Wastewater

Wastewater is a term that is used to describe waste material that includes industrial waste material and sewage waste that is collected in towns and urban areas and treated at urban wastewater treatment plants.

Wastewater Treatment

A process to convert wastewater – where the water which is no longer needed or suitable for its most recent use converted into an effluent that can either be returned to the water cycle with minimal environmental issues or reused.

Where does the wastewater come from:

- ❑ **Residence – human and animal excreta and water used for washing, bathing and cooking**
- ❑ **Commercial Institution**
- ❑ **Dairy and Industrial Establishments – slaughterhouse waste, diary waste, tannery wastewater etc.**

Water Pollution

Water pollution is the contamination of water bodies (e.g., lakes, rivers, oceans, aquifers and groundwater). This form of environmental degradation occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds.

Causes of Water Pollution

1. Industrial Waste
2. Agricultural Chemicals
3. Domestic Sewage
4. Thermal & Radioactive Waste
5. Biodegradable & Non- Biodegradable Waste

Causes of Water Pollution – 1. Industrial Waste

All the industries discharge the waste by-products from the manufacturing processes into rivers and other water bodies. Most of rivers and fresh water streams are badly polluted with industrial effluents from industries such as paper and pulp, refineries, textiles, distilleries and steel industries

Industrial Waste can be categorised as –

i. **Organic substances such as phenol and alcohol that increase the BOD by decreasing the oxygen content**

ii. **Acids and alkalis which change the pH of water thereby posing a threat to aquatic life**

iii. **Toxic substances such as heavy metals like mercury, lead and arsenic that cause extensive, irreversible damage to plant and animal life**

iv. **Oil and other floating impurities that interfere with self-purification of water bodies**

v. **Colour producing dyes that change the colour of water with depleting oxygen content thereby affecting aquatic life**

Causes of Water Pollution – 2. Agricultural Chemicals

- **Fertilizers:** **Excessive use of chemical fertilizers results in accumulation of nitrogen, phosphorous and water on land. These are washed off the land with water through rainfall and irrigation into water bodies thereby polluting the water**

- **Pesticides:** **They not only kill targeted pests but also kill the untargeted helpful organisms. Their effects are long term**

Causes of Water Pollution – 3. Domestic Sewage

- It consists of water borne wastes of the human community

- It contains 99% of water 1% solid; out of which 70% are organic (proteins, carbohydrates, fats) and 30% are inorganic (salts, minerals)

- Mostly it is disposed off such as in treated, partly or untreated form in nearby lakes, rivers or seas, where it causes pollution

Causes of Water Pollution – 4. Thermal & Radioactive Waste

- Different industries and nuclear power plants use water and discharge the heated water into nearby water bodies
- Nuclear reactors, nuclear explosions, nuclear war, medicinal use and research laboratories are the main source of radioactive waste
- These are most toxic as their effect persists for a number of generations

Causes of Water Pollution – 5. Biodegradable & Non-Biodegradable Waste

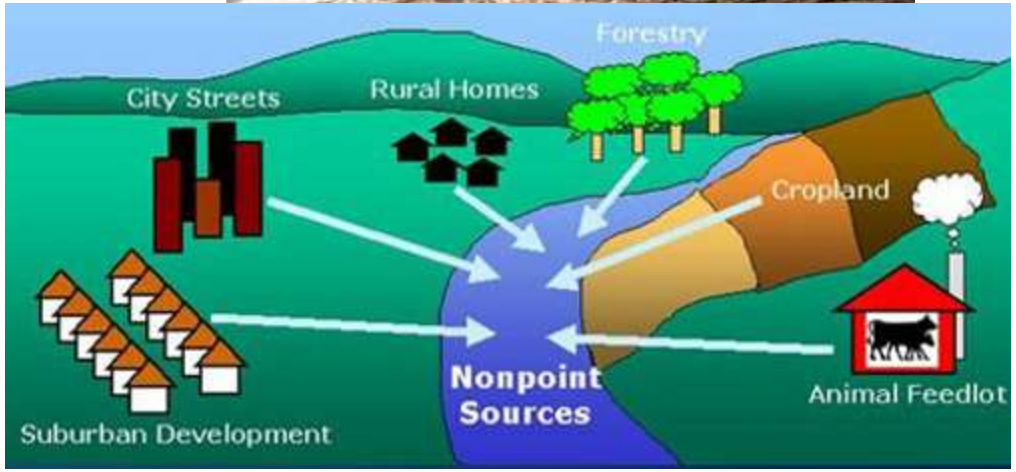
- Biodegradable pollutants consists mainly of organic matter from domestic sewage. They are decomposed by microorganisms naturally or can be artificially decomposed in chemical treatment plants. Excessive biodegradable waste in the environment leads to the problem in dispersal or recycling posing a threat to the environment

- Non- Biodegradable wastes include plastic bags, long chain detergents, aluminium cans, glass and phenolic chemicals which can neither be decomposed nor recycled. These are only used for filling lands

Type of Water Pollution

- Point Source – from a single traced source, e.g., drain pipes, effluent of sewage treatment

- Nonpoint Source – scattered and cannot be traced to a source, e.g., fertilizer/pesticide runoff, sediment pollution from lawns



Difference between Point and Nonpoint Sources

Characters	Point Sources	Nonpoint Sources
1. Definition	These release effluents at a specific site	These release their effluents over a large area
2. Example	Municipal sewage, industrial effluents etc.	Agricultural runoff, city storm water flow etc.
3. Control	Can be effectively checked by easy techniques	Difficult to control

What is Sewage

- Sewage is the mix of water and whatever waste from domestic and industrial life are flushed into sewer

- To retrieve the precious water the sewage is then 'treated', that is, 'cleaned', in what are called 'treatment plants'

What is Sewage Sludge

- Sewage – waster matter (solid + liquid) from domestic and industrial life are flushed into sewer

- Sludge – a residual (semi-solid material) left from the sewage treatment processes

Classification of Wastes According to their Origin and Type

- Municipal Solid wastes: Solid wastes that include household garbage, rubbish, construction & packaging materials, trade refuges etc. are managed by any municipality.

- Bio-medical wastes: Solid or liquid wastes including containers, products generated during diagnosis, treatment & research activities of medical sciences.

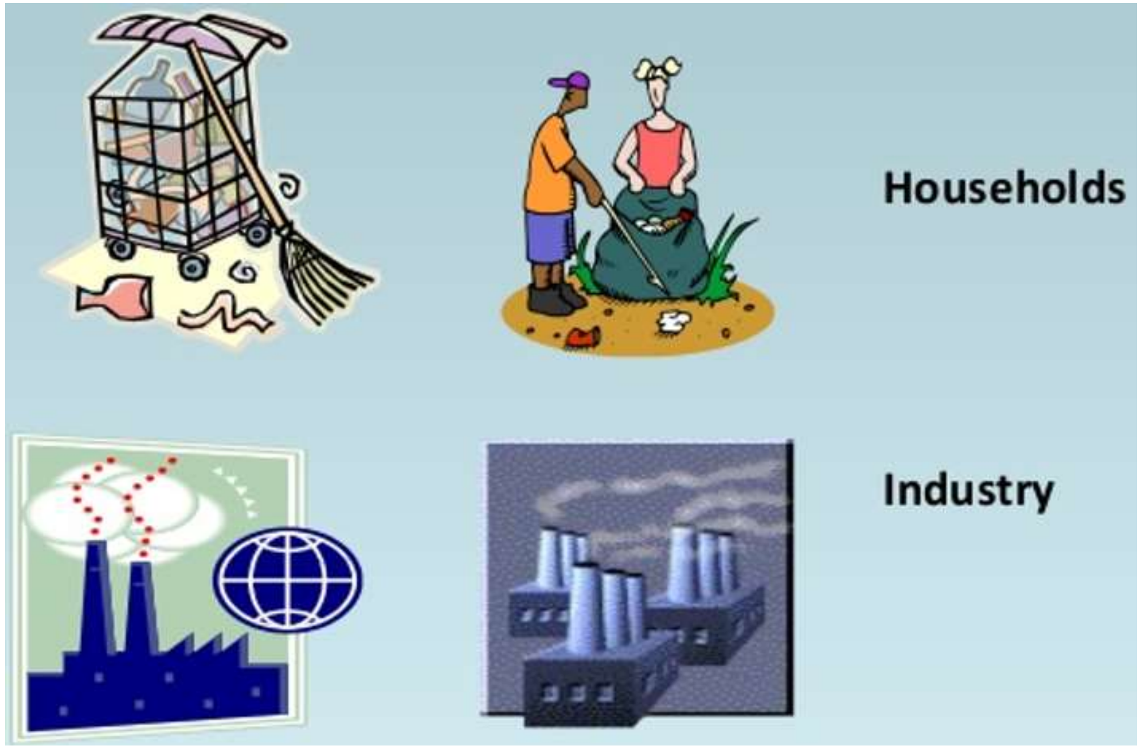
- Industrial wastes: Liquid and solid wastes that are generated by manufacturing & processing units of various industries like chemical, petroleum, coal, metal gas, sanitary & paper etc.

- Agricultural wastes: Wastes generated from farming activities. These substances are mostly biodegradable.

- Fishery wastes: Wastes generated due to fishery activities.

- E-wastes: Electronic wastes generated from any modern establishments. They may be described as discarded electrical or electronic devices. Some electronic scrap components, such as CRTs, wires, circuits, mobile, computers etc.

Sources of Wastes



Wastewater

- Wastewater is a mixture of sewage; water from household use; water used in commercial and industrial applications etc.

- Wastewater contains a variety of biological and chemical pollutants which make it unsafe for humans and the environment

Presence of Organic Matter

- Water is "polluted" by many organic matter in its course of flow
- When organic matter is present in a water supply. the bacteria present in water will begin the process of breaking down this waste.
- With this much of the available dissolved oxygen is consumed by aerobic bacteria. robbing other aquatic organisms of the oxygen they need to live.
- Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose this waste.
- A large quantity of organic waste in the water supply guarantees a large number bacteria present to decompose this waste.
- In this case. the demand for oxygen will be high (due to all the bacteria) so the BOD level will be high.
- As the waste is consumed or dispersed through the water. BOD levels will begin to decline.

Biochemical Oxygen Demand (BOD)

- Biochemical oxygen demand or BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.
- It is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20°C.
- The BOD indicates the total of carbonaceous and nitrogenous oxygen demand.
- Dissolved oxygen is measured initially after dilution and after incubation at 20°C for the time period of the test.
- It is necessary to have a population of microorganisms present that is capable of degrading the organic material in the sample.
- Many unchlorinated domestic or industrial wastewaters will afford sufficient bacteria for this purpose.

Calculation of BOD

$$BOD = \frac{D_i - D_f}{P}$$

where:

D_i = initial dissolved O_2 concentration

D_f = final or 5-day dissolved O_2 concentration

P = volumetric fraction of wastewater

Example: 5 ml wastewater is added to a 300 ml BOD flask

$P = \frac{5}{300} = 0.0167$ $D_i = 8$ mg/L $D_f = 2$ mg/L

$$BOD = \frac{8 - 2}{0.0167} = 359 \text{ mg/L}$$

Advantages and Disadvantages of BOD

Advantages:

- This test measures only the biodegradable organic matter.
- Heavily polluted waters can be easily used to calculate BOD.
- It is an inexpensive method.
- The test can be implemented on a large area

Disadvantages:

- This test takes 5 days to complete which might reduce the reliability of the results
- Wastewater with toxic particles such as industrial wastes needs to be pre-treated before conducting BOD tests
- Industrial waste can inhibit microbes and hinder oxidation.
- Extremely active bacteria are required for this test

Chemical Oxygen Demand (COD)

- The Chemical Oxygen Demand or COD test is a measure of oxygen required from a strong chemical oxidant for the destruction of an organic material
- The chemical oxidant selected for the COD test is potassium dichromate ($K_2Cr_2O_7$)
- The sample is oxidised by a boiling mixture of $K_2Cr_2O_7$ and sulfuric acid using an excess of $K_2Cr_2O_7$
- After digestion, the remaining unreduced $K_2Cr_2O_7$ is measured to determine the amount consumed by titrating with ferrous ammonia sulfate (FAS) until the end point is indicated by a sharp colour change
- The COD takes about 2 to 3 hours to run compared to 5 days for a BOD test and can be run with a relatively simple and inexpensive kit

Advantages and Disadvantages of COD Test

Advantages:

- COD results are available much sooner than BOD results
- COD test oxidises a wide range of chemical compounds
- COD test can be standardized very easily

Disadvantages:

- The major disadvantage is that the results are not directly applicable to 5-day BOD results without correlation studies over a long period of time
- One more limitation is its inability to differentiate between biologically oxidisable and biologically inert organic matter

Total Organic Carbon and Total Carbon

- Total Organic Carbon (TOC) test is a more direct indication of organic content than the BOD or COD test.
- Total organic carbon (TOC) is a measure of the total amount of carbon in organic compounds in pure water and aqueous systems.
-
- The TOC test does not provide all of the information that the BOD and COD tests provide.
-
- The BOD test indicates the actual oxygen needed for biologically destroying the organic matter
- The COD test indicates the chemical oxidation requirements for destruction
- The TOC test indicates the total organic matter present and is independent of the oxidation state of the pollutant.
- A typical analysis for total carbon (TC) measures both the total carbon present and the so-called "inorganic carbon" (IC), the latter representing the content of dissolved carbon dioxide and carbonic acid salts. Subtracting the inorganic carbon from the total carbon yields TOC.
- Another common variant of TOC analysis involves removing the IC portion first and then measuring the leftover carbon. This method involves purging an acidified sample with carbon-free air or nitrogen prior to measurement, and so is more accurately called non-purgeable organic carbon (NPOC).

Total Organic Carbon and Inorganic Carbon

TOC

- Total Organic Carbon (TOC) is the amount of carbon bound in an organic compound or material derived from decaying vegetation, bacterial growth and metabolic activities of living organisms or chemicals

IC

- Carbon that is not present as organic compounds, principally carbonate materials such as carbonate, bicarbonate, dissolved carbon dioxide etc.

Total Carbon = TOC + IC

Stages of TOC Analysis

- **Acidification:** Removes IC
- **Oxidation:** Converts remaining sample into CO_2 and other gases
- **Detection and Quantification:** Conductivity or Non-dispersive Infrared (NDIR)

Wastewater Treatment

Purpose:

- To manage water discharged from homes, businesses and industries to reduce the threat of water pollution
- To eliminate offensive smell
- To remove solid content of the sewage
- To destroy the disease causing microorganisms
- To remove or modify pollutants so that water can be safely discharged to the environment

Process:

- Wastewater treatment uses microbes to decompose organic water in sewage
- If too much untreated sewage or other organic matter is added to a lake or stream, dissolved oxygen level will drop too low to support sensitive species of fish and other aquatic life. Wastewater treatment systems are designed to digest much of the organic matter before the wastewater is released .
- Treatment of wastewater typically involves primary, secondary and sometimes tertiary steps
- Secondary treatment is entirely dependent upon the activity of microbes such as *Acidovorax*

Wastewater Treatment

Primary Treatment:

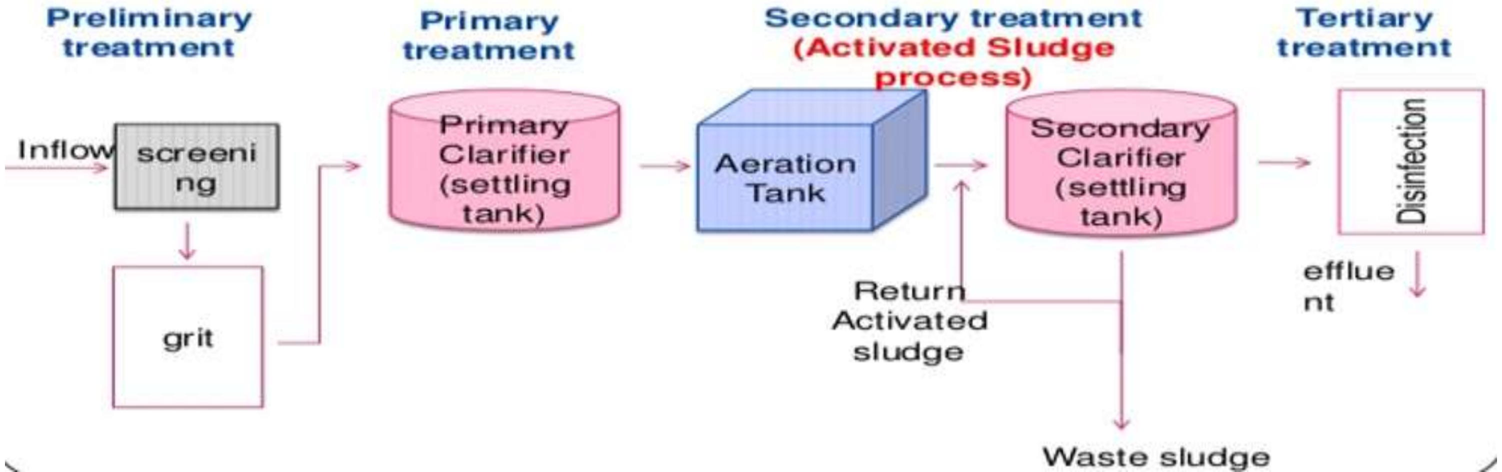
- Physically removes large solids using grates, screens and settling tanks
- Large pieces of debris are removed by screening and suspended particles are removed from water through settling process

Secondary Treatment:

- Elimination of organic and inorganic contaminant, through the effect of microbiological activity upon wastewater material
- The most widely used and effective methods of secondary treatment involve activated sludge treatment

Tertiary Treatment:

- Removal of further nutrients and pathogens using methods such as filtration, passage through wetlands, or disinfection by treatment with chlorine, ozone or ultraviolet light
- Tertiary treatment is not always included in wastewater treatment systems



Preliminary Treatment

- It removes all materials that can be easily collected from the raw sewage before they damage or clog the pumps and sewage lines of primary treatment clarifiers
- Objects are commonly removed during pre-treatment include trash, tree limbs, leaves, branches and other large objects
- The influent in sewage water passes through a bar screen to remove all large objects like cans, rags, sticks, plastic packets etc. carried in the sewage stream
- This is most commonly done with an automated mechanically raked bar screen in modern plants serving large populations, while in smaller or less modern plants a manually cleaned screen may be used
- The raking action of a mechanical bar screen is typically paced according to the accumulation on the bar screens and/or flow rate
- The solids are collected and later disposed in a landfill or incinerated

Bar Screens

Primary Treatment (Physical or Mechanical)

- Typical materials that are removed during primary treatment include
  - Fats, oils and greases
  - Sand, gravels and rocks
  - Larger settleable solids including human waste
  - Floating materials

- **Screening**: to remove large objects that could plug lines or block tank inlets

- **Sedimentation tank** (settling tank or clarifiers): settleable solids settle out and pumped away while oils float to the top and are skimmed off; settleable solids are then passed for aeration in aeration tanks

- Sewage is held in sedimentation tanks for 2-10 hours
- Greasy materials, fats, oil etc. rise to the surface, forming scum which is skimmed off
- The organic matter that settle down is called primary sludge
- 30-40% BOD removal – treatment efficiency
- Sedimentation is enhanced by addition of alum at the treatment plant which produces a sticky flocculent precipitate
- Settleable solids are then passed for aeration in aeration tanks

Aeration Tanks

- The fluids from primary treatment are carried to aeration tanks
- Continuously aerated for the growth of aerobic m.os. Flocculation occurs
- These m.os degrade the organic matter present in the effluents

Secondary Treatment (Biological)

- Typically uses biological treatment process, in which microorganisms convert non-settleable solids to settleable solids. Sedimentation process follows allowing the settleable solids to settle out

- Four methods include
  - Activated sludge
  - Trickling filters
  - Oxidation ponds or lagoons
  - Biological contractor systems/Rotating disc

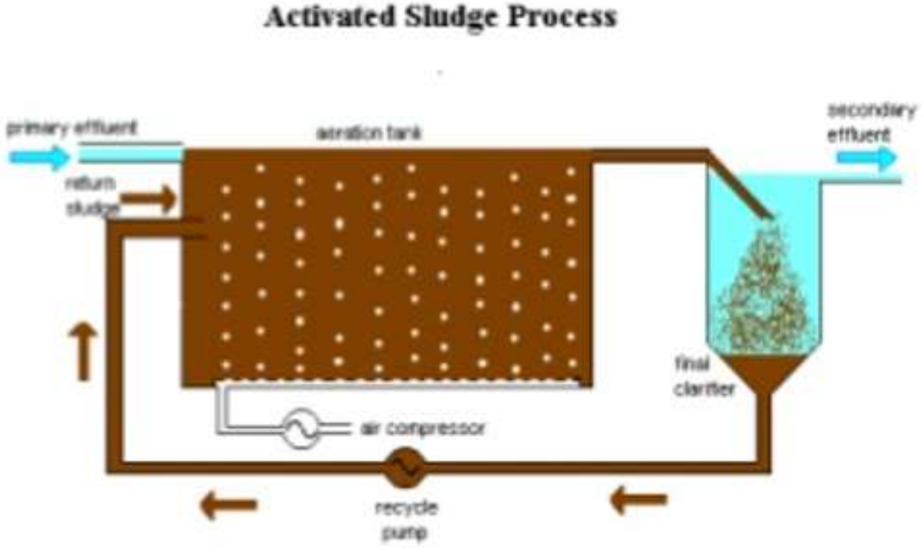
Activated Sludge System

- Aerobic sewage treatment in which flocculated biological growth is circulated and in contact with organic waste in presence of oxygen is called activated sludge process
- It is a process in which air or oxygen is forced into sewage liquor to develop a biological floc which reduces the organic content of the sewage
- The sludge is returned to the aeration system to re-seed the new sewage entering the tank

Sewage from primary treatment

Components:

- An aeration tank where biological reactions occur
- An aeration source that provides oxygen and mixing
- A tank, known as the clarifier, where solids settle and are separated from treated wastewater
- A means of collecting the solids either to return them to the aeration tank or to remove them from the process



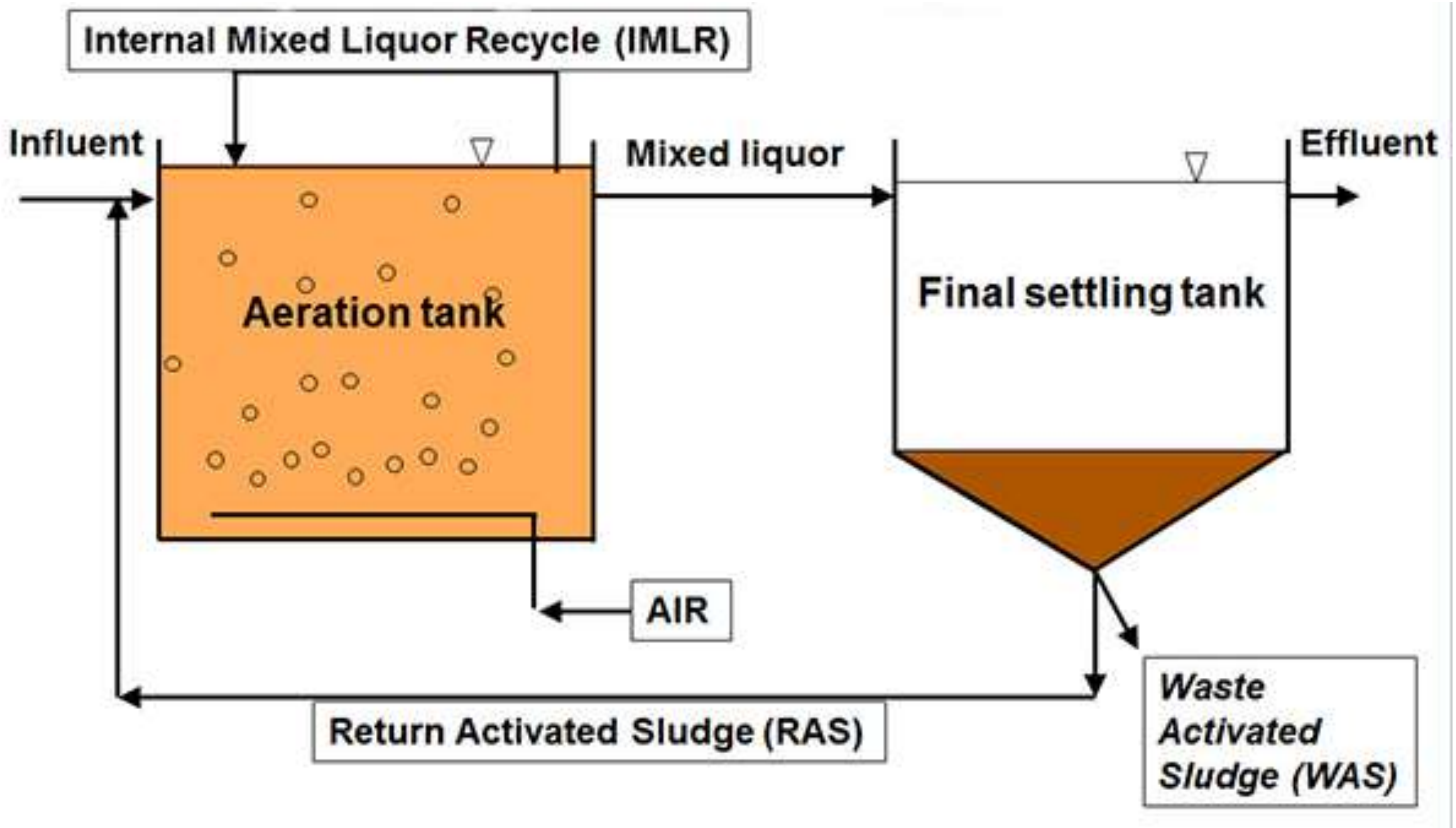
Process Mechanism for Activated Sludge Process

- Aerobic bacteria travel through the aeration tank. They multiply rapidly with sufficient food and oxygen. By the time the waste reaches the end of the tank (4-8hours), the bacteria have used most of the organic matter to produce new cells.

- The organisms settle to the bottom of the clarifier tank, separating from the clearer water. This sludge is pumped back to the aeration tank where it is mixed with the incoming wastewater a process called wasting. The relatively clear liquid above the sludge, the supernatant, is sent on for further treatment as required.

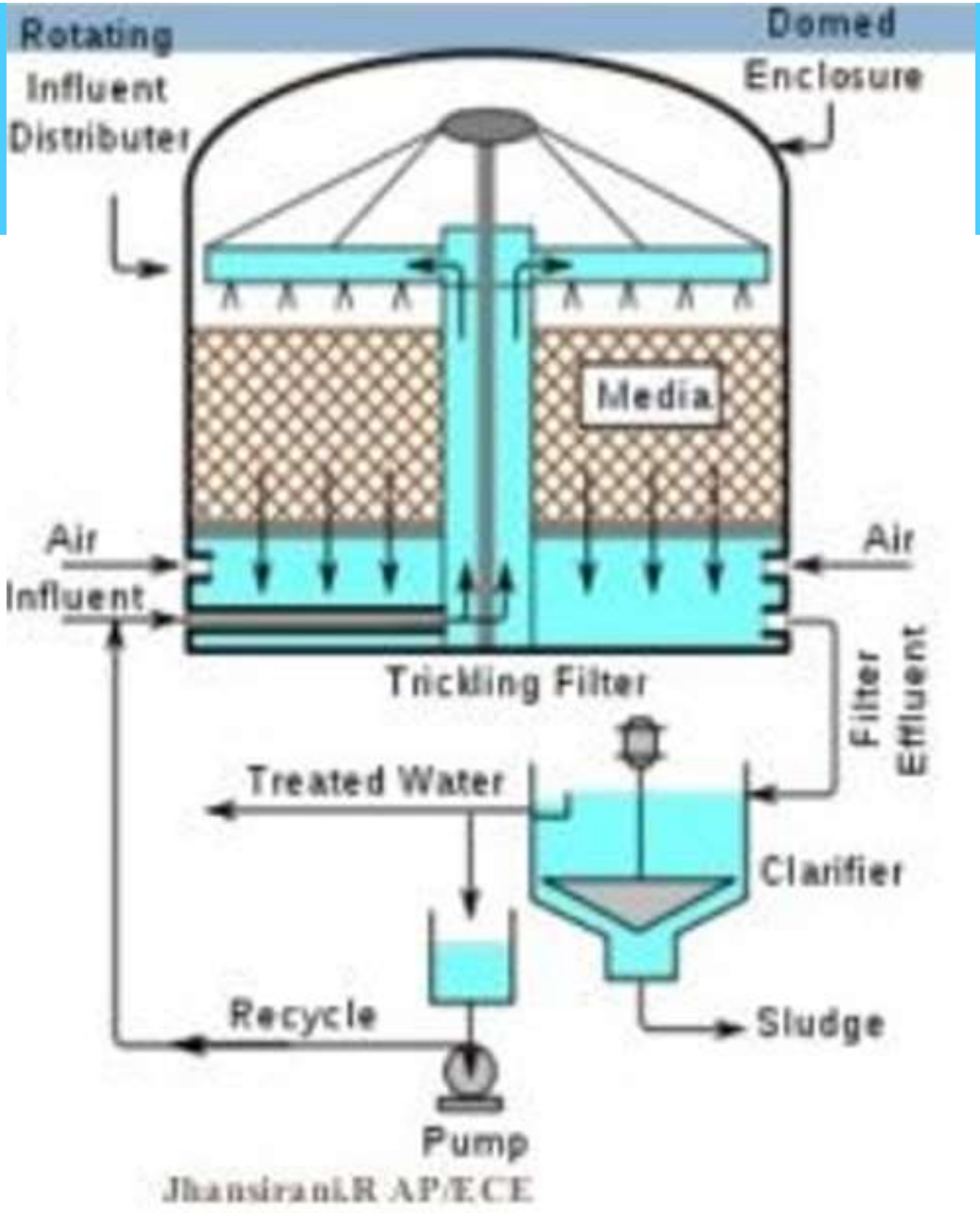
Activated Sludge Organism:

- Particles of the flock in activated sludge consists of mixed species of bacteria
- They embedded themselves in a mass of polysaccharide gum called zooglea
- *Zooglea ramigera* and related organisms need complex nutrient requirement
- Oxidise sewage rapidly; active in floc formation
- Other m.os in zooglea are Esherichia, sps of Pseudomonas, Alkaligens, Bacillus, Sphaerotilus, several protozoans etc.


Internal Mixed Liquor Recycle (IMLR)
Influent
Mixed liquor
Effluent
Aeration tank
Final settling tank
AIR
Return Activated Sludge (RAS)
Waste Activated Sludge (WAS)

Trickling Filters

- It consists of a bed of crushed stone/pebbles covered with slime which consists of aerobic bacteria, algae, fungi, protozoa, worms and insect larvae
- Sewage is degraded by the aerobic bacteria when it passes through the bed and is collected at the bottom of the filter
- It helps in better removal of organic matter and also keeps the filter moist when the flow rate is slow



Biological Contractor System/Rotating Disc

- ❑ A biofilm based design
- ❑ Series of disc of several diameters are mounted on a shaft
- ❑ Discs rotate slowly; their lower part (40%) is submerged in wastewater
- ❑ Aeration provided
- ❑ Rotation causes accumulated biofilm to slough off when thick
- ❑ Equivalent to floc accumulation

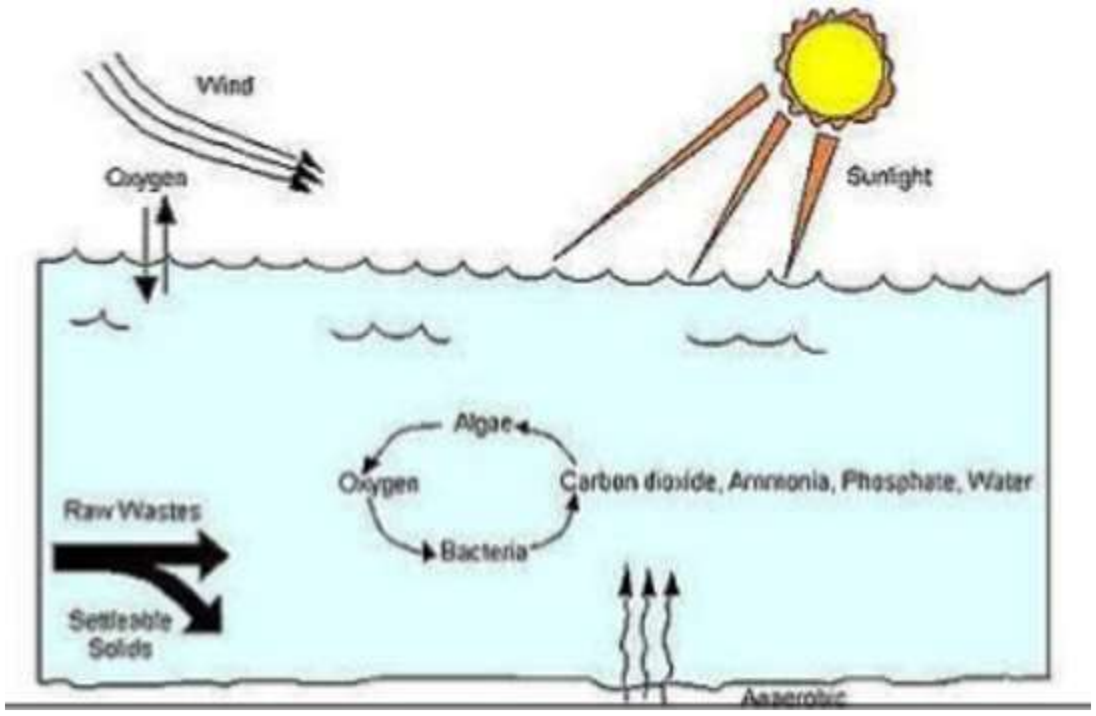
Oxidation Pond

- Large shallow ponds designed to treat wastewater through the interaction of sunlight, bacteria and algae

- Algae grow within the pond and utilize sun light to produce oxygen during photosynthesis

- This oxygen is used by the aerobic bacteria in the oxidation pond to break down the organic waste in the wastewater

- The broken down solids settle down in the pond resulting in effluent that is relatively well treated



Microbial Process in Wastewater Treatment

- Many microbial activities are observed
- Microorganisms associated, do not persist long (fragile)
- Secondary treatment is entirely dependent upon the activity of microbes, e.g., biofilters (trickling filters), activated sludge etc.

- Microbes frequently present in activated sludge: *Achromobacter, Flavobacterium, Nitrosomonas, Beggiatoa, Thiothrix, Nocardia, Mycobacterium, Geotrichum, Nitrobacter*
- Biofilters Host: Nematodes, insect larvae, microfungi, algae

Beneficial Bacteria

- **<u>Biofilm forming bacteria</u>** are present in the trickling filter phase of the secondary treatment process, considered to be beneficial in the removal of organic materials

- Pseudomonas, Zooglea, Chromobacter are namely a few of whom are aerobic heterotrophic organisms.
- Flavobacterium – such bacteria are exposed to oxygen during the treatment to break down the organic molecules

Beneficial Bacteria

Tertiary Treatment

- Removes disease causing organisms from wastewater

- Three different disinfection processes are
  1. Chlorination
  2. UV light radiation (physical treatment)
  3. Ozonation

Chlorination

- Chlorine is a strong oxidant that rapidly kills many harmful microorganisms.
- Chlorine is used in two forms – Cl2 gas form or hypochlorite tablets
- Cl reacts with water to form HOCl, which rapidly dissociate to form hypochlorite ion
- Cl is effective against enteric bacteria
- This is the most common process
- Advantage – low cost and effective
- Disadvantage – chlorine residue could be harmful to environment
- The drawback of chlorine is that chlorine from any source reacts with natural organic compounds in the water to form potentially harmful chemical by products like trihalomethane(THMs) and haloacetic acids(HAAs) both of which are carcinogenic in large quantities.
- The formation of these compounds may be minimised by effective removal of as amany organics from the water as possible prior to chlorine addition.
- Dechlorination is done to avoid harmful effects

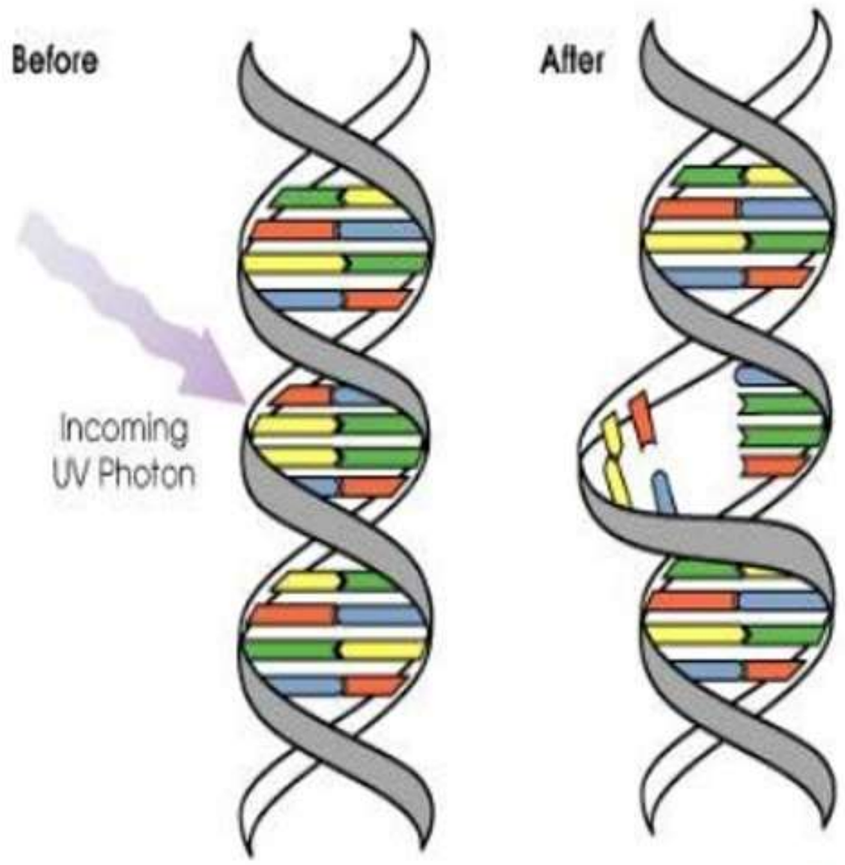
Ozonation

- Disinfection is achieved by formation of free radicals as oxidising agents
- More effective against viruses and bacteria than chlorination
- Advantage – safer than chlorination, fewer disinfection by-product
- Disadvantage – high cost, low solubility of ozone in water

- Because of its high oxidation potential, ozone oxidizes cell components of the bacterial cell wall. This is a consequence of cell wall penetration. Once ozone has entered the cell, it oxidizes all essential components (enzymes, proteins, DNA, RNA). When the cellular membrane is demaged during this process, the cell will fall apart. This is called lysis.

UV Radiation

- Damage the genetic structure of bacteria, viruses and other pathogens
- Advantages
  1. No chemicals are used
  2. More rapid
  3. Water tastes more natural
  4. No by-products formed
- Disadvantage – high maintenance of the UV lamp



Solid Waste Management

- Solid waste management is a term that is used to refer to the process of collecting and treating solid wastes. It also offers solutions for recycling items that do not belong to garbage or trash.
- Waste management is all about how solid waste can be changed and used as a valuable resource.
- One of the negative effects of industrialization is the creation of solid waste.

Solid Waste Treatment Processes:

1. **Landfill**
2. **Composting**
3. **Incineration**

Landfill

- Most traditional method of waste disposal
- Waste is directly dumped into disused quarries, mining voids or borrow pits
- Disposed waste is compacted and covered with soil
- Gases generated by decomposing waste material are often burnt to generate power
- This method is usually used for domestic waste

Difference between Dump and Landfill

A dump is an open hole in the ground where trash is buried and where animals often swarm. They offer no environmental protection and are not regulated.

A landfill is a carefully designed and monitored structure that isolates trash from the surrounding environment (e.g., groundwater, air, rain). This isolation is accomplished with the use of a bottom liner and daily covering of soil.

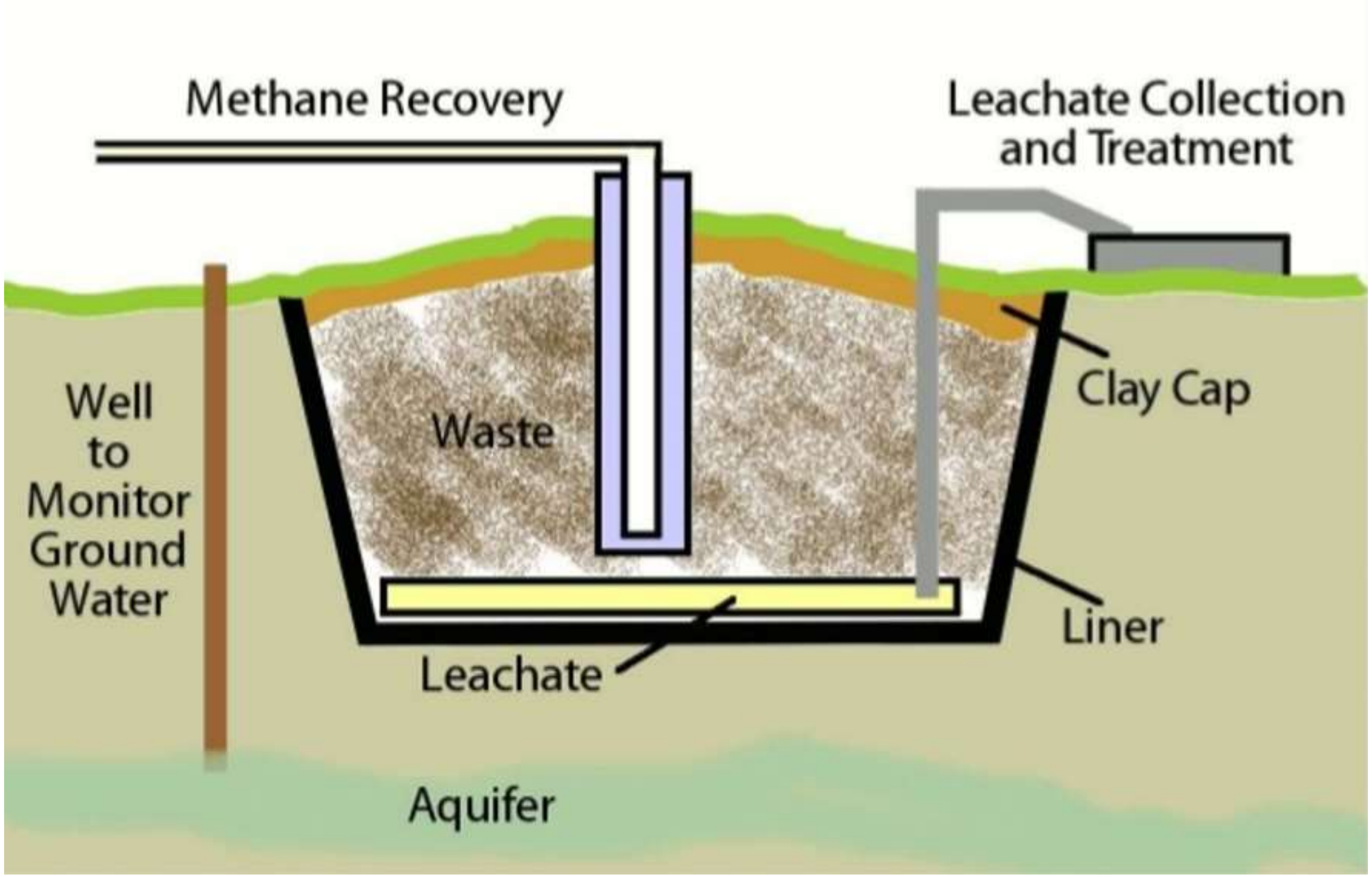
What is a Landfill

An engineered site where waste is isolated from the environment below the ground or on top until it is safe and completely degraded biologically, chemically and physically.

What is a Landfill

- This is the simplest and least expensive way to dispose of solid waste.
- In a landfill inorganic and organic solid wastes are deposited together in low lying land.
- Because exposed waste can cause aesthetic and odor problems, attract insects and rodents each day's waste deposit is covered with a layer of soil creating a sanitary landfill.
- For 30 to 50 years after filling a landfill, the organic content of the solid waste undergoes slow, anaerobic microbial decomposition.
- The products of anaerobic metabolism include carbon dioxide, water , methane, various low molecular weight alcohols and acids.
- Extensive methane are produced during this decomposition process, potentially providing a source of needed natural gas.

Essential Components of a Landfill



Why Landfills are Important

- To prevent contamination of waste into the surrounding environment, especially groundwater due to open dumping

- Some materials cannot be recycled, used for energy or composted

- Increasing population resulting in increase in waste

What Happens to the Waste in Landfills

- Designed to bury the waste in layers of soil
- Compacting the layers to reduce volume
- Slowdown of waste decomposition with minimal amounts of oxygen and moisture
- Finally covering them with soil each day so as to minimize human health and environment problems
- And for careful filling, monitoring and maintenance while they are active and for up to 30 years after they are closed

Reactions Occurring in Landfills

- Biological – Aerobic and Anaerobic Decomposition
- Chemical – Dissolution, Evaporation, Adsorption, Decomposition, Oxidation, Reduction
- Physical – Movement and settlement of leachate and gas

Advantages and Disadvantages of Landfilling

Advantages:

- Burying can produce energy by the conversion of landfill gas, i.e., methane and CO_2
- Landfill by-products can be used as direct/indirect fuel for combustion
- Easy monitoring due to specific location
- Can be reclaimed and used as parks or farming land
- All recyclable materials can be used before closing
- Organic material can also be separated and used for compost or production of natural gas
- Relatively cheap

Disadvantages:

- Problems faced when poorly designed or operated
- Surrounding areas might become heavily polluted
- Dangerous chemicals can seep into groundwater system
- Many insects and rodents are attracted, which can cause dangerous diseases

Composting

- The organic portion of solid waste can be biodegraded by composting, the process by which solid heterogeneous organic matter is degraded by aerobic, mesophilic and thermophilic microorganisms.

- Composting is a microbial process that converts organic materials into a stable, sanitary, humus like product.

- Reduced in bulk, it can be used for soil improvement.

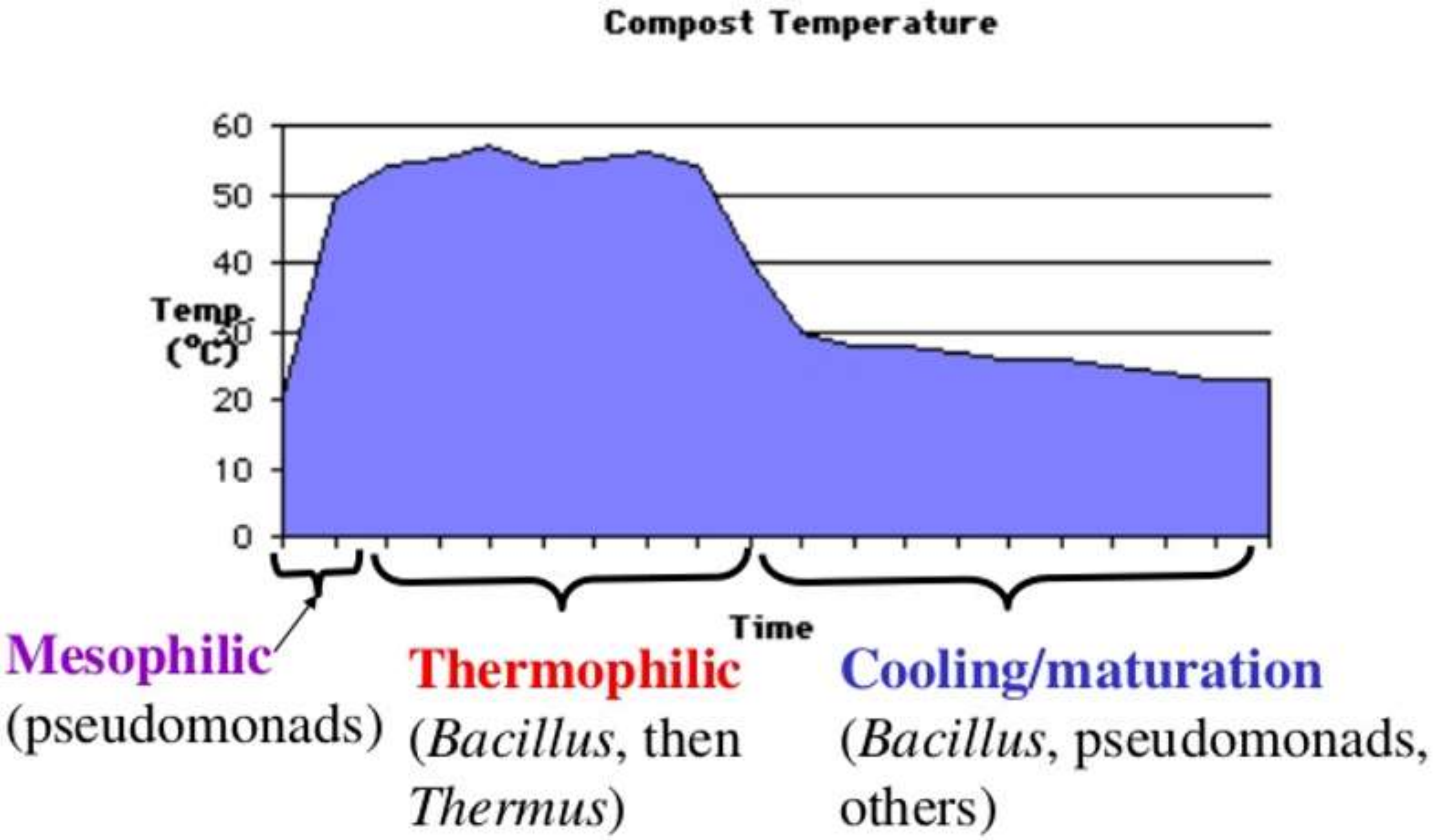
- Composting requires sorting of solid waste into its organic and inorganic components

- This can be accomplished at the source by the separate collections of garbage(organic waste) and trash (inorganic waste)

Composting

- Disposal by composting
- Biological method of decomposing solid waste
- Under aerobic or anaerobic condition or both
- Final end product is manure
- Aerobic composting process involves piling up of refuse and its regular turning, either manually or mechanically to ensure sufficient supply of air
- The process starts with mesophilic bacteria which oxidize the organic matter to CO_2 and liberate heat. The temperature rises to 45^{o}C and at this point thermophilic bacteria take over and continue the decomposition. During this phase the temperature rise to about 60^{o}C. After about three weeks, the compost is stabilized and this is indicated by the appreciable fall in temperature. The final compost should have earthy smell and dark colour.
- Moisture content is a critical factor in aerobic composting process. A moisture content of about 55% should be established so that the biological activity may proceed at an optimum rate.

Phases of Composting



Different Method of Composting

Windrow method:

- Solid waste is arranged in long rows, is a simple but relatively slow process typically requiring several months to achieve biodegradation of the metabolizable components and stabilization of the waste material.
- Odor and insect problems are controlled in this process by covering the windrows with a layer of soil or finished compost.

Aerated pile method:

- Waste is arranged in piles and forced aeration is used to provide needed oxygen
- Perforated pipes are buried inside the compost pile and air is pumped through the pile, oxygenating and cooling it.
- The heat generated in the aerated pile process is used to evaporate water for the final drying of the product.

Continuous feed composting process:

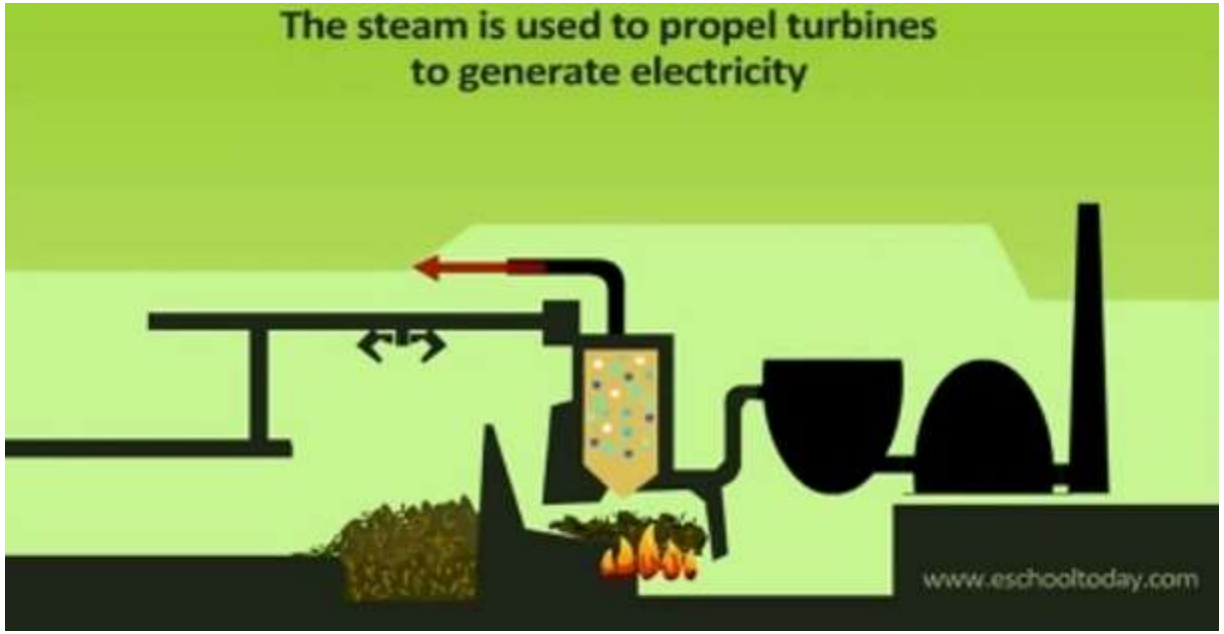
- This process uses reactor that permits controls of environmental parameters.
- This reactor is analogous to an industrial fermenter and permits the production of a relatively uniform product.
- By optimizing conditions, composting in the reactor is accomplished in just two to four days.

Chemical and Physical Factors in Compost Pile

- Temperature
- C/N Ratio – the ratio of Carbon and Nitrogen
- Nutrients – usually plenty in the organic residues
- Oxygen
- pH
- Moisture – optimal is 50-60%
- Particle size

Incineration

- Incineration is a waste treatment process that involves the combustion of solid waste at 1000^{o}C
- Waste materials are converted into ash, flue gas and heat
- The ash is mostly formed by the inorganic constituents of the waste and gases due to organic waste
- The heat generated by incineration is used to generated electric power



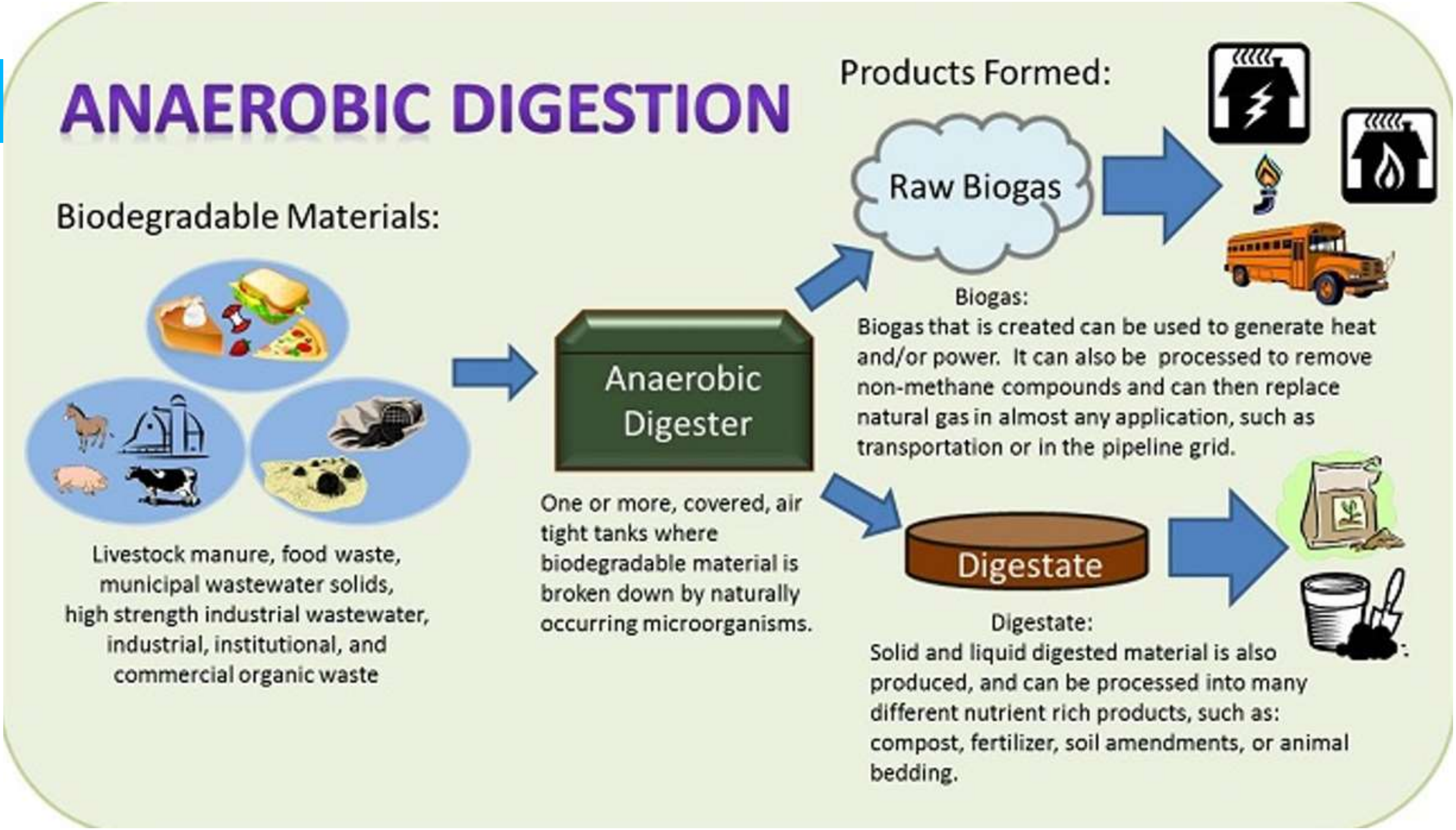
Advantages and Disadvantages of Incineration

Advantages:

- Minimum land is needed compared to other disposal methods
- The weight of the waste is reduced to 25% of its initial value
- No risk of polluting local streams and groundwater as in landfill
- Incineration plants can be located close to residential areas
- Gases are used to generate power

Disadvantages:

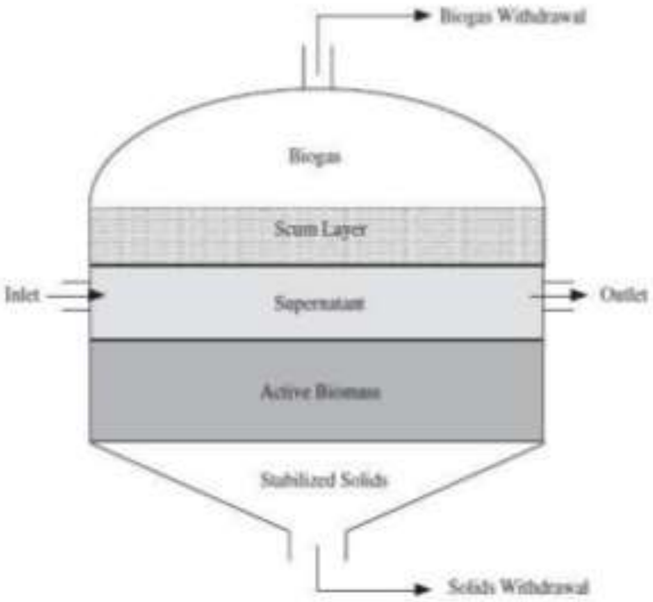
- Expensive
- Requires skilled labour
- The chemicals released into the air could be strong pollutants and may destroy the ozone layer
- High energy requirement


ANAEROBIC DIGESTION
Products Formed:
Biodegradable Materials:
Raw Biogas
Biogas:
Biogas that is created can be used to generate heat and/or power. It can also be processed to remove non-methane compounds and can then replace natural gas in almost any application, such as transportation or in the pipeline grid.
Anaerobic Digester
Livestock manure, food waste, municipal wastewater solids, high strength industrial wastewater, industrial, institutional, and commercial organic waste
One or more, covered, air tight tanks where biodegradable material is broken down by naturally occurring microorganisms.
Digestate
Digestate:
Solid and liquid digested material is also produced, and can be processed into many different nutrient rich products, such as: compost, fertilizer, soil amendments, or animal bedding.

ANAEROBIC DIGESTION

Anaerobic Digester

- A digester is a large container in which substances are treated with heat or enzymes to promote decomposition or to extract essential components



Suspend Growth Anaerobic Digester

1

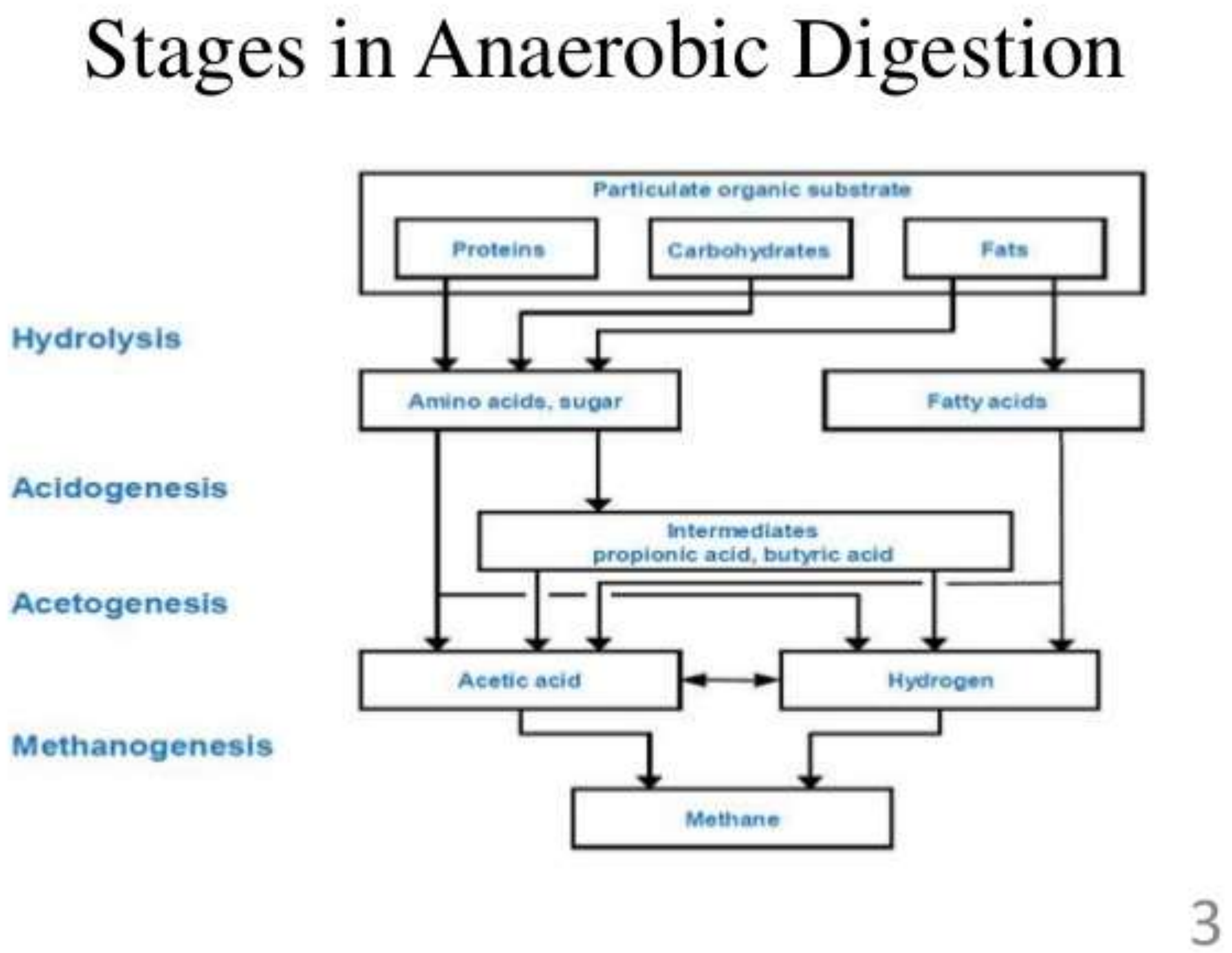
ANAERGBIC DIGESTION

Anaerobic Digestion

- Anaerobic digestion is a naturally occurring process of decomposition and decay
- Here, the organic matter is broken down to simpler chemical compounds under anaerobic conditions
- Anaerobic digestions is
  - Digestion of Organic Material
  - In absence of Oxygen
  - Forming end products of Methane and Carbon dioxide

2

ANAEROBIC DIGESTION



ANAEROBIC DIGESTION

Hydrolysis

- Large Organic Compounds are converted into simple monomeric compounds
- It is accomplished through extracellular enzymes
- Example:
  - Cellulose gets converted to starch using cellulases
  - Casein gets converted to amino acids using Proteases
  - Triglyceride gets converted to fatty acids using lipases

ANAERORBIC DIGESTION

Acidogenesis

- The soluble monomeric compounds formed by hydrolysis undergo fermentation
- The products obtained due to acidogenesis are propionic acid and butyric acid and which are intermediaries and others such as acetic acid, ethanol, hydrogen and carbon dioxide.
- Example of bacteria that bring about fermentation are Lactobacillus sp.
- In this stage due to acid production the pH falls down

Chemical and Physical Factors in Compost Pile

Acetogenesis

- Some of the acetate is produced through mixed acid fermentation
- Rest of acetate is produced through secondary fermentation of products obtained in previous stage
- Acetate formation is important for formation of methane
- Example of acetogenic bacteria: Acetobacter sp.

ANAEROBIC DIGESTION

Methanogenesis

- This is the last metabolic stage in anaerobic digestion
- Methane is formed either from acetate or carbon dioxide and hydrogen
- The bacteria responsible for carrying out methanogenesis are called methogens and are classified as
  - Litotrophic or Hydrogenotrophic i.e. they produce methane from CO2 and H2
  - Acetotrophs or Acetoclastic, these convert acetate to methane
  - Methylotrophs, convert methanol to methane