Subject: Chemistry

Faculty: Dr. P Vinodkumar

Topic: Introduction to Water

Unit No: 1
Lecture No: L7
Link to Session Planner (SP): S.No..of SP
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Introduction:

Water is one of the few basic resources that all living things on the planet require.

Water is a nearly colorless, composed of chemical elements two hydrogen atoms and oxygen atom and existing in gaseous, liquid, and solid states.

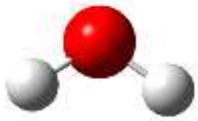

Figure. Structure of water

All are aware of the uses of water for drinking, cooking, bathing & for farming etc. But few know the importance of water as an engineering material

As an engineering material water is used for producing steam, in boilers to generate hydro-electric power, furnishing steam for engines, for construction of concrete structures for manufacturing purposes & as a solvent in chemical process.

Sources of water

The two important sources of water are (1) Surface water and (2) Underground water.

1) Surface Water

Rain water: Rain water is the purest form of natural water. However, it dissolves considerable amount of gases (CO_2, SO_2, NO, NO_2 …etc.) and suspended solid particles from atmosphere, during its journey through it and becomes polluted.

River water: River are formed by rain and spring waters. During its flow over the surface of land, it dissolves minerals of the soil such as chlorides, sulfates, bicarbonates of sodium, calcium, magnesium ions etc.

Spring or well water or Lake water: it contains constant chemical composition. The minerals present in the lake water in the form dissolved form and high quantity of organic matter.

Sea water: It is the most impure form of natural water. It contains larger percentage of the dissolved salts (above 3.5%) out of which about 2.6% is NaCl. The NaCl which is present in the dissolved form in sea water. The other salts present in the sea water are sulphates of sodium, bicarbonates of potassium, magnesium, calcium, bromides of potassium, magnesium etc.

2) **Underground Water:** Spring & well waters are the underground water sources. They are in general clearer in appearance due to the filtering action of the soil. They contain more of the dissolved salts generally; underground water is of high organic purity.

Impurities in Water:

Suspended impurities: These impurities impart turbidity, color and odour of water. It may be inorganic (clay, sand)

Suspended impurities:

- Impart turbidity, color and odour of water.
- Usually contains inorganic (clay and sand) and organic (oil globules, vegetables and animal matter).
- Can be removed by normal filteration

Colloidal impurities:

- Products from organic waste, finely divided silica and clay etc.
- Usually contains inorganic (clay and sand) and organic (oil globules, vegetables and animal matter).
- Cannot be removed by normal filteration

Dissolved impurities:

- Dissolved salts like carbonates, bicarbonates, chlorides and sulphates of calcium, magnesium, iron and sodium.
- Dissolved gases like O_2, CO_2 etc. also come under this category.

Microorganisms:

- They include bacteria’s, fungi and algae and other pathogens

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Hardness of water or Hard water

Hard water: Hard water is defined as water that does not give lather with soap. The presence of calcium and magnesium salts in water causes it to be hard.

When soap is mixed with hard water, Sodium stearate will react with dissolved calcium and magnesium salts and produce calcium stearate or magnesium stearate which is white precipitate

$$[2C_{17}H_{35}COONa] + Ca^{+2} \rightarrow [(C_{17}H_{35}(COO)_2Ca] \downarrow + 2Na^{+}$$

(soap) (soluble) (insoluble) (soluble)

$$[2C_{17}H_{35}COONa] + Mg^{+2} \rightarrow [(C_{17}H_{35}COO)_2Mg] \downarrow + 2Na^{+}$$

(soap) (soluble) (insoluble) (soluble)

Soft Water: Soft water readily produce a lot of lather when mixed with little soap.

$$\text{Na-Stearate} + H_2O \longrightarrow \text{Stearic Acid } [C_{17}H_{35}COOH]$$

$$\text{Stearic Acid} + \text{Na-Stearate} \longrightarrow \text{Formation of lather}$$

Differences

HARD WATER	SOFT WATER
1. Does not produce lather with soap solution readily, but forms a white curd.	1. Lathers easily on shaking with soap solution.
2. Contains dissolved calcium and magnesium salts in it.	2. Does not contain dissolved calcium and magnesium.
3. Cleansing quality of soap is depressed and a lot of soap is washed.	3. Cleansing quality of soap is not depressed and soap is not wasted.
4. More fuel and time for cooking.	4. Less fuel and time for cooking.

Types of Hardness

The hardness of water is of two types

1) Temporary hardness (or) Carbonate hardness

(2) Permanent hardness (or) Non-Carbonate hardness

Temporary Hardness: Caused by two dissolved bicarbonate salts Ca(HCO_3) and Mg(HCO_3). The hardness is called "Temporary Hardness" Because it can be removed easily by means of boiling.

$$Ca(HCO_3)_2 \ \text{on heating} \rightarrow CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

$$Mg(HCO_3)_2 \ \text{on heating} \rightarrow Mg(OH)_2 \downarrow + 2CO_2 \uparrow$$

Permanent hardness: Due to the dissolved chlorides, sulphates and nitrates of calcium and magnesium

Ex: $CaCl_2$, $CaSO_4$, $Ca(NO_3)_2$, $MgCl_2$, $MgSO_4$, $Mg(NO_3)_2$

These Hardness cannot be removed easily by boiling. Hence it is called "Permanent Hardness". Only chemical treatment can remove this.

Total Hardness of Water = Temporary Hardness + Permanent Hardness

Expression and Units of Hardness

Degree of Hardness:

- The Concentration of hardness as well as non-hardness constituting ions are, generally expressed in the term of "Equivalent amount of $CaCO_3$"
- The choice of $CaCO_3$ in particular is due to its molecular weight (m.wt) is "100" (Equivalent wt = 50), and moreover, it is insoluble salt that can be precipitated in water treatment.
- The degree of hardness is being calculated from the following formula,

  $$\text{Hardness causing in salt in terms of } CaCO_3 = \frac{\text{Amount of the hardness causing salt x 100}}{\text{Molecular weight of hardness causing salt}}$$

- Based on the degree of hardness, name of the water is commercially classified as follows

Classification	Hardness (mg/litre)
Soft water	0-70
Moderate	70-150
Hard water	150-300
Very hard water	> 300

The hardness of water is being expressed by 4 different units

(1) **Parts per million (PPM):** PPM is the number of parts of $CaCO_3$ equivalent hardness per 10^6 parts of water. i.e.,

1 PPM = 1 part of $CaCO_3$ equivalent hardness in 10^6 parts of water.

(2) **Milli grams per Litre (mg/litre):** mg/L is the number of milligrams of $CaCO_3$ equivalent hardness present per litre of water. i.e.,

1 mg/L = 1 mg of $CaCO_3$ equivalent hardness of 1 L of water.

(3**) Degree of Clark (ºcl):** ^{o}cl is the number of parts of $CaCO_3$ equivalent hardness per 70,000 parts of water. i.e.,

1 ppm = 0.07^ocl

(4) **Degree of French (ºFr):** ^{o}Fr is the number of parts of $CaCO_3$ equivalent hardness per 10^5 parts of water.

1^oFr = 1 part of $CaCO_3$ equivalent hardness per 10^5 parts of water

I**nterconversion formula:** The hardness of water can be converted into all the four units by making use of the following

1 ppm = 1mg/L = 0.07 ^{o}cl = 0.1 ^{o}Fr

1^o cl = 1.43 ^{o}Fr = 14.3 ppm = 14.3 mg/L

Causes and Effects of Hardness

The following are the disadvantages when hard water is used for various purpose:

DOMESTIC USE:

(a) **Washing and Bathing**: Hard water does not form lather easily with soap, causes wastage of soap

(b) **Drinking**: Hard water causes bad effects on our digestive system. Prevalence for stone formation in kidneys

(c) **Cooking:** The boiling point of water is increased due to the presence of salts. Hence, more fuel and time are required for cooking.

INDUSTRIAL USE:

(a) **Textile Industry:** Hard water causes wastage of soap. Precipitates of calcium and magnesium soap adhere to the fabrics and cause problem

(b) **Paper Industry:** Calcium and Magnesium salts in water may affect the quality of paper.

(c) **Sugar Industry**: Water containing sulphates, carbonates, nitrates affect the crystallization of sugar.

(d) **Pharmaceutical Industry:** Hard water may form some undesirable products while preparation of pharmaceutical products.

Numerical Problems

1. A sample of water gives an analysis 13.6 mg/L of $CaSO_4$. 7.3 mg/L of $Mg(HCO_3)_2$. Calculate the total hardness and permanent hardness.

   Ans:

Salt	Quantity Present (mg/L)	M.Wt	Eq. of $CaCO_3$
$CaSO_4$	13.6	136	$\frac{13.6 \times 100}{136} = 10$
$Mg(HCO_3)_2$	7.3	146	$\frac{7.3 \times 100}{146} = 5$

The Total hardness of H_2O = Temporary hardness + Permanent Hardness

= 5 + 10 = 15 mg/L

Permanent hardness = 10 ppm (or) 10 mg/L

2. Calculate the total hardness of 1000 litre of a sample of water containing the following impurities 16.2 mg/L of $Ca(HCO_3)$, 11.1 mg/L of $CaCl_2$, 60 mg/L of $MgSO_4$ and $Ca(HCO_3)_2$, 11.1 mg/L of $CaCl_2$, 60 mg/L of $MgSO_4$ and 19 mg/L if $MgCl_2$.

   Ans:

Salt	Quantity present (mg/L)	M.Wt	Eq. of $CaCO_3$
$CaH(CO_3)_2$	16.2	162	$\frac{16.2 \times 100}{162} = 10$
$CaCl_2$	11.1	111	$\frac{11.1 \times 100}{111} = 10$
$MgSO_4$	60	120	$\frac{60 \times 100}{120} = 50$
$MgCl_2$	19	95	$\frac{19 \times 100}{95} = 20$

Total hardness of H_2O = Temporary hardness + Permanent Hardness

= 10 + 10 + 50 + 20 = 90 mg/L

Total hardness for 1000 litres = 90 x 1000 = 90,000 mg/L

3. A Sample of hard water contains the following dissolved salts per litre. $CaCl_2$ = 111 mgs, $CaSO_4$ = 1.36 mgs, $Ca(HCO_3)_2$ = 16.2 mgs, $Mg(HCO_3)_2$ = 14.6 mgs, Silica = 40 gms, Turbidity = 10 mgs. Calculate the temporary, permanent and total hardness of water in ppm, ^{O}cl & ^{O}Fr

Ans:

Salt	Quantity present (mg/L)	M.Wt	Eq. of $CaCO_3$
$CaCl_2$	111	111	$\frac{111 \times 100}{111} = 100$
$CaSO_4$	1.36	136	$\frac{1.36 \times 100}{136} = 1$
$Ca\ (HCO_3)_2$	16.2	162	$\frac{16.2 \times 100}{162} = 10$
$Mg(HCO_3)_2$	14.6	146	$\frac{14.6 \times 100}{146} = 10$

Note: Si & Turbidity must not be considered because they do not cause hardness to water.

Total hardness of H_2O = hardness of $Ca(HCO_3)_2 + Mg(HCO_3)_2$ in terms of $CaCO_3$ equivalents

= 10 + 10 = 20 mg/L

Permanent hardness = Hardness of $CaCl_2$+ $CaSO_4$ in terms of $CaCO_3$ equivalents

= 100 + 1 = 101 mg/L

4. Calculate the temporary & permanent hardness of water in °cl, containing the following dissolved salts. $CaCO_3$=50 mg/L, $MgCl_2$=9.5 Mg/L, $CaCl_2$=2.2 mg/L and $MgSO_4$=12 mg/L

Note: $CaCO_3$ is an insoluble salt. It does not cause hardness. If CaCO3 is given as H.C.S, It must be considered as $Ca(HCO_3)_2$, whose hardness is expressed in the term of CaCO3 equivalent

Ans:

Salt	Quantity Present (mg/L)	M.Wt	Eq. of $CaCO_3$ (mg/L)
$CaCO_3$	50	100	50

$MgCl_2$	9.5	95	$\frac{9.5 \times 100}{95} = 10$
$MgSO_4$	12	120	$\frac{12 \times 100}{12} = 20$
$CaCl_2$	22.2	111	$\frac{22 \times 100}{111} = 20$

Temporary Hardness of Water = [Hardness of $CaCO_3$]

= 50 ppm/50 mg/L

= 50 x 0.7 = 3.5 ^{o}cl

Permanent Hardness of Water = Hardness of $MgCl_2$ + $MgSO_4$ + $CaCl_2$

= 10 + 10 + 20

= 40 mg/L

= 40 x 0.7

= 2.8^{o} cl

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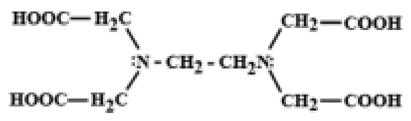
Determination of Hardness of Water by EDTA Method

1. This method is also called as complexometric method as it involves formation of complex molecules.
2. EDTA (Ethylene Diamine Tetra Acetic Acid) forms complexes with different metal ions at different p^H.
3. Calcium & Magnesium ions form complexes with EDTA at p^H 9-10, to maintain the p^H 9-10 NH_4Cl, NH_4OH buffer solution is used.
4. An alcoholic solution of Eriochrome Black-T (EBT) is used as an indicator
5. The disodium salt of EDTA under the trade name Triplex-III is used for complexation.



Structure of EDTA

Basic Principle

- To the hard water sample, the blue colored indicator EBT is added along with the NH_4Cl, NH_4OH buffer solution. EBT forms an unstable, wine-red complex with Ca^{+2} & Mg^{+2}

$$Ca^{+2}/Mg^{+2} + \text{EBT},\ P^H\ 9\text{-}10 \rightarrow \{Ca - EBT|Mg - EBT\}$$

(from hard water) (Complex), (unstable, wine-red color)

- The wine red colored (Ca-EBT, Mg-EBT) complex is titrated with EDTA replaces EBT from (Ca-EBT, Mg-EBT) complex and form stable colorless (Ca-EDTA, Mg-EDTA) complex releasing the blue colored indicator EBT into H_2O

$$\{Ca - EBT|Mg - EBT\} + \text{EDTA},\ P^H\ 9\text{-}10 \rightarrow \{\text{Ca} - \text{EDTA}|\text{Mg} - \text{EDTA}\}$$

(Complex), (stable, colorless)

- Hence the color change at the end point is wine red to blue color

Steps involved in the titration

1. **Preparation of Standard Hard Water:**

- Dissolve 1gm of pure, dry $CaCO_3$ in minimum quantity of dilute HCl and evaporate the solution to dryness on a water bath.
- Dissolve the residue in distilled water to make 1 litre in a standard flask and shake well.

Molarity of standard hard water solution = $\frac{Wt.of\ the\ CaCO_3}{m.wt\ of\ the\ CaCO_3} = \frac{1}{100}$ = 0.01 M

2. **Preparation of EDTA Solution**:
   - Dissolve 4 gm of pure EDTA crystals along with 0.1 gm of $MgCl_2$ in one litre of distilled water.
3. **Preparation of Indicator (EBT):**
   - Dissolve 0.5 gms of Erichome Black-T in 100 ml of alcohol.
4. **Preparation of Buffer Solution**:
   - Add 67.5 gm of NH_4Cl to 570 ml of concentrated ammonia solution and dilute with distilled water to one litre
5. **Standardization of EDTA Solution:**
   - Pipette out 20 ml of standard hard water solution into a conical flask. Add 2-3 ml of buffer solution and 2-3 drops of EBT indicator.
   - Titrate the wine red colored complex with EDTA taken in a burette after rinsing it with EDTA solution till the wine red color changes to clear blue.
   - Not the burette reading and let the volume be "x" ml, repeat the titration to get concurrent values.
6. **Standardization of Hard Water Sample:**
   - Pipette out 20 ml of the water sample into a 250ml conical flask, add 2-3 ml of buffer solution and 2-3 drops of EBT indicator.
   - Titrate the wine red colored solution with EDTA taken in the burette till a clear blue colored endpoint is obtained
   - Let the volume of EDTA be "y" ml, repeat the titration to get concurrent values

7. **Standardization for Permanent Hardness**:
   - Pipette out 100 ml of hard water sample in a beaker and boil till the volume reduces to 20 ml. All the bicarbonates of Ca^{+2} and Mg^{+2} decomposes to $CaCO_3$ and $Mg(OH)_2$
   - Cool the solution and filter the water into a flask, wash the beaker and precipitate with distilled water and add the washing to conical flask
   - Add 2-3 ml of buffer solution and 2-3 drops of EBT indicator and titrate with EDTA solution taken in the burette till a clear blue color end point is obtained.
   - Note the burette reading. Let the volume be "z" ml, repeat the titration to get concurrent values

Numerical Problems

1. Molarity of standard hard water solution = 0.01 M.

   - Molarity of EDTA solution (M_2): $\frac{V_1M_1}{n_1} = \frac{V_2M_2}{n_2}$

V_1=volume of standard hard water

M_1=molarity of standard hard water

V_2= volume of EDTA

M_2=molarity of EDTA

n1 & n2 are no. of moles of Ca^{+2} and EDTA = 1 each i.e., n1=1, n2=1

$$M_2 = \frac{M_1V_1}{V_2} = \frac{20 \times 0.01}{titre\ value\ (xml)}$$

   - Molarity of hard water sample (M_3):

$$\frac{V_2M_2}{n_2} = \frac{V_3M_3}{n_3}$$

V_2= volume of EDTA

M_2= molarity of EDTA

V_3= volume of standard hard water

M_3= molarity of standard hard water

$$M_3 = \frac{V_2M_2}{V_3} = \frac{titre\ value\ (4ml \times M_2)}{20}$$

Total Hardness of Water = M_3 x 100 gms/1 litre

= M_3 X 100 X1000 mg/L or ppm •

Permanent Hardness of Water: $M_3 = \frac{V_2M_2}{n_2} = \frac{V_4M_4}{n_4}$

V_2= volume of EDTA

M_2= molarity of EDTA

V_4 = volume of water sample containing permanent hardness (100 ml)

M_4= molarity of water sample containing permanent hardness

Permanent Hardness of the water Sample = M_4 x 100 x 1000 ppm

Temporary Hardness of the water Sample

= (Total Hardness – Permanent Hardness)

= (M_3 x 100 x1000 –M_4 x 100 x1000) ppm

BOILER TROUBLES

A boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat. The steam so generated is used in industries and generation of power. In modern pressure boilers and laboratories, the water required is used pure than the distilled water.

A boiler feed water should correspond with the following composition:

- ➢ Its hardness should be below 0.2ppm.
- ➢ Its caustic alkalinity (due to OH^-) should lie between 0.15ppm to 0.45ppm.
- ➢ It's should be free from dissolved gases like O_2, CO_2, in order to prevent boiler corrosion.

Excess of impurities in the boiler feed water generally cause the following problems:

1. Sludge's and Scale formation 2. Caustic embrittlement

Boilers are employed for the steam generation in power plants, where water as continuously heated to produce steam. As more and more water is removed from water in the form of steam, the boiler water gets concentrated with dissolved salts progressively reaches the saturation point. At this point the dissolved salts are precipitated out and slowly settle on the inner walls of the boiler plate. The precipitation takes place in two ways.

SLUDGES

Sludge is a soft, loosy and slimy precipitate formed within the boiler. It is formed at comparatively colder portions of the boiler and collects in the area where flow rate is slow.

Ex: $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$.

Reasons for formation of sludges:

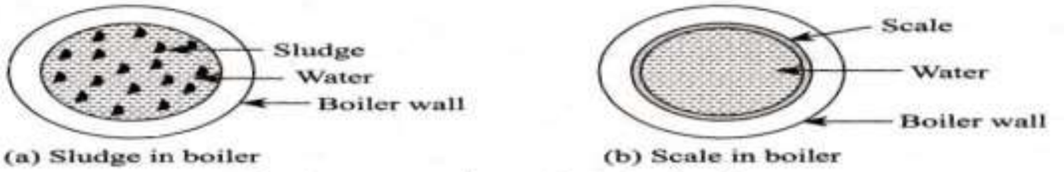
The dissolved salts whose solubility is more in hot water and less in cold water produce sludges.

Disadvantages of sludges:

1. Sludges are bad conductors of heat and results in the wastage of heat and fuel.
2. Excessive sludge formation leads to the settling of sludge in slow circulation areas such as pipe connections, plug openings, gauge–glass connections leading to the choking of the pipes.

Prevention of sludge formation:

- **a.** By using soft water which is free from dissolved salts like $MgCO_3$, $MgCl_2$, $CaCl_2$ and $MgSO_4$ can be prevent sludge formation.
- **b.** By blow down operation carried out frequently can prevent sludge formation.



(a) Sludge in boiler (b) Scale in boiler

Sludges and scales in boiler

SCALES

Scales are hard, adhering precipitates formed on the inner walls of the boilers. Scales are stick very firmly on to the inner walls of the boiler. It is removed with chisel and hammer. Scales are formed by decomposition of calcium bicarbonate in low pressure boilers.

Reasons for formation of scales:

- **a. Decomposition of calcium bicarbonate:** The calcium bicarbonate at high temperature decomposes to calcium carbonate which is insoluble salt, forms scale in low pressure boilers.

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$$

- **b. Hydrolysis of Magnesium salts:** Magnesium salts gets hydrolyzed at high temperature forming $Mg(OH)_2$ precipitation which forms salt type scale.

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

- **c. Decomposition of calcium sulphate:** The solubility of $CaSO_4$ in water decreases with the increase in temperature and forms precipitation on the surface of the boiler further which forms hard scale. This type of scales is formed in high-pressure boilers.

- **d. Presence of silica:** Sio_2 present even in small quantities, deposits as Calcium silicates ($CaSiO_3$) or Magnesium silicates ($MgSiO_3$). The deposits form hard scale and are very difficult to remove.

Disadvantages of Scales:

1. **Wastage of heat and fuels**: Scales poor thermal conductivity so that rate of heat transformation is reduced.

2. **Lowering of boiler safety** is due to overheating of the boiler material becomes softer and weaker, which causes distortion of boiler.

3. **Decrease in efficiency** of the boiler due to scales deposited in the values and condensers of the boiler cause choking.

4. **Danger of explosion** which happens the formation of the scales, the boiler plate faces higher temperature outside and lesser temperature inside due to uneven expansion. The water comes suddenly contact with overheated portion and larger amount steam is formed immediately, this results in development of sudden high pressure which may cause explosion of the boiler.

Prevention of scales:

a. If the scale formation is soft it can be removed by a scrapper, wire brush.

b. By giving thermal shocks, by sudden heating and sudden cooling which makes scale brittle and removed by scrubbing with wire brush.

c. If scale is very hard that is formed by $CaCO_3$ can be removed by washing with 5-10% HCl and $CaSO_4$ can be removed with EDTA solution.

CAUSTIC EMBRITTLEMENT

The formation of brittle and in crystalline cracks in the boiler shell is called caustic embrittlement.
The main reason for this is the presence of alkali-metal carbonates and bicarbonates in feed water. In lime-soda process, it is likely that, some residual Na_2CO_3 is still present in the softened water. This Na_2CO_3 decomposes to give NaOH and CO_2, due to which the boiler water becomes "Caustic Soda".

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

The H_2O evaporates, the concentration of NaOH increase progressively creating a concentration cell as given below thus dissolving the iron of the boiler as sodium ferrate (Na_2FeO_2).

(-)Anode: 'Fe' at bents | Conc.NaOH ‖ Dil.NaOH | 'Fe' at plane Surface: Cathode (+)

This causes embrittlement of boiler parts such as bends, joints, reverts etc, due to which the boiler gets fail. The iron at plane surfaces surrounded by dilute NaOH becomes cathodic while the iron at bends and joints surrounded by highly concentrated NaOH becomes anodic which consequently decayed or corroded.

Caustic embrittlement can be prevented:

a. By maintaining the pH value of water and neutralization of alkali.

b. By using Sodium Phosphate as softening reagents, in the external treatment of boilers.

c. Caustic embrittlement can also be prevented by adding Tannin or Lignin or Sodium sulphate which prevents the infiltration of caustic-soda solution blocking the hair-cracks.

INTERNAL TREATMENT OF WATER

Suitable chemicals are added to the boiler water either to precipitate or to convert the scale into compounds is called **internal treatment** of the boiler feed water. Internal treatment can be done following types.

1. Calgon conditioning: Involves in adding calgon to boiler water. It prevents the scale and sludge formation by forming soluble complex compound with $CaSO_4$.

Calgon = Sodium hexa meta phosphate = $Na_2\,[Na_4\,(PO_3)_6]$

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

$$2CaSO_4 + [Na_4P_6O_{18}]^{-2} \rightarrow [Ca_2\,P_6O_{18}]^{-2} + 2Na_2SO_4$$

2. Phosphate conditioning: The addition of sodium phosphate in hard water reacts with the hardness causing agents and gives calcium and magnesium phosphates which are soft and non-adhere and can be removed easily by blow-down operation.

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

$$3MgSO_4 + 2\,Na_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3Na_2SO_4$$

Genarally three types of Phosphates are employed.

i. Tri sodium Phosphate (Na_3PO_4): is too alkaline used for treat to too acidic water.

ii. Di sodium Phosphate ($Na_2\,HPO_4$): is weakly alkaline used for treat to weakly acidic water.

iii. Sodium dihydrogen Phosphate ($Na\,H_2PO_4$): is too acidic used for treat to too alkaline water.

3. Colloidal conditioning: The addition of organic substances such as Kerosene, tannin, Gel. These substances gets coated over the scale forming precipitates and gives a loose and non-sticky precipitates which can be removed by using blow-down operation.

Ion exchange process (or) deionization or demineralization

Ion exchange resins are insoluble, cross-linked, long chain organic polymers. The functional groups attached to the chains can exchange hardness producing cations and anions present in the water

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 are cation exchange resins, represented as RH^+

Anion exchange resins: - The resins containing amino or quaternary ammonium or quaternary phosphonium(or) Tertiary sulphonium groups, treated with "NaoH solution becomes capable of exchanging their OH- ions with other anions. These are called as anion exchanging resins represented as ROH-

PROCESS: The process involves the following steps:

1) The first chamber is packed with cat-ion exchange resin (RH+). When the hard water is passed through a bed of cation exchange resin it exchanges H+ with Ca^+, Mg^{+2}, K^+, Na^+ etc of hard water.

$$2RH^+ + Ca^{2+} \rightarrow R_2\,Ca^{+2} + 2H^+$$
$$2RH^+ + Mg^{2+} \rightarrow R_2\,Mg^{+2} + 2H^+$$

   Thus, the hardness producing cations (Ca2+, Mg2+ etc) are removed

2) The second chamber is packed with anion exchange resin. The water coming out of the first chamber contains H+, Cl^-, SO_4^{2-} and HCO^{3-} ions. It is now passed through anion exchange resin bed which can exchange OH- ions with anions like Cl^-, SO_4^{2-}

$$R^1OH + Cl^- \rightarrow R^1Cl + OH^-$$
$$2R^1OH + {SO_4}^{2-} \rightarrow {R_2}^1SO_4 + 2OH^-$$

   Thus, hardness producing anions like Cl^-, SO_4^{2-} are removed.

3) Thus, H+ ions produced from first chamber combine with OH- ions produced from second chamber to form water.

$$H^+ + OH^- \rightarrow H_2O$$

4) The output water is also called as deionized water after this the ion exchanges get exhausted. The cation exchanges are activated by mineral acid (HCl) and anion exchanges are activated by dil NaOH solution.

   Hence, the water produced from ion-exchange process is completely free from all cations and anions of salts.

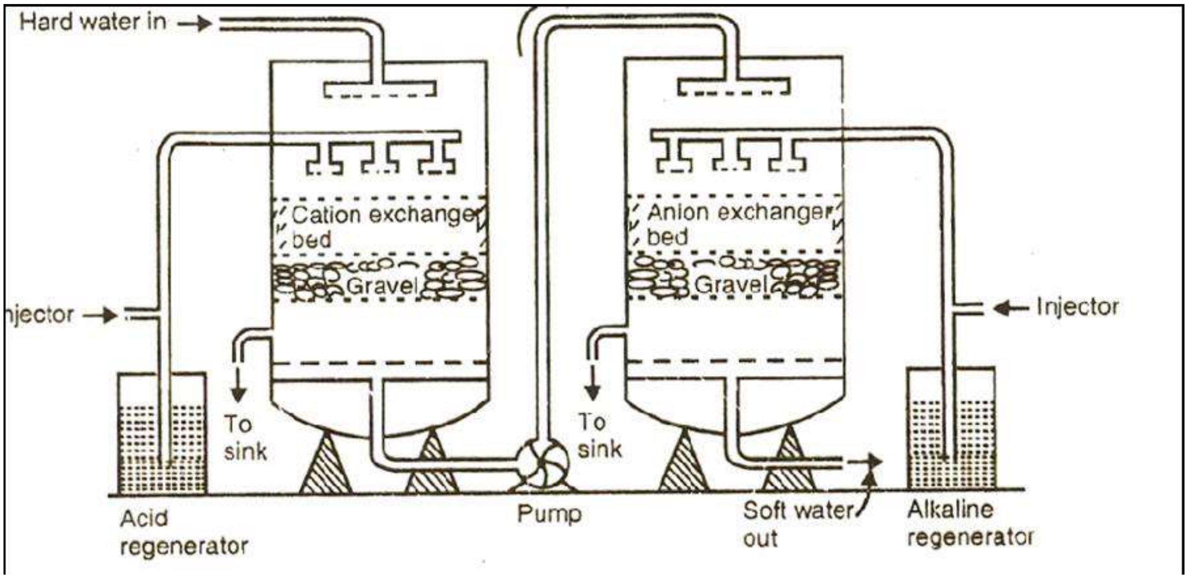


Figure. Ion exchanger

Advantages: -

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

Disadvantages: -

- ✓ The equipment is costly and common expensive chemicals required.
- ✓ It water contains turbidity, and then output of this process is reduced.
- ✓ The turbidity must be below 10 ppm.

Potable Water and Its Specifications

Potable water: The water which can be drinkable by human beings is called Potable water.

Specifications of portable water:

- This water should be colorless, odourless and tasteless
- Free from pathogenic bacteria and dissolved gases like H_2S.
- pH must be 7.0 to 8.5.
- Dissolved chloride and fluoride content must less then 125 ppm and 1.5 ppm, respectively
- The optimum hardness of water must be 125 ppm. The turbidity in drinking water should not exceed 25ppm.
- The recommended maximum concentration of total dissolved solids in potable water must not exceed 500ppm.

Steps involved in treatment of potable water

The treatment of water for drinking purposes mainly includes the removal of suspended impurities, colloidal impurities and harmful pathogenic bacteria. Various stages involved in purification of water

1) Screening:

- In this process, water is passed through a screen. The floating matter is arrested by the screen and the water is free from the floating matter.

2) Aeration: The water is then subjected to aeration which

- Helps in exchange of gases between water and air.
- Increases the oxygen content of water
- Removes the impurities like ‘Fe’ and ‘Mn’ by precipitating as their hydroxides

3) Sedimentation:

- The process of removing big sized suspended solid particles from water is called ‘Plain Sedimentation’
- In this process, water is stored in big tanks for several hours. 70% of solid particles settle down due to the force of gravity

4) Coagulation:

- The process of removing fine suspended and colloidal impurities by adding coagulants like alum, ferrous sulphates and sodium aluminate.

- When coagulant is added to water, “Floc Formation” takes place due to hydroxide formation which can gather tiny particles together to form bigger particles and settle down quickly

5) **Filtration:**

- The process of passing a liquid containing suspended impurities through a suitable porous material so as to effectively remove suspended impurities and some micro-organisms is called “Filtration”. It is mechanical process.
- When water flows through a filter bed, many suspended particles are unable to pass through the gaps and settle in the bed.

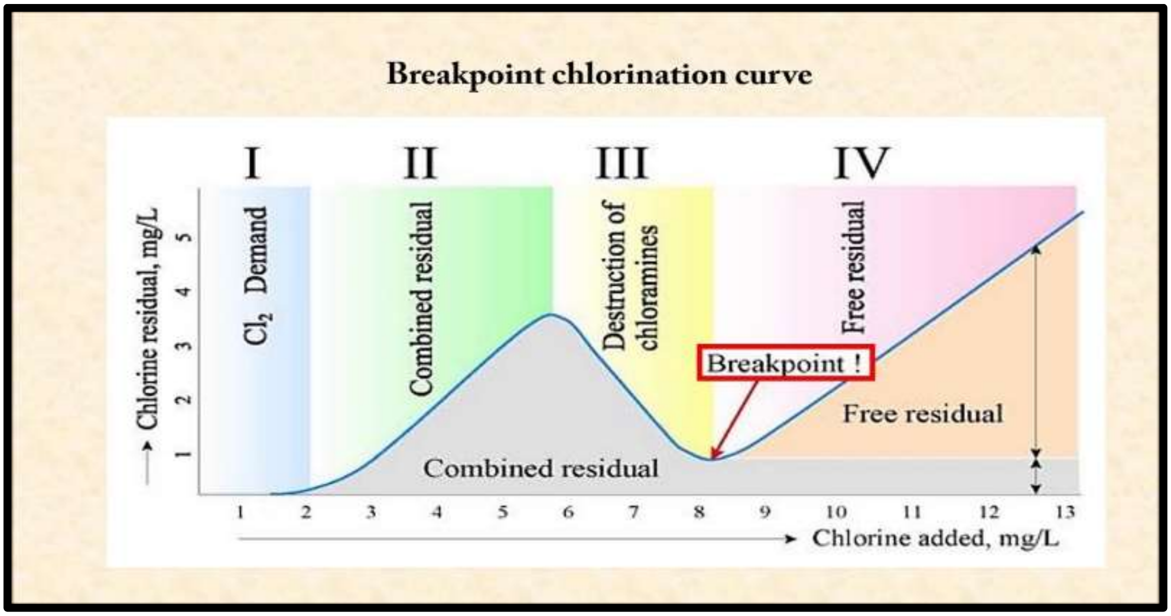
6) **Disinfection / Sterilization**

Destruction of harmful pathogenic bacteria by chlorination, in this process, chlorine is utilized as a powerful disinfectant. It is done by following methods:
i) Boiling: By boiling water for 10-15 minutes, all the disease producing bacteria is killed and the water becomes safe for use.
ii) By adding Bleaching powder: 1 kg of bleaching powder ($CaOCl_2$) is added to 1000 kiloliters of water and left undisturbed for several hours that produces hypochlorous acid (powerful germicide).
iii) By using Chlorine:
Chlorination is the process of purifying the drinking water by producing a powerful germicide like hypochlorous acid. When this chlorine is mixed with water it produces hypochlorous acid which kills the germs present in water.
$H_2O + Cl_2 \rightarrow HOCl + HCl$
Chlorine is basic (means pH value is more than 7) disinfectant and is much effective over the germs. Hence chlorine is widely used all over the world as a powerful disinfectant. Chlorinator is an apparatus, which is used to purify the water by chlorination process.
Advantages
(1). Effective and economic
(2). It leaves no salt impurities
(3). Chlorine is available in pure form
(4). It requires little space for storage.
Disadvantages:
(1). Bad taste and unpleasant odour.
(2). Irritation on mucous membrane if used in excess.
(3). Ineffective at high pH value.

Break-Point of Chlorination:

- By chlorination, organic matter and disease producing bacteria are completely eliminated which are responsible for bad taste and bad odour in water.

- Calculated amount of chlorine must be added to water because chlorine after reacting with bacteria and organic impurities or ammonia, remains in water as residual chlorine which gives bad taste, odour and toxic to human beings.
- When certain amount of chlorine is added to the water, it leads to the formation of chloro-organic compounds and chloramines.
- The point at which free residual chlorine begins to appear is known as "Break-Point".
- The amount of chlorine required to kill bacteria and to remove organic matter is called break point chlorination.
- Break point determines whether chlorine is further added or not.



From the graph, it is clear that

- In phase I, 'a' gm of chlorine added oxidizes reducing impurities of water.
- In phase II, 'b' gm of chlorine added forms chloramines in NH_3 is present and other chloro-compounds.
  $H_2O + Cl_2 \rightarrow HOCl$ (Hypochlorous acid)
  $HOCl + NH_3 \rightarrow NH_2Cl + H_2O$ (Monochloramine)
  $HOCl + NH_2Cl \rightarrow NHCl_2 + H_2O$ (Dichloroamine)
  $HOCl + NHCl_2 \rightarrow NCl_3 + H_2O$ (Trichloroamine)

- In phase III, 'c' gm of chlorine added causes destruction of chloramines and bacteria. At this point free residual chlorine begins to appear. The addition of chlorine to water at the dip or break is called break point chlorination.
- The remaining 'd' gm of chlorine is residual Chlorine. At this point, oxidant demand has been destroyed and disinfection can proceed.

Advantages:

- Complete destruction of pathogens.

- Complete oxidation of organic compounds, ammonia and other reducing impurities.
- Prevents weed growth.
- Prevents growth of microbes.

Factors affecting efficiency of chlorine:

- Efficiency increases with rise of temperature.
- Initially, micro-organisms death rate is maximum with time and then keeps on decreasing.
- Kills micro-organism of low p^H value.

iv) By Chloramines:

When chlorine and ammonia are mixed in the ratio of 2:1 by volume, chloramine is formed.

$$Cl_2+NH_3 \rightarrow ClNH_2+ HCl$$
$$ClNH_2 +H_2O \rightarrow HOCl + NH_3$$
$$SO_2 + Cl_2 + H_2O \rightarrow H_2SO_4 + 2HCl$$
$$Na_2SO_3 + Cl_2 + H_2O \rightarrow Na_2SO_4 + 2HCl$$

Hypochlorous acid, which is formed by the dissolution of chloramines in water, reacts with microorganisms and inactivates the enzymes present in it so that the micro-organisms are destroyed.

v) UV Light

- 254nm UV light damages the RNA & DNA in bacteria.
- Also destroys chemical contaminants present in water.
- The water should be free from turbidity if you choose UV light method

Dechlorination:

- If excess of chlorine is added then it can be dechlorinated by passing it through activated carbon or by adding SO_2 / Na_2SO_3.

  $$Cl_2 + Na_2SO_3 \rightarrow NaSO_4 + 2HCl$$
- Reducing unpleasant odor and taste.

Subject: Chemistry

Faculty: Dr. P Vinodkumar

Topic: Desalination of Water by Reverse Osmosis

Unit No: 1
Lecture No:
Link to Session Planner (SP): S.No..….of SP
Date Conducted:

Desalination of Water (Brackish water) by Reverse Osmosis

Desalination

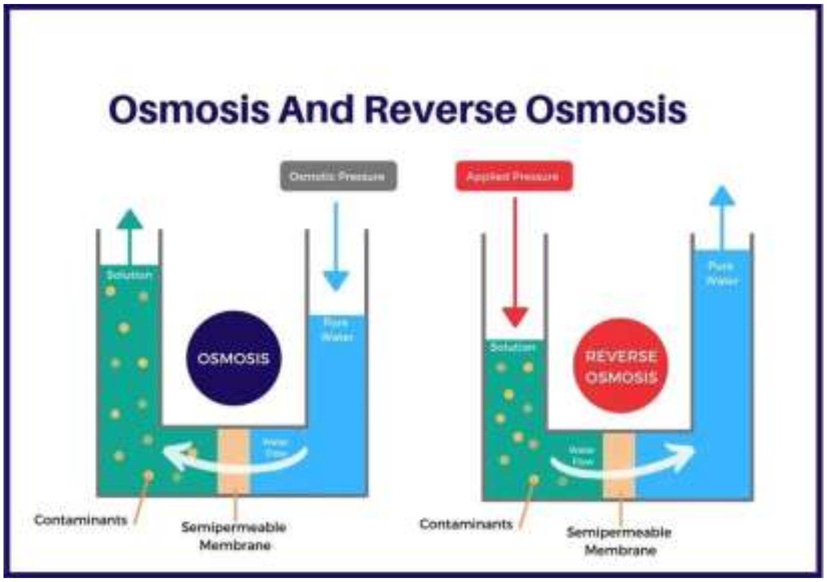
- Water containing high concentrations of dissolved solids with a peculiar salty or brackish taste is called brackish water. Sea water is an example of brackish water containing about 3.5% of dissolved salts.

Common method used to treat this water is Reverse Osmosis

Osmosis: When two solutions of unequal concentration are separated by a semi-permeable membrane which does not permit the passage of dissolved solute particles. i.e., molecules and ions. Flow of solvent takes place from the dilute solution to concentrated solution this is called as “Osmosis”.

Reverse Osmosis: A process in which pressure greater than the osmotic pressure is applied on the high concentration side of the membrane, the flow of solvent takes place from concentrated solution to dilute solution across the membrane

This membrane filtration is also called “Super Filtration” or “Hyper-Filtration”.



Method of purification

The reverse osmosis cell consists of a chamber fitted with a semi-permeable membrane, above which sea water/impure water is taken and a pressure of **15 to 40 kg/cm^2** is applied on the sea water/impure water. The pure water is forced through the semi permeable membrane which is made of very thin films of **cellulose acetate**. However superior membrane made of **Polymethacrylate** and **Polyamide** polymers have come to use

ADVANTAGES:

- Simple and reliable process
- Both ionic and non-ionic colloidal and high molecule weight organic matter is removed from the water sample
- Cost of purification of water is less and maintenance cost is less
- This RO water can be used for high pressure boilers