DIGITAL ASSIGNMENT-1

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Water Softening by Lime-Soda, Zeolite, Ion Exchange Process...

What is Water Softening?

Water softening is a process through which calcium, magnesium & other certain metal cations in hard water are removed. It is an important process, because it can extend the lifespan of household appliances & pipelines and many other water-based applications.

Water is softened on a large scale by the addition of just enough lime to precipitate the calcium as carbonate and the magnesium

as hydroxide, whereupon sodium carbonate is added to remove the remaining calcium salts. In areas where the water is hard, home water softeners are used, making use of the properties of natural or artificial zeolite minerals.

Lime - Soda Process :

Soda-lime is a process used in water treatment to remove hardness from water. This process is now obsolete but was very useful for the treatment of large volumes of hard water.

Addition of lime ($Ca(OH)_2$) and soda (Na_2CO_3) to the hard water, precipitates calcium as the carbonate, and magnesium as its hydroxide. The amounts of the two chemicals required are easily calculated from the analysis of the water and stoichiometry of the reactions. The lime-soda uses lime ($Ca(OH)_2$) & soda ash (Na_2CO_3), to precipitate hardness from solution.

Carbon dioxide & carbonate hardness (Calcium & Magnesium bicarbonate) are complexed

by lime. In this process, calcium and magnesium ions are precipitated.

Reactions :-

$$\underset{\text{(lime)}}{Ca(OH)_2} + CO_2 \longrightarrow CaCO_3\downarrow + H_2O$$

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

$$Ca(OH)_2 + Mg(HCO_3)_2 \rightarrow \underbrace{MgCO_3}_{\text{soluble}} + CaCO_3\downarrow + 2H_2O$$

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

$$Ca(OH)_2 + \underbrace{MgSO_4}_{\text{Mg non-carbonate hardness also removed}} \longrightarrow CaSO_4 + Mg(OH)_2\downarrow$$

$$\underset{\text{(soda-ash)}}{Na_2CO_3} + \underbrace{CaSO_4}_{\text{Ca non-carbonate hardness removed by soda-ash}} \longrightarrow Na_2SO_4 + CaCO_3\downarrow$$

To precipitate $CaCO_3$, requires a pH of about 9.5 & to precipitate $Mg(OH)_2$ requires a pH of about 10.8, therefore an excess lime of about 1.25 meq/L is required to raise the pH.

Lime-soda Process is of 2 types!

(1) Cold Lime-Soda (2) Hot Lime-Soda

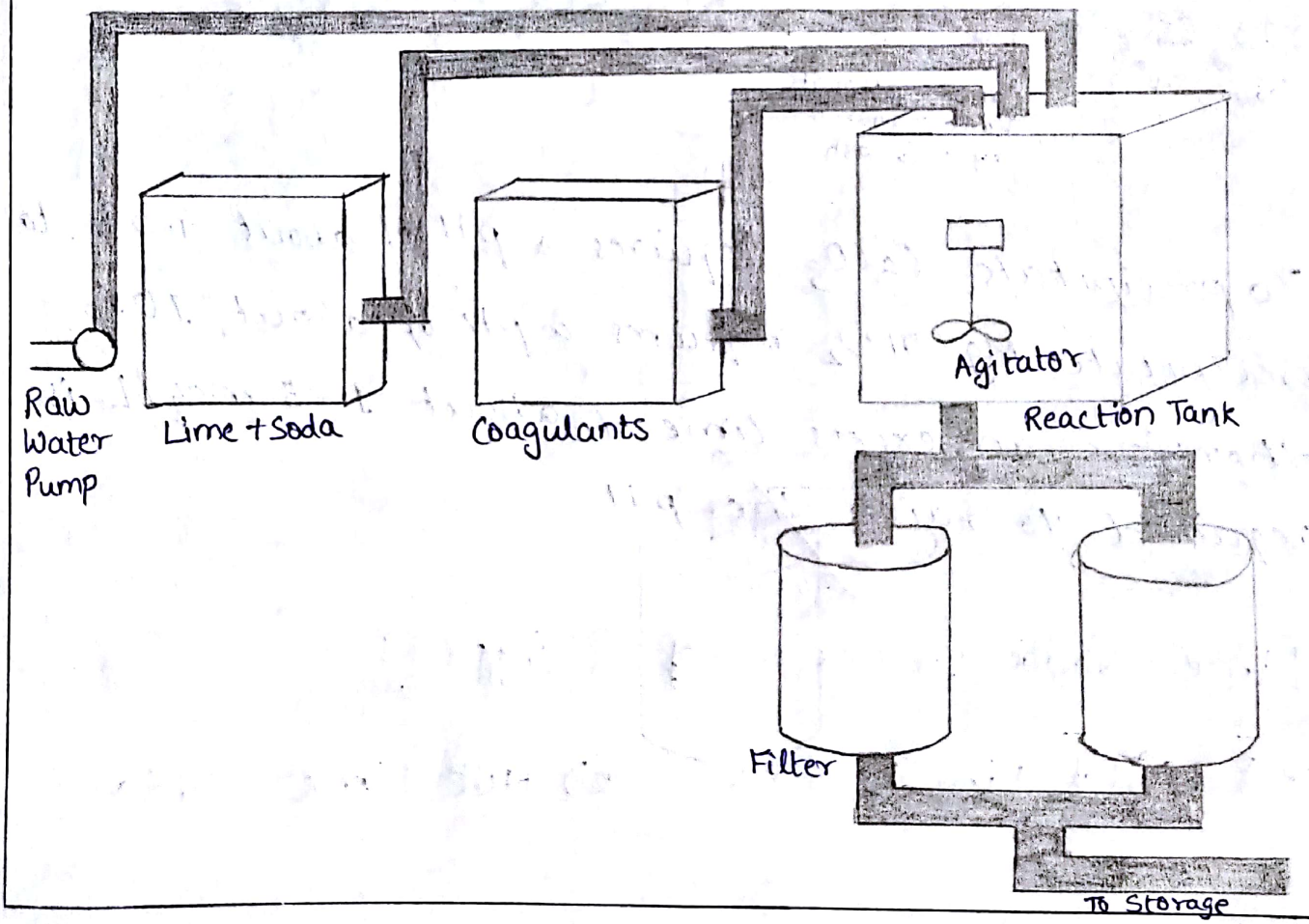
Limitations of Lime-Soda Process :

(1) It requires careful operation and skillful supervision.

(2) Sludge disposal is a problem.

(3) Water contains insoluble salts like sodium sulphate and cannot be used in high pressure boilers.

(4) Cannot produce water completely free of hardness.



Zeolite Process:

Zeolite is micro-porous mineral which is used as catalyst in many industrial purposes such as water purification and air purification.

The zeolites are hydrated alumino-silicates and general composition $Al_x Si_y O_{2(x+y)}$ (without water molecules). Zeolites are of two types – (1) Natural (2) Synthetic / Artificial

The natural zeolite that is used for water softening is gluconites or greensand. *Permutit* is the synthetic zeolite that is most used in water softening and its chemical formula is $Na_2O.Al_2O_3.3SiO_2.2H_2O$. It is more porous, glassy and has higher softening capacity than greensand.

A permutit is packed into the reservoir from which the hard water is allowed to pass. When water passes through the permutits, exchange of ions takes place, i.e Calcium and Magnesium is replaced by Sodium & Aluminium.

Limitations of Zeolite Process :

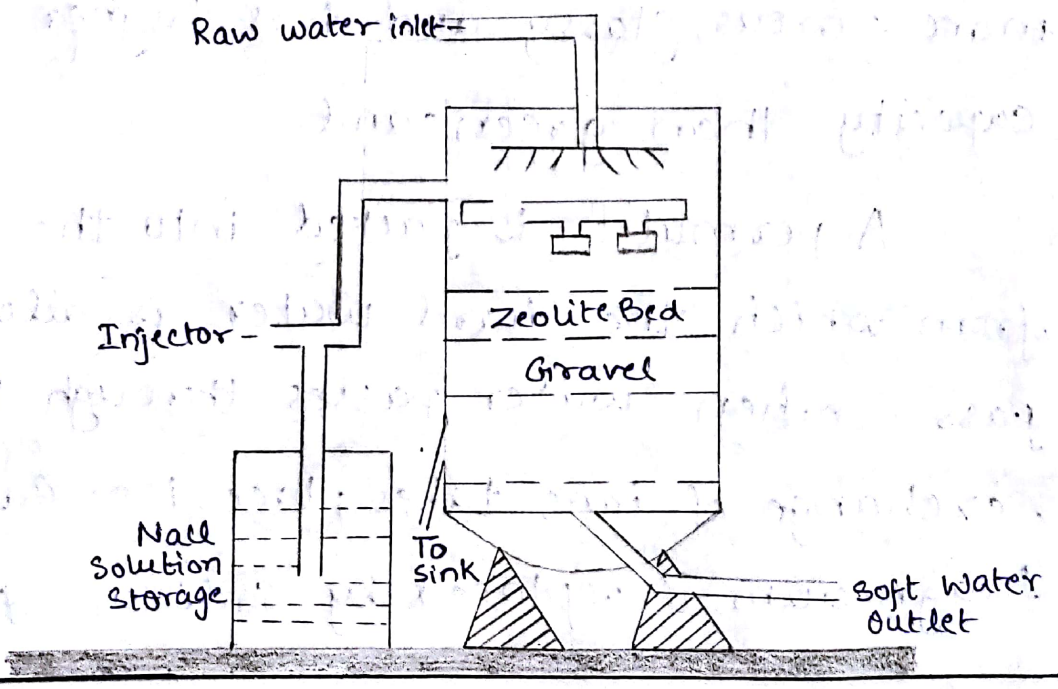
(1) Turbid water cannot be used - the suspended impurities will clog the pores of zeolite.

(2) Mineral acids should be removed / neutralized - mineral acids destroy the zeolite.

(3) Zeolite treatment replaces only the cations like Mg^{2+} and Ca^{2+}, leaving all the anions like HCO_3^- & CO_3^{2-} in the soft water.

(4) HCO_3^- will decompose in boiler and release CO_2 — corrodes the boiler

(5) If water contains large amounts of coloured ions like Mn^{2+} & Fe^{3+}, it must be pre-treated because the corresponding MnZe & FeZe cannot be easily regenerated.



Ion - Exchange Process :

Ion-exchange finds its major industrial application in the treatment of water. To obtain soft water, the hard water is passed through a column of cation exchanger containing sodium ions. After the column is used for some time, calcium and magnesium begin to appear in the water leaving the column. Then the column must be regenerated by passing a concentrated solution of common salt slowly through the column; the excess sodium ions displace the ions that produce the hardness so that, after flushing with water, the bed of exchangers is ready to be used again.

At first, the exchangers used for this purpose were natural aluminosilicates but later, synthetic resins came to be used instead.

Reactions :-(1) Removal of carbonate hardness

$$Ca(HCO_3)_2 / Mg(HCO_3)_2 + Na_2X \longrightarrow CaX/MgX + 2NaHCO_3$$

(2) Removal of non-carbonate hardness –

$$Ca/Mg\text{-}SO_4 + Na_2X \rightarrow Ca/Mg\text{-}X + Na_2SO_4$$

$$Ca/Mg\text{-}Cl_2 + Na_2X \rightarrow Ca/Mg\text{-}X + 2NaCl$$

Advantages of Ion-Exchange :

(1) It is compact & low capital cost.

(2) Chemicals used are safer for the operator to handle & operation is much easier.

Limitations of Ion-Exchange :

(1) $CaSO_4$ fouling, iron fouling

(2) Adsorption of organic matter

(3) Organic contamination from the resin, bacterial and chlorine contamination.