UNIT-I

WATER QUALITY & ITS TREATMENT

TERMINOLOGY

Basic Terms	Definations
Hardness	Property or characteristics of water which does not produce lather with soap
Temporary hardness	Hardness due to the presence of bicarbonates of calcium and magnesium
Permanent hardness	Hardness due to the presence of chlorides and sulphates of calcium and magnesium
Dissolved Oxygen	A minimum amount of oxygen present in water at room temperature and pressure is about 8 mg/lit
Screening	Process of removing floating matter from water
Sedimentation	Process of removing high molecular weight suspended particles from water
Coagulation	Process of removing suspended and colloidal impurities by adding coagulants(alum, Ferrous sulphate, sodium aluminate)
Demineralisation	Process of removal of all ions(cations/anions) present in water
Cation Exchange Resin	Resin containing acidic functional group ($-COOH$,$-SO_3H$) capable of exchanging H^+ ions with other cations of hard water
Anion Exchange Resin	Resin containing basic functional groups ($-NH_2$,$-OH$) are capable of exchanging their anions with other anions of hard water
Zeolite/Permutite	Naturally occurring hydrated sodium aluminosilicate .Its general formula is $Na_2O.Al_2O_3.xSiO_2.yH_2O$
Desalination	Process of removing common salt (sodium chlorine) from the water
Calgon	Sodium Hexameta phosphate $Na_2[Na_4(PO_3)_6]$
Acidity	Water with p^H less than 6.5,due to the presence of HCl,H_2SO_4,HNO_3
Alkalinity	Water with the presence of soluble hydroxides, carbonates and bicarbonates
Priming	Process of production of wet steam

Foaming	Formation of stable bubbles above the surface of water
Sludge	Loose and slimy precipitates of $MgCl_2$,$MgCO_3$, $MgSO_4$,$CaCl_2$
Scale	Hard and adherent coating of $Ca(HCO)_3$,$CaSO_4$,$Mg(OH)_2$
Caustic Embrittlement	Corrosion observed in boiler due to the formation of sodium hydroxide
Chlorination	Process of adding chlorine to water
Break point of Chlorine	Process of decrease of residual chlorine to a minimum point at which oxidation of chloramines and other impurities complete and free residual chlorine begin to apper
Reverse Osmosis	Two Solution of different concentrations are separated by a semipermiable membrane,solvent flows from a region of higher concentration to lower concentration
Electrodialysis	Process of separating ions of the salt from salt water through ion selective membrane by passing direct current

CONCEPTS

INTRODUCTION: Water, the most important creation on which all the living organism depends. Water covers ¾ of the earth's surface. Only one percent is available for human use in the form of surface water .Water is used for industrial purposes and also for municipal supply.

SOURCES OF WATER: The main sources of water are

a)Rain b)Ground water c)Surface water d)Sea water.

TYPES OF IMPURITIES IN WATER: The natural water is usually contaminated by different types of impurities. The impurities present in water may be classified as follows;

i)suspended matter: suspended matter are in the form of organic or inorganic particles, immiscible liquids (oils or greases) ,soaps, detergents ,etc. These matters settle down on standing. Removal of these impurities can be done by filtering the water sample.

ii) DISSOLVED GASES: Dissolved gases such as O_2, CO_2, N_2, hydrogen sulphide , methane etc. Which impart undesirable taste and odour of water .They can be removed either by increasing the temp or by chemical treatment.

iii)DISSOLVED IMPURITIES: Water soluble compounds like carbonates of Mg & alkalis, bicarbonates , sulphates ,chlorides of Ca, Mg , Fe etc. make water hard.

iv) SOLUBLE COLLOIDAL SUBSTENCES: These can neither settle down nor filtered. They consist of products from organic wastes, clay, etc.

v) MICRO ORGANISMS: They include bacteria, viruses, protozoa, frogs , helminthes, etc .

HARDNESS OF WATER: Those water which does not produce lather or produce very little lather with soap is called Hardness of water. The hardness of water is caused by the presence of dissolved salts such as bicarbonates, sulphates, chlorides and nitrates of bivalent metal ions like Ca & Mg.

When soap comes in contact with hard water, sodium-sterate (soap) will react with dissolved Ca & Mg salts and produce Ca & Mg state which is forms white ppt.

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

Sodium sterate calcium sterate

TYPES OF HARDNESS: The hardness of water is of two types.

i) Temporary hardness ii) Permanent hardness.

i) Temporary hardness: It is caused by the presence of bicarbonates of Ca & Mg .These can be removed by boiling which converts the bicarbonates into the insoluble carbonates or hydroxides. This is also called as carbonate hardness.

$$Ca(HCO_3)_2 \longrightarrow CaCO_3\downarrow + H_2O + CO_2.\uparrow$$

$$Mg(HCO_3)_2 \longrightarrow Mg(OH)_2\downarrow + 2CO_2.\uparrow$$

ii)PERMANENT HARDNESS: It is caused by the presence of sulphates , chlorides, nitrites, etc., of Ca , Mg ,Fe, etc. This is known as non-carbonate hardness or non-alkaline hardness. It cannot removed by boiling.

Total hardness = Temporary hardness + permanent hardness.

MEASURMENT OF HARDNESS: The hardness is measured in milligram per liter. It is usually expressed in terms of $CaCo_3$ equivalent per liter. The reason for choosing $CaCo_3$ as standard is because it's molecular weight is 100 which is easy for calculation and it is the most insoluble salt which is ppted from water.

$$\text{Equivalents of CaCO3} = \frac{Amount\ of\ hardness\ causing\ salt\ \times 100}{Molecular\ weight\ of\ the\ hardness\ causing\ salt}$$

UNITS OF HARDNESS: There are four different units in which the hardness of water is expressed as given below;

i)Parts per million(PPM) : It is the parts of $CaCo_3$ equivalent hardness per 10^6 parts of water.

ii)Milligrams per liter(mg /l): It is the number of milligram of $CaCo_3$ equivalent hardness per liter of water.

1mg/l = 1 gm of $CaCo_3$ equivalent hardness per liter of water.

iii)Degree Clark(°Cl): It is the number of grains of $CaCo_3$ equivalent per gallon of water.

1 °Cl = 1 part of $CaCo_3$ per 70,000 parts of water.

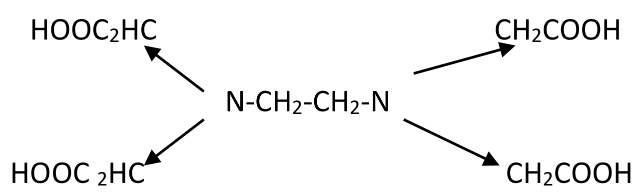
iv)Degree French(°Fr): It is defined as the parts of $CaCo_3$ equivalents per 10^5 parts of water.

1 °Fr = 1 part of $CaCo_3$ equivalent hardness per 10^5 parts of water.

Inter conversion of Units:

1ppm = 1mg/l = 0.07 °Cl = 0. 1 °Cl

Estimation of hardness of water by EDTA method: The hardness of water is generally due to presence of soluble salts of Ca & Mg and can be determined by Complex metric titration. This involves use of a standard solution of EDTA (Ethylene Diammine Tetra Acetic acid) as a complexing agent and EBT(Eriochrome Black-T) as an indicator . EDTA form quite stable colourless complex with Ca & Mg ions while EBT which is an azodye forms a soluble , unstable a wine red coloured complex with Ca & Mg ion at pH 9-10.



Structure of EDTA

For estimation of hardness EDTA is not used as such rather it's disodium salt is used. Disodium salt of EDTA is easily ionized and highly stable. The water sample buffered to pH

9-10 (by adding NH_4OH & NH_4Cl mixture) and titrated against standard solution of EDTA by using EBT as indicator.EBT forms a wine red unstable complex with Ca & Mg ions. When EDTA is added ,it forms very stable complex with free metal ions as well as Ca & Mg ions which are present in the indicator complexes. Then the indicator becomes free and at pH9-10 it in parts a blue colour indicating the end point of the reaction.

The complex is represented as

The overall reaction taking place here can be written as

(M-EBT) complex + EDTA -------------→ (M-EDTA) complex + EBT(free)

Disadvantages of Hardness water:

* Hard water affects the cleaning ability of soap. When soap is added Ca & Mg ions present in hard water reacts with it forming ppt. When hard water is used for washing large amount of soap is consumed.

* Hard water can causes "scaling" inside the pipes that transport water .Therefore, if we use hard water in turbines and heat exchangers, their pipes will be corroded.

* Hard water when used for drinking for long period can lead to stomach disorders.

UNITS OF HARDNESS:

The following are the general units used in measurement of hardness:

i) Parts per million (PPM): It is defined as the number of parts by weight of $CaCO_3$ equivalent hardness present per 10^6 parts of water.
ii) Milligrams per liter(mg/lit): It is defined as the number of milligrams of $CaCO_3$ equivalent hardness present per 1 liter of water.
iii) Clarke's degree(°Cl): It is defined as the number of parts of $CaCO_3$ equivalent hardness present per 70,000 parts of water.
iv) French degree(°Fr): It is defined as the number of parts of $CaCO_3$ equivalent hardness present per 10^5 parts of water.

Relationship between various units

1 ppm = 1 mg/lit = 0.1 °Fr = 0.07 °Cl

Problems on hardness of water:

Hard salt	Molecular weight	Equivalent weight
$Mg(HCO_3)_2$	146	73
$Ca(HCO_3)_2$	162	81
$MgCl_2$	95	47.5
$MgSO_4$	120	60
$CaCl_2$	111	55.5
$CaSO_4$	136	68
$Mg(NO_3)_2$	148	74

Problem 1:-Calculate temporary , permanent & total hardness of a sample of water containing $Ca(HCO_3)_2$=40.5 mg/L ;$Mg(HCO_3)_2$=46.5 mg/L ; $MgSO_4$=27.6 mg/L;$CaCl_2$=22.4 mg/L;$CaSO_4$=32.1 mg/L ?

Solution: Calculation of $CaCO_3$ equivalents.

Hard salt	Weight(mg/L)	Molecular weight	$CaCo_3$ equivalent= Weight/M.W*100(mg/L)
$Ca(HCO_3)_2$	40.5	162	40.5/162 × 100=25
$Mg(HCO_3)_2$	46.5	146	46.5/146 × 100=31.8
$MgSO_4$	27.6	120	27.6/120 × 100=23
$CaCl_2$	22.4	111	22.4/111 × 100=20.1
$CaSO_4$	32.1	136	32.1/136 × 100=23.6

Temporary Hardness=Hardness due to $Ca(HCo_3)_2$ & $Mg(HCo_3)_2$

= 25+31.8

= 56.8 mg/L.

Permanent Hardness =Hardness due to $MgSo_4$, $CaCl_2$ & $CaSo_4$

= 23+20.1+23.6

= 66.7 mg/L.

Total hardness= Temporary Hardness + Permanent Hardness.

= 56.8 + 66.7

= 123.5 mg/L.

Problem 2:- A sample of water on analysis has been found to contain the following ; $Ca(HCO_3)_2$ =10.5 ppm ; $Mg(HCO_3)_2$=12.5 ppm ; $CaSO_4$ =7.5 ppm ; $CaCl_2$=8.2ppm ; $MgSO_4$=2.6ppm.Calculate temporary & permanent hardness in Degree clark ?

Solution: Calculation of $CaCo_3$ equivalents.

Hard salt	Weight(ppm)	Molecular weight	$CaCo_3$ equivalent= Weight/M.W*100
$Ca(HCO_3)_2$	10.5	162	10.5/162 × 100=6.48
$Mg(HCO_3)_2$	12.5	146	12.5/146 × 100=8.56
$MgSO_4$	2.6	120	2.6/120 × 100=2.16
$CaCl_2$	8.2	111	8.2/111 × 100=7.38
$CaSO_4$	7.5	136	7.5/136 × 100=5.51

Temporary hardness = Hardness due to $Ca(HCO_3)_2$ & $Mg(HCO_3)_2$

= 6.48+8.56

=15.04ppm

=15.04 × 0.07 °Cl = 1.05 °Cl

Permanent hardness = Hardness due to $MgSO_4$, $CaCl_2$ & $CaSO_4$

= 5.51+7.38+2.16 = 15.05ppm

=15.05 × 0.07 °Cl = 1.05 °Cl

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Method of treatment of water for Domestic purpose:- Water which is used for domestic purpose should be colourless & odourless. It should be free from any kind of toxic substances , micro-organisms and other harmful substances. It should not be too hard or too soft .Water which is available from natural resources should undergo various treatments to make it suitable for domestic purpose.

The following are different steps in treatment of water.

A) **Removal of suspended impurities**

1. Screening: The process of removing floating matter from water is known as screening. In this process water is passed through a screen. The floating matter is arrested by the screen and water is free from floating matter.
2. Sedimentation: The process of removing high molecular weight suspended particles from water is called sedimentation.70% of solid particles settle down due to force of gravity.

3. Coagulation: The process of removing fine suspended and colloidal impurities by adding coagulants like alum, ferrous sulphate, sodium aluminates is called coagulation.
4. Filtration: The process of passing a liquid containing suspended impurities through a suitable porous material so as to effectively remove suspended impurities.

B. Disinfection (or) Sterilization:- The process of killing pathogenic bacteria and other micro-organisms is called Sterilization or Disinfection. The water which is free from pathogenic bacteria and safe for drinking is called potable water. The chemicals used for killing bacteria are called disinfectants.

1. By adding Bleaching powder **:-** Water is mixed with required amount of bleaching powder and the mixture is allowed to stand for several hours.

$CaOCl_2 + H_2O$ ----------> $Ca(OH)_2 + Cl_2$.

$Cl_2 + H_2O$-------------->$HOCl + HCl$.

Germs +HOCl----------> Germs are killed.

2. Chlorination**:-** Chlorine is mixed with water in a chlorinator which is a high tower having a number of baffle plates .Water and required quantity of Conc. Chlorine solution are introduced from it’s top during their passage through the tower . They get thoroughly mixed and then sterilized water is taken out from the bottom.

Advantages:

- Storage requires less space.
- Effective and economical.
- Produces no salts.
- Ideal disinfectant.
- This is a stable.

Disadvantages:-

- Excess of chlorine causes unpleasant taste and odour.
- More effective at below pH6.5 and less effective at high temp.

3. Ozonization **:-** Ozone is an excellent ,disinfectant which can be prepared by passing silent electric discharge through pure and dry oxygen. Ozone is highly unstable and breaks down liberating nascent O_2.

$3\ O_2$--------> $2O_3$.

O_3 -----------> O_2 + (O) nascent oxygen.

This nascent oxygen kills bacteria as well as oxidized the organic matter present in water.

Advantages : Removes color, odour and taste.

Disadvantages : The method is costly.

WATER FOR INDUSTRIAL PURPOSE : Water is one of the most important environmental constituents. Water is of complex technological considerations. Water quality, strictly from technological point of view is defined in terms of appropriate physical, chemical, and biological parameters.

WATER FOR STEAM MAKING: water is used in boilers for generation of steam. Steam is produced at high temperatures. The boiler feed water should not contain excess of impurities, hardness should not excess 0.2ppm and alkalinity should not be very high. These in higher amounts lead to boiler problems like priming and foaming, corrosion, scales, sludges and caustic embrittlement.

BOILER TROUBLES: Boilers are used for steam generation. The bubbles that arise in the boilers due to presence of impurities in the boiler feed water are called boiler troubles. The major boiler troubles are:

1) Priming and Foaming
2) Boiler corrosion
3) Scale & Sludges
4) Caustic Embrittlement.

1) PRIMING AND FOAMING:

PRIMING: Production of wet steam by rapid boiling of water is called Priming.It may be caused due to

a)Very high steam level.

b)High water level.

c)Improper boiler design.

d)Sudden boiling etc.

It can be avoided by

a)Maintaining low water level.

b)Using softened water.

c)Fitting mechanical steam purifier.

d)Using a well designed boiler.

FOAMING : The production of persistent bubbles or foam in boiler water surface is called foaming.

It may be caused by

a) The presence of oil or soapy substances.

b) Certain dissolved salts.

It may be avoided by

a) Adding antifoaming agents like cotton seed oil and castor oil.

b) Adding sodium aluminate which coagulates the oily or soapy substences.

2) BOILER CORROSION: The decay of boiler material by a chemical or electrochemical attack by it's environment is called Boiler corrosion. It is due to

a) Dissolved oxygen.

b) Dissolved carbon dioxide .

c) Acids from dissolved salts.

a) Dissolved oxygen : Water usually contains 8mg/L of dissolved O_2 at room temp.It attacks boiler material causing rust formation.

$$2Fe + 2\,H_2O + O_2 \text{ -------------->} 2Fe(OH)_2\downarrow$$

$$4\,Fe(OH)_2 + O_2 \text{ --------------->} \underset{\text{Rust}}{2(Fe_2O_3.2H_2O)}\downarrow$$

Removal of dissolved O_2: By adding calculated quantity of sodium sulphide or sodium sulphate or hydrazine.

$$Na_2S + 2O_2 \text{ ------------->} Na_2SO_4.$$

$$2Na_2SO_3 + O_2 \text{ -------->} 2\,Na_2SO_4.$$

$$N_2H_4 + O_2 \text{ ----------->} N_2 + 2H_2O.$$

b)Dissolved CO_2 : It gives carbonic acid which has a slow corrosive effect on the boiler material.

$$CO_2 + H_2O \text{ ---------->} H_2CO_3.$$

Removal of dissolved CO_2: By adding calculated quantity of NH_4.

$$2NH_4OH + CO_2 \text{ --------------->} (NH_4)_2CO_3. + H_2O.$$

c)Acids from dissolved salts: The magnesium salts present water liberates acids on hydrolysis.

$$MgCl_2 + H_2O \text{ -------------->} Mg(OH)_2 \downarrow + 2HCl.$$

The liberated HCl reacts with iron in chain reactions producing HCl again and again.

$$Fe + HCl \text{ ----------->} FeCl_2 + H_2.$$

$$FeCl_2 + 2H_2O \text{ ----------->} Fe(OH)_2 \downarrow + 2HCl.$$

3)Scales and Sludges :-

Scales: A hard ,adhering coating on the inner walls of the boiler is called Scale. Salts like $CaSO_4$ and $Ca(HCO_3)_2$ are responsible for scale formation in boilers.

Disadvantages:

- Scale act as a bad conductor of heat .
- Scale formation can reduce the efficiency of a boiler.
- At high temp , cracks may be formed on scale, leading to explosion.

Removal of Scales:

- By thermal shocks.
- With the help of a wire brush ,wood piece or scraper.
- Carbonate Scales can be removed by 5-10% HCl

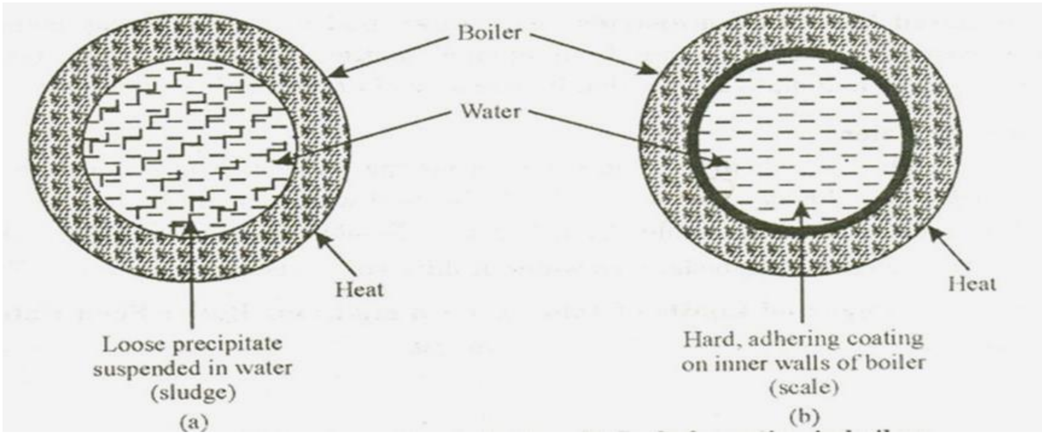


Diagram: (a) Sludge formation in boilers (b)Scale formation in boilers

Sludge:- A loose and slimy ppt formed within the boiler is called Sludge.Sludges can be formed by substances which have greater solubility in hot water than in cold water . Salts like $MgSO_4$,$MgCO_3$, $MgCl_2$,$CaCl_2$,etc,.are responsible for sludge formation in boilers.

Disadvantages:-

- Sludge is a bad conductor of heat, hence it wastes a portion of heat generated.
- Excessive sludge formation reduces the efficiency of the boiler.

Prevention:

- Frequent blow down operation should be carried out .
- By using well-softened water.

4)Caustic Embrittlement:-This is a type of corrosion caused by the formation of NaOH are generally by using highly alkaline water or Na_2Co_3 present in water softened by lime-soda process.

$$Na_2CO_3 + H_2O \text{------->} 2NaOH + CO_2.\uparrow$$

This NaOH passes into the minute hair cracks present on the boiler by capillary action and attacks the surrounding area dissolving iron 0f boiler as sodium ferroate(Na_2FeO_2).

$$Fe + 2NaOH \text{--------->} Na_2FeO_2 + H_2.$$

This causes the embrittlement of boiler parts particularly at bends, rivets, joints etc,. causing failure of boiler.

Prevention:

- By adding Na_2SO_4, tannin, etc,. to the boiler water which blocks hair cracks.

- By using sodium phosphate as the softening agent instead of sodium carbonate.

WATER TREATMENT:- The hardness producing salts can be removed from the water by two methods.

INTERNAL TREATMENT:-This process is carried out inside the boiler . It is effective for low-pressure boilers .It includes colloidal, Phosphate, calgon ,carbonate and alluminate conditioning.

i)Colloidal conditioning:-Colloidal substances like Kerosene, agar-agar, etc,. are added to the water to avoid scale formation.

ii)phosphate conditioning:- This is used in case of high –pressure boilers Na_2Po_4, $Na_2P_2O_7$,Na_2HPO_4, NaH_2PO_4 are mainly used. The nature of phosphate used depends on the acidity of the boiler water.

$$3CaSO_4 + Na_3PO_4 \longleftrightarrow Ca_3(PO_4)_2 + 3Na_2SO_4.$$

Calcium phosphate is formed as sludge which is removed by blow-down operation.

iii)Carbonate conditioning:- This method is used in low pressure boilers. When sodium carbonate is added to boiler water calcium sulphate is converted into calcium carbonate.

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

Therefore deposition of $CaSo_4$ as scale does not take place and sludge of $CaCo_3$ can be removed by blow-down operation.

iv) Calgon conditioning:-Sodium hexameta phosphate{ $Na_2[Na_4(PO_3)_6]$ or $(NaPO_3)_6$} known as calgon prevents scale formation by forming soluble compounds with calcium salts.

$$Na_2[Na_4(PO_3)_6] + 2\ CaSO_4 \longrightarrow Na_2[Ca_2(PO_3)_6] + 2\ Na_2SO_4.$$

v) Sodium alluminate conditioning:- Sodium alluminate gets hydrolyzed producing NaOH and ppt of $Al(OH)_3$. NaOH forms $Mg(OH)_2$ with mg salts.

$$2NaOH + MgCl_2 \longrightarrow \underset{\text{ppt}}{Mg(OH)_2} + 2\ NaCl.$$

EXTERNAL TREATMENT:-The external treatment carried out outside the boiler. It is mostly required in case of high-pressure boilers. This can be done by Ion-exchange process.

ION-EXCHANGE PROCESS (OR)DE-IONIZATION(OR)DE-MINERALIZATION PROCESS:- Ion-exchange resins are insoluble ,cross linked, long chain organic polymers. The functional groups are attached to the chains can exchange hardness producing cation & anions present in water.

The Ion-exchange resins may be classified as;

a)Cation exchange resin:-Cation exchange resins(RH^+)are mainly styrene-divinyl benzene copolymers, which on sulphonation or carboxylation become capable to exchange their hydrogen ions with the cations in water.

$$2RSO_3H + Mg^{2+} \xrightarrow{\text{Sulphonation}} (RSO_3)_2Mg + 2H^+.$$

b)Anion exchange resins:- Anion exchange resins ($R^1\,OH^-$)are mainly Styrene-divinyl benzene copolymers or Amino formaldehyde copolymers which contain amino or quaternary ammonium groups as an integral part of the resin matrix.These ,after treatment with dil.NaOH solution ,become capable to exchange their OH^- anions with anions in water.

$$2\,R^1\,OH^- + 2Cl^- \longrightarrow 2R^1Cl^- + 2OH^-.$$

$$2\,R^1\,OH^- + So_4^{2-} \longrightarrow R_2^1So_4^- + 2OH^-.$$

PROCESS:-

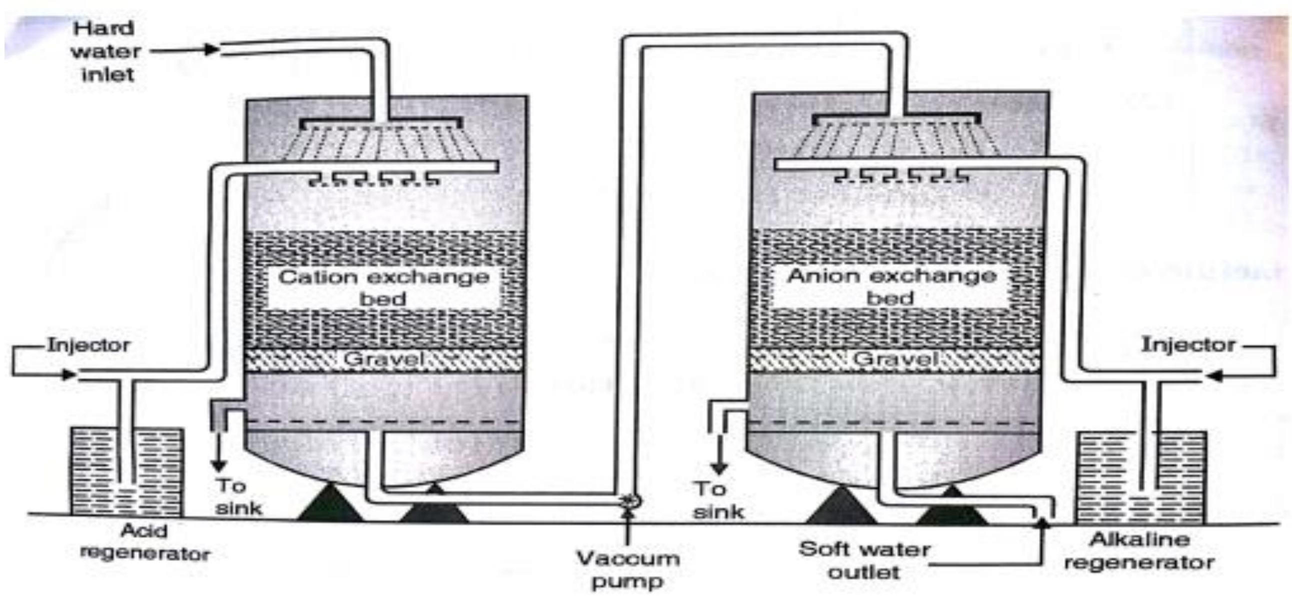


Diagram : Ion Exchange Resin Chamber

The hard water is passed first trough cation exchange column ,which removes all the cations like Ca^{2+}.Mg^{2+}, etc,. from it, and equivalent amount of H^+ ions are released from this column to water.Thus;

$$2RH^+ + Ca^{2+} \text{------------->} R_2Ca^{2+} + 2H^+.$$

$$2RH^+ + Mg^{2+} \text{------------->} R_2Mg^{2+} + 2H^+.$$

After cation exchange column ,the hard water is passed through anion exchange column, which removes all the anions like So_4^-,Cl^-,etc,. present in the water and equivalent amount of OH^- ions are replaced from this column to water.Thus;

$$2\,R^1\,OH^- + 2Cl^- \text{----------------->} 2R^1Cl^- + 2OH^-.$$

$$2\,R^1\,OH^- + So_4^{2-} \text{--------------->} R_2^1So_4^- + 2OH^-.$$

$$2\,R^1\,OH^- + Co_3^{2-} \text{---------------->} R_2^1Co_3^{2-} + 2OH^-.$$

H^+ and OH^- ions (released from cation & anion exchange column)get combined to produce water molecule.

$$H^+ + OH^- \text{--------------->} H_2O.$$

Thus ,the water coming out from the exchanger is free from cations as well as anions. Ion free water is known as de-ionized or de-mineralised water.

Regeneration:-The exhausted cation exchange column is regenerated by passing a solution of dil.HCl or dil.H_2So_4.The regeneration can be represented as;

$$R_2Ca^{2+} + 2H^+ \text{------------->} 2RH^+ + Ca^{2+} \text{ (washing).}$$

The exhausted anion exchange column is regenerated by passing a solution of dil.NaOH. The regeneration can be represented as;

$$R_2^1So_4^- + 2OH^-. \text{--------------->} 2\,R^1\,OH^- + So_4^{2-}\text{(washing)}$$

Advantages:-

- The softened water by this method is completely free from all salts and fit for use in boilers.
- It produces very low hardness nearly 2ppm.
- Highly acidic or alkaline water can be treated by this process.

Disadvantages:-

- The equipment is costly.
- More expensive chemicals are required for regeneration.
- Turbid water can not be treated by this method.

ZEOLITE METHOD:

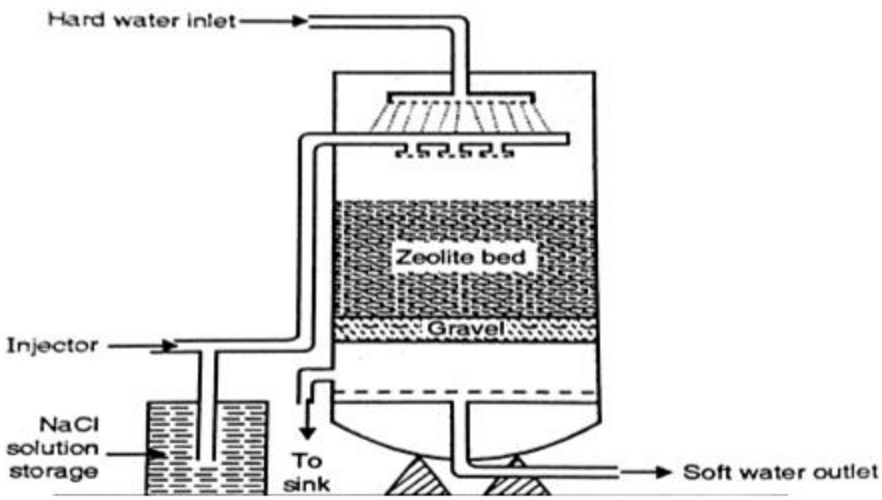


Diagram: Zeolite Exchange Resin Chamber

DISSOLVED OXYGEN METHOD(OR)WRINKLER'S METHOD:

Dissolved oxygen (DO) determination measures the amount of dissolved (or free) oxygen present in water or wastewater. Aerobic bacteria and aquatic life such as fish need dissolved oxygen to survive. If the amount of free or DO present in the wastewater process is too low, the aerobic bacteria that normally treat the sewage will die. DO is determined by the titrimetric method developed by Winkler.

Principle

The determination of dissolved oxygen is based on the oxidation of potassium iodide by dissolved oxygen. The liberated iodine is titrated against a standarded solution of sodium thiosulphate ausing starch as indicator. The dissolved molecular oxygen in water is unable to react with KI. So an oxygen carrier like manganese hydroxide is used to bring about the reaction between KI and Oxygen. Action of potassium hydroxide on manganous sulphate gives manganese hydroxide.

Reactions:

$$2NaOH + MnSO_4 \rightarrow Mn(OH)_2 + K_2SO_4 \qquad \dots(1)$$

$$2Mn(OH)_2 + O_2 \rightarrow 2MnO(OH)_2 \qquad \dots(2)$$

$$MnO(OH)_2 + H_2SO_4 \rightarrow MnSO_4 + 2?H_2O + (O) \qquad \dots(3)$$

$$2KI + H_2SO_4 + (O) \rightarrow K_2SO_4 + H_2O + I_2 \quad \ldots(4)$$

$$I_2 + I^- \rightarrow I^{3-} \quad \ldots(5)$$

$$2S_2O_3^{2-} + I^{3-} \rightarrow 3I^- + S_4\,O_6^{2-} \quad \ldots(6)$$

Procedure:

2 ml of Mangnese sulphate solution and 2ml of alkaline potassium iodide solution are added to 250ml of water sample. The bottle is stoppered and shaken well for 10-15 min and allowed to stand for few minutes to settle the precipitate. Then 2-3 ml of concentrated sulphuric acid is added, stoppered and shaken to dissolve the precipitate.100 ml of the solution is pippetted out from the bottle into a clean conical flask and titirated against standard hypo solution using starch as an indicator. End point is disappearance of blue colour.

Calculation:

Volume of hypo solution consumed = V_1 ml

Normality of hypo solution = N_1 ml

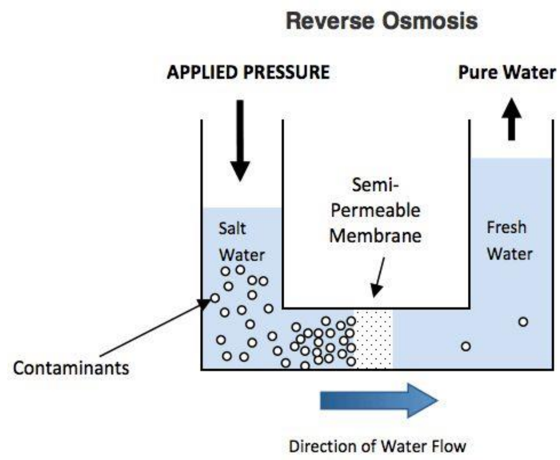
Normality of the dissolved oxygen = $\frac{V_1 N_1}{100}$

Weight of dissolved oxygen per litre of water = $\frac{V_1 \times N_1 \times 8}{100}$ gm

= $\frac{V_1 \times N_1 \times 8 \times 10^6}{100 \times 1000}$ ppm

DE-MINERALIZATION OF BRACKISH WATER:- Water containing high amount of dissolved salts with salty taste is called Brackish water. It contains about 3.5% of dissolved salts. The removal of NaCl from sea water is known as desalination or de-mineralization. It can be done by techniques like Electro dialysis , Reverse Osmosis, etc,.

REVERSE OSMOSIS METHOD:- In this method two solutions of different conc. Are separated by a semi-permeable membrane .The semi-permeable membrane are cellulose acetate, Polyamide polymer. semi-permeable membrane can allow only solvent(water) but not solute(salts) particles . The flow of solvent occurs from a region of low conc. To high conc. Is known as Osmosis. The force which drives the molecules through the membrane is called Osmotic pressure . When hydrostatic pressure in excess of Osmotic pressure is applied on the higher conc. Side, the solvent flows in the reverse direction i.e;from high conc. to low conc. This is called Reverse Osmosis. In this method ,a pressure in the range of 15-40kg/cm² is applied on the brackish water.



Advantages:-

- Cost of purification of water is less, and maintenance cost is less.
- This water can be used for high pressure boilers.

ELECTRODIALYSIS:

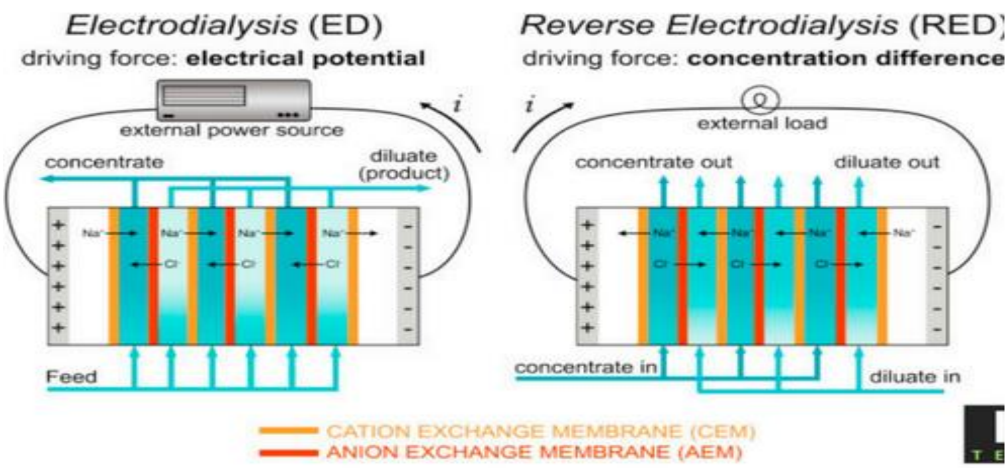
Principle: Electro dialysis is a the process of separating ions of the salt from the salt water through ion selective membranes by passing direct current.

Description:

An electro dialysis cell consists of alternate cation (C) and anion (A) selective membrane. An ion selective membrane has permeability for only one kind of ions with specific charge. Therefore cation selective membrane is permeable to cations only but not to anions while anions selective membrane is permeable to anions only but not to cations. The cathode is placed near the cathode selective membrane and the anode is placed near the anion selective membrane.

Process:

Brackish water is fed into the electro dialysis cell and direct current is applied through the electrode perpendicular to the direction of water flow. As the current passes through the electrodes from the compartment 2,4 and 6 cations (Na^+) move towards the cathode through cation selective membrane and anions (Cl^-) move towards the anode through anions selective membrane (A). The net result is the decrease of ion from 2,4 and6 compartments 1,3 ,5 and 7 is increased .Now the compartments 2,4,and 6 are filled with pure water and the compartments 1,3,5, and 7 are filled with concentrated brine solution. Thus the salinity is removed from salt water.



Questions:

1. Describe the estimation of hardness of water by EDTA method.
2. Explain the procedure involved in estimation of chloride ion present in water.
3. Explain principle & procedure for determination of dissolved oxygen in water by wrinkle's method.
4. Summarize about the boiler troubles in boiler feed water.
5. Give brief note on five conditioning methods in internal treatments of boiler feed water.
6. Describe ion-exchange process for demineralisation of water with neat sketch.
7. Describe zeolite process for demineralisation of water with neat sketch.
8. Explain desalination of brackish water by reverse osmosis.
9. Explain desalination of brackish water by electro dialysis.
10. Describe in brief acidity and alkalinity analysis of water.