Water chemistry

- Importance of water quality standards(drinking, irrigation and recreation with reference Nepal standard)
- Degree of hardness, scale formation in boiler and softening of hard water(permutit and resin ion exchange)
- Water pollution with reference to turbidity, COD,BOD, heavy metals, radioactive substances, plastics(microplastics)
- Industrial wastewater and its treatment(aerobic and anaerobic)

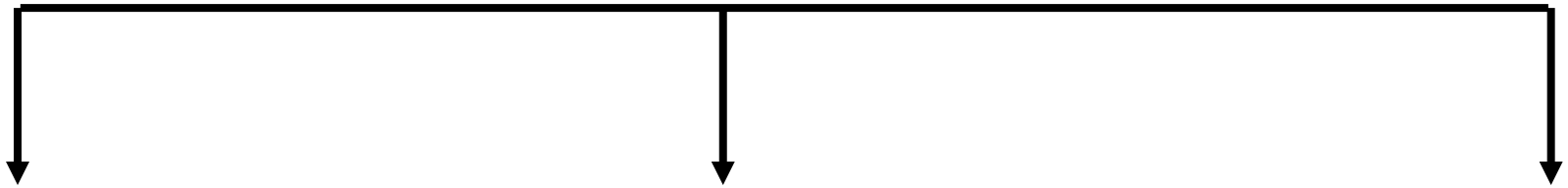
- Water is essential for the survival of all form of life.
- About 80% of the earth's surface is covered by water.
- The sources of water are surface water, underground water, rain water and sea water.
- Water is used in several purposes like Drinking, Agriculture, Domestic and Industrial consumption.
- As water is very essential to all field, certain parameters have been issued by Government of Nepal to implement the National Drinking Water Quality Standards,2062 under the provision of *Water Resources Act,2049, section 18,subsection 1.*
- Before using the water for different purposes, the nature and amount of contaminants present in water should be determined and removed.
- By knowing the concentration of contaminants present in water, we can say that whether water is alkaline, acidic, hard, soft or highly toxic.

- Hence, the treatment of water is essential so that it may be used safely for different field.
- There are several parameters of water to check water quality standards.
- These parameters include physical parameter, chemical parameter and biological parameter.
- Water quality parameters are essential indicators used to evaluate the suitability and safety of water for various purposes.
- They indicate the physical, chemical and biological properties of water.

National Drinking Water Quality Standard, 2079

S.N	Parameter	Unit	Maximum concentration on limit	Remarks
1	Physical parameters			
i.	Turbidity	NTU(Nephelometric turbidity unit)	5	NHBGV
ii.	pH		6.5-8.5	NHBGV
iii.	Color	TCU(Transmission control unit)	5	NHBGV
iv.	Electrical Conductivity	$\mu S/cm(microsimens\ per\ cm)$	1500	NHBGV
2	Chemical parameters			
i.	Iron(Fe)	mg/L	0.30	NHBGV
ii.	Arsenic	mg/L	0.05	HBGV
iii.	Ammonia	mg/L	1.50	NHBGV
iv.	Chlorides	mg/L	250	NHBGV
v.	Total hardness	mg/L	500	NHBGV
vi.	Residual chlorine	mg/L	0.10-0.50	
3	Microbiological Parameters			
i.	E.Coli	CFU/100ml	0	HBGV

Water Quality Standards



Physical parameters

- *Turbidity*
- *pH*
- *Color*
- *Taste and odor*
- *Electrical conductivity*

Chemical parameters

- *Acidity*
- *Alkalinity*
- *Chlorine*
- *Hardness*
- *DO*
- *BOD*

Biological parameters

- *Bacteria*
- *Algae*
- *Viruses*

Importance of Water Quality Standards:-

- To ensure that it is safe or not for human ,wild life and marine life to drink.
- To measure the quality of water.
- To identify specific pollutants i.e. source of pollution.
- Identifying trends, shorts and long-term in water quality.
- Environmental planning methods
- To protect water quality from degradation.

Hardness of water

- Water contains many dissolved minerals which make water either alkaline or hard water.
- Hardness of water is the ability of water to produce lather with soap.
- The water which produce lather easily with soap is called soft water.
- The water which can not produce lather easily and consumes more soap is called hard water.
- Hard water is not suitable for industrial purposes because of scale and sludge formation in the system but it is suitable for drinking purposes due to the presence of minerals which are essential to our body.
- Water becomes hard due to presence of dissolved minerals of calcium, magnesium and iron.

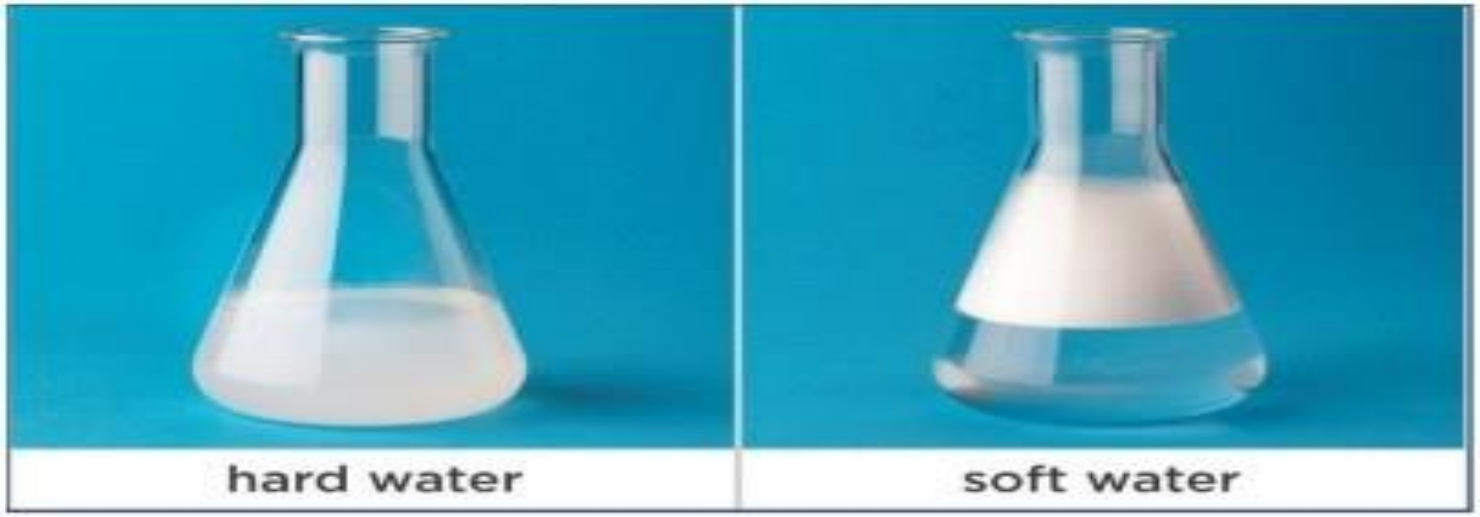
- On the basis of dissolved salt solution of calcium and magnesium, hardness of water are of two types.

a) Temporary hardness:- If water contains bicarbonate of calcium and magnesium, then it is called temporary hardness. The temporary hardness of water can be removed by boiling process.
Reaction:-

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3\downarrow + CO_2\uparrow + H_2O$$
$$Mg(HCO_3)_2 \xrightarrow{\Delta} MgCO_3\downarrow + CO_2\uparrow + H_2O$$

b) Permanent hardness:- If water contains chloride and sulphate of calcium and magnesium, then it is called permanent hardness. The permanent hardness of water can be removed by permutit method and ion-exchange method.

- When hard water is treated with soap solution, the metallic bivalent ions present in water combine with anions of soap forming white ppt(scums).Thus, there is no lather produce until all bivalent metal ions get combine with soap.



$$Ca^{++} + 2C_{17}H_{35}COONa \longrightarrow (C_{17}H_{35}COO)_2Ca\downarrow + 2Na$$

Hard water from soap — Calcium stearate curdy ppt.

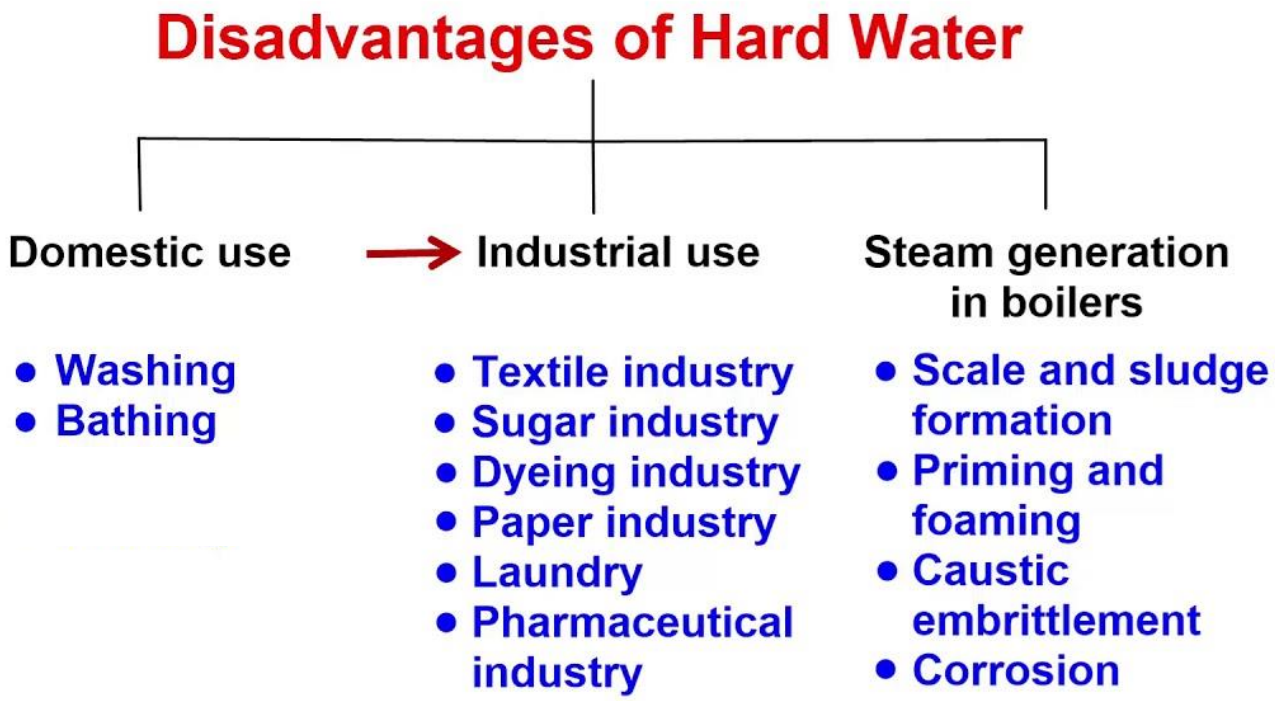
$$Mg^{++} + 2C_{17}H_{35}COONa \longrightarrow (C_{17}H_{35}COO)_2Mg\downarrow + 2Na$$

Hard water from soap — Magnesium stearate insoluble ppt.

Degree of hardness of water

- Hardness of water is generally expressed in terms of equivalent hardness of single salt.
- For the measurement of hardness, we use the calcium carbonate as a reference for single salt because it is insoluble in water and it has 100 molecular weight.
- Hardness of water is calculated in terms of parts per million(PPM).
- The number of parts of calcium carbonate or equivalent calcium and magnesium salts present per million parts of water is called degree of hardness.
- If the concentration of water in terms of $CaCO_3$ is below 75 mgL^-,then such type of water is considered as soft water. Similarly, if it has concentration in between 70-150 mgL^-, considered as moderate hard water and 151-300 mgL^-, considered as hard water and above 300 mgL^-,considered as very hard water.

Disadvantages of hard water



Softening of hard water

- The removal of hardness of water by using different techniques are called softening of hard water.
- Generally, there are three methods for softening of hard water.

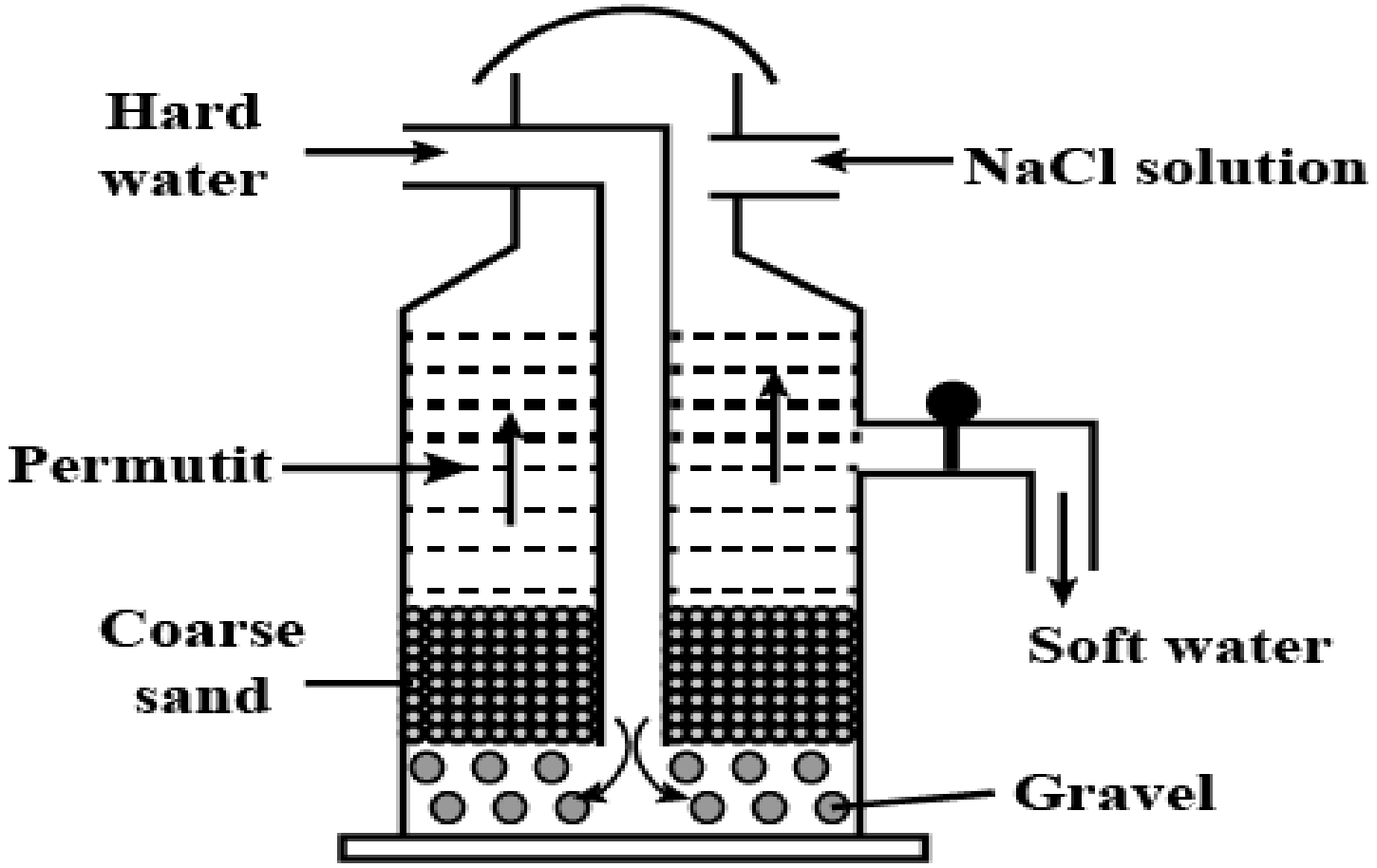
a. Soda-ash method
b. Permutit process(zeolite)
c. Ion exchange method(de-ionization method)

Permutit method

- Permutit process is one of the best method for softening of hard water.it is used to remove both temporary and permanent hardness of water.
- This process consist of tank or column in which gravel, sand and permutit are placed in alternate layers.
- Permutit is an artificial zeolite which is hydrated sodium alumina-orthosilicate and has formula $Na_2Al_2Si_2O_8.XH_2O$.
- Zeolite can be represented by Na_2Z where Z= $Al_2Si_2O_8.XH_2O$
- The hard water is poured from top into the base of tank.
- As water passes through the permutit, the ions of calcium and magnesium which are responsible for hardness are exchanged with the sodium ions of permutit.

- Due to this exchange of ions, calcium and magnesium ions get trapped in permutit and sodium ions passes from the permutit to water. As a result , water becomes soft with the removal of calcium and magnesium ions.
- During this process, the exchange of cations with zeolite is reversible process. Thus, CaZ and MgZ is regenerated into Na_2Z by reacting with a 10% solution of sodium chloride which is passed through the another inlet.
- The soluble salt of calcium and magnesium thus formed is washed away by water and the regenerated permutit again works.

- The diagram of permutit method is show below.



- Reaction involved in permutit process are following.

- **Chemical Reaction:**

$$Ca(HCO_3)_2 + Na_2Ze \rightarrow CaZe + 2\,NaHCO_3$$

$$CaSO_4 + Na_2Ze \rightarrow CaZe + Na_2SO_4$$

$$MgCl_2 + Na_2Ze \rightarrow MgZe + 2NaCl$$

$$Mg(NO_3)_2 + Na_2Ze \rightarrow MgZe + 2NaNO_3$$

- Exchange of Na ions continues until Na ions are exhausted

Regeneration:

$$CaZe + 2NaCl \rightarrow Na_2Ze + CaCl_2$$

$$MgZe + 2NaCl \rightarrow Na_2Ze + MgCl_2$$

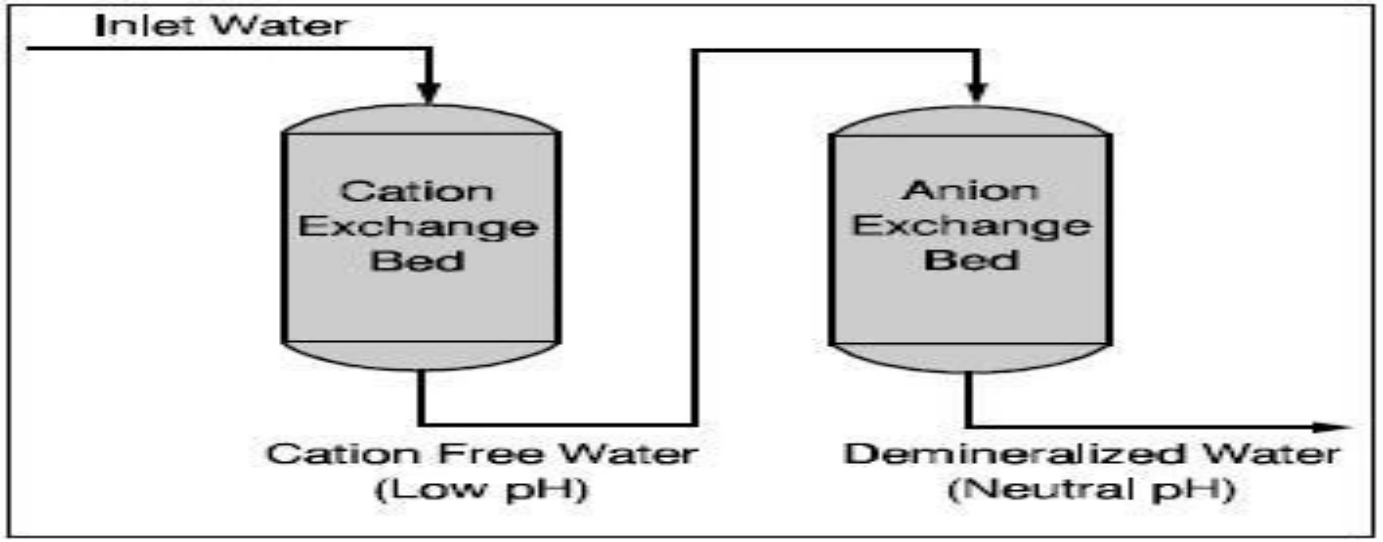
- $CaCl_2$ and $MgCl_2$ led to drain and Na_2Ze can be reused.

Ion-exchange method

- Ion exchange method are used for efficient removal of dissolved ions from water.
- In this process, ion –exchange resins are used.
- Resins are organic polymer having acidic or basic functional groups.
- Resins having acidic functional group exchange their H^+ with cations present in hard water and basic functional group exchange their anions with anions present in hard water.
- This process is also called de-ionization method.
- Water which is free from all the ions is called de-ionization water or demineralized water.
- Deionized water is very important in industrial application and research work.
- Distilled water and deionized water are not same. Distilled water is prepared by distillation of impure water and it is free from those component which has higher boiling point than water.

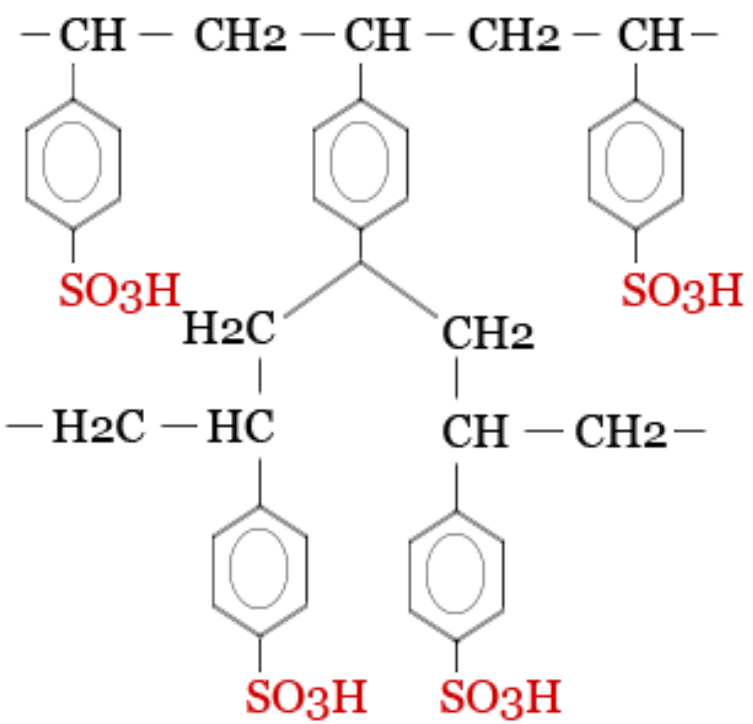
- The reaction involved in ion exchange method are following.
  In cation exchange resin:-
  $R\text{-}SO_3H(Resin) + M^+(cation\ of\ water) \longrightarrow RSO_3M + H^+$
  In anion exchange resin:-
  $-CH_2Me_3Cl(Resin) + A\text{-}(anion\ of\ water) \longrightarrow -CH2Me_3A + Cl^-$

- The instrumental diagram of ion-exchange method is following.

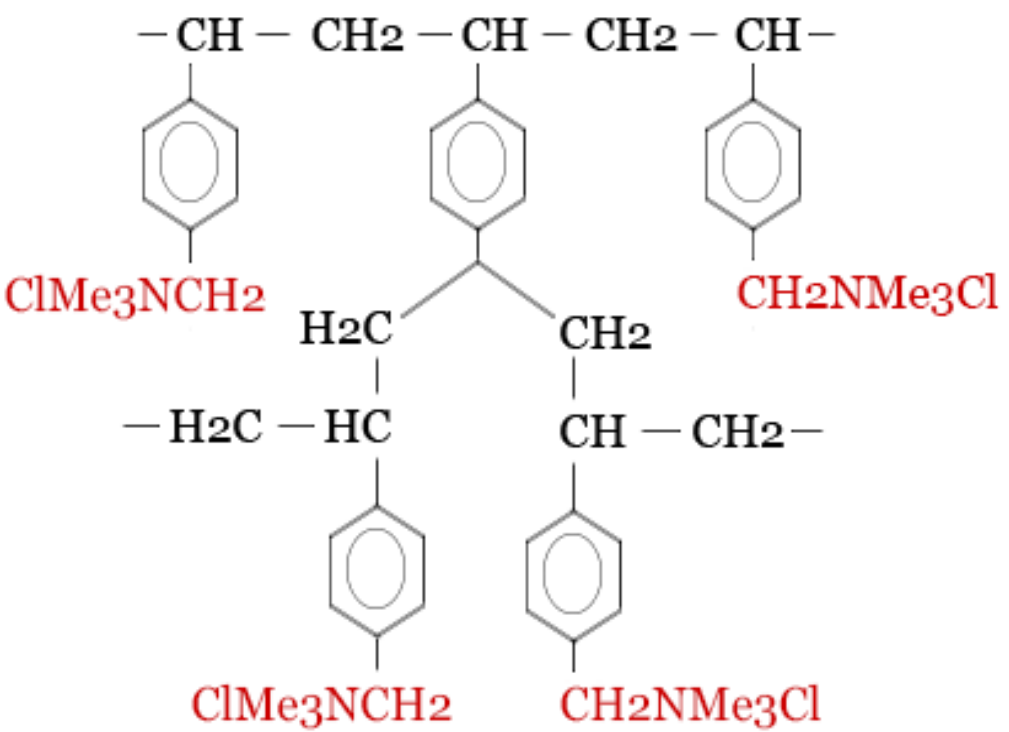


Ion Exchange Resin

Cation exchange resin



Anion exchange resin



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Water pollution:-

- Water pollution with reference to
- Turbidity
- COD
- BOD
- Heavy Metals
- Radioactive substances
- Plastics(Microplastics)

- Water pollution can be defined as the presence of solid, liquid and gaseous contamination in such concentration that they may alter the quality of water.
- The substances which cause the water pollution is called water pollutants.
- The process of deterioration of quality of water is called water pollution.
- When undesirable and toxic substances introduced in lakes, streams, rivers, ocean and other water body, they get dissolved or suspended in water body which results pollution in water and quality of water is decreased.
- The source of water pollution may be natural or manmade. Man-made sources of water pollution are domestic effluents, industrial effluents, agricultural effluents and surface runoff.

- Following are some common water pollutants(prescribed by syllabus) which are highly responsible for water pollution.

➢Turbidity

➢Organic materials(COD & BOD)

➢Heavy Metals

➢Radioactive material

➢Plastics(Microplastics)

Turbidity

- Turbidity is a measure of the level of particles such as sediment, plankton, organic by-product in a body of water.
- Turbidity is caused by suspended organic and inorganic particles such as clay, slit, sediments, algae, plant pieces, melting Glaciers, sawdust, wood ashes or chemicals etc.
- As the turbidity of water increases, it becomes denser and less clear due to which water becomes polluted.

Effect of turbidity:-

- Raising water temperature
- Decrease the amount of dissolved oxygen(DO)
- Blocks sunlight for photosynthesis in aquatic plants
- Reducing biomass and growth rate of aquatic plants
- Hindering visibility which makes difficult for predators to find prey.

Organic matters

- Organic matters are anything that contains carbon compounds formed by living organisms.
- Generally, domestic wastewater and industry of food and beverage production can release excess organic matters in water body.
- If high amount of organic matters are present in water, then there will be high demand of dissolved oxygen(DO) .
- And the amount of oxygen required by micro-organism for biological oxidation of organic matters as food is called biological oxygen demand(BOD).
- Thus, the larger the BOD value indicates that water is polluted due to the large amount of organic matters.
- Similarly, chemical oxygen demand(COD) is another major indicator of water pollution.

- Chemical oxygen demand(COD) is the capacity of water to consume oxygen during the decomposition of organic matters in water.
- COD is higher than BOD in polluted water.
- Hence, the greater the COD & BOD ,the more rapidly oxygen is depleted in the streams, rivers and other water body. These means less oxygen is available to aquatic life. As a result, aquatic organisms become stressed, suffocated and finely die.

Heavy metals

- Heavy metal is defined as any metallic chemical element that has a relatively high density and is toxic or poisonous even at low concentration.
- Generally, waste water contains Lead(Pb), Mercury(Hg), Copper(Cu), Zinc(Zn), Nickel(Ni), Cadmium(Cd), Chromium(Cr) and Arsenic(As) as a heavy metals.
- Heavy metals are non-biodegradable and carcinogenic in nature.

Sources of heavy metals:-

- Natural sources:- volcanic eruption, weathering, rock abrasion etc.
- Anthropogenic sources:- power plant, biomedical wastes, industrial effluents, mining & smelting operation, agricultural activities etc.

Effect of heavy metals:-

- Can cause harm to various organs, including the neurological system, liver, lungs, kidneys, stomach, skin and reproductive system.
- Can cause DNA damage and instigate genotoxicity in aquatic animals.
- Can change the pH value of water.
- Sensory abnormalities, hearing loss and blurred vision and sensitivity to light.
- Heavy metal can adversely affect on plant during seed germination, photosynthesis, respiratory, mineral uptake, proteins contents etc.

Radioactive substances

- Radioactive substances are those chemicals whose nucleus of the atom is unstable.
- The elements which have high atomic number, unstable in nature, can undergo radioactive decay, toxic in nature and can emit Alpha, Beta and Gama radiation are called radioactive substances. For examples:-Radium, Uranium and Thorium.
- Radioactive substances introduce into water body from different nuclear testing, nuclear power plants, reprocessing reactor and dumping of waste materials and finally water gets polluted.

Sources of radioactive substances:-

- Nuclear power plant
- Mining
- Nuclear weapons
- Radioactive decay
- Defensive weapon development
- Nuclear airburst tests
- Uses of radioactive isotopes
- Radium and uranium are naturally found in almost all rocks and soil in small amount.

Effect of radioactive substances:-

- Due to radioactive substances different diseases like anemia, leukemia, cardiovascular diseases, cancer, skin redness, hair loss, acute radiation syndrome in human heath.
- Affect reproductive organs of plant and reduce plant reproduction.
- Decrease the soil fertility.
- Can cause genetic mutations in living organisms and in their descendants.
- Creates the toxic environment in marine life.

Plastics(Microplastics)

- Plastic is the polymer made by long chain of carbon.
- The production and use of plastics have been increased day by day, as a result plastic pollution is occurring now a days.
- Plastic pollution is the accumulation of plastic products like plastic bags, plastic ropes, plastic bottles, plastic papers, and other utensils in the environment(air, water and soil) that creates the problems for wildlife, aquatic life and human populations.
- Mostly, microplastic products are highly used in now a days. Generally, they are synthesized to use in cosmetics, drug delivery, fertilizers, household and industrial detergents, paints and products etc.
- Microplastics are synthetic, high molecular weight polymer having the size less than 5mm.it has low biodegrading rate and accumulating in the environment to show adverse effect.

Sources of microplastic:-

- Synthetic textiles
- Vehicle tyres
- Road marking
- Marine coating
- Personal care products and cosmetics
- City dust
- Plastic pellets

Effect of Microplastics:-

- Can cause genetic damage, immunotoxicity, neurotoxicity and genotoxicity to marine life.
- Show variety of toxic effect on human body like oxidative stress, metabolic disorder, immune response, reproductive and development toxicity.
- Affecting root growth of plants
- Reducing leaf growth
- Decreased seed germination and declined grain yield.
- Declined photosynthesis and chlorophyll.

Remedies of water pollution:-

- Waste water treatment
- Reducing plastic product, reuse and recycling
- Water conservation
- Stormwater management
- Septic tanks
- Stabilization of ecosystem
- Dead body should not thrown in water bodies
- Awareness about heavy metals, radioactive substances should be created among the people.
- Banning nuclear tests
- Proper disposal of radioactive wastes
- Using alternative ecofriendly source of energy.

Industrial waste water and its treatment

- Water is the key component in industrial manufacturing processes. The large volume of water is consumed in industry and after completing the manufacturing process, it again release the water as a form of wastewater.
- Industrial wastewater is the aqueous discard that results from substances having being dissolved or suspended in water. Such industrial wastewater contain more toxic and hazardous substances which are very harmful to human health, aquatic life and all kind of environment.
- Thus , treatment of industrial wastewater should be compulsory before discharging it into the water body or any places.
- Industrial wastewater treatment is the process used for treating wastewater that is produced by industries as an undesirable by-products. After treatment, this wastewater can be reused in different field.

- Low economic resources and technical limitations are major shortcomings to combat the management of industrial wastewater.
- The management of industrial wastewater has facing problems in police maker, good engineers and stakeholders.
- The most commonly used industrial wastewater treatment techniques are:-

➢Adsorption
➢Coagulation
➢Ozonation
➢Membrane filtration
➢Ion exchange method
➢Chemical oxidation and
➢Biological treatments

- Basically there are two approaches for the treatment of industrial wastewater, one is conventional approach which is focused on removal of organic matters , microorganisms and suspended particles and another is current approach which is focused on eco-friendly sustainable process.
- The industrial wastewater treatment may be aerobic treatment or anaerobic treatment.
- Aerobic wastewater treatment requires the use of oxygen, while anaerobic does not requires the oxygen. Both processes utilize natural organisms like bacteria to further breakdown the organic waste present in wastewater.
- There are three key industrial wastewater treatment steps:-

i. Primary treatment

ii. Secondary treatment

iii. Tertiary treatment

Primary treatment:-

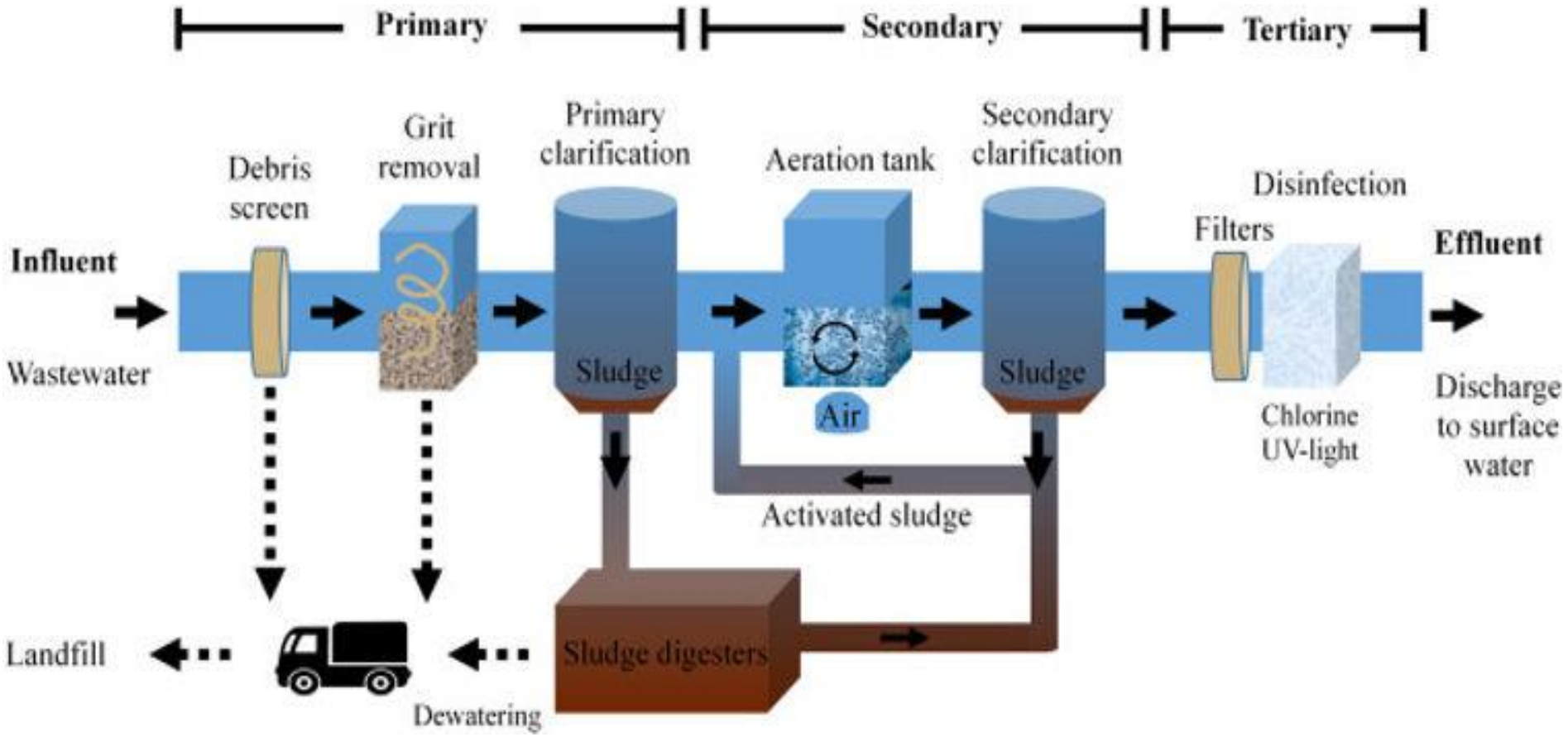
a. The primary step of the industrial wastewater treatment process is the removal of solid wastes that will either suspended or easily settle out by gravity.
b. This step includes the physical process like screening, grit removal and sedimentation etc.

Secondary treatment:-

a. The secondary step is related with biological wastewater treatment.
b. In this step, bacteria and microorganism are used to breakdown the organic wastes.
c. This process is designed in such a way that to reduce the amount of organic materials in the wastewater before it is discharge to a disposal field for final treatment.

Tertiary treatment:-

a. Tertiary treatment is a method of wastewater treatment that consists of removing non-biodegradable pollutants.
b. It follows primary and secondary treatment.
c. This steps helps to remove the heavy metals and radioactive metals.
d. Tertiary treatment process includes the following techniques like membrane separation processes(microfiltration, ultrafiltration and reverse osmosis), adsorption, disinfection, advanced oxidative processes etc.


Primary
Secondary
Tertiary
Debris screen
Grit removal
Primary clarification
Aeration tank
Secondary clarification
Disinfection
Filters
Influent
Wastewater
Sludge
Air
Sludge
Effluent
Chlorine UV-light
Discharge to surface water
Activated sludge
Landfill
Sludge digesters
Dewatering