

UNIT- V

WATER TECHNOLOGY

UNIT V: WATER TECHNOLOGY Hardness of water-determination of hardness by complexometric method-boiler troubles (priming and foaming, scale formation, boiler corrosion, caustic embrittlement)-internal treatments-softening of hard water (zeolite process and related sums, ion exchange process)-treatment of industrial waste water Portable water and its specifications-steps involved in purification of water-chlorination, break point chlorination-reverse osmosis and electro dialysis.

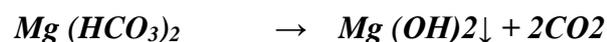
Hardness of water: -

The water which does not give lather with soap is called hard water. The Hard water contains dissolved calcium & magnesium salts.

Types of Hardness:- Hardness in water is of two types.

(1) Temporary hardness and (2) permanent hardness

TEMPORARY HARDNESS:- (BI CARBONATE HARDNESS.) It is due to the presence of $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$ in water Which can be removed simply by boiling.



PERMANENT or NONCARBONATE HARDNESS:-

1. It is due to presence of chlorides and sulphates of Ca, Mg, Fe and other heavy metal salts in water
2. It is not destroyed upon boiling. It can be eliminated by different techniques like, Lime Soda process, Ion exchange process, Zeolite process, etc.

Total Hardness= Temporary Hardness + Permanent Hardness.

Units of Hardness

Most Commonly used

- **Parts per million (ppm)**

1ppm=1 part of CaCO_3 equivalence hardness causing substance present in 10^6 parts of water

- **Milligrams per liter (mg/litre)**

1mg/L=1mg of CaCO_3 equivalence hardness causing substance present in one liter of water

1mg/L=1ppm

Relationship; 1L water = 1Kg = 1000 g = 1000 X 1000 mg = 10^6 mg

1mg/L = 1mg of CaCO_3 eq per 10^6 mg of water

= 1 part of CaCO_3 eq per 10^6 parts of water = 1ppm

- **Clare's Degree($^{\circ}Cl$)**

1 $^{\circ}$ Clarke= 1part of CaCO_3 equivalent hardness in 70000 parts of water

- **Degrees French ($^{\circ}Fr$)**

1o Fr = 1 part of CaCO_3 eq per 10^5 parts of water

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BOILER TROUBLES:

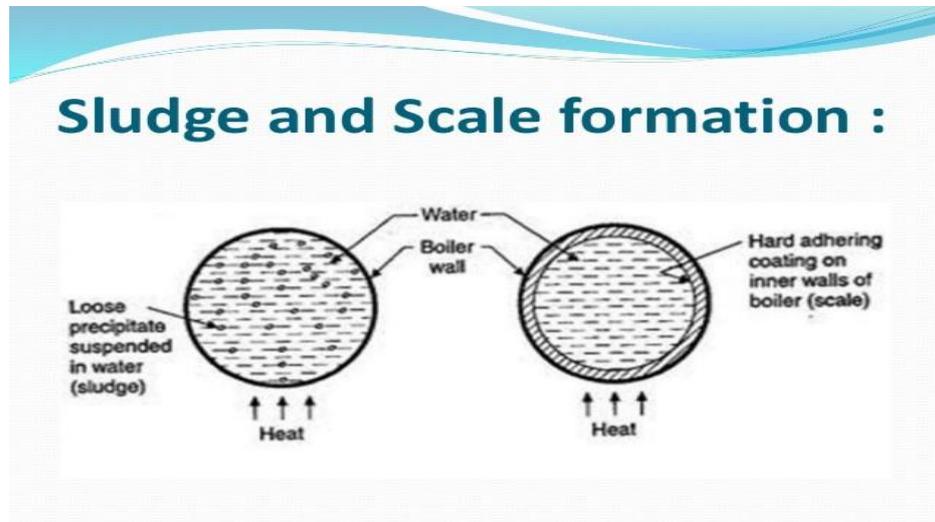
1. **Scale and sludge formation:** (It is caused by dissolved salts present in boiler water)
2. **Caustic embrittlement:** (It is caused by Na_2CO_3 salt in boiler water)
3. **Boiler Corrosion :** (It is caused by O_2, CO_2 , Mineral acids in boiler water)
4. **Priming and Foaming:** (It is caused by Oil and silica in boiler water)

1. *Scale and sludge formation:*

1. In boilers, water evaporates continuously and the concentration of the dissolved salts increases progressively.
2. When the dissolved salts concentration increases and reaches saturation point, they are thrown out of water in the form of precipitates on the inner wall of the boiler.
3. If the precipitation takes place in the form of loose and slimy precipitate it is called *sludge*.
4. If the precipitated matter forms a hard adhering crust or coating on the inner walls of the boiler, it is called *scale*.

SLUDGE:

1. It is a soft, loose and slimy precipitate formed within the boiler.
2. Eg; $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$, etc. 10



1. **Disadvantages:-** Sludge's are poor conductor of heat which tends to waste a portion of heat generated.
2. Sludge formation disturbs the working of the boiler as it settles in the region of poor water circulation such as pipe connection; plug opening, gauge-glass connection thereby causing even choking of the pipes.

Prevention: By using well softened water by frequent "Blow Down" operation

SCALES: are hard deposits which stick firmly to the inner surfaces of the boiler. These are difficult to remove.

Formation of Scales:

1. **Decomposition of $Ca(HCO_3)_2$:** $Ca(HCO_3)_2 \rightarrow CaCO_3 \downarrow + H_2O + CO_2$
2. **Deposition of $CaSO_4$:**- The solubility of $CaSO_4$ in water decreases with rise in temperature i.e. This is the main cause of scales
3. **Hydrolysis of Magnesium Salts:** $MgCl_2 + 2H_2O \rightarrow Mg(OH)_2 \downarrow + 2HCl \uparrow$
4. **Presence of Silica:** - Silica present in small quantities deposits as calcium & magnesium silicates $CaSiO_3$ or $MgSiO_3$.

Disadvantages:

- 1. Wastage of fuel:** Scales have a low thermal conductivity so rate of heat transfer decrease from boiler to inside water
- 2. Lowering of boiler safety:** the overheating of boiler tube makes explosion to bear the pressure of steam especially in high pressure boilers.
- 3. Decrease in Efficiency:** scales may deposit in the valves and condensers of the boilers and choke them partially.
- 4. Danger of explosion:** The thick scales formed if cracked due to uneven expansion sudden high pressure is developed which causes explosion of boiler.

Removal of Scales:- By External Treatment Method

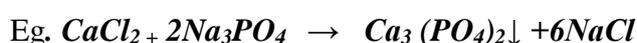
1. If scales are loosely adhering they can be removed with the help of scrapper or wire brush or piece of wood.
2. If Scales are brittle By giving thermal shocks (i.e., heating the boiler and then suddenly cooling)
3. If the scales are. CaCO_3 scales which are dissolved by using 5-10% of HCl and CaSO_4 scales can be dissolved by adding EDTA with which they form soluble complexes.
4. By frequent blow-down operation if scales are loosely adhering.

Prevention of scales : by Internal Treatment Method

- 1. An internal treatment is accomplished by adding a proper chemical to the boiler water*
- 2. The Chemical substance reacts with Scales and Converts into sludge which can be removed by blow-down operation*

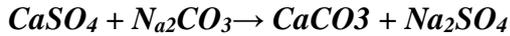
1) Phosphate Conditioning:

In high pressure boilers, scale formation can be avoided by adding sodium phosphate, which reacts with scales and converts into soft sludge of Ca and Mg phosphates which can be removed by blow-down operation.

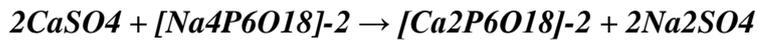


The main phosphates employed are NaH_2PO_4 (acidic) Na_2HPO_4 (alkaline)

2) **Carbonate Conditioning:** In low pressure boilers, scale formation can be avoided by adding Sodium carbonate to boiler water, when CaSO_4 is converted to CaCO_3 in equilibrium.



3) **Calgon Conditioning:** Involves adding calgon (*sodium hexa meta phosphate* (NaPO_3)₆) to boiler water. It prevents the scale and sludge formation by forming soluble complex compound with CaSO_4 .



Colloidal conditioning: colloidal substances like, Kerosene Tannin agar-agar, which are added to low pressure boilers

These substances deposit over scales and convert into sludge

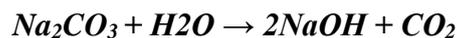
Treatment with Sodium Aluminate:

NaAlO_2 is added to boiler water *which* is Hydrolyzed to give NaOH and $\text{Al}(\text{OH})_3$ (Flocculent ppt)

NaOH Reacts with MgCl_2 Scales and converts into $\text{Mg}(\text{OH})_2$ Sludge

Caustic embrittlement:-

- It is a type of boiler corrosion caused by using highly alkaline water in the boiler.
- During softening process by Lime-Soda process, free Na_2CO_3 is usually present in small proportion.
- In high pressure boilers, Na_2CO_3 decomposes to give NaOH and CO_2 and this makes the boiler water '*caustic*'.



- The NaOH containing water flows into minute hair cracks always present in inner side of boiler by capillary action.
- Here water evaporates and the dissolved caustic soda concentration increases progressively
- This caustic soda (NaOH) attacks the surrounding area, thereby dissolving iron of the boiler as sodium ferroate. This causes embrittlement of boiler parts (like bends, joints, etc.,) causing even failure of the boiler.

Caustic cracking can be explained by considering the following concentration cell:

Iron at rivets, bends, joints, (-)	Concentrated NaOH	Dil NaOH	at plane surfaces (+) Cathod
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The iron surrounded by dil. NaOH becomes the cathodic side; while the iron in contact with con. NaOH becomes anodic part; which is consequently dissolved or corroded.

Prevention of caustic embrittlement: Caustic embrittlement can be avoided:

- By using Na₃PO₄ as softening reagent instead of Na₂CO₃.
- By adding tannin or lignin to boiler water since these block the hair cracks thereby preventing infiltration of caustic soda solution in these.
- By adding Na₂SO₄ to boiler water. Na₂SO₄ is added to boiler

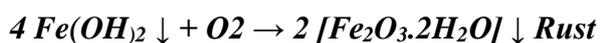
BOILER CORROSION:

Boiler corrosion is the decay of boiler material by a chemical or electrochemical attack of its environment. It occurs due to the presence of dissolved gases like O₂, CO₂, H₂S and acids formed by the hydrolysis of salts like MgCl₂.

The main reasons for boiler corrosion are; *dissolved oxygen.* *Dissolved CO₂:* *Acids*
from Hydrolysis of Mg salts

1. Dissolved oxygen:

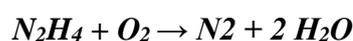
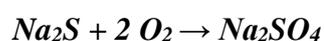
Dissolved oxygen in water attacks boiler material at high temperature and high pressure and corrodes boiler.



Prevention:

Dissolved O₂ should be removed before put in use in boilers. This can be done by

Mechanical de aerator



2. Dissolved CO₂:

Dissolved CO₂ forms carbonic acid which has a slow corrosive effect on the boiler material. Water containing bicarbonates release CO₂ on heating which forms carbonic acid with water



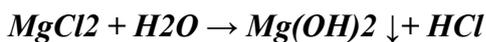
Prevention: Dissolved CO₂ is removed by i. Chemical treatment: By adding a calculated quantity of ammonia



CO₂ is removed by mechanical de aeration along with O₂.

3. Acids from Hydrolysis of salts:

Water containing dissolved magnesium chloride liberates HCl on hydrolysis



HCl reacts with boiler iron and produce HCl again and again in a chain reaction.



Thus even a small amount of MgCl₂ can cause corrosion of iron to a large extent.

Prevention: The HCl formed is neutralized with alkalies.

PRIMING AND FOAMING:

Priming:

1. When a boiler is steaming (i.e., producing steam) rapidly,
2. Some particles of the liquid water (Droplets) are carried along with the steam.
3. This process of '*wet steam*' formation is known as '**Priming**'.

Causes: Priming is caused by:

1. The presence of large amount of dissolved salts
2. High steam velocities
3. Sudden boiling
4. Improper boiler design
5. Sudden increase in steam production rate.

Prevention:

1. By fitting mechanical purifiers
- 2.. Avoiding rapid change in steam rate
3. Maintaining low water levels in boilers
4. Effective softening and filtration of boiler feed water
5. Blow down of the boiler.

Foaming:

The phenomenon of formation of persistent foam or bubbles on the surface of water inside the boiler, which do not break easily.

Causes: dissolved impurities and suspended matter like Oils and silica have a greater tendency to produce foam. Suspended impurities and oils lower the surface tension producing foam.

Prevention:

1. Adding antifoaming chemicals like castor oil. , Gallic acid and tannic acids

HARD WAER SOFTENING METHODS (Removal of Hardness producing salts from the water)

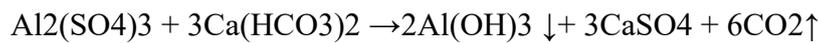
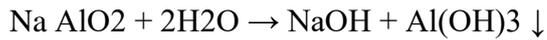
1. *Lime-Soda, process*
2. *Zeolite process (permutite method)*
3. *Ion-exchange process (Demineralization process)*

Lime-Soda process:

In this process, *lime* (Ca(OH)_2) and *soda* (Na_2CO_3) are the reagents used to precipitate the dissolved salts of Ca^{+2} and Mg^{+2} as CaCO_3 and Mg(OH)_2 which are later on filtered off.

Cold lime soda process:

1. Calculated amounts of lime and soda are mixed with water at room temperature.
2. The precipitates formed are finely divided which do not settle down and can't be filtered easily.
3. So, it is essential to add small amounts of coagulants (like alum, aluminium sulphate, sodium aluminate) which hydrolyse to flocculent, gelatinous precipitate of Al(OH)_3 and entraps the precipitate.

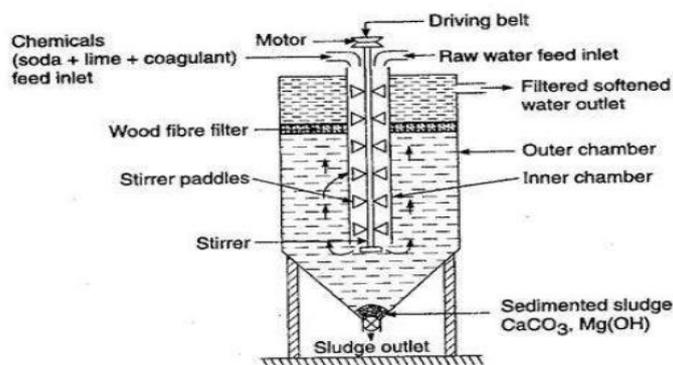


This method provides water residual hardness reduce up to 60-80 PPM

Method:

1. Raw water and calculated quantities of chemicals (lime+soda+coagulant) are fed from the top into inner vertical circular chamber fitted with a vertical rotating shaft carrying a number of paddles.
2. As the raw water and chemicals flow down, there is vigorous stirring and continuous mixing whereby softening of water takes place.
3. The heavy sludge settles down in the outer chamber by the time softened water reaches up.
4. The softened water then passes through a filtering media

▪ **COLD-LIME-SODA PROCESS:**



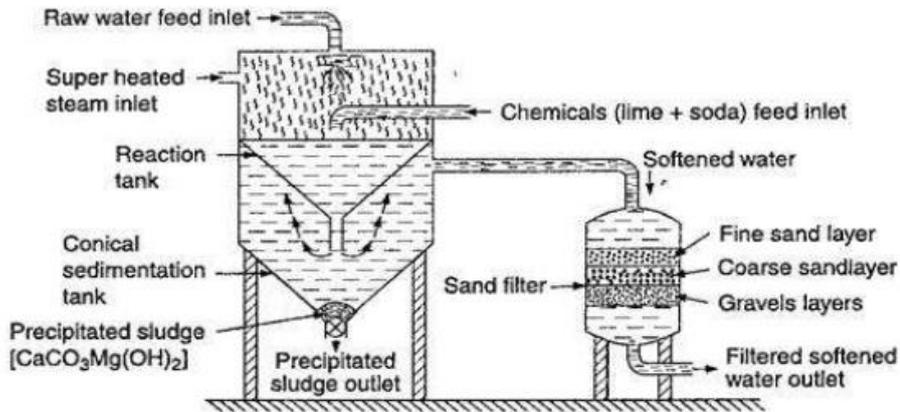
Hot Lime Soda Process:

It involves treating water with softening chemicals at a temperature of 800-1500 C. Since hot process is operated at a temperature close to the boiling point of the solution,

1. The reaction proceeds faster,
2. Softening capacity of hot process is increased,
3. The precipitate and sludge formed settle down rapidly and hence no coagulants are needed,

4. Hot lime soda process produces water of residual hardness of 15-30ppm.

▪ **HOT-LIME-SODA PROCESS:**



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Process:

It contains essentially three parts

- 1) A reaction tank in which water, chemical and steam are thoroughly mixed.
- 2) A conical sedimentation vessel in which sludge settle down.
- 3) A sand filter which ensures complete removal of sludge from the softened water.

Calculation of lime and soda required for the softening of hard water by the lime soda process

Hardness producing substance	Chemical reaction with lime and soda	Need
Permanent Hardness		
Ca Salts	$\text{CaCl}_2 + \text{Na}_2\text{CO}_3 \longrightarrow \text{CaCO}_3 \downarrow + 2\text{NaCl}$	S
Mg salts	$\text{MgSO}_4 + \text{Ca}(\text{OH})_2 \longrightarrow \text{Mg}(\text{OH})_2 \downarrow + \text{CaSO}_4$ $\text{CaSO}_4 + \text{Na}_2\text{CO}_3 \longrightarrow \text{CaCO}_3 \downarrow + \text{Na}_2\text{SO}_4$	L + S
Temp. Hardness		
Ca(HCO₃)₂	$\text{Ca}(\text{HCO}_3)_2 + \text{Ca}(\text{OH})_2 \longrightarrow 2\text{CaCO}_3 \downarrow + 2\text{H}_2\text{O}$	L
Mg(HCO₃)₂	$\text{Mg}(\text{HCO}_3)_2 + 2\text{Ca}(\text{OH})_2 \longrightarrow 2\text{CaCO}_3 \downarrow + \text{Mg}(\text{OH})_2 \downarrow + 2\text{H}_2\text{O}$	2L
Acids		
HCl	$2\text{H}^+ + \text{Ca}(\text{OH})_2 \longrightarrow \text{Ca}^{2+} + 2\text{H}_2\text{O}$	L+S
H₂SO₄	$\text{Ca}^{2+} + \text{Na}_2\text{CO}_3 \longrightarrow \text{CaCO}_3 \downarrow + 2\text{Na}^+$	L - S
HCO₃⁻	$\text{HCO}_3^- + \text{Ca}(\text{OH})_2 \longrightarrow \text{CaCO}_3 \downarrow + \text{H}_2\text{O} + \text{CO}_3^{2-}$	L + S
FeSO₄	$\text{Fe}^{2+} + \text{Ca}(\text{OH})_2 \longrightarrow \text{Fe}(\text{OH})_2 \downarrow + \text{Ca}^{2+}$ $\text{Ca}^{2+} + \text{Na}_2\text{CO}_3 \longrightarrow \text{CaCO}_3 \downarrow + 2\text{Na}^+$	L/2
NaAlO₂	$\text{NaAlO}_2 + \text{H}_2\text{O} \longrightarrow \text{Al}(\text{OH})_3 \downarrow + \text{NaOH}$	

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Equivalents of CaCO₃:-

1. The concentrations of hardness as well as non-hardness constituting ions are usually expressed in terms of equivalent amount of CaCO₃.
2. The choice of CaCO₃ in particular is due to its molecular weight 100 (equivalent weight=50) and it is the most insoluble salt that can be precipitated in water treatment.
3. Hardness of the hardness causing salt in terms of CaCO₃

$$\text{CaCO}_3 \text{ Equivalents} = \frac{\text{Mass of Hardness producing salt}}{\text{Molecular mass of that salt}} \times 100$$

Now the 100 parts by mass of CaCO₃ are equivalent to : (i) 74 part of Ca(OH)₂ and (ii) 106 parts of Na₂CO₃

Lime required for softening:

$$= \frac{74}{100} [\text{Temp. Ca}^{2+} + 2 \times \text{Temp. Mg}^{2+} + \text{Perm. (Mg}^{2+} + \text{Fe}^{2+} + \text{Al}^{3+}) + \text{CO}_2 + \text{H}^+ (\text{HCl or H}_2\text{SO}_4) + \text{HCO}_3^-]$$

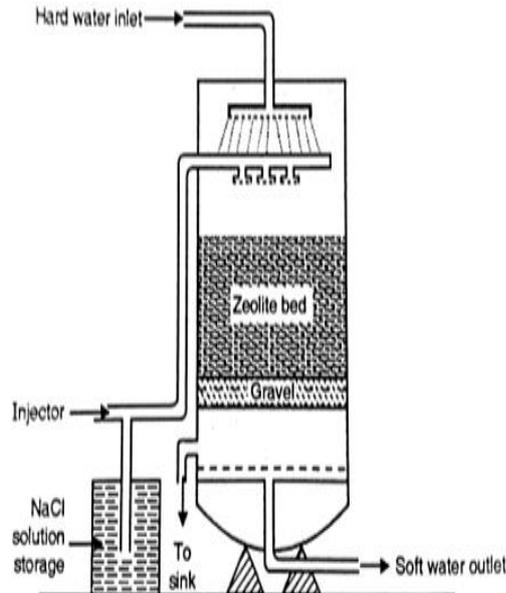
Soda required for softening:

$$= \frac{106}{100} [\text{Perm. (Ca}^{2+} + \text{Mg}^{2+} + \text{Fe}^{2+} + \text{Al}^{3+}) + \text{CO}_2 + \text{H}^+ (\text{HCl or H}_2\text{SO}_4) - \text{HCO}_3^-]$$

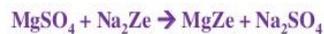
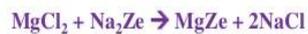
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Zeolite (or) permutite process:-

1. The chemical formula of zeolite is hydrated sodium aluminum silicate represented as Na₂OAl₂O₃.xH₂O yH₂O (x=2 to 10 &y=z-6).
2. Zeolites are capable exchanging ions with sodium ions.
3. It is capable of exchanging hardness producing ions (Ca⁺², Mg⁺²) present in water.
4. Zeolite can be written as *Na₂Ze*



- They exchange Na^+ ions with the hardness, producing ions (Ca^{2+} , Mg^{2+} , etc) in water.
- Sodium Zeolite is denoted as Na_2Ze
- PROCESS: In this process 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
- The following reactions taking place:



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Process:-

1. The apparatus is made of cylindrical metallic vessel Which is packed with Zeolite bed
2. Raw water is poured inside the apparatus through Zeolite bed and thus chemical ion exchange reactions are takes place.
3. All the hardness producing ions of Ca^{2+} , Mg^{2+} ions are exchanged by zeolite of Na^+
4. After the use of this process for a certain time, Zeolite is exhausted .i.e all Na^+ ions are replaced by $\text{Ca}^{2+}/\text{Mg}^{2+}$ and therefore this will not be used for soften the water. That bed is called Exhausted zeolite bed
5. Exhausted zeolite bed can be regenerated or reactivated by reacts with brine solution 10% NaCl

Regeneration of Zeolite bed



Advantages:-

1. Hardness of water is removed
2. It is about 10ppm in the soft water obtained by this process. It is easy to operate
3. It occupies less space and sludge or Scale is not formed

Disadvantages:-

1. If the hard water containing acid destroys the zeolite bed.
2. The turbidity (or) suspended particles present in water will block the pores of zeolite.
3. Bicarbonate & carbonate ions present in water are converted as sodium salts resulting the alkalinity of water. The colored ions like Mn^{2+} & Fe^{2+} cannot be removed by this process.

Ion exchange process (or) deionization or demineralization:-

Ion exchanges Resins are of two types. Anionic & Cationic.

These are co-polymers of styrene & divinyl benzene.i.e. Long chain organic polymers with a micro porous structure.

cation exchange resins:-

The resins containing acidic functional groups such as $-COOH$, $-SO_3H$ etc. are capable of exchanging their H^+ ions with other cations cation exchange resins represented as RH^+

Anion exchange resins:-

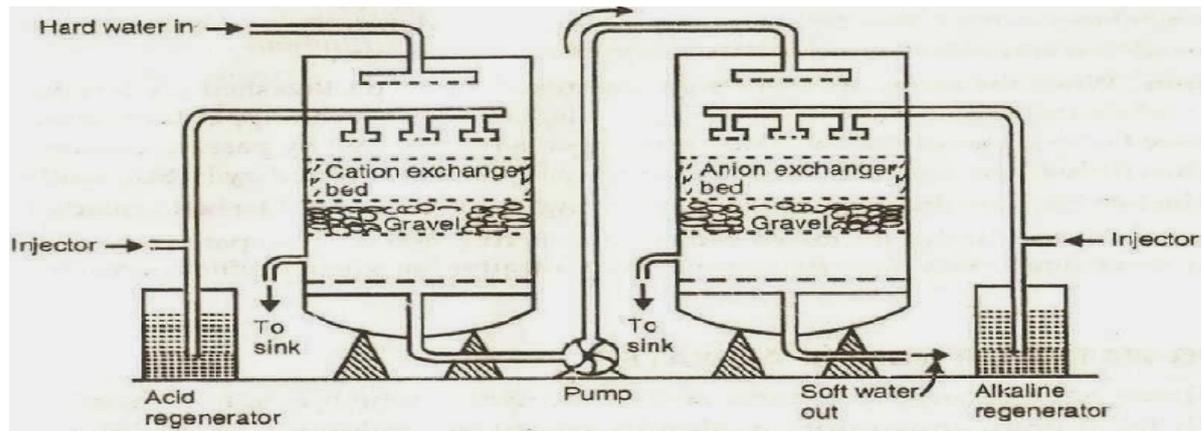
The resins containing amino or quaternary ammonium or quaternary phosphonium treated with "NaOH solution becomes capable of exchanging their OH^- ions with other anions. These are called as Anion exchanging resins represented as $R OH^-$

Process:

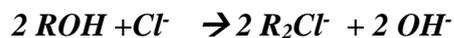
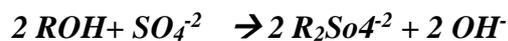
1. The hard water is passed first through cation exchange column.
2. It removes all the cation (Ca^{2+} & Mg^{2+}) and equivalent amount of H^+ ions are released from this column.

Reactions occurring at cation exchange Resin:





Reactions occurring at anion exchange Resin:

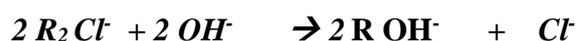
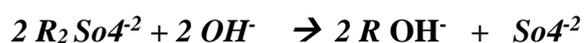


3. After this the hard water is passed through anion exchange column, which removes all the anions like SO_4^{2-} , Cl^- , CO_3^{2-} etc and release equal amount of OH^- from this column.
4. The output water is also called as de-ionized water after this the ion exchanges get exhausted.
5. The cation exchanges are activated by mineral acid (HCl) and anion exchanges are activated by dil NaOH solution.

Regeneration of cation exhausted bed by acids (HCl)



Regeneration of Anion exhausted bed by NaOH



Advantages:-

1. The process can be used to soften highly acidic or alkaline wate.
2. It produces water of very low hardness. So it is very good for treating for use in high pressure boilers.

Disadvantages:-

1. The equipment is costly and common expensive chemicals required.
2. If water contains turbidity, and then output of this process is reduced. The turbidity must be below 10

Desalination

The removal of dissolve solids (NaCl) from water is known as desalination process. It can be carried out by (1) Reverse osmosis and (2) electro dialysis.

Reverse osmosis process:-

Electro dialysis and reverse osmosis are part of the membrane process.

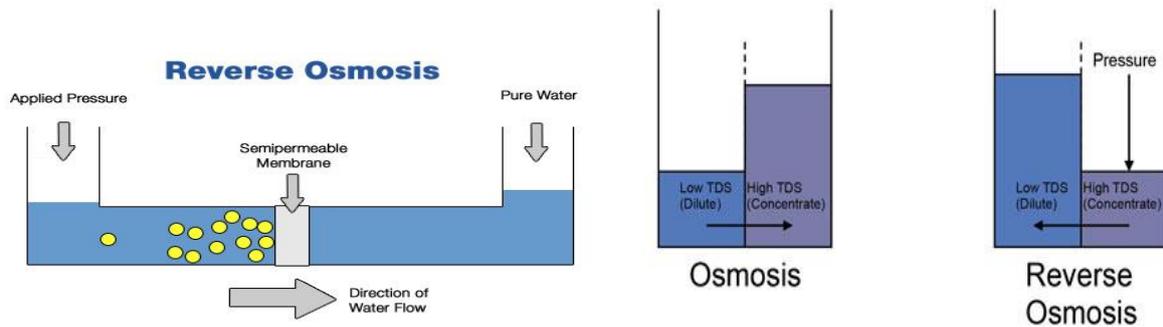
Osmosis:

Two different concentrated solutions are separated by semi permeable membrane; solvent molecule can flow from the lower concentration to the higher concentration solution the phenomenon is called osmosis

Reverse osmosis:

Atmospheric pressure or applied pressure is greater than that of osmotic pressure in that condition solvent molecule can flow from higher concentration to lower con solution is called reverse osmosis

1. RO system is used desalination of sea water.
2. Sea water and pure water are separated by a semi-permeable
3. It is used to make pure water. It removes the ionic and non ionic substances in the water.
4. It also can remove suspended colloidal particles.
5. The life of a membrane is nearly 2 years and it should be replaced after this period. By this process, sea water is made to fit for drinking water obtained after being treated by this process is used in boilers



Electro dialysis:

It is a technique used for the desalination of saline (Sea or Brackish Water) water and is a membrane process

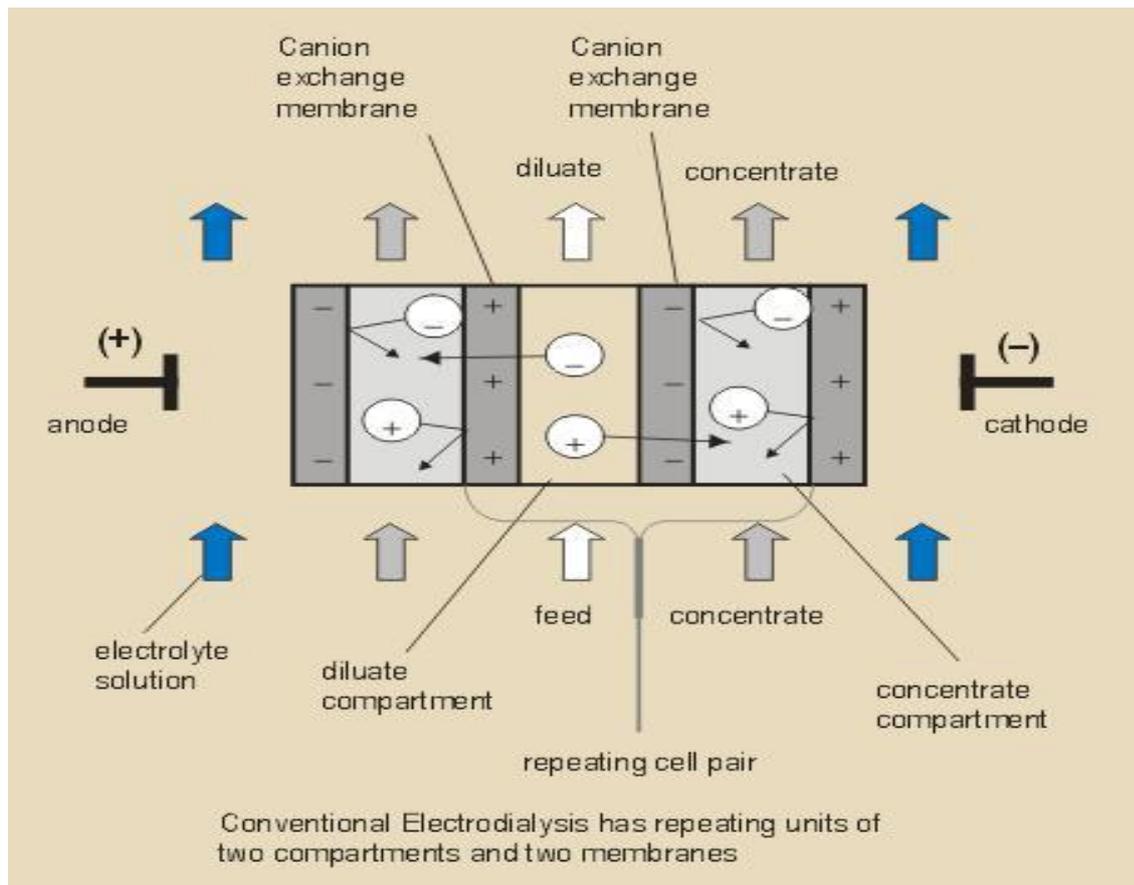
Principle –under the influence of electric current across the salt water solution, charged ions move towards respective electrodes through ions and selective membrane

Process -

1. Electro dialysis cell can be divided into three chambers through the ion selective membrane
2. It consist of two electrodes and side chambers ,connected to current
3. ion selective membranes which are permeable to either cation or anion
4. Sea water is allowed into three chambers(Compartment) then current is passed through the electrodes electrolysis is taken place in middle chamber there by All the cataions (Na^+) move toward negative electrode chamber whereas negative ions move towards positive electrode chamber from middle chamber So that which contain ions free (salt free) water
5. When electrode chambers become more concentrated with brine (NaCl ,) They should be replaced by fresh one

Advantages

1. It is the best method for getting drinking water from sea water
2. The cell is compact and hence is to handle and economical



Municipal Water Treatment:

The type of treatment is given to water largely depends upon the quality of raw water and also upon specified standards.

In general water treatment for municipal supply or domestic use consists of following stages:

Removal of suspended impurities:

1. Screening:

The raw water is passed through screens having large no. of holes where floating materials are retained.

2. Sedimentation & Coagulation:

It is a process of allowing water to stand undisturbed in big tanks about 5m deep when most of suspended particles settle down at the bottom due to force of gravity. It is called sedimentation

Coagulation:

coagulation is the process of removing fine suspended and colloidal impurities by addition of coagulants (chemicals) to water before sedimentation.

Coagulant when added to water form insoluble gelatinous, flocculent precipitate which suspended in water adsorbs and entangles very fine suspended impurities forming bigger flocs, which settle down easily.

Eg. Alum [$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$],

$NaAlO_2$, $FeSO_4 \cdot 7H_2O$.



3. Filtration:

The process of removing colloidal matter and most of the bacteria, microorganism by passing water through a bed of fine sand and other proper sized granular materials.

2. Removal of microorganisms: (disinfection.)

Water used particularly for drinking purpose must be freed from diseases producing bacteria, microorganism etc

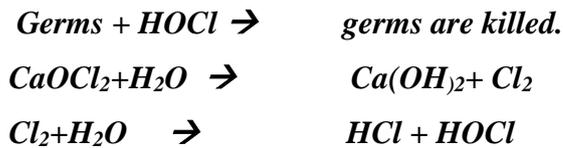
The process of killing the pathogenic micro organism is called disinfection.

The chemicals or substances which are added to water for killing the bacteria is known as disinfectant

Process

a) **Boiling:** water boiled for 10-15 minutes kills all the disease producing bacteria. (not suitable for large quantity of H_2O)

b) **Adding bleaching powder:** 1 kg of bleaching powder per 1000 kilo litres of water is mixed and water is allowed to stand undisturbed for several hours. .The chemical action produces hypochlorous acid, which is a powerful germicide.



The disinfecting action of bleaching powder is due to the chlorine made available by it.

Drawbacks:

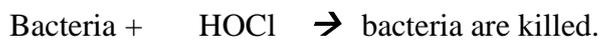
Bleaching powder introduces calcium in water which makes it harder.

Bleaching powder deteriorates due to its continuous decomposition during storage.

Excess of bleaching powder gives bad taste and smell to treated water.

c) By chlorination:

Chlorine (either in gas or in concentrated solution form) produces hypochlorous acid which is a powerful germicide.

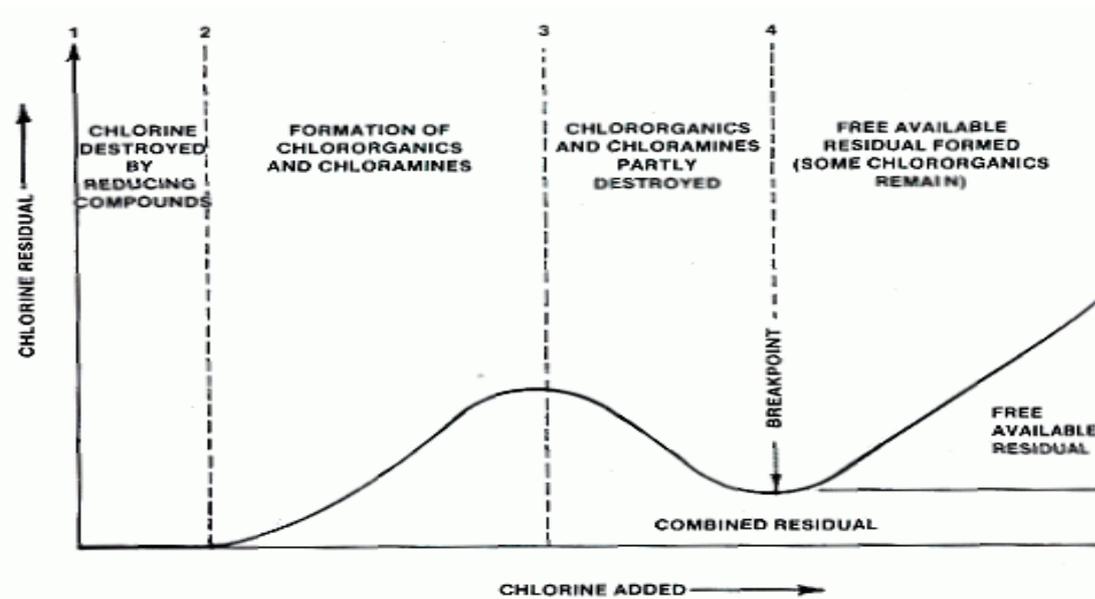


Chlorinator:

It is a high tower having a no. of baffle plates. Water and proper quantity of conc. Cl_2 treated water is taken out from the bottom. For filtered water about 0.3-0.5 ppm of Cl_2 is sufficient.

Break point of chlorination.

1. The process of applying calculated amounts of chlorine to water in order to kill the pathogenic bacteria is called chlorination.
2. Chlorine is a powerful disinfectant than chloramines and bleaching powder.
3. Calculated amount of chlorine must be added to water because chlorine after reaction with bacteria and organic impurities or ammonia, remains in water as residual chlorine
 - a. Residual chlorine gives bad taste, odour and toxic to human beings.
4. *The amount of chlorine required to kill bacteria and to remove organic matter is called break point chlorination.*



Advantages of break point chlorination:

1. It removes taste, colour, oxidise completely organic compounds, ammonia and other reducing impurities.
2. It destroys completely (100%) all disease producing bacteria.
3. It prevents growth of any weeds in water

From the graph it is clear that the area under represents,

1-2 : chlorine added oxidises reducing impurities of water.

2-3: chlorine added forms chloramines and chloro compounds.

3-4: chlorine added causes destruction of bacteria.

After 4: chlorine is residual chlorine.

So, 4 is the break point for the addition of chlorine to water. This is called break point

De chlorination:

The over chlorination is removed by passing the water through a bed of granular carbon and also by addition of SO₂ and sodium thiosulphate.

