

MODULE 4**Environmental Pollution and Water Chemistry**

Environmental Pollution: Air pollutants: Sources, effects and control of primary air pollutants: Carbon monoxide, Oxides of nitrogen and sulphur, hydrocarbons, Particulate matter, Carbon monoxide, Mercury and Lead. Secondary air pollutant: Ozone, Ozone depletion.

Waste Management: Solid waste, e-waste & biomedical waste: Sources, characteristics & disposal methods (Scientific land filling, composting, recycling and reuse).

Water Chemistry: Introduction, sources and impurities of water; boiler feed water, boiler troubles with disadvantages -scale and sludge formation, boiler corrosion (due to dissolved O₂, CO₂ and MgCl₂). Sources of water pollution, Sewage, Definitions of Biological oxygen demand (BOD) and Chemical Oxygen Demand (COD), determination of COD, numerical problems on COD. Chemical analysis of water: Sulphates (gravimetry) and Fluorides (colorimetry). Sewage treatment: Primary, secondary (activated sludge) and tertiary methods. Softening of water by ion exchange process. Desalination of sea water by reverse osmosis.

(RBT Levels: L3)

Course outcome: Environmental pollution, waste management and water chemistry.

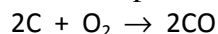
ENVIRONMENTAL POLLUTION**Air pollution**

Air pollution occurs due to the presence of harmful gases, dust, smoke which enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty. The main pollutants in the atmosphere are SO₂ (sulphur dioxide), CO (carbon monoxide), oxides of nitrogen, particulate matter, mercury, lead etc.,

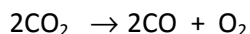
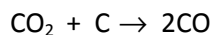
Primary air pollutant: Pollutants that are emitted directly from either natural events or from human activities are called primary air pollutant.

1. Carbon monoxide**Sources:**

- Oxidation of methane: Methane is formed during decay of vegetable matter. Oxidation of methane releases carbon monoxide into the atmosphere.
- Automobile exhaust- carbon monoxide is formed during the combustion of fuel such as petrol and is released into the atmosphere through the exhaust
- Incomplete combustion of fossil fuels: coal when undergoes incomplete oxidation, forms carbon monoxide and pollutes the atmosphere.



- Industries: carbon monoxide is released by industries such as iron and steel and petroleum .

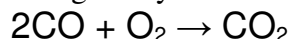


Ill effects:

- Haemoglobin in blood can form a complex with oxygen and hence functions as carrier of oxygen.
- When the atmosphere is polluted with carbon monoxide, on inhalation, CO combines with the hemoglobin to form carboxy haemoglobin and hence oxygen carrying capacity of the blood decreases.
- This causes, headache, dizziness, unconsciousness.
- When inhaled for a long duration it may cause even death.

Control:

- Using catalytic converter in automobiles.

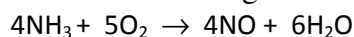
**2. Oxides of nitrogen**

Nitric oxide, nitrogen dioxide and nitrous oxide are the three main oxides of nitrogen found in the atmosphere

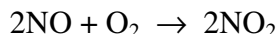
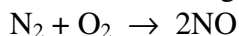
Sources:

The sources for the oxides of nitrogen are:

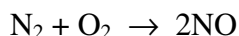
- Bacterial decomposition of nitrogenous compounds – bacteria in the soil act on the ammonium compounds present in the soil, convert them to ammonia and finally release oxides of nitrogen into the atmosphere.



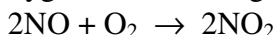
- Combustion during lightning – during lightning, oxygen and nitrogen in the atmosphere combine to give oxides of nitrogen.



- Industries and automobile exhaust - Air is sucked into the IC engines. At high temperatures, nitrogen and oxygen in the air combine to form nitric oxide.



Nitric oxide escapes through the exhaust. It gets cooled rapidly and combines with oxygen in the air to give nitrogen dioxide.

**Ill effects:**

Pollution due to oxides of nitrogen affects human and plant life:

The oxides of nitrogen combine with moisture in the atmosphere to form nitrous and nitric acid. This leads to increase in the acidity of rain water

Formation of photochemical smog: oxides of nitrogen combine with hydrocarbons present in the atmosphere forming peroxyacyl nitrate.

Peroxyacyl nitrate causes injury to plants and in human beings it causes fatigue and infection of the lungs

Peroxyacyl nitrate formation leads to smog (fog + smoke). Smog reduces visibility.

Fading of dyes is caused in textiles .

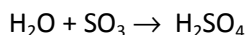
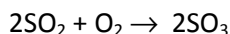
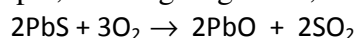
Control:

Using catalytic converter in automobiles. Catalytic converters use Pt/ Rh catalyst.
in the presence of the catalysts, the oxides of nitrogen are converted to nitrogen and oxygen .

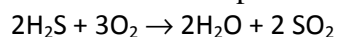
**3. Oxides of sulphur****Sources:**

- Combustion of fossil fuels – coal and crude oil contain up to 3% sulphur.
- roasting of ores – sulphide ores on roasting, are converted to sulphur trioxide. This, when let into the atmosphere, combines with the moisture in the atmosphere to form sulphuric acid.

for example, roasting of galena , the sulphide ore of lead



- oxidation of H_2S – Hydrogen sulphide is formed during the decay of plants. This, on oxidation releases sulphur dioxide into the atmosphere.



- Volcanic eruptions also emit sulphur dioxide.

Ill effects of SO_2 :

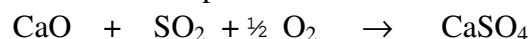
- Sulphur dioxide pollution in the atmosphere affects causes the following damages :
- In humans : it causes eye irritation, cough, lung diseases including lung cancer and asthma
- In plants: it causes damage of leaves, bleaching of chlorophyll which turns leaves brown, damage to crops and to growth of plants.
- Others: Yellowing of paper and wearing away of leather are other ill effects.

Control:

- The gases evolved during combustion of fossil fuels are passed through calcium carbonate when SO_2 is converted to calcium sulphite.



- lime is added to coal and roasted at high temperature so that CaO formed combines with SO_2 to form calcium sulphate.



4. Particulate matter

Particulate matters are solid or liquid suspensions in air. They are also called aerosols. These comprise of dust particles, ash, smoke, fumes and mist.

Sources:

- Volcanic eruptions.
- Soil erosion: wind blows away soil and the dust particles are introduced into the atmosphere.
- Industrial operations such as crushing of solid materials- solid materials are crushed, ground and powdered in industries. During these operations dust is released into the atmosphere.
- Burning of coal: The noncombustible matter in coal is left behind as ash during the combustion of coal.
- Incomplete combustion of compounds containing carbon, processing of coal, cement asbestos: These operations also release dust into the atmosphere.
- Mist – condensation of vapours, sprays etc lead to dispersion of liquids in the atmosphere thus forming mist.

Ill effects

- Presence of particulate matter in the atmosphere has the following effects:
- Decrease in visibility: Particulate matter interfere in the transmission of light and hence affect visibility.
- Particulate matters enter the lungs causing wheezing, bronchitis, and asthma in human beings.
- In plants the particulate matter settle on the leaves blocking the stomata thereby affecting the plant growth.

Control:

Reduce vehicle emissions and increase fuel efficiency:

- Diesel vehicles, including trucks, are a key source of fine particles. Reduce diesel emissions by replacing older engines with newer and cleaner engines
- Walk, cycle, take public transit and carpool whenever possible

Reduce the amount of particulate matter produced through smoke:

- Stop smoking; if you do smoke, do not smoke indoors
- Mulch garden refuse instead of burning it
- Limit the use of fireplaces and wood stoves. When using these appliances, make sure that wood is burned properly. Use wood that is well seasoned instead of wet or green. Stoves should also meet CSA (Canadian Standards Association) or EPA (Environmental Protection Agency) emission standards

- Switch to cleaner burning appliances. For example, pellet stoves produce less particulate matter than traditional wood stoves
- Take action to reduce wildfires. Practice safe backyard burning and careful use of campfire

5. Mercury pollutant

Sources:

Mercury occurs naturally in the earth's crust, but human activities, such as mining and fossil fuel combustion, have led to widespread global mercury pollution. Mercury emitted into the air eventually settles into water or onto land where it can be washed into water.

Effects:

- Health effects: Deteriorates nervous system, imparts hearing, speech and vision, causes involuntary muscle movements and corrodes skin and membrane.
- Environment effects: Animals that eat fish contaminated with mercury are affected the same way as humans. When pH values are between 5 and 7 the mercury concentration of mercury in the water will increase due to mobilization of mercury in the ground. Once mercury has reached surface water or soils micro organisms can convert it to methyl mercury, a substance that can be absorbed quickly by most organisms and known to cause nerve damage.
- Control:

6. Lead pollutant

Sources:

- The exhaust from automobiles which use lead tetraethyl as antiknocking agent-
- when TEL is used as antiknocking agent, lead is converted to halide and released into the atmosphere. This leads to increase in the concentration of lead in the atmosphere.
- Paint pigments : Litharge and red lead (oxides of lead) and lead chromate are used as pigments. These cause lead pollution
- Plumbing systems- lead pipes are used for plumbing and these may cause lead pollution

Ill effects:

- Lead competes with calcium and enters the blood and bone marrow.
- The lead interferes in the manufacture of red blood corpuscles and abnormal multiplication of blood cells and thus leads to anaemia and blood cancer in human beings.
- Lead enters the blood and various organs of the body including the brain and the Kidneys leading to dysfunction of the kidney and damage to the brain.

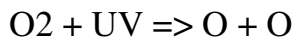
Control:

Lead smelting plants should their storage piles in such a way that the movements of lead materials are minimized to lessen exposure to wind and air.

Fixed conveyors rail cars and rail dampers in all transfer points should be enclosed using dry type dust collecting materials and design.

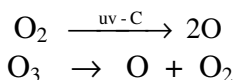
Secondary pollutant: A **secondary pollutant** is not directly emitted as such, but forms when other pollutants (primary pollutants) react in the atmosphere.

Ozone: Ozone is a gas found in the atmosphere consisting of three oxygen atoms: O₃. Ozone is formed in the atmosphere when energetic ultraviolet (UV) radiation dissociates molecules of oxygen, O₂, into separate oxygen atoms. Free oxygen atoms can recombine to form oxygen molecules but if a free oxygen atom collides with an oxygen molecule forms ozone. Ozone molecules can also be decomposed by ultraviolet radiation into a free atom and an oxygen molecule. Ozone is thus continuously created and destroyed in the atmosphere by UV radiation coming from the sun. This highly energetic UV radiation is called UVC (wavelength 280 nm) and is very harmful for human health.

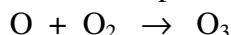


Ozone depletion

Formation of ozone in the atmosphere: Ozone absorbs uv radiations and is broken into atomic and molecular oxygen.



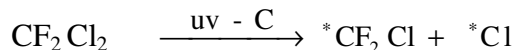
The products formed combine again to form ozone and hence a dynamic equilibrium is set up due to which the concentration of ozone in the atmosphere remains constant.



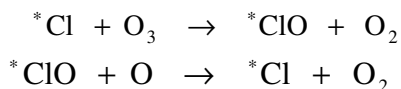
The ozone layer protects the earth from the harmful uv radiations. If the concentration of ozone is reduced (ozone depletion), the concentration of uv radiations reaching the earth increases. This leads to irritation of the eyes, skin cancer and damage to immune system in human beings. In agriculture it causes decrease in productivity.

Causes of ozone depletion

Chlorofluorocarbons (CFCs) are used as refrigerants, aerosols and as industrial solvents. CFCs are noncombustible and volatile. They reach the atmosphere and are broken down into chlorine free radicals by uv radiations.



The chlorine free radical brings about the degradation of ozone



Thus CFCs reduce the concentration of ozone in the atmosphere causing ozone hole.

Ill effects

- Due to ozone hole, the uv radiation increases causing eye infections, skin cancer in human beings and decrease in photosynthesis in plants.
- The temperature on the earth's surface is raised and this leads to global warming.

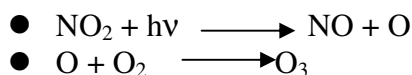
Control of ozone depletion:

Ozone depletion can be controlled by using alkanes that immobilize the chlorine atoms of CFC's by forming halo alkanes with them.

Using hydrogen containing CFC's which are destroyed in the troposphere itself and not taken to stratosphere for ozone depletion.

Photochemical Smog:

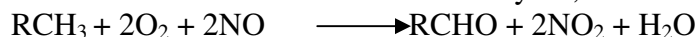
Photochemical smog is when photons of sunlight hit molecules of different kinds of pollutants in the atmosphere. It is a mixture of pollutants that are formed when nitrogen oxides and volatile organic compounds (VOCs) react to sunlight, creating a brown haze above cities. It tends to occur more often in summer, because that is when we have the most sunlight.

Mechanism of Photochemical smog:**1. Troposphere Ozone:**

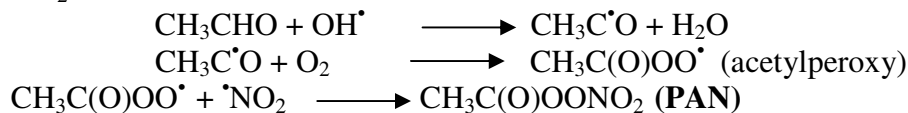
Sources: Exhaust gases From Motor vehicles and Unburnt Hydrocarbons

2. Volatile Organic Compounds (VOC)

Carbon-based molecules such as Aldehydes, Ketones and Hydrocarbons



Sources: Paint thinners, solvents and petroleum constituents, Trees: emits isoprene and terpenes And methane from termites, cows and cultivation

3. Peroxy acetyl Nitrates (PAN): Are secondary pollutants formed from peroxyacid radicals and NO_2 **Effects on human health:**

- Headaches, Eyes, nose, chest and throat irritations, Birth defects and low weight birth, impaired lung function, Coughing and wheezing, Limits visibility, Decreases UV radiation, Yellow/black color over cities, Causes respiratory problems and bronchial related deaths.
- Smog inhibits the growth of plants and can lead to extensive damage to crops, trees and vegetation. When crops and vegetables are exposed to smog, it interferes with the ability to fight infections, thus increasing susceptibility to diseases.

Note:

Ozone - Cause acute respiratory problems, Aggravate asthma, Cause temporary decreases in lung function in healthy adults, Lead to hospital admissions and emergency room visits, Impair the body's immune system

Peroxy acetyl nitrate (PANs)

- Respiratory and eye irritants, Mutagenic- causing skin cancer

Volatile organic compounds (VOCs)

- Global warming- Methane, Carcinogenic- benzene, Form Ozone

Control:

Minimize the usage of vehicles and frequently check engines smoke emission.

Prevent high usage of coals

Reduce pesticides use.

WATER CHEMISTRY**INTRODUCTION:**

Water is one of the most basic and essential component of all life. It covers nearly 72% of the earth's surface. It is the second most important substance required to sustain human, animal, and plant lives. Water is essential resource for living system, industrial processes, agricultural production, and domestic use.

Pure water is a clear, colorless, and odorless liquid that is made up of one oxygen and two hydrogen atoms. The chemical formula of the water molecule, H_2O , was defined in 1860 by the Italian scientist **Stanislao Cannizzarro**. Water is a very powerful substance that acts as a medium for many reactions, which is why it is often referred to as the "universal solvent." Although pure water is a poor conductor of electricity, impurities that occur naturally in water transform it into a relatively good conductor. Water has unusually high boiling ($100^\circ C/212^\circ F$) and freezing ($0^\circ C/32^\circ F$) points. It also shows unusual volume changes with temperature. As water cools, it contracts to a maximum density of 1 gram per cubic centimeter at $4^\circ C$ ($39^\circ F$). Further cooling actually causes it to expand, especially when it reaches the freezing point. The fact that water is denser in the liquid form than the solid form explains why an ice cube floats in a beverage, or why a body of water freezes from the top down. While the density property of water is of little importance to the beverage example, it has a tremendous impact on the survival of aquatic life inhabiting a body of water. Water exists in many forms in the nature. i.e. in the form of clouds, rain, snow, ice and fog. The distribution of water on the earth is as follows.

Sources of water:

1. Surface water: It is available on the surface of the earth either still form or in flowing from. Example: rain water, river water, lake water and sea water.
2. Under ground water: It is developed by any type of well or spring from beneath the surface of the ground whether the water flows from the well or spring by natural force or is withdrawn by pumping, other mechanical device, or artificial process. Example: Springs, well and tube wells.

Impurities in water:

1. Dissolved impurities: Dissolved gases like oxygen, carbon dioxide, hydrogen sulphide etc.,.
2. Suspended impurities: These are mostly insoluble minerals such as clay, sand etc. These cause turbidity to water.
3. Microscopic matter: These consist of mainly bacterial and other micro organisms like algae and fungi.
4. Dissolved impurities: Dissolved salts are mainly the carbonates, bicarbonates, chlorides and sulphates of Ca, Mg, Fe, Na and K. The presence of these salts imparts a sort of hardness in water.
5. Organic matter: It includes vegetable and animal matter.
6. Colloidal impurities: It consist of proteins, amino acids, ferric hydroxide, clay etc.

Boiler feed water

The boilers are used in industries to generate steam. This steam is used in power production, sterilization etc. The water used to generate steam in boiler s called boiler feed water.

Boiler Troubles:

Water used to generate steam is contaminated; it brings problem to boiler and reduces its efficiency. The major boiler troubles are

1. Scale and sludge formation
2. Boiler corrosion

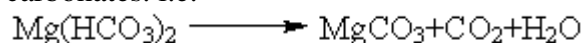
1. Scale formation:

During the production of steam, water evaporates continuously leaving behind the dissolved salts in the boiler. Concentration of the salt increases and reaches saturation level to get precipitated. If the precipitate is hard and strongly adhering on the inner walls of the boiler is known as scale.

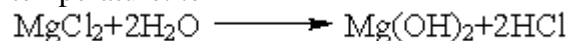
Causes for scale formation:

The various dissolved salts of water are responsible for scale formation

1. Decomposition of bicarbonates: bicarbonates undergo decomposition and forms insoluble carbonates. i.e.



2. Presence of silica: Impurities like calcium silicates, magnesium silicates are highly insoluble in hot water, they precipitate and deposit as scale
3. Hydrolysis of salts of magnesium: Magnesium salts are precipitated as their hydroxides at high temperature.i.e

**Prevention of scale formation:**

The scale formation in boilers can be controlled by two methods.

1. By feeding soft water (external treatment): Water used in boilers is purified by removing suspended and hardness impurities. Suspended impurities are removed by sedimentation and filtration process and hardness is removed by lime soda or ion exchange methods.

Prevention of sludge formation:

2. By internal treatment: Process of adding chemicals directly to water in boilers to remove the scale forming impurities which were not removed during external treatment methods is known as internal treatment. In this process, an ion is prohibited to exhibit its original character by complexing or by converting into more soluble salt by adding appropriate reagent.

Example: colloidal conditioning, phosphate conditioning, carbonate conditioning.

Disadvantages of Scale:

1. Wastage of fuel: Scales have a poor conductor of heat, so the rate of heat transfer from boiler to water is greatly reduced.
2. Reduces boiler efficiency: Decomposition of scales in the valves and condensers of the boiler, choke them partially.
3. Increase in cleaning expenses: Scales must be removed regularly and this cleaning process is very expensive.

4. Lowering of boiler safety: The overheating of the boiler tube makes the boiler material softer and weaker.

5. Danger of explosion: The scale formation also leads to uneven expansion of boiler material.

Sludge formation:

During the production of steam, water evaporates continuously leaving behind the dissolved salts in the boiler. Concentration of the salt increases and reaches saturation level to get precipitated. If the precipitate is soft, loose and suspended in boiler feed water is called as sludge.

Causes for sludge formation:

The impurities of water which causes sludge formation are MgCO_3 , MgSO_4 , and MgCl_2 etc. If the sludge is not removed periodically, then it will form scale.

Prevention of sludge formation:

Sludge formation can be prevented by using softened water, more over sludge can be removed by flowing off technique i.e. by drawing off some of the concentrated water from the bottom of the boiler through a tap.

Disadvantages of scale and sludge formation:

1. The sludge is bad conductor of heat. So it requires more heating of boiler to produce steam which results in wastage of fuel.
2. Because of more and more heating of boiler, there is a chance of explosion of the boiler
3. It reduces the efficiency of boiler.
4. Sludge's need to be removed regularly and this cleaning process is expensive.

2. Boiler corrosion

The decay of boiler material due to the presence of impurities in boiler feed water is called boiler corrosion.

Causes for Boiler corrosion:

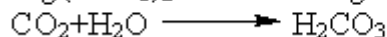
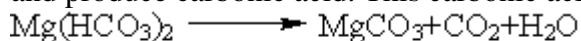
1. Corrosion due to dissolved Oxygen:

When water containing dissolved oxygen is heated in the boiler, the free gas is evolved under high pressure of the boiler and attacks the boiler material and forms the rust.



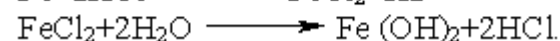
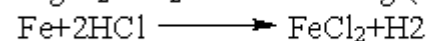
2. Corrosion due to dissolved carbon dioxide:

The CO_2 is obtained from the decomposition of bicarbonates. So formed CO_2 is react with H_2O and produce carbonic acid. This carbonic acid is slightly acid and corrosive in nature.



3. Corrosion due to MgCl_2 :

The salts like MgCl_2 in boiler feed water forms hydroxides and acid. The acid so formed will attack the boiler parts and causes corrosion.



Prevention of boiler corrosion:

Boiler corrosion can be controlled by reducing the quantities of O₂, CO₂ and any acid from the feed water.

1. By removing oxygen: Dissolved oxygen can be removed by treating boiler feed water with sodium sulphite or hydrazine.
2. By removing carbon dioxide: Lime stone easily removes carbondioxide or by adding ammonium hydroxide.
3. Finally acidic impurities if there any can be removed by treating with alkaline agents like ammonium hydroxide.

Sources of water pollution

There are many causes for water pollution but two general categories exist: direct and indirect contaminant sources. Direct sources include effluent outfalls from factories, refineries, waste treatment plants etc.. that emit fluids of varying quality directly into urban water supplies.

Water pollutants sources are of two types.

1. Point sources: point source pollution is defined as any single identifiable source of pollution from which pollutants are discharged, these are discrete and identifiable and hence easy to monitor and regulate.

Example: Industrial discharge, factory smoke, municipal sewage etc.,

2. Non point source pollution: When a source of pollution cannot be readily identified ie. Sources are scattered or diffuse they are called as non point source of pollution.

Examples: Run off from farm lands, parking lots, agriculture logging, animal wastes, etc.,

Additional information:

Sewage And Waste Water: Sewage, garbage and liquid waste of households, agricultural lands and factories are discharged into lakes and rivers. These wastes contain harmful chemicals and toxins which make the water poisonous for aquatic animals and plants.

Dumping: Dumping of solid wastes and litters in water bodies causes huge problems. Litters include glass, plastic, aluminum, Styrofoam etc. Different things take different amount of time to degrade in water. They affect aquatic plants and animals.

Industrial Waste: Industrial waste contains pollutants like asbestos, lead, mercury and petrochemicals which are extremely harmful to both people and environment. Industrial waste is discharged into lakes and rivers by using fresh water making the water contaminated.

Oil Pollution: Sea water gets polluted due to oil spilled from ships and tankers while traveling. The spilled oil does not dissolve in water and forms a thick sludge polluting the water.

Acid Rain: Acid rain is pollution of water caused by air pollution. When the acidic particles

caused by air pollution in the atmosphere mix with water vapor, it results in acid rain.

Global Warming: Due to global warming, there is an increase in water temperature. This increase in temperature results in death of aquatic plants and animals. This also results in bleaching of coral reefs in water.

Eutrophication: Eutrophication is an increased level of nutrients in water bodies. This results in bloom of algae in water. It also depletes the oxygen in water, which negatively affects fish and other aquatic animal population.

Definition of BOD: Biological Oxygen Demand is an important measure of water quality. BOD is defined as “The amount of oxygen required by microorganism to oxidize the organic matter in a water sample over a period of 5 days under aerobic condition at 20 °C”.

Definition of COD: It is defined as “The amount of oxygen required for the complete oxidation of both organic & inorganic matter present in 1 litre of waste water using strong oxidizing agent”.

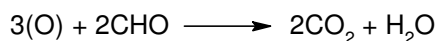
DETERMINATION OF COD OF WASTE WATER:

Definition of COD: It is defined as “The amount of oxygen required for the complete oxidation of both organic & inorganic matter present in 1 litre of waste water using strong oxidizing agent”.

Characteristics of COD:

- 1) The unit of COD is mg/dm³ or ppm.
- 2) In general COD > BOD since both biodegradable and non biodegradable organic load are completely oxidized.

Principle: In this method, the given samples of water containing organic and inorganic impurities are oxidized by K₂Cr₂O₇ in acidic media in the presence of catalyst Ag₂SO₄ and HgSO₄. (Added to prevent the interference the chloride and silver ions). The unreacted K₂Cr₂O₇ is titrated against FAS solution in the presence of a redox indicator, ferroin which shows its color change in the oxidized (bluish green) and reduced states (reddish brown).



Procedure: Preparation of standard solution: Standard FAS solution is prepared by adding dilute H₂SO₄ (Added to prevent hydrolysis of FAS) to a known weight of FAS salt.

1. Pipette out known amount of the waste water into a clean conical flask.
2. Add 10 ml of K₂Cr₂O₇ and 10 ml 1:1 H₂SO₄ into a conical flask.
3. Add 1 g of Ag₂SO₄ followed by 1 g of HgSO₄ and warm if necessary.
4. Titrate with standard FAS using ferroin as indicator till color changes from bluish green to reddish brown.

5. Note down the volume of FAS consumed as ' V_1 ' ml.

Perform the blank titration without waste water sample. Note down the volume as ' V_2 ' ml.

Calculations:

Normality of FAS = ' A ' N

Volume of FAS consumed during blank titration = $B \text{ cm}^3$

Volume of FAS consumed during Back titration = $C \text{ cm}^3$

Volume of FAS consumed for the titration = $(B - C) \text{ cm}^3$

Volume of water sample = $V \text{ cm}^3$

1 ml of 1N FAS = 8 mg of oxygen

$(B - C) \text{ cm}^3$ of ' A ' N FAS = $A * (B - C) * 8 \text{ mg}$ of oxygen

$V \text{ cm}^3$ of water sample = $\frac{A * (B - C) * 8}{V} \text{ mg}$ of oxygen

Therefore 1000 cm^3 of water sample = $\frac{A * (B - C) * 8 * 1000}{V} \text{ mg/dm}^3$ of oxygen

Chemical analysis of water:

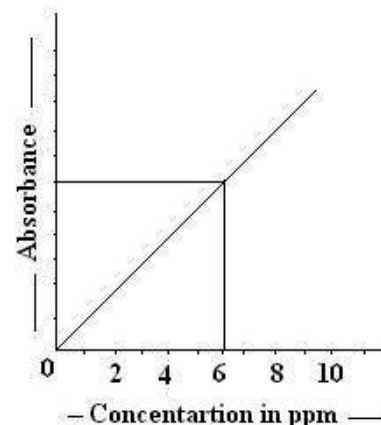
Determination of Fluoride by Colorimetric method

Fluoride contents in water sample are determined by colorimetric method. Fluorides have dual significance in water. High concentration causes *dental fluorosis* and low concentration causes *dental caries*. Significant sources of fluoride are found in coke, glass and ceramic, electronics, pesticides and fertilizer manufacturing, steel and aluminum processing and electroplating industries.

Principle: Fluoride is estimated colorimetrically using SPANDS method. (SPANDS = Sodium 2-(P-Sulphophenyl Azo)-1, 8-dihydroxy-3, 6 Naphthalene Disulphonate trisodium salt). The method utilizes the reaction between fluoride and a complex of Zirconium with SPANDS. The fluoride reacts with the complex, dissociating a portion of it into a colorless anion $[\text{ZrF}_6]^{2-}$ and the reagent. As the amount of fluoride is increased the color produced by Zr- SPANDS complex becomes progressively lighter. The decrease in intensity is related to the concentration of fluoride ions.

Procedure:

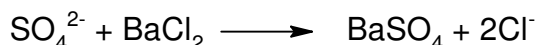
1. Prepare a reference solution by adding 10 ml of SPANDS in HCl and dilute to 100 ml with distilled water. Use this solution to set zero in the colorimeter at 570 nm.
2. Prepare a series of standard solution of NaF in the concentration range up to 2.0 mg/L in 100 ml standard flask.
3. Add 50 ml of distilled water and 10 ml of Zr- SPANDS reagent to each of the standard solution dilute up to the mark, mix well and measure the absorbance at 570 nm.
4. Draw the calibration curve by plotting the concentration of fluoride ion against absorbance.
5. Take the suitable aliquot of water sample to be analyzed and repeat the steps 3 and 4.
6. Calculate the concentration of fluoride ion in the test sample using calibration curve.



Determination of Sulphate by Gravimetric method

Sulphate ions (SO_4^{2-}) in water are due to the dissolved salts such as sulphates of sodium, potassium, magnesium etc.

Principle: In gravimetric method, sulphate ions (SO_4^{2-}) are quantitatively precipitated as BaSO_4 by treating with BaCl_2 in the presence of HCl , separated by filtration, dried and weighed as BaSO_4 .



The precipitate of BaSO_4 is filtered through a quantitative filter paper and is washed with hot water. The precipitate is ignited in silica crucible and weighed as BaSO_4 .

Procedure:

1. Take 1000 ml of water in large beaker, heat it on a hot plate and evaporate to reduce the volume to 100 ml.
2. Add half test tube of dilute HCl and heat the solution nearly to boiling.
3. To the hot solution add 1 test tube of BaCl_2 solution slowly with constant stirring. Digest the solution on water bath for about 30 min.
4. Filter the solution using No.40 quantitative filter paper through a funnel & wash the precipitate with hot water several times to remove chloride ions.
5. Heat the funnel in an aluminium cone till filter is dry. Transfer the filter paper into a previously dried & weighed silica crucible and heat.
6. Transfer the hot silica crucible into desiccators and cool it. Weigh the crucible along with the precipitate of BaSO_4 .
7. Repeat the process of heating, cooling and drying till a constant weight is obtained.

Calculation:

Volume of water taken = 1000 ml

Weight of empty silica crucible = W_1 g

Weight of silica crucible + BaSO_4 precipitate = W_2 g

Weight of BaSO_4 = $(W_2 - W_1)$ g

Amount of Sulphate = $\frac{(W_2 - W_1) \times 96}{233.33}$ g/l

1000 ml of water contains $\frac{(W_2 - W_1) \times 96}{233.33}$ g/l

10⁶ ml of water contains $\frac{(W_2 - W_1) \times 96 \times 10^6}{233.33 \times 1000}$ ppm

SEWAGE: Water containing any one of the waste is called as **effluent or sewage**.

SEWAGE TREATMENT: The water containing heavy load of BOD, pathogenic bacteria, colour and annoying smell can't be directly discharged into the rivers as they mainly affect the aquatic life and causes many water borne diseases. The domestic sewage therefore needs proper treatment which is carried out in 3 stages

- Primary treatment
- Secondary treatment
- Tertiary treatment

Primary treatment: It involves

Screening: Removal of large suspended or floating matter in sewage using mesh screens.

Silt and Grit removal: Removal of heavy particles like sand, glass pieces etc. using grit chambers.

Removal of oil and grease: is mainly done using skimming tanks by blowing air through the sewage and oils are lifted to the surface as foams (soapy mixture) which is then skimmed off.

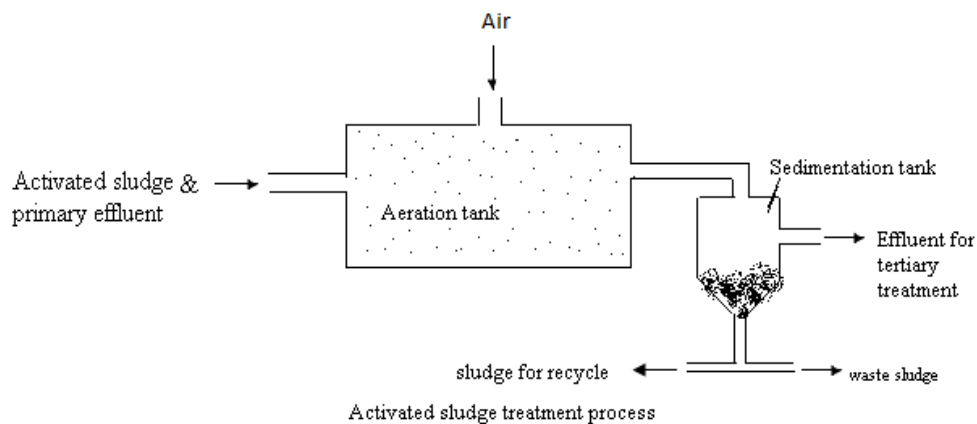
Sedimentation process: involves addition of coagulants like alum, ferrous salts etc. and there by ppt. out the suspended particles by sedimentation process.

Secondary treatment:

It involves aerobic biological oxidation of sewage water. The sewage water after sedimentation is subjected to aerobic oxidation during which the organic matter is converted into H_2O and CO_2 and N_2 to NH_3 and finally to nitrates and nitrites.

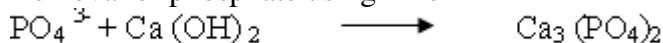
Activated Sludge Method (Biological treatment): Activated sludge is a thick greasy mud containing aerobic bacteria.

This method involves extensive aeration of the sewage water after primary treatment is mixed with activated sludge and allowed to enter in a large aeration tank for biological treatment. Air is continuously passed into tank to maintain the aerobic condition. Under these condition microorganisms present in activated sludge attack on organic matter of sewage and decomposes them into CO_2 and H_2O . The effluent after this treatment is passed to sedimentation tank where sludge will settle down. The clear effluent is sent to tertiary treatment. A part of sludge is used for further treatment and rest is disposed off and used as manure.



Tertiary treatment: It involves

Removal of phosphate using lime



Removal of heavy metals by sulphides.



Degasification of NH_3 , H_2S , and CO_2 by stripping hot water.

Disinfection of microorganisms by chlorine. Acid kills microorganisms.



Softening of water by Ion exchange process:

In this method all the ions present in water are removed. In this insoluble ion exchange resins are used. Resins means it is a long chain organic polymer with functional groups. Depending upon the functional groups attached to resins they are classified into

1. **Cation Exchange Resin:**

These resins exchange its H^+ ions with cations of water sample. Generally it is expressed as RH^+

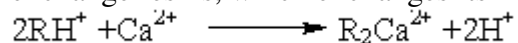
2. **Anion Exchange Resin:**

These resins exchange its OH^- ions with anions of water sample. Generally it is expressed as ROH^-

Working:

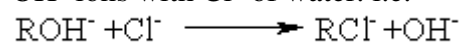
The ion exchange resin contains two compartments. One is cation exchange resin and another is anion exchange resin. For the regeneration of respective resins, acid and alkali regeneration units are connected to compartments. The schematic diagram of ion exchange unit as shown in fig.

The water sample containing high minerals are first allowed to pass through cation exchange resins, which exchanges its H^+ ions with Ca^{2+} ions of water .i.e



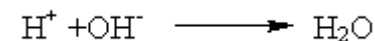
Now the water sample is free from cations.

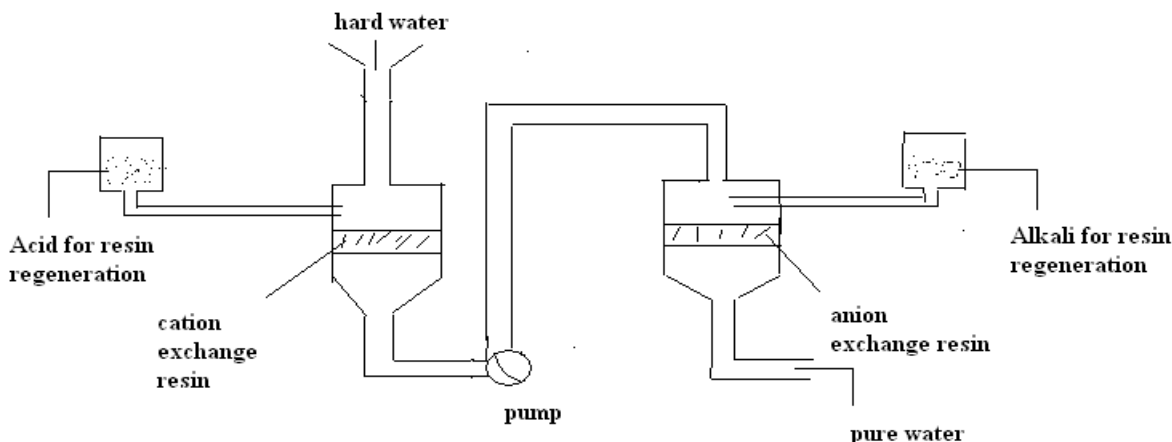
The same water is further allowed to pass through anion exchange resin, which exchanges its OH^- ions with Cl^- of water. i.e.



Now the water is totally free from all the ions.

Now H^+ ions formed at cation exchange resin and OH^- ions formed at anion exchange resin will combine to form pure water.



**Advantages:**

1. The ion exchange apparatus, once set up, is easy to operate and control.
2. Both acidic and alkaline water can be softened.
3. Water of very low hardness is produced.
4. Water produced by this method is used as boiler feed water.

Disadvantages:

1. Equipment and process is costly.
2. Turbid water needs to be filtered first before softening.

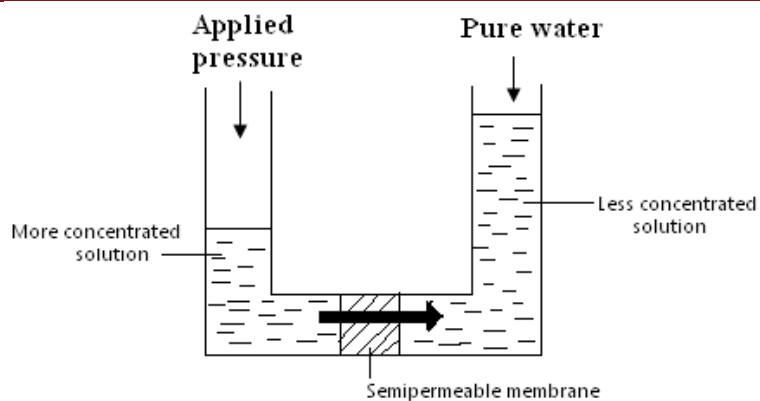
POTABLE WATER-Water that is fit for human consumption and free from pathogenic bacteria and toxic chemicals is called potable water.

DESALINATION-The process of removal of dissolved salts from sea water to the extent that water becomes usable is described as desalination. The important methods of desalination are a) Reverse Osmosis. B) Electrodialysis.

REVERSE OSMOSIS:

Principle: - The principle of osmosis is that water flows from lower concentration to higher concentration side through semi permeable membrane. If the pressure is applied on solution side, the solvent will flow in the reverse direction. This is called reverse osmosis.

It is studied that sea water exerts an osmotic pressure of about 4500-5500 KPa. In reverse osmosis, hydrostatic pressure which is greater than osmotic pressure is applied on the salt solution side then water flows from salt solution to fresh water side. This water can be used for human consumption.



Reverse Osmosis

Application:

1. It is economical, simple and continuous.
2. The process needs extremely low energy.
3. It has long life and membrane is easily replaceable.
