Types of impurities :-

1) Dissolved impurities.

- **Inorganic impurities :-**
  Carbonates, bicarbonates, Sulphates, chlorides of calcuim, magnesium, iron, potassium & aluminium

- **Organic impurities :-**
  Organic water products, amino acids, proteins etc
  Gases : O_2, CO_2, oxides of nitrogen & sulphur, H_2S

2) Suspended Impurities :-

Inorganic : sand & clay
Organic : Vegetable and animal matter

3) Biological Impurities :

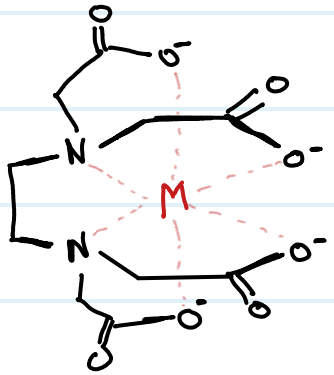
Pathogenic bacteria, algae, fungi

* Determination of Hardness of water using EDTA

1) Complexometric titration method where EDTA is used.
2) Forms different complexes at different pH.
3) Calcium & Magnesium ions form complexes with EDTA at pH 9-10. To maintain the pH 9-10 NH_4Cl, NH_4OH buffer solution is used.
4) The disodium salt of EDTA is used for compleration.
5) An alcoholic solution of Eriochrome Black-T (EBT) is used as an indicator.

- Advantages of EDTA method.

→ High accuracy.
Wide applicability.
Simple procedure.
Fast results.
Low costs.



M-EDTA complex

☆ Softening of water:-

Removal of hardness causing salts from water is called 'Softening of water'.

Three types of process:-

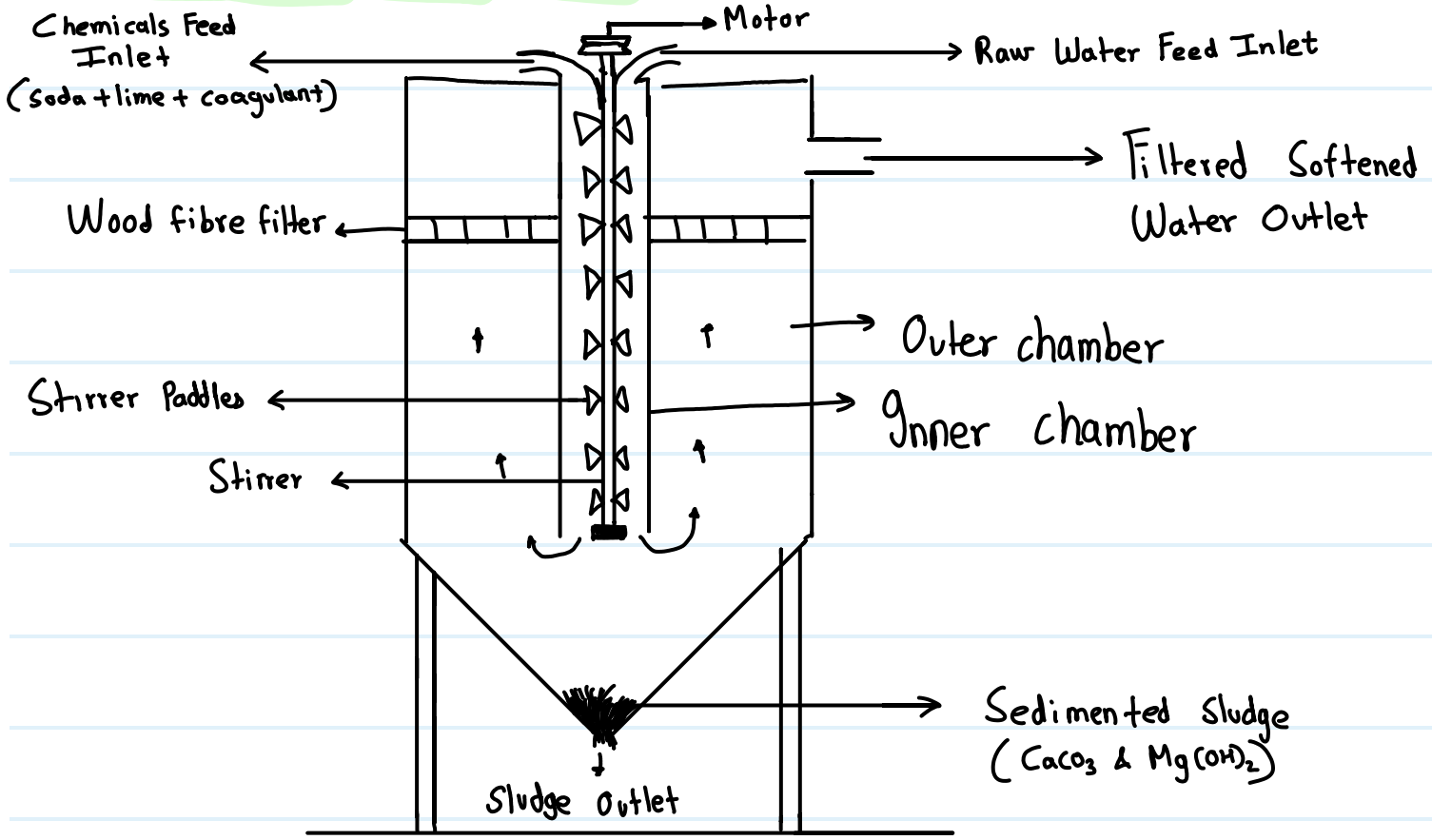
1] Lime-Soda Process.
2] Zeolite-Permutit Method.
3] Ion-Exchange Method / Demineralization method.

* Lime - Soda Process.

This process is based on converting soluble calcium & magnesium salts into insoluble calcium carbonate and magnesium hydroxide precipitates by addition of calculated amounts of lime [$Ca(OH)_2$] & soda [Na_2CO_3]. The precipitate is removed by filteration. Any free dissolved CO_2 and acids are also removed by this process.

Differents types of Lime-Soda process are:-

A] Cold Lime-Soda Process:



In this method Lime & Soda are mixed with hard water at <u>room temperature</u>.

Working:

1] Generally, the precipitates formed in this process are finely divided, in order to settle the precipitates, coagulants like alum, ferrous sulphate etc are added.

2] The hardwater to be softened is mixed with calculated quantity of chemicals (Lime + Soda + Coagulant) from the top into the inner chamber. On vigorous stirring, the chemical reactions take place and hardness producing salts gets converted into insoluble precipitates.

3] The sludge is removed from the bottom of the outer chamber while the softened water passes through a wooden fibre filter to ensure the complete removal of any residual sludge particles.

4] The clear softened water is withdrawn from the top of the outer chamber.

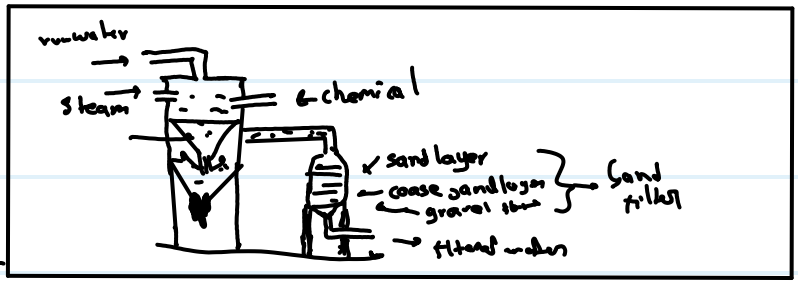
5] The softened water from this process contains a residual hardness of 50 - 60 ppm.

B] Hot Lime-Soda Process

Here the process is carried at temperature of 80° to 150°c at high temp. It consists of three parts :-

- "Reaction Tank" in which complete mixing of water, chemicals and steam takes place and water gets softened.
- "Conditional Sedimentation Vessel" where the sludge settle down.
- "Sand Filter" where sludge is completely removed.

The softened water from this process contains a residual hardness of 15-30 ppm.



- Advantages of Lime-Soda process:-

1] This process is economical.

2] Mineral content of water is reduced.

3] This process ↑ pH of water which ↓ pathogenic bacteria.

4] Manganese & Iron salts are also removed by this process.

5] The process improves the corrosion resistance of water.

- Disadvantages of Lime-Soda Process:

1] Due to residual hardness, water is not useful for high pressure boilers.

2] Large amount of sludge is formed which creates disposal problems.

Calcium & Magnesium Bicarbonate $\longrightarrow$ Only Lime

$Ca(HCO_3)_2$ & $Mg(HCO_3)_2$ $\longrightarrow$ L

$$L = \frac{74}{100}\left[\text{Temporary } Ca^{+2} + 2 \times \text{Temporary } Mg^{+2} + \text{Permanent}\left(Mg^{+2} + Fe^{+2} + Al^{+3} + H^{+}(HCl \text{ or } H_2SO_4)\right) + CO_2 + HCO^{-}_3 - NaAlO_2\right] \times \frac{\text{Vol. of Water}}{10^6} \times \frac{100}{\%\text{ of purity}}\ \text{kg}$$

all in terms of their $CaCO_3$ equivalents.

$MgSO_4$ & $MgCl_2$ $\longrightarrow$ L + S

Ca SO_4 & $CaCl_2$ $\longrightarrow$ S

$$S = \frac{106}{100}\left[\text{Permanent}\left(Ca^{+2} + Mg^{+2} + Al^{+3} + Fe^{+2} + H^{+}(HCl \text{ or } H_2SO_4)\right) - HCO^{-}_3\right] \times \frac{\text{Vol. of Water}}{10^6} \times \frac{100}{\%\text{ of purity}}\ \text{kg}$$

all in terms of their $CaCO_3$ equivalents.

* Zeolite Process

Zeolite is 'Hydrated sodium alumino silicate'. It's general formula is:

$Na_2O.Al_2O_3.xSiO_2.yH_2O$; $x = 2-10$ & $y = 2-6$

Eg:- $Na_2OAl_2O_3.3SiO_2.2H_2O$ - Natrolite

Natural Zeolite are generally non-porous.

The artificial zeolite is called Permutit. These are prepared by heating together with chain clay, feldspar & Soda ash. These are Porous and have greater softening capacity than natural zeolite.

Working:-

Hard water is passed through a bed of Zeolite at ordinary temperature. The Hard Water percolates (filtered), Ca^{2+}, Mg^{2+} present in hard water are exchanged with Na^+ ions.

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

$$Na_2Ze + Mg(HCO_3)_2 \longrightarrow MgZe + 2NaHCO_3$$

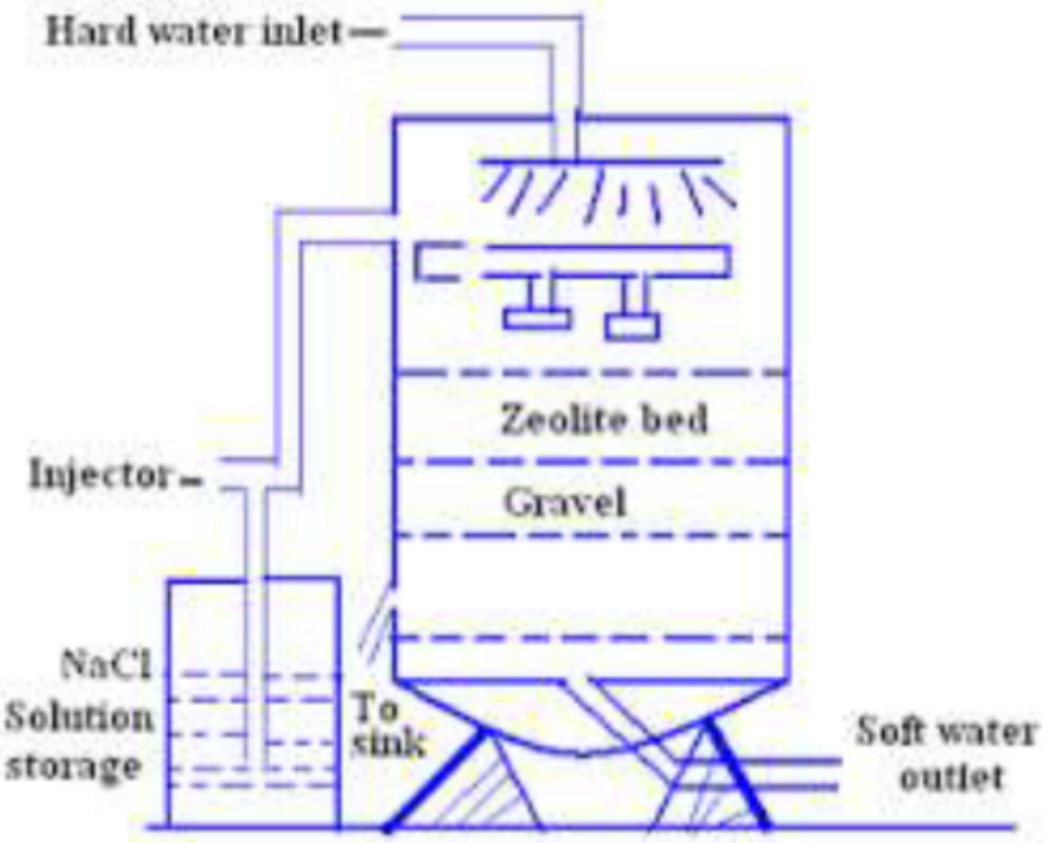
$$Na_2Ze + CaCl_2/CaSO_4 \longrightarrow CaZe + 2NaCl / Na_2SO_4$$

$$Na_2Ze + MgCl_2/MgSO_4 \longrightarrow MgZe + 2NaCl / Na_2SO_4$$

Regeneration of Zeolite: On Continuous passing of hard water through sodium zeolite bed it is converted to calcium & magnesium Zeolite which is known as 'Exhausted Bed'. Hence, it must be regenerated. This can be done by washing Zeolite bed with 10 % sodium chloride solution.

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

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



- Advantages:

1] Equipment is small & easy to handle.

2] Requires less time for softening.

3] Water obtained from this process contains a residual hardness upto 10 ppm.

4] Easy to regenerate.

5] No sludges is formed in this process.

- Disadvantages:

1] Highly turbid water cannot be treated by this process.

2] This process exchanges only Ca^{2+} & Mg^{2+} ions by sodium ions & hence the softened water contains more sodium salts.

3] All the acidic ions like HCO_3^-, CO_3^- etc are not removed by this process.

4] Sodium bicarbonate decomposes in the boiler releasing CO_2 which leads to corrosion.

5] While Na_2CO_3 is hydrolysed to NaOH which creates caustic embrittlement of the boiler.

* BOD

It is measure of amount of oxygen required for biological oxidation of organic matter under aerobic conditions at 20°C for period of 5 days.

- Drinking water should have BOD less than 1ppm.

$$BOD = [(DO)_{blank} - (DO)_{incubated}] \times \text{Dilution Factor}$$

↳ 5 days at 20°C

$$\text{Dilution factor} = \frac{\text{Volume of sample after dilution}}{\text{Volume of sample before dilution}} = \frac{\text{Vol. taken for titration}}{\text{Total vol. to which it is diluted}}$$

- Significance of BOD

1] BOD gives the extent of bio-degradable pollutants in waste water sample.

2] It helps in pollution control in water.

3] It also express self-purification capacity of any water body

* COD

It is measure of amount of oxygen required for chemical oxidation of organic matter when refluxed in acidified potassium dichromate in presence of Ag_2SO_4 or $HgSO_4$ catalyst for 3 hours

- Drinking water should have COD less than 1ppm.

$$COD = \frac{(V_b - V_t) \times N_{FAS} \times 8 \times 1000}{Y} \quad mg/L \text{ or } ppm$$

V_b = Volume of FAS required for blank titration.

V_t = Volume of FAS required for reaction mass after time

Y = Volume of waste water sample taken

- Significance of COD

1] COD gives the extent of bio-degradable & non-biodegradable pollutants in waste water sample.

2] It helps in rapid determination of pollutants level in water compared to BOD.

3] It is taken as a basis for calculation of efficiency & designing of water treatment plants