INSTITUTE OF AERONAUTICAL ENGINERRING
(AUTONOMOUS)
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ENERGY FROM WASTE
(AEE551)
IARE-R16 B.Tech VII SEM
COMMON FOR ALL

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COURSE OUTLINE

UNIT	TITILE	CONTENT
II	WASTE TREATMENT AND DISPOSAL	Land fill method of solid waste disposal land fill classification, types, methods and sitting consideration; Layout and preliminary design of landfills: Composition, characteristics, generation movement and control of landfill leach ate and gases, environmental monitoring system for landfill gases.
III	BIO-CHEMICAL CONVERSION	Energy generation from waste bio-chemical conversion: Sources of energy generation, anaerobic digestion of sewage and municipal waste, direct combustion of MSW-refuse derived solid fuel. Industrial waste, agro residues and anaerobic digestion.

COURSE OUTLINE

UNIT	TITILE	CONTENT
IV	THERMO-CHEMICAL CONVERSION	Biogas production, land fill gas generation and utilization, thermo-chemical conversion: Sources of energy generation, gasification of waste using gasifies briquetting, utilization and advantages of briquetting, environmental benefits of bio-chemical and thermo-chemical conversion.
V	E-WASTE MANAGEMENT	E-waste: E-waste in the global context: Growth of electrical and electronics industry in India, environmental concerns and health hazards; Recycling E-waste: A thriving economy of the unorganized sector, global trade in hazardous waste, impact of hazardous e-waste in India; Management of e-waste: E-waste legislation, government regulations on e-waste management, international experience, need for stringent health safeguards and environmental protection laws of India.

TEXT BOOKS

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COURSE OBJECTIVES

At the end of the course, the students will be able to:

I. Understand the principles associated with effective energy management and to apply these principles in the day to day life.

II. Develop insight into the collection, transfer and transport of municipal solid waste.

III. Explain the design and operation of a municipal solid waste landfill.

IV. Evaluate the main operational challenges in operating thermal and biochemical energy from waste facilities and device key processes involved in recovering energy from wastes.

UNIT 1

INTRODUCTION TO WASTE AND WASTE PROCESSING

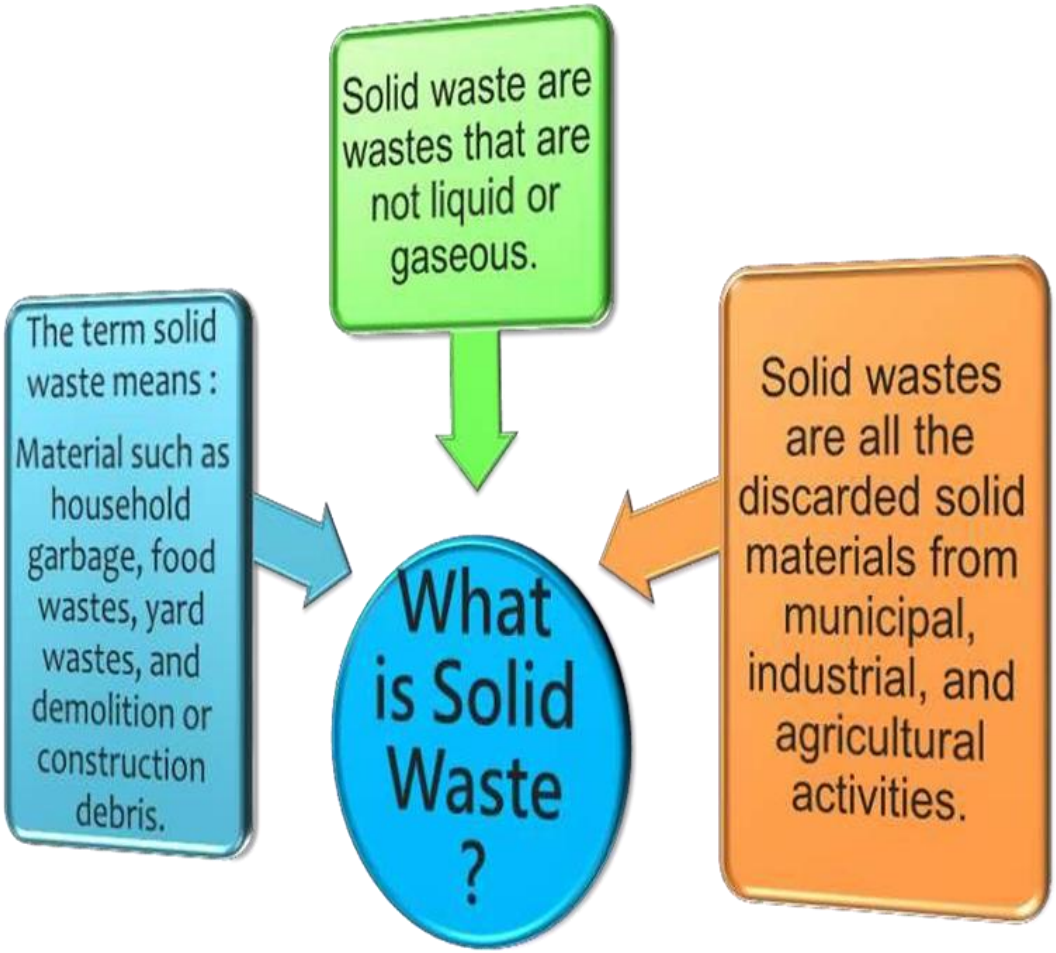
CONTENTS

- What is solid waste?
- Composition of MSW
- Properties of MSW
- Waste collection and transfer
- Minimization and recycling
- Aerobic composting
- Biomedical waste treatment
- Incineration

INTRODUCTION TO SOLID WASTE

- **Definition-** Any useless, discarded, unwanted material that is not a liquid or gas is referred as **solid waste or refuse.**

- It is non liquid , non gaseous material ranging from municipal garbage to industrial waste that contain complex and sometimes hazardous substances.



INTRODUCTION TO SOLID WASTE

- As per the Municipal Solid Waste (Management &Handling) Rule, 2000 garbage is define as Municipal Solid Waste which includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes.
- Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue, and waste from streets. This garbage is generated mainly from residential and commercial complexes.

CLASSIFICATION OF SOLID WASTE

- It is based on Sources, types of solid waste, composition of solid waste and the rate at which it is generated, discarded or disposed.

1. **Residential**– it refers to wastes generated from dwelling, apartment, town houses. It consists of left over food, vegetables, peeled material, plastic, clothes, wood, ashes, etc.
2. **Commercial**– Waste from stores, hotels, markets, restaurants, shopping malls, etc. It consists of grocery material, leftover food, metals, E-waste, etc.
3. **Institutional**– waste generated from schools, colleges, offices. It consists of paper, plastic, glass, E-waste.
4. **Municipal waste-** waste generated from house holds, commercials buildings, street sweeping, hotels and restaurants, clinics and dispensaries, construction and demolition, horticulture and sludge.

5. Industrial– consists of process waste, ashes, demolition and construction waste, hazardous waste from various industrial processes.

6. Agricultural– Includes spoiled food grains and vegetables, agricultural remains, litter generated from fields, farms, vineyards etc.

CHARACTERISTICS OF MSW:

Type of Waste	Quantity
Compostable / Bio-degradable matter	30% - 55%(can be converted into manure)
Inert material	40% - 45% (to go to landfill)
Recyclable materials	5% - 10% (Recycling)

TYPE BASED CLASSIFICATION

- It is based on the physical, chemical and biological characteristics of waste.

1. **Refuse**- This is all putrescible and non putrescible waste except body waste. It consists of **rubbish and garbage.**

2. **Rubbish**– Portion of refuse which is non putrescible solid waste. (packaging material)

3. **Garbage–** consists of putrescible component of solid waste. Includes vegetable, animal waste resulting from handling, sale, storage, preparation, cooking and serving of food.

TYPE BASED CLASSIFICATION

Garbage consist of four broad categories of waste

- **Organic waste:** kitchen waste, vegetables, flowers, leaves, fruits.
- **Toxic waste:** old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish.
- **Recyclable:** paper, glass, metals, plastics.
- **Soiled:** hospital waste such as cloth soiled with blood and other body fluids.

TYPE BASED CLASSIFICATION

1. **Ashes and residues** – Total inorganic includes remains from burning of wood, coal, charcoal and other combustible material for cooking and heating in houses. When produced in large amount in factories and power plants it is classified as industrial waste.
2. **Combustible and non combustible waste-** Generated from household and institutions excluding food waste.
    - Combustible – paper, textile, cardboard , rubber, garden trimmings.
    - Non combustible material – glass, crockery, cans, dirt, ferrous and non ferrous material.

TYPE BASED CLASSIFICATION

3. **Bulky waste**– Household waste which cannot be accommodated in the normal storage containers and need special collection mechanism. (refrigerators, washing machines, furniture etc.)

4. **Street Waste**– waste collected from streets, walkways, parks, playgrounds. Include paper, cardboard, plastic, dirt leaves in large quantities.

5. **Biodegradable and non biodegradable waste-** Organics are biodegradable waste and inorganic and recyclable material is non biodegradable such as Plastic, metal, glass, etc.

TYPE BASED CLASSIFICATION

6. **Dead animals**- those who die naturally or accidently killed on the road. It does not include waste from slaughter house.
7. **Construction and demolition waste**– Include stones, concrete, bricks, roofing and plumbing material, electric wires etc.
8. **Farm waste**– results from diverse agricultural activities like planting, harvesting, rearing of animals, poultry waste.
9. **Hazardous waste** – Include the waste from institutions, and industries which have characteristics of Ignitability, corrosively, reactivity, toxicity.

TYPE BASED CLASSIFICATION

10. **Sewage waste**- These are the solid byproducts of sewage treatment. Mostly organic derived from treated organic sludge separated from raw and treated sewage. Waste is sticky and rich in pathogens.

11. **E waste**– these are the electronic products nearing the end of their useful life. It include discarded computers, televisions, fax machines, copiers, cell phones, batteries.

COMPOSITION OF SOLID WASTE

1. The composition and characteristics of municipal solid wastes vary throughout the world. Even in the same country it changes from place to place as it depends on number of factors such as social customs, standard of living, geographical location, climate etc.
2. MSW is heterogeneous in nature and consists of a number of different materials derived from various types of activities. Even then it is worthwhile to make some general observation to obtain some useful conclusions. ·
3. The major constituents are paper and putrescible organic matter; Metal, glass, ceramics, plastics, textiles, dirt and wood are generally present although not always so, the relative proportions depending on local factors; The average proportion of constituents reaching a disposal site(s) for a particular urban area changes in long term although there may be significant seasonal variations within a year.

COMPOSITION OF SOLID WASTE

	Low Income Countries (1)	Middle Income Countries (2)	High Income Countries (3)
Composition : (% by weight)			
Metal	0.2 – 2.5	1 – 5	3 – 13
Glass, Ceramics	0.5 – 3.5	1 – 10	4 – 10
Food and Garden waste	40 – 65	20 – 60	20 – 50
Paper	1 – 10	15 – 40	15 – 40
Textiles	1 – 5	2 – 10	2 – 10
Plastics/Rubber	1 – 5	2 – 6	2 – 10
Misc. Combustible	1 – 8	–	–
Misc. Incombustible	–	–	–
Inert	20 – 50	1 – 30	1 – 20
Density (kg/m^3)	250 – 500	170 – 330	100 – 170
Moisture Content (% by wt)	40 – 80	40 – 60	20 – 30
Waste Generation (kg/cap/day)	0.4 – 0.6	0.5 – 0.9	0.7 – 1.8

COMPOSITION OF SOLID WASTE

- **Global warming** is a long-term rise in the average temperature of the Earth's **climate** system; an aspect of **climate change** shown by temperature measurements and by multiple effects of the **warming**. Temperatures today are 0.74 °C (1.33 °F) higher than 150 years ago.
- Many scientists say that in the next 100–200 years, temperatures might be up to 6 °C (11 °F) higher than they were before the effects of global warming were discovered.
- Most noticeable changes by this increase in temperature is the melting of ice caps all around the world. Sea level is rising steadily as a result from continental ice melting into the sea. As a prediction, many cities are soon to be partially submerged in the ocean.

CAUSES OF GLOBAL WARMING

1. **Greenhouse gases:**
   Greenhouse gases cause the greenhouse effect. The primary greenhouse **gases** in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide and ozone.
2. **Burning fossil fuels:**
   When we burn fossil fuels like coal, and gas to create electricity or power our cars, we release CO_2 pollution into the atmosphere.
3. **Deforestation & Tree-Clearing:**
   Plants and trees play an important role in regulating the climate because they absorb carbon dioxide from the air and release oxygen back into it. Forests and bush land act as carbon sinks and are a valuable means of keeping global warming to 1.5°C.

CAUSES OF GLOBAL WARMING

4. **Agriculture & Farming:**
   Animals, livestock like sheep and cattle , produce methane, a greenhouse gas. When livestock grazed at a large scale, as in Australia, the amount of methane produced is a big contributor to global warming.

EFFECTS OF GLOBAL WARMING

- Increase in average temperatures and temperature extremes.
- Extreme weather events
- Ice melt
- Sea levels and ocean acidification
- Plants and animals
- Social effects

WASTE CHARACTERISTICS

CHARACTERISTICS OF WASTE:

1. Physical
2. Chemical
3. Biological

PHYSICAL CHARACTERISTICS

- Information and data on the physical composition of solid wastes.
- These are important in the selection and operation of equipment and facilities, and in the analysis and design of disposal facilities.

Major Physical Characteristics:	Other Physical Characteristics
1. Density 2. Moisture Content 3. Waste Particle Size	1. Colour 2. Shape of components 3. Optical property 4. Magnetic properties

DENSITY

1. Density of waste, i.e. its mass per unit volume (kg/m3).
2. It is a critical factor in the design of a SWM system i.e. the design of sanitary landfills, storage, types of collection and transport vehicles etc.
3. For an efficient operation of landfill, compaction of wastes to optimum density is essential.
4. Any normal compaction equipment can achieve reduction in volume of wastes by 75%, which increases an initial density from 100 kg/m3 to 400 kg/m3.
5. Municipal solid wastes as delivered in compaction vehicles have been found to have a average density of about 300 kg/m3.
6. A waste collection vehicle can drag four times the weight of waste in its compacted state than when it is un-compacted.

MOISTURE CONTENT

- Moisture content is defined as the ratio of the weight of water to the total weight of the wet waste.
- Moisture increases the weight of solid thereby, the cost of collection and transport.
- It 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.
- A typical range of moisture content is 20 to 40%. However, values greater than 40% are not uncommon.

$$\text{Moisture content}(\%) = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} * 100$$

PARTICLE SIZE

1. The size distribution of solid wastes are important in the recovery of materials especially with mechanical means such as trommel screens and magnetic separators.
2. It plays a significant role in the design of mechanical separators and shredders.

The major means of controlling particle size is through shredding.

1. Shredding increases homogeneity, increases the surface area/volume ratio and reduces the potential of liquid flow paths through the waste.
2. Particle size will also influence waste packing densities.
3. Particle size reduction could increase biogas production through the increased surface area available to degradation by bacteria.

OTHER PROPERTIES

1. **Optical property** can be used to separate opaque materials from transparent substances which majorly contains glass and plastic.
2. **Shape** can be used for segregation as flaky substance will behave differently compared to non-flaky substance.
3. **Magnetic separators** are designed based on magnetic characteristics of the waste.
4. **The field capacity** of waste is the total amount of moisture which can be retained in a waste sample subject to gravitational pull. It is used to determine the formation of leachate in landfills. It is a critical measure because excess water in field capacity will form leachate.

CHEMICAL CHARACTERISTICS

- Knowledge of the classification of chemical compounds and their characteristics is essential for the proper understanding of the behavior of waste, as it moves through the waste management system.

- To use solid wastes as fuel, or for any other purpose, their chemical characteristics should be known.

CHEMICAL PROPERTIES INCLUDES…

LIPIDS

1. This class of compounds includes fats, oils and grease
2. principal sources of garbage, cooking oils and fats.
3. Lipids have high heating values, about 38,000 KJ/Kg, which makes them suitable for energy recovery.
4. Since lipids become liquid at temperatures slightly ambient, they add to the content during decomposition.

CARBOHYDRATES

1. These are found primarily in food and yard wastes, which encompass sugar and polymer of sugars (e.g., Starch, cellulose, etc.) With general formula (CH2O)X.
2. Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane.
3. Decomposting carbohydrates attract flies and rats and therfore should not be left exposed for long time.

CHEMICAL PROPERTIES INCLUDES…

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 FIBERS

- These are found in paper products, food and yard wastes that are resistant to biodegradation.
- They are a highly combustible solid waste, having a high proportion of paper and wood products, they are suitable for incineration.

CHEMICAL PROPERTIES INCLUDES...

HEATING VALUE

- Anevaluation of the potential of waste as a fuel for incineration, requires a determination of its heating value expressed as kilojoules per kilogram(KJ/Kg)
- The heating value is determined experimentally using the bomb calorimeter test, in which the waste of specified quantity is heated at constant temperature of 25C.

SYNTHETIC ORGANIC MATIRIALS

- They are highly resistant to biodegradation and therefore, are objectionable and special concern in SWM.
- Plastics have a high heating value, about 32,000 KJ/KG, which makes them very suitable for incineration.

CHEMICAL PROPERTIES

Chemical properties of MSW are very important in evaluating the alternative processing and recovery options:

- Proximate analysis
- Fusing point of ash
- Ultimate analysis (major elements)
- Energy content

CHEMICAL PROPERTIES

- Proximate analysis for the combustible components of MSW includes the following tests:

1. Moisture (drying at 105 C for 1 h)
2. Volatile combustible matter (ignition at 950 C in the absence of oxygen)
3. Fixed carbon (combustible residue left after Step 2)
4. Ash (weight of residue after combustion in an open crucible)

- Fusing point of ash is the temperature at which the ash resulting from the burning of waste will form a solid (clinker) by fusion and agglomeration. Typical fusing temperatures: 1100-1200 C

BIOLOGICAL PROPERTIES

It includes:

1. Biodegradability of Organic Waste:

- Volatile solids (VS) content, determined by ignition at 550C, is often used as a measure of the biodegradability of the organic components.
- The use of VS in describing the biodegradability of the organic components is misleading, as some of the organic constituents are highly volatile but low in biodegradability(e.g., Newsprint and certain plant trimmings).

2. Odours

3. Breeding of flies

COLLECTION OF SOLID WASTE

- Collection of solid waste (by external stakeholders) from its various sources or from communal storage facilities, and transportation of this waste to the place of final disposal.
- It also considers all activities related to loading of waste into collection vehicles, and unloading of waste from collection vehicles at communal collection points, processing places, transfer stations and final disposal sites.
- It is the largest cost element in most municipal solid waste management systems, accounting for 60–70 per cent of costs in industrialized countries, and 70–90 per cent of costs in developing and transition countries (IETC, 1996)

CLASSIFICATION

- Classified based on

  availability of collection services,

  the mode of operation and

  the types of waste materials collected

- Primary Collection of solid waste from the source of generation and transportation of waste to the final disposal site, but more often it involves transportation to communal collection bins or points, processing or transfer station
- Secondary Collection of waste from communal bins, storage points or transfer station, and transportation to the final disposal

COMMUNAL SCHEME OF COLLECTION

- The principal disadvantage of this system is that containers/collection points are located in a public place (lacking ownership by the public) which, in many situations, leads to indiscriminate disposal of waste outside the container.
- Thus, the actual economy of this system mostly depends on public co-operation.
- It is therefore essential to pay more attention to improving the design, and operation and maintenance practices of a communal system to increase public acceptance, and to optimize the productivity of this system.
- The use of portable storage containers maximizes the productivity of labor and vehicles of such collection system

BLOCK COLLECTION

- Waste generators are responsible for bringing their waste to collection vehicles
- This system has low to medium labor and vehicle productivity, but it minimizes the spread of waste on streets

KERBSIDE/ALLEY

- This is the most common collection method in industrialized countries and in the wealthier communities of some developing countries.
- Waste generators place the waste containers or bags (sacks) on the kerb or in the alley on a specific day (or specific days) for collection by external actors.
- A regular and well organized collection service is essential so that generators know exactly when to leave out their waste.

DOOR TO DOOR COLLECTION

- This is more common in industrialized countries, but an increasing number of micro-enterprises and/or community-based organizations are forming in wealthier communities in many developing countries to perform this task.
- This system has yet to receive public attention, but as with the use of bags for waste it maximizes the productivity of crew, as retrieval of containers is not required.

BASED ON MODES OF OPERATION

Hauled containers:

- An empty storage container (known as a drop-off box) is hauled to the storage site to replace the container that is full of waste, which is then hauled to the processing point, transfer station or disposal site
- The time required per trip Thcs = (PThcs + q + m + nx)

Where,

T = time per trip for hauled-container system, h/trip hcs .

PThcs= pick-up time per trip for hauled-container system, h/trip q = at-site time per trip,

h/trip m = empirical haul constant, h/km

n = empirical haul constant, h/km

x = round-trip haul distance, km/trip

HAULED CONTAINER

The pick-up time per trip PThcs is equal to:

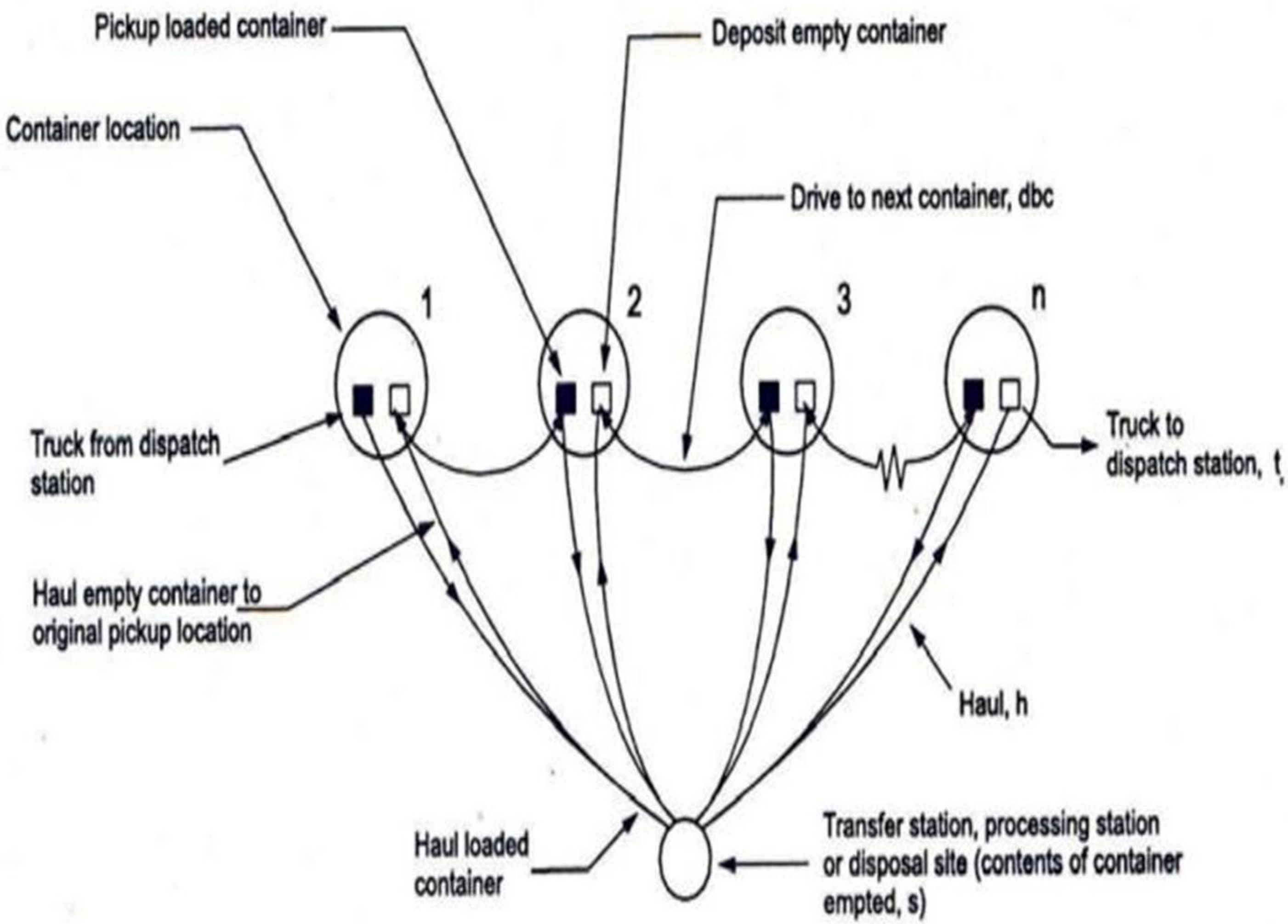
PThcs = pc + uc + dbc Where,

pc = pick-up time per trip, h/trip

uc = time required to unload empty container, h/trip

dbc = average time spent driving between container locations, h/trip(determined locally).

HAULED CONTAINER



Haul container system

STATIONARY CONTAINERS

In this system, containers used for the storage of waste remain at the point of collection. The collection vehicles generally stop alongside the storage containers, and collection crews load the waste from the storage containers into the collection vehicles and then transport the waste to the processing, transfer or disposal site.

STATIONARY CONTAINERS

For systems using mechanically self-loading compactors, the time per trip is:

$T_{scs} = (PT_{scs} + q + m + nx)$ (4.4) Where,

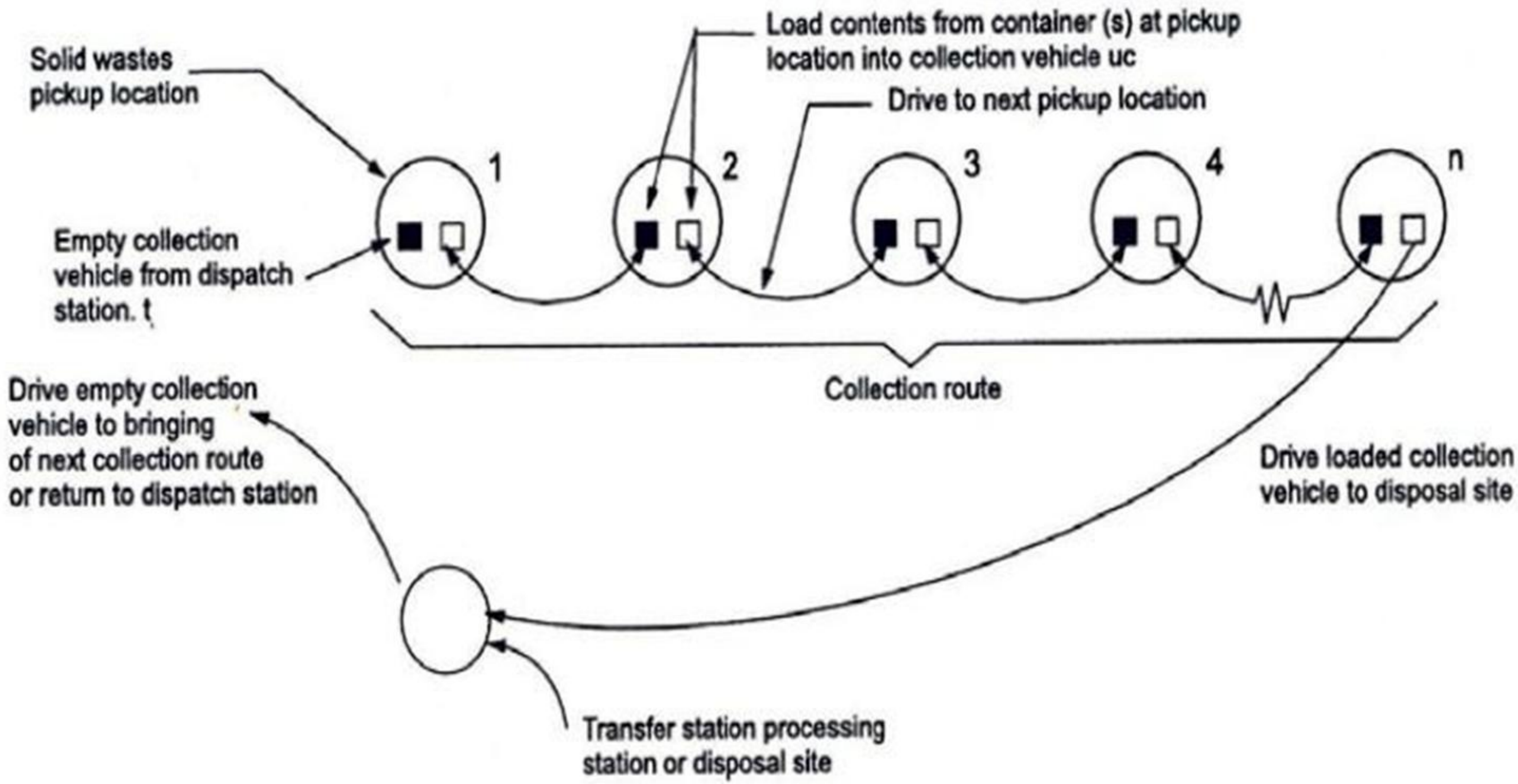
T_{scs} = time per trip for stationary-container system, h/trip

PT_{scs} = pick-up time per trip for stationary-container system, h/trip

q = at-site time per trip, h/trip

m = empirical haul constant, h/km

STATIONARY CONTAINERS



Stationery container system

FREQUENCY OF COLLECTION

- Quantity of waste
- rate of generation
- characteristics of waste
- Climate
- density and type of housing
- availability of space within the premises
- size and type of storage facilities (small, large, individual or communal)
- attitude of generators

TRANSFER STATION

- Transfer station is a centralized facility, where waste is unloaded from smaller collection vehicles and re-loaded into large vehicles for transport to a disposal or processing site. This transfer of waste is frequently accompanied by removal, separation or handling of waste.
- In areas, where wastes are not already dense, they may be compacted at a transfer station. The technical limitations of smaller collection vehicles and the low hauling cost of solid waste, using larger vehicles, make a transfer station viable.
- Also, the use of transfer station proves reasonable, when there is a need for vehicles servicing a collection route to travel shorter distances, unload and return quickly to their primary task of collecting the waste.

TYPES OF TRANSFER STATION

Small to medium transfer stations:

- These are direct-discharge stations that provide no intermediate waste storage area. The capacities are generally small (less than 100 tones/day) and medium (100 to 500 tones/day).
- Depending on weather, site aesthetics and environmental concerns, transfer operations of this size may be located either indoor or outdoor.
- More complex small transfer stations are usually attended during hours of operation and may include some simple waste and materials processing facilities. For example, it includes a recyclable material separation and processing center.
- The required overall station capacity (i.e., the number and size of containers) depends on the size and population density of the area served and the frequency of collection.

TYPES OF TRANSFER STATION

Large transfer stations:

- These are designed for heavy commercial use by private and municipal collection vehicles. The typical operational procedure for a larger station is as follows:
- when collection vehicles arrive at the site, they are checked in for billing, weighed and directed to the appropriate dumping area; collection vehicles travel to the dumping area and empty the wastes into a waiting trailer, a pit or a platform; after unloading, the collection vehicle leaves the site, and there is no need to weigh the departing vehicle, if its weight (empty) is known; Transfer vehicles are weighed either during or after loading. If weighed during loading, trailers can be more consistently loaded to just under maximum legal weights and this maximizes payloads and minimizes weight violations.

MINIMIZATION OF SOLID WASTE

- Minimizing solid waste, also known as waste prevention or source reduction is the design , purchase, manufacture, or use of products and materials to reduce the amount or toxicity of solid waste generated.
- It is not recycling, although these two solid waste management strategies are often confused with each other.
- Recycling is an effective way to manage waste materials once they have been generated; minimizing solid waste actually reduces the amount of material used and therefore the amount discarded.

BIOMEDICAL WASTE MANAGMENT

1. **Hospital waste** refers to all waste, biological or non- biological that is discarded and not intended for further use.
2. **Bio-medical waste** means any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biological, and including categories mentioned in Schedule I.
3. **Infectious waste**: The wastes which contain pathogens in sufficient concentration or quantity that could cause diseases. It is hazardous.

   Eg. culture and stocks of infectious agents from laboratories, waste from surgery, waste originating from infectious patients.

SOURCES

- Hospitals
- Nursing homes
- Clinics
- Medical laboratories
- Blood banks
- Mortuaries
- Medical research & training centers
- Biotechnology institution/production units
- Animal houses etc.
- Such a waste can also be generated at home if health care is being provided there to a patient (e.g. injection, dressing material etc.)

STORAGE

Color coding	Type of container	Waste categories
Yellow 	Plastic bags	Cat 1 human anatomical waste Cat 2 Animal Waste Cal 3 Microbiological Waste Cat 6 Solid Waste
Red 	Disinfected container plastic bags	Cat 3 Microbiological Cat. 6 Soiled Dressing
Blue/white 	Plastic bags, puncture proof containers	Cat. 4 Waste sharp Cat.7 Plastic disposable
Black 	Do	Cat. 5 Discarded medicine Cat. 9 Incineration ash Cat 10 Chemical Waste

TRANSPORT

- The waste may be temporarily stored at the central storage area of the hospital and from there it may be sent in bulk to the site of final disposal once or twice a day depending upon the quantum of waste. During transportation following points should be taken care of:

1. Ensure that waste bags/containers are properly sealed and labeled.
2. Bags should not be filled completely, so that bags can be picked up by the neck again for further handling. Hand should not be put under the bag. At a time only one bag should be lifted.
3. Manual handling of waste bags should be minimized to reduce the risk of needle prick injury and infection.
4. BMW should be kept only in a specified storage area.

TRANSPORT

5. After removal of the bag, clean the container including the lid with an appropriate disinfectant.
6. Waste bags and containers should be removed daily from wards / OPDs or even more frequently if needed (as in Operation Theatres, ICUs, labor rooms). Waste bags should be transported in a covered wheeled containers or large bins in covered trolleys.
7. No untreated bio -medical waste shall be kept stored beyond a period of 48 hours

DISPOSAL OF BIOMEDICAL WASTE

INCINERATORS:

- A high temperature dry oxidation process, which reduces organic and combustible waste to inorganic incombustible matter.
- Usually used for the waste that can not be reused, recycled or disposed of in landfill site
- The incinerator should be installed and made operational as per specification under the BMW rules 1998
- Certificate may be taken from Central pollution control board(CPCB)/State Pollution Control Board.

Types of incinerators are:

i. Double chamber pyrolytic incinerators
ii. Single-chamber furnaces
iii. Rotary kilns

INCINERATORS

Characteristics of waste suitable for incineration are:

- Low heating volume above 2000 Kcal/Kg for single chamber incinerators and above 3500 Kcal/Kg for pyrolytic double chamber incinerators.
- Content of combustible matter above 60%.
- Content of non combustible matter below 50%.
- Content of non combustible fines below 20%.
- Moisture content below 30%.

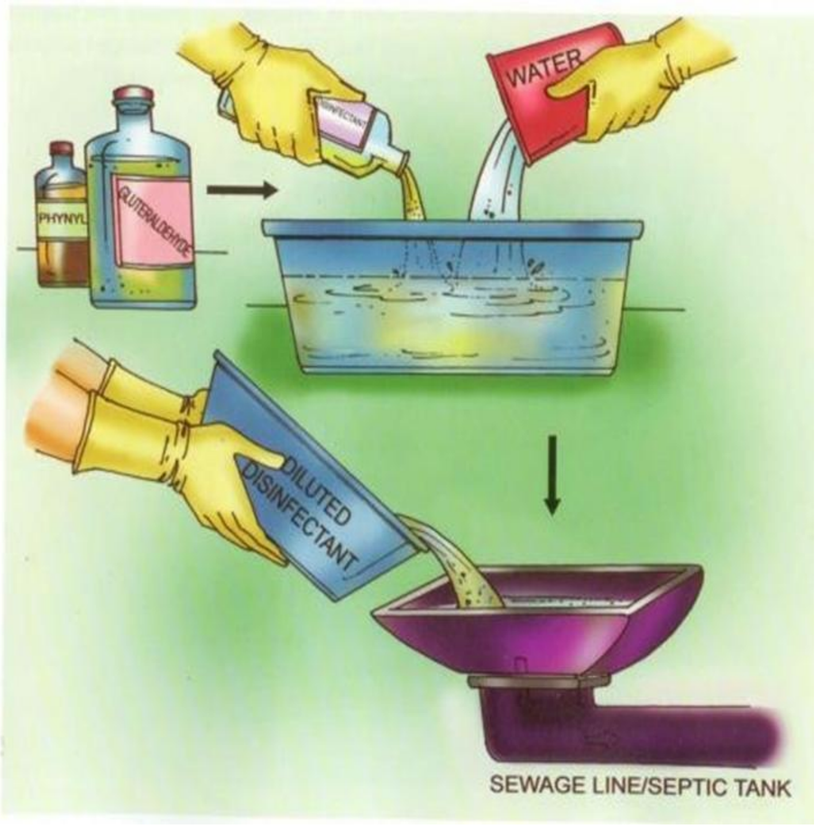
AUTOCLAVE AND MICROWAVE TREATMENT

- In this type of disposal method the waste components are kept under heat in a autoclave machine.
- Standards for the autoclaving and microwaving are also mentioned in the Biomedical waste (Management and Handling) Rules 1998. – All equipment installed/shared should meet these specifications.

Autoclaves

CHEMICAL DISINFECTING AND SHREDDING

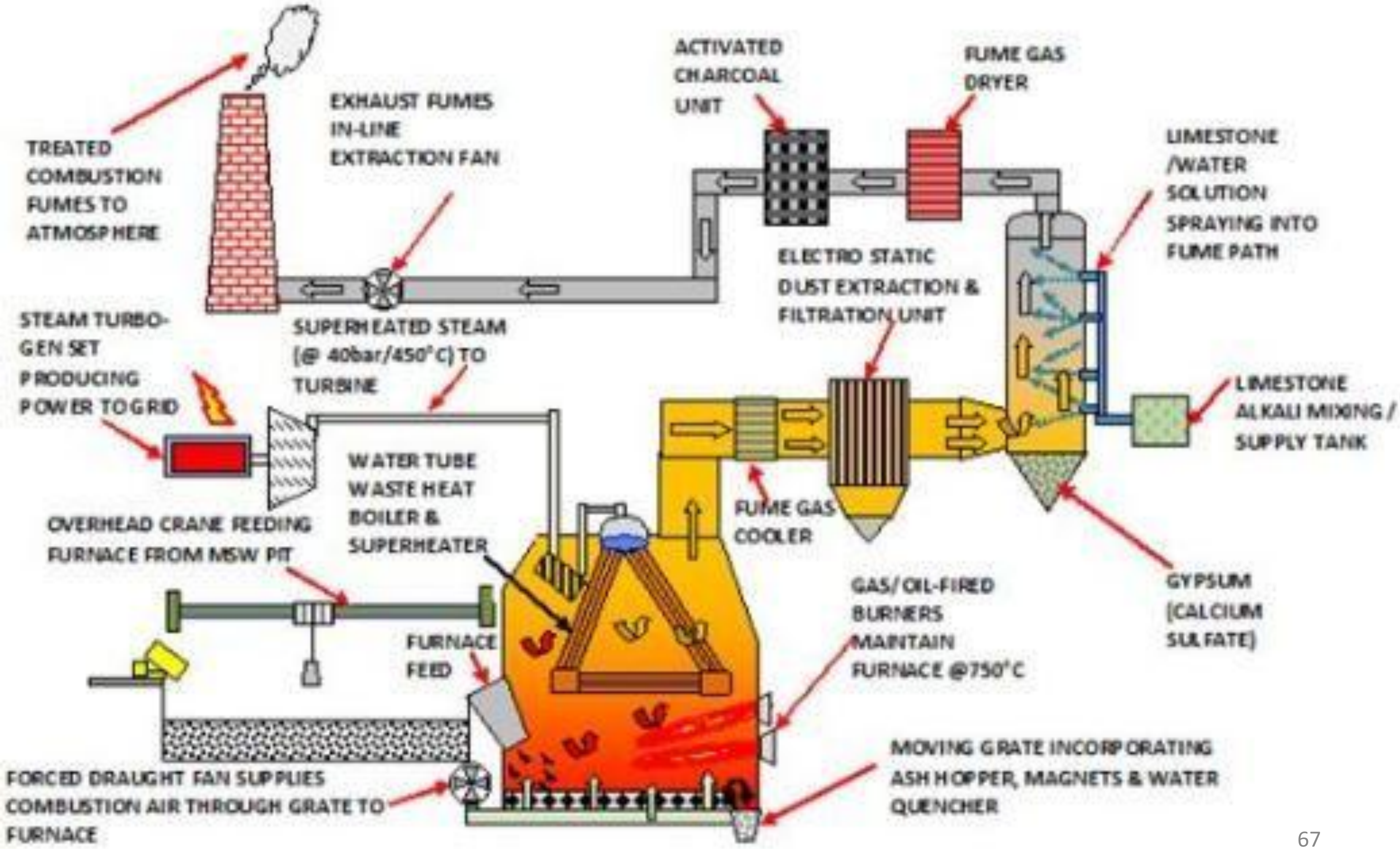
- In chemical disinfecting components are placed in chemical solution and removed for sterilization.
- In shredding the plastic (I.V. bottles, I.V. sets, syringes, catheters etc.) sharps (needles, blades, glass etc) should be shredded but only after chemical treatment/microwaving/ autoclaving.
- Needle destroyers can be used for disposal of needles directly without chemical treatment.



INCINEARTION

- Municipal solid waste incineration is basically a waste treatment process that involves the combustion of waste as an alternative method to using the scarce number of remaining landfill sites.
- Some facilities practice recycling techniques where the recyclable materials are sorted (mostly still by hand) from the incoming waste before being segregated, bagged, and transported to one of the various recycling plants. The remaining waste is tipped into a storage pit from where it is loaded into a hopper on the side of the furnace by an overhead gantry crane.

INCINEARTION



Furnace :

- The furnace consists of a rectangular steel box lined with fire-brick on the inside and insulated on the outer shell. Oil/gas burners/registers of normal boiler furnace design are fitted, and these project the flames towards the floor of the furnace.
- Running along the floor of the furnace is a steel-link fire grate that is mechanically driven, picking up the waste at one end from under the loading hopper and, through providing a combustion bed, burning the waste as it moves along the floor.
- At the end of the grate, the waste that has by now turned to ash falls off the grate into a quench tank. From here it passes under a magnet to remove any ferrous metals before passing into a storage hopper. This residue is known as bottom ash.

COMPONENTS OF INCINERATOR PLANT

- Along with fly-ash, it contains a large portion of the heavy metals such as lead and cadmium. The ash is sent to a landfill or, better, used as aggregate in the road construction industry.
- Combustion air is provided from a forced draft fan that supplies the air to the grate, helping to break-up and mix the waste. This along with the air supplied to the furnace burners ensures complete combustion of the waste, albeit in excess air.
- Complete combustion takes place at around a temperature of 550°C. Along with this, recent EU directives call for temperature of 850°C to be maintained for 2 seconds per new load, eliminating any bacteria/viruses contained in the new charge of waste.

COMPONENTS OF INCINERATOR PLANT

- **Gas Cooler** – The gases are still at a high temperature; exiting the furnace after the waste heat boiler at around 200°C. So, before passing to the treatment plant proper they are cooled using a normal water tube cooler.

- **Particulate Filtration** – These minute particulates being assigned a PM10 category are particularly dangerous to us humans as they clog up the respiratory and vascular systems, especially that of the elderly and babies.

- **Scrubbers:** A wet scrubber consists of a vertical steel tower with the fumes entering at the bottom and passing upwards. A solution of lime and water is sprayed into the path of the fumes removing the sulfur oxide and some of the dioxins (produced from combustion of plastics). These all fall to the bottom of the scrubber forming a slurry of calcium sulfate – (gypsum). This is the material used for producing wall boards, and it is sold off to the building industry.

COMPONENTS OF INCINERATOR PLANT

- **Gas Drier / De-activated Carbon Unit:** The fumes leave the wet scrubber and enter a drier to remove the moisture before passing through an activated carbon unit/dry scrubber that extracts more heavy metals from the fumes.
- **Fume Extraction Fan/Chimney:** The fumes are drawn through the activated carbon unit by a centrifugal fume extraction fan that forces them into the chimney. (Some systems incorporate fine, high-pressure water sprays inside the chimney).
- From here the fumes, still containing various pollutants, are propelled high into the atmosphere where they form a plume before dispersing and falling to the ground.

UNIT II

INTRODUCTION TO WASTE AND WASTE PROCESSING

CONTENTS

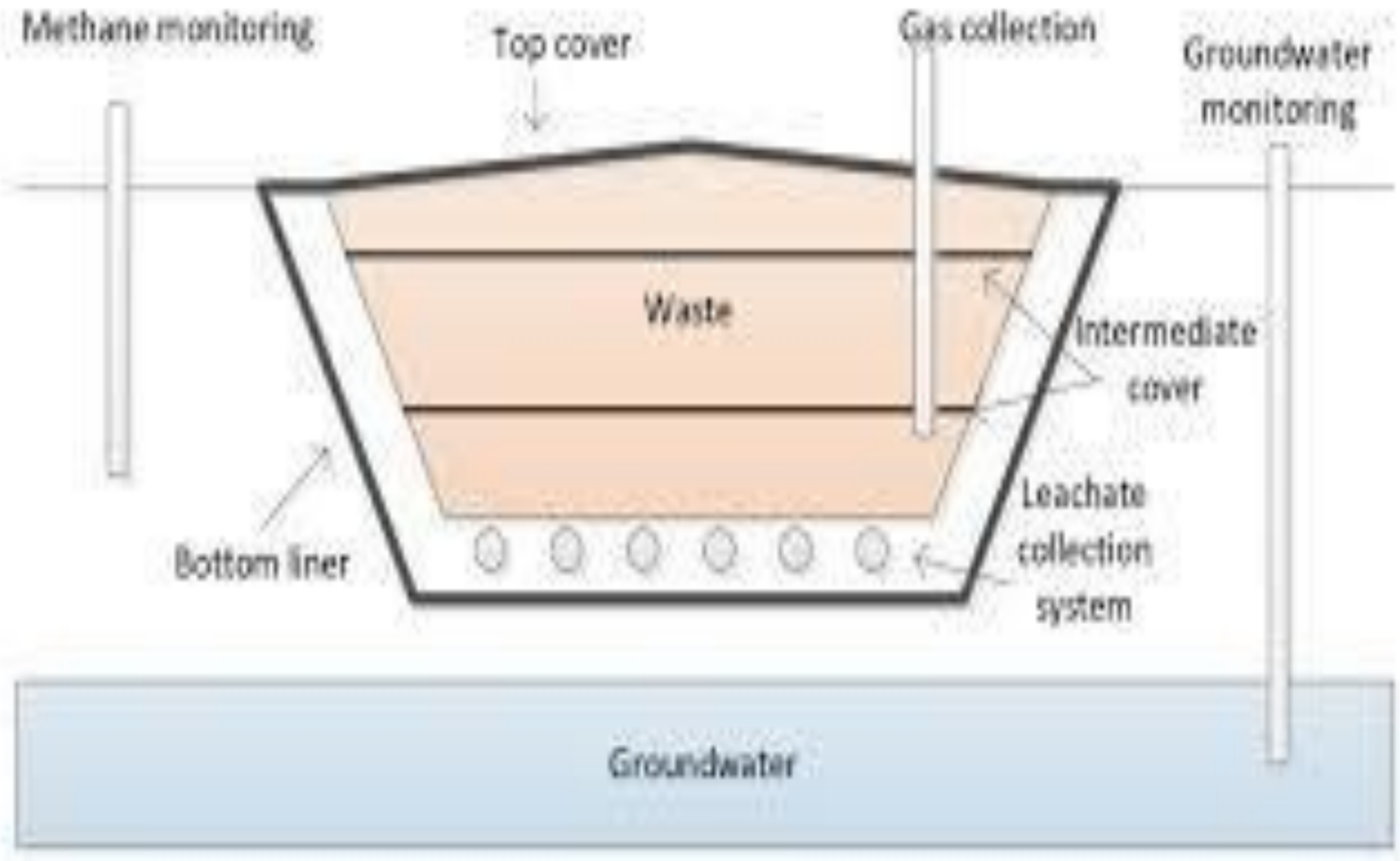
- What is LANDFILL
- Components of landfill
- Site selection for sanitary land fill
- Control of landfill gas
- Leachate formation and migration
- Environmental impact of landfill

LANDFILL

Land fill:

An engineered method for land disposal of solid or hazardous wastes in a manner that protects the environment.

ESSENTIAL COMPONENTS OF LANDFILL



TYPES OF LANDFILLS

- Sanitary landfills
- MSW landfills
- Construction and demolition landfill
- Industrial waste landfills
- Secure landfills
- Class I-HAZARDOUS
- Class II-NON- HAZARDOUS
- Class III-INERT WASTE

METHODS OF LANDFILING

- **Trench method:** This involves the excavation of a trench into which waste is deposited, and the excavated material is then used as cover.
- **Area method:** Wastes may be deposited in layers and so form terraces over the available area. However, with this type of operation, excessive leachate generation may occur, which may render the control difficult.
- **Cell method:** This method involves the deposition of wastes within reconstructed bounded area. It is now the preferred method in the industrialized world, since it encourages the concept of progressive filling and restoration. Operating a cellular method of filling enables wastes to be deposited in a tidy manner, as the cells serve both to conceal the tipping operation and trap much of the litter that has been generated.

METHODS OF LANDFILING

- **Canyon/depression:** This method refers to the placing of suitable wastes against lined canyon or ravine slide slopes. (Slope stability and leachate gas emission control are critical issues for this type of waste placement.)

OPERATING REQUIRMENTS FOR SOLID WASTE LANDFILL

Operating requirements for a solid waste landfill:

- Detection and exclusion of hazardous waste from the facility
- Use of appropriate cover material for the landfill
- Disease vector control
- Control of gas production (especially those which can combust readily)
- Monitoring of air and groundwater quality
- Access to facility
- Run-on and run-off control systems
- Restricting liquids entering the landfill
- Record keeping requirements

SITE SELECTION CRITERIA FOE LANDFILL

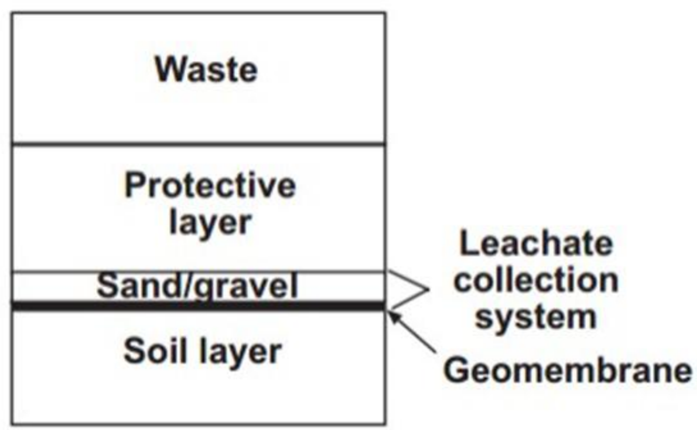
- Land area and volume must be sufficient enough so that the landfill can serve for the projected number of years.
- The slope of the region should not be very steep.
- Irrigation pipelines and water supply wells should not be situated close to the boundary of the landfill.
- Residential development should be planned away from the landfill site.
- Unstable areas posing seismic risks should be avoided.
- The depth to groundwater and proximity to water wells must be thoroughly analyzed.
- The visual impact of the landfill must be minimized (landscaping, aesthetic development of landfill).
- Agricultural land should not be used for landfill development.
- The landfill must not cause flood hazard in the event of heavy rainfall.

LANDFILL LINERS

Landfill liners are designed to create a barrier between the waste and the environment, and to drain the leachate to collection and treatment facilities. Liners may be single, composite, or double. Selection of liner is based on chemical compatibility, stress-strain characteristics, survivability and permeability.

Single liner:

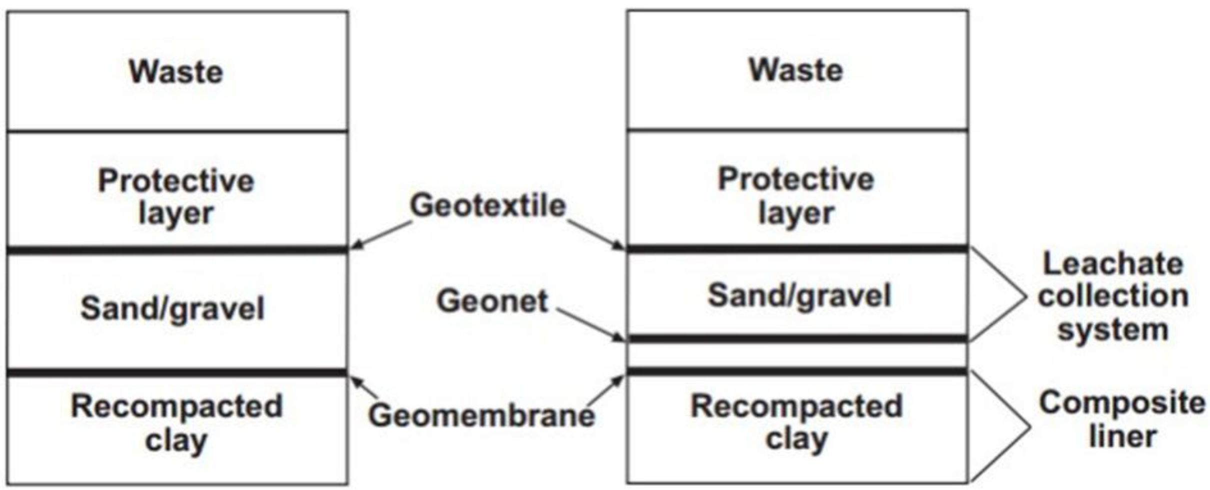
Single liners consist of a clay liner, a geosynthetic clay liner or a geomembrane. Single liners are sometimes used in landfills containing construction debris. Clay liner is easily available and is durable. Synthetic geo-membranes are composed of polymers such as: Thermoplastics(PVC);crystalline thermoplastics (HDPE,LDPE); thermoplastic elastomers (chlorinated polyethylene, chloryl sulphonated polyethylene); (elastomersneoprene, ethylene propene diene monomer).



DOUBLE LINER

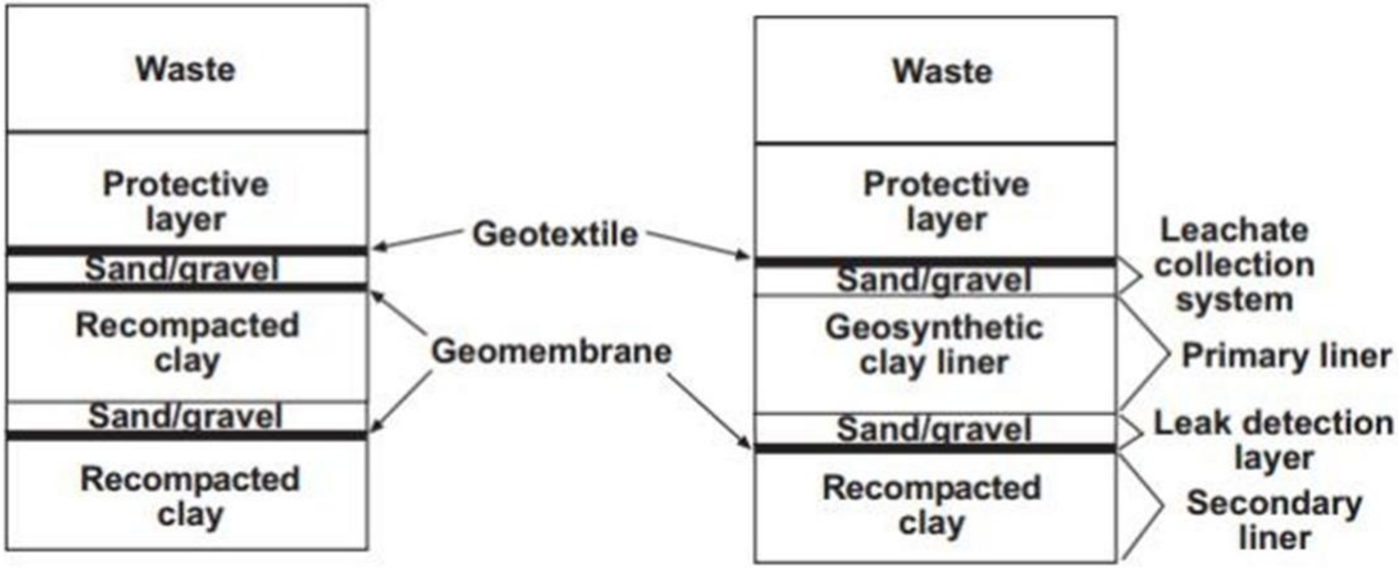
Double liner :

A double liner consists of either two single liners, two composite liners, or a single and a composite liner. The upper (primary) liner collects the leachate, while the lower (secondary) liner acts as a leak detection system. Double liners are to be used in MSW landfills, and especially in hazardous waste landfills. A double liner is more resistant to stress cracking and increased strain due to tensile yield.



Composite liner :

A composite liner consists of a geomembrane in combination with a clay liner. These are more effective at limiting leachate migration into the subsoil.



BASIC DEFINITIONS

- **Geotextile:** A permeable fabric made of plastic threads that separates the base of the landfill from the underlying soil. It allows water to pass through it but prevents soil from coming into the base.
- **Geomembrane:** A synthetic membrane with very low permeability that controls the movement of fluid in any engineering structure or system.
- **Landfill cover**: A daily cover of compacted soil or earth is applied on top of the waste deposited in a landfill. This cover minimizes the interaction between waste and the surrounding environment. It also reduces odours.

LANDFILL GAS COMPOSITION

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

1. Landfill gas contains a high percentage of methane due to the anaerobic decomposition of organic matter, which can be utilized as a source of energy.
2. **Methane**: This is a colorless, odorless and flammable gas with a density lighter than air, typically making up 50 – 60% of the landfill gas.
3. **Carbon dioxide**: This is a colorless, odorless and non-inflammable gas that is denser than air, typically accounting for 30 – 40%.
4. **Oxygen**: The flammability of methane depends on the percentage of oxygen. It is, therefore, important to control oxygen levels, where gas abstraction is undertaken.
5. **Nitrogen**: This is essentially inert and will have little effect, except to modify the explosive range of methane.

LANDFILL GAS COMPOSITION

HAZARDS

- Landfill gas consists of a mixture of flammable, asphyxiating and noxious gases and may be hazardous to health and safety, and hence the need for precautions.
- Some of the major hazards are listed below:

1. **Explosion and fire:** Methane is flammable in air within the range of 5 – 15% by volume, while hydrogen is flammable within the range of 4.1 – 7.5% (in the presence of oxygen) and potentially explosive. Fire, occurring within the waste, can be difficult to extinguish and can lead to unpredictable and uncontrolled subsidence as well as production of smoke and toxic fumes.
2. **Trace components**: These comprise mostly alkanes and alkenes, and their oxidation products such as aldehydes, alcohols and esters. Many of them are recognised as toxicants, when present in air at concentrations above occupational exposure standards.
3. **Global warming:** Known also as greenhouse effect, it is the warming of the earth‟s atmosphere by the accumulation of gases (methane, carbon dioxide and chlorofluorocarbons) that absorbs reflected solar radiation.

HAZARDS

Migration During landfill development, most of the gas produced is vented to the atmosphere, provided the permeable intermediate cover has been used. While biological and chemical processes affect gas composition through methane oxidation, which converts methane to carbon dioxide, physical factors affect gas migration.

The physical factors that affect gas migration include:

1. **Environmental conditions:** These affect the rate of degradation and gas pressure build up.
2. **Geophysical conditions:** These affect migration pathways. In the presence of fractured geological strata or a mineshaft, the gas may travel large distances, unless restricted by the water table.
3. **Climatic conditions:** Falling atmospheric pressure, rainfall and water infiltration rate affect landfill gas migration.

CONTROL OF LANDFILL GAS

Control To control gas emission, it is necessary to control the following:

- Waste inputs (i.e., restrict the amount of organic waste).
- Processes within the waste (i.e., minimize moisture content to limit gas production).
- Migration process (i.e., provide physical barriers or vents to remove the gas from the site and reduce gas pressure). Note that since gas migration cannot be easily prevented, removal is often the preferred option. This is done by using vents (extraction wells) within the waste or stone filled vents, which are often placed around the periphery of the landfill site. Some of the gas collection systems include impermeable cap, granular material, collection pipes and treatment systems.

LEACHATE FORMATION

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

LEACHATE FORMATION

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

1. Water availability;
2. Landfill surface condition;
3. refuse state;
4. Condition of surrounding strata.

LEACHATE MIGRATION

- Leachate migration It is generally difficult to predict the movement of escaped leachate accurately.
- The main controlling factors are the surrounding geology and hydrogeology.
- Escape to surface water may be relatively easy to control, but if it escapes to groundwater sources, it can be very difficult both to control and clean up.
- The degree of groundwater contamination is affected by physical, chemical and biological actions. The relative importance of each process may change, however, if the leachate moves from the landfill to the sub-surface region.

LEACHATE CONTROL

- The best way to control leachate is through prevention, which should be integral to the site design. In most cases, it is necessary to control liquid access, collection and treatment, all of which can be done using the following landfill liners:
- **Natural liners**: These refer to compacted clay or shale, bitumen or soil sealants, etc., and are generally less permeable, resistant to chemical attack and have good sorption properties. They generally do not act as true containment barriers, because sometimes leachate migrates through them. Synthetic (geo-membrane) liners: These are typically made up of high or medium density polyethylene and are generally less permeable, easy to install, relatively strong and have good deformation characteristics. They sometimes expand or shrink according to temperature and age.

TREATMENT

Treatment Concentrations of various substances occurring in leachate are too high to be discharged to surface water or into a sewer system.

These concentrations, therefore, have to be reduced by removal, treatment or both. The various treatments of leachate include:

Leachate recirculation:

- It is one of the simplest forms of treatment.
- Recirculation of leachate reduces the hazardous nature of leachate and helps wet the waste, increasing its potential for biological degradation.
- **Biological treatment**: This removes BOD, ammonia and suspended solids. Leachate from land filled waste can be readily degraded by biological means, due to high content of volatile fatty acids (VFAs).

TREATMENT

- The common methods are aerated lagoons (i.e., special devices which enhance the aerobic processes of degradation of organic substances over the entire depth of the tank) and activated sludge process, which differs from aerated lagoons in that discharged sludge is recirculated and is often used for BOD and ammonia removal. While under conditions of low COD, rotating biological contactors (i.e., biomass is brought into contact with circular blades fixed to a common axle which is rotated) are very effective in removing ammonia.

- **Physicochemical treatment**: After biological degradation, effluents still contain significant concentrations of different substances. Physicochemical treatment processes could be installed to improve the leachate effluent quality. Some of these processes are flocculation-precipitation. (Note that addition of chemicals to the water attracts the metal by floc formation). Separation of the floc from water takes place by sedimentation, adsorption and reverse osmosis.

ENVIRONMENTAL EFFECT OF LANDFILL

- The environmental effects of a landfill include wind-blown litter and dust, noise, obnoxious odours, vermin and insects attracted by the waste, surface runoff and in aesthetic conditions. Gas and leachate problems also arise during the operation phase and require significant environmental controls.
- In what follows, we will describe some of the major environmental effects below:
- Wind-blown litter and dust are continuous problems of the ongoing landfill operation and a nuisance to the neighborhood. Covering the waste cells with soil and spraying water on dirt roads and waste in dry periods, in combination with fencing and movable screens, may minimize the problem of wind-blown litter and dust. However, note that the problem will remain at the tipping front of the landfill.

ENVIRONMENTAL EFFECT OF LANDFILL

- Movement of waste collection vehicles, emptying of wastes from them, compactors, earthmoving equipment, etc., produce noise. Improving the technical capability of the equipment, surrounding the fill area with soil embankments and plantations, limiting the working hours and appropriately training the workforce will help minimize noise pollution.
- Birds (e.g., scavengers), vermin, insects and animals are attracted to the landfill for feeding and breeding. Since many of these may act as disease vectors, their presence is a potential health problem.
- Surface run-off, which has been in contact with the land filled waste, may be a problem in areas of intense rainfall. If not controlled, heavily polluted run-off may enter directly into creeks and streams. Careful design and maintenance of surface drains and ditches.

ENVIRONMENTAL EFFECT OF LANDFILL

- An operating landfill, where equipment and waste are exposed, appears in aesthetic. This problem may be reduced by careful design of screening soil embankments, plantings, rapid covering and re-vegetation of filled sections.
- Gas released, as a result of degradation or volatilization of waste components, causes odour, flammability, health problems and damage of the vegetation (due to oxygen depletion in the root zone). The measures to control this include liners, soil covers, passive venting or active extraction of gas for treatment before discharge into the atmosphere.
- Polluted leachate appears shortly after disposal of the waste. This may cause groundwater pollution and pollution of streams through sub-surface migration. Liners, drainage collection, treatment of leachate, and groundwater and downstream water quality monitoring are necessary to control this problem.

UNIT III

BIO-CHEMICAL CONVERSION

CONTENTS

- What is bio chemical conversion
- What is composting
- Types of bio chemical conversion
- Process of biochemical conversion
- Aerobic composting
- Anaerobic composting
- Industrial and agro waste

BIOCHEMICAL CONVERSION

- Biochemical conversion of biomass involves use of bacteria, microorganisms and enzymes to breakdown biomass into gaseous or liquid fuels, such as biogas or bio ethanol. The most popular biochemical technologies are anaerobic digestion (or biomethanation) and fermentation.
- Anaerobic digestion is a series of chemical reactions during which organic material is decomposed through the metabolic pathways of naturally occurring microorganisms in an oxygen depleted environment.
- Biomass wastes can also yield liquid fuels, such as cellulosic ethanol, which can be used to replace petroleum-based fuels.

WHAT IS COMPOSTING

- Composting is the process of controlled aerobic decomposition of biodegradable organic matter
- During composting, microorganisms break down organic matter into carbon dioxide, water, heat, and compost:

$$\text{Organic matter} + O_2$$

$$\downarrow$$

$$\text{Compost} + CO_2 + H_2O + NO^- + SO^{2-} + \text{heat}$$

MATERIALS FOR COMPOSTING

- Food and drink industry waste;
- Paper, card, timber and other biodegradable waste;
- Household waste;
- Organic sludge including sewage;
- Agricultural waste.
- **Note** : Wastes from meat, dairy products, and eggs should not be used in household compost:

  they attract unwanted vermin;

  they do not appropriately decompose in the time required.

MAIN COMPOSTING AGENTS

- **Micro-organisms** are key to composting

Microorganisms	**Temperature range of activity, °C**
➢ Psychrophiles ➢ Mesophiles ➢ Thermophiles	0 - 30 30 – 45 45 – 50

MAIN COMPOSTING AGENTS

Microorganisms	Populations according to the thermal conditions	
	< 40 ºC	40-70 ºC
• BACTERIA		
Mesophiles	10^8	10^6
Thermophiles	10^4	10^9
• ACTINOMICETES		
Thermophiles	10^4	10^8
• FUNGI		
Mesophiles	10^6	10^3
Thermophiles	10^6	10^7

MAIN COMPOSTING AGENTS

- **Bacteria:**
  - + strong ability of growth in moist medium
  - + large spectrum of activity
  - + active in a large range of pH values
  - + difficult to adapt in acid medium
- **Fungi:**
  - + ability to live in medium with low moisture;
  - + competitors of heterotrophic bacteria
  - + active in a large range of pH: 2 – 9;
  - + low requirements considering the nitrogen content

MAIN COMPOSTING AGENTS

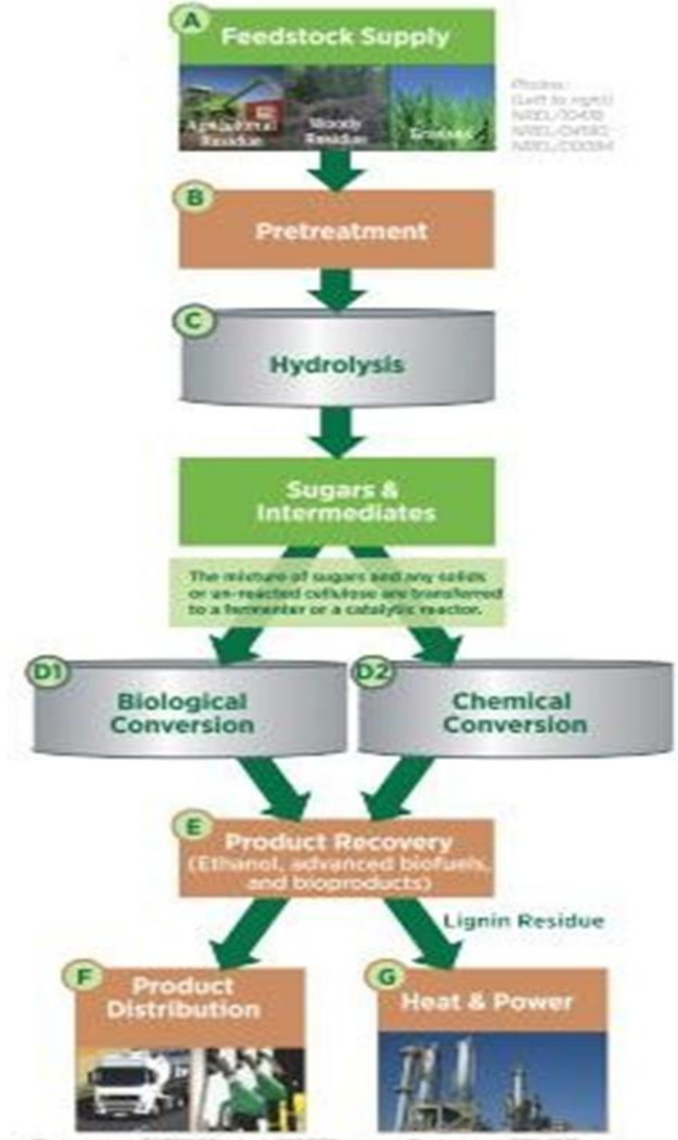
- Actinomycetes:
  1. Aerobic and thermophilic;
  2. They are assimilated by bacteria and fungi;
  3. Use organic nitrogen;
  4. Active in neutral and slightly alkaline media;
  5. Act in the ending phase of the composting process.
- Other agents:
  1. Duckweeds (algae)
  2. Cyanophytes
  3. Prothozoe
  4. Enzymes

STEPS TO PERFORM BIOCHEMICAL CONVERSION

1. **Feedstock Supply**: Feed stocks for biochemical processes are selected for optimum composition, quality, and size. Feedstock handling systems tailored to biochemical processing are essential to cost effective, high-yield operations.
2. **Pretreatment:** Biomass is heated (often combined with an acid or base) to break the tough, fibrous cell walls down and make the cellulose and hemicellulose easier to hydrolyze (see next step).
3. **Hydrolysis:** Enzymes (or other catalysts) enable the sugars within cellulose and hemicellulose in the pretreated material to be separated and released over a period of several days.
4. **Biological Conversion:** Microorganisms are added, which then use the sugars to generate other molecules suitable for use as fuels or building-block chemicals.

STEPS TO PERFORM BIOCHEMICAL CONVERSION

5. **Chemical Conversion:** Alternatively, the sugars can be converted to fuels or an entire suite of other useful products using chemical catalysis.
6. **Product Recovery:** Products are separated from water, solvents, and any residual solids.
7. **Product Distribution:** Fuels are transported to blending facilities, while other products and intermediates may be sent to traditional refineries or processing facilities for use in a diverse slate of consumer products.
8. **Heat & Power:** The remaining solids are composed primarily of lignin, which can be burned for heat and power.


A
Feedstock Supply
Woody Residue
B
Pretreatment
C
Hydrolysis
Sugars & Intermediates
The mixture of sugars and any solids or un-reacted cellulose are transferred to a fermenter or a catalytic reactor.
D1
Biological Conversion
D2
Chemical Conversion
E
Product Recovery
(Ethanol, advanced biofuels, and bioproducts)
Lignin Residue
F
Product Distribution
G
Heat & Power

CONTROL PARAMETERS

Porosity of substrate (free volume) – defined by the spaces inside the biomass occupied by air and water.

- Porosity depends on:
- Particle size distribution;
- Level of humidity;
- Height of the pail.

1. The particle size distribution, bulk density, and porosity of a compost mixture are group of factors that can lead to anaerobic conditions.	2. These physical characteristics of the compost mixture can interact with high moisture levels to reduce oxygen transport.

CONTROL PARAMETERS

- Quantity of oxygen

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + 2 800 KJ/mol

To treat 1kg organic matter 1,6 kg of O_2 are required !

O_2 could be supplied by means of:

- Mechanical mixing;
- Forced ventilation (aeration)

Oxygen requirement during the composting process:

- First stage – 5 - 15%
- Second stage – 1 - 5%
- Air: 10 – 100 $N.m^3/h$

CONTROL PARAMETERS

Moisture: Water is one of the important elements for the microorganisms activity because:

- Is necessary for the nutrient substances exchange through the cell membrane;
- forms transport medium for extracellular enzymes;
- creates medium for soluble substances;
- is important for chemical reactions performance
- < 40% moisture – degradation will proceed at a slow rate (under 25 -30% it stops);
- > 65% moisture - O_2 distributes very difficult in the biomass (anaerobic conditions established)

CONTROL PARAMETERS

Temperature is a key parameter determining the success of composting process! Heat is produced as a by-product of the microbial breakdown of organic material

- Defines the thermophilic stage of the composting process;
- Easy to monitor
- Provides disinfection of the product- at 55C almost all pathogenic are killed;
- Kills the weeds‘ seeds at 65C and more
- t > 70C kills also bacteria responsible for composting process!
- First stage: 55-65C ; Second stage: 35 - 45C, t< 25C end of the composting process.
- Values of released energy for main substances:
- Glucosis-**19 kJ/g** Lipides-**39 kJ/g** Proteins-**23 kJ/g**

Ratio C/N, C/P and C/S

C, N, P, K → naturally existing in biomass

C/N: 30 atoms C : 1 atom N

Important: balanced ratio C/N

C – source of energy for heterotrophic microorganisms;

N – important for syntesis of protheins

C
- 1/3 used by microorganisms
- 2/3 converted to CO_2

C/N < 30 →

- Excess of N that leads to release of NH_3
- NH_3 is stimulated by: ↑t , ↑N, ↑pH

C/N > 30 →

- Inhibited decomposing process;
- Increased composting time

Optimal ratio C/N:

- at the start 25 -30
- At the end < 20 (10:1)

Carbon-to-nitrogen ratios may need to be adjusted depending on the bioavailability of these elements !!!

C/P: 'P' acts as a catalyst of biochemical reactions!

Optimal ratio: 100 < C/P < 200

C/S: Optimal ratio: 100 < C/S < 300

SLUDGE FORMATION

1. **Primary Sludge**: Sludge settled in primary settling tanks comes under this category which contains 3% to 7% solids out of which approximately 60% to 80% are organic. Primary sludge solids are usually gray in color, slimy, fairly coarse, and with highly obnoxious odors. This sludge is difficult to dewater without treatment, hence digestion is necessary. This type of sludge can be digested readily by aerobic or anaerobic bacteria under favorable operating conditions.

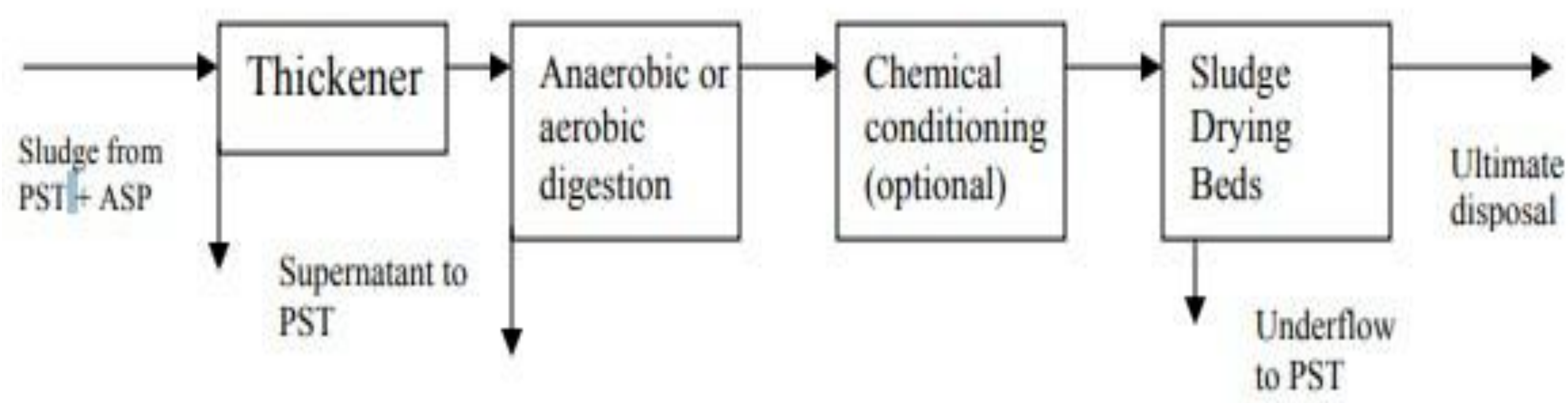
2. **Secondary Sludge**: This type of sludge from secondary settling tanks has commonly a brownish, flocculent appearance and an earthy odor. It consists mainly of microorganism containing 75% to 90% organic fraction and remaining inert materials. The organic matter may be assumed to have a specific gravity of 1.01 to 1.05, depending on its source, whereas the inorganic particles have high a specific gravity of about 2.5.

SLUDGE FORMATION

3. **Tertiary Sludge:** The nature of sludge from the tertiary (advanced) treatment process depends on the unit process followed like membrane processes or chemical methods, etc. Chemical sludge from phosphorus removal is difficult to handle and treat. Tertiary sludge from biological nitrification and denitrification is similar to waste activated sludge.

Sludge thickener:

In sludge thickeners, greater amount of water is removed from the sludge than what could obtain from sedimentation tank. This reduces overall volume of the sludge considerably. The thickening of the sludge can be achieved either by gravity thickening, application of air floatation or by centrifugation.



SLUDGE TREATMENT

1. **Gravity thickening:**

Gravity thickening is accomplished in a tank similar in design to a sedimentation tank. This is most commonly used for concentrating the sludge for achieving saving in the digester volume and sludge handing cost. This is used for primary sludge and for combine primary and secondary sludge, and it is not suitable for ASP sludge alone.

2. **Air floatation:**

By applying air under pressure or vacuum the thickening of the sludge can be achieved. This is normally preferred for ASP sludge. This requires additional equipment, power for operation, skilled supervision for operation and maintenance, hence it is costly.

The floatation units can be of two types (i) pressure type and (ii) vacuum type.

i. **Pressure type floatation unit:** In pressure type floatation unit, a portion of the subnatant is pressurized from 3 to 5 kg/cm2 and then saturated with air in the pressure tank. The effluent from the pressure tank is mixed with influent sludge immediately before it is released into flotation tank (Figure 22.3). Once the pressure is released, excess dissolve air rises up in the form of extremely small air bubbles, attaching themselves to the sludge particles.

ii. **Vacuum type floatation:** The vacuum type floatation unit employs the addition of air to saturation and applying vacuum to the unit to release the air bubbles which float the solids to the surface. The solids concentrated at the surface are skimmed off.

i. Centrifugation

Thickening by centrifugation is used only when the land available is limited and sludge characteristics will not permit adoption of other methods. This will require high maintenance and operational cost. A centrifuge acts both ways to thicken and to dewater sludge. The centrifuge process separates liquid and solid by the influence of centrifugal force which is typically 50 to 300 times that of gravity

ANAROBIC DIGESTION

Anaerobic digestion is defined as being biological oxidation of degradable organic sludge by microbes under anaerobic condition. It occurs in absence of oxygen and organic matter acts as food source for microorganisms. Most microbes used in this digestion are obligate anaerobes or facultative type. This process is employed for treatment of the organic sludge. During oxidation of organic matter anaerobically following reaction occurs:

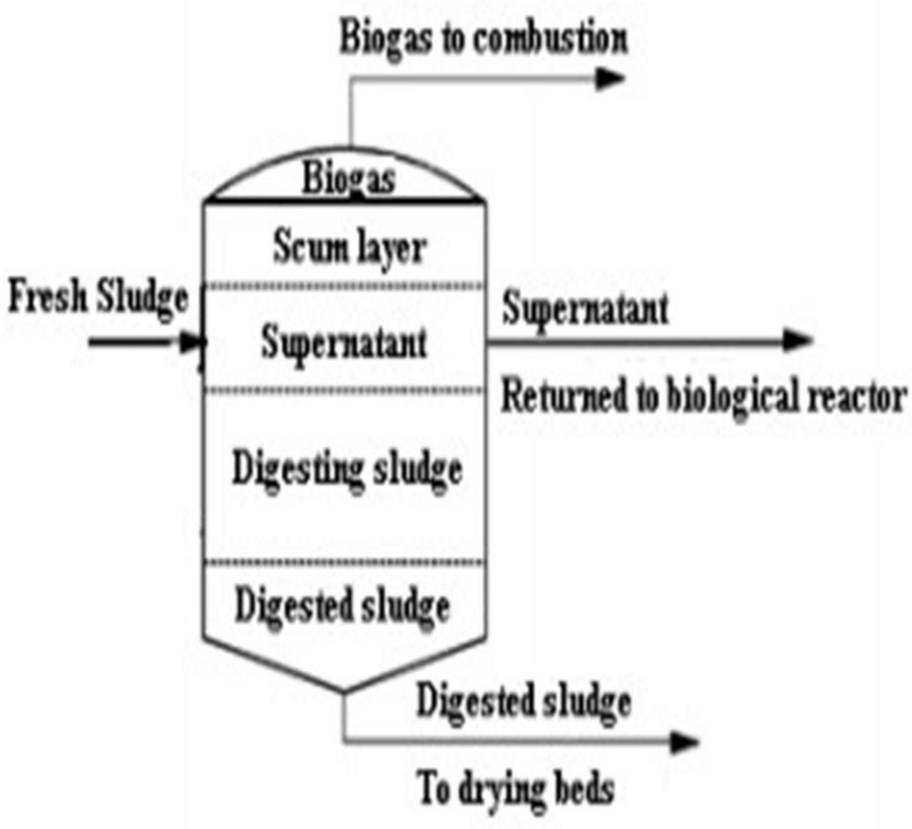
$$\text{Organic matter} \xrightarrow[\text{(Anaerobic bacteria)}]{} CO_2 + CH_4 + \text{new cell} + \text{energy for cells} + \underset{(H_2S,\ H_2,\ N_2\ \text{etc.})}{\text{Other products}}$$

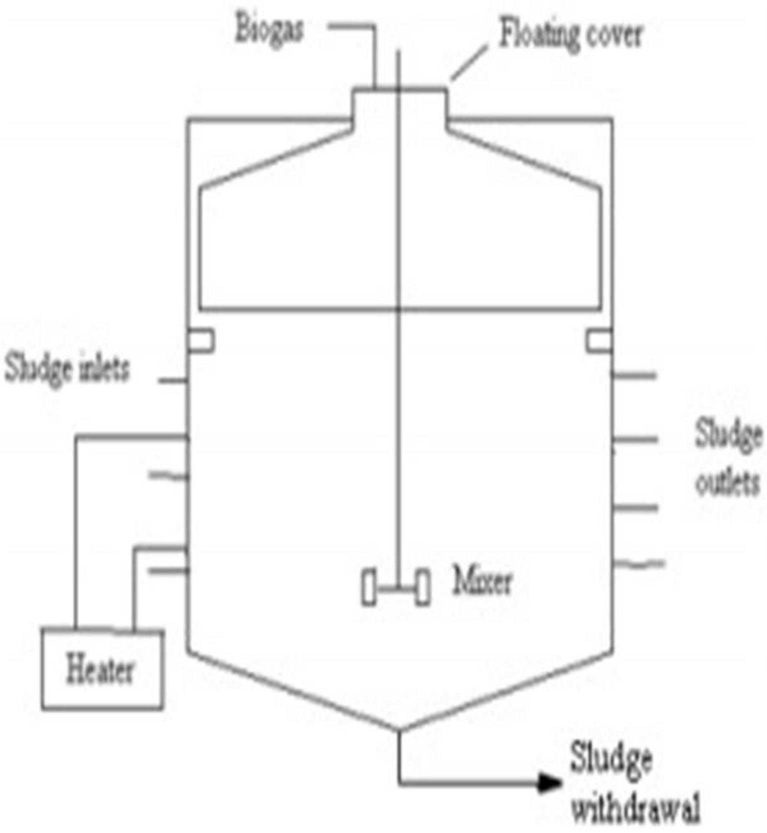
TYPES OF DIGESTERS

1. **Low rate digester:**

   Conventional low rate digesters are single stage digesters and may have floating covers or fixed cover. Most municipal plants have floating type covers. They are having diameter ranging from 4.5 m to 38 m. Side water depth (SWD) is generally 6 to 9 m and free board of 0.6 to 0.75 m is provided. When fresh sludge is being added digested sludge is recycled along with that and added at middle of digester. When sludge is added once every day no withdrawal of supernatant and sludge is done. The digester sludge is withdrawn once every two weeks. During rainy days when sludge cannot be applied on sludge drying beds it is not withdrawn from digester till suitable weather conditions favors.

TYPES OF DIGESTERS



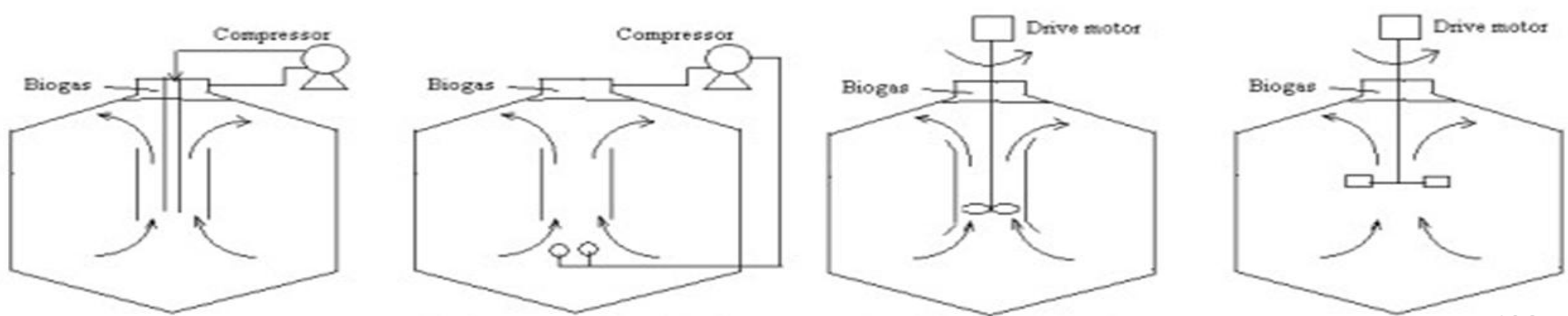


(a) Conventional Standard rate digester

(b) High rate digester, continuous flow stirred tank, single stage process

2. High rate digester:

High rate digesters usually have fixed cover. Mixing is continuous hence entire digester volume is active, which is only about 50% in case of conventional digesters. Due to mixing, better contact between fresh sludge and active microbes occurs and hence, higher loading and less retention time is provided in this. When fresh sludge is being added, the digested sludge may be displaced to holding tank where supernatant is separated. Alternatively mixing is stopped, stratification forms and sludge is withdrawn and fresh sludge added and mixing is restored.



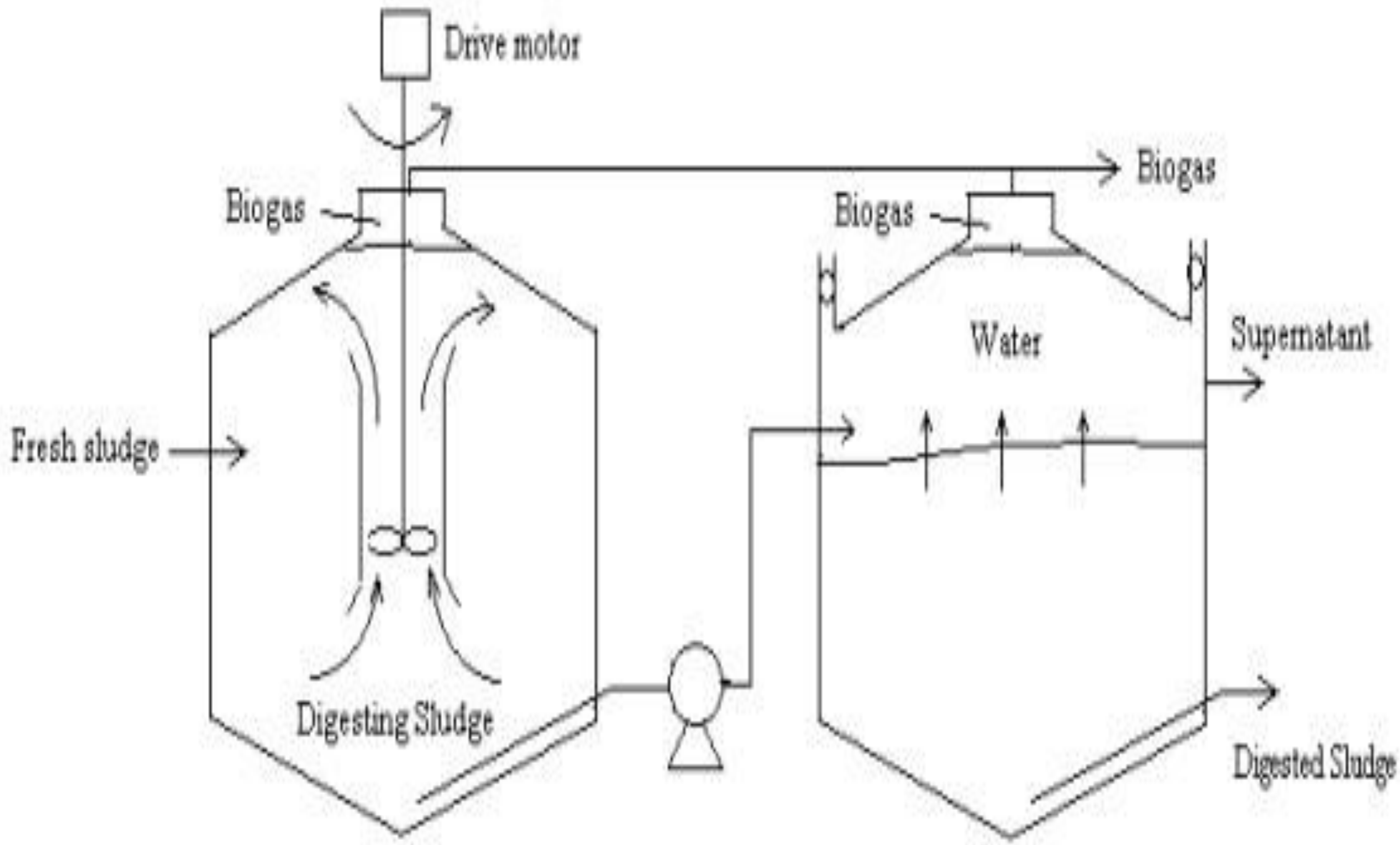
Gas Recycle and Draft tube | Gas Recycle and Gas injection | Impeller and Draft tube | Impeller

TYPES OF DIGESTERS

3. Two stage digester:

Generally this type of digester is provided when population served ranged from 30,000 to 50,000. In first stage, mainly liquefaction of organic solids, digestion of soluble organic materials and gasification occurs. First stage is usually high rate digester with fixed cover and continuous mixing is preferred. In second stage, some gasification occurs however main use is supernatant separation, gas storage and digested sludge storage. This second stage is usually conventional digester type with floating cover and it is provided with intermittent mixing. Organic loading on first stage is much more than second stage.

TYPES OF DIGESTERS



UNIT IV
THERMO -CHEMICAL CONVERSION

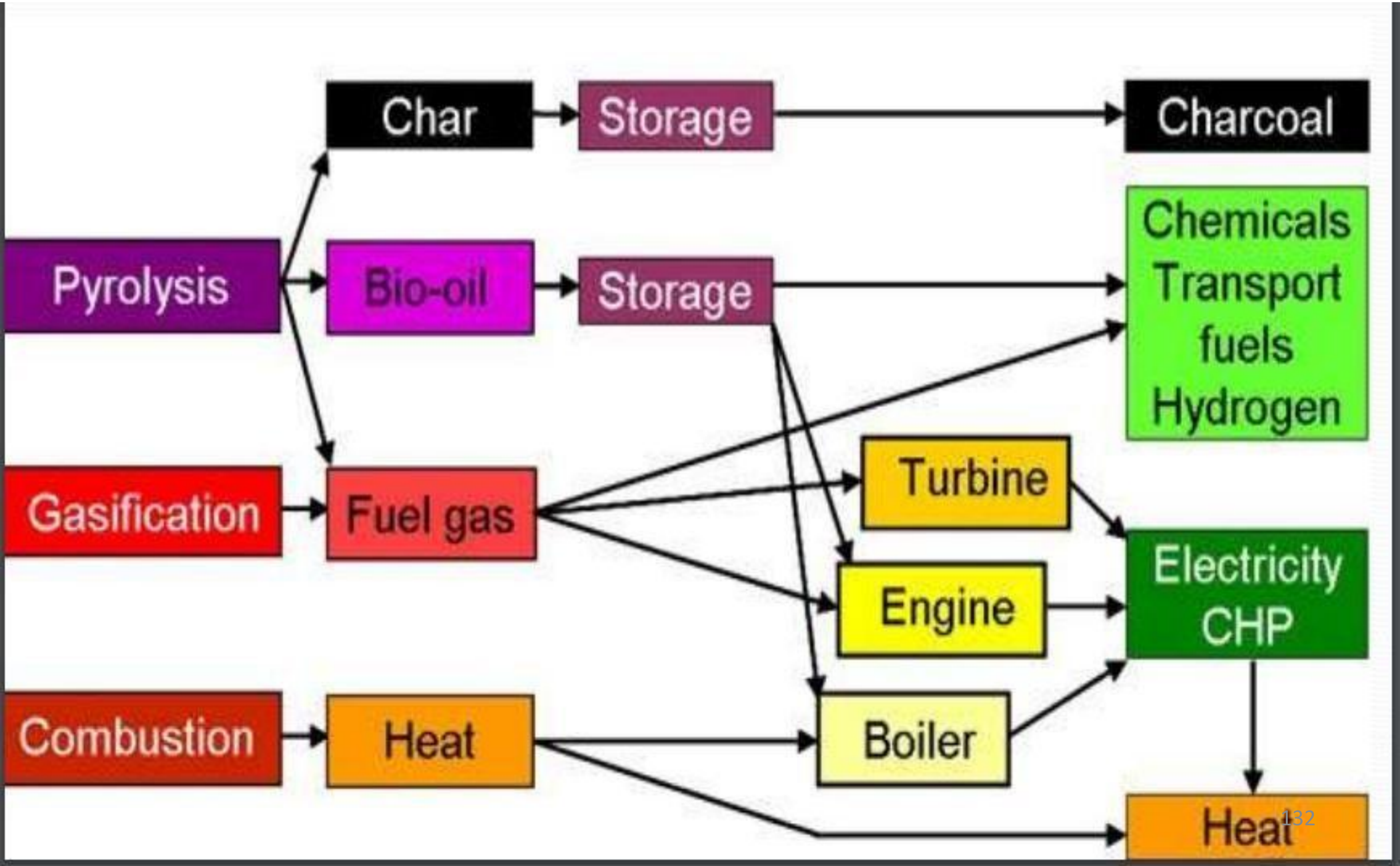
CONTENTS

- What is Thermo chemical conversion
- Types of thermo chemical conversion
- Combustion
- Gasification
- Types of Gasifiers
- Biomass briquetting

THERMOCHEMICAL CONVERSION

- Thermal conversion processes use heat as the dominant mechanism to convert biomass into another chemical form.
- Also known as thermal oil heating, it is a type of heating in which a liquid phase heat transfer medium is heated and circulated to one or more heat energy users within a closed loop system.
- Thermo chemical processes are most commonly employed for converting biomass into higher heating value fuels.
- Major thermal conversion route include direct combustion to provide heat, liquid fuel and other elements to generate process heat for thermal and electricity generation.

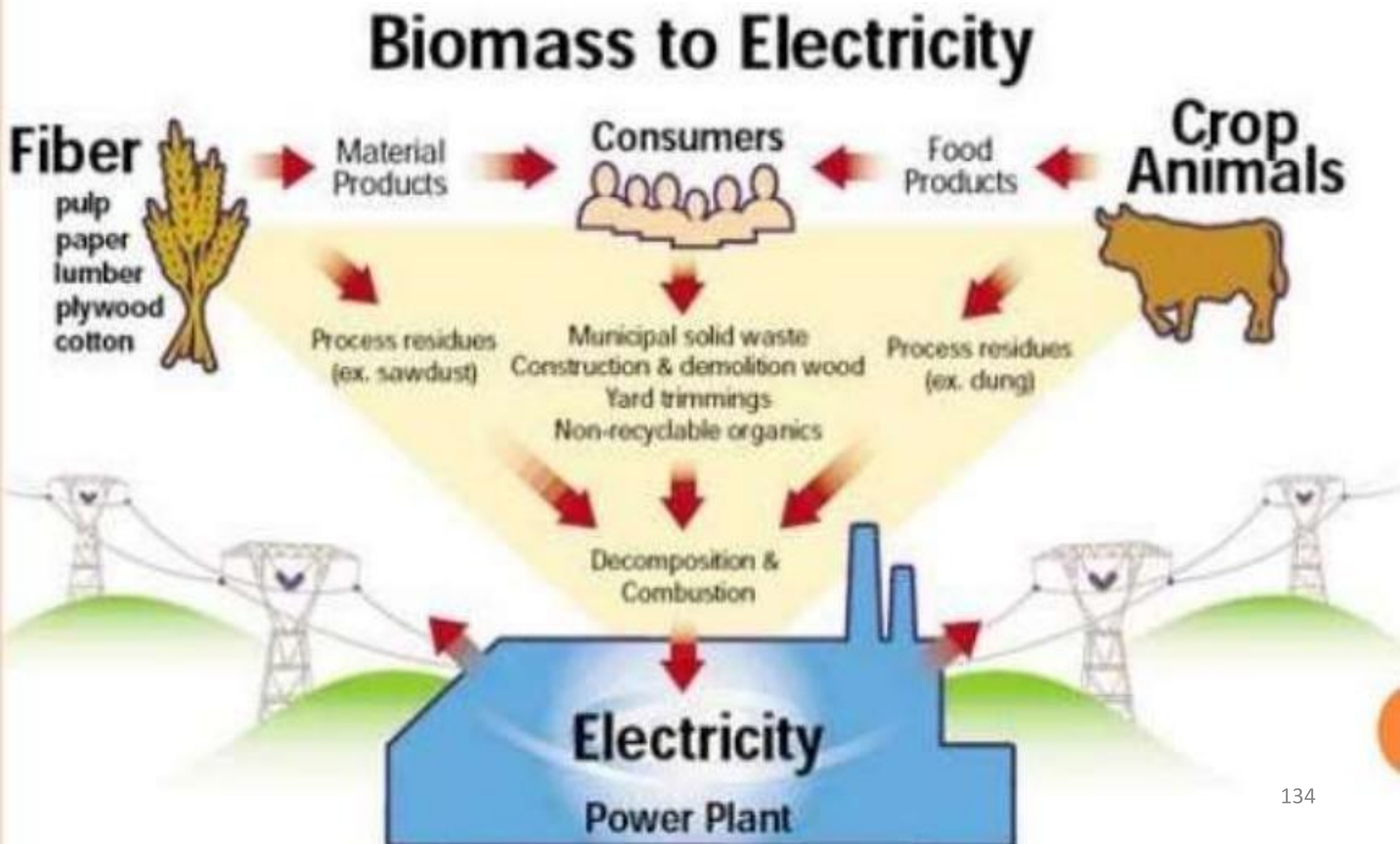
TYPES OF THERMOCHEMICAL CONVERSION



COMBUSTION

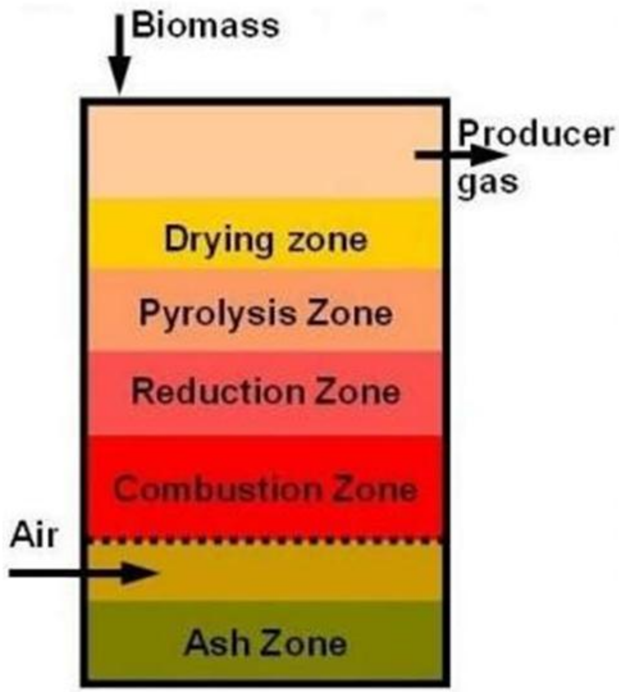
- Combustion is defined as the exothermic reaction between fuel and oxygen to form mainly carbon dioxide and water vapors.
- Combustion is the process by which more than 90% of the world‘s primary energy supply is realized in order to provide heat and energy services.
- It is estimated that in the developing world at least one and a half billion people fulfill their energy needs from wood, either as firewood or indirectly as charcoal.
- Biomass can also be co-combusted with coal in coal-fired plants.

COMBUSTION


Biomass to Electricity
Fiber
pulp
paper
lumber
plywood
cotton
Material Products
Consumers
Food Products
Crop Animals
Process residues (ex. sawdust)
Municipal solid waste
Construction & demolition wood
Yard trimmings
Non-recyclable organics
Process residues (ex. dung)
Decomposition & Combustion
Electricity
Power Plant

GASSIFICATION

- Gasification process is a process of conversion of solid fuel into gaseous fuel for wide applications.
- It produces gaseous fuels like H2,CO,CH4,N2 of low calorific value.
- Biomass Gasification converts biomass into electricity and products, such as ethanol, methanol, fuels, fertilizers, and chemicals.
- In this operation feedstock is heated to high temperatures, producing gases which can undergo chemical reactions to form a synthesis gas.



Basic gasification process with different zone.

GASSIFICATION

- Biomass is heated with no oxygen or only about one-third oxygen for efficient combustion, it gasifies to a mixture of carbon monoxide and hydrogen—synthesis gas or syngas that has an energy content of 5 to 20 MJ/Nm3 (depending on the type of biomass and whether gasification is conducted with air, oxygen or through indirect heating).
- This energy content is roughly 10 to 45% of the heating value of natural.
- This whole process completed at elevated temperature range of 800– 1300 ◦C with series of chemical reaction that is why it come under thermo chemical conversion.

GASSIFICATION PROCESS

- During gasification, the material is heated to a high temp, which causes a series of physical and chemical changes that result in evolution of volatile products and solid residues.
- The amount of volatile products and their compositions depend on:

The reactor temp

Type of fuel material.

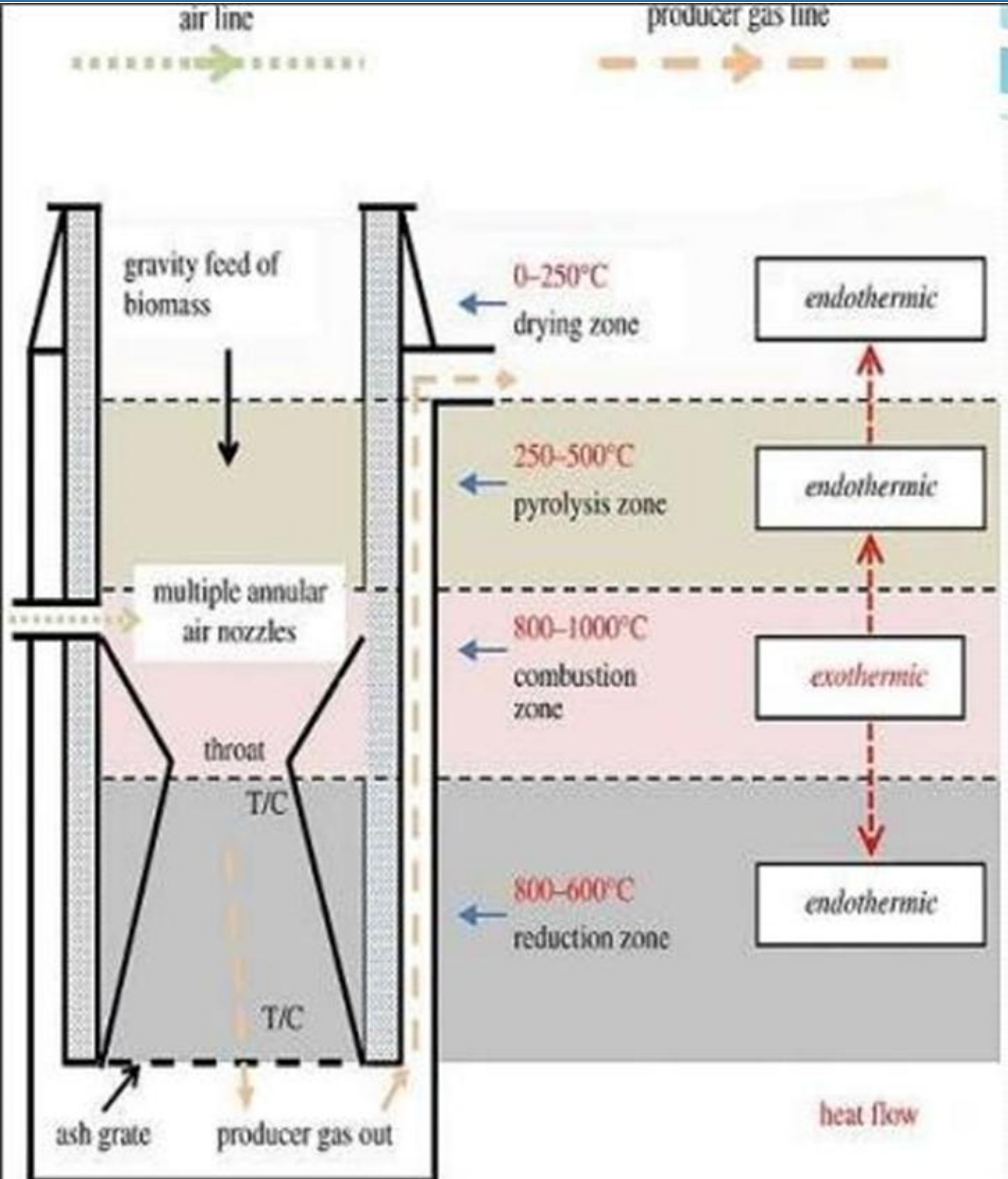
Characteristics of fuel material.

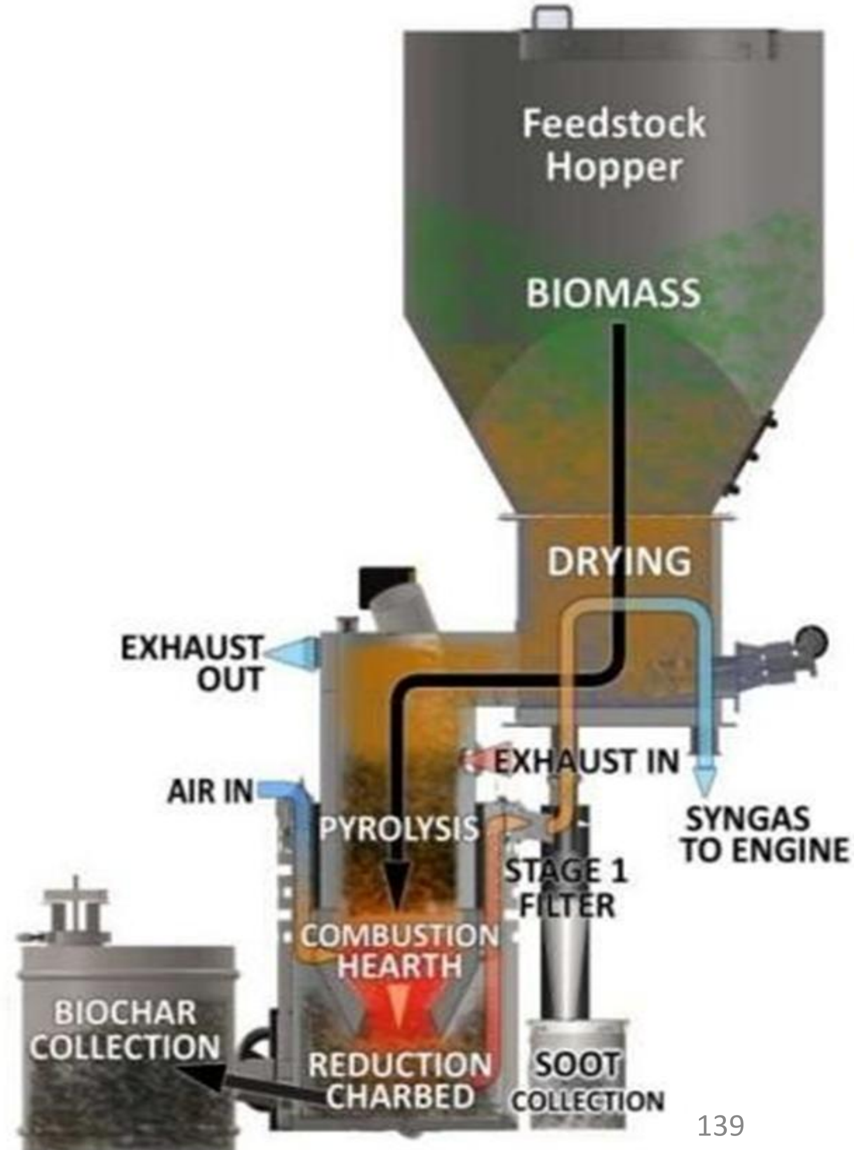
GASSIFICATION PROCESS

Gasification is made up for five discrete thermal processes:

1. **Drying:** The fuel wood pellets are heated and dried at the top of the gasifier unit. Moisture contained in the wood pellets is removed in this region to a level below 20%.
2. **Pyrolysis:** The dried wood pellets enter the second zone called the ―Pyrolysis‖ zone. In this process gaseous products from devolatilization are partially burnt with the existing air.
3. **Combustion:** In the combustion zone the outputs from the above zone, react with the remaining char in the absence of oxygen at a temperature of around 800-900 °C.
4. **Cracking:** In this zone Tar is breakdown into H2,CO and flammable gases by exposure to high temp.
5. **Reduction:** In this region the hot gases formed in the above process is converted in to ―Producer Gas‖ by the endothermic reactions

GASSIFICATION PROCESS





REACTIONS INVOLVED IN GASSIFICATION

Combustion zone			
$C + O_2$	→	CO_2	+ 393 MJ/kg mole
$2H_2 + O_2$	→	$2H_2O$	- 242 MJ/kg mole
Reaction zone			
$C + CO_2$	→	$2CO_2$	- 164.9 MJ/kg mole
$C + H_2O$	→	$CO + H_2$	- 122.6 MJ/kg mole
$CO + H_2O$	→	$CO + H_2$	+42 MJ/kg mole
$C + 2H_2$	→	CH_4	+ 75 MJ/kg mole

CLASSIFICATION OF GASSIFIERS

Design of gasifier depends upon type of fuel used, air introduction in the fuel column and type of combustion bed.

Two types:

1. Fixed Bed Gasifiers
   a) Up-draught Gasifier
   b) Down-draught Gasifier
   c) Cross-draught Gasifier
2. Fluidized Bed Gasifiers
   a) Circulating Fluidized
   b) Bubbling Bed

CLASSIFICATION OF GASSIFIERS

1. **FIXED BED GASSIFIERS:**

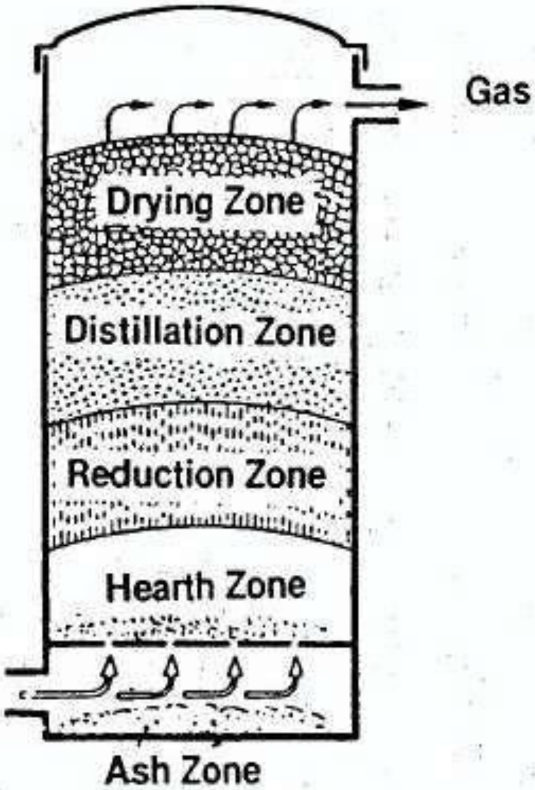
- The fixed bed type gasifier simply consisting of cylindrical reactor in which solid biomass fuel gasifying and produced gas move either upward or downward.
- These types of gasifier are simple in construction and generally operate with high carbon conversion, long solid residence time; low gas velocity and low ash carry over.
- Several type of fixed bed gasifiers were operating worldwide and further these can be classified according to the way in which primary air to gasify the biomass enters into the gasifier.

a. UPDRAFT GASSIFIER:

As the name indicates, air is introduced at the bottom and biomass at top of the reactor.

CLASSIFICATION OF GASSIFIERS

- A metallic grate is provided at the bottom of the reactor which supports the reaction bed.
- Complete combustion of char takes place at the bottom of the bed, liberating CO_2 and H_2O.
- These hot gases (∼1000 ◦C) pass through the bed above, where they are reduced to H_2 and CO and cooled to 750 ◦C.
- Continuing up the reactor, the reducing gases (H_2 and CO) pyrolyze the descending dry biomass and finally dry the incoming wet biomass, leaving the reactor at a low temperature (∼500 ◦C).
- The gas is drawn at upper side.



Updraft gasifier

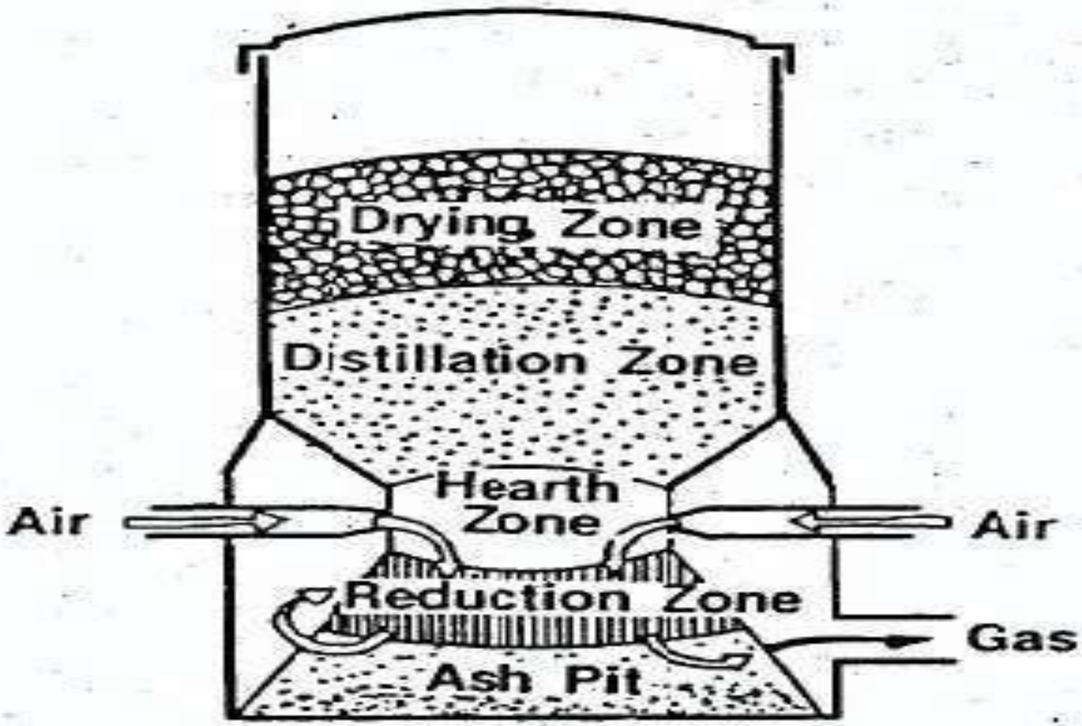
T:700-1200
Tar:low
Scale:<5MW
Feedstock:very critical

CLASSIFICATION OF GASSIFIERS

b. DOWNDRAFT GASSIFIER:

- In a downdraft gasifier, feedstock is introduced at the top and the gasifying agent is introduced through a set of nozzles located on the sides of the reactor.
- Reaction zones in a downdraft gasifier are similar to those in the updraft unit, except the locations of the oxidation and reduction zones are interchanged.
- The most important difference is that the pyrolysis products in the downdraft type are allowed to pass through the high temperature oxidation zone. Hence, they undergo further decomposition.
- Also, the moisture vaporized from the biomass enters the gasification zone and serves as a gasifying agent.
- The final product gases, which leave the gasifier from the bottom at a fairly high temperature (700oC), contain substantially less tar than the updraft gasifiers.

DOWN DRAFT GASSIFIER



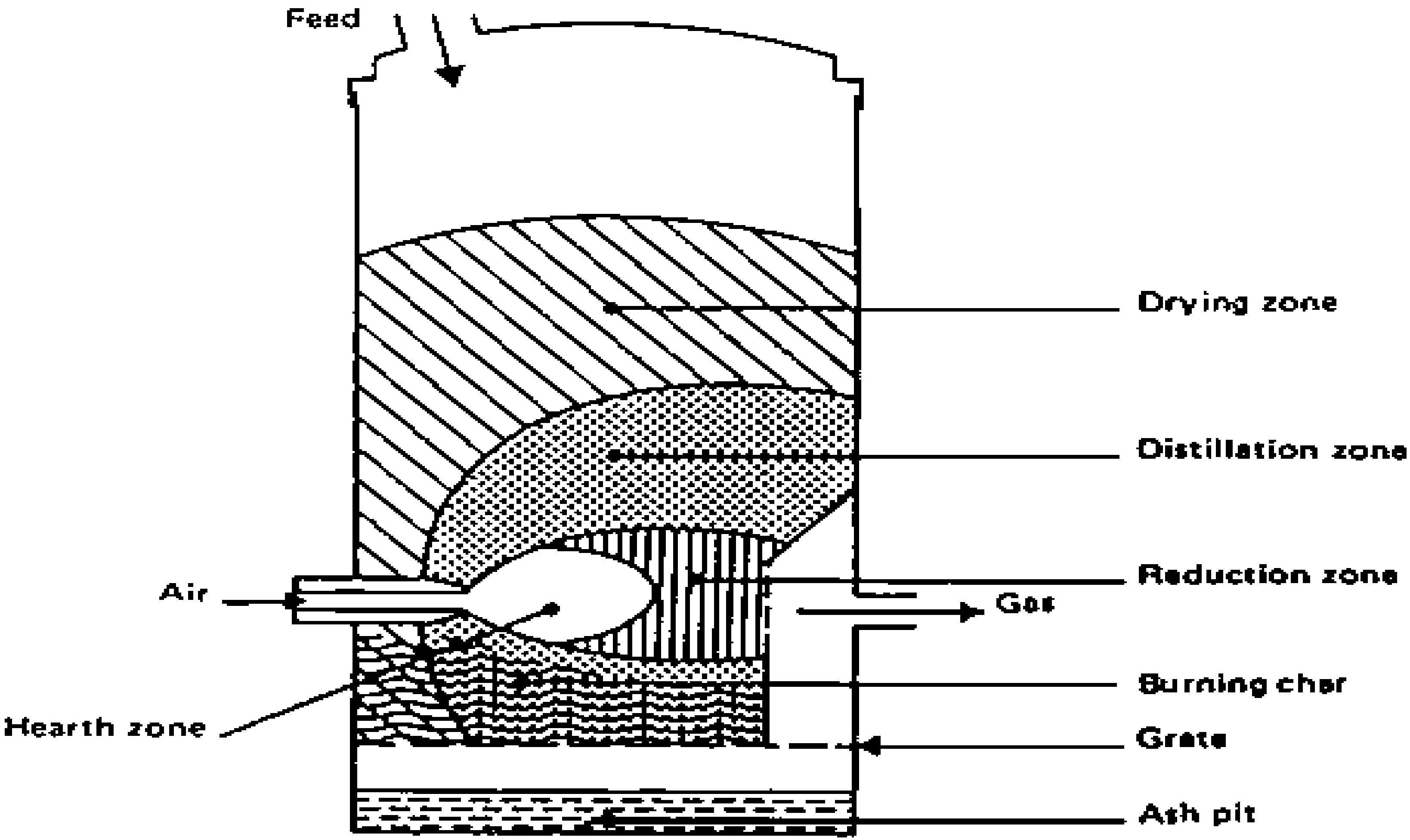
Downdraft gasifier

T:700-900
Tar:very high
Control:very easy
Scale:<20MW
Feedstock:critical

CROSS DRAFT GASSIFIER

- Cross-draft gasifiers exhibit many operating characteristics of the down draft units.
- Air or air/steam mixtures are introduced in the side of the gasifi near the bottom while the product gas is drawn off on the opposite side.
- Normally an inlet nozzle is used to bring the air into the center of the combustion zone .
- The velocity of the air as it enters the combustion zone is considerably higher in this design, which creates a hot combustion zone.
- The combustion (oxidation) and reduction zones are both concentrated to a small volume around the sides of the unit.
- Cross-draft gasifiers respond rapidly to load changes.
- They are normally simpler to construct and more suitable for running engines than the other types of fixed bed gasifiers.
- However, they are sensitive to changes in biomass composition and moisture content.

CROSS DRAFT GASSIFIER

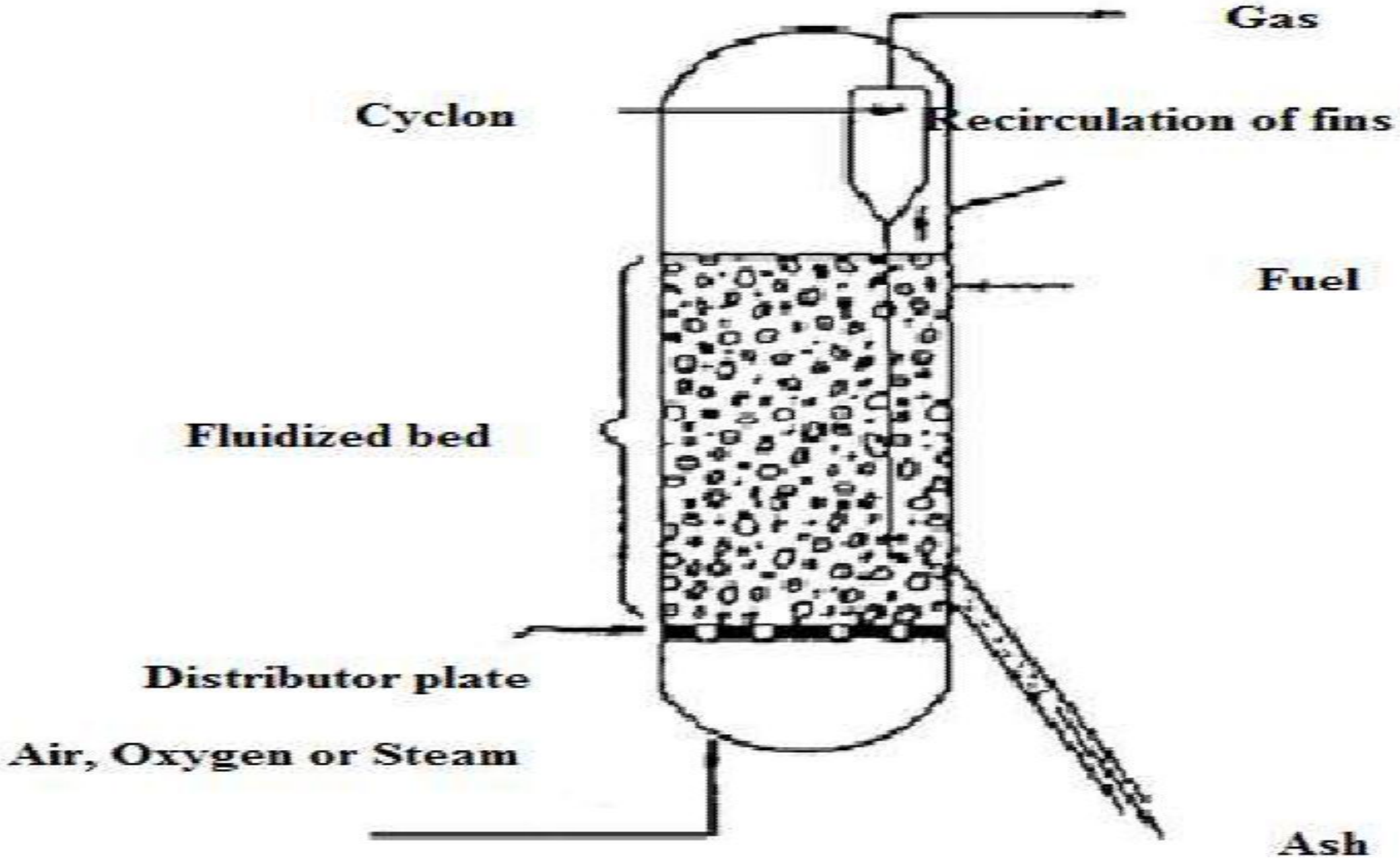


Crossdraft gasifier

FLUIDIZED BED GASSIFIER

- Fluidized bed (FB) gasification has been used extensively for coal gasification from many years, its advantage over fixed bed gasifiers being the uniform temperature distribution achieved in the gasification zone.
- In this type of gasifier, air is blown through a bed of solid particles at a sufficient velocity to keep these in a state of suspension.
- The bed is externally heated and the feedstock is introduced as soon as a sufficiently high temperature is reached.
- The fuel particles are introduced at the bottom of the reactor, very quickly mixed with the bed material and almost instantaneously heated up to the bed temperature.
- As a result of this treatment relatively large amount of gaseous materials produced. Further gasification and tar-conversion reactions occur in the gas phase.
- Ash particles are also carried over the top of the reactor .

FLUIDIZED BED GASSIFIER



ADVANTAGES OF GASSIFICATION

- Provides Sustainable & Affordable alternative to fossil fuel based power plants at low power levels. This technology can assure 'Continuous power supply' even at 'Peak load conditions'.
- Efficiency of the system is very high when compared to other Renewable energy systems such as Wind and Solar.
- Gasification is Eco-Friendly as it is "CO_2 Neutral", generates very little SO_2 & Nitrogen Oxides compared to conventional fossil fuel based power plants.
- It is a cost effective solution as it combines 'Low Unit Capital Cost' with 'Low Unit Cost of Production'. Cost of installation per kWe is about the same as for large power levels.
- Economic, Social and Environmental benefits associated with Biomass make it as an attractive renewable energy option.

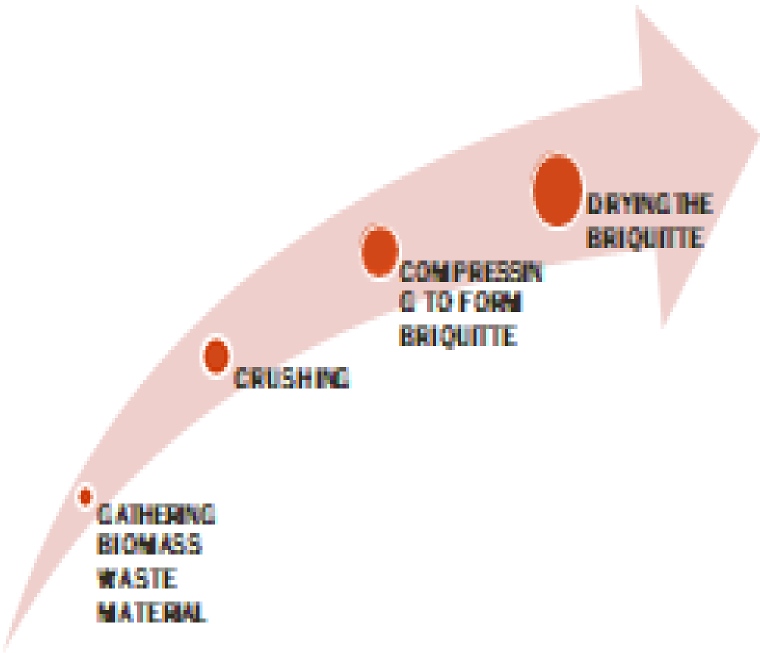
DISADVANTAGES OF GASSIFICATION

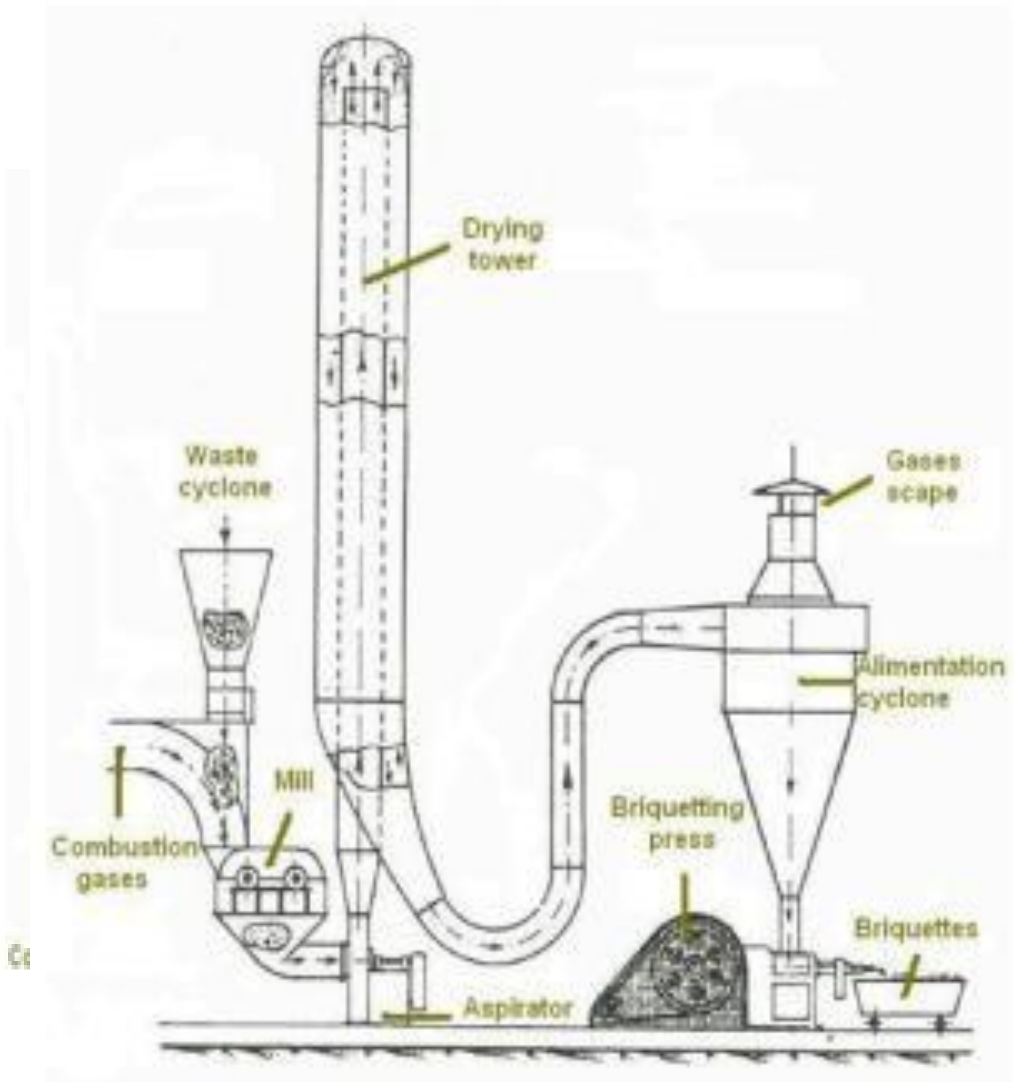
- Gasification is a complex and sensitive process.
- Gasifiers require at least half an hour or more to start the process.
- Getting the producer gas is not difficult, but obtaining in the proper state is the challenging task. The physical and chemical properties of producer gas such as energy content, gas composition and impurities vary time to time.
- Some amount of tar is released in the gas.
- All the gasifiers have fairly strict requirements for fuel size, moisture and ash content. Inadequate fuel preparation is an important cause of technical problems with gasifiers.

BIOMASS BRIQUITTING

- A briquettes is basically a block of compressed biomass waste obtained from natural materials like agricultural waste, forestry waste, seed covers, coal pieces, etc. These briquettes act as the best substitute for non renewable fuel that is nature friendly.
- This poses no harmful effect on the environment and is atmosphere friendly. The main use of these briquettes is as a substitute to fuel, coal, cooking and even in boilers.
- Briquetting is one of the compaction technologies for densification of waste materials and convert it into something useful. The raw materials used in preparing briquetting consist of coal, charcoal, wood, saw dust, paper, stalks, etc.
- They are compressed in special briquetting press machine to generate a uniform shaped briquette that can be used to ignite fire and generate energy. The briquettes prepared come in different shape and size depending on the application for which it is to be used.

PROCESS OF BIOMASS BRIQUITTING





PROCESS OF BIOMASS BRIQUITTING

- In briquetting process the materials are first crushed into small size so that they can be compressed properly and burn easily. Special crushing machine is available in the market to crush the raw materials.
- The briquette are highly preferred in the locations where fuel is hard to find and is costly. Thus at such places briquetting can become the best option for getting fuel at cheap price and easy way. The main advantage in briquetting plant is that it does not require any binder to bind the materials together to form a briquette. Thus it is also known as binder-less technology.
- The briquettes are chosen over coal and other non renewable fuel that are hard to obtain and generate. The advantage of briquetting is the high calorific valve useful in easy ignition. Also other key factors for briquetting are low production cost, waste material management and conversion of waste to revenue.

ADVANTAGES AND DISADVANTAGES

ADVANTAGES	DISADVANTAGES
• High calorific fraction • Moisture content, density and constant and homogeneous granulometry • Lower ash content • International marketing with standardized composition	• Potentially higher price conditioned by the manufacturing (compaction) process and the availability of other cheaper biofuels closer to the customer premises

BENEFITS OF BRIQUITTING

ENVIRONMENTAL:

- Using renewable energies can contribute to sustainable forest management.
- Neutral CO2 emissions balance.
- Low sulphur emissions (which usually causes acid rain).
- If it has a forest origin under a proper management scheme, it contributes to forest regeneration and prevention of forest fires.
- If it is sourced from agricultural or industrial waste, it enables a residue with a second life.
- Ash from briquettes burning can be used as fertilizer.

BENEFITS OF BRIQUITTING

SOCIAL:

- Creates jobs throughout the supply chain, especially in rural areas, thus preventing rural migration to urban areas.
- If it has a forest origin, it will promote its sustainable management, improving the state of forests: - With direct incidence to the decreased risk of fire and the corresponding damages to human health and properties. - With indirect incidence in perception of the forest as a source of jobs and wealth creation (e.g. tourism).
- It promotes confidence in renewable energy at local and rural levels.

BENEFITS OF BRIQUITTING

ECONOMIC:

- Positive life cycle economic balance, cost €/kWh lower than fossil fuels.
- Decreases the dependence on energy imports, thus favoring greater energy price stability by not depending on international markets volatility.
- Local added value, fostering local or regional businesses along the supply chain (forest operators, transportation and warehousing, briquette manufacturers, dealers, installers and maintenance services providers, etc.)
- Enables the valorization of sub-products and even waste.

UNIT V

E-WASTE MANAGEMENT

CONTENTS

- What is E- Waste
- E- Waste generation in India
- Recycling
- Impact of hazardous E-Waste in India
- E-Waste legislation.
- Safeguards and environmental protection laws

WHAT IS E-WASTE

- Electronic waste, or e-waste, is a term for electronic products that have become unwanted, non-working or obsolete, and have essentially reached the end of their useful life. Because technology advances at such a high rate, many electronic devices become —trash‖ after a few short years of use.

- In fact, whole categories of old electronic items contribute to e-waste such as VCRs being replaced by DVD players, and DVD players being replaced by Blu-ray players. E-waste is created from anything electronic: computers, TVs, monitors, cell phones, PDAs, VCRs, CD players, fax machines, printers, etc.

COMPOSITION OF E-WASTE

- E-waste consists of all waste from electronic and electrical appliances which have reached their end- of- life period or are no longer fit for their original intended use and are destined for recovery, recycling or disposal.
- It includes computer and its accessories monitors, printers, keyboards, central processing units; typewriters, mobile phones and chargers, remotes, compact discs, headphones, batteries, LCD/Plasma TVs, air conditioners, refrigerators and other household appliances.5 The composition of e-waste is diverse and falls under hazardous‘ and non-hazardous‘ categories.
- Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood and plywood, printed circuit boards, concrete, ceramics, rubber and other items. Iron and steel constitute about 50% of the waste,

E-WASTE IN INDIA

- According to the Comptroller and Auditor- General‟s (CAG) report, over 7.2 MT of industrial hazardous waste, 4 lakh tones of electronic waste, 1.5 MT of plastic waste, 1.7 MT of medical waste, 48 MT of municipal waste are generated in the country annually.
- In 2005, the Central Pollution Control Board (CPCB) estimated India‟s e-waste at 1.47 lakh tones or 0.573 MT per day.11 A study released by the Electronics Industry Association of India (ELCINA) at the electronics industry expo – "Componex Nepcon 2009" had estimated the total e-waste generation in India at a whopping 4.34 lakh tones by end 2009.12 The CPCB has estimated that it will exceed the 8 lakh tonnes or 0.8 MT mark by 2012.13.

E-WASTE IN GLOBAL CONTEXT

- China already produces about 2.3 million tones of e-waste domestically, second only to the U.S. with about three million tonnes. The EU and the U.S. would account for maximum E-waste generation during this current decade.

- As per the Inventory Assessment Manual of the UNEP, 2007, it is estimated that the total E-waste generated in the EU is about 14-15 kg per capita or 5MT to 7MT per annum. In countries like India and China, annual generation per capita is less than 1kg.

E-WASTE IN GLOBAL CONTEXT

- In Europe, E-waste contributes up to 6 million tones of solid waste per annum. The e-waste generation in the EU is expected to grow at a rate of 3 per cent to 5 per cent per year. In the past, e-waste had increased by 16 per cent to 28 per cent every five years which is three times faster than average annual municipal solid waste generation.

- As per the United States Environmental Protection Agency (USEPA), it generated 2.6 MT of E-waste in 2005, which accounted for 1.4 per cent of total wastes. Electronic waste is generated by three major sectors in the U.S.

GROWTH OF E-WASTE IN INDIA

- Electronics Industry in India took off around 1965 with an orientation towards space and defense technologies. It was followed by developments in consumer electronics mainly with transistor radios, black & white televisions, calculators and other audio products. It was during Prime Minister Smt. Indira Gandhi‟s tenure that the Electronics Commission composed of scientists and engineers was set up for the development of what she described as „a vital industry‟.
- It was during Prime Minister Rajiv Gandhi‟s tenure that electronics received much more serious attention followed by concrete programme of action to unleash a countrywide electronics revolution. The period between 1984 and 1990, which has been called as the „golden period‟, witnessed continuous and rapid growth in the electronics industry.

GROWTH OF E-WASTE IN INDIA

- In 1997, the Information Technology Agreement (ITA) was signed at the World Trade Organization (WTO) whereby India eliminated all customs duties on the Information Technology (IT) hardware by 2005.

Total Computer Sale : 2003—2009[32]

Year	Units
2003-04	3,124,22
2004-05	3,809,724
2005-06	5,046,558
2006-07	6,341,451
2007-08	7,344,306
2008-09	6,796,107

Quantity of WEEE (Waste Electrical and Electronic Equipment) generated in Indian States[42]

State/UT	WEEE (tonnes)
Andaman and Nicobar Islands	92.2
Andhra Pradesh	12780.3
Arunachal Pradesh	131.7
Assam	2176.7
Bihar	3055.6
Chandigarh	359.7
Chhattisgarh	2149.9
Dadra and Nagar Haveli	29.4
Daman and Diu	40.8
Delhi	9729.2
Goa	427.4
Gujarat	8994.3
Haryana	4506.9
Himachal Pradesh	1595.1
Jammu and Kashmir	1521.5
Jharkhand	2021.6
Karnataka	9118.7

ENVIRONMENTAL HEALTH HAZARD OF E-WASTE

Lead	A neurotoxin that affects the kidneys and the reproductive system. High quantities can be fatal. It affects mental development in children. Mechanical breaking of CRTs (cathode ray tubes) and removing solder from microchips release lead as powder and fumes.
Plastic	Found in circuit boards, cabinets and cables, they contain carcinogens. BFRs or brominated flame retardants give out carcinogenic brominated dioxins and furans. Dioxins can harm reproductive and immune systems. Burning PVC, a component of plastics, also produces dioxins. BFR can leach into landfills. Even the dust on computer cabinets contains BFR.
chromium	Used to protect metal housings and plates in a computer from corrosion. Inhaling hexavalent chromium or chromium 6 can damage liver and kidneys and cause bronchial maladies including asthmatic bronchitis and lung cancer.
beryllium	Found in switch boards and printed circuit boards. It is Carcinogenic and causes lung diseases.

ENVIRONMENTAL HEALTH HAZARD OF E-WASTE

Mercury	Affects the central nervous system, kidneys and immune system. It impairs foetus growth and harms infants through mother‟s milk. It is released while breaking and burning of circuit boards and switches. Mercury in water bodies can form methylated mercury through microbial activity. Methylated mercury is toxic and can enter the human food chain through aquatic.
Cadmium	A carcinogen. Long-term exposure causes Itai-itai disease, which causes severe pain in the joints and spine. It affects the kidneys and softens bones. Cadmium is released into the environment as powder while crushing and milling of plastics, CRTs and circuit boards. Cadmium may be released with dust, entering surface water and groundwater.
Acid	Sulphuric and hydrochloric acids are used to separate metals from circuit boards. Fumes contain chlorine and sulphur dioxide, which cause respiratory problems. They are corrosive to the eye and skin.

RECYCLING OF E-WASTE

The E-waste recycling process is highly labor intensive and goes through several steps. Below is the step-by-step process of how E-waste is recycled,

- **Picking Shed:**

When the E-waste items arrive at the recycling plants, the first step involves sorting all the items manually. Batteries are removed for quality check.

- **Disassembly:**

After sorting by hand, the second step involves a serious labor intensive process of manual dismantling. The e-waste items are taken apart to retrieve all the parts and then categorized into core materials and components. The dismantled items are then separated into various categories into parts that can be re-used or still continue the recycling processes.

RECYCLING OF E-WASTE

1. **First size reduction process:**

   Here, items that cannot be dismantled efficiently are shredded together with the other dismantled parts to pieces less than 2 inches in diameter. It is done in preparation for further categorization of the finer e-waste pieces.

2. **Second size reduction process:**

   The finer e-waste particles are then evenly spread out through an automated shaking process on a conveyor belt. The well spread out e-waste pieces are then broken down further. At this stage, any dust is extracted and discarded in a way that does not degrade the environmentally.

3. **Over-band Magnet:**

   At this step, over-band magnet is used to remove all the magnetic materials including steel and iron from the E-waste debris.

4. **Non-metallic and metallic components separation:**

The sixth step is the separation of metals and non-metallic components. Copper, aluminum, and brass are separated from the debris to only leave behind non- metallic materials. The metals are either sold as raw materials or re-used for fresh manufacture.

5. **Water Separation:**

As the last step, plastic content is separated from glass by use of water. One separated, all the materials retrieved can then be resold as raw materials for re- use. The products sold include plastic, glass, copper, iron, steel, shredded circuit boards, and valuable metal mix.

E-WASTE LEGISLATIONS

Various legislations cover different aspects of E-waste are

- The hazardous waste (management and handling) rules, 1998 as amended in 2008 for Toxic content – registration mandatory for recyclers.
- Municipal Solid Waste Management & Handling Rules for non Toxic content.
- Basel convention for regulating transboundary movement
- Foreign Trade policy restricts import of second-hand computers and does not permit import of E-waste.
- Guidelines‘ by Central Pollution Control Board (2008).

E-WASTE MANAGEMENT RULES

- Spelling the end of unauthorized units handling such refuse, the E-waste (Management and Handling) Rules 2010 — drafted by the Ministry of Environment and Forests to address the e-waste problem and to regularize the informal sector, which was notified last year — which came into effect across the country, including the Capital, on May 1, 2012.

SALIENT POINTS ON E-WASTE RULES

Responsibility of each element in the e-waste Value Chain:

1. **Producers – Extended/Individual Producer Responsibility**
2. **Dealers**
3. **Collection agencies/ collection centers**
4. **Dismantler**
5. **Recycler**
6. **Consumer and bulk consumers**

- Procedure for Authorization of producers, collection agencies, dismantlers, recyclers and enforcement agencies
- Procedure for registration/renewal of registration of recyclers.

SALIENT POINTS ON E-WASTE RULES

- Regulations for import of E-waste
- Liability of producers, collection agencies, transporter, dismantlers and recyclers
- Elimination of hazardous substances used in E-equipments.
- Setting up of Designated Authority to ensure transparency, audit and inspect facilities, examine authorization/ registration etc.


Thank you