WATER

SOURCES OF WATER:

A) Surface Waters

B) Underground Waters

A) Surface Waters:

1. Rain Water:

Rain water is the purest form of natural water as it is obtained as a result of evaporation from the surface water. However, during the journey downwards thro the atmosphere, it is contaminate with industrial gases like CO_2, SO_2, NO_2 and suspende organic and inorganic solid particles.

2. River Water:

Rivers are fed by rain & spring waters. River water contains dissolved minerals of the soil such as chlorides, sulphates, bicarbonates of Na, Ca, Mg & Fe.

3. Lake Water:

Lake water has more constant chemical compositio contains much lesser amounts of dissolved minerals than well water, but has high organic ma

4. Sea Water:

It is most impure form of natural water. Rivers join sea & throw the impurities carried by the Sea water contains 3.5% of dissolved salts out of which 2.6% is NaCl.

B) Underground Waters:

A part of the rain water, which reaches surface of the earth, percolates into earth. As this water journeys downwards, it co in contact with mineral salts in soil. Wat meet a hard rock when it retreads upward and it may come out in form of spring.

Spring and well water is clearer in appearance due to filtering action of soil but contains more of dissolved salts.

Characteristics imparted by impurities in Water

The different types of impurities are:

- Physical Impurities
- Chemical Impurities
- Biological Impurities.

1. Physical Impurities:

a) Colour:

colour in water is caused by metallic substance like salts of Fe, Mn and dissolved salts. The change in colour of water is not harmful unless t is associated with any toxic chemicals. Yellow uge indicates the presence of Cr (chromium), ellowish-red – Fe, red-brown – algae, peat

Turbidity:

urbidity is due to colloidal, suspension like clay, silt and microorganisms. Turbidity expresses the optical properties of water

c) Taste:

Taste is interlinked with odour directly. However the presence of dissolved mineral in H_2O produces taste but not odour. eg bitter taste is due to the presence of Fe, Al, Mn. Soapy taste is due to sodium bicarbonate, brackish taste - salts

d) Odour:

odour in water is undesirable for domestic as well as industrial purposes. Bad odour is due to micro organisms, decaying vegetation like algae, bacteria, fungi and weeds. Odour is due to presence of inorganic and organic compounds of N, S, P etc. Presence of algae in water produce grassy odour, growth of iron and sulphur bacteria produce offensive odour.

) Chemical impurities in H_2O:

Inorganic & organic chemicals released from dyes, paints, varnishes, drugs, insecticides, detergent etc. pollute water. Thus the basic chemical impurities includes:

a) Acidity :

Surface waters & ground waters attain acidity from industrial wastes like acid mine, drainage etc. Acidity is caused by CO_2, H_2SO_4 and mineral acids.

b) Gases :

All natural waters contain dissolved atmosphere CO_2. Dissolved O_2 from Industrial wastes pollute water and dissolved NH_3 in water is due to nitrogeneous organic matter.

c) Mineral Matters :

Mineral matters are from rocks & industrial effluents These include mineral acids, Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{2+}, CO_3^{2-}, Mn^{2+}, HCO_3^-, Cl^-, SO_4^{2-} etc.

3) Biological Impurities :

These include algae, pathogenic bateria, fungi, virus etc. a) Micro-organisms : These include algae, fungi, bacteria which often form slime thereby causing fouling & corrosion. b) Water bodies : These includes bacteria and planktons. These are inhabitated by different group of worms like flat worms, hair worms, tiny round worms, etc.

RDNESS OF WATER:

Hardness of water is the characteristic which prevents the lathering of soap. This is due to certain salts of Ca, Mg and heavy metals dissolved in water. A sample of hard water, when treated with soap, does not produce lather, but forms a white scum or precipitate. This precipitate is due to formation of insoluble soaps of Ca and Mg.

$$2C_{17}H_{35}COONa + CaCl_2 \rightarrow (C_{17}H_{35}COO)_2Ca\downarrow + 2NaCl$$

Sodium stearate (soap) — Ca. stearate insoluble.

$$2C_{17}H_{35}COONa + MgSO_4 \rightarrow (C_{17}H_{35}COO)_2Mg\downarrow + Na_2SO_4$$

Magnesium stearate (insoluble)

Thus water which does not produce lather with soap readily but forms a white curd is called hard water. and water which lathers easily with soap is called soft water..

Hardness is of 2 types:

1) Temporary or Carbonate Hardness:

This is caused by the presence of dissolved bicarbonates of Ca, Mg, heavy metals. It is destroyed by boiling of H_2O, when bicarbonates are decomposed, yielding insoluble carbonates or hydroxides which are deposited as a crust at the bottom of vessel.

Thus, $Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 \downarrow + H_2O$
insoluble.

$Mg(HCO_3)_2 \xrightarrow{\Delta} Mg(OH)_2 \downarrow + 2CO_2$

2) Permanent Hardness or Non Carbonate Hardness:

This is due to the presence of chlorides and sulphates of Ca, Mg, Fe, heavy metals: This is not destroyed by boiling.

Equivalents of $CaCO_3$:

The concentration of hardness and non-hardness is expressed in terms of equivalent amount of $CaCO_3$ since it permits the multiplication and division of concn. wh required. Moreover, its mol. wt. is 100 and insoluble salt that can be precipitated in water treatment.

The equivalent of $CaCO_3$ =

$$\Rightarrow \frac{\text{mass of hardness producing substance} \times \text{chemical equivalent of } CaCO_3\ (50)}{\text{Chemical equivalent of hardness producing substance}}$$

Units of Hardness:

PPm: Parts Per Million is the parts of $CaCO_3$ equivalent hardness per 10^6 parts of H_2O 1ppm = 1 part of $CaCO_3$ eq hardness in 10^6 parts of H_2O.

2) Milligrams Per litre mg/l:

It is the no/. of milligrams of $CaCO_3$ equivalent hardness present per litre of H_2O.

1 mg/l = 1mg of $CaCO_3$ eq hardness of 1l H_2O

But 1l of H_2O weighs = 1Kg = 1000g
= 1000 x 1000mg
= 10^6mg

1mg/l = 1mg of $CaCO_3$ eq per 10^6 mg of H_2O
= 1 part of $CaCO_3$ eq per 10^6 parts of H_2O
= 1ppm.

3) Clarke's degree °cl:

It is the no/. of grains of $CaCO_3$ eq hardness per gallon (10 lb) of H_2O or it is parts of $CaCO_3$ eq hardness per 70000 parts of H_2O.

1°clarke = 1 grain of $CaCO_3$ eq hardness per gallon of H_2O

1° cl = 1 part of $CaCO_3$ eq hardness per 70000 parts of H_2O.

4) **Degree French °Fr:**

It is the parts of $CaCO_3$ eq hardness per parts of H_2O. Thus

$1°Fr = 1$ part of $CaCO_3$ eq hardness per 10^5 part of H_2O.

5) **Milliequivalent per litre : meq/l.**

It is the no. of milli equivalents of hardness present per litre.

$1\,meq/l = 1\,meq$ of $CaCO_3$ per l of H_2O

$= 10^{-3} \times 50$ g of $CaCO_3$ per l.

$= 50$ mg of $CaCO_3$ eq per l.

$= 50$ mg/l of $CaCO_3$ eq $= 50$ ppm.

Disadvantages of Hard Water:

1. **In domestic Use:**

i) **Washing:**

During washing hard water does not lather freely with soap and it produces sticky precipitates of Ca & Mg soaps. The formation of such insoluble sticky precipitates continues till all Ca & Mg salts are precipitated. After that, the soap gives lather with water.

$$\underset{\text{soap}}{C_{17}H_{35}COONa} + H_2O \rightleftharpoons C_{17}H_{35}COOH + NaOH.$$

$C_{17}H_{35}COOH + C_{17}H_{35}COONa \longrightarrow$ lather

stearic acid soap.

This causes a wastage of lot of soap being used. This sticky precipitates adheres on the fabric giving spots and streaks as well as stains.

ii) Balthing:

Due to hard water, the cleansing quality of soap is depressed and a lot of soap is wasted.

iii) Cooking:

Due to dissolved salts in hardwater, its boiling point is elevated thereby consuming lot of time and fuel while cooking. Certain foods like pulses, beans, peas dont cook soft and Tea, coffee prepared from hardwater gives unpleasant taste. Moreover the dissolved salts are deposited as carbonates on the inner walls of water heating utensils.

iv) Drinking:

Hardwater causes bad effect on our digestive system forming calcium oxalate crystals in urinary tracks.

2) Industrial Use:

Textile and dyeing industry:

i) Textile industry and dyeing industry: hard water

Much of the soap is wasted due to hard water and precipitates of Ca & Mg adhere to the fabrics

These fabrics when dyed later on, do no produce exact shades of colour. Fe salts produce coloured spots on fab

ii) Sugar industry:

Hardwater causes difficulties in crystallizati of sugar and sugar produced may be deliquescent.

iii) Paper Industry:

Ca & Mg salts react with the chemicals employed for proper finish to paper and thus affect the colour & quality of the paper.

iv) Concrete making:

The salts present in hardwater affects the hydration of cement and its strength.

v) Pharmaceutical Industry:

Hardwater if used for preparing pharmaceutica products like drugs, ointments etc may produce undesirable products in them.

3) In Steam Generation in Boilers:

Boilers are employed for steam generation. If hard water is fed directly to the boilers, there araise boiler troubles like scale & sludge formation, corrosion, priming, foaming, caustic embrittlement.

BOILERS TROUBLES:

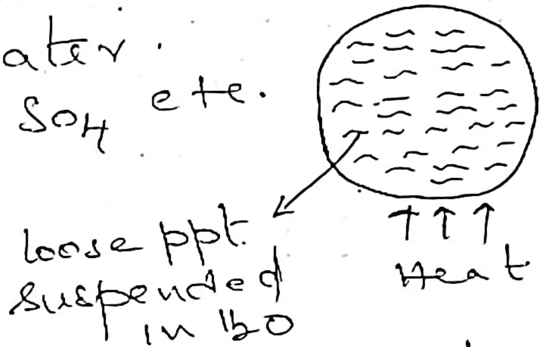
SCALE AND SLUDGE FORMATION:

In boilers, water evaporates continuously and the concentration of dissolved salts increase progressively. When their concentration reach saturation point, they are thrown out of water in form of precipitates on the inner walls of the boiler.

If the precipitation occurs in the form of loose and slimy ppt then it is called sludge. If the precipitate is hard getting adhere on the inner walls of the boilers, it is called scale.

Sludge:

Sludge is a soft, loose, slimy precipitate formed within the boiler. It can be scrapped off with wire brush. It is formed at colder portions of the boiler and these are formed by substances which have greater solubilities in hot H_2O than in cold water.
eg $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$ etc.



Sludge.

Disadvantages of sludge:

1. Sludges are poor conductor of heat, so they waste the heat generated.

2) If sludges are formed with scales, the sludges are entrapped in the scales and both get deposited.

3) It disturbs the working of the boilers. It settles in regions of poor water circulation, such as pipe connection, plug opening, gauge glass connection thereby causing choking of pipes.

Prevention of Sludge formation:

1) By using soft H_2O 2) By frequently blow down operation

Scales:

Scales are hard deposits which stick very firmly to inner surfaces of boiler. These are main sources of boiler. Formation of scales are due to the following:

1) Decomposition of $CaCO_3$:

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

In high pressure boilers, $CaCO_3$ is soluble.

$$CaCO_3 + H_2O \longrightarrow Ca(OH)_2 \text{ soluble} + CO_2\uparrow$$

2) Decomposition of $CaSO_4$:

The solubility of $CaSO_4$ in H_2O decreases with rise of temperature. ∴ $CaSO_4$ get precipitated as hard scale. This is main cause of scales in high pressure boilers

3) Hydrolysis of Magnesium salts:

Dissolved Mg salts undergo hydrolysis at high temp. inside the boiler forming $Mg(OH)_2$ ppt. which form a soft scale.

$$MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2 \downarrow + 2HCl \uparrow$$

4) Presence of Silica: (SiO_2)

SiO_2 get deposited as calcium silicate $CaSiO_3$ or $MgSiO_3$ which stick very firmly on inner side of the boiler surface.

Disadvantages of scale formation:

1. Wastage of fuel:

Scales have low thermal conductivity, so heat transfer is decreased. ∴ over heating is done which causes increase in fuel consumption. The wastage of fuel depends on thickness and nature of scale.

2. Lowering of boiler safety:

Due to scale formation, overheating of boiler makes the boiler material softer & weaker and this causes distortion of boiler tube and makes boiler unsafe to bear the pressure of the steam

3. Decrease in efficiency:

Scales may sometimes deposit in valves and condensers of the boiler and choke them partially. This results in decrease efficiency of the boilers.

4) Danger of explosion:

When thick scales crack, due to uneven expan the water comes suddenly in contact with ove heated iron plates. This causes in formation of large amt of steam suddenly. So sudden high pressure is developed which may cause explosion of the boiler.

Removal of Scales:

This can be done 1) by using scraper piece of wood, wire brush.

2) By thermal shocks which involves heating the boiler & cooling the boiler suddenly in cold water

3) By dissolving them in chemicals like HCl which could dissolve $CaCO_3$ scales. $CaSO_4$ scales can be dissolved by addition of EDTA

4) By blow down operation. It is the partial removal of hard H_2O thro tap at the bottom of boiler, when the hardness in the boiler becomes alarmingly high.

Prevention of Scale formation

1) External treatment:

Softening of H_2O methods →

Internal Treatment: **Sequestration**;

Internal treatment is accomplished by adding a proper chemical to boiler water either
a) to precipitate the scale forming impurities in form of sludge which can be removed by blow down operation.
b) to convert them into compounds which stay in dissolved form in water and thus dont cause any harm.

The internal treatment methods are:

1) **Colloidal Conditioning**:
In low pressure boiler scale formation can be avoided by adding organic substances like kerosene, tannin, agar-agar, which get coated over the scale forming precipitate thereby yielding non sticky and loose deposits which can be removed by blowdown operation.

2) **Phosphate Conditioning**:
In high pressure boilers, scale formation is avoided by addition of sodium phosphate which forms non adherent, removable, soft sludge of Ca & Mg phosphates which is removed by blow down operation.

$3CaCl_2 + 2Na_3PO_4 \rightarrow Ca_3(PO_4)_2\downarrow$

The main phosphates are: NaH_2PO_4 sod dihydrogen phosphate (acidic) and Na_2HP disodium hydrogen phosphate (weakly alkali Na_3PO_4 trisodium phosphate (alkaline)

iii) Carbonate Conditioning:

In low pre boilers, scale formation can be avoided by adding Na_2CO_3

$$CaSO_4 + Na_2CO_3 \rightleftharpoons CaCO_3 + Na_2SO_4.$$

Consequently, deposition of $CaSO_4$ doesn't occur and Ca is precipitated as loose sludge of $CaCO_3$ (removed by blowdown)

iv) Calgon Conditioning:

Addition of Calgon (sodium hexa meta phosphate $(NaPO_3)_6$ to boiler H_2O prevents scale & sludge formation by forming solubl. complex compound with $CaSO_4$.

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

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

8. Treatment with sodium aluminate [$NaAlO_2$]

$NaAlO_2$ get hydrolysed to NaOH and a gelatinous precipitate of aluminium hydroxide. NaOH so formed precipitates $Mg(OH)_2$.

$$NaAlO_2 + 2H_2O \rightarrow NaOH + \underset{\text{gelatinous ppt.}}{Al(OH)_3 \downarrow}$$

$$MgCl_2 + NaOH \rightarrow Mg(OH)_2 \downarrow + 2NaCl.$$

The flocculent precipitate of $Mg(OH)_2$ & $Al(OH)_3$ produced inside the boiler entraps suspended & colloidal impurities including oil drops & silica. This loose precipitate can be removed by blow down operation.

CAUSTIC EMBRITTLEMENT:

Caustic embrittlement is a boiler corrosion caused by highly alkaline H_2O in boiler. During softening process by lime soda process free Na_2CO_3 is present in small quantity in softened H_2O. In high pressure boilers, Na_2CO_3 decomposes to give NaOH & CO_2 which makes

$$Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2$$

the boiler caustic. The NaOH containing H_2O, flows into minute hair cracks by capillary action. Here water evaporates and dissolved caustic soda concentration increases. This attacks the surrounding area thereby dissolving iron of boiler as sodium ferroate. This Causes embrittlement of boiler parts li bends, joints, rivets etc

Caustic embrittlement can be avoided by u

1) sodium phosphate as softening reag instead of Na_2CO_3

2) tannin or lignin to boiler H_2O as thes blocks the hair cracks thereby preventin caustic soda.

Boiler Corrosion :

Boiler corrosion is decay of boiler material by che or electro-chemical attack by its environmen The main causes of boiler corrosion are :

1) Dissolved oxygen :

H_2O contains 8 ml of dissolved O_2 per litre at room temp. Dissolved oxygen in H_2O attack th boiler material at high temp.

$$2Fe + 2H_2O + O_2 \longrightarrow 2Fe(OH)_2 \downarrow$$

$$4Fe(OH)_2 \downarrow + O_2 \longrightarrow 2[Fe_2O_3 2H_2O]$$

rust.

This can be removed by adding Na_2SO_3 or N_2H_4 (hydrazine) or Na_2S.

$$2Na_2SO_3 + O_2 \longrightarrow 2Na_2SO_4.$$

$$N_2H_4 + O_2 \longrightarrow N_2 + 2H_2O$$

$$Na_2S + 2O_2 \longrightarrow Na_2SO_4.$$

Preparation of EDTA solution:

Dissolve 4g of pure EDTA crystals and 0.1g $MgCl_2$ in 1l distilled H_2O. 23

Preparation of indicator:

Dissolve 0.5 g of eriochrome Black T in 100 ml alcohol

Preparation of buffer soln:

add 67.5 g of NH_4Cl to 570 ml of conc. NH_3 & dilute to 1l dis H_2O.

5. Standardization of EDTA Solution:

Fill the burette with EDTA. Pipette out 50ml standard hard H_2O in conical flask. Add 10 ml buffer soln & 5 drops of indicator. Titrate against EDTA till wine red changes to blue. Let the volume be V_1 ml.

6. Titration of unknown hard H_2O:

Titrate 50 ml H_2O sample and titrate against EDTA. The titre value be V_2 ml.

7. Titration of Permanent Hardness:

Take 250 ml water sample in beaker, boil till the volume is reduced to 50 ml. Filter, wash the precipitate with distilled H_2O and washings are made upto 250 ml by dis H_2O. Titrate 50 ml of this boiled H_2O sample and titrate against EDTA. Let the volume be V_3 ml.

50 ml of Standard hard H_2O = V_1 ml of EDTA.

50 × 1 mg of $CaCO_3$ = V_1 ml EDTA

∴ 1 ml EDTA = $\frac{50}{V_1}$ mg of $CaCO_3$ eq

50 ml of sample hard H_2O = V_2 ml EDTA

= $\frac{V_2 \times 50}{V_1}$ mg of $CaCO_3$

1 l (1000 ml) sample hard H_2O = $1000 \frac{V_2}{V_1}$ mg of $CaCO_3$

Total hardness = $1000 \frac{V_2}{V_1}$ ppm.

50 ml of boiled H_2O = V_3 ml EDTA.

= $\frac{V_3 \times 50}{V_1}$ mg of $CaCO_3$ eq

1000 ml of boiled H_2O = $1000 \frac{V_3}{V_1}$ mg of $CaCO_3$ eq

Permanent Hardness = $1000 \frac{V_3}{V_1}$ ppm

Temporory Hardness = Total − Permanent Hardn

= $1000 \left[\frac{V_2}{V_1} - \frac{V_3}{V_1} \right]$ ppm

= $1000 \frac{(V_2 - V_3)}{V_1}$ ppm.

Advantages:

The method has greater accuracy

Convenience & more rapid proced

Waste Water Treatment:

Waste H_2O has number of impurities which it has picked up while being used. It is necessary t remove the impurities or to alter their nature a They cause serious pollution of H_2O resources. The waste H_2O are of two types: ① Sewage which includes human, animal & household wastes ap solution and note volume as V_2 ml.

Permanent Hardness:

Take 250 ml water sample in beaker. Boil till the volume s reduced to 50ml. Filter, make up the filtrate to 250ml by adding dist H_2O. Titrate 50 ml of filtrate against soap solution. The titre value be V_3 ml.

Calculation:

50 ml of Std. Hard H_2O = (V_1-V) ml of soap solution

50 ml of hard H_2O = (V_2-V) ml of " "

$$= \frac{V_2-V}{V_1-V} \text{ mg. of } CaCO_3 \text{ eq}$$

∴ 1l (1000 ml) of hard H_2O $= \frac{V_2-V}{V_1-V} \times 1000$ mg of $CaCO_3$ eq

Total hardness $= \frac{V_2-V}{V_1-V} \times 1000$ mg/l. or ppm

50 ml of boiled H_2O = V_3-V ml of soap soln

1 l of boiled H_2O $= \frac{V_3-V}{V_1-V} \times 1000$ ppm.

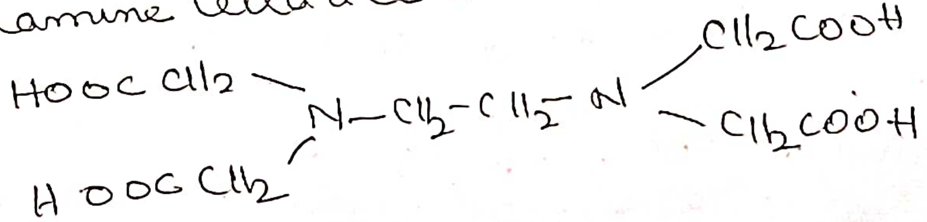
Temporary Hardness = Total − Permanent Hardness

$$= \frac{1000}{V_1-V}\left[(V_2-V)-(V_3-V)\right] \text{ ppm}$$

$$= 1000 \frac{(V_2-V_3)}{(V_1-V)} \text{ ppm.}$$

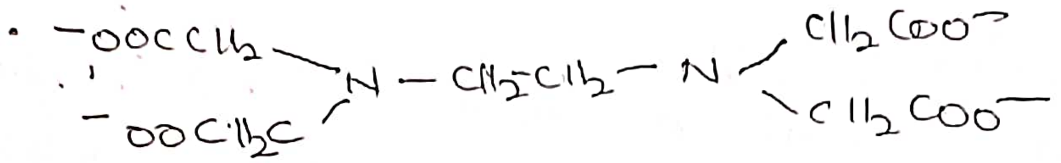
3) EDTA Method:

EDTA ethylene diamine tetra acetic acid is a complexometric method.

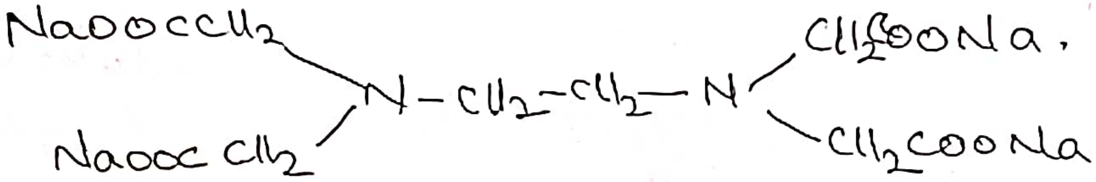


$$\begin{matrix} HOOCCH_2 & & CH_2COOH \\ & N-CH_2-CH_2-N & \\ HOOCCH_2 & & CH_2COOH \end{matrix}$$

In form of sodium salt, it yields anion:



It forms complex with Ca & Mg ions. It be employed as its disodium salt



The end pt is determined by EBT eriochrome black T indicator which is an alcoholic solution of blue dye which forms an unstable wine red complex with Ca^{2+} & Mg^{2+} ion in hard H_2O around pH = 10. Thus,

$$\underset{(Ca^{2+}, Mg^{2+} \text{ of } H_2O)}{M^{2+}} + EBT \xrightarrow{pH=10} \underset{\text{wine red.}}{[M-EBT] \text{ Complex}}$$

During titration with EDTA, EDTA Combines with M^{2+} ions forming stable Complex of M-EDTA by releasing free EBT (blue colour)

$$\underset{\text{wine red}}{[M-EBT] \text{ Complex}} + EDTA \xrightarrow{\text{titration}} [M-EDTA] \text{ complex} + EBT \text{ (blue)}$$

The change of wine red to blue is end point.

Preparation of standard Hard H_2O:

Dissolve 1g of pure dry $CaCO_3$ in minimum amt. of dil HCl, evaporate & dissolve the residue in 1l distilled H_2O.

ntages of Zeolite Process:

1. It removes hardness producing 10ppm hardness water
2. The equipment is compact occupying a small space.
3. It requires less time for softening

Disadvantages:

1. The treated H_2O contains more sodium salts than in lime soda process.
2. This method replaces only Ca^{2+} & Mg^{2+} ion by Na^+ ions in softened water. When but leaves all acidic ions such softened H_2O containing $NaHCO_3$, Na_2CO_3 is used in boilers, it causes corrosion.
3. High turbid water can be softened as fine impurities get deposited on zeolite bed thereby creating problem for its working.

3) ION EXCHANGE or De-ionization or Demineralization process:

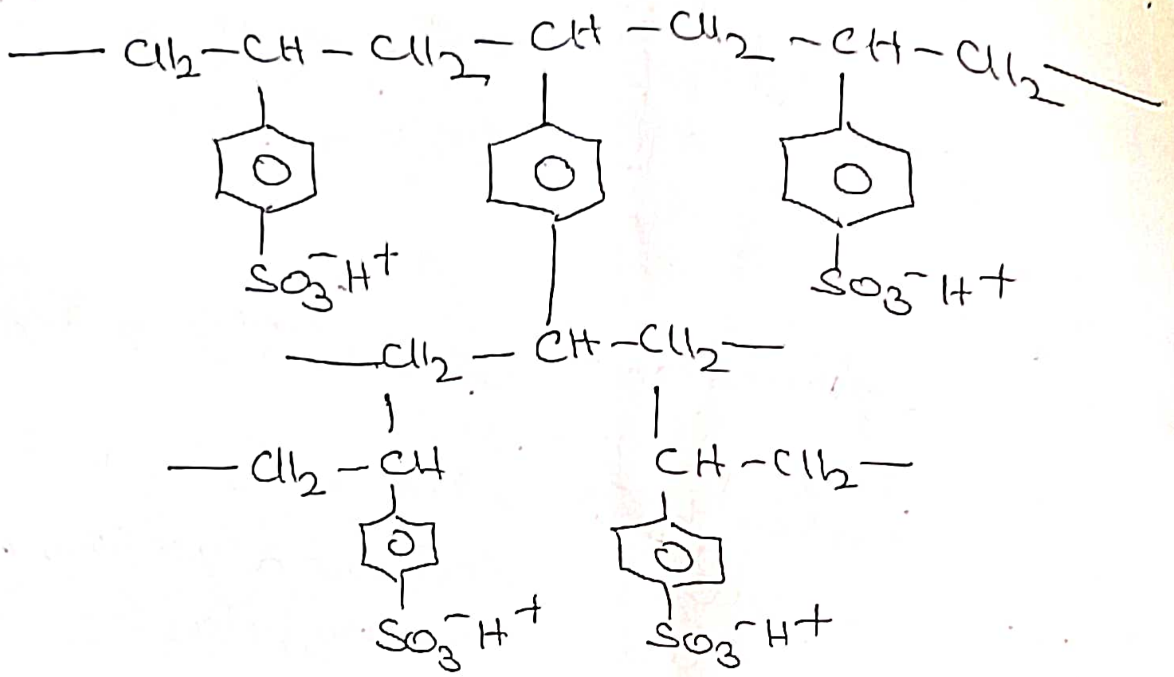
Ion exchange resins are insoluble cross linked long chain organic polymers with microporous structure with functional groups attached to chains. These are responsible for ion exchanging properties. They are classified as follows:

i) Cation exchange resins (RH^+) eg Styrene divinyl benzene copolymers on sulphonation or carboxylation become capable of exchanging their H^+ ions with cations in hard water.

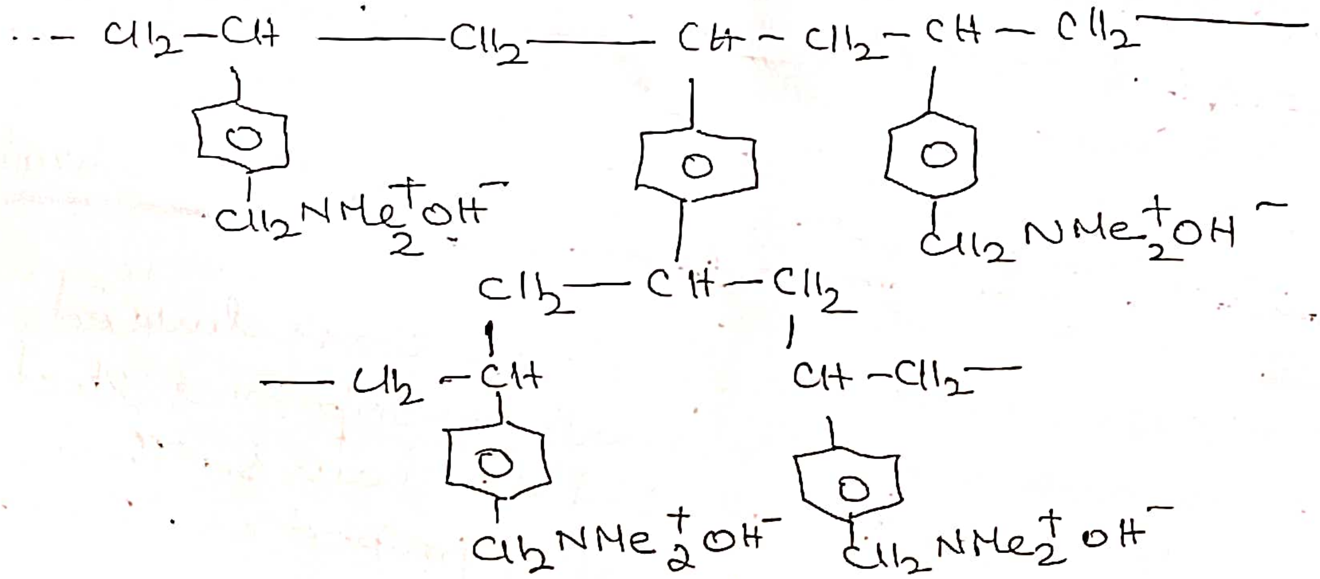
ii) Anion exchange resins ($R'OH$)

eg amine formaldehyde copolymers contain amino or quaternary ammonium/ phosphonium groups:

When these are treated with NaOH, they Capable of exchaging OH^- ion in water.



Cation exchange resin.



Anion exchange resin.

The hard H_2O is passed thro cation exchange coloumn which removed cations like Ca^{2+} Mg^{2+} and equivalent amount of H^+ ions are released from coloumn to water.

$$2RH^+ + Ca^{2+} \rightarrow R_2Ca^{2+} + 2H^+$$

$$2RH^+ + Mg^{2+} \rightarrow R_2Mg^{2+} + 2H^+$$

After this, the water is then passed thro anion nge coloumn which removes all anions ke SO_4^{2-}, Cl^- and release OH^- ions.

$$R'OH^- + Cl^- \longrightarrow R'Cl^- + OH^-$$

$$2R'OH^- + SO_4^{2-} \longrightarrow R_2'SO_4^{2-} + 2OH^-$$

$$2R'OH^- + CO_3^{2-} \longrightarrow R_2'CO_3^{2-} + 2OH^-$$

H^+ & OH^- ions released from cationic & anionic resins get combine to produce H_2O.

$$H^+ + OH^- \longrightarrow H_2O.$$

The water coming out of exchanger is free from cations & anions & ∴ ion free water is known as deionized or demineralised water.

Regeneration:

When capacities of cation & anion exchanger to exchange H^+ & OH^- ions respectively are lost, they are said to be exhausted.

The exhausted cation exchange column is regenerated by passing dil HCl / H_2SO_4

$$R_2Ca^{2+} + 2H^+ \longrightarrow 2RH^+ + Ca^{2+} \text{(washings)}$$

The exhausted anion exchange coloumn is regenerated by dil NaOH. $R_2'SO_4^{2-} + 2OH^- \longrightarrow 2R'OH + SO_4^{2-}$ washing

The washings are passed to sink / drain.

Advantages:

1. The process is used to soften acidic & alkaline H_2O of very low hardness.
2. It produces H_2O of very low hardness.

Disadvantages:

1. Equipment is costly & expensive chemicals are needed.
2. If water is turbid then output is reduced.

DRINKING WATER or MUNICIPAL WATER:

Drinking water should be clear, odourless, cool & pleasant in taste. Its turbidity should not exceed 10 ppm and should be free from dissolved gases like H_2S and also from minerals like Pb, As, Cr, Mn salts. Its pH should be about 8.0 and it should be free from disease producing microorganisms.

Purification:
The following treatment process are employed for purification of drinking H_2O.

A) Removal of suspended impurities:

1) Screening:
The raw H_2O is passed thro screens having large no. of holes, where floating matters are retained.

2) Sedimentation:
Sedimentation is the process of allowing water to stand undisturbed in big tanks, about 5m deep, when most of suspended particles settles down at the bottom, due to the force of gravity. The top clear H_2O is drawn out with pumps. The retention period in sedimentation tank ranges from 2-6 hrs.

H_2O contains fine clay particles & colloidal , it is necessary to apply sedimentation th coagulation. Sedimentation with coagulation e process of removing fine suspended & colloidal rities by addition of chemicals to water before imentation. Coagulant forms an insoluble atinous, flocculant precipitate which adsorbs. d entangles very fine suspended impurities ming bigger flocs which settle down easily.

chemical coagulants used are :

Alum $K_2SO_4\ Al_2(SO_4)_3\ 2H_2O$

$$\underset{\text{Coagulant}}{Al_2(SO_4)_3} + \underset{(\text{in } H_2O)}{3Ca(HCO_3)_2} \longrightarrow \underset{\substack{\text{Aluminium hydroxide}\\ (\text{flocculant ppt})}}{2Al(OH)_3\downarrow} + 3CaSO_4 + 6CO_2$$

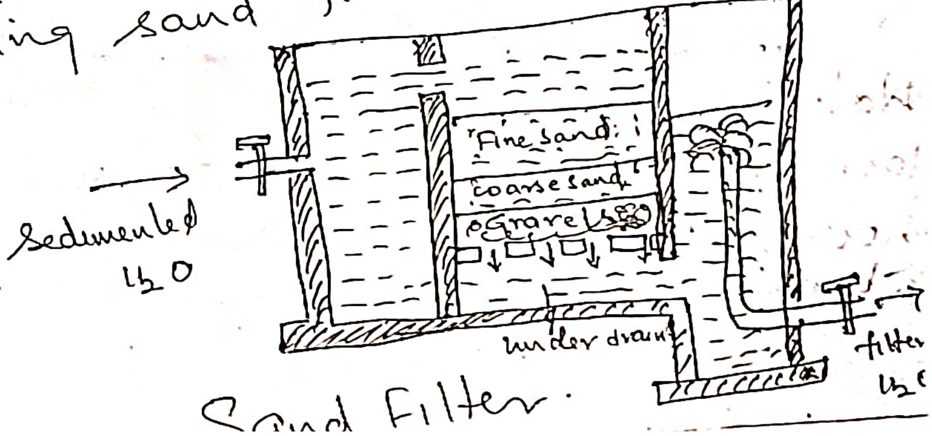
) **Sodium Aluminate** : $NaAlO_2$

$$NaAlO_2 + 2H_2O \longrightarrow \underset{\substack{\text{gelatinous}\\ \text{floc.}}}{Al(OH)_3\downarrow} + NaOH$$

$$2NaOH + MgSO_4 \longrightarrow Mg(OH)_2\downarrow + Na_2SO_4$$

) **Filtration**:

ltration is the process of removing colloidal matter & ost of microorganisms by passing H_2O thro bed of ine sand & proper sized granular materials. Filtration s carried out by using sand filter.



Sand Filter.

A sand filter consists of thick top lay of fine sand placed over coarse sand layer gravels. It is provided with inlet for H_2O and underdrain channel at bottom for exit of filtered water. Sedimented H_2O entering the sand filter is distributed over fine sand bed. During filtration, sand pores get clogged due to retention of impurities the pores. When the rate of filtration is slow, the working of filter is stopped & the top sand layer is scrapped off and replaced with clean sand.

B) Removal of Micro-Organisms:

After the process of sedimentation, coagulation & filtration water still has some amount of pathogenic bacteria. Consequently, drinking water should be free from these disease producing bacteria.

The process of destroying the disease producing bacteria from H_2O is called disinfection and the chemicals which are used for killing bacteria are known as disinfectant. The disinfection of water can be carried out by following methods.

1) By Boiling:

By boiling H_2O for 10-15 mts so that all disease producing bacteria are killed

2) By adding Bleaching Powder:

Water is mixed with 1kg of bleaching powder per 1000 kilolitres of H_2O and allowed to stand for several hours. The chemical action produces hypochlorous acid which is a powerful germicide.

$$CaOCl_2 + H_2O \rightarrow Ca(OH)_2 + Cl_2.$$

$Cl_2 + H_2O \rightarrow HCl + HOCl$
hypochlorous acid.

Germs + HOCl → Germs are killed..

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

Disadvantages:

Bleaching powder introduces Ca in H_2O thereby making
t more hard. Bleaching powder deteriorates due to
ts continuous decomposition during storage. So
whenever it is to be added, it has to be analysed
er its chlorine effect. Only calculated quantity is
to be used as excess gives bad taste & bad smell.

3) By Chlorination:

Chlorine produces hypochlorous acid (powerful germicide)

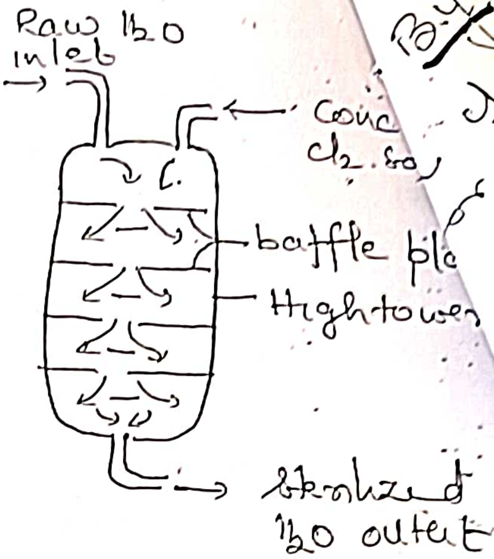
$Cl_2 + H_2O \rightarrow HOCl + HCl.$

bacteria + HOCl → Bacteria are killed.

ls enzyme is essential for metabolic process of micro-
rganism, death of microorganisms results due to inactive
ation of enzyme by hypochlorous acid, producing
OCl^- (hypochlorite ions) which cannot combine with
nzymes in cells of microorganisms. Thus chlorine is
nore effective disinfectant at low pH of below 6.5
This is due to fact that HOCl is 80 times more
lestructive to bacterias than OCl^- ions.

Liquid chlorine is most effective when applied
to filtered H_2O at such a point where adequate
nixing is done. Chlorinatione is done by use of

chlorinator which is a high tower with no. of baffle plates. H_2O & proper quantity of Cl_2 solution is introduced at the top. During their passage thro tower, they get mixed thoroughly. The treated water is taken out from bottom. For filtered H_2O, about 0.3–0.5 ppm of Cl_2 is sufficient.



Break point Chlorination or free residual Chlorination:

Break pt. chlorination involves the addition of sufficient amount of chlorine to oxidise organic matter, reducing substance, free NH_3 in raw H_2O leaving behind free chlorine which posses disinfecting action against disease producing bacteria. This point indicates free residual Cl_2 to appear and all tastes, odour disappear at break point resulting in appearence of H_2O free from bad tastes & odours.

Dechlorination:

Overchlorination after the break point produces unpleasant taste & odour in H_2O. This excess chlorine can be removed by addition of SO_2 & Na_2SO_3.

$$SO_2 + Cl_2 + 2H_2O \longrightarrow H_2SO_4 + 2HCl$$

$$Na_2SO_3 + Cl_2 + H_2O \longrightarrow Na_2SO_4 + 2HCl$$

By using chloramine $ClNH_2$:

hen Cl_2 & NH_3 are mixed in ratio 2:1, chloramine s formed. It is much more lasting than Cl_2.

$$Cl_2 + NH_3 \longrightarrow ClNH_2 + HCl.$$

$$ClNH_2 + H_2O \longrightarrow HOCl + NH_3.$$

5) Disinfection by ozone:

ozone is excellent disinfectant produced by passing electric discharge thro cold & dry O_2

$$3O_2 \xrightarrow[\text{discharge}]{\text{electric}} 2O_3 \text{ (ozone)}$$

ozone is highly unstable & break down into nascent oxygen.

$$O_3 \longrightarrow O_2 + \underset{\text{nascent oxygen.}}{[O]}$$

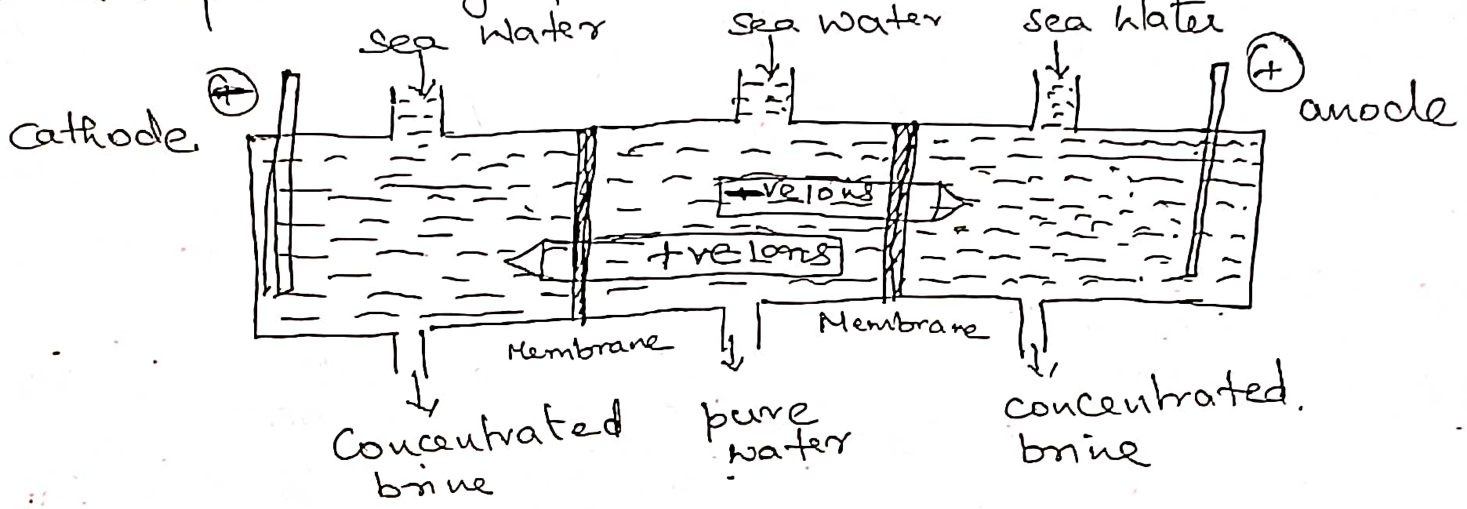
he nascent oxygen is powerful oxidising agent & kills ll bacteria & oxidises organic ~~or~~ matter in H_2O.

Desalination of Brackish Water:

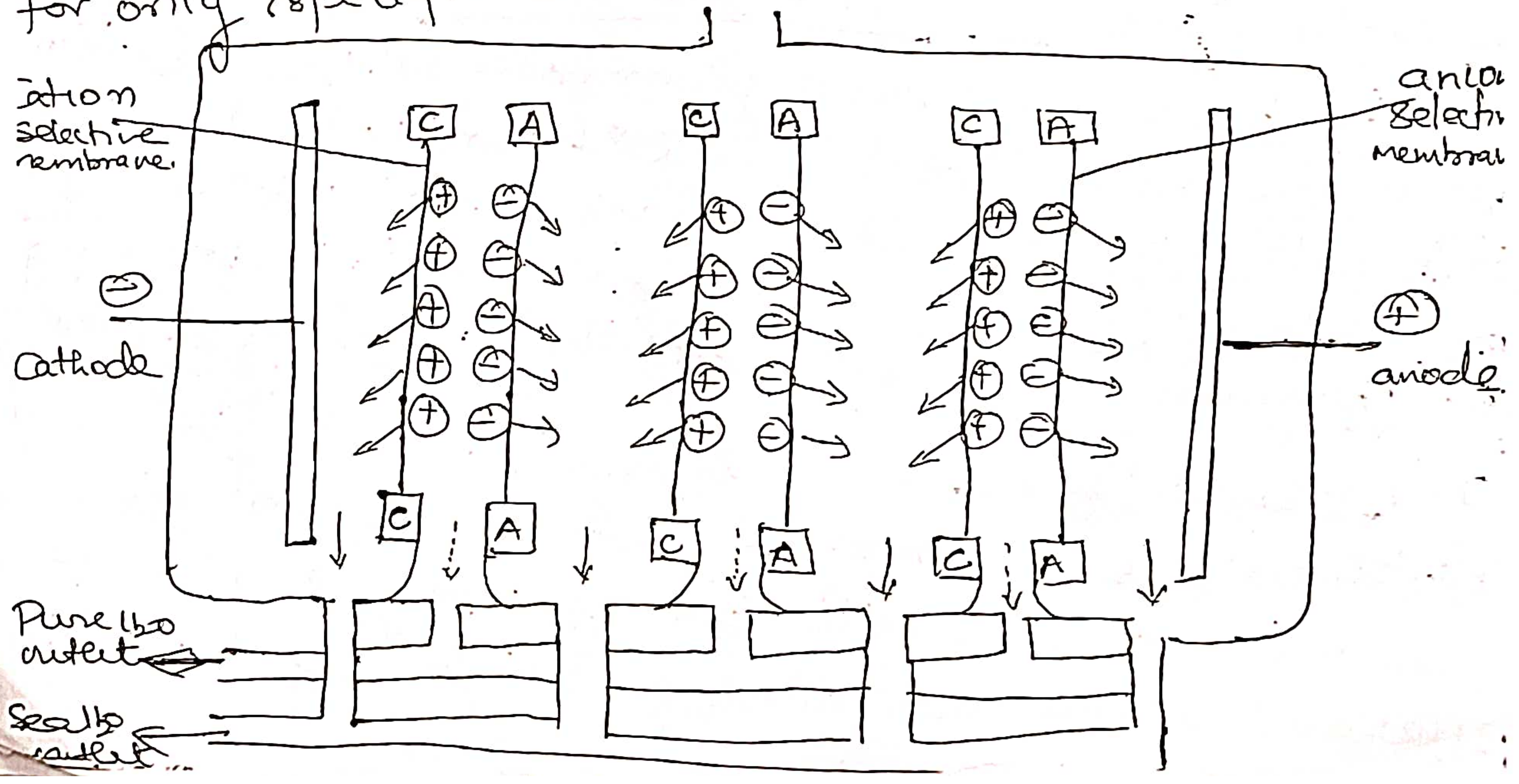
The process of removing common salt (NaCl) from 2O is known as desalination. The water containing salts with peculiar salty or brackish taste is called brackish water. Brackish water is unfit for drinking. The common methods for desalination are as follows

1. Electrodialysis:

Electrodialysis is a method in which the salt ions re pulled out of salt H_2O by passing direct current using electrodes and thin rigid plastic membrane pair. When direct electric current is passed thro saline H_2O, Na^+ ions start moving towards cathode & Cl^- ion towards anode, thro membrane ∴ the concn. of brine (NaCl) decreases in central compartment while it increases in other two sides. Pure H_2O is removed from central compartment while concentrated brine is removed from side compartment and replaced by fresh brine water.



For efficient separation, ion selective membranes are used. Ion selective membrane has permeability for only specific ions.

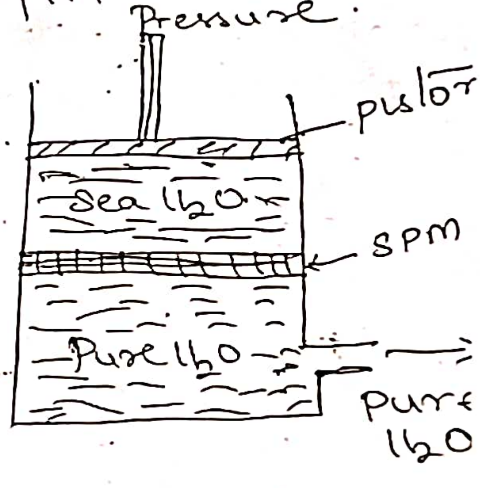


T electrodialysis cell consists of large no. of ed. sets of rigid plastic membranes Saline ater is passed under pressure of 5-6kg/m² between membranes pairs & electric field is applied perpendicular to the direction of H_2O flow. The ions move towards oppositely charged electrodes Thus we get alternate streams of pure H_2O & concentrated brine

2) Reverse Osmosis :

When two solutions of unequal concentrations are separated by semipermeable membrane, the flow of solvent takes place from dilute to concentrated region known as osmosis. The pressure required for osmosis is called osmotic pressure.

When a pressure excess of osmotic pressure is applied on concentrated region, the solvent flow move from Concentrated to dilute region known as reverse osmosis. In reverse osmosis, the pure H_2O is separated from its contaminants rather than removing contaminants from H_2O. The membrane filtration is also called as super-filtration or hyperfiltration.



Reverse osmosis involves the separation by applying pressure to impure/sea H_2O to force its pure H_2O thro semipermeable membrane leaving behind the dissolved salts

Advantages:

1) Reverse osmosis possess advantage of removing ionic & non ionic aswell as high molecular weight organic matter.

2) It removes colloidal silica which is not removed by demineralization

3) The maintainence cost is only the replacement of semimerpeable membrane.

Chemical Analysis of Water:

1) Alkalinity:

The alkalinity of H_2O is due to caustic alkaline of OH^- & CO_3^{2-} ions and temporary hardness of HCO_3^- ions. These can be estimated by titrating agains acid using phenolphthalein & methyl orange as indicators

$$\left.\begin{array}{l}\left.\begin{array}{l}\text{i. } [OH^-]+[H^+]\longrightarrow H_2O \\ \text{ii. } CO_3^{2-}+H^+\longrightarrow HCO_3^-\end{array}\right\} P \\ \text{iii. } HCO_3^-+H^+\longrightarrow H_2O+CO_2\end{array}\right] M$$

The titration of H_2O sample against a standard acid upto phenolphthalein end pt. marks completion of i & ii only. This amount of acid used corresponds to hydroxide plus one half of normal Carbonate present

The titration of H_2O sample against sd. acid to methyl orange end pt. marks the completion of i, ii, iii. Hence the amount of acid used after the phenolphthalein end pt. corresponds to one half of normal Carbonate