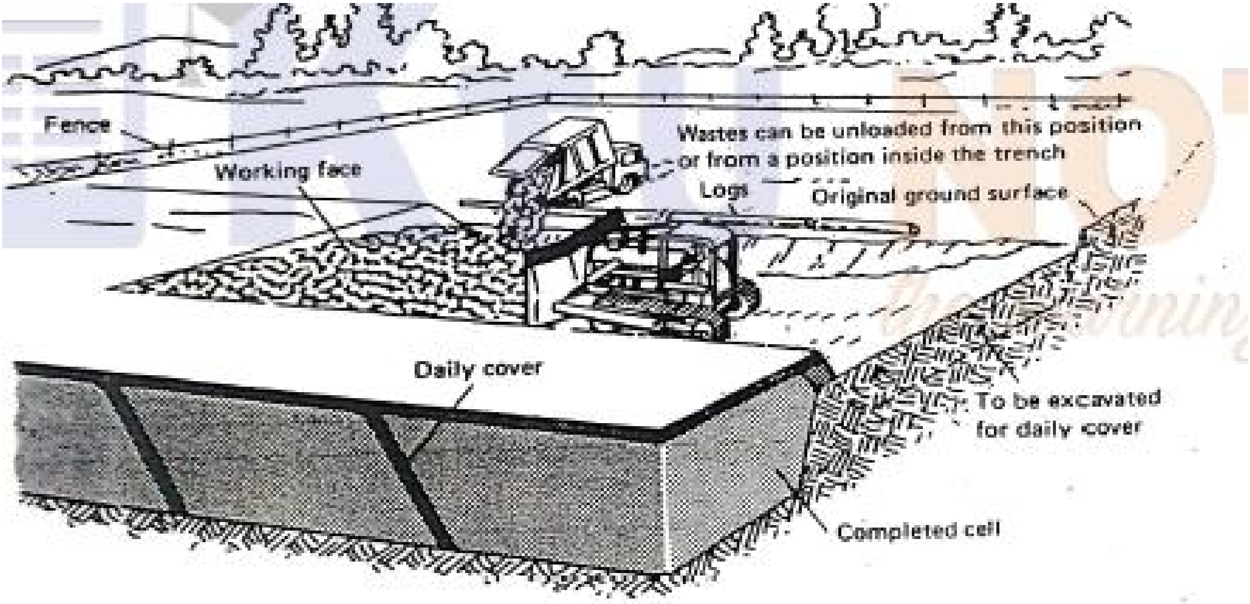


Generalized phases in generation of landfill gases (I—initial adjustment, II—transition phase; III—acid phase; IV—methane fermentation; V—maturation phase) (Tchobanoglous et al., 1993).

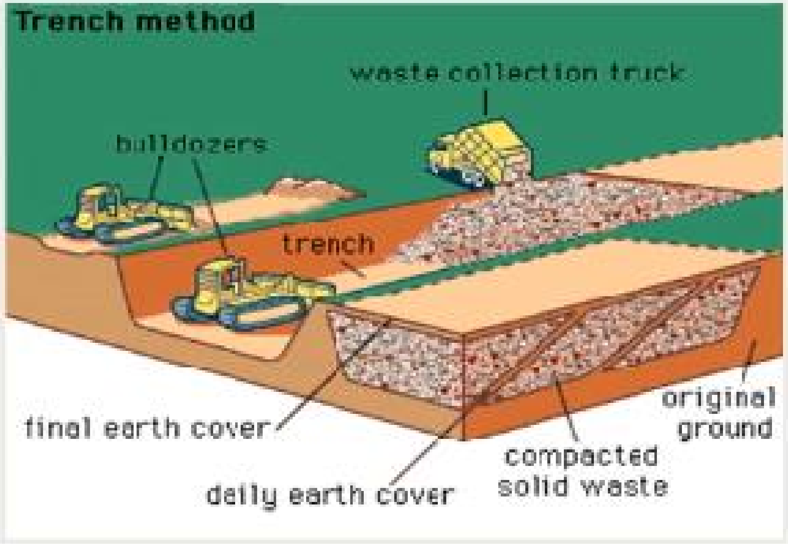
Landfilling Methods

1. Excavated cell/Trench Method

- Suited where adequate depth of cover material is available at site and water table is not near the surface.
- Trenches varying dimensions (15 to 25 ft wide,100 to 400ft length and 3 to 6ft depth, side slopes 1.5:1 to 2:1) are constructed by making a excavation and soil is stockpiled to form an embankment behind the first trench.
- Trenches are lined with synthetic membrane liners or low permeability clay to limit the movement of both landfill gases and leachate.
- Solid waste is placed in the trench spread into layers (18 to 24 in)and compacted and covered at the end of each day with the excavated material (daily and final cover).
- The depth of fill is determined by the established finished grade and depth to groundwater or rock. If trenches can be made deeper, more efficient use is made of the available land area.

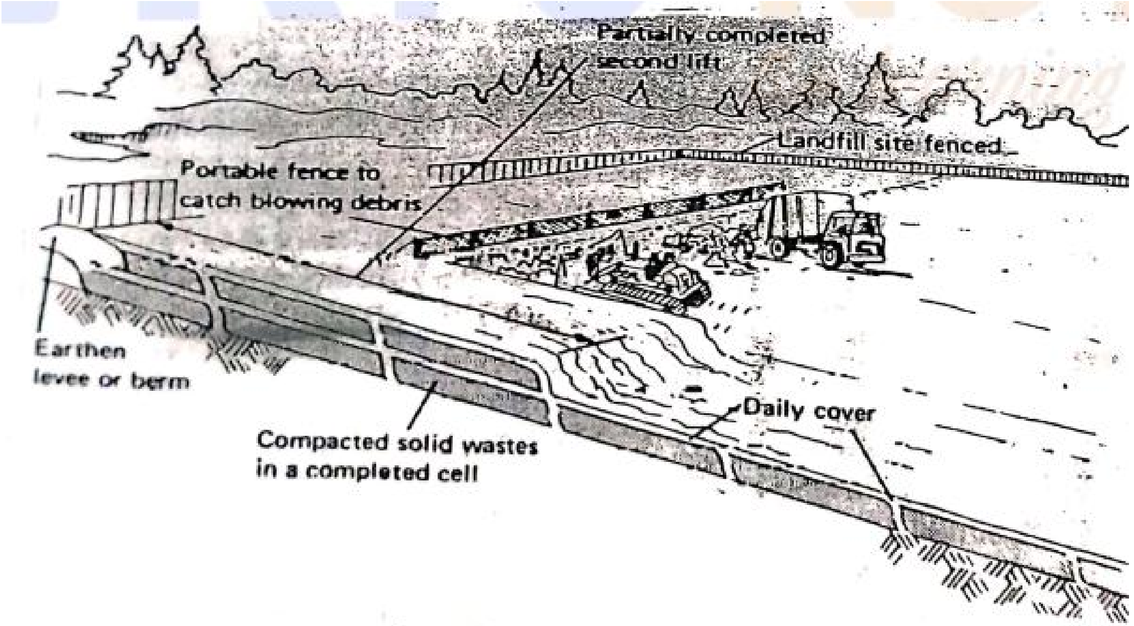


Trench method of operation for a sanitary landfill.

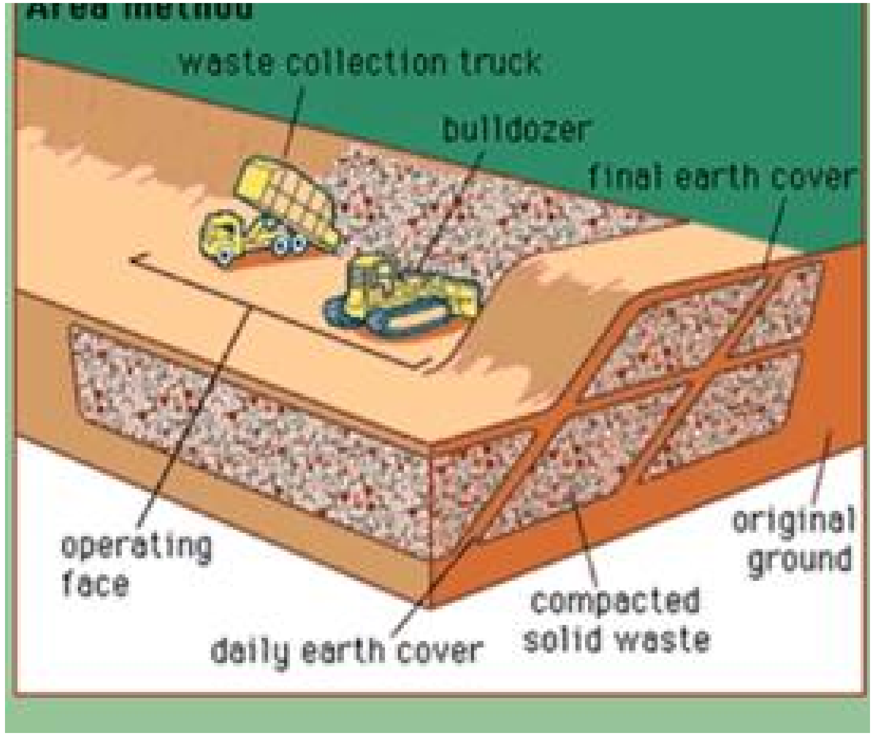


Ramp Method:

- Flat and rolling terrain, the existing natural slope of the land is utilized. Terrain is unsuitable for excavation of cells or trenches.
- The wastes are unloaded and spread in long , narrow strips on the surface of the land in series of layers that vary in depth from 16 to 30 in
- Each layer is compacted as the filling progresses during the course of the day until thickness of the compacted wastes reaches a height varying from 6 to 10 in.
- At the end of each day s operation a 6-12 in layer of cover material is placed over the completed fill
- The width and length of the fill slope are dependent on the nature of the terrain, the volume of solid waste delivered daily to the site and the number of unloading trucks. Side slopes are 20 to 30 percent.
- Cover material is hauled in by truck from a nearby land or other borrow pit areas. Movable temporary cover materials like geomembranes are also used.
- The base of the landfill is established by the previously determined elevation of bedrock, groundwater and bottom liners and leachate collection and removal systems.

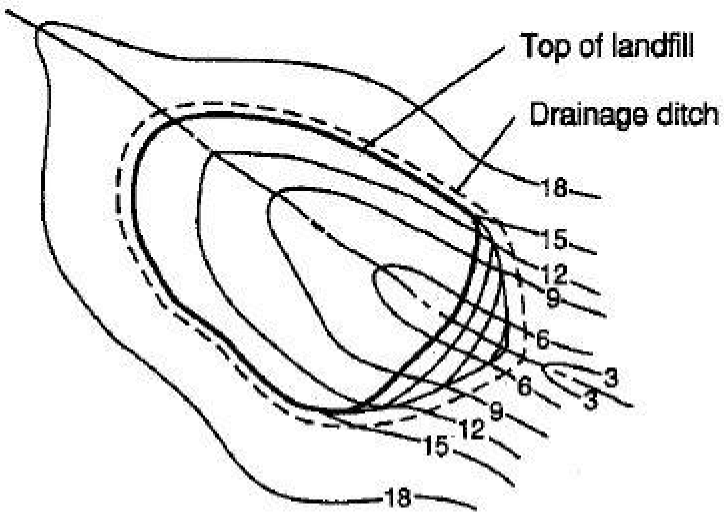


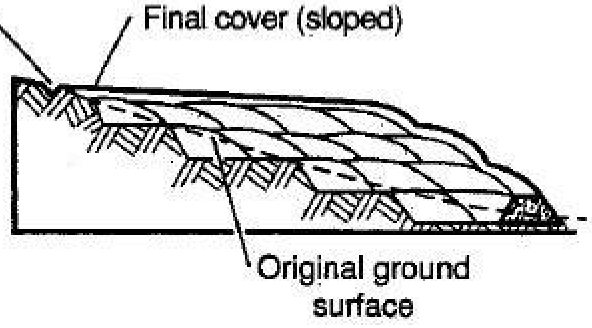
Area method of operation for a sanitary landfill.



3)Canyon/Depression Method:

- Canyons, valleys, ravines, dry borrow pits and quarries.
- In those areas where the ravine is deep, the solid waste should be placed in ‘‘lifts’’ from the bottom up with a depth of 8 to 10 ft.
- Depends on the geometry f site,characteristics of available cover material, hydrology and geology of site,type of leachate and gas control facilities and access to site.
- Control of surface drainage is a critical factor in the development of canyon/depression sites. Filling of each lift starts at the head of the canyon and ends at the mouth, so as to prevent the accumulation of water behind the landfill.
- Cover material is excavated from canyon walls or floor before the liner is installed.





Basic requirements of site to be used as landfill:

i)Full or partial hydrogeological isolation:

- If a site cannot be located on land which naturally contains leachate security, additional lining materials should be brought to the site to reduce leakage from the base of the site and help reduce contamination of groundwater and surrounding soil.
- If a liner - soil or synthetic - is provided without a system of leachate collection, all leachate will eventually reach the surrounding environment.

ii)Formal engineering preparations:

- Designs should be developed from local geological and hydrogeological investigations. A waste disposal plan and a final restoration plan should also be developed.

iii)Permanent control:

- Trained staff should be based at the landfill to supervise site preparation and construction, the depositing of waste and the regular operation and maintenance.

iv) Planned waste emplacement and covering:

- Waste should be spread in layers and compacted. A small working area which is covered daily helps make the waste less accessible to pests and vermin.

Questions

- With neat sketch explain the various parts of an Incinerator
- Explain the composition of Incinerator effluent gas
- Define incineration and is merits and demerits
- Explain the components of Sanitary landfill with neat sketch
- What are the environmental factors affecting incineration
- With neat sketches explain different types of landfill techniques for solid waste disposal
- Explain working of municipal incinerator with neat sketch
- Explain incineration process of solid waste

COMPOSTING

GENERAL

- Composting – disposal method
- Composting is defined as a controlled aerobic biological conversion if organic wastes into a complex, stable material.
- This is also a very good method, where at the source itself we can go for the degradation process.
- The final product has a number of beneficial uses, most commonly used for agriculture and landscaping.
- The composting of MSW, agricultural wastes (plant residues, animal manures), food factory waste and municipal waste treatment solids (bio solids) is increasingly used world wide as a means of waste management

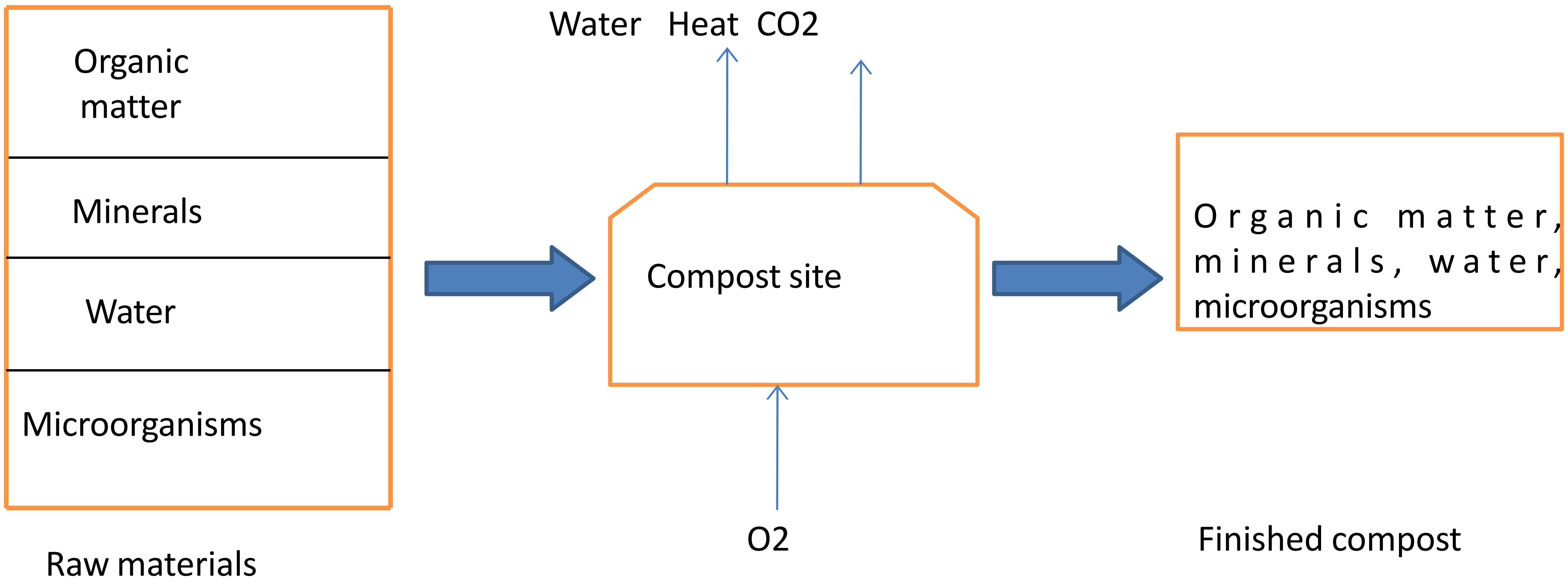
- Composting is the transformation of organic material (plant matter) through decomposition into a soil-like material called compost.
- Insects and earthworms microorganisms (bacteria and fungi) help in this transformation.
- The most active player in composting are bacteria, fungai, protozoa and rotifers.
- These organisms are naturally present in most organic materials including food wastes, soil leaves grass clipping and other organics

- This can be possible at the household level, at the community level, and also at apartments where 60% is construction and the remaining 40% will be the open area.

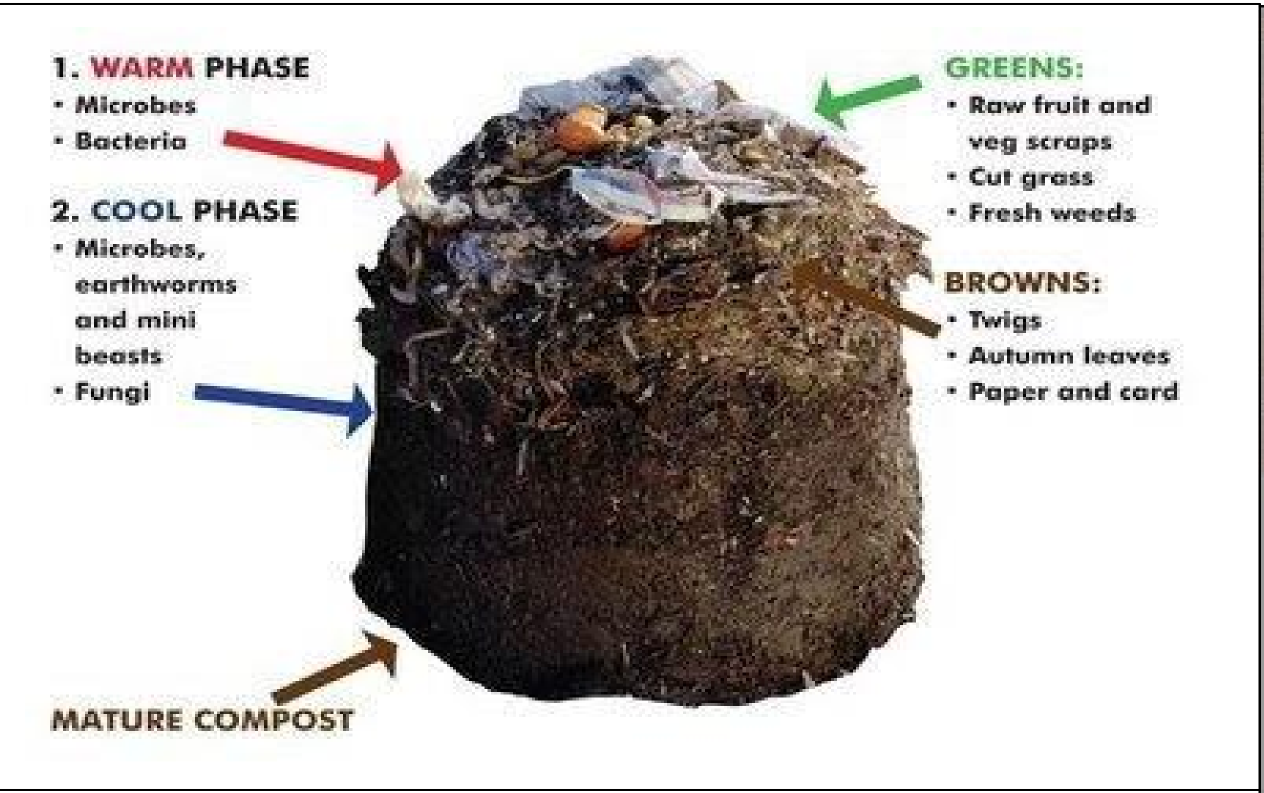
- Overall composting operation

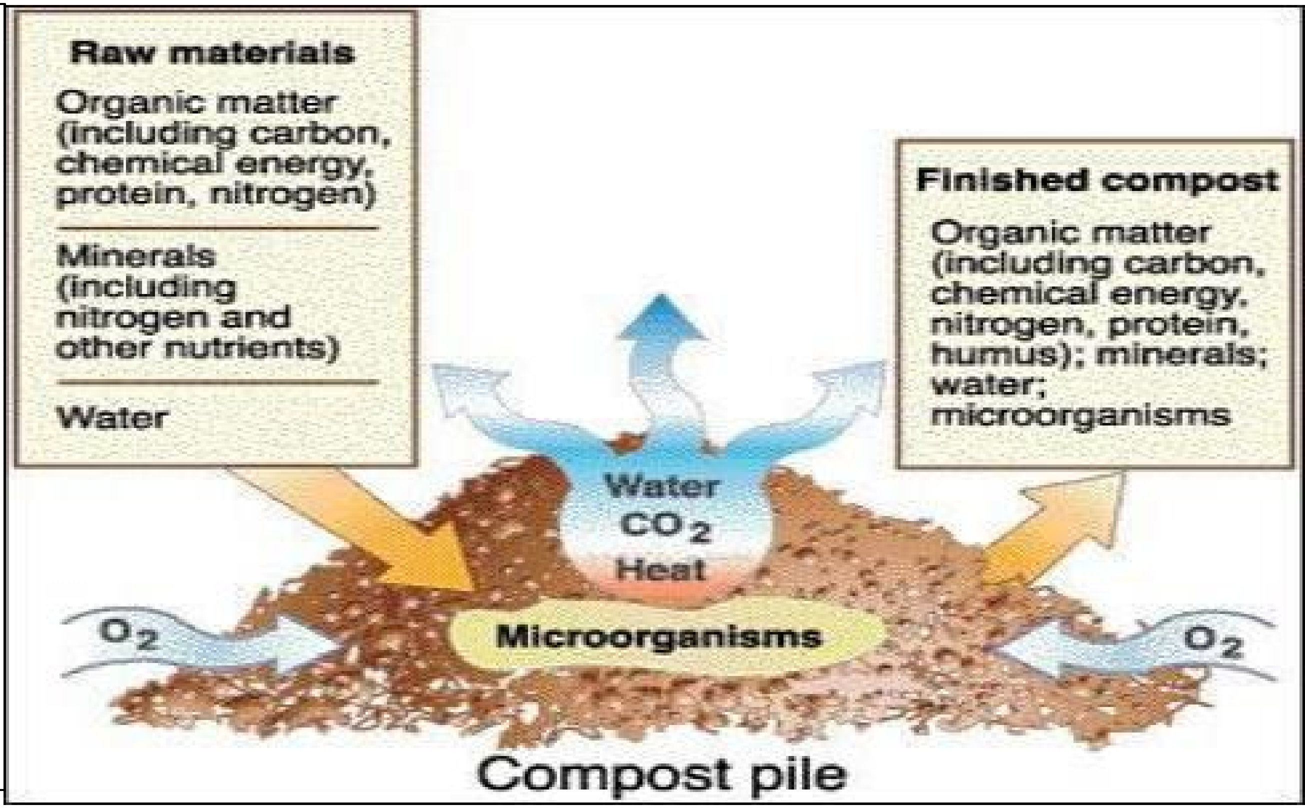
$$\text{Organic matter} + O_2 + \text{aerobic bacteria} \longrightarrow CO_2 + NH_3 + H_2O + \text{other end products} + \text{energy}$$

- End product – compost
- By product - CO_2, water
- Compost is
  - Dark in color
  - Crumbly texture
  - Earthy odour
  - Resembles rich topsoil



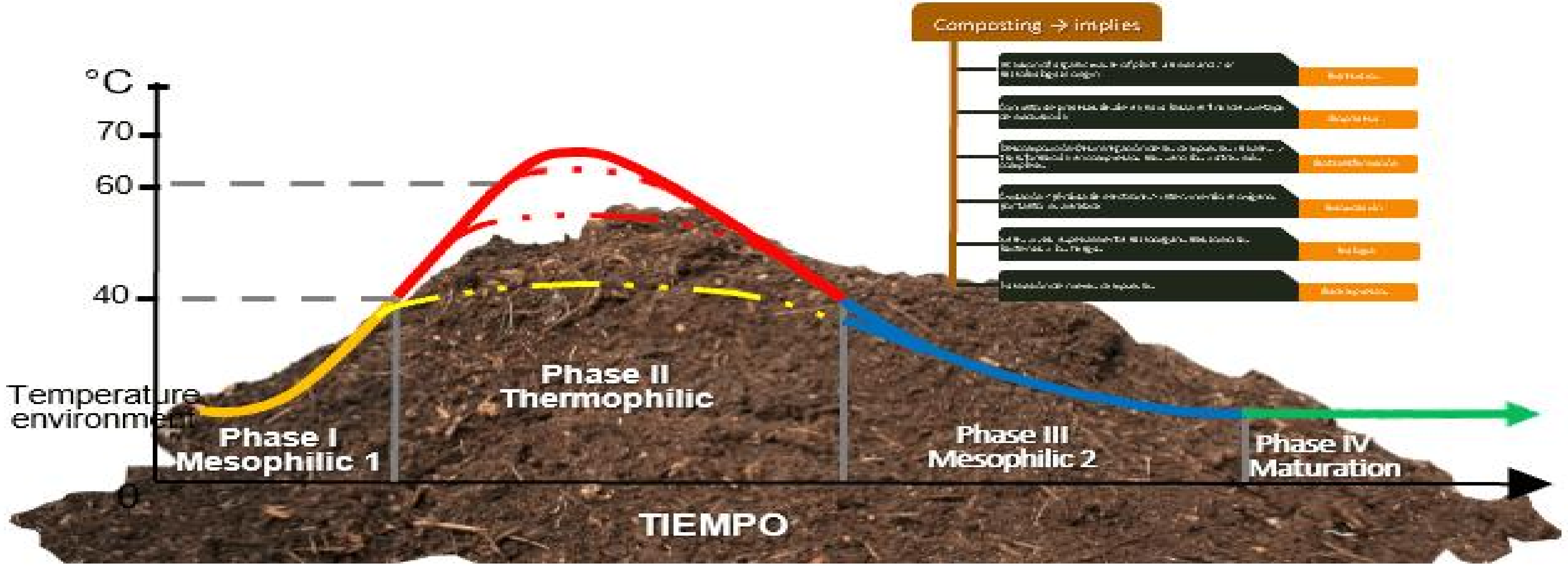
Composting process


1. WARM PHASE
• Microbes
• Bacteria
2. COOL PHASE
• Microbes, earthworms and mini beasts
• Fungi
GREENS:
• Raw fruit and veg scraps
• Cut grass
• Fresh weeds
BROWNS:
• Twigs
• Autumn leaves
• Paper and card
MATURE COMPOST

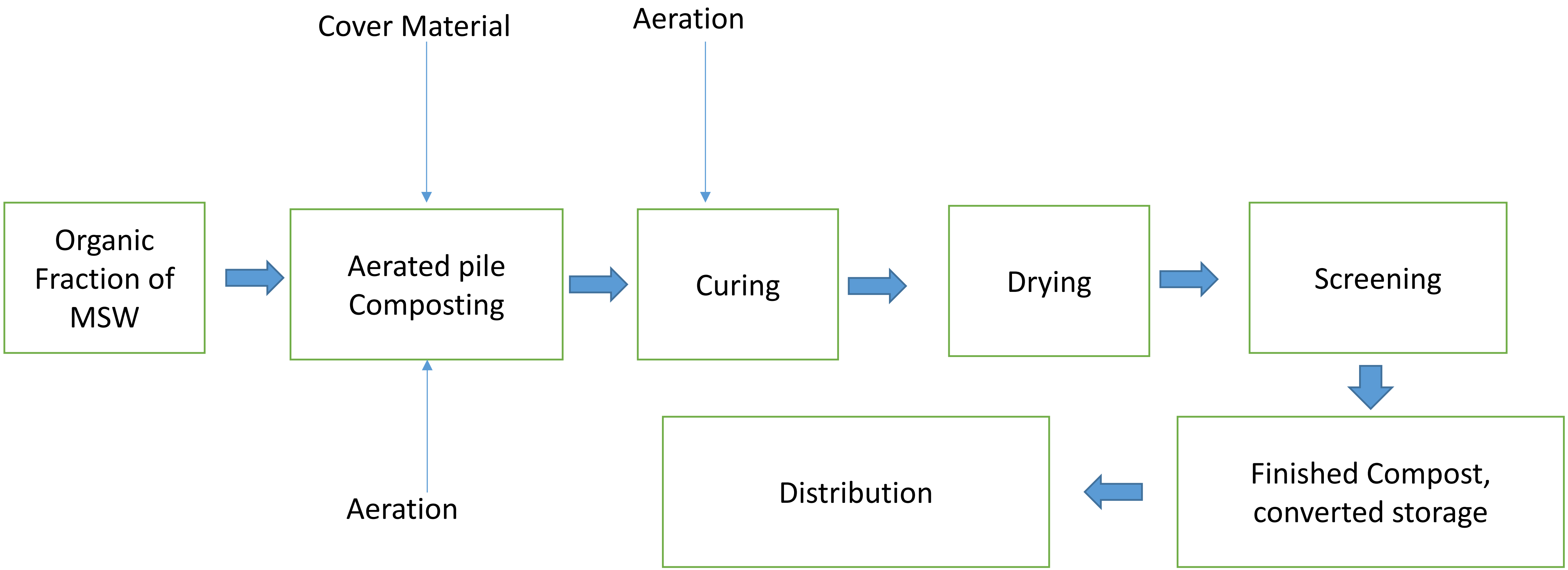

Raw materials
Organic matter (including carbon, chemical energy, protein, nitrogen)
Minerals (including nitrogen and other nutrients)
Water
Finished compost
Organic matter (including carbon, chemical energy, nitrogen, protein, humus); minerals; water; microorganisms
Water
CO_2
Heat
O_2
Microorganisms
O_2
Compost pile

Phases of composting

- Initial decomposition is carried out by the mesophilic microorganisms, which rapidly breakdown the soluble, readily degradable compounds.
- As the temp rises about 40^o, the mesophilic are replaced thermophilic , at temperature of 55^o and above, many microorganisms that are human or plant pathogens are destroyed.
- During the thermophilic phase, high temperatures accelerates the breakdown of proteins, fats and complex carbohydrates like cellulose and hemicellulose the major structural molecules in plants.
- Temperature gradually decreases and mesophilic microorganism one again take over for the final phase of curing or maturation of the remaining organic matter.


Composting → implies
°C
70
60
40
0
Temperature environment
Phase I
Mesophilic 1
Phase II
Thermophilic
Phase III
Mesophilic 2
Phase IV
Maturation
TIEMPO

Flow Chart Showing the steps involved in the aerobic composting process



STAGES

- Five basic stages
  1. Preparation
  2. Digestion
  3. Curing
  4. Screening or finishing
  5. Storage or disposal

1. Preparation

– Involves several steps

- Sorting of recyclable materials
- Removal of non combustibles
- Grinding
- Adding of water sludge

2. <u>Digestion</u>

– Digestion process vary from backyard composting process to highly controlled mechanical digester

– On basis of digestion composting types fall into two categories

  - Windrow composting – open atmosphere
  - Mechanical composting – enclosed atmosphere

3. <u>Curing</u>

- Also called ageing or maturing phase
- Compost become biologically stable
- Long period curing – pathogen destruction
- Uncured compost – produce phytotoxins –substance toxic to growth plants
- Takes few days to several months
- Cured compost is then marketed

4. <u>Screening or finishing</u>

- Done to meet market specifications
- Sometimes done before compost curing
- Non compostable fraction retained on coarse screen – send to landfill
- Retained on fine screen send to beginning of composting process for further composting

5. Storage or disposal

- Storage is necessary because its use is seasonal
- Composting plant must have six months storage area
- Many composting operation combine their curing period with storage period

TYPES

- Composting methods are

1. Windrow composting
2. Aerated static pile composting
3. In-vessel composting system
    - Vertical composting reactor
    - Horizontal composting reactor
    - Rotating drum
4. Anaerobic composting

1. Windrow composting

- Least expensive
- Most common approach
- Windrows – regularly turned elongated pile with haystack shape in cross section and up to hundred meters or more in length
- Optimum size and shape depends on

-Particle size

-Moisture content

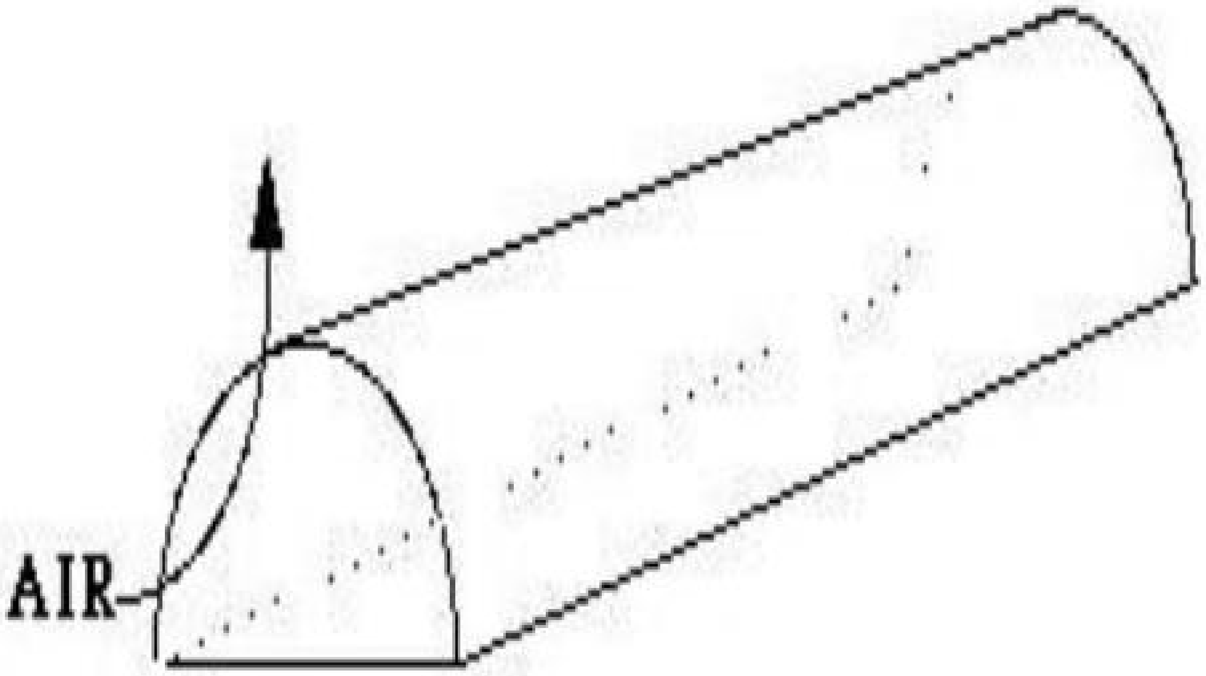
-Pore space

-Decomposition rate

- Mostly, height - 1.5 to 3 m

  width - 3 to 6 m

- Located on impermeable and firm surface
- Aeration – by turning pile once in week but frequent aeration is required if pile contains more bio-solids
- Turning moves material from pile surface to core so they can undergo composting
- Machines equipped with augers, paddles are used
- Heat will be released as steam to atmosphere


AIR

2. Aerated static pile composting

- Mechanically aerated
- Piles are placed over network of pipes connected to blowers
- Blower – supplies air for composting
- Air can be supplied under negative or positive pressure
- Negative pressure – drawing air out of pile
- Positive pressure – forcing air into pile

- Air circulation provides
  - Needed oxygen for composting microbes
  - Prevents excessive heat build up in piles
  - But odour nuisance occurs – controlled by traps or filters
- Inner portion of pile – temperature is adequate to destroy pathogens and weed seeds
- But surface of piles will not reach the desired temperature for destruction of pathogens because piles are not turned
- This problem can be overcome by placing a layer of finished compost of 15 to 30 cms thick
- This layer act as insulating blanket and helps to maintain desired temperature

- Used for

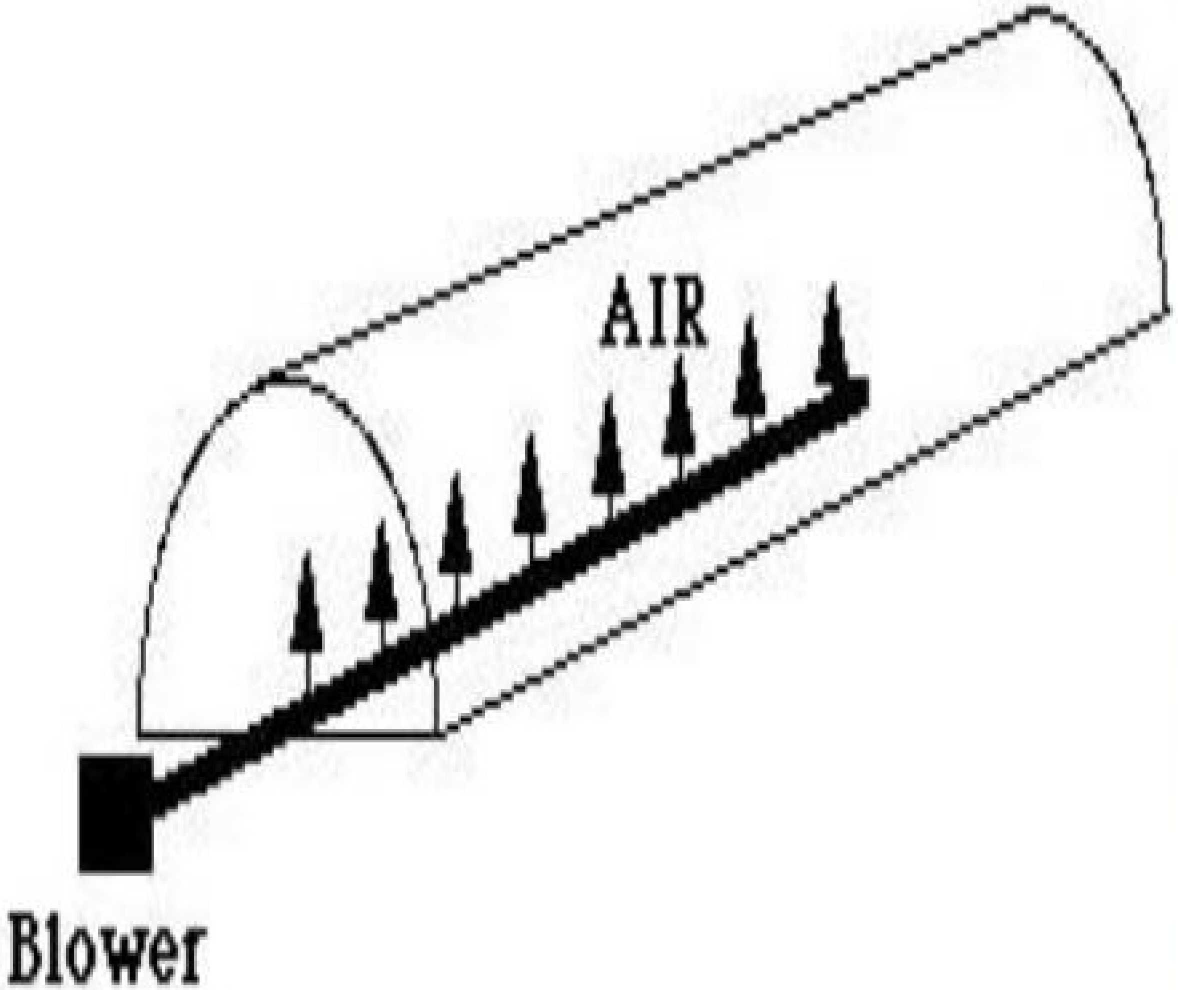
  -Yard trimmings

  -Bio-solids composting

  -Industrial composting

- Can be done under roof or in open
- To make compost – 6 to 12 weeks
- Land requirement - less than windrow composting

AERATED STATIC PILE



3. In-vessel composting system

- Enclose feedstock in chamber or vessel that provide adequate mixing, aeration and moisture
- Types vary with requirements for pre-processing materials

-Drums	single or multi-composting units
-Digester bins	rotates or stationary
-Tunnels	continuous or batch type

- Require further composting after discharging from vessel
- Positive pressure – forcing air into pile

- Advantages
  - All environmental conditions can be controlled to allow rapid composting
  - Retention time – one to four weeks
  - minimal odours
  - Little or no leachate
- Commonly used

i. Vertical composting reactors

ii. Horizontal composting reactors

iii. Rotating drum

i. Vertical composting reactors

- Generally over 4m high
- Can be housed in silos or other large structures
- Organic material feed from top
- Moves by gravity
- Aeration – pressure induced – airflow opposite to downward materials flow

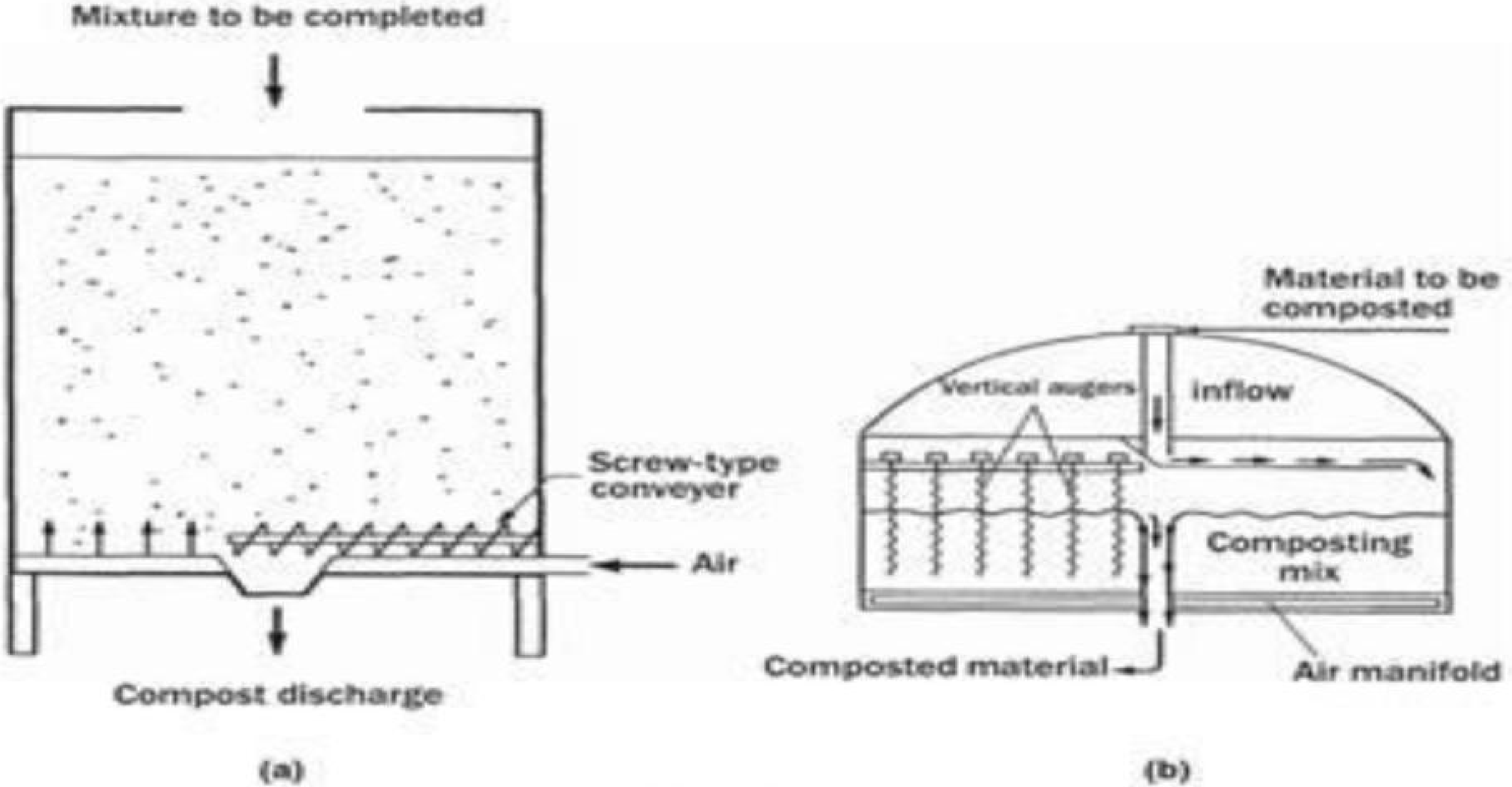


Figure 7.9 Vertical reactors.

- Advantages
  - Successfully used in industries with uniform feed stock
- Disadvantages
  - Process control is difficult due to height of reactors
  - Temperature and oxygen cannot be maintained at optimum levels
  - Rarely used in heterogeneous materials like MSW

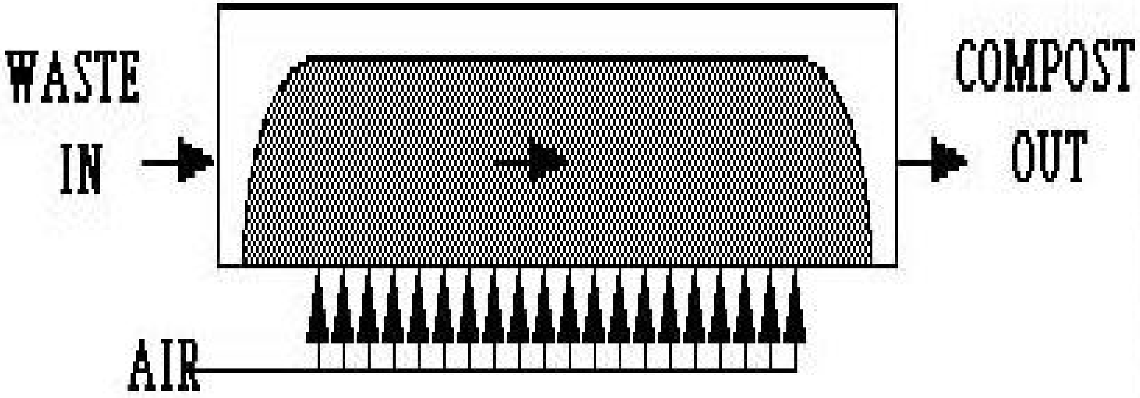
ii. Horizontal composting reactors

- Can avoid high temperature, oxygen, moisture contents by giving short airflow pathway

Types

  - Static or agitated
  - Pressure or vacuum induced aeration
- Static system – require loading and unloading mechanism
- Agitated system – turning process
- Used in heterogeneous MSW
- Systems with agitation and bed depths less than 2 to 3 m - effective

Horizontal Bed Reactor



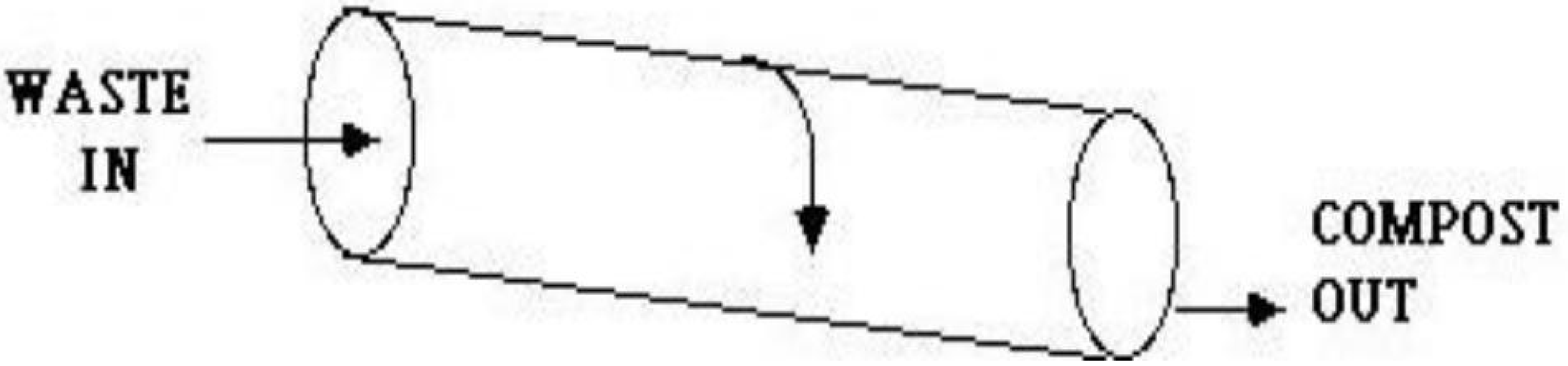
An example of in-vessel composting.

iii. <u>Rotating drum</u>

- Also known as digesters
- Advantage over vertical and horizontal
  - Less cost
  - Less residence time – few hours or days
- Processing is physical than biological
- Normally followed after biological processing

Rotating Drum

ROTATING DRUM



4. Anaerobic composting

- Facultative bacteria break down organic materials in absence of oxygen
- Produce methane and CO_2
- Advantage
  - Methane generated – marketed or converted to electricity
- Can be
  - Single stage digesters
  - Two stage digesters

- Single stage digesters
    - entire process in one air tight container
    - Feed stock shredded
    - Water and nutrients added
    - Agitation – continuous stirrers
- Two stage digesters
    - Liquid supernatant is circulated to second stage digester
    - Supernatant – generally continas high concentratons of dissolved and suspended solids, organic materials, nitrogen, phosphorous and other materials.
    - These material impose as extra load om the liquid treatment processes.
    - Aeration in this digester can be eliminated

DESIGN CONSIDERATIONS

- For best results in composting
  - Appropriate mixing of sludge
  - Needs optimum mass balance, moisture, temperature, pH, nutrients, air
  - Mass balance diagram can be used for all three composting methods

Item	Comment
Particle size	Size of SW between 25 and 75 mm
Carbon to nitrogen ratio	Between 25 and 50
Seeding	1 – 5 % by weight of decomposed SW
Moisture content	50 - 60%
Mixing/turning	Depend on type of operation
Temperature	First few days – 122◦ F to 131◦ F remaining days - 13◦ F to 140◦ F
Control of pathogens	Temperature - 140◦ F to 158◦ F
Air requirements	Air with at least 50%of oxygen
pH control	7 to 7.5
Degree of decomposition	Measured by COD
Land requirements	Capacity of 50 tons/day – 15 to 20 acres

ADVANTAGES OF COMPOSTING

- Form of source reduction or waste prevention
  - Materials can be completely diverted from disposal facilities
- Reduce waste stream volume
  - Diverting organic materials will frees up landfill space needed for non compostable materials
- Economic advantage
  - For communities where cost of using other options are high

4. Suitable for wide variety of end uses like landscaping, top soil blending and growth media
5. Compost increases water content and retention of sandy soil
6. Compost increases aeration and water infiltration of clay soil
7. Windrow and aerated static pile process require relatively simple mechanical equipment and is simple to operate
8. In vessel process require small area and have ability to control odours

DISADVANTAGES OF COMPOSTING

1. Windrow and aerated static pile process require large area and odour control is a problem
2. Ambient temperature and weather condition influence Windrow and aerated static pile composting
3. In vessel process have limited flexibility to handle changing odour and its maintenance is expensive

- <u>Vermiculture</u>

- Involves use of special types of earthworms to convert organic waste into worm casting which improves soils structure an fertility
- Vermicomposting is a simple and effective process that can be done indoors in the kitchen itself as it requires very little space and does not cause problems such as odour
- Some common worm species used for vermicomposting are Eisenia Fetida, Eudrilus Engeniae, Perionyx Excavatus

Pit Composting

- Another method of composting oranic waste to put it in pits and let it trun into compost over a period of six months or more.

- This process requires more space and time but the main benefits is that waste is not visible as it is buried in the pit.

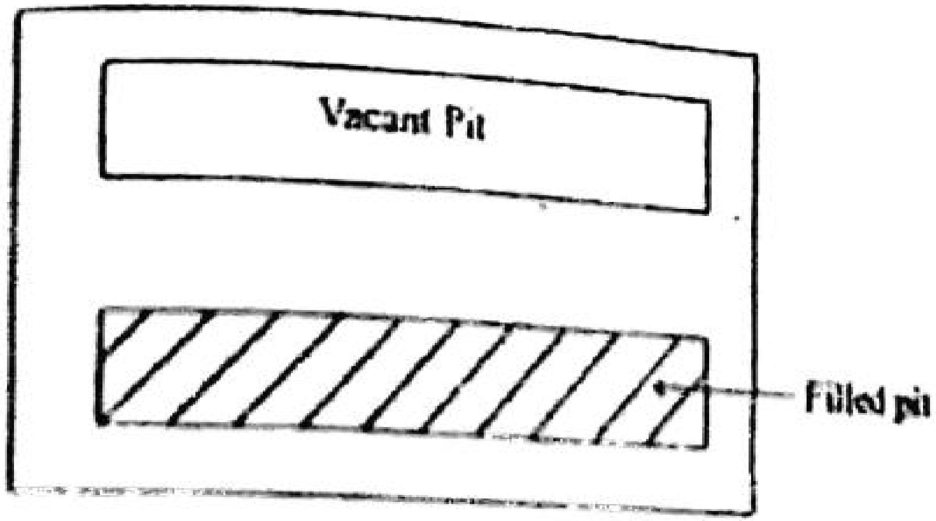
A compost pit in a Delhi park, India

INDORE PROCESS

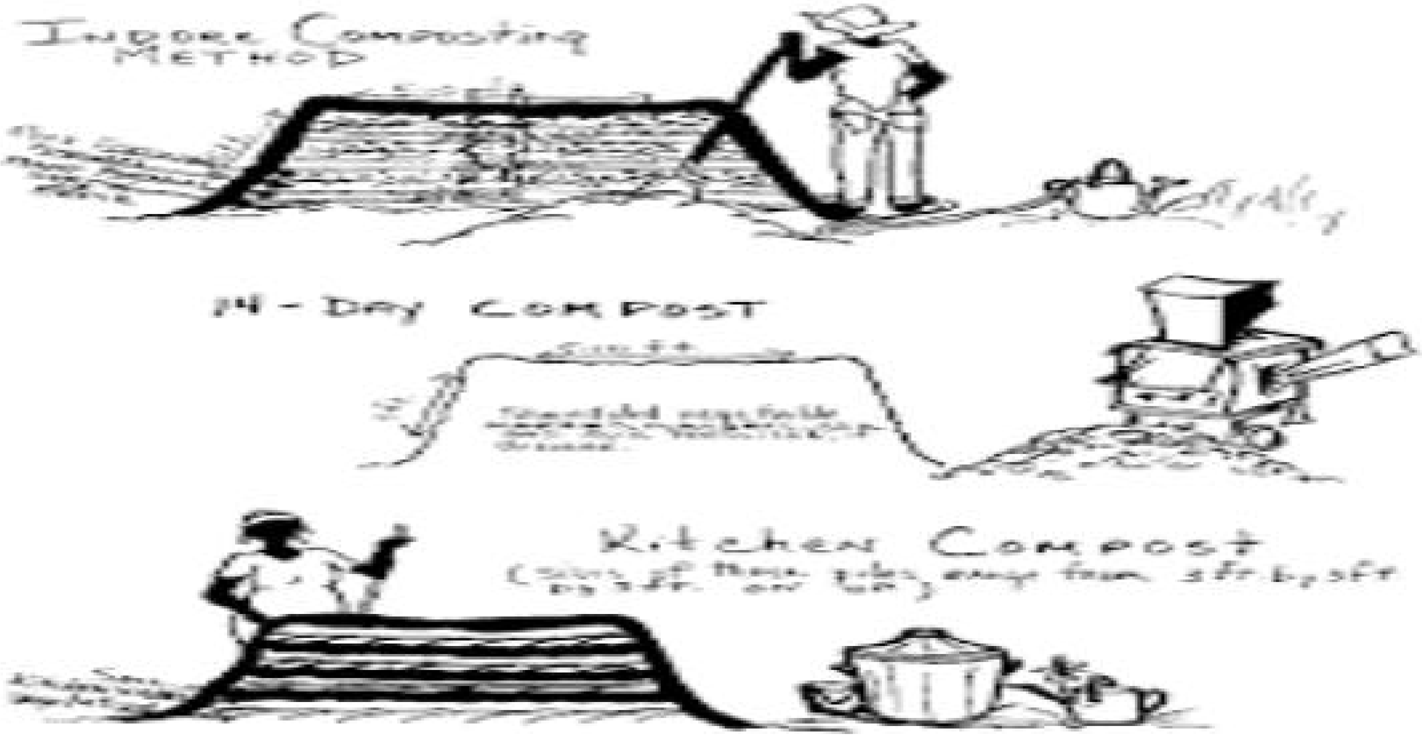
- Involves filling of alternate layers of MSW and night soil, similar thickness.
- To ensure aerobic condition the material is turned at specific intervals for which a 60 cm strip on the longitudinal side of pit is kept vacant.
- The first turn is manually given using long handled rakes 4-7 days after filling.

- ***<u>METHODOLOGY</u>***
- The method involves putting layers of different materials on top of each other to form a heap
- The base , formed of 1 meter wide and 3m long with twigs and cane shoot
- The filling process should complete within a week.
- After 2 to 3 weeks the heap should be taken apart and rebuilt for proper decomposition
- Again, a layer of coarse material should be laid down first (even decomposition)
- The material which was on the outside of the heap, should be placed into the middle of the new heap and watered then it should be covered with remaining material.
- After another 3 weeks this process may have to be repeated depending on how much the heap has decomposed

- It nearly takes 3 months for complete decomposition
- During the process urine (dilutes with 4 parts water) /ash are sprinkled over the layers of soil can accelerate process of decomposition.
- Also it adds the valuable nutrients to the compost
- Too much quantities of urine and ash can be destructive to the microorganisms in the heap.
- **Advs.**
- The Indore method produces compost in a short space of time and the process can be controlled weed seed and diseases are killed
- **Disadvs.**
- The Indore method requires a lot of water and is very labour intensive
- It works best when a lot of material to use



Indore heap method

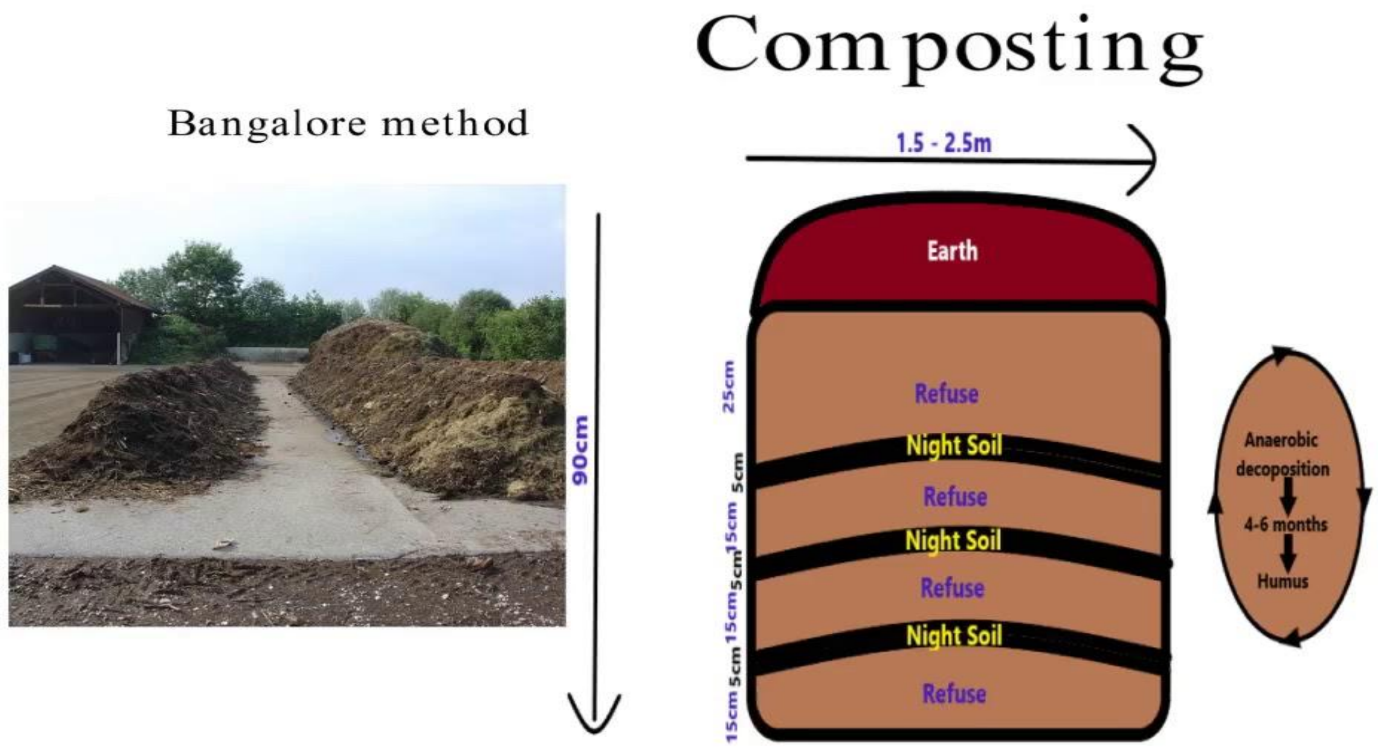


Bangalore Process

- Dry waste of material 25cm thick is spread in a pit and a thick suspension of cow dung in water is sprinkled over for moistening.
- A thin layer of dry waste is laid over the moistened layer
- Method carried out in pits where waste was anaerobically stabilized by alternate layers of MSW and night soil until it rises a height of 0.5m
- The pit is completely filled an final layer is laid to prevent fly breeding, entry of rain water and energy conservation
- The material is allowed to decompose for 4 to 6 months are used as manure
- It is left exposed without covering for 15 days it is given a turning then plastered with mud or damp grass so that it is closed from outside air.
- This allows anaerobic microorganisms to decompose the heap

- **Advs.**
- The Bangalore method uses less water and labour than other methods as turning is not required
- Suitable for area where less rainfall

- **Disadvs.**
- Weed seeds and diseases can survive due to low temp

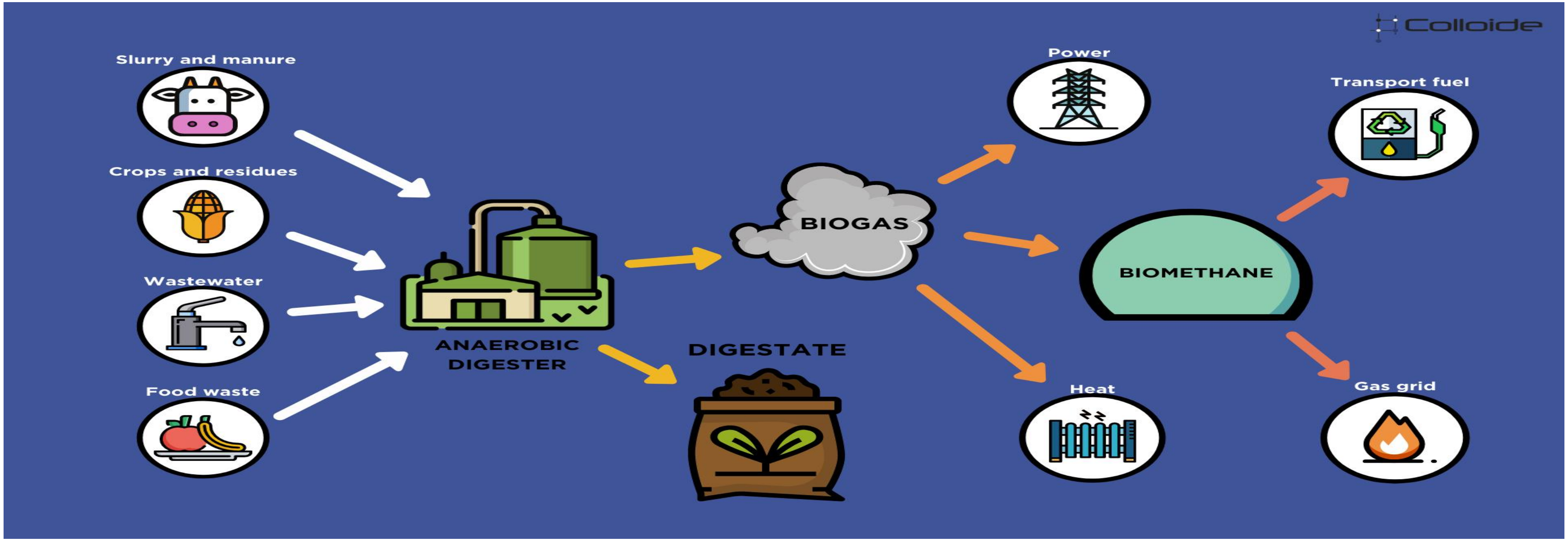


ANAEROBIC DECOMPOSITION

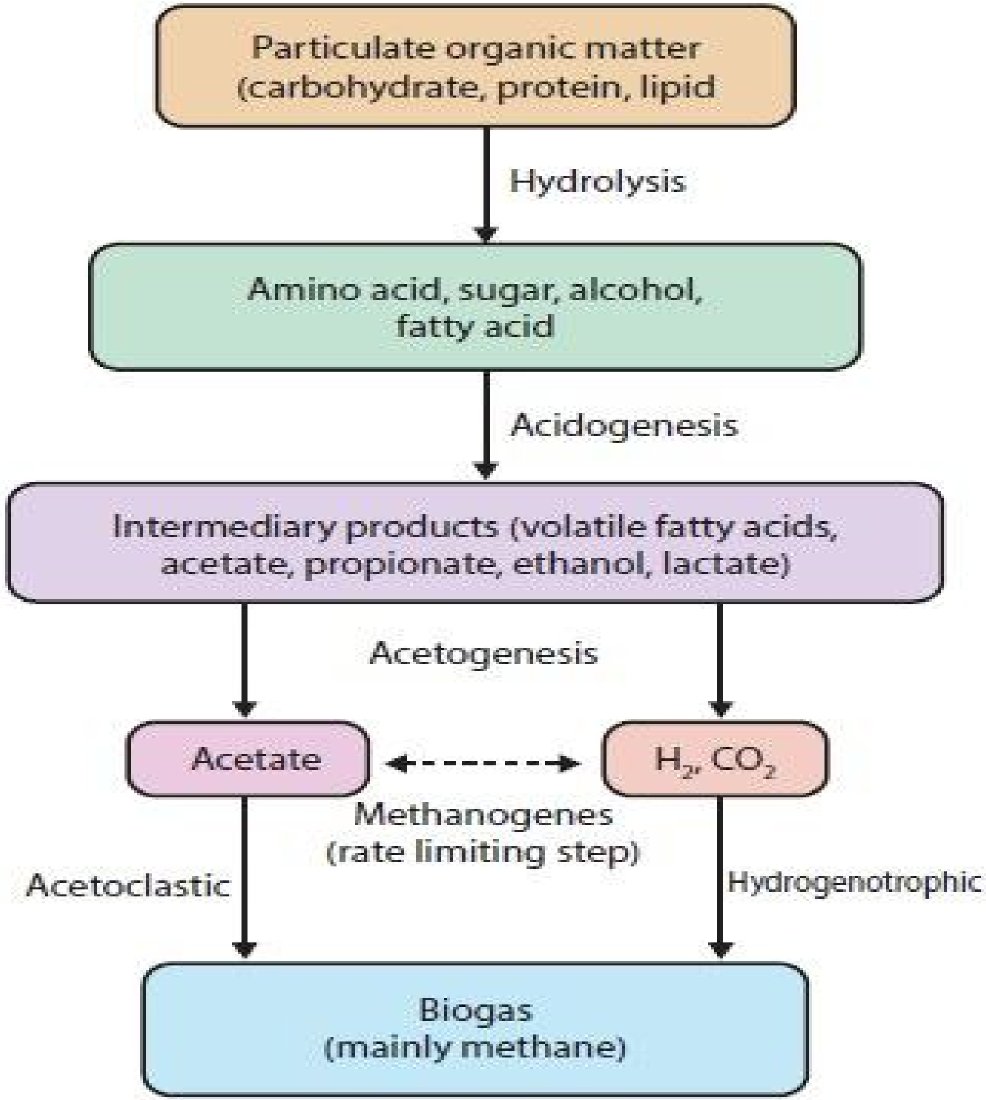
- It is a controlled process involving microbial decomposition of organic matter in absence of oxygen
- It involves the process of decaying biodegradable material in the absence of any terminal electron acceptors like sulphate,nitrate and oxygen
- It consist of a number of biochemical reactions carried out by several types of microrganisms that survive in oxygen free condition.
- During the process biogas is produced which is mainly composed of methane (40-70 vol%) and CO_2 (30-60 vol%) as major gases with trace amount of hydrogen sulphide(0-3 vol%, nitrogen and hydrogen (0-1 vol %)and water vapours

ANAEROBIC DECOMPOSITION

- The material left after the digestion process is called digestate which is rich in nutrients.
- Digestate is a wet mixture that can be separated into a solid and a liquid
- Biogas is a renewable energy source that can be used a fuel or can be used in variety of ways for production of heat and /or electricity
- A range of anaerobic digestion technologies convert livestock manure, municipal wastewater solids, food waste, high strength industrial waste water and residuals , fats , oils, and grease and various organic waste streams into biogas.


Colloide
Slurry and manure
Crops and residues
Wastewater
Food waste
ANAEROBIC DIGESTER
BIOGAS
DIGESTATE
Power
Transport fuel
BIOMETHANE
Heat
Gas grid

Anaerobic Digestion



1. Hydrolysis Process

- In this process, the insoluble complex organic matters such as protein, polysaccharides, and fats are converted to soluble monomers such as a peptide, fatty acids, and saccharides.
- It is a slow process
- This stage is a rate limiting stage

- The biochemical reaction involved is-

$$nC_6H_{10}O_5 + nH_2O \xrightarrow{Hydrolysis} nC_6H_{12}O_6$$

2.Acidogensis

- In this process, hydrolysed products are converted into simple molecules with low molecular weight, such as volatile fatty acids (propionic acid, butyric acid, valeric acid &isovaleric acid)and alcohols, aldehydes, and certain gases such as CO2, NH3, and H2.
- This stage is affected by a diverse group of bacteria which is capable of bringing down the pH inside the reactor to 4

- The biochemical reaction involved is-

$$nC_6H_{12}O_6 \xrightarrow{\text{Acid formers}} 3nCH_3COOH$$

3. Acetogenesis

- The products of acidogenesis stage are converted to acetate, H2 and CO2 by acetogenic bacteria.
- Based on metabolism, there are 2 groups of acetogenic bacteria
- -proton reducing acetogenic bacteria or H2 forming bacteria generating
- acetate, CO2 and H2.
- -Acetate-oxidizing bacteria or homoacetogens catalyse acetate conversion to CO2 and H2.
- This stage can be regarded as a preparation stage for methanogensis and the mostly major biochemical reaction carried out by homoacetogens

$$2CO_2 + 4H_2 \longrightarrow CH_3COOH + 2H_2O$$

4. Methnogensis

- Final stage in the other anaerobic digestion process in which methanogens create methane from the final product of acetogenesis as well as from some of the intermediate products from hydrolysis and acidogenesis.
- There are two pathways in general known to utilise acetic acid and C02 to create methane and the biochemical reaction are

$$CH_3COOH \longrightarrow CH_4 + CO_2$$

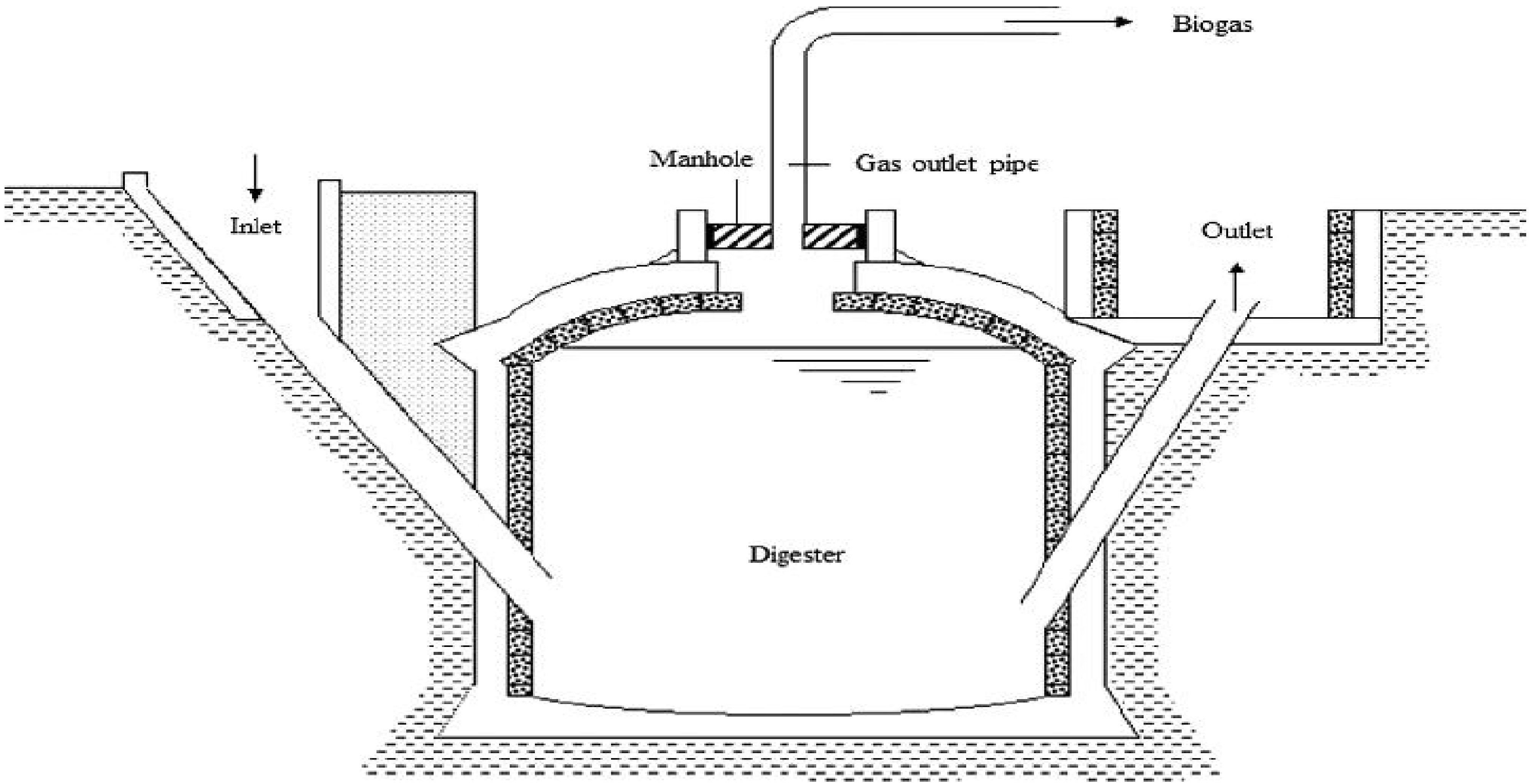
$$CO_2 + 4H_2O \longrightarrow CH_4 + 2H_2O$$

BIO-DIGESTORS

- It is a closed container in which the segregation and feeding of the organic substrate take place.
- In this digester, the biodegradation of substrate takes place under anaerobic condition and in the presence of methogenic bacteria, producing the methane rich biogas
- The generated gases can be utilised for cooking and for electricity generation
- The fully stabilized digested slurry can be used for fertilizers or soil conditioners
- 3 types-
-     - Fixed dome type
-     - floating drum type
-     -Bag type
- These digester can be further divided into two ways based on feeding process
- Continuous mode(material is added continuously and biogas production is uninterrupted
- Batch mode(material is loaded in one single operation and left until biogas production ceases)

1. Fixed dome type digester

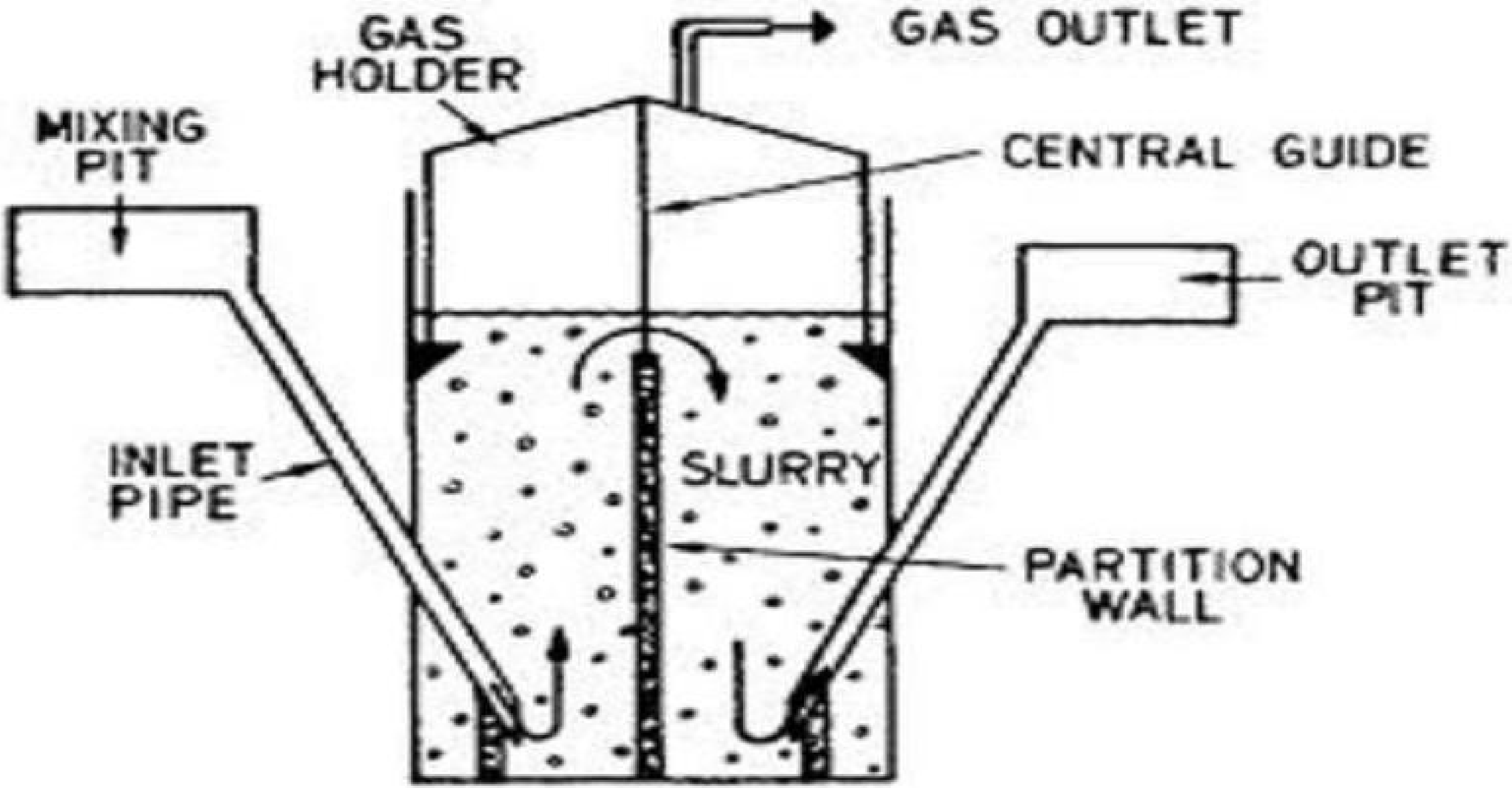
- It consists of an airtight container or fermentation chamber(constructed by brick, stone or concrete)feed and digestate pipes and a fixed dome on the top for biogas storage . The reaction and biogas storage chambers are connected
- Sealing is achieved by building up several layers of mortar on the digesters inner surface.
- The design- originated in Jiangsu, China as early as 1936.
- First fixed dome design in India was named as Janata model which could not become successful because of construction problem.
- The major problem was gas leakage because this ceiling should be there properly onto the dome and that become obsolete and then came its successor like this is the very popular model Deenbandhu model with improved design and consumed less building material


Biogas
Manhole
Gas outlet pipe
Inlet
Outlet
Digester

- **Advs.**
- Low initial cost
- Long useful life span (>=20 years)
- Low construction costs
- Require less space
- **Disadv.**
- Masonry gas holders require special sealants
- High technical skills for gas tight construction as gas leaks occur quite frequently
- Fluctuating gas pressure
- Excavation can be difficult and expensive in bed rock

Floating drum Type digester

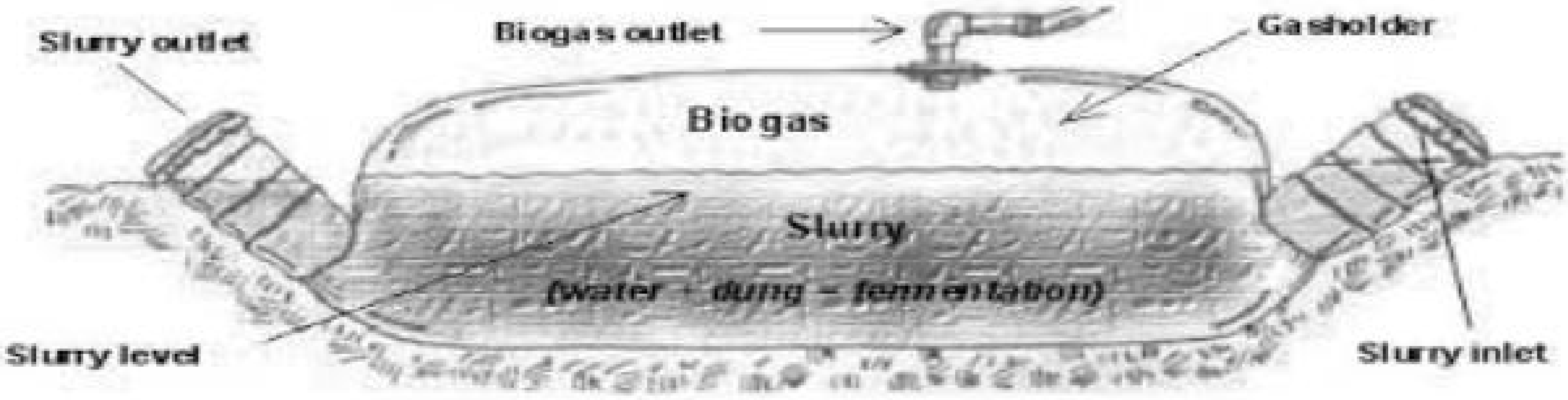
- Jashu Bhai J Patel (1956) first designed a floating drum biogas plant popularly called gobar gas plant.
- Floating drum plants consist of an underground digester (cylindrical or dome shaped) and a moving gas holder.
- The gas holder floats either directly on the fermentation slurry in a water jacket of its own.
- The gas collected in the gas drum which rise or moves down according to the amount of gas stores.
- The gas drum is prevented from tilting by a guiding frame.
- When the biogas is produced the drum moves up and when it is consumed the drum


GAS HOLDER
GAS OUTLET
MIXING PIT
CENTRAL GUIDE
OUTLET PIT
SLURRY
INLET PIPE
PARTITION WALL

- **Advs.**
- Easy operation
- Constant gas pressure
- Stored gas volume can be seen by the position of the drum
- **Disadv.**
- The steel drum is relatively expensive and its maintenance cost is high
- Panting should be carried out regularly to prevent rusting
- The lifespan of drum is short (upto 15 years , in tropical coastal region about 5 years)
- Gas holder can get stuck the resultant floating scum if organic substrate is fibrous.
-

3. Bag /balloon type digesters

- Comprises of a long cylinder of either PVC or polyvinyl chloride or a material known as red mud plastic that is developed in 1974 from the residue of bauxite smelted in the aluminium production plant.
- Incorporated in the bag are inlet and outlet pipes for the feedstock and slurry and a gas outlet pipe
- The feedstock inlet pipe is situated so that pressure in the bag is kept below 40 cm of water pressure
- Gas produced is stored in the bag under a flexible membrane
- A complete 50 m3 volume digester weigh just 270 kg- can be easily installed in a shallow trench


Slurry outlet
Biogas outlet
Gasholder
Biogas
Slurry
(water + dung = fermentation)
Slurry level
Slurry inlet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- Feedstock is fed into the bag semi continuously with the feed displacing as equal amount of slurry removed from the outlet
- If the red mud plastic or PVC is unobtainable the design can be constructed from concrete with a flexible gas collecting membrane situated at the top of the container
- **Diadvs.**
- Fabrication materials if damaged are difficult to repair
- Remote or rural lack access to repair materials and facilities