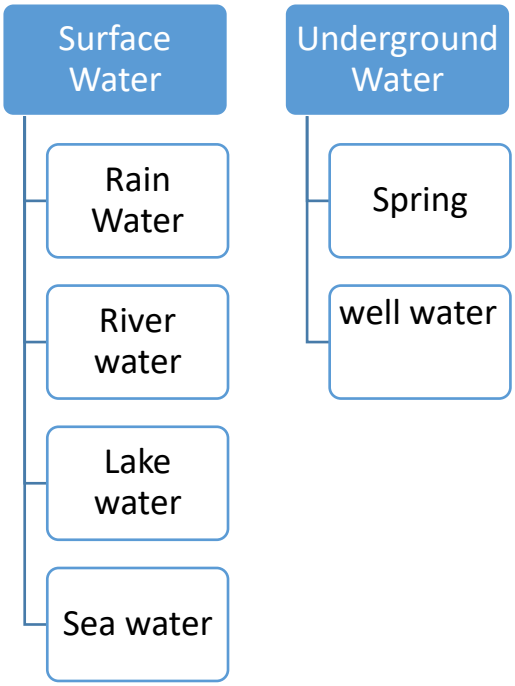
Unit 1 :- Water Treatment

Contents :-

Q.1) What are sources of water ?

Ans :-

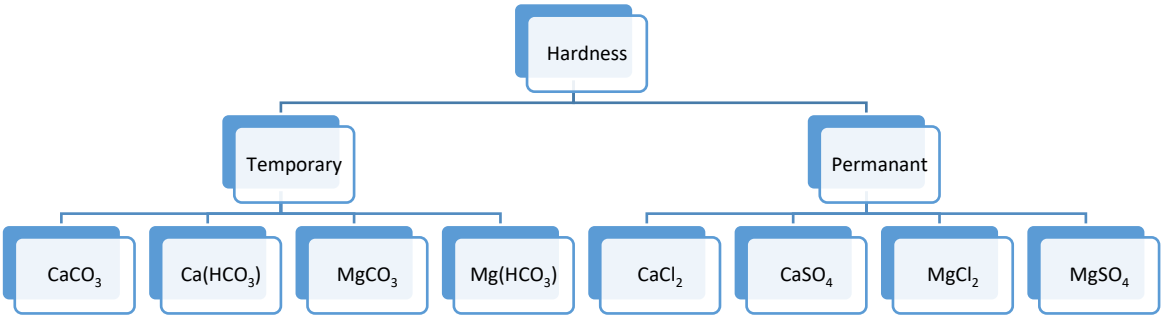


Q.2) What is hardness ? Define types of hardness ?

Ans :- Hardness in water is that characteristics which prevents the lathering of soap .

There are two types of hardness :

1) Temporary Hardness:-It is caused by the presence of dissolved carbonates and bicarbonates of calcium and magnesium .
2) Permanent Hardness :-It is due to the presence of chlorides and sulphates of calcium and magnesium .



Q.3) What are different unit of hardness ?

Ans :-1) Parts per million (ppm) :-

1 ppm = 1 part of CaCO3 eq hardness in 10^6 parts of water

2) Milligrams per litre (mg/L) :-

1 mg/L = 1 part of CaCO3 eq hardness in 10^6 parts of water

= 1 ppm

3) Clarke degree (°Cl) :-

1°Clark= 1 part of CaCO3 eq hardness in 70,000 parts of water

4) Degree French (°Fr) :-

1°Fr = 1 part of CaCO3 eq hardness in 10^5 parts of water

5) Milliequivalents per litre (meq/L):-

1 meq/L = 50ppm

Q.4)What is softening of water ? Write different methods of softening of water ?

Ans:- The process of removing hardness –producing salts from water is known as softening of water .

There are three methods of water softening :

1) Lime soda process
2) Zeolite process
3) Ion exchange process

Q.5) Explain Lime soda process in detail?

Ans :- In this method soluble calcium and magnesium salts in water are chemically converted into insoluble compounds by adding calculated amounts of lim

b) Removal of carbonate hardness by lime	$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$	(5)
	$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + MgCO_3 + 2H_2O$	(6)
	$MgCO_3 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + Mg(OH)_2\downarrow$	(7)
c) Removal of calcium non-carbonate hardness	$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaCl$	(8)
	$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$	(9)
d) Removal of magnesium non-carbonate hardness	$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCl_2$	(10)
	$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$	(11)
e) Sodium aluminate dissociation	$Al_2O_4^{--} + 2H_2O \longrightarrow Al(OH)_3\downarrow + 2OH^-$	(12)
f) Soluble silica with Mg hardness	$Mg(HCO_3)_2 + 2H_4SiO_4 \longrightarrow MgSi_3O_6(OH)_2 + 6H_2O + 2CO_2$	(13)
g) Hardness removal by sodium aluminate	$Na_2Al_2O_4 + Mg(HCO_3)_2 + 4H_2O \longrightarrow 2NaHCO_3 + Mg(OH)_2\downarrow + 2Al(OH)_3\downarrow$	(14)
	$Na_2Al_2O_4 + Ca(HCO_3)_2 + 2H_2O \longrightarrow 2Na_2CO_3 + CaCO_3\downarrow + 2Al(OH)_3\downarrow$	(15)
	$Na_2Al_2O_4 + 2Ca(HCO_3)_2 + 2H_2O \longrightarrow 2NaHCO_3 + 2CaCO_3\downarrow + 2Al(OH)_3\downarrow$	(16)

e and soda.

Above are some reactions involved in soda lime process .

There are two types of soda lime process :-

A) **Cold lime-soda process :-** In this method , calculated quantity of chemical (lime and soda) are mixed at room temperature . At room temperature , the precipitates formed are finely divide , so they do not settle down easily and cannot be filtered easily . So it is essential to add

small amounts of coagulants like alum, aluminium sulphate , sodium aluminate , etc. Cold lime soda process provides water contanining a residual hardness of 50 to 60 ppm.

Method :- Raw water and calculated quantities of chemicals (lime + soda+coagulant) are fed from the top into the inner vertical circular chamber , fitted with a vertical rotating shaft carrying a number of paddles . As the raw water and chemicals flow down there is vigorous stirring and continuous mixing , whereby softening of water takes place . The heavy sludge settles down in the outer chamber by the time the softened water reaches up . The softened water then passes through a filtering media to ensure complete removal of sludge .Sludge settling at the bottom of the outer chamber is drawn off occasionally.

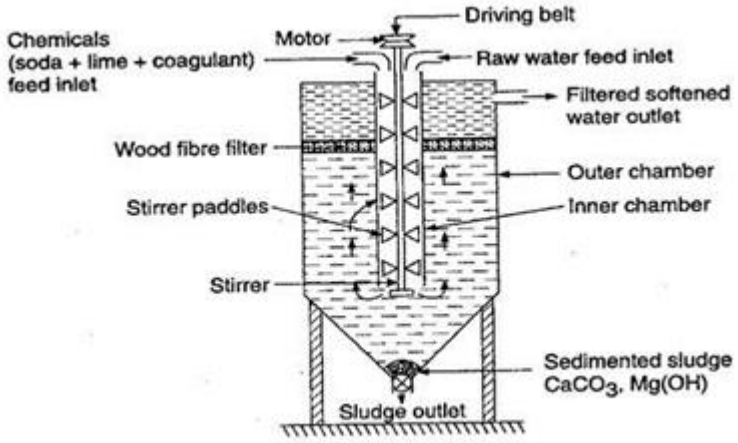


Fig . Cold soda lime process

B)Hot lime-soda process :-It involves water treating with softening chemicals at the temperature of 80-105°C. Since hot process is operated at a temperature close to the boiling point of the solution so :

a)the reaction proceed faster

b)the softening capacity of hot process is increased to many fold

c)the precipitate and sludge formed settle down rapidly and hence no coagulants are needed

d)much of the dissolved gases driven out of the water

hot lime soda process produces water of comparatively lower residual hardness of 15 to 30 ppm.

Hot lime- soda plant consists essentially of three parts :

a)a reaction tank in which raw water , chemicals and steam are thoroughly mixed

b)conical sedimentation vessel in which sludge settle down
c)sand filter which ensures complete removal of sludge from the softened water.

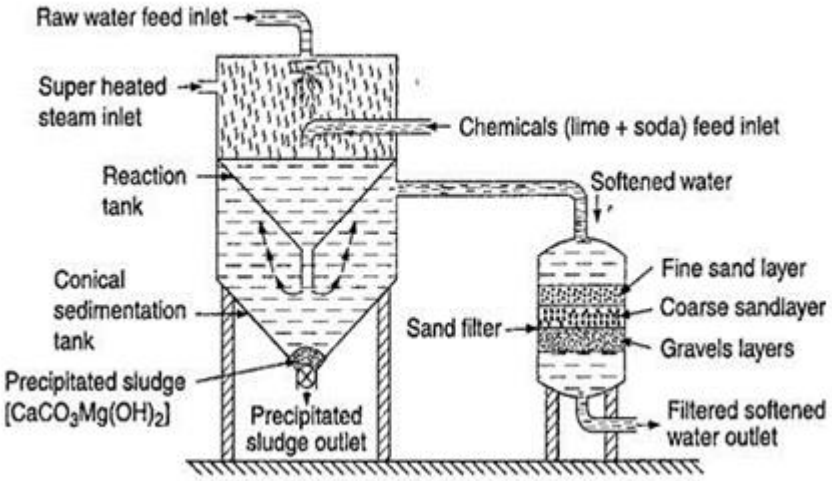


Fig. Hot soda – lime process

Advantages of lime soda process:-

- It is very economical
- If the process is combined with sedimentation with coagulation , lesser amounts of coagulants shall be needed
- The process increases the pH value of the treated water ,thereby corrosion of the distribution pipes is reduced .
- To certain extent , iron and magnese are also removed from the water .
- Besides the removal of hardness the quantity of minerals in the water are reduced.
- Due to alkaline nature of treated water , amount of pathogenic bacterias in water is considerably reduced .

Disadvantages of lime soda process:-

- For efficient and economical softening , careful operation and skilled supervision is required .
- Disposal of large amounts of sludge poses a problem
- This can remove hardness only upto 15 ppm which is not good for boilers .

Q.**6) Give Working, limitation , advantages and disadvantages of zeolite process.**

Ans:- **Process :-** For softening of water by zeolite process , hard water is percolated at a specified rate through a bed of zeolite , kept in a cylinder . The hardness-causing ions are retained by the zeolite as CaZe and MgZe; while outgoing water contains sodium salts .

Reaction taking place during the softening process are :

$$Ca(HCO_3)_2 + Na_2Z \rightarrow CaZ + 2NaHCO_3$$

$$Mg(HCO_3)_2 + Na_2Z \rightarrow MgZ + 2NaHCO_3$$

$$CaSO_4 + Na_2Z \rightarrow CaZ + Na_2SO_4$$

$$CaCl_2 + Na_2Z \rightarrow CaZ + 2NaCl$$

$$MgSO_4 + Na_2Z \rightarrow MgZ + Na_2SO_4$$

$$MgCl_2 + Na_2Z \rightarrow MgZ + 2NaCl$$

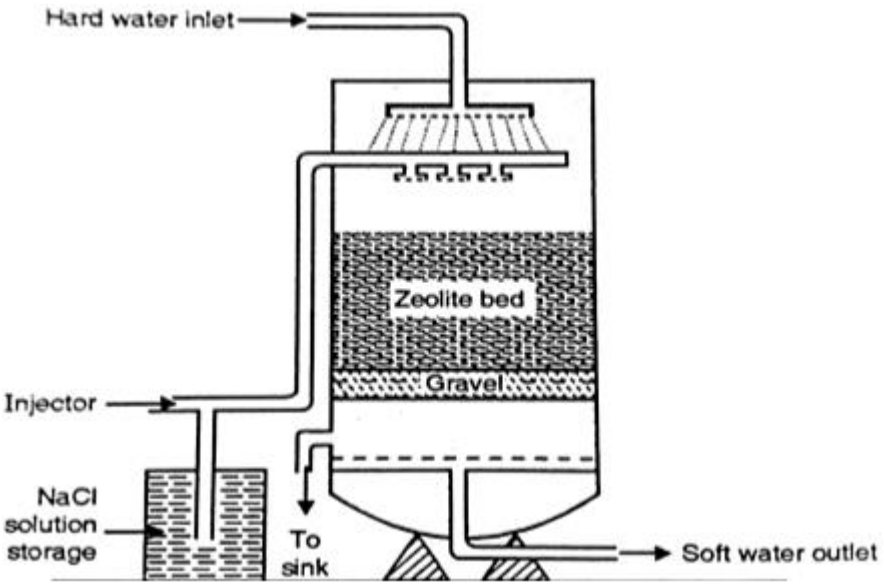


Fig . Zeolite process

Regeneration: - After some time, zeolite is completely converted into calcium and magnesium zeolites and it ceases to soften water .i.e. it gets exhausted. At this stage, the supply of hard water is stopped and the exhausted zeolite is reclaimed by treating the bed with a concentrated NaCl solution.

Limitations:-

- If the supply of water is turbid, the suspended matter must be removed before the water is admitted to the zeolite bed; otherwise the turbidity will clog the pores of zeolite bed, thereby making it inactive.
- If water contains large quantities of colored ions such as Mn^{2+} and $Fe^{2+,}$ they must be removed first, because these ions produce manganese and iron zeolites which cannot be easily regenerated.
- Mineral acid if present in water destroy the zeolite bed therefore they must be neutralized with soda before admitting the water to the zeolite softening plant.

Advantages:-

- It removes the hardness almost completely and water of about 10ppm hardness is produced.
- The equipment used is compact , occupying a small space
- No impurities are precipitated so there is no danger of sludge formation in the treated water at a later stage
- The process automatically adjusts itself for variation in hardness of incoming water
- It is quite clean
- It requires less time for softening
- It requires less skill for maintenance as well as operation.

Disadvantages:-

- The treated water contains more sodium salts than in lime soda process.
- The method only replaces Ca^{2+} and Mg^{2+} ions by Na+ ions , but leaves all the acidic ions

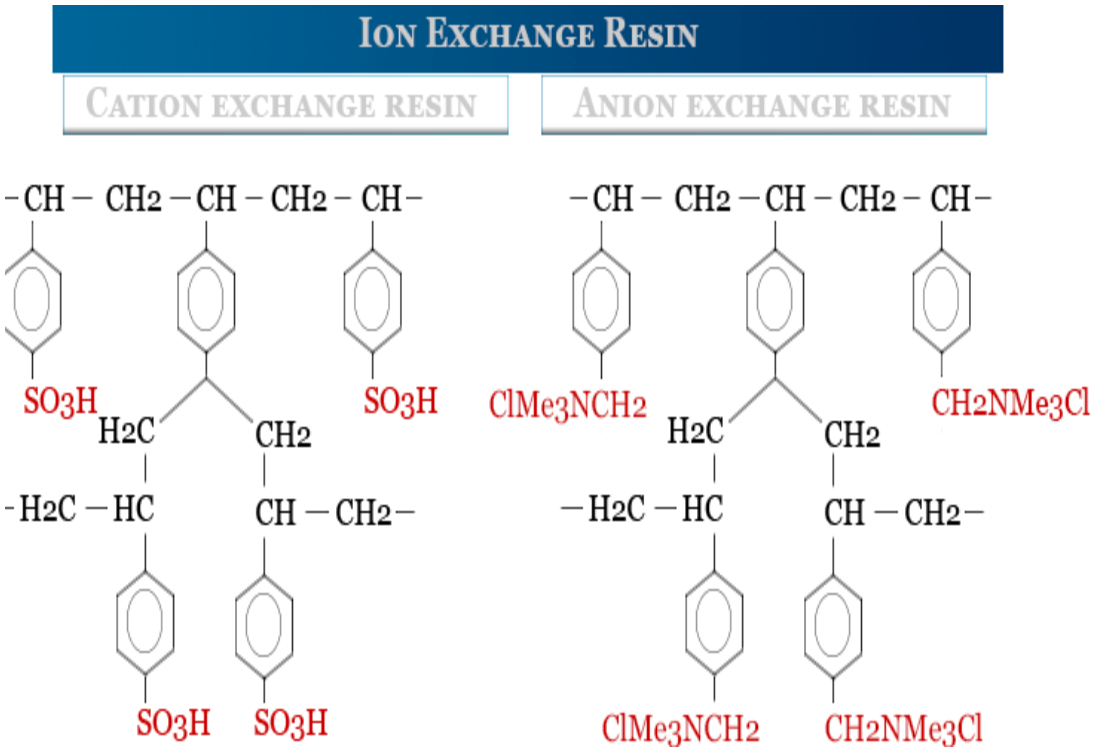
- High turbidity water cannot be treated efficiently by this method because fine impurities get deposited on the zeolite bed thereby creating problem for its working.

Q.7) Explain ion exchange process in detail .

Ans:- Ion exchange resins are insoluble , cross linked , long chain organic polymers with a microporous structure and the functional groups attached to the chains are responsible for the ion exchanging properties .

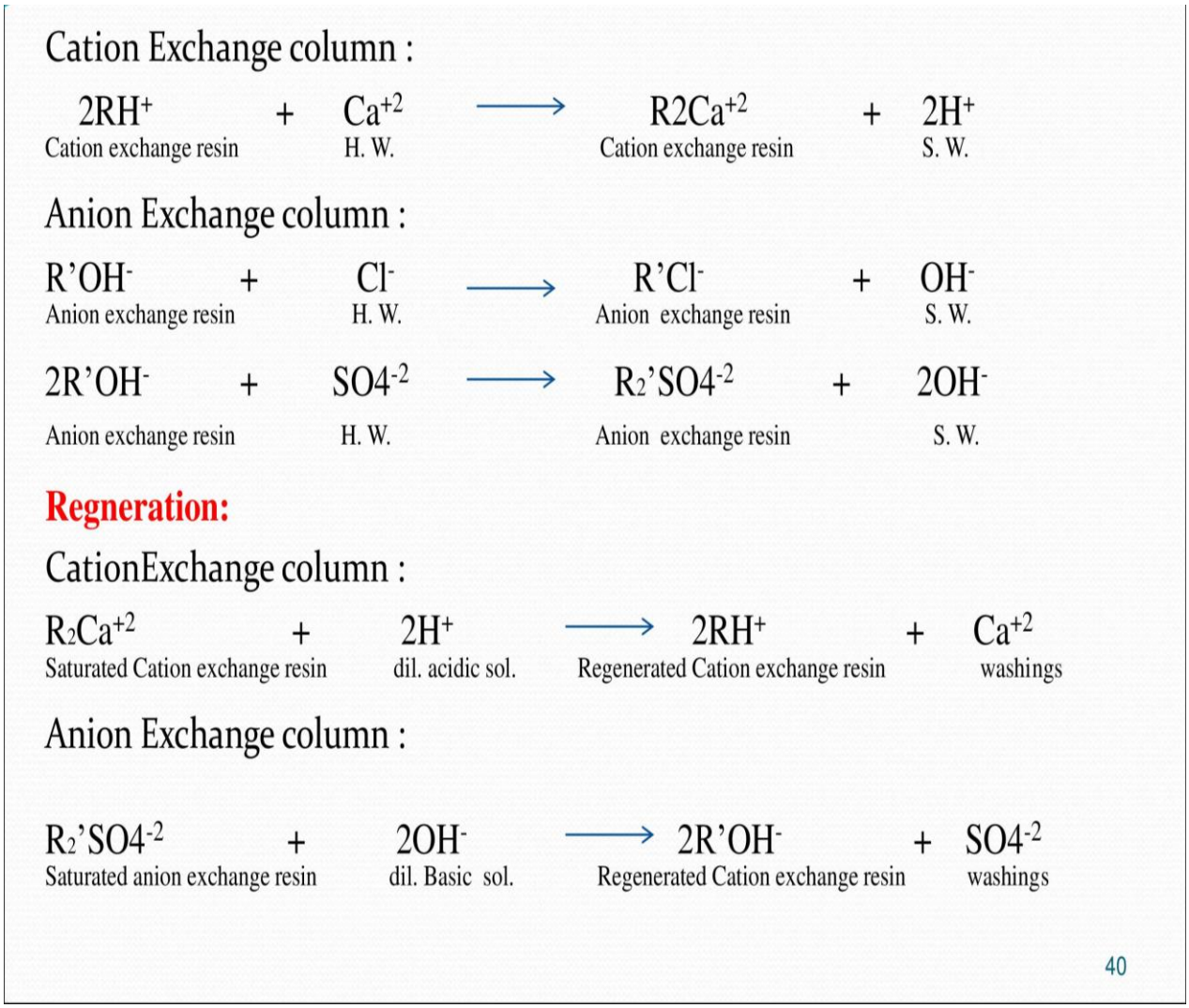
There are two types of ion exchange resins :

1) Cation Exchange Resins (RH+) are mainly strene -divinyl benzene copolymers , which on sulphonation or carboxylation , become capable to exchange their hydrogen ions with the cations in the water .



2) Anion exchange resins (ROH) are styrene -divinyl benzene or amine - formaldehyde copolymers which contain amino or quaternary ammonium or tertiary sulphonium groups as an integral part of resin matrix . These , after treatment with dil. NaOH solution become capable to exchange their OH- anions in water.

Process:- The hard water is passed first through cation exchange column , which removes all the cations like Ca^{2+} , Mg^{2+} from it and equivalent amount of H+ ions are released from this column to water .
After cation exchange column , the hard water is passed through anion exchange column which removes all the anions like SO_4^{2-} , Cl^- present in the water and equivalent amount of OH^- ions are released from this column to water .



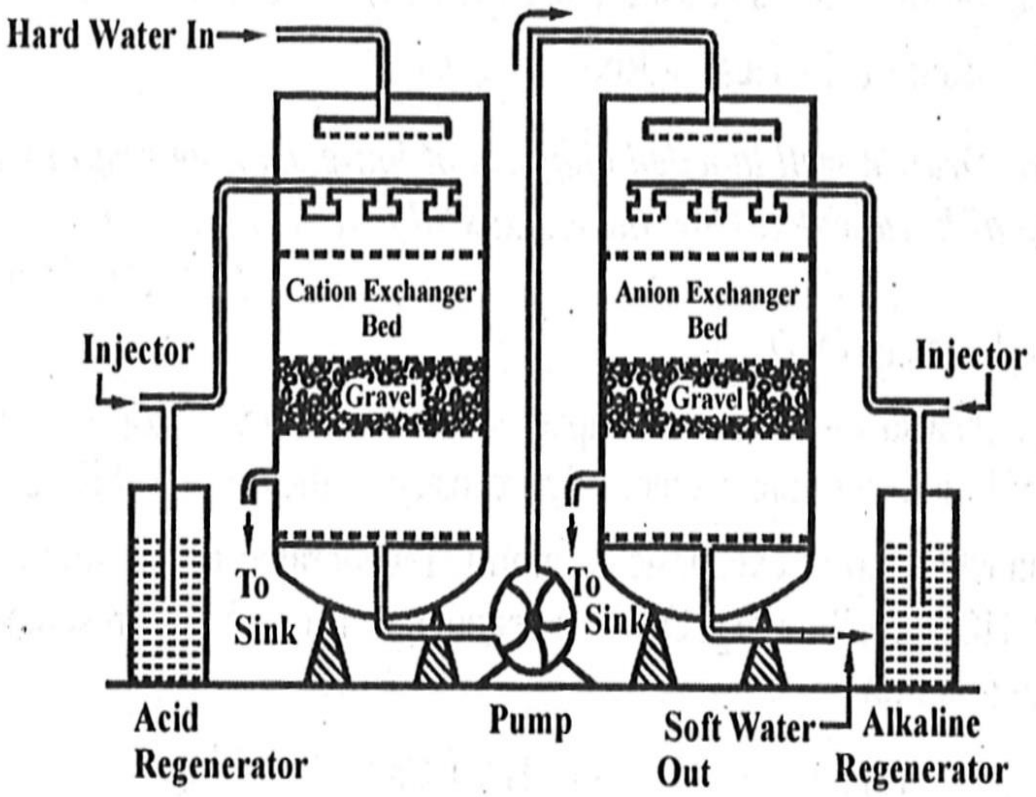


Fig. Demineralization of Water

Advantages :-

- The process can be used to soften highly acidic or alkaline waters.
- It produces water of very low hardness .say it is good for treating high pressure boilers .

Disadvantages :-

- The equipment is costly and more expensive chemicals are needed.
- Turbidity in water reduces output of process.

Q.8) Give comparison of three process .

Ans:-

COMPARISON OF PROCESSES

Lime-Soda Process	Zeolite process	Ion exchange method
Residual hardness: 15-20ppm	0-15 ppm	0-2 ppm
Operating Cost: Low	high	higher
Suspended impurities (SP): Present	May clog the zeolite pores So water must be free SP	So water must be free SP
Acidic water can be treated	No. Because zeolite undergoes disintegration	Acidic and Alkaline water both can be treated
Coagulation, Settling, filtration and the removal of precipitates involved	No	No
Multi step and Complicated process involved	Simple operation	Simple operation
Treated water: Lesser amount of dissolved solid	More dissolved solids (Na-Salts)	No dissolved solids

Q.9) Explain different types of boiler troubles .

Ans :- There are four types of boiler troubles :

1. Scale and sludge formation
2. Caustic Embrittlement
3. Boiler Corrosion
4. Priming and Foaming

Scale and sludge formation :- In boilers water evaporates continuously and the concentrations of the dissolved salts after reaching to saturation point become precipitate .

If the precipitate in the form of loose and slimy precipitate ,it is called sludge .

If the precipitated matter form a hard adhering or coating on the inner wall of boiler called as scale.

Disadvantages of sludge formation :-

- Sludges Are poor conductor of heat so they tend to waste a portion of heat generated .
- Excessive sludge formation disturbs the working of the boiler .

Prevention of sludge formation :-

- By using well softened water
- By frequently blow down operation .

Disadvantages of scale formation :-

- Wastage of fuel
- Lowering of boiler safety
- Decrease in efficiency
- Danger of explosion

Prevention of scale formation :-

- With the help of scrapers or piece of wood or wire brush ,
- By giving thermal shocks
- By adding chemicals
- By frequent blow down operation

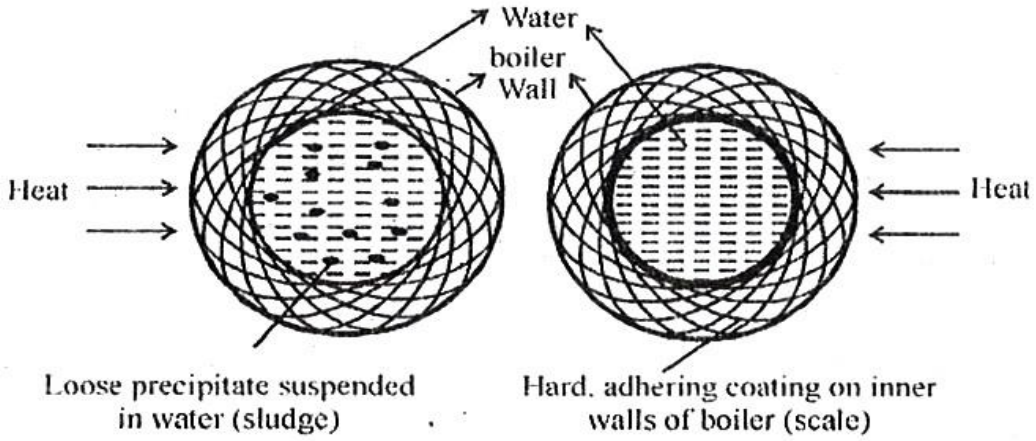
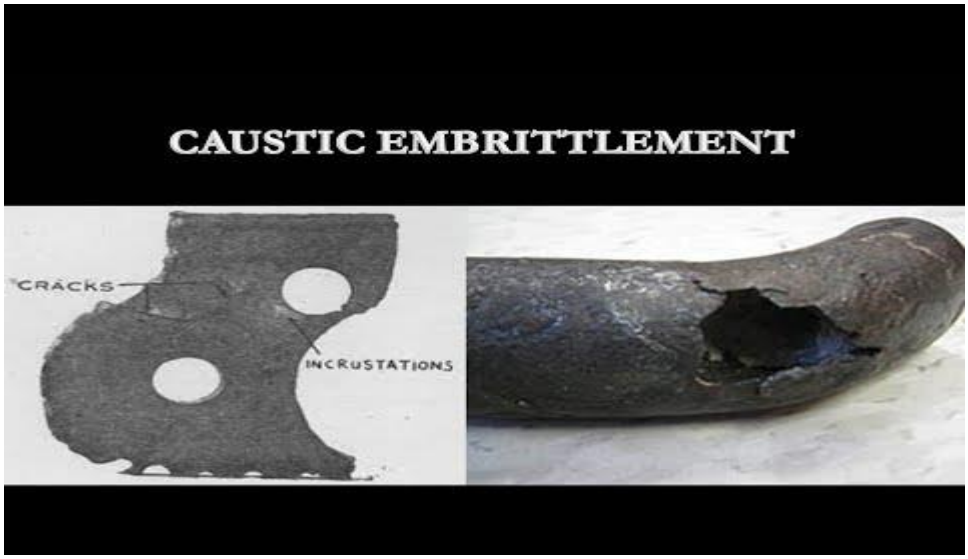


Fig. : Scale and Sludge in Boilers

Caustic Embrittlement :-It is type of boiler corrosion caused by using highly alkaline water in the boiler . It causes cracks in boiler .



Caustic embrittlement can be avoided :-

- By using sodium phosphate as a softening reagent instead of sodium carbonate
- By adding lignin to boiler water
- By adding sodium sulphate to boiler water

Boiler Corrosion :-

It is decay of boiler material by a chemical or electro chemical attack by the environment .

Causes of boiler corrosion :-

- Dissolved oxygen
- Dissolved carbon dioxide
- Acids from dissolved salts

Priming and Foaming :-

When a boiler is producing steaming rapidly some particles of liquid waterare carried along with the steam .This process wet steam formation is called as priming .

Foaming is the production of persistent foam or bubbles in boilers , which do not break easily .

Priming is caused by :-

- The presence of larger amount of dissolved solids

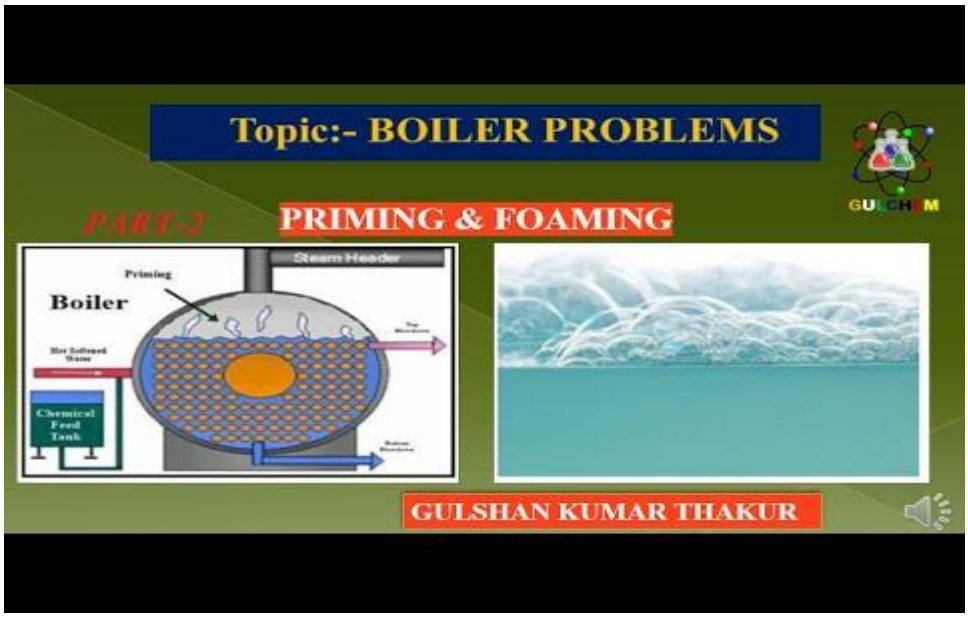
- High steam velocities
- Sudden boiling
- Improper boiler design

Priming can be avoided by :-

- Fitting mechanical mechanical steam purifiers
- Avoiding rapid change in steaming process
- Maintaining low water levels in boilers
- Efficient softening and filtration of the boiler - feed water

Foaming can be avoided by a:-

- Adding anti-foaming chemicals like castor oil
- Removing oil from boiler water by adding compounds like sodium aluminate



Q.10) How the calgon , phosphate and carbonate conditioning done ?

Ans:- **1) Calgon Conditioning:-**It involves adding calgon (sodium hexa meta phosphate) to boiler water . It prevents the scale and sludge formation by forming soluble complex compound with $CaSo_4$

$$Na_2[Na_4(PO_3)_6] \longrightarrow 2Na^+ + [Na_4P_6O_{18}]^{2-}$$

$$2CaSO_4 + [Na_4P_6O_{18}]^{2-} \longrightarrow \underset{\text{soluble complex ion}}{[Ca_2P_6O_{18}]^{2-}} + 2Na_2SO_4$$

Phosphate Coditioning :- (Mathematical Part is given in classroom teaching)

Scale formation can be avoided by adding sodium phosphate which reacts with hardness of water forming non-adherent and easily removable soft sludge of calcium and magnesium phosphate.

$$3CaCl_2 + 2Na_3PO_4 \longrightarrow Ca_3(PO_4)_2 + 6NaCl$$

Carbonate Conditioning :- (Mathematical Part is given in classroom teaching)

Scale formation can be avoided by adding Na_2CO_3 to the boiler water.

It is used only in low pressure boilers.

The scale forming salt like $CaSO_4$ is converted into $CaCO_3$, which can be removed easily.

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$$

Q.12) Explain drinking water or municipal water treatment .

Ans :- Purification water for domestic use can be done in two steps:

A) Removal of suspended impurities

B) Removal of micro-organisms

A) Removal of suspended impurities :-

1) Screening :- The raw water is passed through screens , having large number of holes , when floating mattersare retained by them .

2) Sedimentation :- It is a process of allowing water to stand undisturbed in big tanks , about 5m deep when most of the suspended particles settle down at the bottom due to force of gravity .

3) Filtration :- It is the process of removing colloidal matter and most of the bacterias , micro - organisms , etc by passing water through a bedof fine sand and other proper -sized granular materials . Filtration is carried out by using sand filter .

B) Removal of micro-organism :-

1) By boiling :- boiling water for 10-15 min all the disease producing bacterias are killed and water becomes safe for use .

2) By adding bleaching powder :- By adding it germs are killed

3) By chlorination :- By adding chlorine bacterias are killed .

4) Coagulation process-

Coagulation consist of adding a floc forming chemical reagent to a water to combine with nonsettleable colloidal solids so they can stick together. ν Colloids are negatively charged particles. The addition of a coagulant, which has positively charged particles, would neutralize the negative charge on the colloids. ν Slow settling suspended solids to produce a rapid settling floc. The floc is subsequently removed in most cases by sedimentation. ν Flocculation is the slow stirring or gentle agitation to aggregate the destabilized particles and form a rapid settling floc. ν Mixing of the coagulated suspension to promote colloidcontact forming larger solids called flocs that can be removed by gravity settling

Colloidal Particles ν particulates in water source that contribute to colour and turbidity ν mainly clays, silts, viruses, bacteria, fulvic and humic acids and organic particulates ν at pH levels above 4.0, particles or molecules are generally negatively charged ν have a very large ratio of surface area to volume

Uses of Coagulation The primary purpose of the coagulation process is the removal of turbidity from the water. Turbidity is a cloudy appearance of water

caused by small particles suspended therein. Water with little or no turbidity will be clear.

Methods of Coagulation Process ν mixing water with coagulant chemicals such as alum or ferric chloride ν the purpose of rapid mixing is to provide a uniform dispersion of coagulant chemical throughout the influent water ν coagulant chemicals can be mixed by several methods, including: – Mechanical method: flume mixer – Hydraulic method: flash mixer