Water Pollution

Definition

- Water pollution means undesirable changes in physical, chemical or biological properties of water that makes it unfit for use by human and other living beings.
- There are certain symptoms of water pollution: changed colour, offensive smell, bad taste, unchecked growth of aquatic weeds, oily material floating on surface, and death of fish and other aquatic organisms.

Important Facts on Water pollution

- Only about 3% surface water is fresh water
- One fifth of the world's population lacks the access of clean water
- Over 2.6 billion people do not have adequate toilets.
- More than 2 million children are killed by diarrheal diseases each year
- Demand of water will double in next 30 years

Causes of Water Pollution

Water is uniquely vulnerable to pollution. Known as a "universal solvent," water is able to dissolve more substances than any other liquid on earth. That's why water is so easily polluted. Toxic substances from farms, towns, and factories readily dissolve into and mix with it, causing water pollution.

Water pollutants: Types

Water pollutants have been classified into following categories:

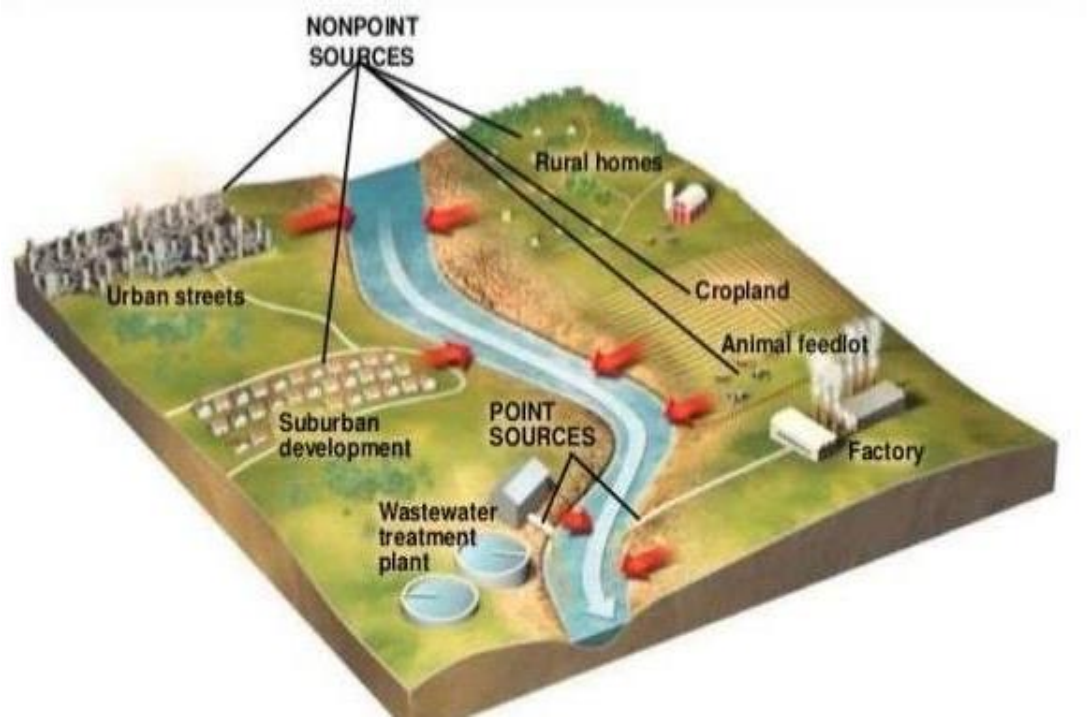
- **Organic pollutants:** Majority of them are derivatives of living beings while some compounds are synthetic. They include (a) Natural organic pollutants, (b) Sewage and industrial effluents, (c) Synthetic organic chemicals (SOCs), (d) Microbiological pollutants, and (e) Oils.
- **Inorganic pollutants:** These include variety of inorganic chemicals like mineral acids, bases, salts, metals, heavy metals etc. They come from natural sources (rocks) as well as manmade sources (industries).
- **Radioactive pollutants:** These include different radioactive substances which are released into water from natural sources (rocks) as well as manmade sources (nuclear waste, weapons etc.).
- **Suspended solids and sediments:** These include insoluble impurities like soil, sand and other solid particles which either remain as suspension in water or form sediments. Sources

include soil erosion (by agriculture, mining, construction), sewage and other effluents.

- **Heat or thermal pollution:** Heated water from thermal power plants and industries is often discharged in water bodies. This increases temperature of water and decreases dissolved oxygen.

Sources of water pollution

- Major sources of water pollution include: Nature (death and decay of plants and animals), soil erosion, agricultural run-off, mining (acid mine drainage), municipal sewage, industrial effluents, accidental spillage etc.
- There are two types of sources of water pollution:
  - **Point sources:** Sources whose location can be identified as single point. e.g., sewage and industrial effluent
  - **Non-point or diffused or area sources:** Sources that are scattered over a large area or that cannot be identified as single point. e.g., run-off from agricultural land, forests, construction etc



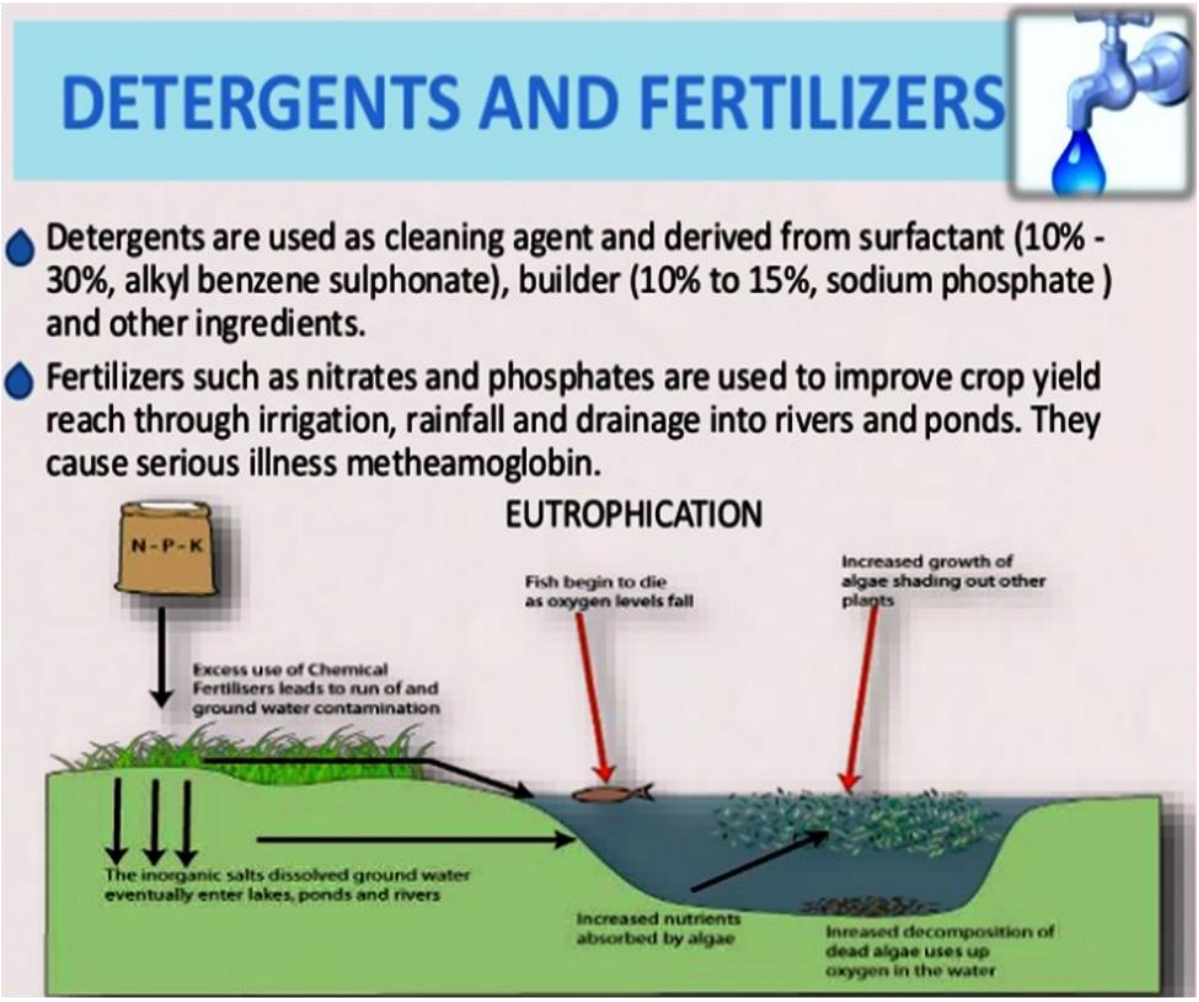
Effects of water pollution

Water pollution has following types of adverse effects on properties of water:

- **Physical effects:** It includes increased temperature, depletion of dissolved oxygen (DO), increased turbidity, altered colour, oily surface etc. This results in reduced photosynthesis and loss of aquatic life.
- **Oxidation effects:** It includes biological and chemical oxidation. As a result of this

different impurities get oxidized (e.g., sulphides into sulphate, ammonia into nitrite and nitrates) at the cost of dissolved oxygen.

- **Toxic chemical effects:** This includes poisonous effects of different compounds which results into fatal diseases or deaths of living beings. e.g., toxic metals like cadmium, mercury, chromium cause damage to liver, kidney and brain. Similarly pesticides, acids, dioxins cause damage.
- **Micro-organism effects:** Different micro-organisms (e.g., bacteria, virus) found in dirty water cause a number of water borne diseases e.g., cholera, typhoid, hepatitis, dysentery etc.
- **Nutrient effects and Eutrophication:** Agricultural run-off brings lots of nutrients (nitrates and phosphates) to water bodies. This results into excessive growth of water weeds (chiefly algae) all over the surface and death of underlying organisms due to oxygen shortage. Finally the aquatic ecosystem collapse (destroyed). This is called Eutrophication.



Algal bloom

Industrial Wastes and Effluents

- Industrial wastes and their effluents include poisonous materials like acids, alkalis, salts, phenols, cyanides, zinc, insecticides which make water toxic and deoxygenated and eventually do not support aquatic life.
- Mercury causes Minamata disease
- Oils reduce rate of oxygen uptake by water, retards light intensity by 90%
- Arsenic causes black foot disease; asbestos causes asbestosis, Beryllium causes Berylliosis and Cadmium causes Itai-Itai disease.

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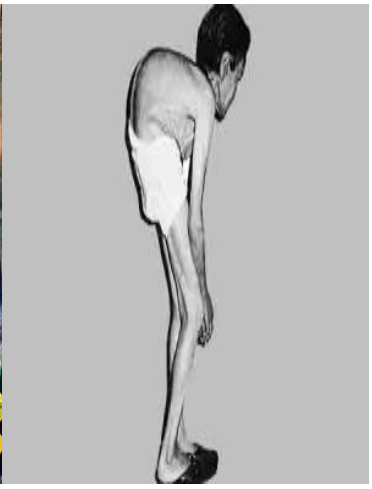
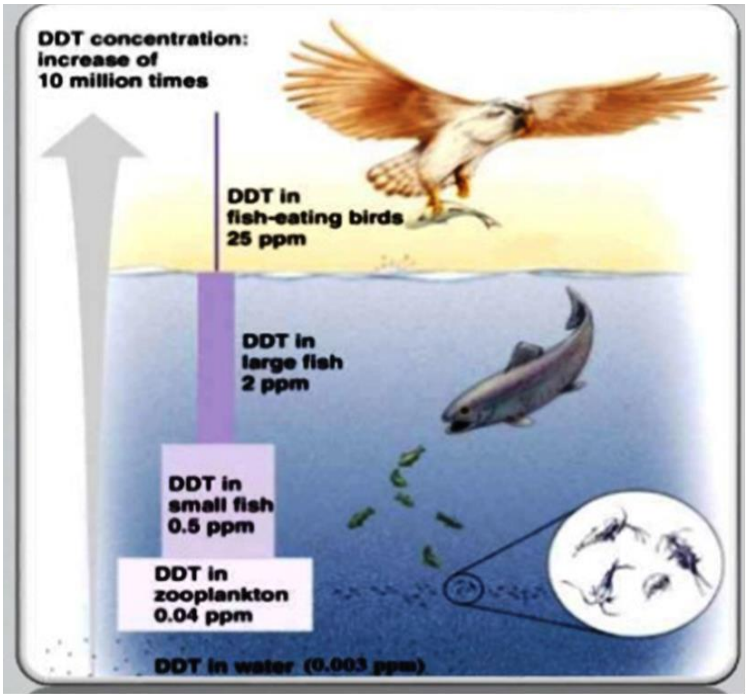


Minamata disease **Blackfoot disease** **Itai-Itai disease**

Insecticides and Pesticides



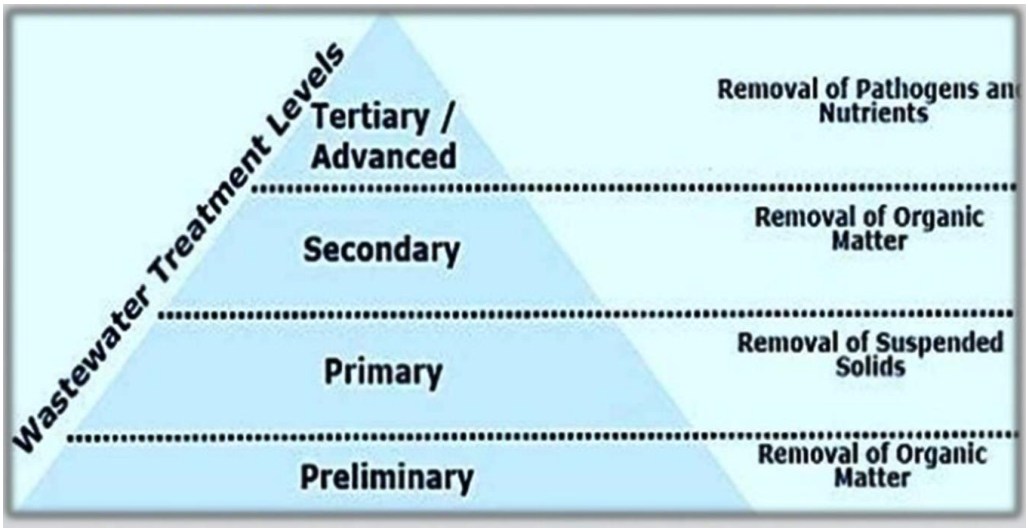
- These are biologically active chemicals used for pest control. They include DDT (Dichloro Diphenyl Trichloroethane), aldrin etc.
- Increased accumulation of these substances in food chain at high trophic level is called **biological magnification**.

Control measures and prevention of water pollution

- Following strategies are adopted for controlling water pollution:
  - Two approaches are used: **input control** and **output control**. Input control means 'reducing generation of pollutants' while output control means 'controlling pollutants after being produced'.
  - Output control further involves two strategies: volume reduction and strength reduction. Volume reduction means reducing total volume of pollutant while strength reduction means reducing harmful effects of pollutants.
  - Both, volume and strength of the polluted water can be reduced by different types of water treatment plants (WTP). This includes **Sewage Treatment Plants (STP)** and **Effluent Treatment Plants (ETP).**
  - In these treatment plants, pollutants are removed through sequential steps that include: **Primary treatment**, **Secondary treatment** and **Tertiary treatment.**
  - In **Primary treatment** bigger impurities are removed using physical processes (sedimentation, filtering, decanting).
  - In **Secondary treatment** organic compound are oxidized by biological oxidation (in presence of bacteria).
  - In **Tertiary treatment**, the remaining impurities are oxidized by chemical oxidants and disinfection is done by UV-rays, ozone etc.

Waste water Treatment

Waste water treatment process can be conveniently classified as below:



Preliminary Treatment

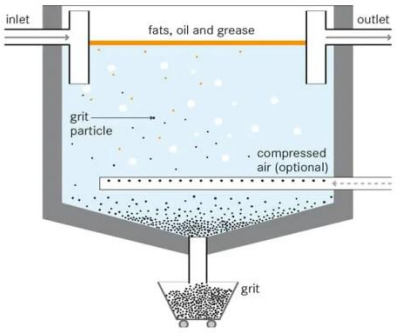
It involves the removal of floating material, settleable inorganic solids and greasy materials.

- **Screeners**- Device with opening and further classified as coarse (75-150mm), medium (20-70mm) and fine (< 20 mm)

- **Shredder**- Special device that cut and retain floating and suspended material
- **Grit Chambers**- Heavy inorganic material can be removed. Based on principle of sedimentation
- **Skimming Tank**- Greasy material can be removed using skimming tank which is divided into 3 compartments.

Screener

shredder



Grit Chamber

Skimming Tank

Primary Treatment

- It is aimed at removal of suspended organic solids that can not be removed in preliminary treatment. It involves the process of sedimentation
- Sedimentation is the separation from water by gravitational settling if suspended particles are heavier than water
- Sedimentation tank have inlet zone, settling zone, outlet zone and sludge zone
- Chemicals are added to aid sedimentation such as: alum, iron salts, lime etc.

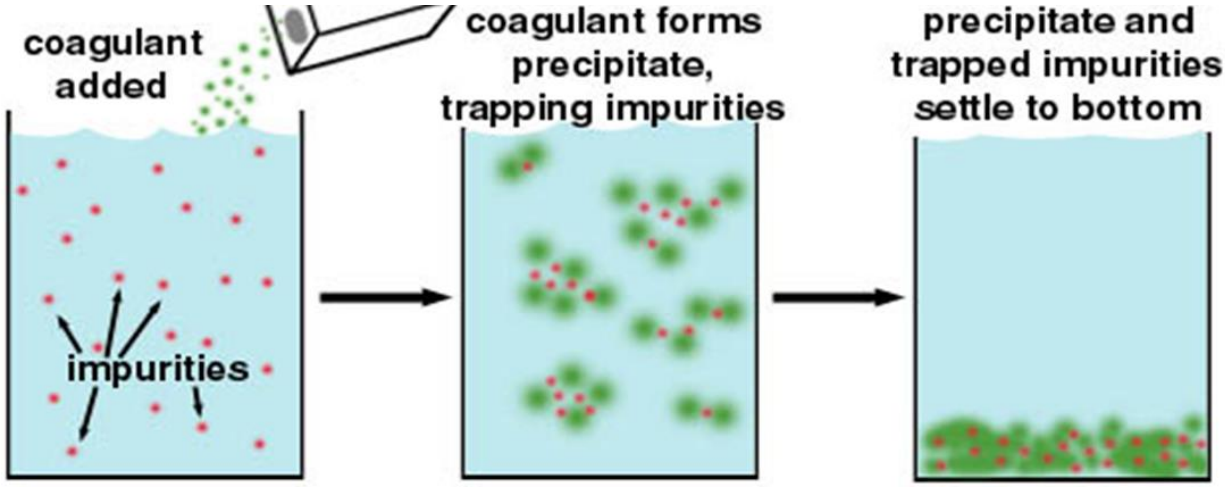
- **Coagulation**

- Coagulation is the process to remove dirt and other particles suspended in water. (Colloidal Particles)

- By addition of chemical coagulant there will be a ionic later compression followed by electric charged neutralization, which promotes aggregates formation among the colloidal particles and settle down to the bottom of the sedimentation tank.

- The combined weight of the dirt and the coagulant become heavy enough to sink to the bottom during sedimentation process.

- Commonly available / used coagulants are Alum (Aluminium Sulphate) , Ferrous Sulphate and Ferric Chloride.

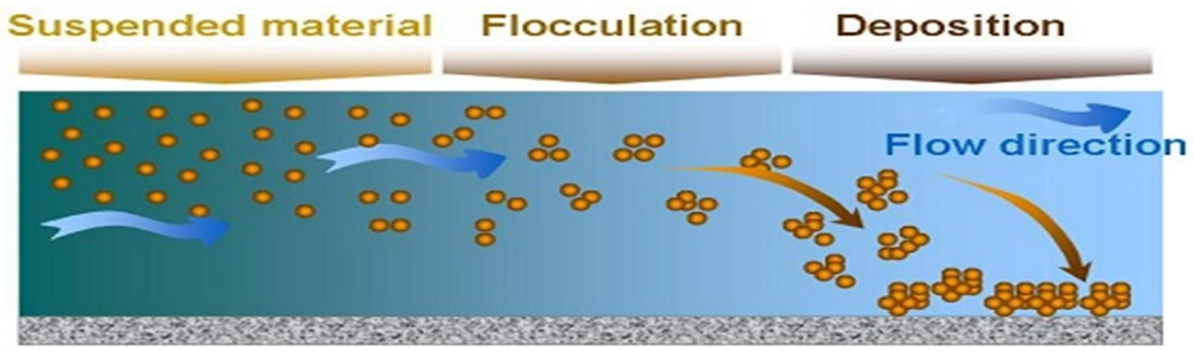
- 

- **Flocculation**

The process by which fine particulates are caused to clump together into "Floc".

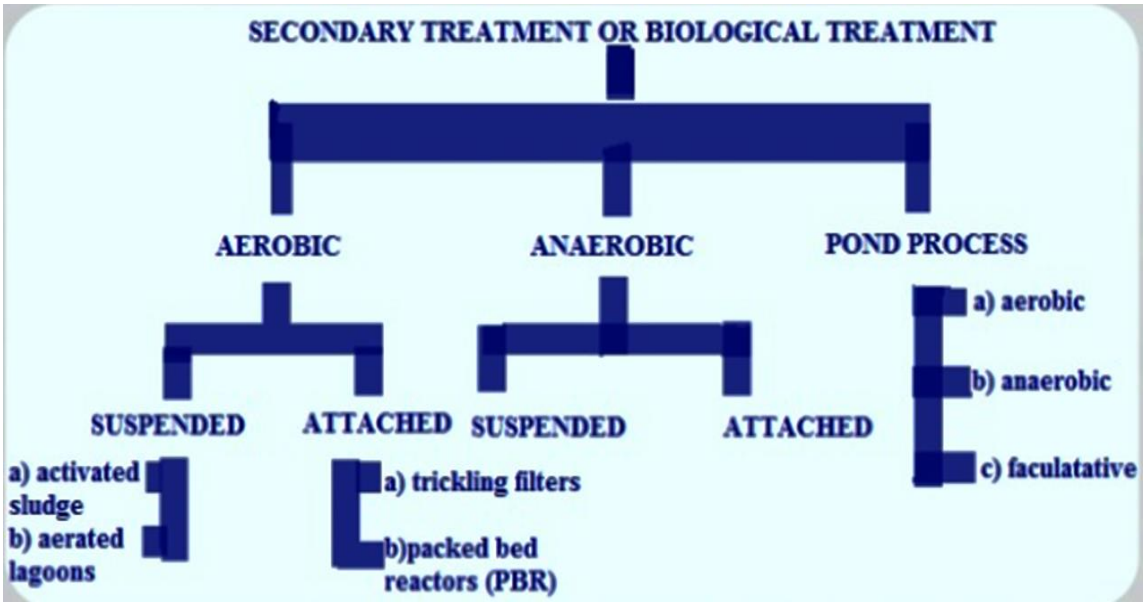
The Floc may then float to the top of the liquid, settle to the bottom of the liquid, or can be readily filtered from the liquid.

Commonly used Flocculants are polyphosphates, lignosulfonates, polyelectrolyte and various water-soluble synthetic polymers.



Secondary/Biological Treatment

- It is required to remove dissolved and fine colloidal organic matter. This process involves the use of microorganisms that decompose the unstable organic matter to stable inorganic forms.



Secondary treatment/ Activated Sludge Process (ASP)/ Biological treatment

- Highly active aerobic bacteria added to the aeration tank.
- Oxygen supplied to the bacteria through surface aerator .
- After primary treatment water enter to aeration tank, where microorganisms are already present.
- In presence of oxygen and organic matter the bacteria oxidized the organic waste and started growing very fast by utilizing the organic matter present in wastewater.
- After 5 to 10 days the whole aeration tank will be full of bacterial floc, which are floating on the surface of the tank.

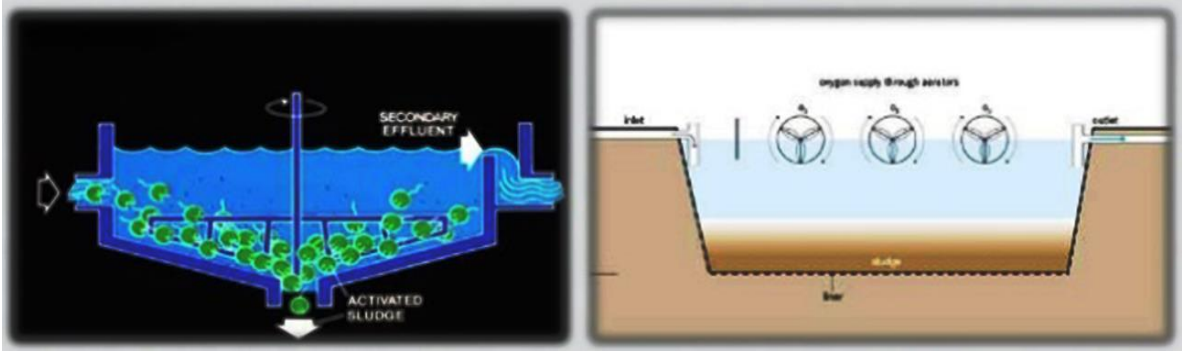
- Then the water pass to the secondary clarifier, where the floating bacterial cell settle down to the bottom of tank, which is called Activated Sludge.
- A portion of the activated sludge is recycled to the aeration tank for next batch of wastewater treatment, which is called Returned Activated Sludge (RAS) or recycled activated sludge.

Aerobic Suspended growth Treatment Process

- **Activated sludge process:** The sewage containing organic matter with microorganism is aerated in an aeration tank.
  Advantage: Cost-effective, sludge has higher fertilizer value

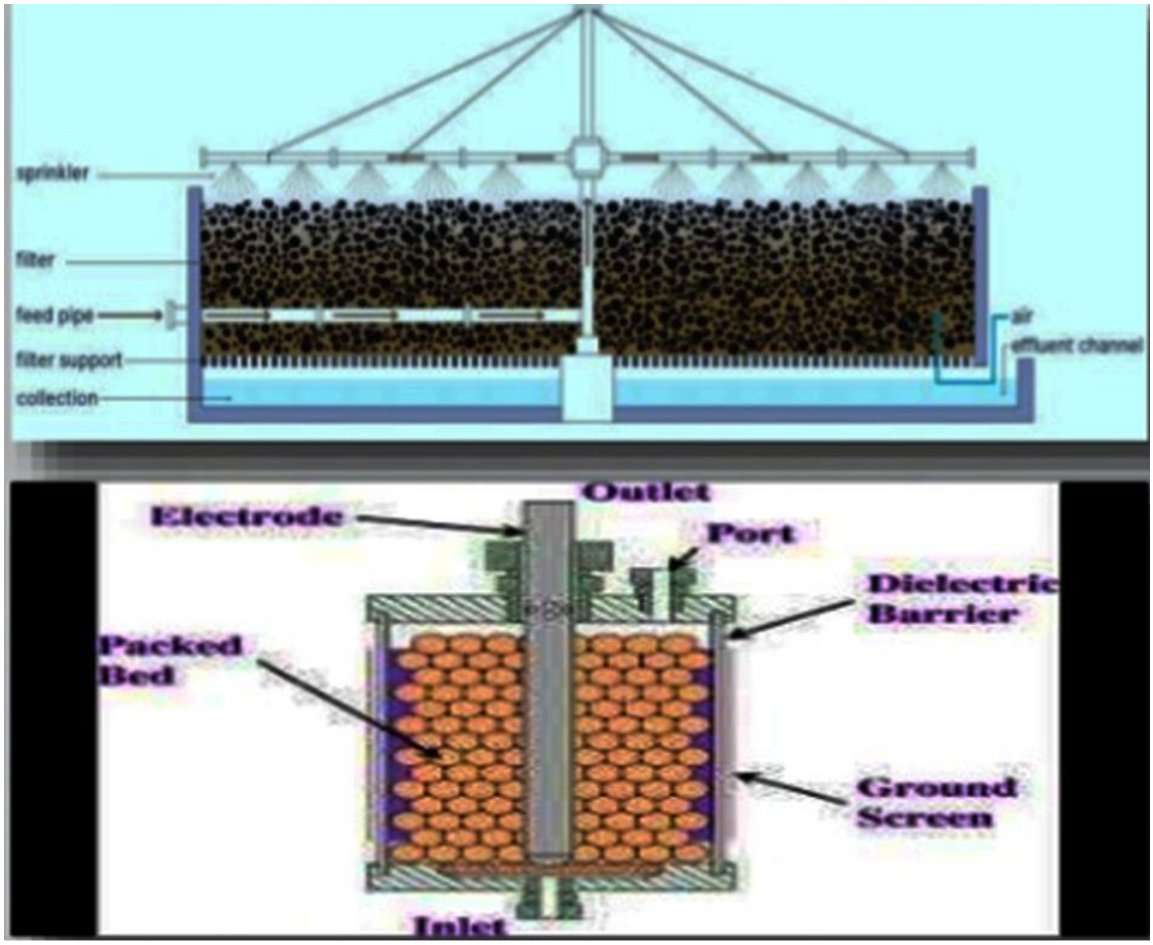
$$\text{Organic Matter} + O_2 \longrightarrow CO_2 + NH_3 + H_2O + \text{New Cells}$$

- **Aerated Lagoon:** They are also known as aerated ponds, are the facultative stabilization ponds where in surface aerators are installed to overcome bad odors.



Aerobic Attached Growth Treatment Process

- **Trickling Filters:** It has a bed of coarse, hard, porous material over which sewage is percolated or trickled and microorganisms attached to medium degrade the organic matter.
- **Packed bed reactors:** A reactor is packed with a medium to which microorganism get attached and form biofilms.

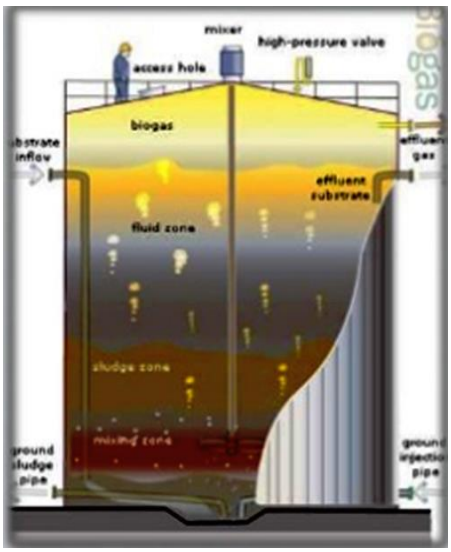


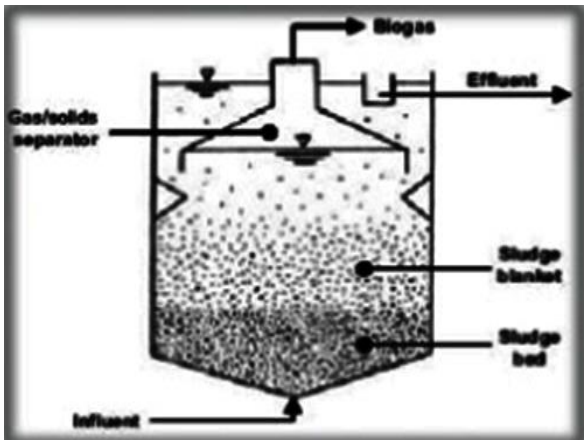
Anaerobic Suspended Growth Treatment Process

- **Anaerobic Digestion:** Process is carried out in a air tight reactor. It involves three stages namely: hydrolysis, acidogenesis (clostridium sp., cornylbacterium), methanogeneis (methanococci, methanobacillus)

Anaerobic Attached Growth Treatment Process

- **Anaerobic Filter Process:** Consist of column fitted with solid media for treatment of organic matter in sewage. Solid media bacterium is retained in the column.





Tertiary Treatment

Only 1-2% domestic sewage receives tertiary treatment which is the most advance phase of sewage treatment. The tertiary treatment is needed under the following circumstances

- When the quality of effluent to be discharged does not meet the standard requirement
- When there is necessary to remove dissolved solids by Ion Exchangers
- To remove nitrogen and phosphorus
- To remove pathogenic organisms through disinfection

Disinfection

- The removal of pathogenic microorganisms from water is called disinfection.

Types of disinfection:

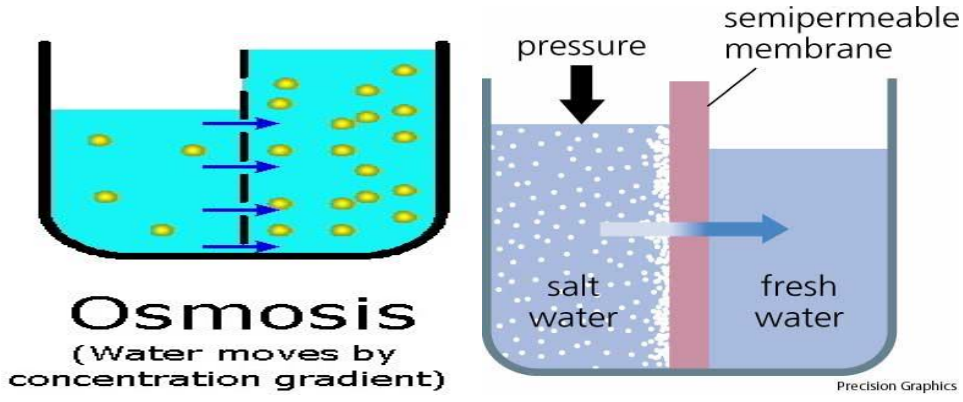
- Chlorination
- Ozonization
- Bleaching powder
- UV radiation
- Chlorination is the most popular method of water treatment process.

Advanced treatment

- Fluoridation
- De-fluoridation

- Reverse osmosis
- Ion exchange
- **Fluoridation** is the addition of fluoride to water to bring the range from **1.0 mg/l to 1.5 mg/ l ,**within the drinking water limit. The used for increase fluoride in water are, sodium fluoride, sodium silico-fluoride and hydro fluro-silicic acid.
- **De-fluoridation** is the removal of excess of fluoride (> 1.5 mg /l) from water, which can be achieved by addition of lime to water. Fluoride will be precipitated as calcium fluoride(CaF2) and settle at the bottom of tank.
- Fluoride deficiency causes dental caries
- Excess fluoride causes dental fluorosis

Reverse osmosis (De-salinisation)

- The removal of unwanted salt from water.
- Osmosis= The movement of solvent from lower to higher concentration through a semi-permeable membrane when the osmotic pressure greater than normal pressure.(P0 > P)
- Reverse osmosis= The movement of solvent from higher to lower concentration through a semi-permeable membrane when the exerted pressure is greater than osmotic pressure.(P >P0)
- 

Ion-exchange:

- Removal of hardness of water.
- Sodium ion can be exchanged with Calcium and magnesium ion.

- $Mg^{2+} + Na_2R \leftrightarrow MgR + 2Na^+$
- $Ca^{2+} + Na_2R \leftrightarrow CaR + 2Na^+$
- Sodium resin available in market added to hard water, the resin free the sodium ion in water and picked up the calcium and magnesium ion and settle to the bottom of tank.
- **Sodium does not contribute to the hardness**.
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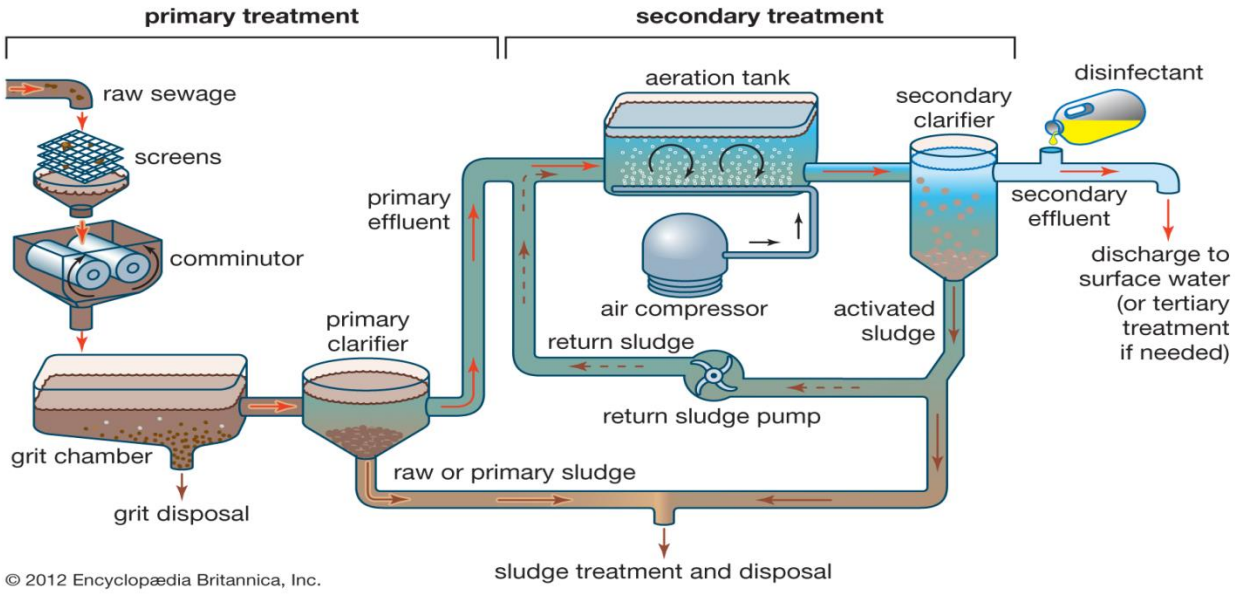
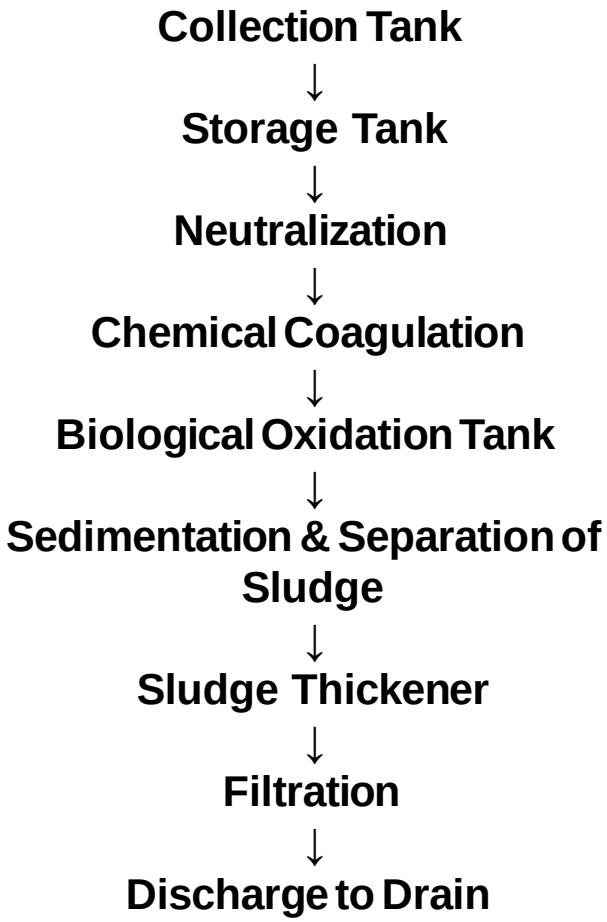
Water Treatment Processes Summary



Process Flow Chart of Effluent Treatment Plant (ETP)

Industries generate huge amount of liquid waste and industrial effluents. Before releasing these liquids to outwards, the plant which treats this effluent to a harmless form for the environment is known as **Effluent Treatment Plant (ETP)**.



The details of all process are described below:

Collection Tank: Commencing part, wastes from different section enter here.
Storage Tank: Wastewater from the collection tank is properly mixed here using blower pipes.
Neutralization: pH is controlled here.
Chemical Coagulation: Chemical coagulants such as $Fe_2(SO_4)_3$ (Iron sulfate), $Al_2(SO_4)_3$ (Aluminum sulfate) etc. are used for coagulation.
Biological Oxidation Tank: The treatment of wastewater by microorganisms such as algae, fungi, or bacteria under aerobic or anaerobic conditions during which organic matter in wastewater is oxidized or incorporated into cells. Blowing air during the process helps the growth and efficacy of wastewater treatment using microorganisms.

Sedimentation & Separation of Sludge: The sedimentation process allows suspended particles to settle out after the biological oxidation process. A layer of accumulated solids, called **sludge**, forms at the bottom of the tank and is periodically removed.
Sludge Thickener: After exceeding the required level of recycling, sludge passed through thickening chamber. Thickening of sludge increases its solids content and reduces the volume of free water thereby minimizing the unit load on downstream processes such as digestion and

dewatering. The most commonly used thickening processes include gravity thickening, dissolved air flotation, and rotary drum thickening.

Filtration: Filtration layer consists of sand and rock bed that filters the remaining sludge from the treated water after the sedimentation process.

Discharge to Drain: Release of the treated wastewater to environment with the check of final load of effluent in it.

Besides it, there are certain common measures to control pollution like:

- Domestic and industrial waste waters should be discharged into rivers only after proper treatment through sewage treatment plants (STPs) and ETPs.
- Solid wastes must not be mixed with liquid wastes and should not be thrown into to water bodies. They should be separately managed.
- Sources of drinking water should be protected from pollution. Polluting activities (e.g., industrial use, discharging effluents, bathing, washing, cattle rearing etc.) must be avoided in vicinity of source of drinking water.
- Water bodies should be regularly cleaned of aquatic weeds, plants and other crude impurities like polythene, metals, garbage etc. Special breeds of fish, which feed on mosquito eggs and bacteria, can be cultured in water bodies.
- Afforestation must be done for reducing soil erosion and improving local soil hydrology. Use of agrochemicals need to be minimized.
- Public awareness regarding water pollution and its control measures should be created.

- Q No 1. Calculate the wastewater flow and characteristics (BOD loading) for a population of 75,000 in a city. Per capita consumption of water is 135L / day

Assume

i. Wastewater generation is 80% = 135 X 0.8= 108 lit/capita/day

ii. BOD loading is 50 gm/capita/Day

➢ Total wastewater generation/ day = 75,000 x 108 L/day= **1.35×10^7 l/day**

$$\text{BOD loading in mg/L} = \frac{\text{Total BOD loading mg/day}}{\text{Total wastewater generation l/day}}$$

$$= \frac{75{,}000 \times 50 \times 1000 \text{ mg/day}}{75000 \times 108 \text{ l/day}} = \mathbf{463 \text{ mg/l}}$$

Q No 2. Calculate the population equivalent of a city, given average sewage generation is 95000 x 10^3 l / day and average BOD_5 as 300 mg/l, assume BOD loading 50gm/capita/ l.

Sol : Sewage flow = 95000 X 10^3 l/ day, BOD loading 300 mg /l

Total BOD/day = 95,000 x 1000 x 300 mg/lit

BOD loading = 50,000mg/l

- Population = $\frac{95{,}000 \text{ x } 1000 \text{ x } 300 \text{ mg/l}}{50{,}000 \text{ mg/l}}$ = **57,000**