

MODULE IV ENVIRONMENTAL POLLUTION AND WATER CHEMISTRY

Environmental Pollution:

Pollution may be defined as the excessive discharge of undesirable substances into the environment, thereby adversely altering the natural quality of the environment and causing damage to human, plants or animal life.

Air Pollution:

Air pollution may be defined as the excessive discharge of undesirable foreign substances into the atmospheric air, thereby adversely affecting the quality of air and causing damage to human, plants or animal lives.

Air pollutants are classified into two major categories.

1. Primary Air Pollutants
2. Secondary Air Pollutants

Primary Air Pollutants

Primary Air Pollutants are the pollutants that are directly emitted into the atmosphere through natural or human activity. Examples of primary air pollutants are SO_x, NO_x and CO.

1. Carbon Monoxide

Sources:

- CO is released by the partial combustion of fuel in automobiles, industries and oil refineries.
$$2C + O_2 \rightarrow 2CO$$
- Cigarette and beedi smoke and domestic heat appliances are the other sources.

Effects:

- CO causes headache, visual difficulty, paralysis and even death in human beings.
- Presence of CO reduces oxygen carrying capacity of blood.
- May cause heart diseases

Control:

- Modification of internal combustion engines.
- Development of substitute fuels for gasoline.
- Development of pollution free power source such as fuel cells.

2. Oxides of Nitrogen:

Nitrogen Oxide (NO) and nitrogen dioxide (NO₂) are referred to as oxides of nitrogen (NO_x)

Sources:

- Combustion of Coal, oil, gas and gasoline.
- Produced naturally by lightning.
- Other sources are acid manufacture, explosive industry and acid pickling plants.

Effects:

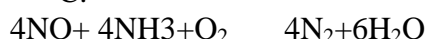
- In high NO₂ areas ,respiratory illness among children have been reported.
- It is unpleasant in odour and leads to irritation of eyes and even lung' s congestion.

Control:

- Removal of oxides of nitrogen during combustion by using **LOW NO_x BURNERS**.
- Removal of oxides of nitrogen after combustion.

Above method is done by treating the flue gases after combustion by following two techniques namely

a. Selective Catalytic Reduction (SCR): Conversion of NO into N₂ and water By using NH₃ in the presence of a catalyst vanadium or tungsten oxide at 300-400⁰ C.



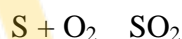
b.Sorption: Treatment of flue gas by using sorbents like ammonia, carbon or lime stone.

3.Oxides of Sulphur:

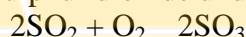
Sulphur dioxide(SO₂) and sulphur trioxide(SO₃) are referred together as oxides of sulphur(SO_x)

Sources:

- SO₂ is formed in thermal power plants when sulphur containing coal and fuels are fired.



- SO₃ is formed by the oxidation of sulphur dioxide under influence of light.



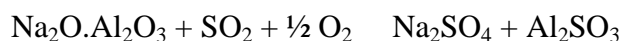
- Petroleum industries, oil refineries, sulphuric acid plants and sulphide ore roasting plants are also the sources of SO_x.

Effects:

- Cardiac, respiratory and pulmonary diseases.
- Eye irritation, throat trouble
- Corrosion of Metal

Control:

- Large amount of sulphur is removed by crushing and washing the coal before combustion.
- Absorption of SO₂ on a suitable adsorbent (sodium aluminate) to form stable sulphates in fluidized bed at 315°C with subsequent regeneration.



- Absorption of SO₂ from flue gases on activated carbon followed by regeneration and conversion to sulphuric acid or elemental sulphur.

4. Hydrocarbons

Sources:

- Automobile and industrial exhaust are the major sources.
- Hydrocarbon like methane is produced by bacteria through anaerobic decomposition of organic matter.



Effects:

- Hydrocarbons at high concentration (>500ppm) have carcinogenic effects on lungs.
- Inhalation of vapours of benzene, toluene etc causes much irritation to the mucous membrane.
- Cyclic hydrocarbons affect nervous system.
- The hydrocarbons also lead to the formation of photochemical smog.

Control:

1) Hydrocarbons from auto exhaust can be controlled by process such as incineration, adsorption, absorption etc.



2) By adsorption over the surface of activated carbon .

3) By lowering the temperature by using cold water, the hydrocarbons can be condensed & separated from flue gases.

5. Particulate Matter

Small solid particles and liquid droplets are collectively called as particulates.

Sources:

- Dust
- Smoke: Formed by incomplete combustion of fuel.
- Smog: mixture of smoke (from coal combustion) and fog in suspended droplet form.
- Asbestos: widely used in industry for its mechanical strength and resistance to heat.

Effects:

- Atmospheric dust causes allergic and respiratory diseases.
- Smoke is increasingly related to incidence of cancer.
- Particulates due to their small size damage lung tissues.
- Acid and aldehyde particulates cause eye, nose and throat irritation.

Control:

- Electrostatic Precipitator: Removal of particles by using an electrostatic field to attract the particles onto the electrodes.
- Filters and dust collectors: Dust is collected by passing flue gases through a filter.
- Wet Scrubber: Wet scrubbers rely on a liquid spray to remove dust particles from a gas stream.

6. Mercury:

Sources

- Natural sources of mercury includes volcanoes and release from oceans.
- Man made sources include coal combustion, waste incineration and metal processing industries.

- Lamps including some types of light bulbs
- Dental amalgam(for dental fillings)
- Skin lightening products and other cosmetics.

Effects:

- Elemental and methyl mercury are toxic to the central and peripheral nervous system.
- The inhalation of mercury vapour can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys and may be fatal.
- The inorganic salts of mercury are corrosive to the skin,eyes and gastrointestinal tract and may induce kidney toxicity if ingested.

Control:

- Promoting the use of clean energy sources that do not burn coal.
- Eliminating mercury mining and promoting the use of non-mercury gold extraction.
- Discontinuing the use of nonessential mercury containing products such as few batteries,skin lightening cosmetics and implementing safe disposal of mercury containing products.

7. Lead:

Sources:

- The most common source of lead poisoning is dust and chips from old paint.
- Lead comes from metal smelting, lead-acid battery manufacturing and other factories that use lead.
- Lead enters the water through contact with plumbing, lead based pipes or solder that leaches lead into water through corrosion.

Effects

- Depending upon the level of exposure lead can adversely affect the nervous system, kidney function, immune system, cardiovascular systems.
- Affects oxygen carrying capacity of blood
- Infants and young children are especially sensitive to even low levels of lead which may contribute to behavioural problems and learning deficits.
- Elevated levels of lead in the environment can lead to decreased growth and reproductive rates in plants and animals.

Control:

- Lead smelting plants should design their storage piles in such a way that the movements of lead materials are minimised to lessen exposure to wind and air.
- Elimination of lead contamination in drinking water by processes such as reverse osmosis, distillation and filtration using carbon filters.
- To minimise plant absorption of lead content in agricultural soil it is advised to maintain the soil pH levels at 6.5.

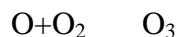
Secondary Air Pollutants

Secondary air pollutants are the air pollutants that are not directly released into the atmosphere but forms when primary pollutants react in the atmosphere. Eg: ground level ozone, nitric acids, sulphuric acids.

Ozone:

Sources:

- Ozone is produced in stratosphere(about 20 km above earth surface in the atmosphere) from oxygen gas by the absorption of UV light.



- Ground level ozone is formed when primary pollutants such as oxides of nitrogen and volatile organic compounds(VOCs) react with sunlight.

Effects:

1. Positive effect at Upper Atmosphere: Ozone Layer is beneficial preventing damaging ultraviolet light from reaching the Earth's surface, to the benefit of both plants and animals.
2. Negative effects at ground level:
 - Irritation of the respiratory system, causing coughing and respiratory infections.
 - Breathing may become more rapid and more shallow than normal, and a person's ability to engage in vigorous activities may be limited.
 - Inflammation and damage to the lining of the lungs.
 - Ozone can damage mucous and respiratory tissues in animals and also tissues in plants (conc.>100ppb near ground level)

Control:

- 1 Cleaner burning gasoline reformulated to reduce VOC, NOx and other pollutants;
- 2 Strict NOx emission limits for power plants and industrial combustion sources;
- 3 Enhanced vehicle inspection programs in states; and
- 4 Strict limitations on the solvent usage in factories.

Ozone Depletion:

Sources:

Man made chemicals like chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), , carbon tetrachloride, methyl chloroform, halons, methyl bromide etc destroy ozone layer

present in the stratosphere. Hence they are known as **ozone depleting substances** (ODS).

[A **halon** may be any of a group of organohalogen compounds containing bromine and fluorine and one or two carbons.]

Halons were used for firefighting. Methyl bromide was used in agriculture and other substances were used as coolants, foaming agents, solvents etc.

Ozone depleting substances are inert. They do not have a natural sink and slowly rise up. In the stratosphere they breakdown by absorbing UV radiation as shown below.



The third reaction regenerates chlorine atoms. The free chlorine atoms again react with ozone and the process continues resulting in depletion of ozone layer.

Effects of ozone layer depletion:

- Skin Cancer and eye Damage
- Immune System Damage
- Accelerated aging of skin

Control:

- Encouraging growth of plants that produce oxygen .
- Controlling the release of ozone depleting substances such as chloroflouro carbons.
- Usage of eco-friendly household cleaning products.
- By following natural remedies to control pests.

Waste Management:

Waste management refers to the activities and actions required to manage the waste from its inception to final disposal. This includes collection, transport, treatment and disposal of waste together with monitoring and regulation.

1. Solid Waste:

Sources:

This include **Wastes Generated from**

- Residential areas and home
- Industries and institutions
- Municipal Services

- Agriculture

Characteristics:

Characteristics of solid waste is important for selecting suitable disposal methods.

Physical Characteristics:

- Density of waste(mass per unit volume)
- Moisture content in wet waste(weight of water to the total weight of waste)
- Size distribution of material(for separation purpose)

Chemical Characteristics:

If solid wastes are to be used as fuel, we must know the chemical characteristics.

- Lipids (found in variety of waste suitable for energy recovery.)
- Proteins(found in food and garden wastes)
- Natural fibres(found in paper products, food wastes suitable for energy recovery)
- Synthetic Organic Material(Plastics suitable for pyrolysis and energy conversion)
- Calorific value of waste.

Disposal Methods:

a.Landfill is the disposal method where the garbage is most commonly dumped into a designated area usually in unusable lands in remote areas.

There are Two Challenges associated with Land fills.

- a) Seeping of solid wastes into underlying soil and water and contaminating both of them.
 - b) Methane emission from waste that leads to uncontrollable fire.
- Such Challenges are overcome through *Scientific Land-filling*.

Scientific Land-filling:

In this technique the base layer is constructed of 90 meters of clay,(avoids waste leakage within the landfill) on top of which there is a drainage layer made up of soil, measuring 15 meters in length and a vegetative layer of 45 centimeters to minimise soil erosion.

Scientific Landfills also reduce production of methane. Since the layers soak most of the impurities in the waste disposed methane generates slowly compared to the generation speed in ordinary landfills. Vertical wells installed in scientific landfills help to extract methane regularly and the gas then can be used for electricity and heat generation purposes.

b.Composting: Due to lack of adequate space for landfills biodegradable yard waste is allowed to decompose. Since biodegradable waste materials are used in composting, environmentally friendly manure is formed from the compost which can be used as organic fertilizer.

There are two important techniques.

- i) **Home-Composting:** With the proper mixture of water, oxygen, carbon and nitrogen, the microorganisms in the waste are able to breakdown organic matter to produce compost.
- ii) **Commercial level Vermi-Composting:** it is a process of organic material degradation using various species of worms such as earth worms. It is a quick and most efficient composting method for heterogeneous mixture of waste.

- c. **Recycling and reuse:** Recycling and reuse is the process of taking useful but discarded items for next use. The process aims at reducing energy loss, consumption of new material and reduction of landfills.

2. Electronic Waste(e-Waste) :

Electronic waste is popularly known as e-waste, consisting of discarded electronic products such as computers, televisions, refrigerators, mobile phones and similar items.

Inappropriate processing of e waste in developing countries can lead to adverse human health effects and environmental pollution. Electronic scrap components such as CPU s contain potentially harmful components such as lead, cadmium, beryllium or brominated flame retardants. During Recycling and disposal of e waste, great care must be taken to avoid unsafe exposure and leaking of materials such as heavy metals from land fills and incinerator ashes.

Sources:

- TV s, computer monitors, laptops, mobile phones, printers, scanners, circuit boards, digital/video cameras, DVD players etc.
- Kitchen equipments (toasters, coffee makers , microwave ovens)
- Laboratory equipments (hot plates, microscopes, calorimeters)

Characteristics:

Hazardous components in e- Waste : Flame retarders which are widely used in plastics to prevent or delay a developing fire in electronic equipment like television housing, computer monitors etc. have proved to be the hazardous material.

Material Composition of e- waste: e- waste contains a mixture of various metals particularly copper, aluminium and steel attached to, covered with or mixed with various types of plastics and ceramics. Precious metals have a wide application in the manufacture of electronic appliances, serving as contact materials due to their high stability and good conducting properties.

However it should be pointed out that the precious metals content have gradually decreased in concentration in scrap due to falling power consumption of modern switching circuits.

Disposal:

Reuse: Reuse has first priority as usable life span of equipment can be extended.

Re Manufacture: Is a process in which used products or cores are disassembled , cleaned, repaired then reassembled to get new equipment.

Recycle: Recycling of e-waste can be broadly divided into three major types namely Disassembling, Upgrading and Refining.

Bio-medical Waste:

Sources:

- Hospitals and clinics
- Labs and research centers
- Blood Banks

Characteristics:

Infectious Waste: Waste that may transmit infection from virus, bacteria and parasites to human .Eg : lab cultures, tissues, blood ,needles and knives.

Radioactive: Unused liquid in radiotherapy and lab research, contaminated glassware etc.

Chemical waste: Expired lab reagents,film developer and disinfectant.

Pharmaceuticals Waste: Expired and contaminated medicines.

Non Risk Waste: Office paper, Wrapper, Kitchen waste etc.

Disposal:**Incineration:**

Is a high temperature dry oxidation process that reduces organic and combustible waste to inorganic incombustible matter resulting in very significant reduction of waste volume and weight.

Chemical Disinfection:

In chemical disinfection certain chemicals are added to waste to kill or inactivate the pathogens it contains .Chemically disinfected waste is rendered suitable for disposal in landfills.

Sanitary Landfills:

The use of landfill for biomedical waste has to be regarded as last option.It should not be dumped in open spaces as this leads to acute pollution problems. Sanitary landfills are however safer if designed to have atleast four advantages over open dumps like

- Appropriate engineering Preparations before the site is ready to accept waste.
- Staff present on site to control operations
- Organised deposit and daily coverage of waste.

Water Chemistry

Water is abundant in nature and it covers 71% of the earth surface

The sources of water are rain, river ,lake ,sea and underground water..

Types of impurities in water:

The impurities present in water may be broadly classified into three types

(i)Physical impurities (ii) Chemical impurities (iii) Bacterial impurities

(a) Suspended impurities (a) Dissolved salts

(b) Colloidal impurities (b)Dissolved gases

boiler feed water:

The setup used to produce steam in industries is known as ‘Boiler’. Water is fed to the boiler and heated to produce steam. The water fed into the boiler is known as “Boilerfeed water”.Boiler feed water should be free from turbidity, oil, dissolved gases, alkali and hardness causing substances.

Requirements for boiler water

Sl.No	Requirements for boiler water	Effects if not treated
1.	Free from hardness causing salts	Sludge and scale
2.	Free from oil and greases	Foaming
3.	Free from dissolved salts, suspended impurities	Caustic embrittlement
4.	Free from dissolved gases, suspended salts	Boiler corrosion



Boiler troubles

Sludge, scale, priming and foaming, caustic embrittlement, boiler corrosion are collectively known as boiler troubles.

A. Sludge and scale

If the water contains hardness causing salts like MgSO_4 , MgCl_2 , CaSO_4 , $\text{Ca}(\text{HCO}_3)_2$ on evaporation, the salts are precipitated to produce scale and sludge.

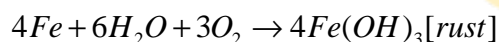
Differences between sludge and scale

Loose, slim, non-adherent precipitate	Hard, thick, strong adherent precipitate
Due to salts like MgSO_4 , MgCl_2	Due to salts like CaSO_4 , $\text{Ca}(\text{HCO}_3)_2$
Due to poor conductance, they decrease the boiler efficiency to lesser extent and causing chocking in the pipelines.	Due to poor conductance, they decrease the boiler efficiency to maximum extent, cause reduced fuel economy, improper boiling, boiler explosion etc.,
It can be prevented by periodical replacement of concentrated hard water by fresh water. This process is known as "blow down" method.	It can be prevented by special methods like i) external treatment of ion exchange , ii) Internal carbonate, phosphate, Calgon conditioning iii) Mechanical hard scrubbing methods.
Loose precipitate suspended in water 	Adherent coating inside the boiler 

B. Boiler Corrosion

It may be due to three major reasons: i) Dissolved Oxygen, ii) Dissolved CO_2 or iii) Dissolved salts like MgCl_2 .

a) Corrosion Due to dissolved oxygen:

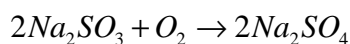


Dissolved oxygen in presence of water, causes corrosion.

Prevention of corrosion from oxygen:

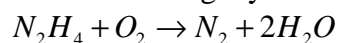
i. Chemical method:

✓ Adding sodium sulphite:



This method results in other precipitates which can have some side effects. So this method is less preferred.

✓ Adding Hydrazine:



This method results in inert gas and water as products. Hence is preferred in industries.

ii. Mechanical deaeration method:

1. This is based on the principle that at high temperature, low pressure and high exposed area, the solubility of gases in water is decreased. So, the gases can be expelled easily.
2. Here, the water is fed into the mechanical deaerator which is provided with vacuum pump, heaters and perforated plates.
3. The out coming water will be free from dissolved gases.

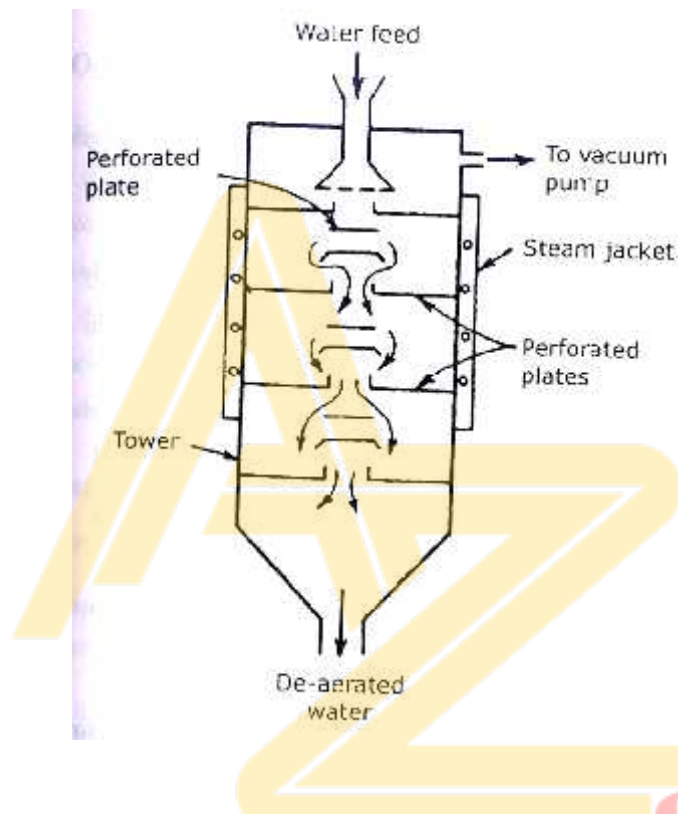
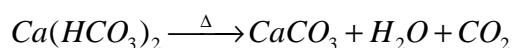
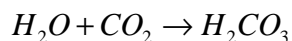


Figure 1. Schematic representation of a basic industrial deaeration setup

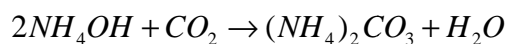
b) Corrosion due to CO_2

Salts like Calcium bicarbonate on heating produces CO_2 . CO_2 dissolves in water to form carbonic acid which corrodes the boiler metal.



Prevention of corrosion due to CO_2 :

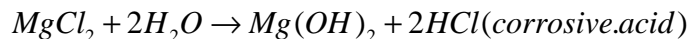
- i. Chemical method: By adding calculated amount of ammonium hydroxide



ii. Mechanical deaeration method (similar to oxygen method)

c) Corrosion due to dissolved salts like $MgCl_2$

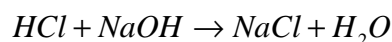
Dissolved salts like $MgCl_2$ cause acid formation. This will be prevented by



alkaline neutralisation.

Neutralisation:

Excess acidic nature is neutralized by adding alkalis and vice versa.



Biological oxygen demand (BOD):

Definition: BOD of sewage is defined as the amount of oxygen required for the biological oxidation of the organic matter under 'aerobic conditions at 20^0c & for a period of 5 days.

Chemical oxygen demand: (COD):

Definition: COD is the amount of oxygen equivalent used while oxidizing the chemically oxidisable impurities in the water, with a strong chemical oxidant, $K_2Cr_2O_7$ in acid medium. It is expressed in mg.dm^{-3} or ppm.

Determination of COD:

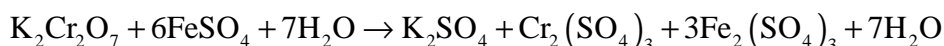
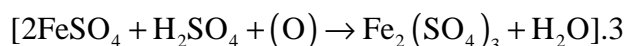
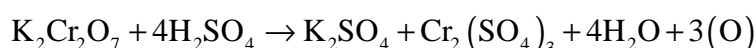
Principle:

A known volume of the waste water sample is refluxed with excess of $K_2Cr_2O_7$ solution in H_2SO_4 medium & in the presence of Ag_2SO_4 & $HgSO_4$. Ag_2SO_4 catalyses the oxidation of straight chain organic compounds, aromatic compounds & pyridine. $HgSO_4$ avoids the interference of Cl^- ions forming soluble complex with them. In the absence of $HgSO_4$, Cl^- precipitates silver ions as $AgCl$.

The amount of unreacted $K_2Cr_2O_7$ is determined by titration with standard Mohr's salt solution. The amount of dichromate solution consumed corresponds to COD of water sample. To calculate the COD a blank titration without the water sample (distilled water) is carried out. Ferroin [1, 10-phenanthroline-iron (II) complex] is used as the indicator in the titration to detect the end point. The indicator is intensively red colour. In the presence of $K_2Cr_2O_7$, the indicator is oxidized to give pale blue colour. The solution becomes blue-green as the titration. As long as $K_2Cr_2O_7$ is present in the solution, the indicator is in the oxidized form imparting blue colour to the solution. Continues due to the reduction of $Cr_2O_7^{2-}$ ions into $Cr(III)$ ions.

When $K_2Cr_2O_7$ is completely exhausted in the solution, the oxidized form of the indicator gets reduced, imparting the red brown colour to the solution. (That is the end point). A standard solution of Mohr's salt is prepared by dissolving known weight of the salt in a known volume of the solution. A test tube of $Dil.H_2SO_4$ acid is added during dissolution to prevent the hydrolysis of the salt in the solution.

The reaction between Mohr's salt & dichromate can be represented as follows:



Procedure:

Preparation of standard Mohr's salt solution:

The given Mohr's salt is accurately weighted and transferred into a clean standard flask. About 1 test tube of Dil.H₂SO₄ is added to the flask. The salt is dissolved made up to the mark with distilled water & shaken well for uniform concentration. The solution is taken in a burette.

Estimation: 25ml of waste water is pipetted out into a 250ml conical flask. 1g of HgSO₄& 2 test tube of silver sulphate/H₂SO₄ mixture is added to it. 25ml of given dichromate solution is also pipetted into it. A porcelain piece is added & the flask is attached with a reflux condenser. The mixture is refluxed for half an hour. The flask is cooled to room temperature; inner side of the condenser is washed with distilled water into the sample. Now one test tube of 1:1 H₂SO₄ is added to it, 1-2drops of ferroin indicator is added & the mixture is titrated with standard Mohr's salt solution till the color changes from blue green to reddish brown. The titration is repeated to get agreeing values.

Blank titration: The above procedure is repeated by taking 25ml of distilled water in place of waste water.

Calculation:

Volume of sample taken.....=Vml

Volume of FAS used in sample titration =A ml

Normality of FAS solution=N

Volume of standard FAS in Blank titration=Bml

Amount of K₂Cr₂O₇ consumed in satisfying the COD in terms of FAS solution = (B-A) =.....-ml

$$N_1.V = N. (B-A)$$

Normality of COD of the sample, $N_1 = N.(B-A)/V$

$$\text{COD of the sample} = \frac{N.(B-A).8}{V} \text{ g.dm}^{-3}$$

or

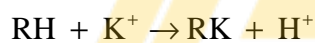
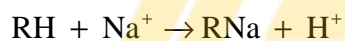
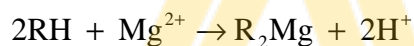
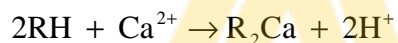
$$\text{COD of the sample} = \frac{N.(B-A).8.1000}{V} \text{ mg.dm}^{-3}$$

Ion exchange (demineralization) process

An elegant way to soften water is to remove all the associated metal ions and their counter anions from water. This is accomplished with the efficient synthetic ion exchange resins. The utility of ion exchange resin rests with its ability to be used and reused, high efficiency, economical cost and long useful life.

Principle of ion exchange process: In ion exchange process the impure water is passed through cation exchange resin and anion exchange resin. Cation exchange resin is capable of exchanging cations present in water for H^+ ions, i.e., when the water passes through the cation exchanger, the cations present in water as impurities are retained by the resin and H^+ ions are released into water. Anion exchanger resin is capable of exchanging anions present in water for OH^- ions, i.e., when water passes through the anion exchanger, the anions present in the water are retained by the resin and OH^- ions are released into water.

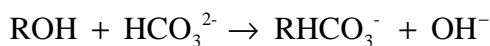
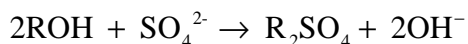
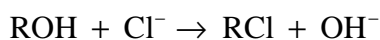
Function of cation exchanger: Commercially significant cation exchange resins are sulfonated copolymers of styrene and divinyl benzene. They are represented as RH and they



The water coming out of cation exchange resin is acidic as H^+ ions are introduced into water in place of metal ions.

exchange cations present in water.

Function of anion exchanger: The anion exchanger resins are copolymers of styrene and divinyl benzene containing active quaternary amino groups. These resins are represented as



As OH^- are introduced into acidic water, neutralization reaction takes place.

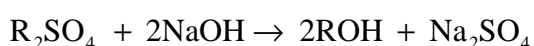
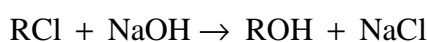
ROH and they exchange anions present in water for OH^- ions.



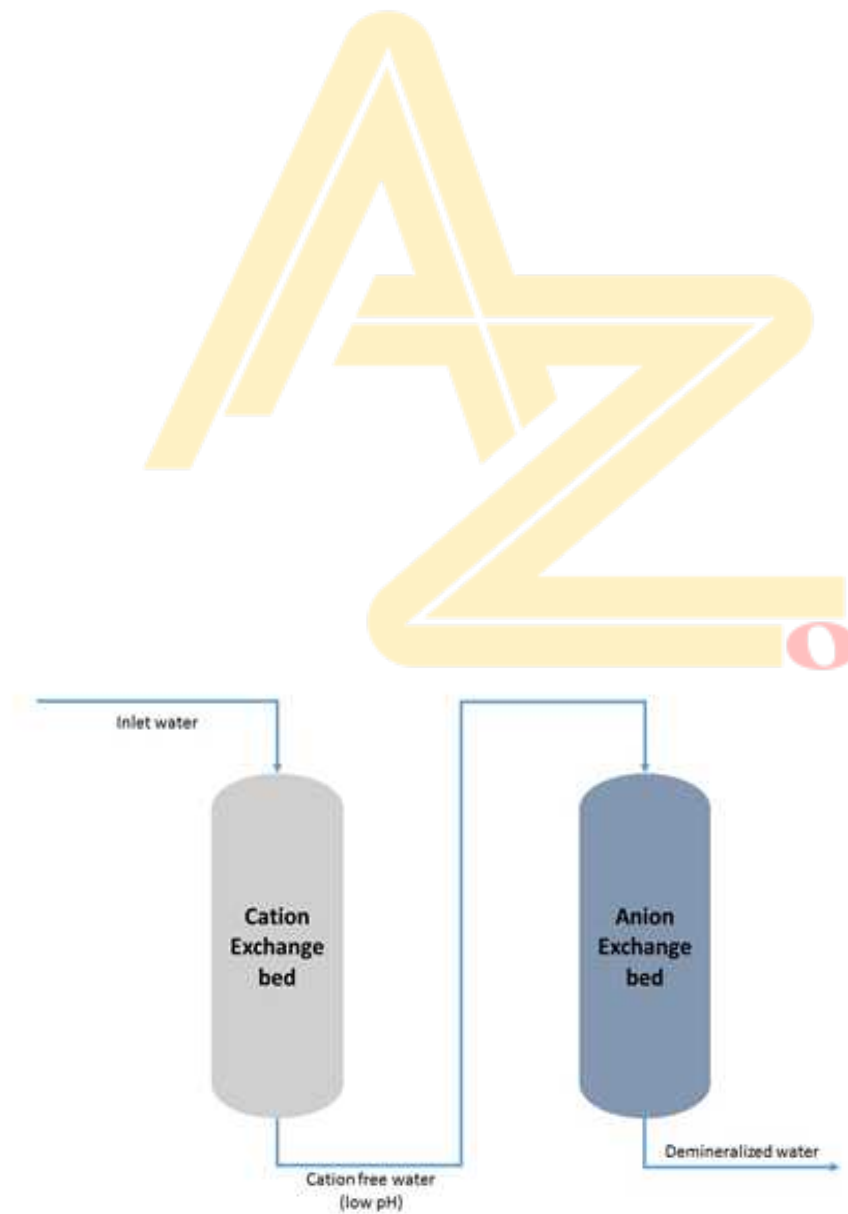
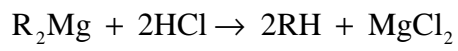
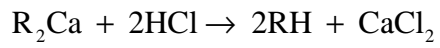
As cations are replaced by H^+ ions and anions by OH^- ions, the net reaction is introduction of water in place of metal salts present in water.

Regeneration :When the resins get exhausted, they can be regenerated by passing HCl and NaOH solutions through cation and anion exchange resins respectively

In anion exchanger :



In cation exchanger :



Chemical Analysis of Water:

Determination of Fluoride By SPADNS Method using Colorimetry

Principle: Under acidic conditions, fluorides react with zirconium dyes (such as SPADNS- Sodium-2-Parasulphophenyl azo-1,8-dihydroxy-3,6-naphthalein disulphonate) to form colourless complex and another dye. The dye becomes progressively lighter as fluoride concentration increases.

Procedure:

1. A blank solution is prepared by adding 10 ml of acid zirconyl SPADNS reagent to 100 ml distilled water. The colorimeter is set to zero at 570nm using this solution.
2. A series of standard solution of fluoride (NaF) in the concentration range 0.0-2.0 mg/L
3. A drop of NaAsO₂(sodium arsenite) is added to remove any residual chlorine to each of standard solutions.
4. 10 ml of acid zirconyl SPADNS reagent is added to each of the standard solutions and optical density is read at 570 nm using colorimeter.
5. A calibration curve is drawn by plotting Concentration versus absorbance.
6. Step 3 and 4 are repeated for analyte water sample
7. Concentration of fluoride ions can be calculated using calibration curve.

Determination of sulphate by gravimetric Method:

Principle: In this determination sulphate ions in water sample are quantitatively precipitated as BaSO₄ by treating with BaCl₂ solution containing HCl. Precipitated BaSO₄ is separated by filtration, then it is dried and weighed.



Procedure: 200 ml of water sample is taken in a beaker and heated to boiling. 1 test tube of HCl is added and then one test tube of BaCl₂ is added to the solution with constant stirring.

The solution is digested on the water bath for 30 min. After checking the completion of precipitate, it is allowed to stand for one hour and filtered through whatman filter paper. Filter paper containing the precipitate is transferred to previously dried and weighed silica crucible(W₁) and burnt in an electric burner. Once the filter paper is burnt off, transferred the crucible to a dessicator for cooling. After cooling weight of crucible (W₂) is noted. The difference in weight W₂-W₁ is equal to the amount of barium sulphate precipitated from the sample. Amount of sulphate is calculated using the following formula.

Calculations:

233.33g of BaSO₄ Contains 96g of sulphate.

W₂-W₁ g of BaSO₄ contains = $\frac{(W_2-W_1) \times 96}{233.33}$ = 'a' mg of sulphate.

That is 200 ml of water sample contains 'a' mg of sulphate.

1000 mL of water sample contains $\frac{1000}{200} \times a$ mg of sulphate.

200

SEWAGE TREATMENT:

- The domestic sewage contains heavy load of BOD, pathogenic bacteria, color & annoying smell. The sewage treatment is carried out in three stages.

(i) Primary treatment (ii) Secondary treatment (iii) Tertiary treatment

(i) Primary treatment involves,

(a) Screening: It is a physical process which removes large suspended or floating matter in the sewage. This is accomplished by using bar screens & mesh screens which retain the floating & suspended coarse particles when sewage water is passed through it.

(b) Slit & grit removal: Grit, i.e., sand, broken glass etc. is removed by passing sewage through grit chambers, in which the velocity of flow of sewage is reduced. Being heavier, slit & grit particles settle down at the bottom.

(c) Removal of oil, grease etc.: oil, grease etc. are removed in skimming tanks. They are converted into a soapy mixture by blowing compressed air through sewage water in skimming tanks, and lifted to the surface in the form of foam. The floating substance is skimmed off

(d) Sedimentation process: It removes finer suspended impurities. This is brought about by plain sedimentation in continuous flow type sedimentation with coagulation. The coagulants used are alum, ferrous sulphate etc. which help in the easy settlement of the finely suspended particles.

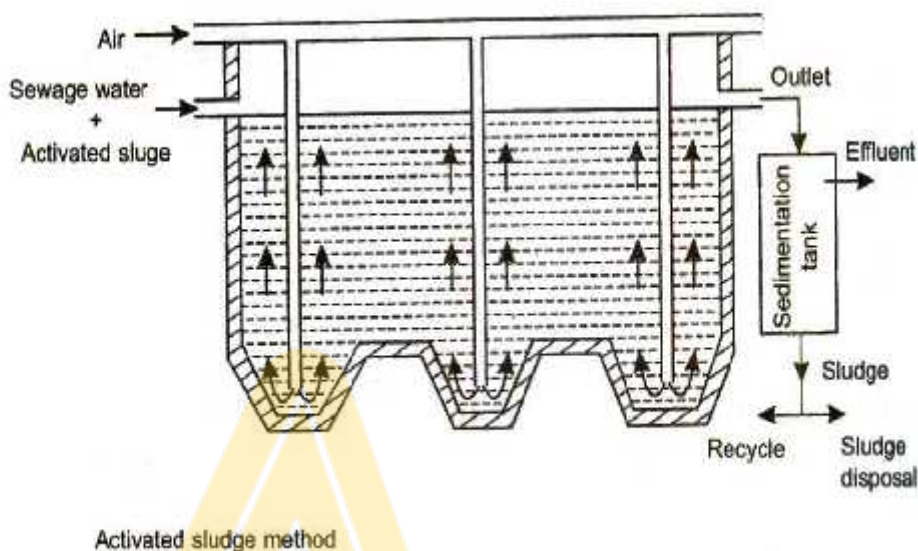
(ii) Secondary treatment: (Biological treatment)

- This process involves an aerobic biochemical oxidation or aeration.
- The sewage water, after sedimentation, is subjected to aerobic oxidation, during which the organic matter is converted into CO₂, the nitrogen into ammonia, & finally into nitrites & nitrates.
- Bases present in the sewage water form salt like ammonium nitrite, ammonium nitrate, calcium nitrate etc.
- Secondary treatment or biological treatment is generally accomplished by activated sludge process

Activated sludge process:

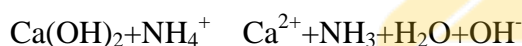
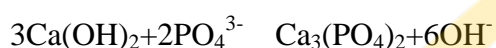
The waste water after the primary treatment is allowed to flow into large tanks where biological treatment is carried out. The sludge from the previous oxidation batch is known as activated sludge. Activated sludge containing aerobic bacteria & microorganisms. (From a previous operation) is mixed with the sediment sewage water. The mixture is aerated & agitated for several hours. During this process, organic matters are oxidized (aerobic oxidation). After the process is complete, the effluent is sent to a sedimentation

tank, where sludge is deposited & water free from organic matter is drawn off. A part of the settled sludge is sent back for seeding fresh batch of sewage. The effluent from secondary treatment has much lower organic load. This water, after chlorination to kill the pathogenic bacteria, is discharged into lakes, rivers, sea.



Tertiary treatment: The aim of tertiary treatment is further purification of wastewater as well as its recycling. The tertiary treatment consist of

(a) Removal of phosphate: The phosphates are removal by adding $\text{Ca}(\text{OH})_2$. A precipitate of calcium phosphate is formed at pH 10-11. At this pH, ammonium salts are converted into ammonia.



(b) Coagulation & sedimentation: The suspended fine particles are removed by sedimentation in the presence of coagulation like alum, ferrous sulphate, etc.

- The flocculent precipitates of $\text{Al}(\text{OH})_3$, or $\text{Fe}(\text{OH})_2$ formed by the coagulants entrap the fine particles & help them to settle down.
- The highly charged ions of the coagulants also neutralize the charges on colloidal particles & make them to coagulate & settle down.

(c) Filtration: For filtration, the water is passed through conventional sand filter beds to remove the last traces of suspended matter.

(d) Degasification: Stripping of ammonia & other gases is done in a degasifier consists of a large tower fitted with a number of perforated plates.

- The hot water trickles through these plates.
- Large surface area & higher temperature promote stripping of dissolved gases like NH_3 , CO_2 , and H_2S etc.

(e) Disinfection: The pathogenic bacteria's are destroyed by disinfection. Among many disinfectants, chlorine is cheap & effective.



- Unionized HOCl attacks the cells of bacteria & kills them. The final composition of tertiary treated waste water is $\text{BOD} < 1\text{ppm}$, $\text{NH}_4^+ < 1\text{ppm}$, $\text{PO}_4^{3-} < 1\text{ppm}$
- The treated water has high clarity, free from odour, low BOD, & therefore, it is nearly equivalent to drinking water & can be recycled.

Potable water:

Water that is fit for human consumptions & meets the stringent microbiological & chemical standards of quality to prevent waterborne diseases & health risks from toxic chemicals is called portable water

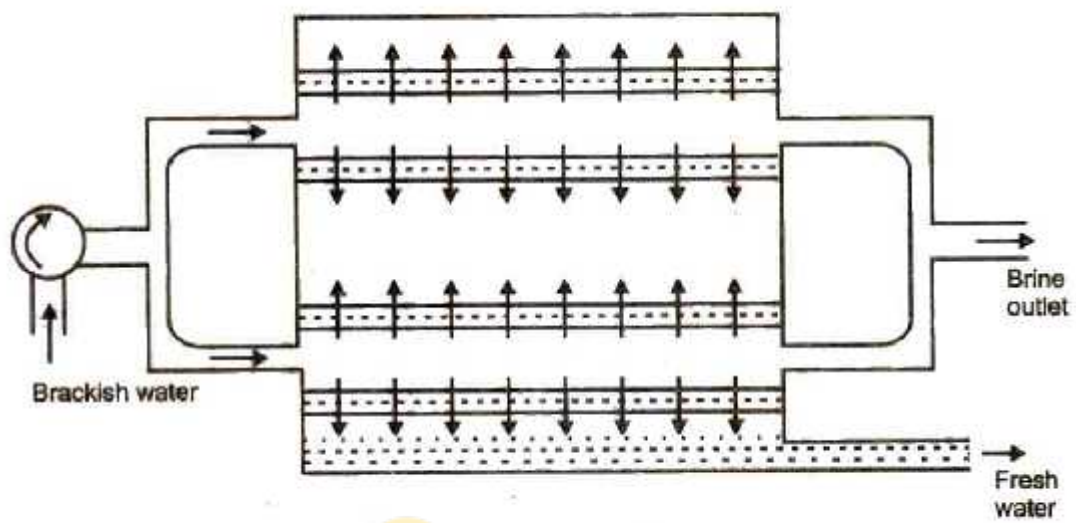
Desalination: (Purification of water):

The process of removal of dissolved salts (demineralization) from sea water to the extent, that water becomes usable is described as 'desalination' or 'desalting'

Desalination of water by Reverse osmosis:

The phenomenon of movement of water molecule from a region of lower concentration to a region of higher concentration in the presence of a semipermeable membrane and by the application of pressure (>Osmotic Pressure) is known as **Reverse Osmosis**.

Procedure: A series of tubes made up of porous material is lined on the inside with extremely thin film of cellulose acetate semi-permeable membrane. These tubes are arranged in parallel array in fresh water. Brackish water is pumped continuously at high pressure (>25atm) through these tubes. Water flows from brackish water into fresh water. The flow of water is proportional to applied pressure which in turn depends on the characteristics of the film. The film may rupture under excessive pressure. Further, greater the number of tubes, larger is the surface area, & more production of fresh water. Concentrated brine & fresh water are withdrawn through their respective outlets. This method, however, has not yet been used on large scale production of fresh water. The technique has not passed beyond the pilot plant & is only successful in the recovery of fresh water from brackish water.



Reverse osmosis method for desalination

