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WATER

☆ Characteristics of Water :-

1. Ph

- Physical
- Chemical
- Biological

1. Physical Characteristics :-

(a) Temperature :- For portable water, temp. of about 10°C is desirable. It shouldn't be more than 25°C.

(b) Colour :- Chemically pure water is blue due to the presence of suspended particles on it.

(c) Taste and ~~Water~~ Odour :- It is measured by a term called odour intensity, which is related with the threshold odour or threshold odour number.

For public supplies, the water should generally free from odour, i.e. the threshold number should be 1 & ~~he~~ should never exceed 3.

(d) Electrical Conductivity :- It is due to the presence of dissolved salts in water.

(e) Turbidity of Water :- It is measured by a turbidity rod and is expressed as the amount of suspended matter in mg/l or ppm.

2. Chemical Characteristics :-

(a) pH :- pH is a measure of the intensity of acidity or alkalinity in a water expressed in terms of the negative logarithm to the base 10 of hydrogen ion concentration.

(6.6-8.4)

$$pH = -\log_{10}[H^+] \Rightarrow pH = \frac{1}{\log_{10}[H^+]}$$

(b) Alkalinity :- It is due to the presence of bicarbonate, carbonate or hydroxide ions.

bicarbonate alkalinity :- pH range 4.5-8.3
carbonate / hydroxide :- pH exceeds 8.3

(c) Acidity :- Most natural waters are buffered by a carbon dioxide / bicarbonate system in which carbonic acid exists in the pH range 4.5 to 8.3.

(d) Hardness :- The property which resists water from forming lather with soap.

solution is termed as hardness of water. Hardness of water is due to the presence of certain impurities which is in the form of bicarbonates, chlorides and sulphates of calcium and magnesium.

It is of two types :-

i) Temporary and ii) permanent hardness

Total Hardness = Non-carbonate Hardness + Alkalinity

(e) Dissolved Oxyzen (DO) :- It is one of most important parameters of water. The concentration of D.O. in water is essential for aquatic life.

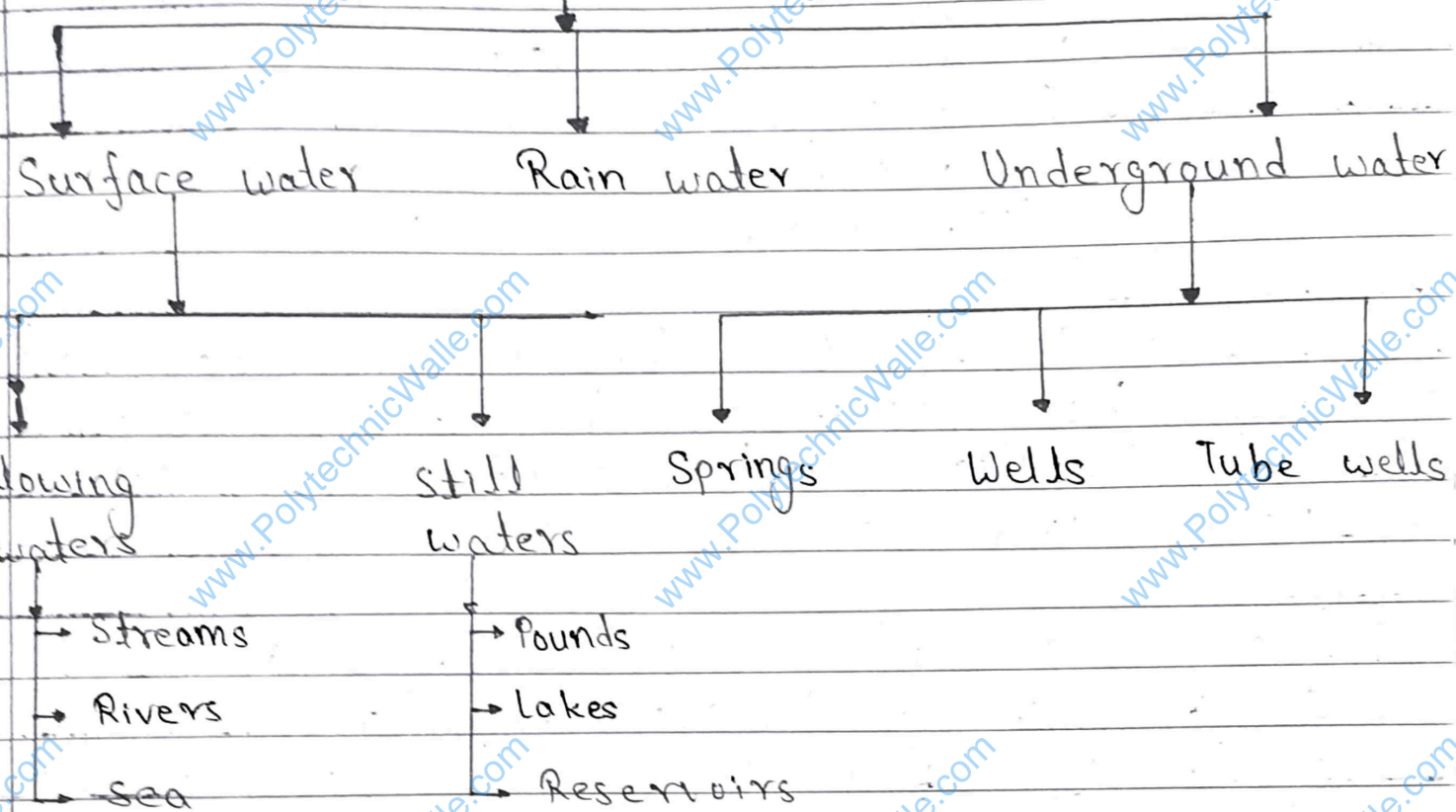
(f) Oxyzen Demand :- When the dissolved oxyzen is low in water then needed oxyzen demand for the oxidation of organic & inorganic matters is called oxyzen demand.

It is of two types :-

i) BOD (Biochemical / Biological Oxyzen Demand)
ii) COD (Chemical Oxyzen Demand)

Imp

Sources of Water :-



1. Surface Water :- Surface sources are those sources of water in which the water flows over the surface of the earth, and is directly available for water supplies.

The important surface water sources are :-

(a) Flowing Waters :- The water that flows on the surface of earth is called flowing waters.

e.g.:- (i) Streams,
(ii) Rivers,
(iii) Sea Water

(b) Still Waters :- The water that doesn't flow on the surface of earth is called still waters.

e.g.:- (i) Ponds,
(ii) Lakes,
(iii) Reservoirs.

2. Underground Water :- The water that found in the underground such as in the cracks and spaces in soil, sand and rock.

or,

The water which gets stored in the ground water reservoir through infiltration etc. is known as underground water. This water is generally pure because it undergoes natural filtration.

(a) Springs :- It is a natural process by which the ground water is brought to the surface.

(b) Wells :- The underground water can be obtained artificially by constructing wells and lifting water from them.

(c) Tubewells :- It is designed to obtain large discharge. It is generally a long pipe of tube.

✱ Impurities in Water :-

1. **Suspended Impurities :-** The water may contain suspended insoluble matter generally known as turbidity. Such impurities comes from clay, mud, fungi, industrial waste and organic matter vegetable and animal matter both. River water mainly contains suspended impurities.

2. **Dissolved Impurities or Chemical Impurities :-** Water of spring or well contains dissolved impurities.

(a) **Mineral Salts :-** Such as bicarbonates, sulphates & chlorides of calcium and magnesium. These salts make the water hard.

The other dissolved impurities are the salts of Na, K, Fe, Mn, silica, alumina etc.

(b) **Gases :-** Among the dissolved gases oxygen is mostly dissolved in natural water. Other gases generally present are CO_2, H_2S, N_2, oxides of nitrogen ammonia etc.

3. **Colloidal Impurities :-** These impurities exist in very finely divided state such that their small quantities aren't

visible to the naked eye. Organic matter containing micro organisms (bacteria) is in the form of colloidal impurity.

4. Biological Impurities or Microscopic Impurities:- Various pathogenic micro-organisms such as fungi, bacteria, viruses etc. also enter into water bodies through sewage and other wastes.

Imp ☆ Soft Water :→ Water which (form) lathers with soap easily is called soft water.
→ It is free from calcium and magnesium salts.
→ e.g.:- Distilled and rain water are soft in nature and quality.
→ Uses :- i) Household activities
ii) Industries
iii) Laboratories
→ It contains sodium and potassium salts.
→ Sodium is linked to heart disease.

☆ Hard Water :-
→ Water which doesn't form lather with soap is called hard water.
→ Hardness of water is caused due to the presence of salts of calcium and magnesium in it.
→ The sources of hard water are

sea, rivers, wells and springs.

→ Uses :- (i) Cleaning
(ii) drinking
(iii) cooking etc.

→ Soap instead of lather forms thick sticky scum.

→ The calcium compounds in it are good for bones and teeth.

Imp ☆ Hardness of Water :-

→ The property which resists water from forming lather with soap solution is termed as hardness of water.

→

Causes of Hardness :- Hardness of water is due to the presence of certain impurities in the form of bicarbonates, chlorides and sulphates of calcium and magnesium. Water containing any of these salts doesn't produce lather with soap easily. ~~and~~

→ Soaps ~~are~~ of the K & Ca salts are of higher fatty acids like stearic acid ($C_{17}H_{35}COOH$), palmitic acid ($C_{15}H_{31}COOH$) etc.

→ When hard water containing Ca^{2+} or Mg^{2+} ions reacts with a soap sol^n, a precipitate of the Ca & Mg salts of the respective fatty acid is formed :-

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

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

Ca^{2+} or $Mg^{2+} + 2C_{15}H_{31}COONa \longrightarrow (C_{15}H_{31}COO)_2Ca \downarrow$ or $+ 2Na^+$ $(C_{15}H_{31}COO)_2Mg \downarrow$

Sodium palmitate (soluble in water)

(Insoluble ppt in water)

Ca^{2+} or $Mg^{2+} + 2C_{17}H_{35}COOK \longrightarrow (C_{17}H_{35}COO)_2Ca \downarrow$ or $+ 2K$ $(C_{17}H_{35}COO)_2Mg \downarrow$

Potassium stearate (Solube in water)

(Insolube ppt in water)

* V.V.I

Types of Hardness :-

- Temporary Hardness
- Permanent Hardness

1. Temporary Hardness or Carbonate Hardness :-

→ Temporary Hardness is due to the presence of dissolved bicarbonates of calcium and magnesium.

→ This hardness can be removed only by boiling of water, when bicarbonates are converted into insoluble carbonates.

→ $Ca(HCO_3)_2 \longrightarrow CaCO_3 \downarrow + H_2O + CO_2$

$Mg(HCO_3) \longrightarrow MgCO_3 \downarrow + H_2O + CO_2$

Total Hardness = T.H + P.H.

2. Permanent Hardness or Non-carbonate Hardness:-

→ Permanent hardness is caused by the dissolved salts of calcium and magnesium, instead of bicarbonates.
- They are chlorides, sulphates, nitrates etc.

→ Permanent hardness cann't be removed by boiling. Removal of this hardness requires certain special chemical treatment

	Temporary Hardness	Permanent Hardness
1.	It is due to the presence of bicarbonates of Ca & Mg.	It is due to the presence of chloride, sulphate salts of Ca+Mg.
2.	It can be removed by boiling & clark's method.	It cann't be removed by boiling & clark's method
3.	Hardness removal is cheap.	Hardness removal is expensive.
4.	It is also called alkali hardness.	It is also called non-alkaline hardness.
5.	It is due to the carbonate hence known as carbonate hardness.	It is due to the other salt hence known as non-carbonate hardness
6.	e.g.:- $Ca(HCO_3)_2 \rightarrow CaCO_3\downarrow + CO_2\uparrow + H_2O$ $Mg(HCO_3)_2 \rightarrow MgCO_3\downarrow + CO_2\uparrow + H_2O$	e.g.:- $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3\downarrow + Na_2SO_4$ $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2NaCl$

Imp (Numericals)

* Degree of Hardness :-

→ The degree of hardness is defined as the ratio of weight of hardness to the molecular weight of hardness multiplied with hundred.

→ Degree of hardness can be expressed as equivalent of $CaCO_3$.

→ Degree of Hardness

$$= \frac{\text{weight of hardness}}{\text{molecular weight of hardness}} \times 100$$

where, 100 = molecular weight of $CaCO_3$

or,

$$= \frac{\text{Weight of hardness}}{\text{equivalent weight of hardness}} \times 50$$

where, 50 = equivalent weight of $CaCO_3$.

* Unit of Hardness :-

1. Parts per million (ppm) [1 ppm = 10^6]

1 ppm = 1 part of $CaCO_3$ equivalent hardness in 10^6 parts of water

2. Milligrams per litre (mg/L) [1 mg/L = 10^6]

1 mg/L = 1 mg of $CaCO_3$ equivalent hardness in 1 litre (10^6 mg) in water.

3. Degree Clarke's (°Cl) [1°Cl = 7×10^{-4}]

1°Cl = 1 part of $CaCO_3$ equivalent hardness per 70000 (7×10^4 or 0.07°Cl) parts of water.

4. Degree French (°Fr) [1°Fr = 10^5]

1°Fr = 1 part of $CaCO_3$ equivalent hardness present in 10^5 parts of water.

Relation b/w units of hardness :-

1 ppm = 1 mg/l = 0.07 °Cl = 0.1° Fr

✱ Boiler's (Steam Generation) :-

→ Most of the water used in industry and powerhouses is in the form of steam. For steam generation, boilers are almost always employed.

→ Boiler's are generally classified according to their pressures into three categories.

a) Low-pressure boilers :- Up to 15 kg/cm²
b) Medium-pressure boilers :- 15 to 30 kg/cm²
c) High pressure boilers :- Over 30 kg/cm²

Imp — # Sludge & Scale

★ Sludge :-

→ It is a soft, loose and slimy precipitate formed in the boiler.

→ Cause :- Sludges are usually formed due to the presence of $MgCO_3$, $MgCl_2$, $CaCl_2$ and $MgSO_4$ etc.

→

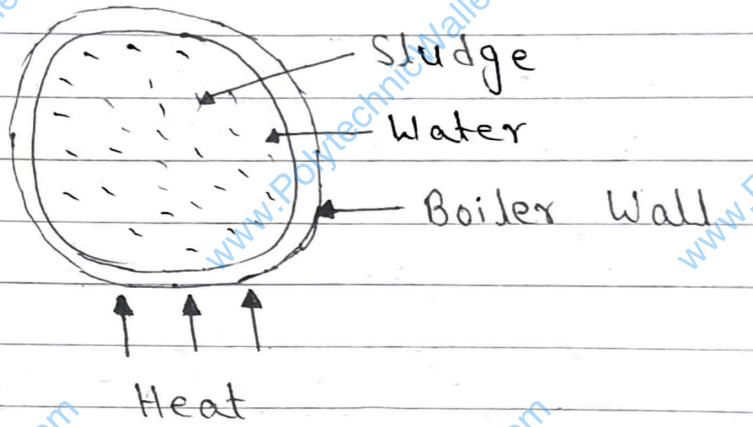


Figure :- Sludge

→ Disadvantages :-

(a) Sludges are bad conductor of heat. Thus, result in the waste of heat and fuel.

(b) Excess sludge decreases the efficiency of the boiler.

★ Scale :-

→ Scales are hard, crusts or coatings formed on the inner walls of the boiler during steam generation. They are difficult to remove, even with the help of a hammer.

→

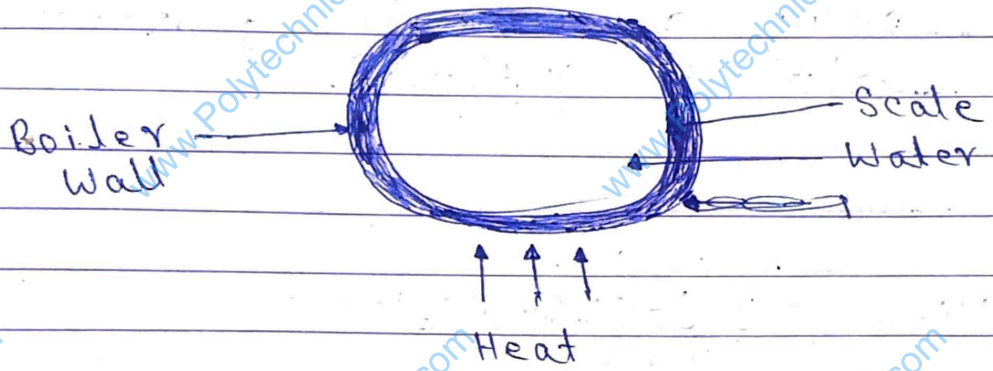


Figure :- Scale

→ Causes :- In boilers, scales are formed mainly due to the presence of $MgCl_2$, $CaSO_4$, $Ca(OH)_2$, $Mg(OH)_2$ & silica.

→ Disadvantages :-

(a) Scale is bad conductor of heat and decreases the efficiency of the boiler.
(b) Excess of scale formation may block the boiler tubes and decreases the efficiency of the boiler.

17th July

Methods of Softening Hard Water

Boiling

Principle : Temporary hard water contains calcium and magnesium bicarbonates. These salts are decomposed on boiling the water forming insoluble calcium and magnesium carbonates which can easily be removed by filtration and thus water is softened.

Chemical Reactions :

$$Ca(HCO_3)_2 \longrightarrow \underset{\text{Insoluble}}{CaCO_3\downarrow} + CO_2\uparrow + H_2O$$

$$Mg(HCO_3)_2 \longrightarrow \underset{\text{Insoluble}}{MgCO_3\downarrow} + CO_2\uparrow + H_2O$$

Limitations :

- Only effective on domestic scale
- Can't be softened the whole of a water supply.

Imp

Clark's Method

Introduction : It is the cheapest method for removing temporary hardness in water. Therefore, it is widely used.

Principle : In this method, sufficient amount of lime is added to the water which converts all the soluble bicarbonates into insoluble carbonates.

Chemical Reactions :

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow MgCO_3\downarrow + CaCO_3\downarrow + 2H_2O$$

Limitations :

- On adding too much excess of lime, ~~wat~~ it becomes harden and not soften the water.
- The permanent hardness of water can not be removed.

Soda Ash

Principle: The permanent hardness can be removed by addition of the calculated quantity of soda (sodium carbonate) by which calcium and magnesium carbonates are precipitated.

Chemical Reactions:

$$CaSO_4 + Na_2CO_3 \longrightarrow \underset{(ppt)}{CaCO_3}\downarrow + Na_2SO_4$$

$$MgCl_2 + Na_2CO_3 \longrightarrow \underset{(ppt)}{MgCO_3}\downarrow + 2NaCl$$

- The temporary hardness is also removed as shown,

$$Ca(HCO_3)_2 + Na_2CO_3 \longrightarrow \underset{(ppt)}{CaCO_3} + 2NaHCO_3$$

Imp Lime Soda (L-S) Process

Principle: L-S process is a very popular and easy method for softening of water. ~~Thi~~ In this process, the soluble hardness-producing salts is converted into insoluble precipitates with the help of soda (Na_2CO_3) and lime ($Ca(OH)_2$). Insoluble precipitates can easily be removed by filtration and settling.

Coagulants Requirement: Alum $[K_2SO_4.Al_2(SO_4)_3.24H_2O]$
or, Sodium Aluminate $[NaAlO_2]$

Functions of Lime [$Ca(OH)_2$]:

Lime is used for removing temporary hardness, permanent Mg hardness, dissolved CO_2 and H_2S gases etc.

Chemical Reactions:

(a) Removal of temporary hardness.

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O \quad \text{---(1)}$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow MgCO_3 + CaCO_3 + 2H_2O$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + Mg(OH)_2\downarrow + 2H_2O \quad \text{---(2)}$$

(b) Removal of permanent hardness due to Mg salts.

$$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCl_2 \quad \text{---(3)}$$

$$MgSO_4 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaSO_4 \quad \text{---(4)}$$

(c) Removal of dissolved CO_2 and H_2S gases:

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O \quad \text{---(5)}$$

$$H_2S + Ca(OH)_2 \longrightarrow CaS\downarrow + 2H_2O \quad \text{---(6)}$$

Functions of Soda [Na_2CO_3]:

In eq^n (3) and (4), the permanent ~~hardness~~ Ca hardness is generated in the water due to formation of calcium salts (e.g. $CaCl_2$ and $CaSO_4$).

This calcium hardness present is removed by soda.

Chemical Reactions :

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl \quad \text{---(7)}$$
$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 + Na_2SO_4 \quad \text{---(8)}$$

- Limitations :

- Proper mixing of chemical and water.
- Giving proper time for the completion of reactions.
- The use of coagulants such as alum or $NaAlO_2$.

- Types :

- Cold lime-soda process : At room temp.
- Hot lime-soda process : At higher temp. (90-100°C)

Zeolites are the inorganic complex salts with the property of exchanging the hardness producing ions (e.g. Ca^{2+}, Mg^{2+}, etc) with simple (e.g. Na^+) ions.

V.V.I

Zeolite Process [Permutit's Process]

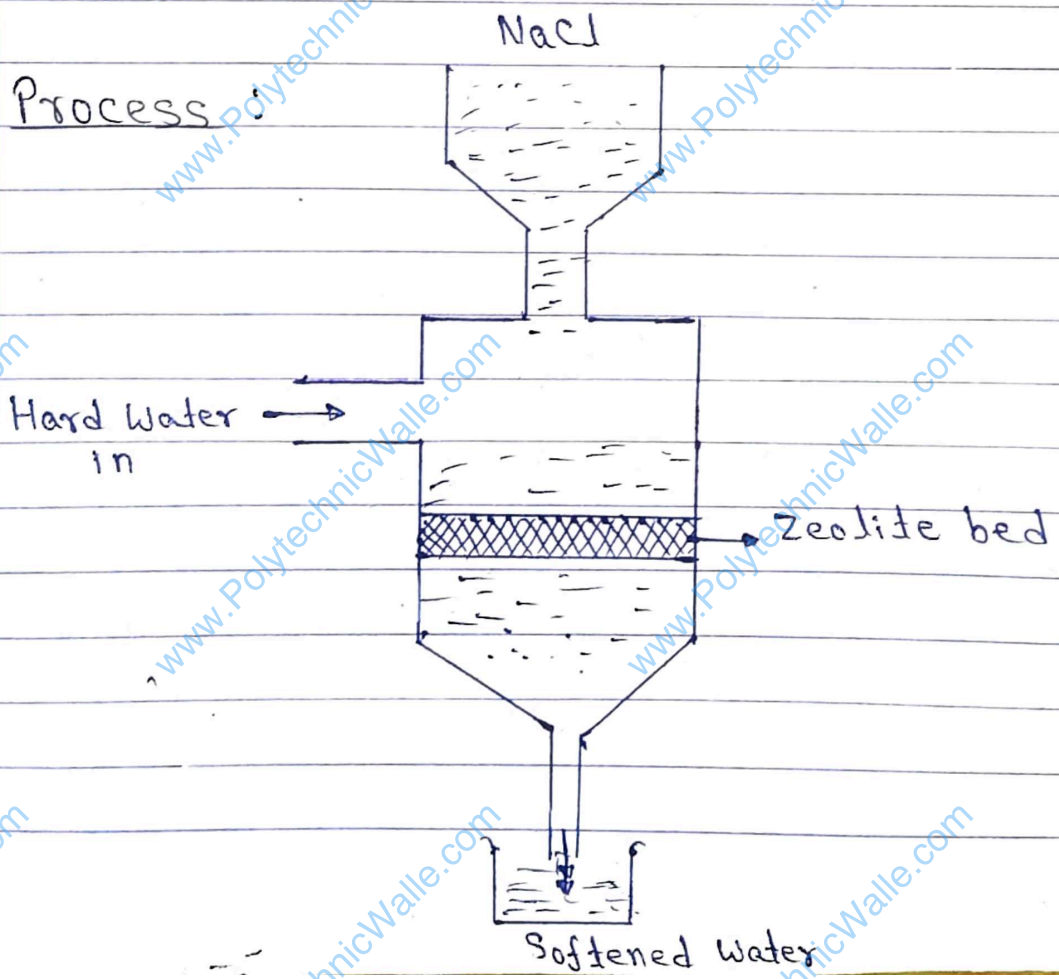
1. Natural Zeolite : Non-porous [ion exchange behavior is slow & less effective]. e.g. ⇒ $Na_2O.Al_2O_3.3SiO_2.2H_2O$ → Natrolite, $Na_2O.Al_2O_3.4SiO_2.4H_2O$ → Greensand, Laumontite
2. Synthetic Zeolite : Porous [ion exchange behavior is fast and more effective]. → Permutit

Sodium Zeolite :

- Hydrated sodium aluminosilicates
- Formula : $Na_2O.Al_2O_3.XSiO_2.YH_2O$ ($X = 2-10$, $Y = 2-6$)
- Also called permutits.
- Represented by Na_2Z.

Principal : ~~Sodium~~ Na^+ ions in zeolites are exchanged with Ca^{2+} and Mg^{2+} ions of hard water.

Process :



Chemical Reactions :

$$Na_2Z + Ca(HCO_3)_2 \longrightarrow CaZ + 2HCO_3\ 2NaHCO_3$$
$$Na_2Z + Mg(HCO_3)_2 \longrightarrow MgZ + 2NaHCO_3$$
$$Na_2Z + CaSO_4 \longrightarrow CaZ + Na_2SO_4$$
$$Na_2Z + MgSO_4 \longrightarrow MgZ + Na_2SO_4$$
$$Na_2Z + CaCl_2 \longrightarrow CaZ + 2NaCl$$
$$Na_2Z + MgCl_2 \longrightarrow MgZ + 2NaCl$$

Re-generation of the Zeolite :

The regeneration or activation of the ion exchanger site of the zeolite is done by passing brine solution (a 10% NaCl sol^n) through the exhausted zeolite.

$$CaZ \text{ or } MgZ \longrightarrow Na_2Z$$

Chemical Reactions :

$$CaZ + 2NaCl \longrightarrow Na_2Z + CaCl_2$$
$$MgZ + 2NaCl \longrightarrow Na_2Z + MgCl_2$$

$CaCl_2$ & $MgCl_2$ removed by washing the zeolite bed with distill : water.

Demineralization or Deionised → Complete removal of hardness

Ion Exchange Process

Complex organic molecules

- Ion Exchange Resin
  - Cation Exchange Resin
  - Anion Exchange Resin

1. Cation Exchange Resin : The ion exchange resin containing acidic groups are called cation exchange resin.

e.g.:- R-COOH or $R-SO_3H$

$$R-COOH + Ca^{2+} \longrightarrow (R-COO)_2Ca + 2H^+$$

$$R-COOH + Mg^{2+} \longrightarrow (R-COO)_2Mg + 2H^+$$

2. Anion Exchange Resin : The ion exchange resin containing basic groups are called anion exchange resin.

e.g.:- $R-NH_3OH$

$$R-NH_3OH + Cl^- \longrightarrow R-NH_3Cl + OH^-$$

$$2\,R-NH_3OH + SO_4^{2-} \longrightarrow (R-NH_3)_2SO_4 + 2OH^-$$

Regeneration of ion exchange resin :

- The exhausted cation exchange resin is regenerated by rxn with dil. HCl or dil. H_2SO_4.

$$(R-COO)_2Ca + 2HCl \longrightarrow 2\,R-COOH + CaCl_2$$

- The exhausted anion exchange resin is regenerated by rxn with dil. NaOH.

$$(R-NH_3)_2SO_4 + 2NaOH \longrightarrow 2\,R-NH_3OH + Na_2SO_4$$

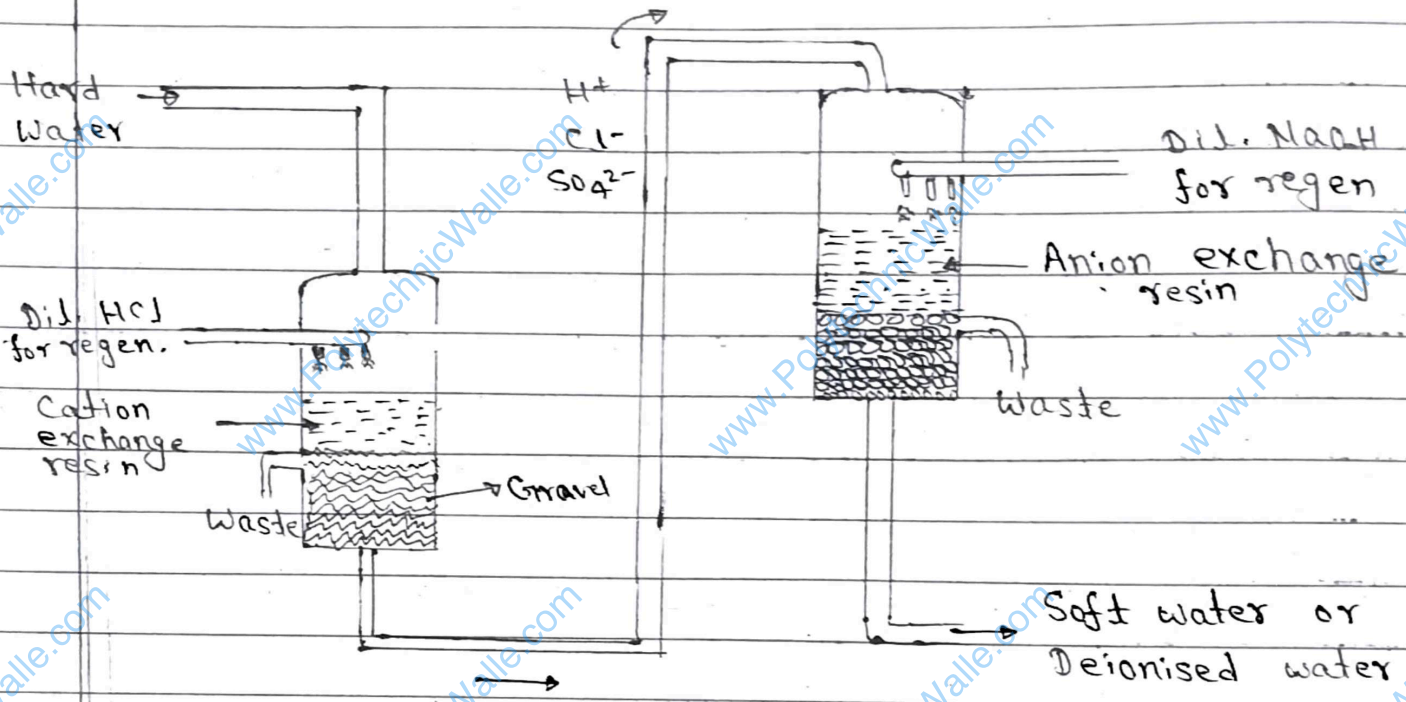


Fig: ION EXCHANGE RESIN