UNIT 4

What are Wastes?

Waste (also known as **rubbish, refuse, garbage, junk**) is unwanted or useless materials. In biology, waste is any of the many unwanted substances expelled from living organisms, metabolic waste; such as urea and sweat.

Kinds of Wastes

Solid wastes: wastes in solid forms, domestic, commercial and industrial wastes Examples: *plastics , bottles, cans, papers, scrap iron, and other trash*

Liquid Wastes: wastes in liquid form Examples: *domestic washings, chemicals, oils, waste water from ponds, manufacturing industries and other sources.*

Bio-degradable :can be degraded (paper, wood, fruits and others)

Non-biodegradable :cannot be degraded (plastics, bottles, old machines, cans, Styrofoam containers and others)

Hazardous wastes: Substances unsafe to use commercially, industrially, agriculturally, or economically and have any of the following properties- ignitability, corrosivity, reactivity & toxicity.

Non-hazardous : Substances safe to use commercially, industrially, agriculturally, or economically and do not have any of those properties mentioned above. These substances usually create disposal problems.

HAZARDOUS WASTE

- Industrial and hospital waste is considered hazardous as they may contain toxic substances
- Hazardous waste could be highly toxic to humans, animals and plants. They are
  - corrosive
  - highly inflammable or explosive
- In the industrial sector the major generators of hazardous waste are the metal' chemical' paper, pesticide, dye and rubber goods industries.
- Direct exposure to chemicals in hazardous waste such as mercury and cyanide can be fatal

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.

HOSPITAL WASTE OR BIOMEDICAL WASTE

- 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"

  -Bio-medical waste rules ,1998

- It may includes wastes like sharp waste, pathological waste, pharmaceutical waste, genotoxic waste, chemical waste, and radioactive waste etc.

EFFECTS OF SOLID WASTE

A:Health hazard

- If solid waste are not collected and allowed to accumulate , they may create unsanitary conditions.
- This may lead to epidemic outbreaks .
- Many diseases like cholera. Diarrhea, dysentery, plague, jaundice, or gastro-intestinal diseases may spread and cause loss of human lives.

CONTD...

- In addition improper handling of the solid wastes ,a health hazard for the workers who come in direct contact with the waste.

B: Environmental impact

- If the solid wastes are not treated properly decomposition and putrefaction(decay) may take place .
- The organic solid waste during decomposition may generate obnozious (intolerable odour)

WASTE MANAGEMENT CONCEPT

- The 3Rs (Reduce, Reuse, Recycle) to be followed for waste management.

REDUCE

- Disposable goods: paper plate, paper bowl, Styrofoam cup, plastic spoon, roll of paper towels, paper napkin; Durable goods: ceramic/plastic plate, metal spoon, glass/plastic drinking cup, dish towel, cloth napkin)
- Recovery of one tonne paper can save 17 trees.

REUSE

- Instead of buying new containers from the market, use the ones that are in the house.
- Don't through away the soft drink can or bottle cover them with home made paper or paint on them and use them as pencil stands or small vases.

RECYCLE

- Use shopping bags made of cloth or jute which can be used over and over

LANDFILL

"…Technique for Solid Waste Disposal…"

Sources of Solid Waste

- Residential
- Commercial
- Institutional
- Construction and demolition
- Municipal services
- Treatment plant sites
- Industrial
- Agricultural
- Biomedical waste

Municipal solid waste (MSW)

Industrial solid waste

Agricultural waste

Hospital waste

Types of Solid Waste

Plastic waste

Agricultural waste

Biomedical waste

Construction waste

Domestic/ Household waste

E- waste

Hazardous waste

Techniques for Solid Waste Disposal

Landfill

Incineration

Deep Sea Dumping

Energy

fuel

Composting

Recycle

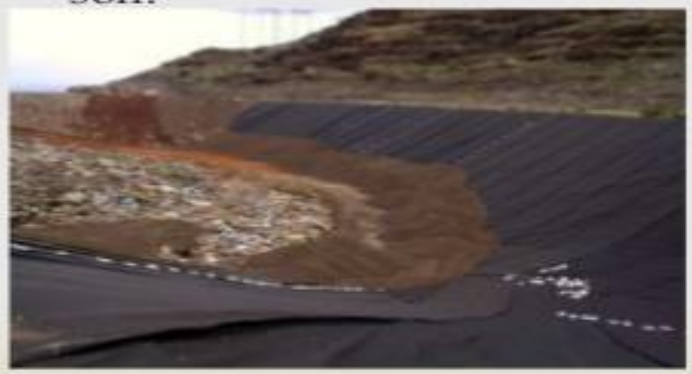
What is a Landfill..????

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.

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.



Why Landfills are important..????

- To prevent contamination of waste into the surrounding environment, especially groundwater due to open dumping.
- Some materials can not be recycled, used for energy or composted.
- Increasing population resulting in increase in waste

What happens to the waste in Landfill…???

- Designed to bury 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 environmental 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 Landfill

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

Advantages of Landfilling

- Burying can produce energy by the conversion of landfill gas i.e. methane & CO_2
- Landfill byproducts can be used as direct/ indirect fuel for combustion.
- Easy Monitoring due to specific location
- Can be reclaimed and it can be 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 of Landfilling

- Problems faced when poorly designed or operated.
- Areas surrounding the landfills become heavily polluted.
- Dangerous chemicals can seep into the ground water system.
- Many insects and rodents are attracted to landfills and can result in dangerous diseases.

Environmental Concerns, Requirements

Concerns

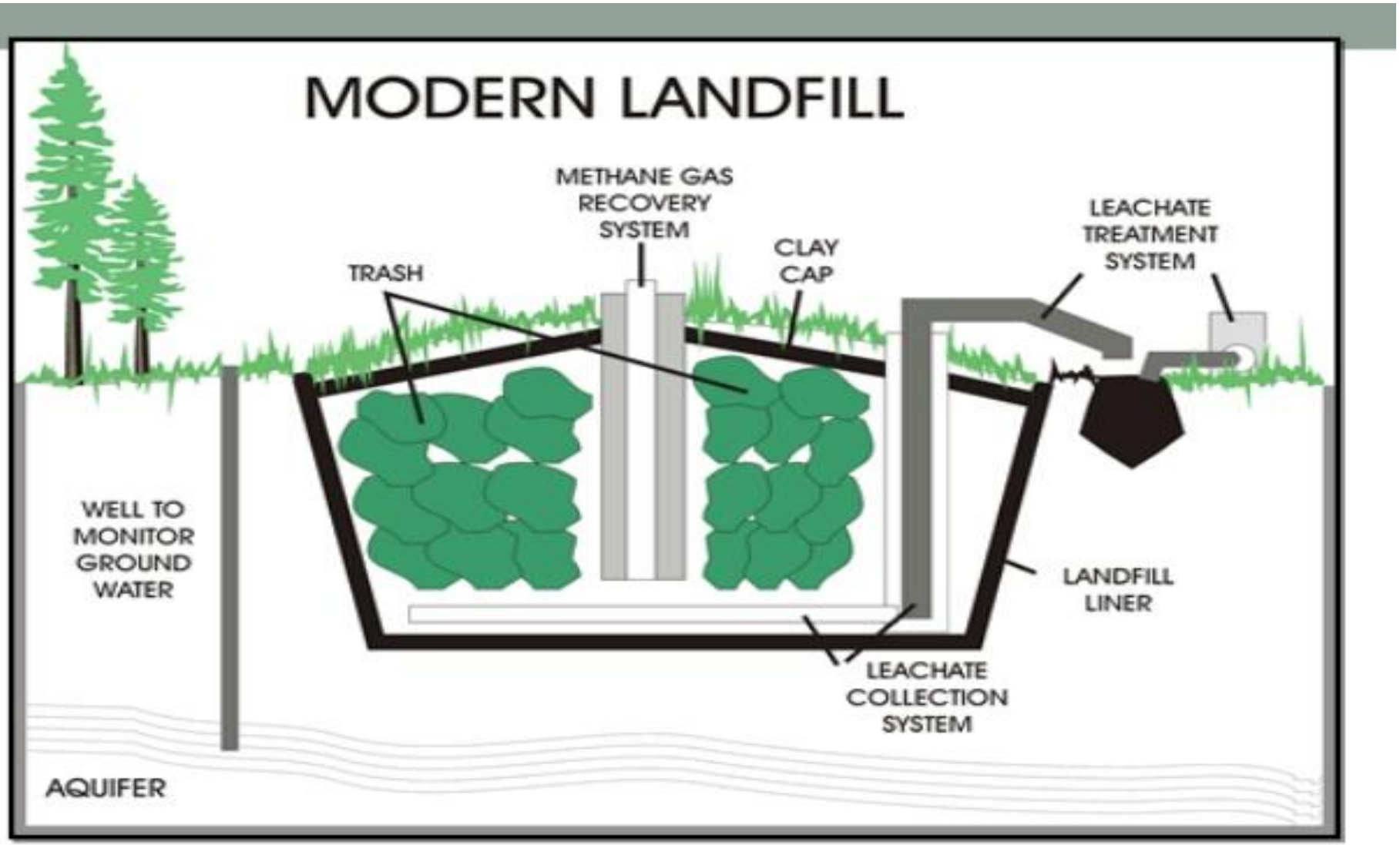
- Availability of Land
- Uncontrolled release of gases
- Uncontrolled release of leachate
- Disease vectors breeding
- Ground water contamination
- Bird Menace
- Odour

Requirements

- **ONLY** for non-biodegradable, inert waste and other waste that are not suitable either for recycling or for biological processing
- Residues of waste processing facilities
- Avoid landfilling mixed waste

Landfill Classification, Types and Methods

- **Sanitary Landfills** - landfill that uses a clay liner to isolate the trash from the environment
- **Municipal solid waste (MSW) landfills** - uses a synthetic (plastic) liner to isolate the trash from the environment
- **Construction and demolition waste landfills** - consist of the debris generated during the construction, renovation, and demolition of buildings, roads, and bridges.
- **Industrial Waste Landfills**- consists of nonhazardous waste associated with manufacturing and other industrial activities
- **Secure Landfills** - landfills for the disposal of hazardous waste.


MODERN LANDFILL
METHANE GAS RECOVERY SYSTEM
TRASH
CLAY CAP
LEACHATE TREATMENT SYSTEM
WELL TO MONITOR GROUND WATER
LANDFILL LINER
LEACHATE COLLECTION SYSTEM
AQUIFER

Characteristics of Landfill

1. solid waste is placed in a suitably selected and prepared (lined) landfill site in a carefully prescribed manner.

2. the waste material is spread out and compacted with appropriate heavy machinery.

3. The waste is covered each day with a layer of compacted soil.

4. Most important feature of modern sanitary landfill design is the technology used to prevent GW pollution.

5. It relies on containment rather than treatment.

Microbial Degradation Process

- Biological process is most important aspect in landfilling which determines the quantity and quality of leachate and gas.
- After the disposal, large part of waste becomes anaerobic(du to absence of oxygen.
- Microbial activity degrade the solid organic carbon and produces **methane** and **carbon dioxide**.
- In an anaerobic process solid and dissolved organic compounds are hydrolyzed and fermented to volatile fatty acids, alcohols, hydrogen and carbon dioxide.
- The methanogenic bacteria convert acetic acid to methane and carbon dioxide.
- Hydrogenophilic bacteria convert hydrogen and carbon dioxide to methane.

Decomposition pathways for common organic waste material

Proteins	carbohydrates	lipids
↓	↓	↓
Amino acids	simple sugar	long chain of volatile fatty acids
↓	↓	↓
Hydrogen/ carbon dioxide	Acetate	Short chain of volatile fatty acids
↓	↓	↓
Methane	Methane + CO_2	← Acetate

Area Method (Above Ground level)

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

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

Trench Method (Below Ground Level)

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

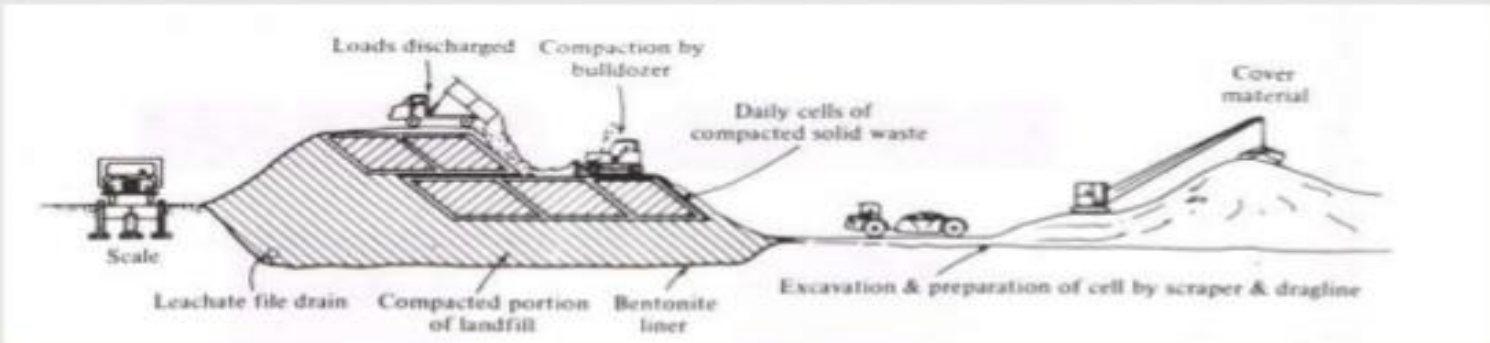
- Good in areas where there is relatively little
- Waste.

Depression/Valley Method

Used where natural or artificial depressions exist and these are used for land filling.

Depends on the geometry of the site, hydrology and geology of the site, and access to site.

The normal practice is to place such that water does not accumulate behind the landfill.



Slope Method

- In hilly regions it is usually not possible to find flat ground for land filling.
- Waste is placed along the sides of existing hill slope.
- Control of inflowing water from hill side slopes is a critical factor in design of such landfills.

Ramp Method

- Used in the case of flat or slightly undulating areas.
- Modification of both the area and the trench method and utilizes certain technique of both

Criteria for Site Selection

Potential landfill site is selected on the basis of

- Responsibility of Development Authorities to identify the landfill sites and hand over the sites to the concerned municipal authority for development, operation and maintenance.
- Near by waste processing facility.
- Soil Conditions and topography
- Surface water Hydrology
- Large enough to last for 20-25 years.

- A buffer zone of no-development shall be maintained around landfill site.
- Temporary storage facility for solid waste shall be established in each landfill site.

Sanitary Landfill Life Cycle

Sanitary landfills are intended as biological reactors (bioreactors) in which microbes will break down complex organic waste into simpler, less toxic compounds over time.
Aerobic decomposition is the first stage followed by 4 stages of anaerobic degradation.

Large organic molecules degraded into smaller molecules

Small organic molecules begin to dissolve and move to the liquid phase

Hydrolysis of these organic molecules

Hydrolyzed compounds undergo transformation and volatilization as CO_2 and CH_4

Rest of the waste remaining in solid and liquid phases

Phases of Degradation

Initial adjustment (Phase I)

Oxygen concentration is high → Microbial populations grow, density increases → Aerobic biodegradation dominates

Transition (Phase II)

Oxygen rapidly degraded → Anaerobic conditions in the layers → Nitrate, sulphates used as electron acceptors

Acid formation (Phase III)

Hydrolysis of the biodegradable fraction of the solid waste → Rapid accumulation of volatile fatty acids (VFAs) in the leachate → Long chain volatile organic acids (VOAs) converted to acetic acid, CO_2 and H_2

↓

High VOA concentrations initiates H_2 production by fermentative bacteria → Stimulates H_2 oxidizing bacteria

Methane fermentation (Phase IV)

VFAs metabolized by the methanogens and converted to CH_4 and CO_2
This is the longest decomposition phase

Final maturation and stabilization (Phase V)

The rate of microbiological activity slows down as nutrients become limiting
Methane production almost completely disappears
O_2 and oxidized species gradually reappears in the gas wells as O_2 permeates downwardly from the troposphere.
The residual organic matter may incrementally be converted to the gas phase

Composting

Compost also known as Farmyard manure is the oldest manure known to mankind and is made up of solid excreta or dung of animals, urine and plant remains which are allowed to decay with the help of soil microorganisms capable of decomposing complex organic debris into substances that are easily assimilated by plants.

The manorial value of farmyard manure depends on the nature of raw materials used and the extent of decomposition by soil microorganisms.

Compost

Benefits of Compost

Compost improves the quality of soil, and for this reason it is considered as a soil conditioner.

It contains a variety of the basic nutrients required for healthy growth of plants.

In addition to, nitrogen, phosphorous, and potassium, certain micronutrients *viz.* manganese, copper, iron, and zinc also found in compost which helps them to control diseases and insects.

Compost improves the structure and texture of the soil enable them to retain nutrients, moisture, and air for the betterment of growth of plants.

Compost

Material required for Composting

Farm refuses

- Weeds
- Stubbles *bhusa*
- Crop residues
- Remnents of fodder
- Hedge clipping

Animal dung

- Cow dung
- Buffalo dung
- Poultry dung

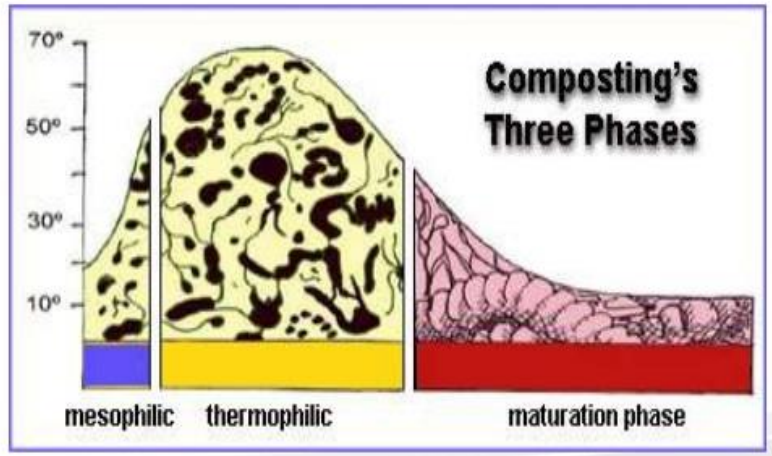
Town refuse

- Night soil
- Street refuse
- Municipal fuse

Phases of Composting

- Initial decomposition is carried out by mesophilic microorganisms, which rapidly break down the soluble, readily degradable compounds.
- As the temperature rises above about 40°C, the mesophilic are replaced by thermophilic, At temperatures of 55°C and above, many microorganisms that are human or plant pathogens are destroyed.
- During the thermophilic phase, high temperatures accelerate the breakdown of proteins, fats, and complex carboydrates like cellulose and hemicellulose, the major structural molecules in plants.
- temperature gradually decreases and mesophilic microorganisms once again take over for the final phase of "curing" or maturation of the remaining organic matter.

Phase of Composting



Organisms involved in composting

Bacteria

- are the smallest living organisms and the most numerous in compost; they make up 80 to 90% of the billions of microorganisms typically found in a gram of compost
- responsible for most of the decomposition and heat generation in compost.
- At the beginning of the composting process (0-40℃), mesophilic bacteria predominate. heats up above 40℃, thermophilic bacteria take over.
- dominated by members of the genus Bacillus.
- At the highest compost temperatures, bacteria of the genus *Thermus dominates.*
- *Eg: Bacillus brevis, B. subtilis*

Actinomycetes

- characteristic earthy smell of soil is caused by actinomycetes.
- organisms that resemble fungi but actually are filamentous bacteria.
- play an important role in degrading complex organics such as cellulose, lignin, chitin, and proteins.
- Their enzymes enable them to chemically break down tough debris such as woody stems, bark, or newspaper.
- Some species appear during the thermophilic phase, and others become important during the cooler curing phase.
- Eg: *Actinobifida chromogena, Microbispora bispora*

Fungi

- they are responsible for the decomposition of many complex plant polymers in soil and compost.
- they break down tough debris, enabling bacteria to continue the decomposition process once most of the cellulose has been exhausted.
- Fungal species are numerous during both mesophilic and thermophilic phases of composting.
- Most fungi live in the outer layer of compost when temperatures are high.
- Eg: *Aspergillus fumigatus, Humicola grisea*

Protozoa

- Protozoa are one-celled microscopic animals.
- They are found in water droplets in compost but play a relatively minor role in decomposition

Rotifers

- Rotifers are microscopic multicellular organisms also found in films of water in the compost. They feed on organic matter and also ingest bacteria and fungi.

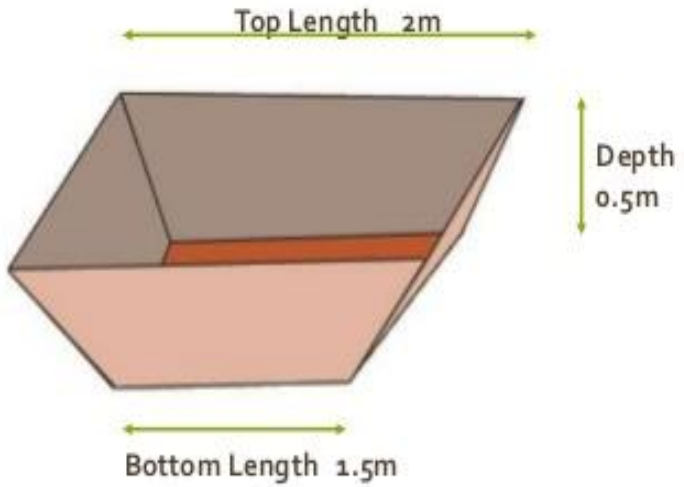
Earthworms

- Earthworms are the most important of the large physical decomposers in a compost pile.
- Earthworms ingest organic matter and digest it with the help of tiny stones in their gizzards.
- The worms leave dark, fertile castings behind. A worm can produce its weight in castings each day.
- These castings are rich in plant nutrients such as nitrogen, calcium, magnesium, and phosphorus that might otherwise be unavailable to plants.

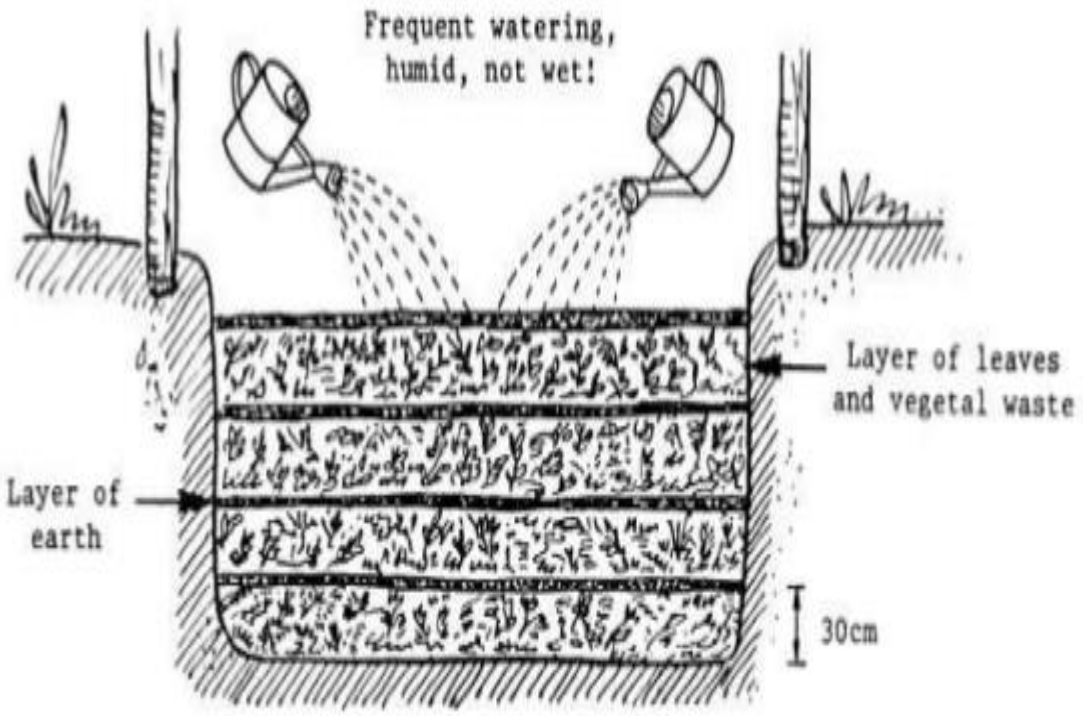
Pit Method of Composting

Pit making

- **Dig the hole for your compost pit.** Your compost hole should be about 0.5m deep. The area of the hole will be determined by the amount of organic matter you want to add. Sizes can be vary according to the requirement.



In China pits have dimensions of 3.5m x2.5m x1.5m (L x B x H).



The pits are filled layer by layer and each layer is about 15cm thick. The bottom layer consists of green plants and aquatic weeds available on the farm followed by silt-straw mixture and animal excreta (layer 3). This layering is repeated until the pit is filled. Finally a layer of mud is made on top of the pit in such a way that water of about 4cm depth is maintained on the surface to create anaerobic conditions.
In a time span of 10 weeks the mud plaster is dismantled and the contents of the pit are turned over.
At the end of 3 months the compost is ready for used on the farm.

In India the pit method is also practiced without any water logging in an elevated place often protected by a shed.

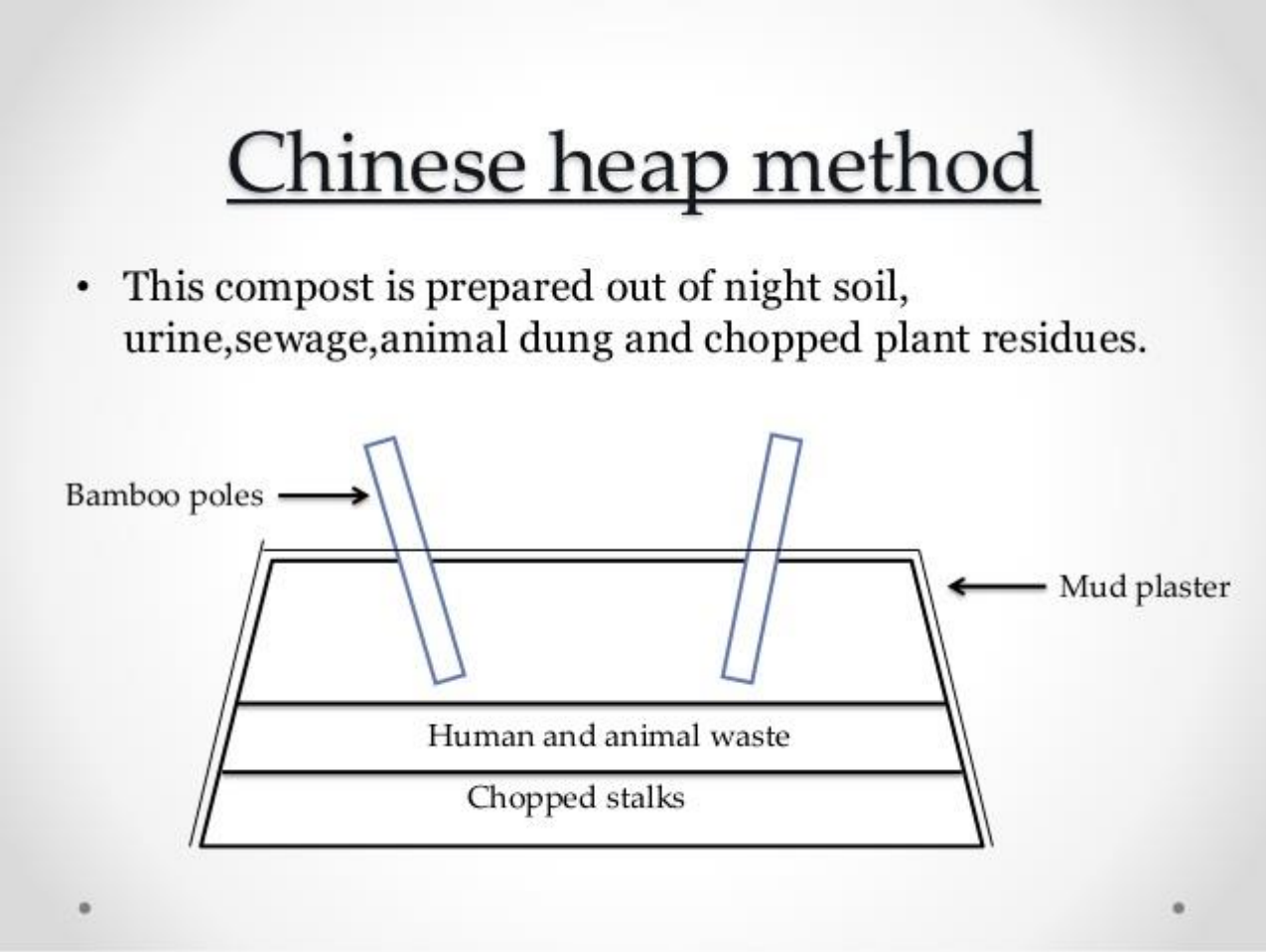
The layering at the bottom is usually the urine soaked bed in the cattle shed. The bed is made of farm materials such as vegetable wastes, fodder remnants, green matter etc. The bed layer is sprinkled with a slurry of cow dung and mixed with well decomposed manure from the previous batch. This sort of layering and sprinkling with cow dung slurry is repeated until the pit is filled.

The compost pit sits for a period of 2-3 months within which the contents are turned over or stirred 3 times.

Heap Method of Composting

- The method for building the heap is as follows: 10cm layer of material that is difficult to decompose (stalks and crop residues). Then sprinkle with water. 10cm of material that is easy to decompose (fruit and vegetable wastes). 2cm of animal manure (if available).
- The heap can be rectangular in shape.
- After wetting with water the heap is mud plastered and allowed to sit.
- Within a period of 2-3 months the heap is broken, materials turned or stirred and again mud plastered.

High Temperature Composting



- The entire heap is shaped finally with mud plaster taking care to insert bamboo or maize stalks into the mud covered heap all the way to the bottom of the heap.
- After 24 hrs. the bamboo poles are withdrawn to leave behind holes for ventilation.
- Within 4-5 days the temperature in the heap reaches 60-70^{0}C when the holes are closed and sealed with mud plaster.
- After a period of 2 weeks the mud plaster is broken and the contents mixed followed by resealing with mud plaster.
- At the end of 2 months the decomposed compost free from pathogens is ready for used on the farm.

Vermicomposting

- Worm composting is using worms to recycle food scraps and other organic material into a valuable soil amendment called vermicompost.
- It is a mesophilic process, utilizing microorganisms and earthworms that are active at 10–32°C.
- The process is faster than composting; because the material passes through the earthworm gut,whereby the resulting earthworm castings ie, rich in nutrients.
- Earthworms consume various organic wastes and reduce the volume by 40–60%.

Earthworms consume biomass and excrete it in digested form called worm casts/Black gold.

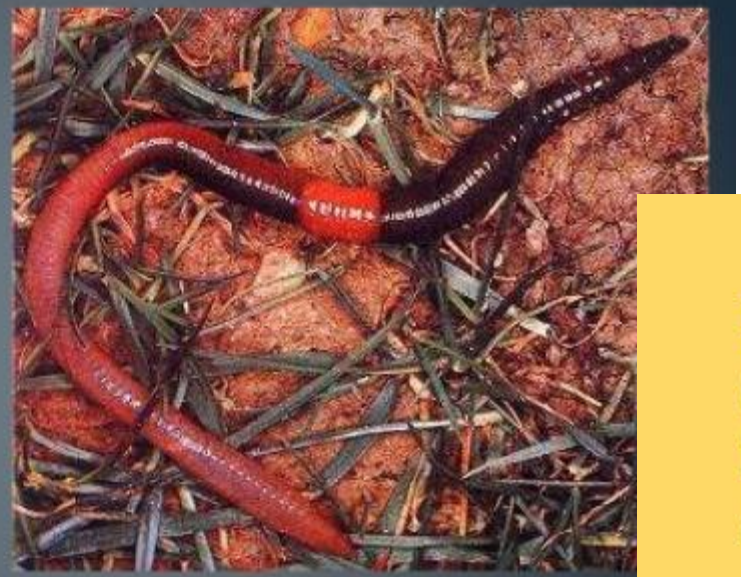
The casts are rich in nutrients, growth promoting substances, beneficial soil micro flora

Vermicomposting materials

- Decomposable organic wastes such as animal excreta, kitchen waste, farm residues and forest litter are commonly used as composting materials.
- In general, animal dung mostly cow dung and dried chopped crop residues are the key raw materials.
- Mixture of leguminous and non-leguminous crop residues enriches the quality of vermicompost.

Red earthworm is preferred because of its high multiplication rate and thereby converts the organic matter into vermicompost within 45-50 days.

Since it is a surface feeder it converts organic materials into vermicompost from top.



Earthworm is physically an aerator, crusher, mixer, chemically a degrader and biologically a stimulator in the decomposer system.

Earthworms are invertebrates.

- mainly divided into two types: (1) burrowing; and (2) non-burrowing.
- The burrowing types Pertima elongata and Pertima asiatica live deep in the soil.
- the non-burrowing types Eisenia fetida and Eudrilus eugenae live in the upper layer of soil surface.
- The non-burrowing earthworms eat 10% soil and 90% organic waste materials; these convert the organic waste into vermicompost faster than the burrowing earthworms.
- They can tolerate temperatures ranging from 0 to 40 °C but the regeneration capacity is more at 25 to 30 °C and 40–45% moisture level in the pile.
- The burrowing type of earthworms come onto the soil surface only at night. These make holes in the soil up to a depth of 3.5 m and produce 5.6 kg casts by ingesting 90% soil and 10% organic waste.

Methods of vermicomposting

- *Bed method :*

Composting is done on the pucca / kachcha floor by making bed (6x2x2 feet size) of organic mixture. This method is easy to maintain and to practice

- *Pit method:*

Composting is done in the cemented pits of size 5x5x3 feet. The unit is covered with thatch grass or any other locally available materials. This method is not preferred due to poor aeration, water logging at bottom, and more cost of production.

Procedure:

- Mostly prepared in either pit or heap method in a shady area in the farm.
- Dimensions: 10x4x2 feet
- 1st layer- bedding material of 1inch thick with soft leaves
- 2nd layer- 9inch thick organic residues layer finely chopped materials
- 3rd layer- Dung + water equal mixture of 2inches layer
- Continue the layers up to ground level.
- Regular watering should be done.

- Red earthworm (1500-2000) should be released on the upper layer of bed.
- Water should be sprinkled immediately after the release of worms.
- Beds should be kept moist by sprinkling of water (daily) and b y covering with gunny bags/polythene
- Bed should be turned once after 30 days for maintaining aeration and for proper decomposition.
- Compost gets ready in 45-50 days.
- The finished product is ¾ of the raw materials used.

Vermicomposting is done under thatched roof to protect worms against rain and sun.

Advantages of vermicompost

- Vermicompost is a rich source of nutrients, vitamins, enzymes, antibiotics and growth hormones. So it gives disease resistance to plants.
- Nutrient content of vermicompost is higher than traditional composts.
- It is a valuable soil amendment.
- Vermicompost harbors certain microbial populations that help in N fixation and P solubilization.
- Its application enhances nodulation in legumes and symbiotic mycorrhizal associations with the roots.

Advantages of vermicompost

- Superiority of vermicompost over other synthetic growth media is more pronounced in plant nurseries.
- It can be used as rooting medium and for establishment of saplings in nurseries.
- It improves taste, lusture and keeping quality of the produce.
- It has immobilized enzymes like protease, lipase, amylase, cellulase and chitinese which keep on their function of biodegradation of agricultural residues in the soil so that further microbial attack is speeded up.
- It does not have foul odour as is associated with manures and decaying organic wastes.

Biochemical oxygen demand

For the beginning…..

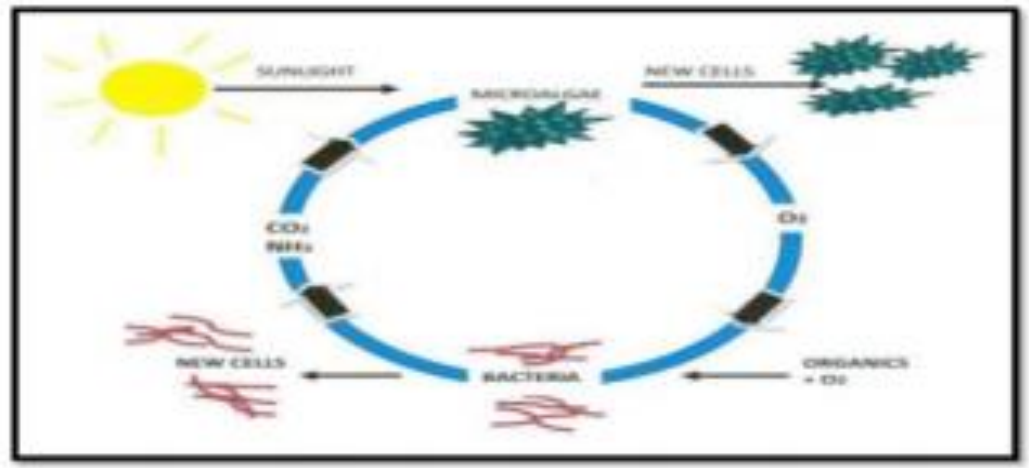
- Water is "polluted" by many organic matter in its course of flow
- When organic matter is present in a water supply, the bacteria present in water will begin the process of breaking down this waste.
- With this much of the available dissolved oxygen is consumed by aerobic bacteria, robbing other aquatic 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.

Cont…

Definition….

- The amount of oxygen absorbed by a sample of sewage during a specific period, generally 5 days at a specific temperature, generally 20° C for the aerobic destruction of the organic matter by living organisms.

- Total BOD is of more significance to food webs than to water quality.



Cont….

- Nitrates and phosphates in a body of water can contribute to high BOD levels.
- Nitrates and phosphates are plant nutrients and can cause plant life and algae to grow quickly.
- When plants grow quickly, they also die quickly.
- This contributes to the organic waste in the water, which is then decomposed by bacteria resulting in a high BOD level.

Is Biochemical oxygen demand different fro
Biological oxygen demand....???

- Bio**chemical** oxygen demand measures the molecular oxygen utilized for the biochemical degradation of organic material (carbonaceous demand) and.....

  .....the oxygen used to oxidize inorganic material such as **sulfides** and **ferrous ion**.

- It also may measure the amount of oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand).

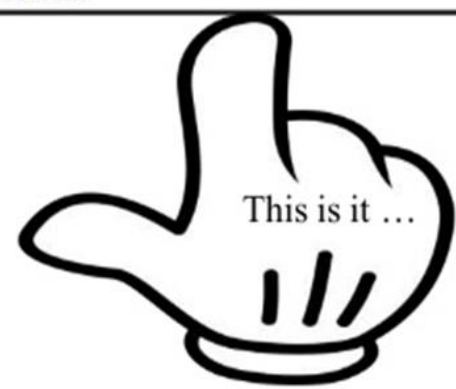
- Biological oxygen demand only addresses the oxygen used up by the bacteria to degrade organic substances.

And we expect…..

Items	BOD standards(mg/L)
Most pristine rivers	<1
Moderately polluted rivers	2-8
Ordinary domestic sewage	150- 200
Municipal sewage efficiently treated	<20

- Any effluent to be discharged into natural bodies of water should have BOD less than 30 mg/L.
- Drinking water usually has a BOD of less than 1 mg/L.
- But, when BOD value reaches 5 mg/L, the water is doubtful in purity.

BOD Level *(in ppm)*	Water Quality
1 - 2	**Very Good** There will not be much organic waste present in the water supply.
3 - 5	**Fair: Moderately Clean**
6 - 9	**Poor: Somewhat Polluted** Usually indicates organic matter is present and bacteria are decomposing this waste.
100 or greater	**Very Poor: Very Polluted** Contains organic waste.



The basics of BOD test..

- The first step is to obtain equal volumes of water from the area to be tested
- Dilute each specimen with a known volume of distilled water which has been thoroughly shaken to insure oxygen saturation.
- Oxygen meter is used to determine the concentration of oxygen within one of the vials.
- The remaining vial is than sealed and placed in **darkness** and tested for oxygen content five days later.
- BOD is then determined by subtracting the second meter reading from the first.

Possibilities...

- Water from an exceptionally clear lake might show a BOD of less than 2 ml/L of water.
- Raw sewage may give readings in the hundreds and food processing wastes may be in the thousands.

THE TITRATION METHOD

$$MnSO_4 + 2NaOH \longrightarrow Mn(OH)_2 + Na_2SO_4$$

$$Mn(OH)_2 + [O] \longrightarrow Mn\,O(OH)_2$$

$$Mn\,O(OH)_2 + 2H_2SO_4 + 2KI \longrightarrow MnSO_4 + K_2SO_4 + I_2 + 3H_2O$$

$$\text{Dissolved } O_2 \text{ in mg/lt} = \left[\frac{8 \times 1000 \times N}{V}\right] v$$

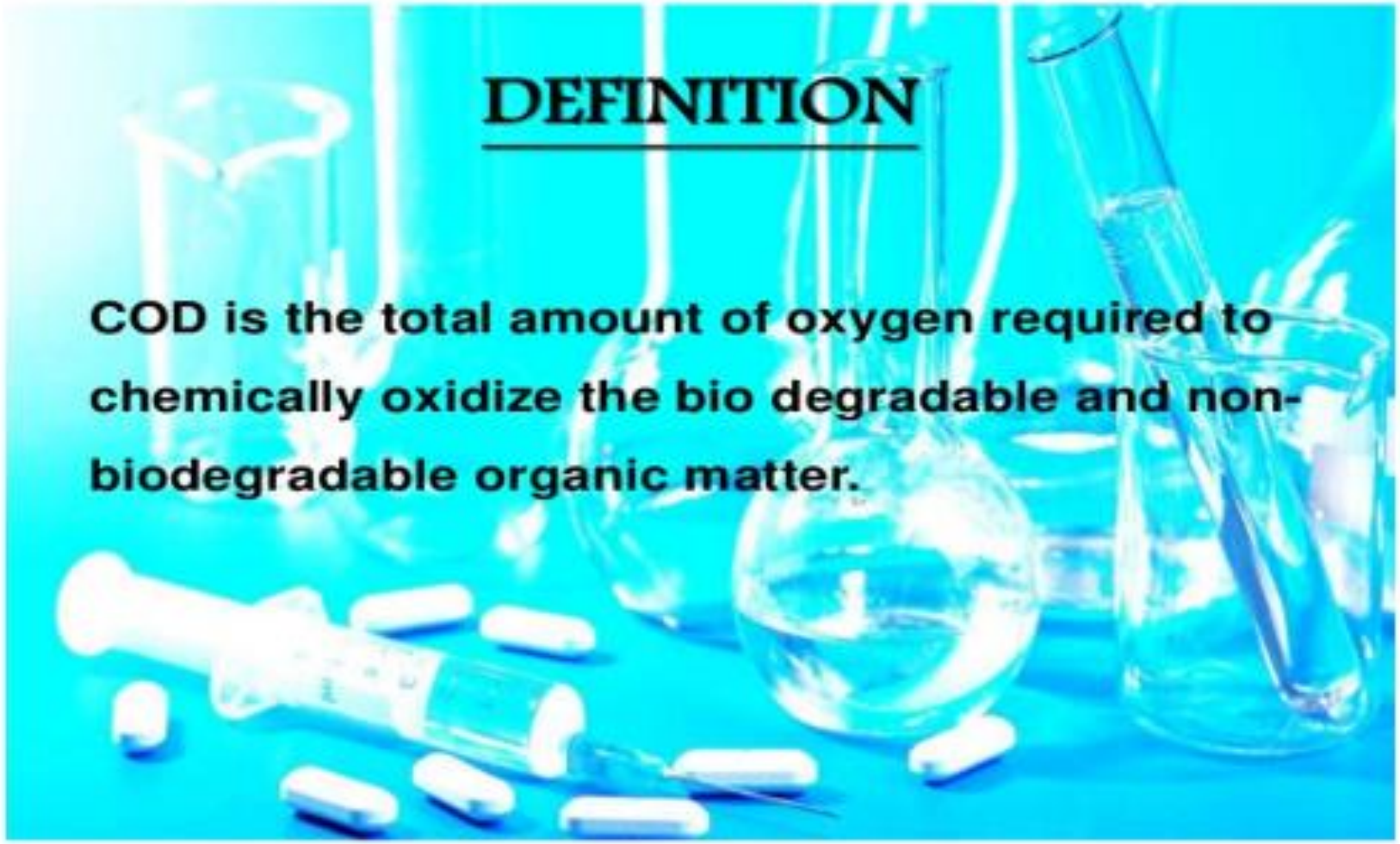
V = volume of sample taken
v = volume of the titrant used
N= normality of titrant

PROCEDURE

Take water sample in a BOD bottle → Add manganese sulphate and alkali-iodide-azide → Mix well

↓

Add conc. H_2SO_4 ← Titrate with sodium thiosulphate with starch as an indicator


DEFINITION
COD is the total amount of oxygen required to chemically oxidize the bio degradable and non-biodegradable organic matter.

HISTORY

- Earlier potassium permanganate was used as an oxidizing agent
- COD values were very much lower than that of 5^{th} day BOD
- It indicated that potassium permanganate was not very effective in oxidizing all the organic matter present
- After that other oxidizing agents like ceric sulphate, potassium iodate and potassium di-chromate were also used


HISTORY (cont.)
• Potassium di chromate was found to be the most effective due to
- Completely oxidize all organic matter
- Relatively cheap
- Easy to purify

COD TEST BY DICHROMATE

PRINCIPLE

- Water sample is refluxed in strong acidic solution with a known excess amount of potassium dichromate.
- After digestion, the remaining unreduced $K_2Cr_2O_7$ is titrated with Ferrous Ammonium Sulfate (FAS)to determine $K_2Cr_2O_7$ consumed.
- This gives us the oxidizable organic matter in terms of oxygen equivalent.

CALCULATIONS

- The COD in mg/l is determined by the formula,

$$\text{COD mg/l} = \frac{(A-B)xNx8000}{\text{ml sample taken}}$$

A = ml of FAS required for blank.

B = ml of FAS requires for sample.

Waste Water Treatment

Waste Water Treatment

- Wastewater treatment is a process used to remove contaminants from wastewater or sewage and convert it into an effluent that can be returned to the water cycle with minimum impact on the environment, or directly reused

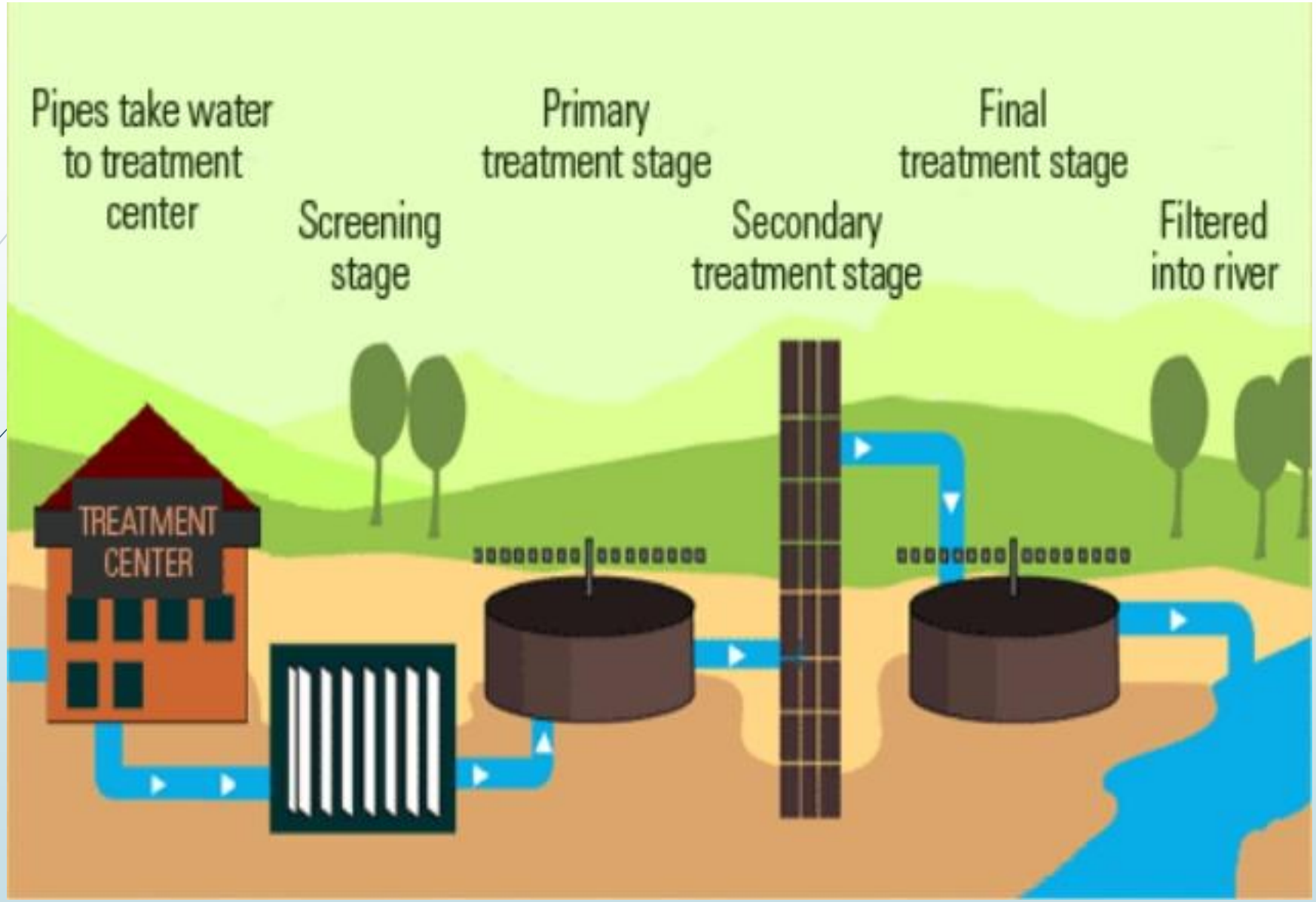
1. Preliminary Treatment
2. Primary Treatment
3. Secondary Treatment
4. Tertiary Treatment

Why treat wastewater?

- Causes a demand for dissolved oxygen (lower DO levels of streams)
- Adds nutrients (nitrate and phosphate) to cause excessive growth
- Increases suspended solids or sediments in streams (turbidity increase)

Objectives of WWT

- Reduce organic content i.e., BOD
- Removal/reduction of nutrients i.e., N,P
- Removal/inactivation of pathogenic microbes


Pipes take water to treatment center
Screening stage
Primary treatment stage
Secondary treatment stage
Final treatment stage
Filtered into river
TREATMENT CENTER

Wastewater Treatment

- Pre-treatment
  - Occurs in business or industry prior to discharge
  - Prevention of toxic chemicals or excess nutrients being discharged in wastewater

Wastewater Treatment

- Water discharged from homes, businesses, and industry enters sanitary sewers
- Water from rainwater on streets enters storm water sewers
- Combined sewers carry both sanitary wastes and storm water

Wastewater Treatment

- Water moves toward the wastewater plant primarily by gravity flow
- Lift stations pump water from low lying areas over hills

Wastewater Treatment

- Preliminary Treatment
  - removes large objects and non-degradable materials branches and tires
  - protects pumps and equipment from damage
  - bar screen and grit chamber Sand and gravel
    Smaller items like
    diapers and bottles

Primary treatment is the physical removal of 20-30% of organic materials present in sewage in particulate form.

Wastewater Treatment

- Bar Screen
  - catches large objects that have gotten into sewer system such as bricks, bottles, pieces of wood, etc.

Wastewater Treatment

- Grit Chamber
  - removes rocks, gravel, broken glass, etc.
- Mesh Screen
  - removes diapers, combs, towels, plastic bags, syringes, etc.

Wastewater Treatment

- Measurement and sampling at the inlet structure
  - a flow meter continuously records the volume of water entering the treatment plant
  - water samples are taken for determination of suspended solids and B.O.D.

Wastewater Treatment

- Suspended Solids – the quantity of solid materials floating in the water column

- B.O.D. = Biochemical Oxygen Demand
  - a measure of the amount of oxygen required to aerobically decompose organic matter in the water

Wastewater Treatment

- Measurements of Suspended Solids and B.O.D. indicate the effectiveness of treatment processes
- Both Suspended Solids and B.O.D. decrease as water moves through the wastewater treatment processes

Primary & Advanced Treatment

Primary Treatment

- Removal of a portion of the suspended solids and organic matter from the wastewater

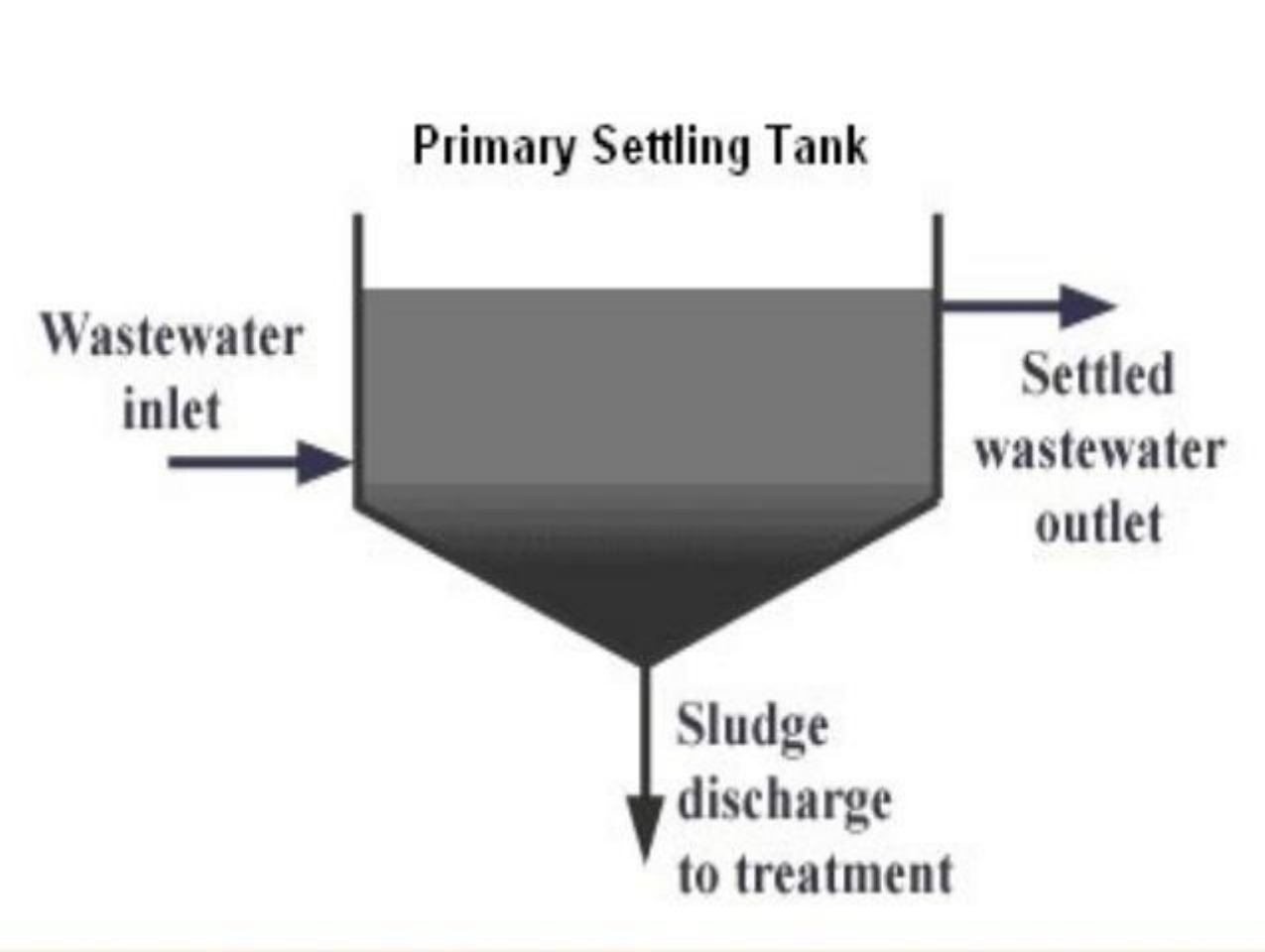
Advanced Primary Treatment

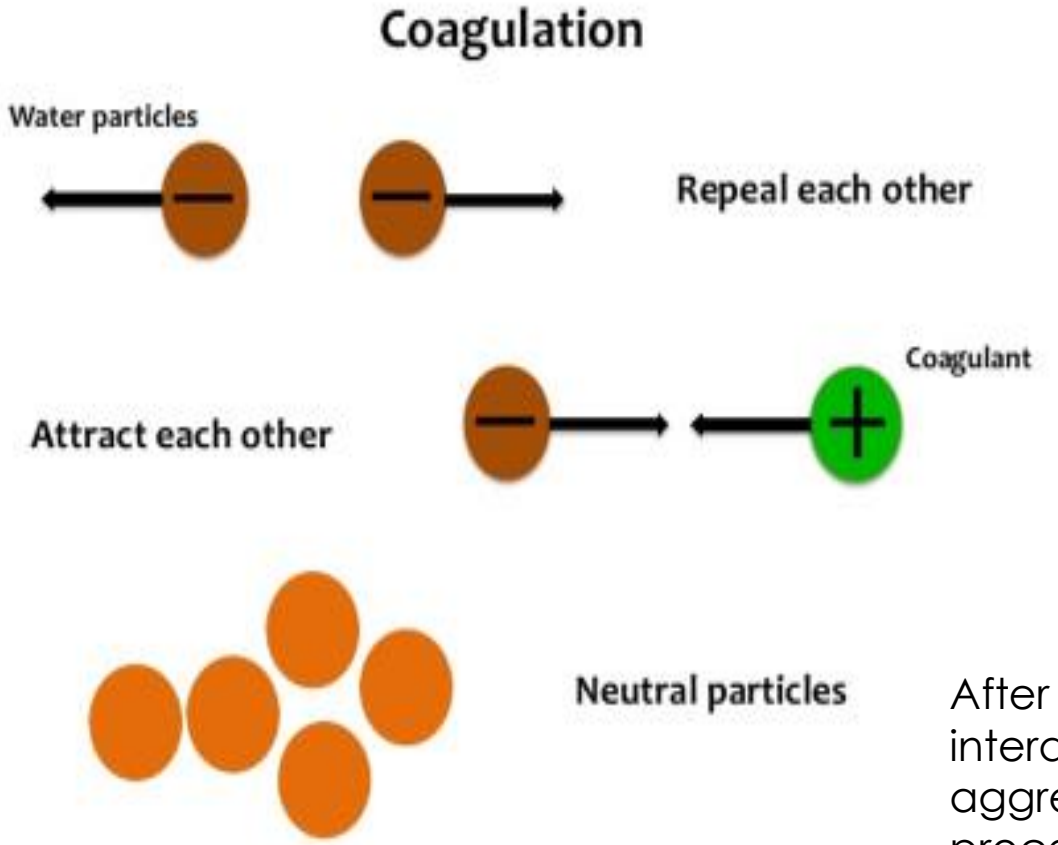
- Enhanced removal of suspended solids and organic matter from the wastewater
- Coagulation and Flocculation

Primary Treatment

Primary treatment consists of following processes/units

- Sedimentation - Primary Settling Tanks
- Coagulation - Secondary Settling Tank
- Flocculation (for smaller suspended solids)


Primary Settling Tank
Wastewater inlet
Settled wastewater outlet
Sludge discharge to treatment



Aluminium sulphate (alum)

After mixing the particles interact forming large aggregated masses a process called flocculation

Wastewater Treatment

- Sludge from the primary sedimentation tanks is pumped to the sludge thickener.

  - more settling occurs to concentrate the sludge prior to disposal

Wastewater Treatment

- Primary treatment reduces the suspended solids and the B.O.D. of the wastewater.
- From the primary treatment tanks water is pumped to the trickling filter for secondary treatment.
- Secondary treatment will further reduce the suspended solids and B.O.D. of the wastewater.

Secondary Treatment

Secondary treatment

Removal of biodegradable organic matter [insoluble or suspension state}and suspended solids

Disinfection is also typically included in the definition of conventional secondary treatment

Secondary Treatment with Nutrient Removal

Removal of biodegradable organics, suspended solids, and nutrients (nitrogen phosphorus, or both nitrogen and phosphorus)

Secondary Treatment

Secondary Treatment Process for Wastewater Applications

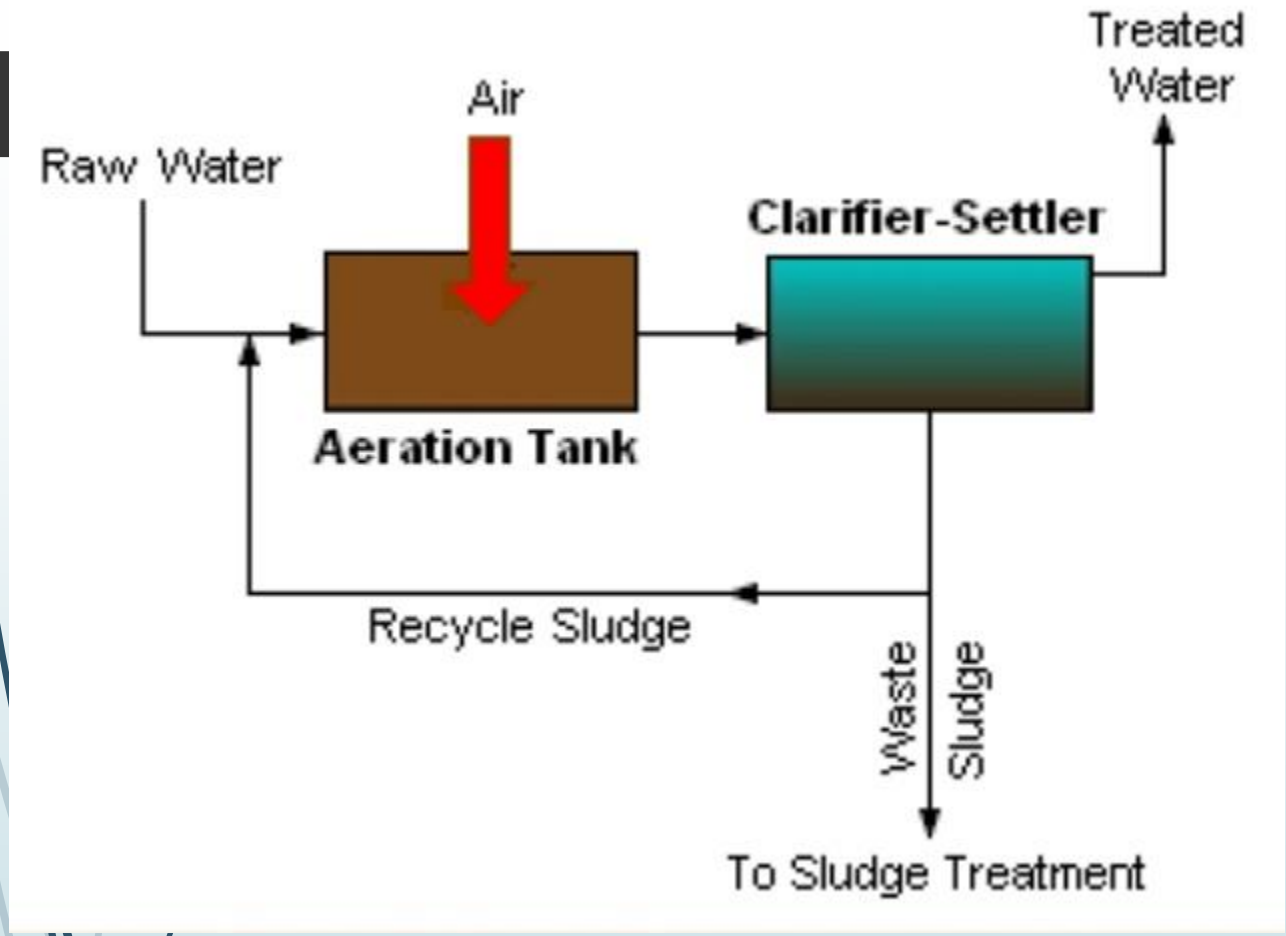
- Aeration Systems
- Biological Treatment Systems
- Sludge and Bio solids Processing Systems

Secondary treatment consists of following processes

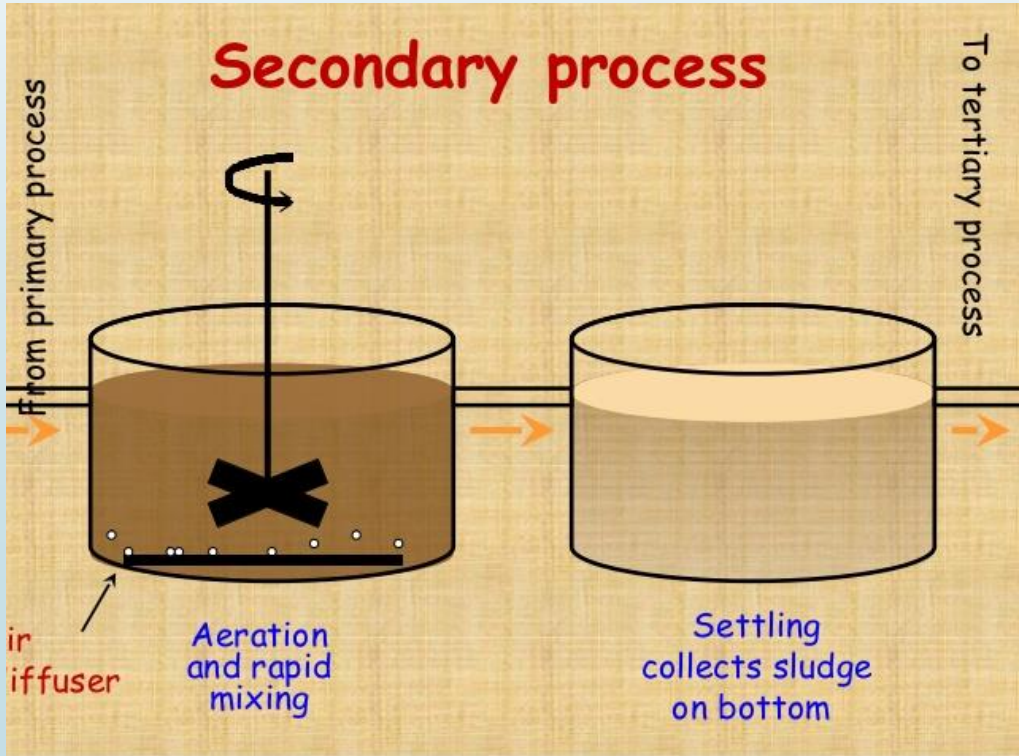
- Activated Sludge Process
- Oxidation Ponds and lagoons
- Trickling Filter

Activated sludge process

- Primary wastewater mixed with bacteria-rich (activated) sludge and air or oxygen is pumped into the mixture
- Both aerobic and anaerobic bacteria may exist
- Promotes bacterial growth and decomposition of organic matter
- BOD removal is approximately 85%
- Microbial removal by activated sludge
  - 80-99% removal of bacteria
  - 90-99% removal of viruses



Due to vigorous aeration the colloidal and finely suspended matter of sewage aggregates which are called floccules. Aerobic microorganisms also becomes trapped within the flocs. Mixing keeps biological flocs suspended and ensures contact between waste water and microrganisms. The flocs are permitted to settle down in secondary settling tank.



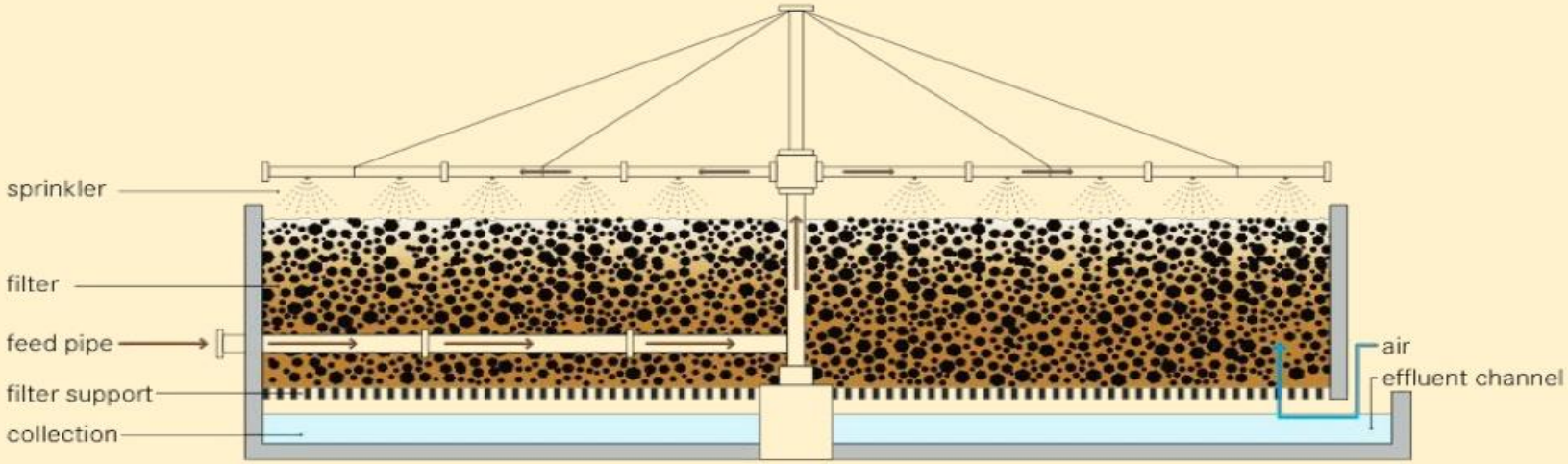
Trickling filters

- Trickling filters are beds made of coke (carbonized coal), limestone chips or specially fabricated plastic media
- Optimize their thickness by insect or worm grazing
- The primary wastewater is sprayed over the filter and microbes decompose organic material aerobically.
- Low pathogen removal
  - Bacteria, 20-90%
  - Viruses, 50-90%
  - Giardia cysts, 70-90%

Tricking filters

Trickling Filter Operation

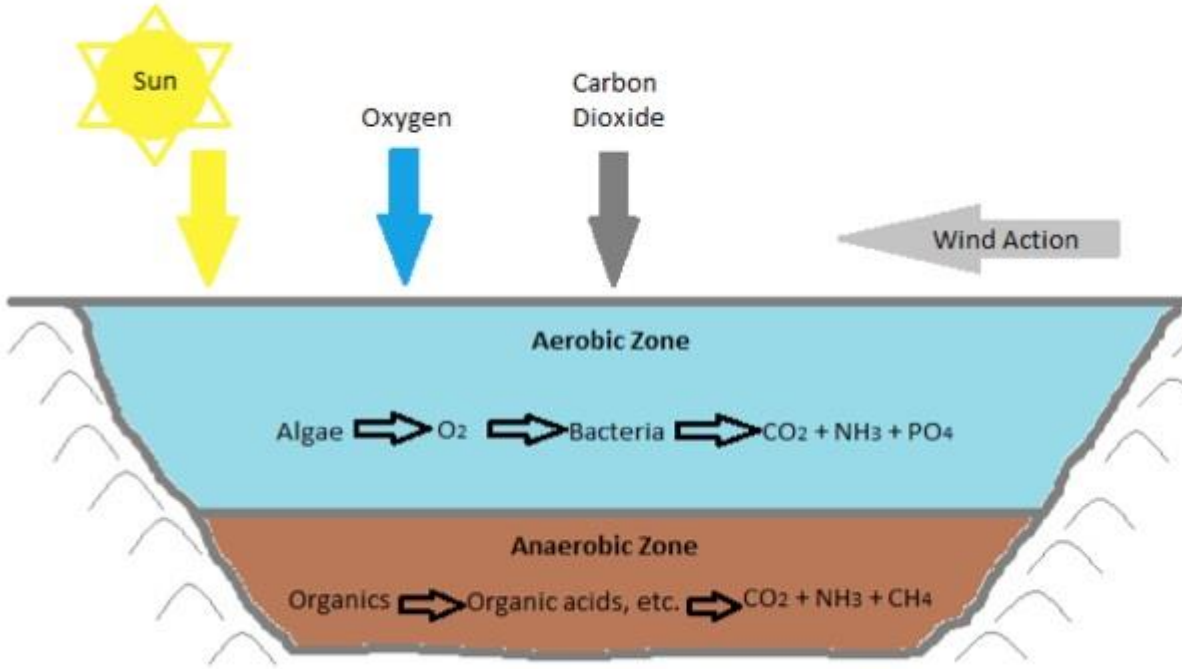
Type of Attached Growth System



The wastewater is distributed over "media" upon which a biological film growth develops containing living organisms that break down organic material.

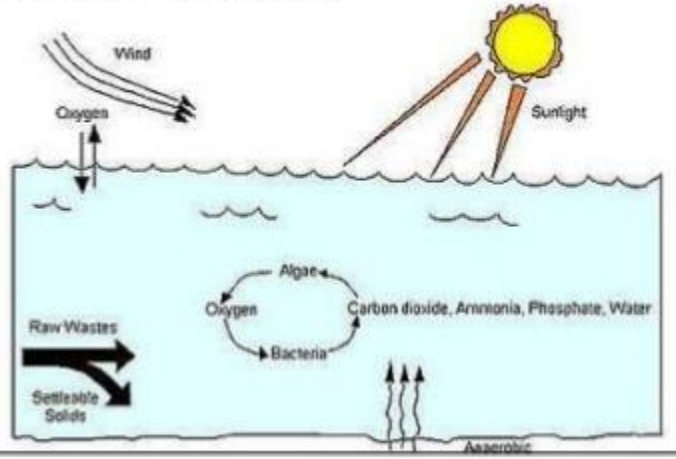
Stabilization or oxidation ponds

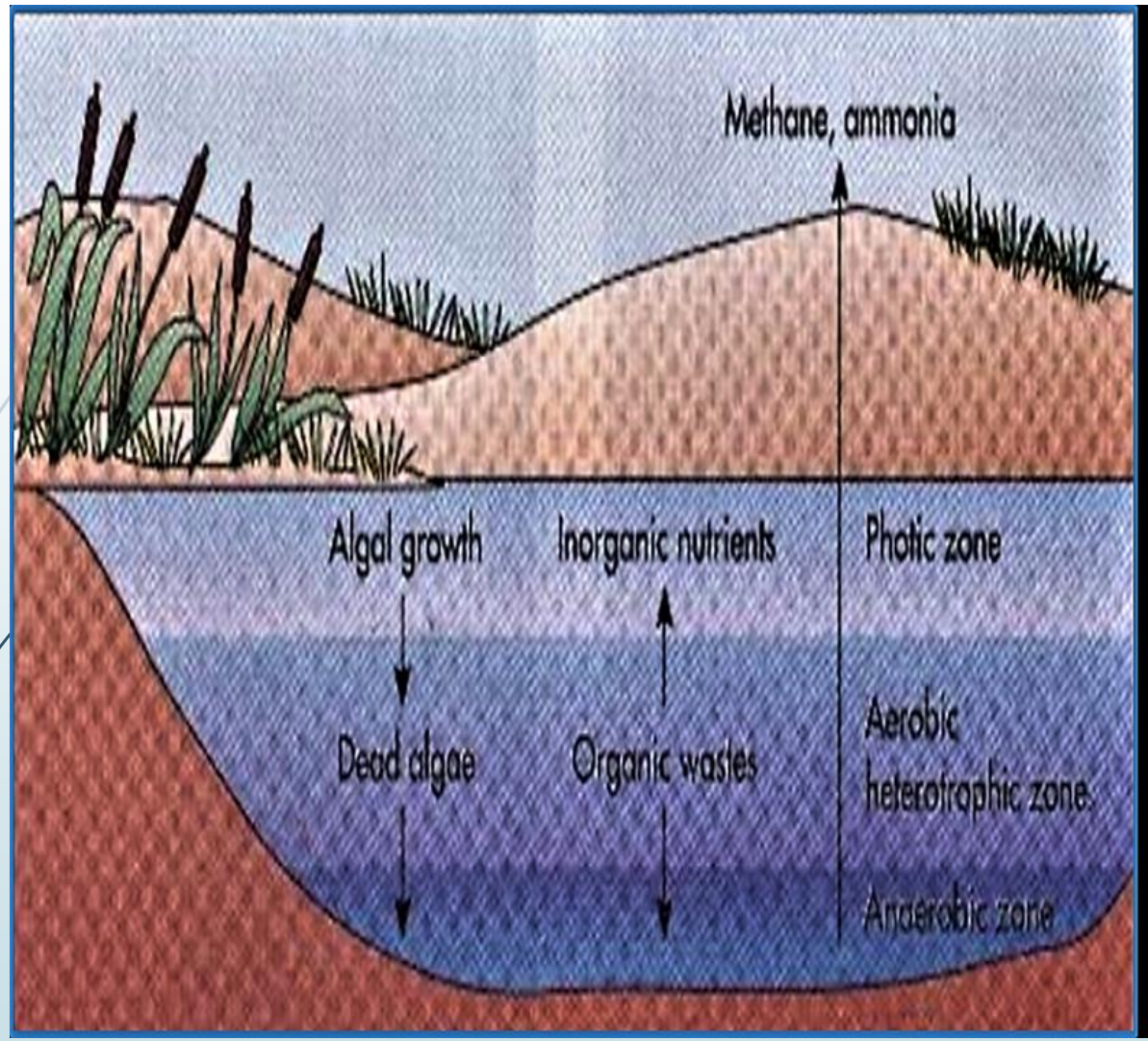
- Oxidation ponds are a few meters deep, and up to a hectare in size.
- They are low cost with retention times of 1 to 4 weeks.
- Odor and mosquitoes can be a problem
- Pathogen removal:
  - Bacteria, 90-99%
  - Virus, 90-99%
  - Protozoa, 67-99%
- Mechanisms include the long detention time, high pH (10-10.5) generated by photosynthesis, predation, sunlight, temperature

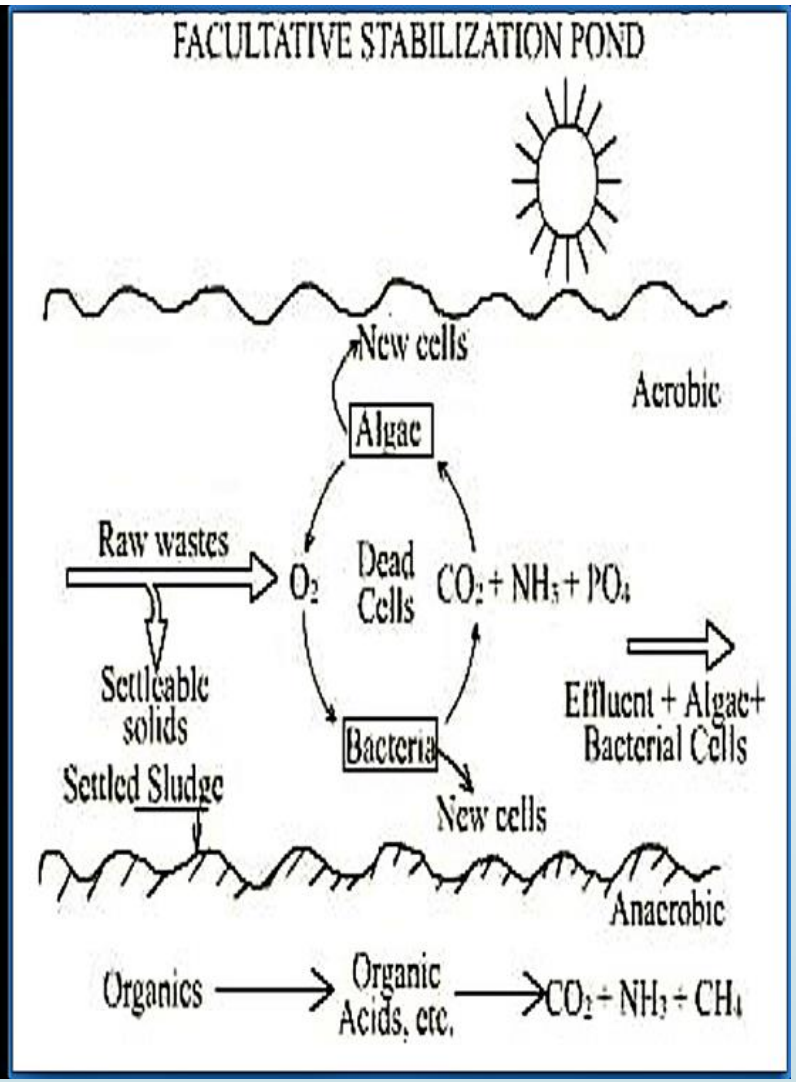


OXIDATION POND

- Oxidation ponds are large, shallow ponds designed to treat waste water through the interaction of sunlight, bacteria and algae.
- Algae grow within the pond and utilize sunlight to produce oxygen during photosynthesis.
- This O2 is used by the aerobic bacteria in the oxidation pond to breakdown the organic waste in the wastewater.
- The broken down solids settle down in the ponds, resulting in effluent that is relatively well treated.

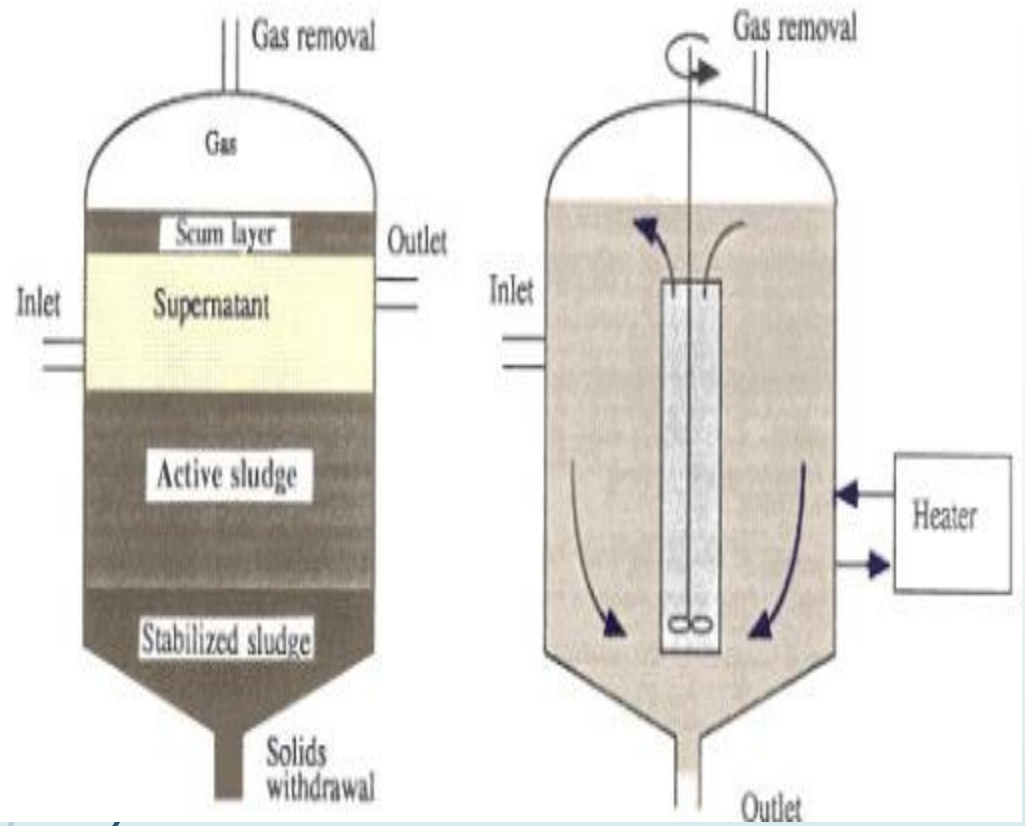



Methane, ammonia
Algal growth
Inorganic nutrients
Photic zone
Dead algae
Organic wastes
Aerobic heterotrophic zone
Anaerobic zone


FACULTATIVE STABILIZATION POND
New cells
Aerobic
Algae
Raw wastes
O_2
Dead Cells
$CO_2 + NH_3 + PO_4$
Settleable solids
Effluent + Algae+ Bacterial Cells
Bacteria
Settled Sludge
New cells
Anaerobic
Organics
Organic Acids, etc.
$CO_2 + NH_3 + CH_4$

Continued…

- Stabilization ponds are the preferred wastewater treatment process in developing countries due to low cost, low maintenance. This is balanced by larger land requirement.



Anaerobic Digesters

- The sludge from aerobic sewage treatment together with the materials settled down in primary treatment are further treated in anaerobic digesters through the process of anaerobic digestion.
- These digesters are used only for processing of settled sewage sludge and the treatment of very high BOD industrial effluents.
- Anaerobic digesters are large fermentation tanks designed to operate anaerobically with continuous supply of untreated sludge and removal of final stabilized sludge product.
- The tanks have provisions for mechanical mixing, heating, gas collection, sludge addition and removal of final stabilized sludge.

Anaerobic digestion involves the following 3 steps

1. **Fermentation-** The fermentation of sludge components to form organic acids from organic polymers is done by a number of bacteria such as *Bacteroides, Clostridium, Lactobacillus* etc. The organic acids formed are butyrate, propionate, lactate, succinate, acetate along with ethanol and H_2 and CO_2.

2. **Acetogenic reactions-** The products produced during fermentation are utilized as substrate by several acetogenic bacteria like *Syntrophomonas*, *Syntrophobacter* and *Acetobacterium*. The products produced as a result of acetogenic reactions are acetate, H_2 and CO_2.

3. **Methanogenesis**- The products produced during acetogenesis are utilized as substrate by methanogenic bacteria. Acetate is used to produced CH_4 $+CO_2$ by *Methanosarcina*. H_2 and HCO_3^- are used to produce methane by several bacteria like *Methanobacterium, Methanococcus*.

The final product of anaerobic digestion is a mixture of gases (70% methane. 30% CO_2), microbial biomass and nonbiodegradable residues (heavy metals, polychlorinated biphenyls, etc.)

Tertiary Treatment

- Removal of residual suspended solids (after secondary treatment),usually by granular medium filtration or micro screens
- Disinfection is also typically a part of tertiary treatment. Nutrient removal is often included in this definition

Tertiary treatment consists of following processes and units

- Membrane Filtration and Separation
- Dechlorination and Disinfection Systems
- Reverse Osmosis (RO) Systems
- Ion Exchange
- Activated Carbon Adsorption
- Physical/Chemical Treatment

- Tertiary treatment is aimed to remove non-biodegradable organic materials, heavy metals and minerals
- The salts of nitrogen and phosphorous must be removed because they cause eutrophication.
- By using activated carbon the organic pollutants can be removed.
- By adding lime phosphorus can be precipitated as calcium phosphate.

- Disinfection is done by chlorination.

Chlorine is added to water either from a concentrated solution of sodium hypochlorite or calcium hypochlorite or as a gas from pressurized tanks.

$Cl_2 + H_2O \longrightarrow HOCl + HCl$

$HOCl + NH_3 \longrightarrow NH_2Cl + H_2O$

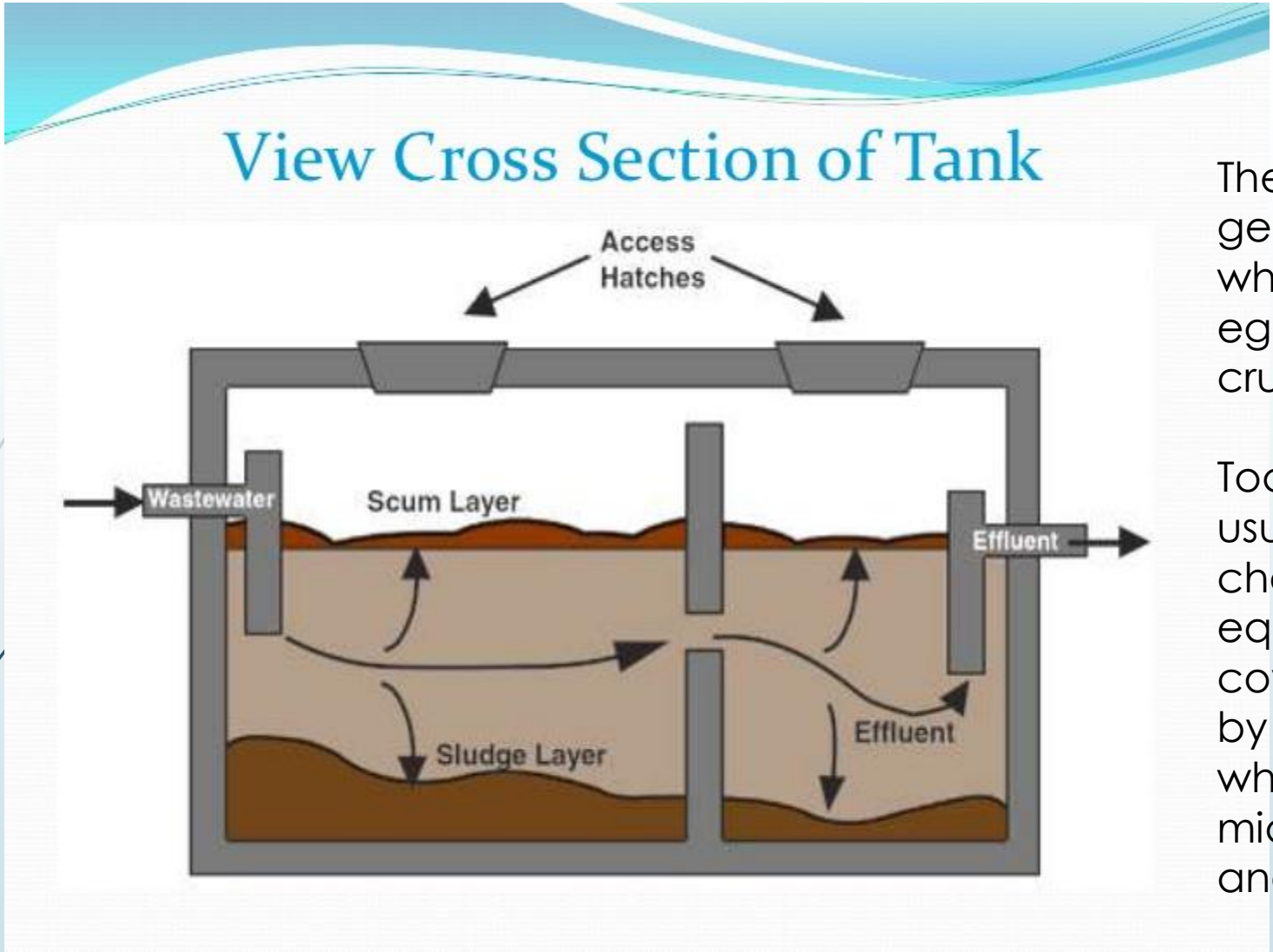
$HOCl \longrightarrow [O] + HCl$

Septic Tank

Working of Septic tank

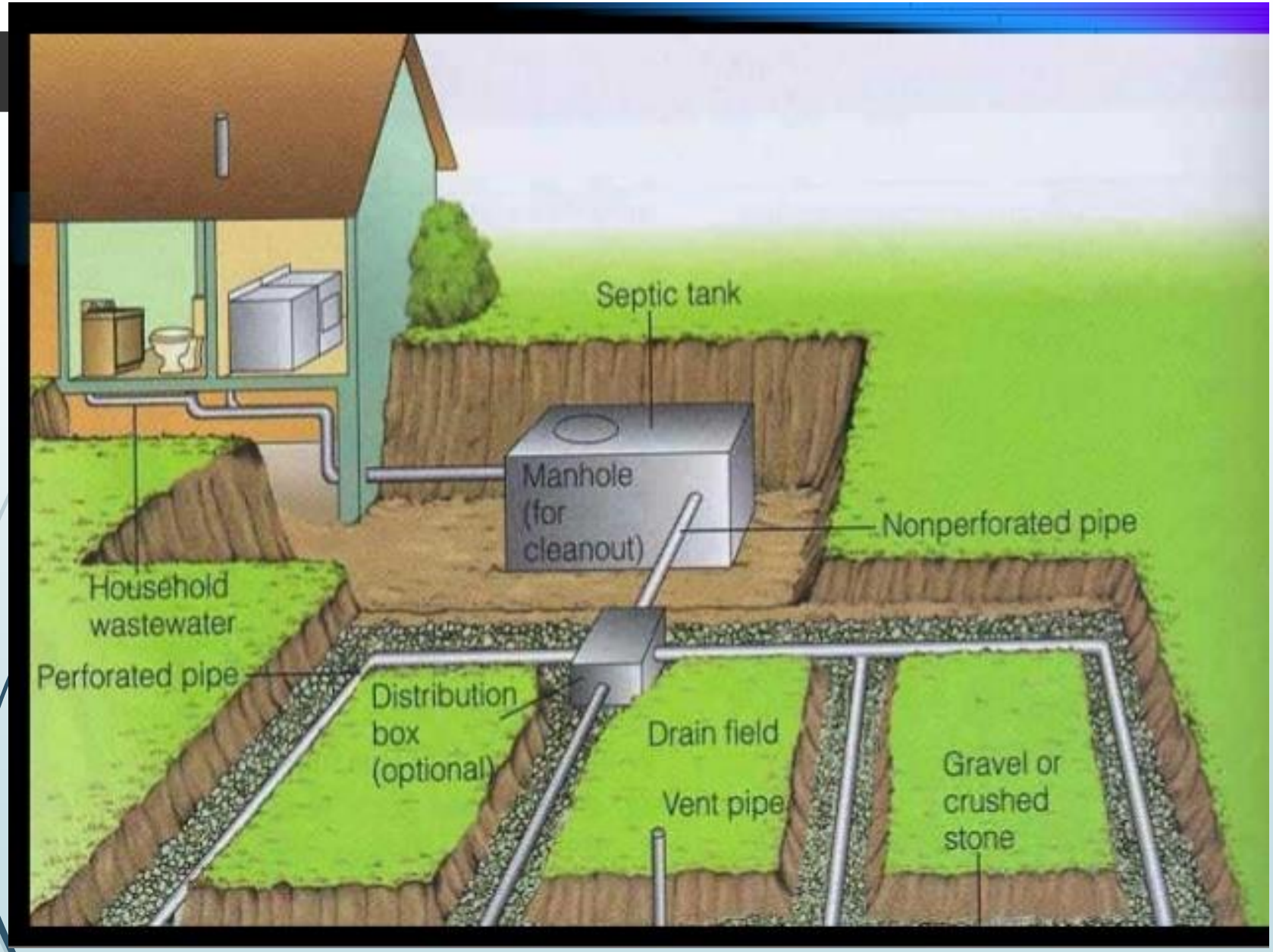
- Septic tank is sludge digestion cum sedimentation tank with large detention time.
- It is suitable for population up to 300.
- The septic tank is a buried, water-tight container usually made of concrete, brick masonry, fiberglass or polyethylene.
- Its job is to hold the wastewater long enough to allow solids to settle down to the bottom (forming sludge), while the oil and grease floats to the top (as scum).

- Compartments and a T-shaped outlet prevent the sludge and scum from leaving the tank and traveling into the drainfield area.
- The liquid wastewater (effluent) then exits the tank into the drainfield.
- Finally, the wastewater percolates into the soil, naturally removing harmful coliform bacteria, viruses, and nutrients.



The pipe connections are generally made via a **T pipe** which allows liquid entry and egress without disturbing any crust on the surface.

Today the design of the tank usually incorporates 2 chambers (each of which is equipped with a manhole cover) which are separated by means of a dividing wall which has openings about midway between the floor and roof of the tank



The waste water usually remains in the septic tank for just 24-72 h, after which it is channeled out to a drain field. This drain field or leach field is composed of small perforated pipes that are embedded in gravel below the surface of the soil.

- **Following reaction occurs:**
- **Organic materials +Nutrients = CH_4 + CO_2 +NH_3 + H_2S + Biomass**
- Sulfates, under the anaerobic conditions of septic tanks, are reduced to hydrogen sulfide (H_2S), a pungent and toxic gas.
- Nitrates and organic nitrogen compounds are reduced to ammonia (NH_3).
- Because of the anaerobic conditions, fermentation processes take place, which ultimately generate carbon dioxide and methane.
- Methane, a potent greenhouse gas. Waste water also contain phosphate

Advantages

1. Ease in construction.
2. No maintenance problem(except periodical cleaning).
3. Cost of construction is less.
4. Effluent can be discharged without any trouble.
5. It is suitable for isolated community.
6. Very little attention and skilled attendance is needed.

Disadvantages

1. If ST is not properly functioning, effluent will be very foul & dark.
2. Leakage of gases from top cover of ST may cause bed smells & environmental pollution.
3. Periodical cleaning, removal and disposal of sludge remains a tedious problem.
4. Unpredictable functioning.
5. Size required is large for larger communities.
6. Effluent contains high BOD.
7. Problem of mosquito nuisance.
8. Problem of ground water contamination

In general it is rare for a septic tank system to require emptying more than once a year and by careful management many users can reduce emptying to every 3 to 5 years. When emptying a tank, only a small residue of sludge should be left in the tank. Anaerobic decomposition is rapidly re-started when the tank re-fills