Environmental Chemistry

Unit I
Water Technology

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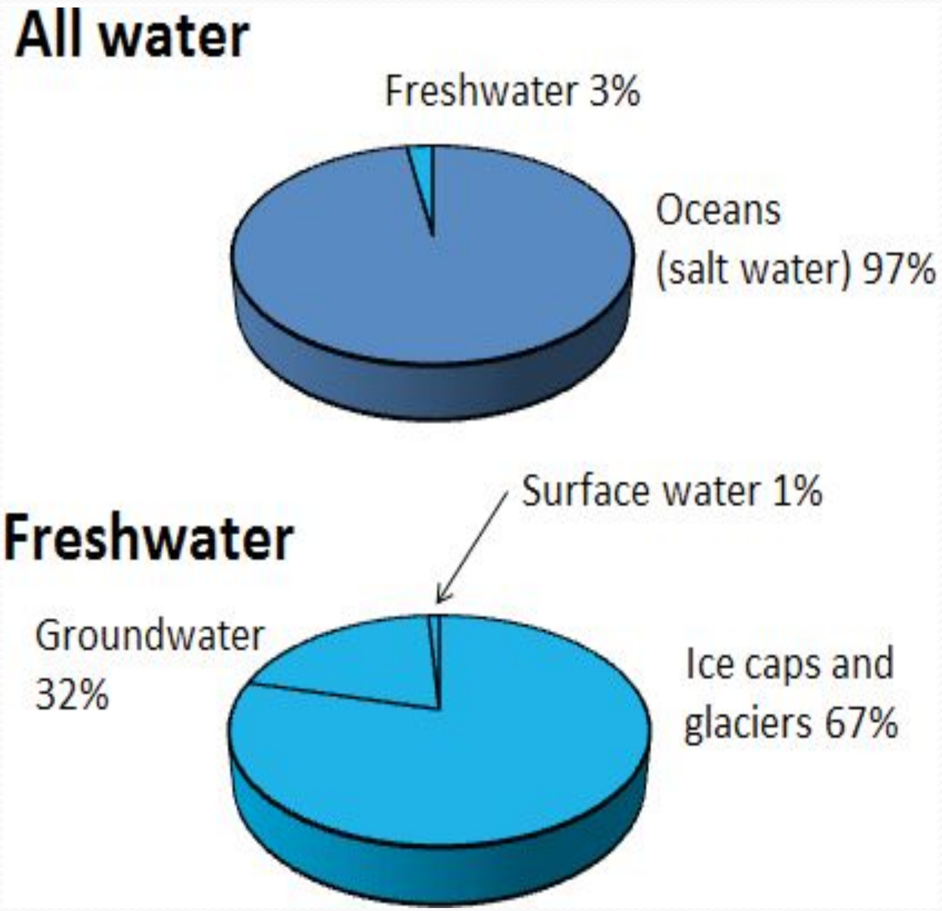
CO1: Understand basic concepts of water technology and identify the hardness and compare water softening methods

Syllabus

- Purification of Domestic water
- Boiler troubles
- Water softening methods of industrial water

Fractions of Water on Earth



- Most of the water on earth (97%) is salty whereas
- only 3% is fresh water, from which more than two thirds is frozen
- The unfrozen fraction is predominantly underground water leaving a small fraction to surface water

Water is Essential for Life

- 80% earths surface covered with water
- It makes up 2/3 of body weight
- We can live without food for several weeks but can only survive without water for few days
- We take water for granted!!!!

In this chapter we will study

- How substances dissolved in water affect its properties
- Concept of Hard & Soft water
- Concept of Temporary & Permanent Hardness
- Determination of hardness in water & associated numericals
- Purification of domestic water
- Boiler Troubles
- Water Softening Methods

Types Of Impurities

1. **Dissolved Impurities**:
   a) Inorganic salts **e.g** sulphates and chlorides of calcium, Magnesium, Iron

   b) Gases like carbon dioxide, nitrogen , oxygen, hydrogen sulphide

   c) Organic salts e.g. sodium acetate, sodium oxalate etc.

2. **Suspended Impurities**:
   a) Clay
   b) mud
   c) Vegetable and animal matters

. **Colloidal Impurities:**

a) Fine size like silica and alumina, organic wastes etc.

- These are soluble materials, other than gases
- Cannot be removed by conventional filters
- Referred as TDS which stands for total dissolved solids.

4. **Micro-organisms Impurities:**

a) Bacteria, Germs, Pathogens, Microbes, Viruses, Parasites

- include
  - algae, beneficial bacteria that decompose wastes
  - harmful bacteria such as those that cause cholera.

Water Quality

The raw or treated water is analyzed by testing their physical, chemical and bacteriological characteristics:

PHYSICAL CHARACTERISTICS

- Turbidity
- Colour
- Taste and Odour
- Temperature

CHEMICAL CHARACTERISTICS

- Acidity
- Alkalinity
- Hardness
- Chlorides
- Chlorine
- Sulphates
- Iron and manganese
- Total Solids
- Lead and arsenic
- Dissolved gases
- Nitrogen
- Metals and chemical substance

BACTERIOLOGICAL CHARACTERISTICS

- Total count of bacteria
- Bacteria Coli (B-coli) Test

- **Effects of Impurities**

  a) Colour of surface water- dissolved organic matters

  b) Taste and Odour- formation of compounds

  c) Turbidity- suspended Impurities

  d) Pathogenicity- micro organisms

Types of Hardness

- It is defined as the soap consuming capacity of water.
- It is due to presence of: salts like bicarbonates, sulphates, chlorides of Mg and Ca
- Units of Hardness: ppm; mg/l; Cl; °Fr
- **Temporary:- or Carbonate Hardness**

  Water that contains bicarbonate of calcium and Magnesium or of both
- Can be removed by boiling

$$Ca(HCO_3)_2 \rightarrow CaCO_3 \downarrow + CO_2 \uparrow + H_2O$$
$$Mg(HCO_3)_2 \rightarrow Mg(OH)_2 \downarrow + 2CO_2 \uparrow$$

2) **Permanent :- or Non- Carbonate Hardness**

Contains chlorides or sulphates of calcium or magnesium or of both cannot be removed by boiling

$$CaCl_2 \rightarrow Ca^{+2} + 2Cl^{-1}$$
$$MgSO_4 \rightarrow Mg^{+2} + SO_4^{-2}$$

Hard & Soft Water

HARD WATER	SOFT WATER
Does not form lather with soap easily	Forms lather with soap easily
Contains dissolved salts of Ca & Mg	Does not contain dissolved salts of Ca & Mg
More wastage of time & fuel as boiling temp. of water gets increased due to impurities	Less wastage of time & fuel
More consumption of soap by hard water	Less consumption of soap by soft water

Disadvantage of Hard Water

Domestic Uses

1. Washing 2. Bathing 3. Drinking 4. Cooking

$$C_{17}H_{35}COO\,Na + H_2O \rightarrow C_{17}H_{35}COOH + NaOH$$

$$C_{17}H_{35}COOH + C_{17}H_{35}COO\,Na \rightarrow \text{Lather}$$

$$\underset{}{C_{17}H_{35}COO\,Na} + \underset{\text{(in water)}}{CaSO_4} \rightarrow \underset{\text{(White Scum)}}{(C_{17}H_{35}COO)_2\,Ca\downarrow} + Na_2SO_2$$

- The white scum or ppt is the calcium salt formed on reaction with soap. This prevents lather formation

Hard water Precipitates

An undesirable side effect of this is that the insoluble calcium carbonate precipitate can form a scale that builds up on kettles, boilers, hot water pipes etc.

Difference between Temporary & Permanent Hardness

Temporary Hardness	**Permanent Hardness**
Also known as carbonate hardness	Also known as non-carbonate hardness
Due to presence of carbonate & bicarbonate salts of Ca & Mg ions	Due to presence of chloride & sulphate salts of Ca & Mg ions in water
Can be removed by boiling & filtering	Cannot be removed by boiling & filtering by can be removed by other chemical methods
Can be determined theoretically once total & permanent hardness is known	Can be determined experimentally

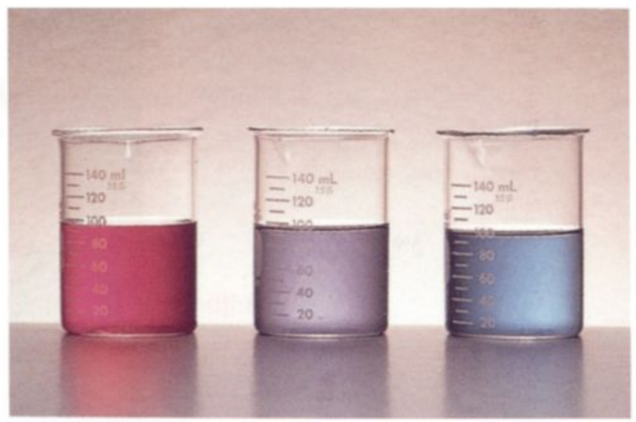
Estimation of Hardness

1. EDTA Method:

Ethylene Diamine Tetra Acetic Acid

$$\begin{array}{lcr} HOOOCH_2 & & CH_2COOH \\ & NCH_2 - CH_2N & \\ HOOOCH_2 & & CH_2COOH \end{array}$$

- Estimation is by titration method at pH 10



Method:

1. Take 50 ml water in conical flask
2. Add buffer and few drops of EBT (Eriochrome Black-T/ Solochrome Black)
3. Titrate against standard EDTA
4. Wine red color changes to Prussian blue at end point
5. Take 3 concordant readings & note the volume of EDTA used at end point

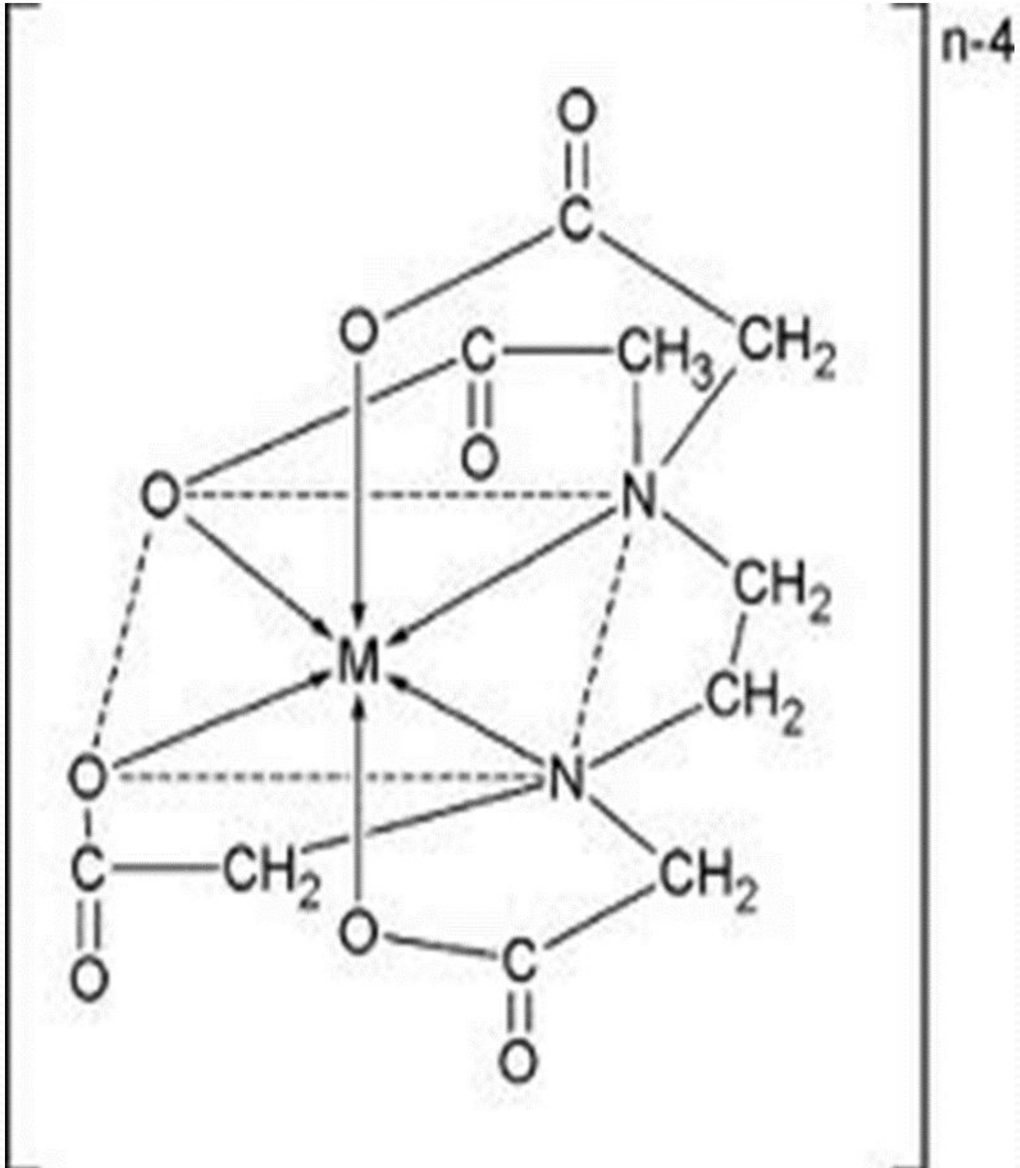
Reactions

- $Na_2H_2Y \Longleftrightarrow 2Na^+ + H_2Y^{2-}$
- $HIn^{2-} + M^{2+} \longrightarrow MIn^- + H^+$

  Blue Indicator — Metal Indicator Complex (Wine Red)
- $MIn^- + H_2Y^{2-} \longrightarrow MY^{2-} + HIn^{2-} + H^+$

  Metal Indicator Complex (Wine Red) — Metal EDTA Complex (Colorless) — Blue Indicator

Structure of Metal EDTA Complex



n is the charge on metal

Calculation of Hardness

- 1ml 1M EDTA = 100 mg $CaCO_3$
- Total Hardness of Water $= \frac{Y \times Z \times 100 \times 1000}{V}$ mg/l or ppm

Y = Volume of EDTA used at end point

Z = Concentration of EDTA

V = Volume of Water sample titrated

Titration of Filtered Boiled Water will give : Permanent Hardness of Water

Temporary Hardness = Total Hardness – Permanent Hardness

Hardness as CaCO3 equivalent

- $CaCO_3$ equivalent of salt = weight of salt per liter x $\frac{\text{equivalent wt of } CaCO_3}{\text{equivalent wt of salt}}$

For a divalent cation

- $CaCO_3$ equivalent of salt = weight of salt per liter x $\frac{\text{Molecular wt of } CaCO_3}{\text{Molecular wt of salt}}$

Numerical on Hardness

- **Q1.** 100 ml of water sample requires 14.6ml of 0.01M EDTA in titration. 100 ml of same water sample when titrated after boiling & filtration , requires 9.9ml of the EDTA. Calculate the carbonate & non-carbonate hardness of the water sample.
- **Solution:**
- Volume of water used for titration V = 100ml
- Concentration of EDTA Z = 0.01M
- Volume of EDTA used at end point Y_1 (un boiled water) = 14.6 ml
- Volume of EDTA used at end point Y_2 (boiled & filtered water) = 9.9 ml

- Total Hardness = $\frac{Y1 \times Z \times 100 \times 1000}{V}$ mg/l or ppm

$$= \frac{14.6 \times 0.01 \times 100 \times 1000}{100} = 146 \text{ ppm}$$

- Permanent Hardness = $\frac{Y2 \times Z \times 100 \times 1000}{V}$ mg/l or ppm

$$= \frac{9.9 \times 0.01 \times 100 \times 1000}{100} = 99 \text{ ppm}$$

- Temporary Hardness = 146 – 99 = 47 ppm $CaCO_3$

Numerical on Hardness

- 50 ml of water sample requires 15ml of .02 M EDTA during titration. Whereas 50 ml of same water sample boiled & filtered requires 11 ml of same EDTA in the titration. Calculate total, permanent & temporary hardness of the water sample.
- Solution:
- Volume of water used for titration V = 50ml
- Concentration of EDTA Z = 0.02M
- Volume of EDTA used at end point Y_1 (un boiled water) = 15 ml
- Volume of EDTA used at end point Y_2 (boiled & filtered water) = 11 ml

- Total Hardness = $\frac{Y1 \times Z \times 100 \times 1000}{V}$ mg/l or ppm

$$= \frac{15 \times 0.01 \times 100 \times 1000}{50} = 600 \text{ ppm}$$

- Permanent Hardness = $\frac{Y2 \times Z \times 100 \times 1000}{V}$ mg/l or ppm

$$= \frac{11 \times 0.01 \times 100 \times 1000}{50} = 440 \text{ ppm}$$

- Temporary Hardness = 600 – 440 = 160 ppm $CaCO_3$

Purification of Domestic Water

Drinking or potable water fit for human consumption should satisfy the following requirements:

- Sparkling clear & free from odour
- Pleasant taste
- Perfectly cool
- Turbidity not more than 10ppm
- No objectionable dissolved gases like H_2S
- Free from objectionable minerals like lead, arsenic, chromium, manganese etc.
- Alkalinity should not be very high
- pH should be around 8
- Should not be hard
- Total dissolved salts should be less than 500ppm
- Should be free from disease causing micro-organisms

- **Natural water from sources like rivers, canals etc. is contaminated and needs purification to make it fit for human consumption. It can be achieved through :**
  Different stages of water treatment plant

1) Screening
2) Aeration
3) Sedimentation
4) Coagulation & Flocculation
5) Filtration
6) Disinfection – chlorination, ozonation, UV irradiation
7) Softening

Screening

- Raw water is passed through screens that retain any large floating and suspended solids present in water like leaves, twigs, paper, rags, and other debris that could obstruct flow through the plant or damage equipment

There are coarse and fine screens.

1. **Coarse screens** are made of corrosion-resistant steel bars spaced 5–15 cm apart, which are used to remove coarse materials from entering the treatment plant. The screens are positioned at an angle of 60º to facilitate removing the collected material by mechanical raking.

2. **Fine screens** They consist of steel bars that are spaced 5–20 mm apart. Suspended matter as small as algae and plankton (microscopic organisms that float with the current in water) can be trapped. The trapped solids are dislodged from the screen by high-pressure water jets using clean water and carried away for disposal.

Screens

Aeration

- After screening, the water is aerated by passing air through it. This process helps in removing soluble gases such as CO_2 and H_2S (both of which are acidic, so this process makes the water less corrosive)

- Iron & manganese cause peculiar tastes and can stain clothing. Aeration removes iron or manganese by oxidation of these substances to their insoluble form & are removed.

Aeration Tanks

Sedimentation

- It is a process of allowing water to stand undisturbed for 2-6 h in big tanks around 5m deep, where most of the suspended particles settle down at the bottom due to the force of gravity.
- The clear supernatant water is drawn from tank using pumps.
- If water has fine clay particles & colloidal impurities then we need to use sedimentation with coagulation

Coagulation & Flocculation

- After aeration, coagulation is done to remove the fine particles (less than 1 µm in size) suspended in the water.
- In this process, a chemical called a coagulant (with a positive electrical charge) is added to the water, which neutralizes the fine particles' negative electrical charge.
- Once their charges are neutralized, flocculants (polymers) are added to promote clumping of fine particles , forming soft, fluffy particles called 'flocs.'
- Now the water is stirred by paddles in a flocculation basin, and the flocs come into contact with each other to form larger flocs
- The flocs are then removed either by filtration, sedimentation or floatation

Chemical Coagulants

- Alum [$K_2SO_4.Al_2(SO4)_3.24H_2O$]- It reacts with alkaline water to form precipitate of aluminium hydroxide

$$Al_2(SO4)_3 + Ca(HCO_3)_2 \longrightarrow 2Al(OH)_3 + 3CaSO_4 + 6CO_2$$

Coagulant alkalinity in water Aluminium hydroxide ppt.

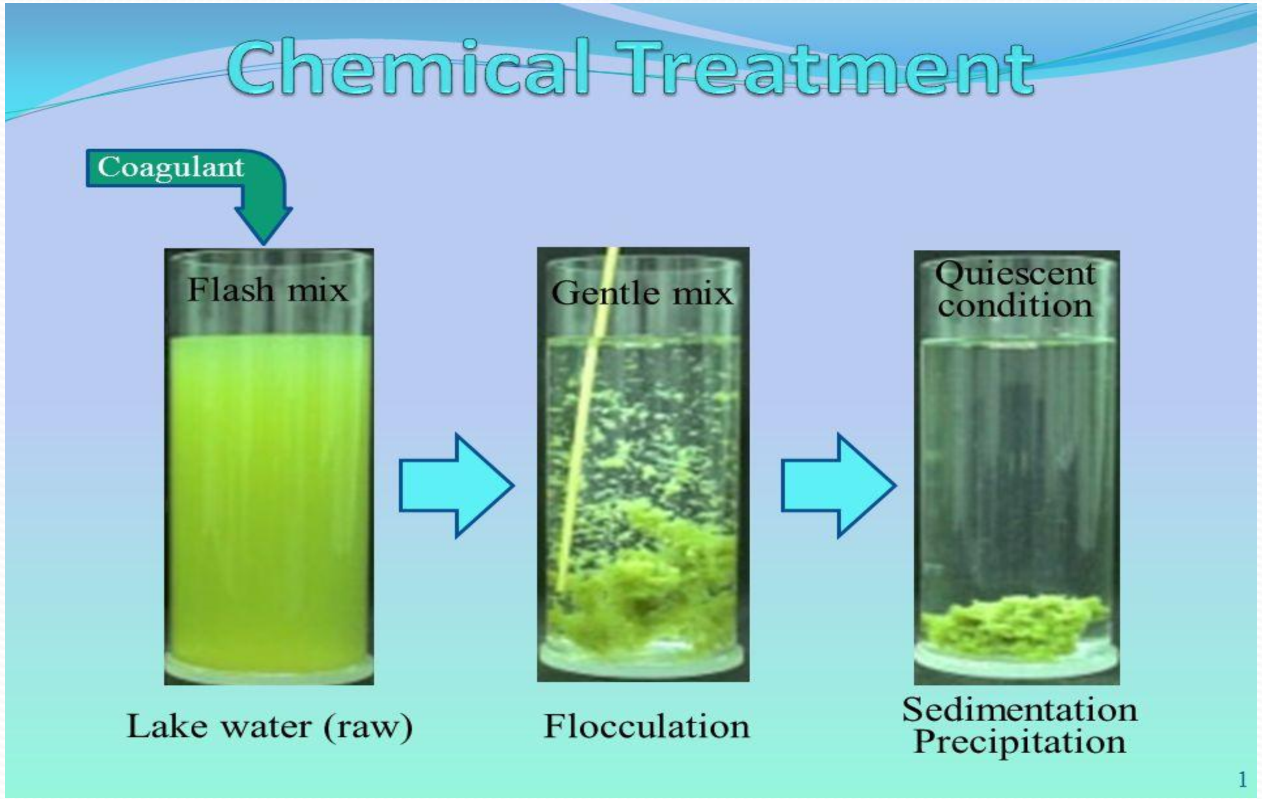
Flocculant

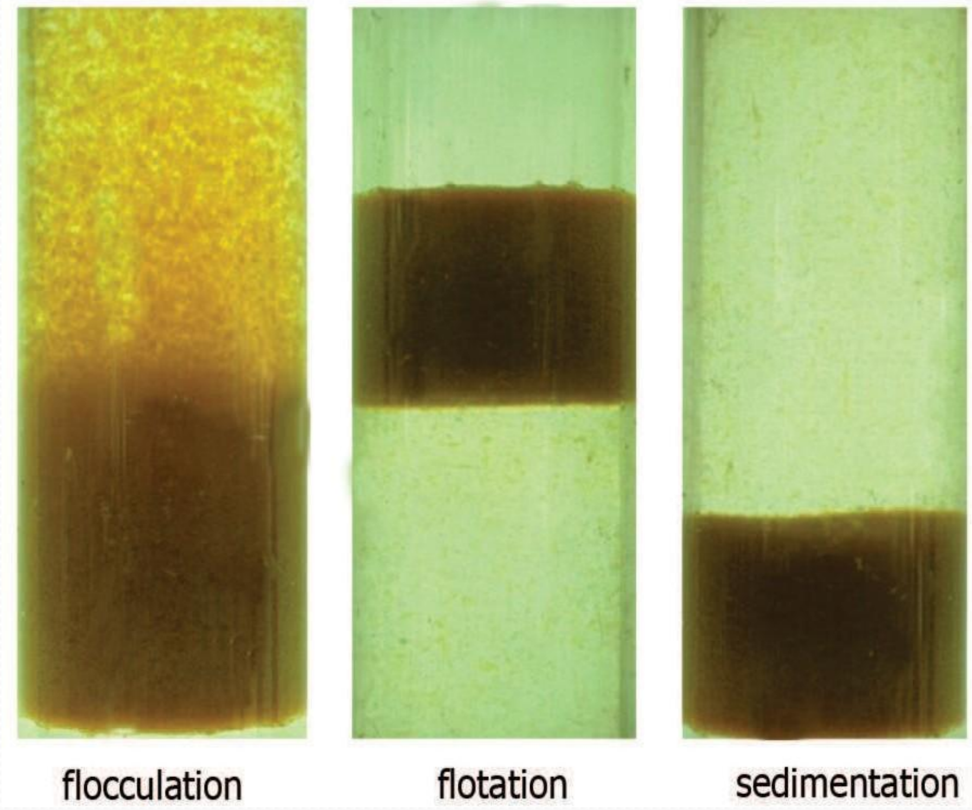
- Sodium Aluminate $NaAlO_2$ – It can be used for neutral or acidic water

$$NaAlO_2 + 2H_2O \longrightarrow Al(OH)_3 + NaOH$$

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

Coagulation & Flocculation

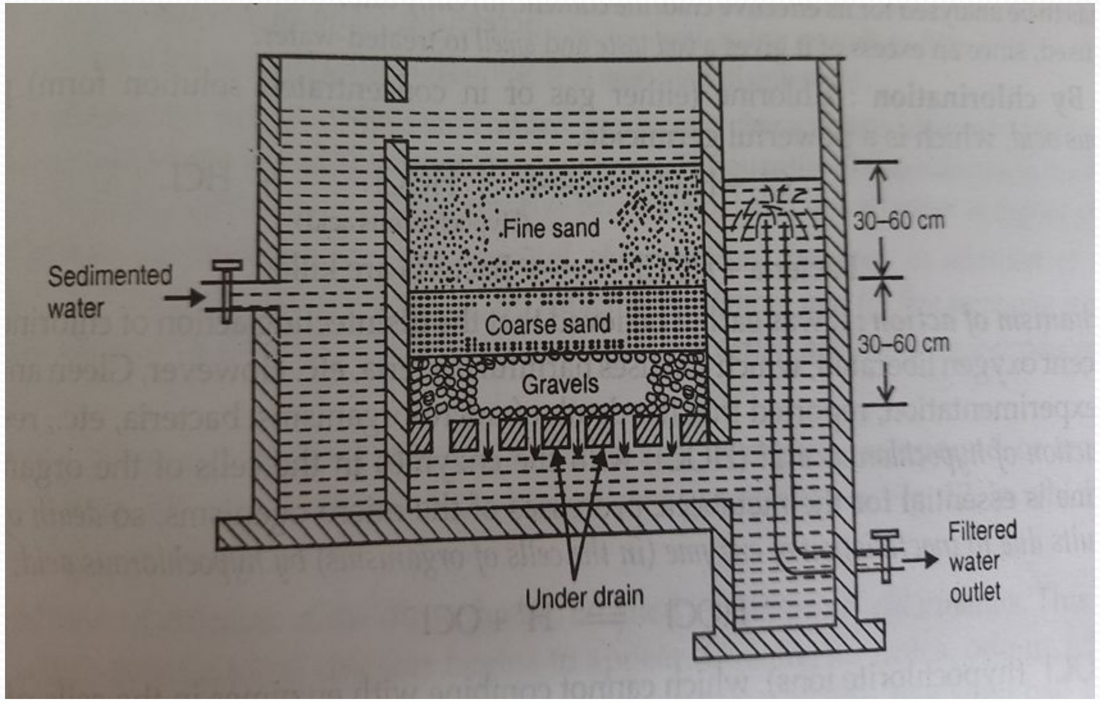




Filtration

- It is a process of removing colloidal matter and most of bacterias and micro-organisms etc.by passing water through a bed of fine sand & proper sized granular materials. It is done using a sand filter.

- **Sand Filter**: It consists of a top thick layer of fine sand placed over coarse sand layer and gravels. The set-up has an inlet for water & under drain channel at the bottom for exit of filtered water. The sedimented water is passed through the sand bed. When the sand pores get clogged with impurities, around 2-3 cm of top layer is scrapped off & replaced with fresh one. The scrapped sand is washed & dried for reuse.



Disinfection - Removal of micro-organisms

- Water after passing through sedimentation, coagulation and filtration still has some percentage of pathogenic micro-organisms. Water required for drinking purposes needs to be treated for this.
- **Disinfection** – It is the process of destroying the disease causing bacteria, microoorganisms etc. from water & making it safe for use. It can be carried out by following methods:

1. **By Boiling** water for 10-15 min. destroys disease causing bacteria. But this is process kills only existing bacteria & doesn't provide protection from future contamination.
2. **By adding bleaching powder** – $CaOCl_2$

Calculated quantity of bleaching powder is added & water is left undisturbed for several hours. The chemical reaction produces hypochlorous acid that is a strong germicide.

$$CaOCl_2 + H_2O \longrightarrow Ca(OH)_2 + Cl_2$$

$$Cl_2 + H_2O \longrightarrow HCl + HOCl \quad \text{(hypochlorous acid)}$$

Drawbacks: i. It makes water hard due to presence of Ca^{+2} ions

ii. It gives a bad taste & bad smell to water

iii. It deteriorates with time

3. By Chlorination

- Chlorine produces hypochlorous acid that is a strong germicide.

$$Cl_2 + H_2O \longrightarrow HCl + HOCl \text{ (hypochlorous acid)}$$

Death of micro-organisms occur due to chemical reaction of hypochlorous acid with the enzymes in the cells of micro-organisms. As enzymes are essential for all metabolic processes, inactivation of enzymes leads to death of micro-organisms.

Advantages: i. It is effective & economical
ii. It can be used at both high & low temperatures
iii. It doesn't leave any salt impurity in treated water
iv. Doesn't deteriorate on standing

Disadvantages: i. Produces unpleasant taste & odour if in excess
ii. Irritates mucus membrane if in excess
iii. Free chlorine should not be more than 0.1 to 0.2 ppm

4. By using chloramine – $ClNH_2$

- Chloramine is formed when chlorine & ammonia are mixed in 2:1 ratio by volume

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

- **Advantages**: i. It is more lasting than chlorine
  ii. Better bactericidal action than chlorine
  iii. Gives a good taste to treated water

- 5. **By using Ozone – O_3**

Ozone is produced by passing silent electric discharge through cold & dry oxygen

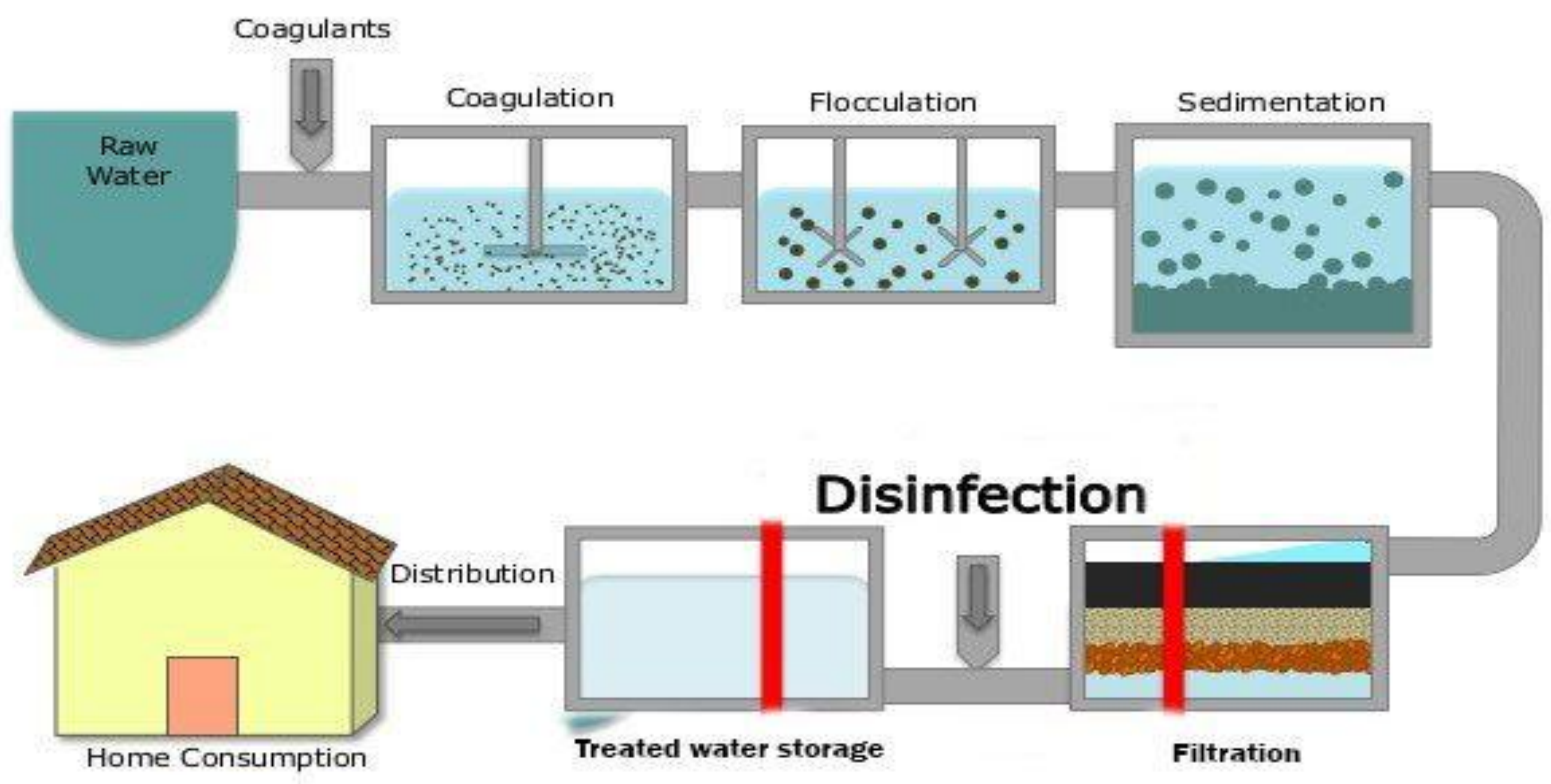
$$3O_2 \longrightarrow 2O_3$$

$$O_3 \longrightarrow O_2 + [O] \text{ Nascent oxygen}$$

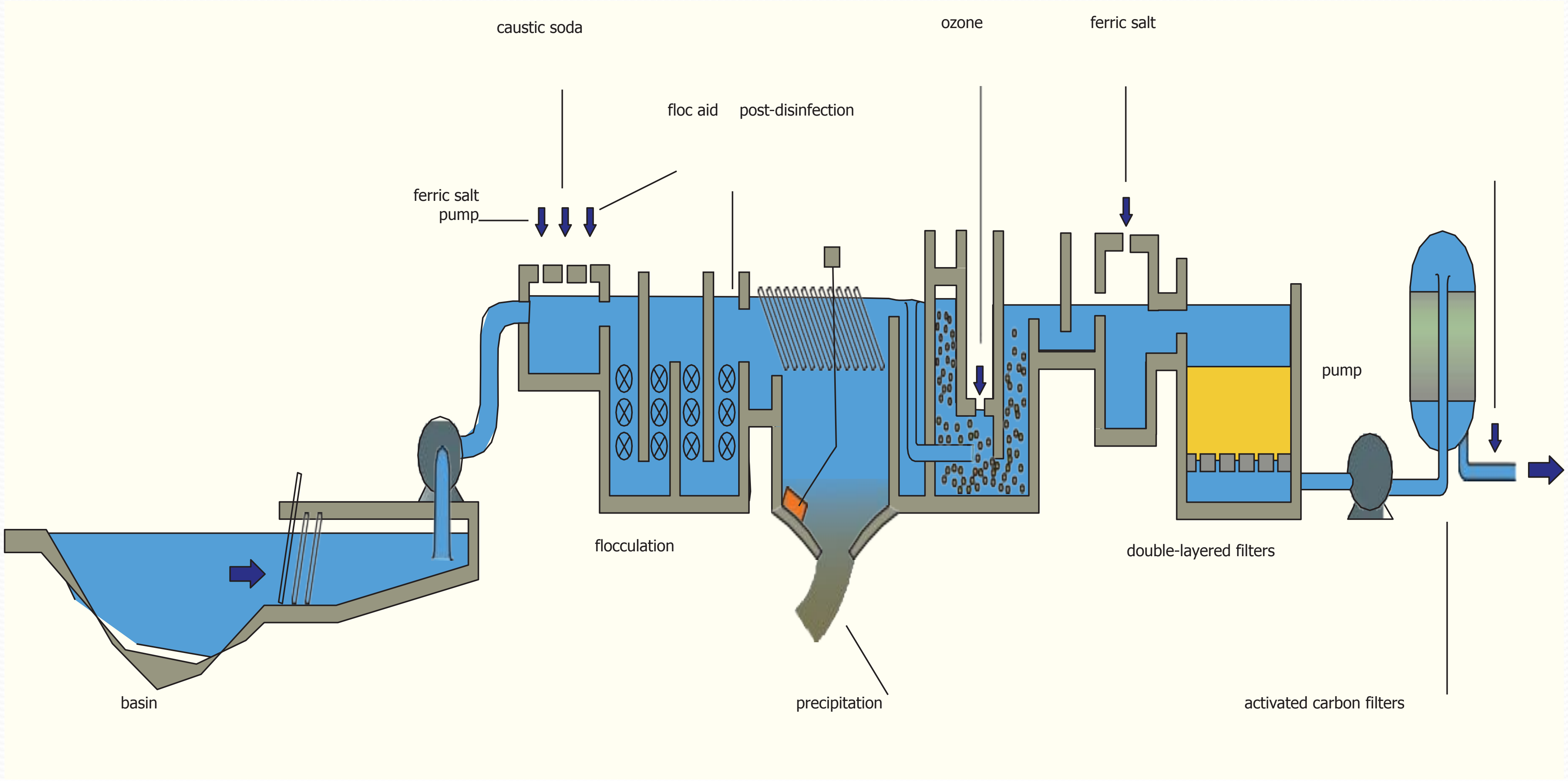
Ozone is highly unstable & releases nascent oxygen. The nascent oxygen is a very powerful oxidizing agent & kills all bacteria & also oxidizes all organic matter present in water.

- **Disadvantage**: i. Method is very expensive so not used by municipal water supply
- **Advantages:** i. It simultaneously removes colour, odour & taste
  ii. Doesn't leave any kind of residue in treated water
  iii. Its excess is not harmful as it decomposes into oxygen

Water Treatment



The production of drinking water from surface water with direct treatment



Disadvantages of using hard water in Boilers

During steam generation if hard water is fed to boilers then it leads to boiler troubles like:

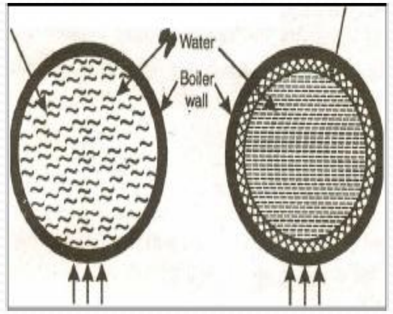
- Scale & Sludge formation
- Boiler Corrosion
- Priming & Foaming
- Caustic Embrittlement

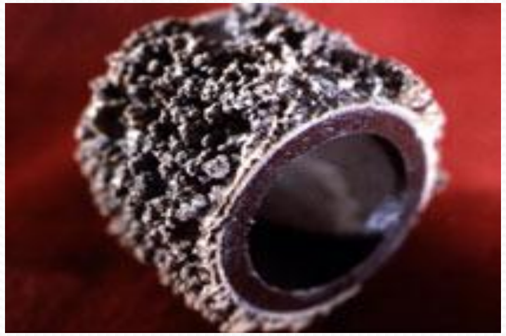
Scale and Sludge

- When water is evaporated in boilers to produce steam continuously the concentration of the salts present in the water increases progressively.
- As the concentration reaches a saturation point the salts are thrown over the inner surface of the boiler as precipitates.

If the precipitates are loose & slimy they are called **Sludges**

If the precipitates are hard & adherent they are called **Scales**





Causes of Sludge formation

- These are generally formed in the colder regions of the boiler
- They accumulate where the flow rate is less
- These are formed by substances having greater solubility in hot water than in cold water e.g.

  $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$

Disadvantages of Sludge Formation

1. Chocking of pipes
2. Low supply of heat
3. Wastage of fuel
4. Get entrapped in scales

Prevention or Removal of Sludges

1. By using Soft Water
2. By Blow Down Operation
3. By scrapping the sludge mechanically with a brush etc.

Causes of Scale Formation

1) Decomposition of Bicarbonates
2) Deposition of $CaSO_4$ due to reduced solubility
3) Hydrolysis of Magnesium Salts
4) Presence of Silica

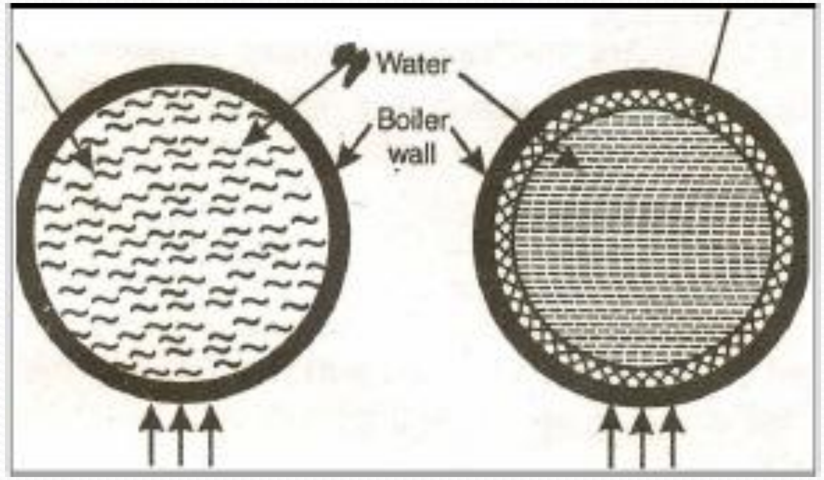
Decomposition of Bicarbonates

Bicarbonates decompose at a low temperature to liberate CO_2.

Remaining Calcium carbonate deposits on the heating surface as a soft scale.

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

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



Deposition of $CaSO_4$

- Salts like $CaSO_4$ & $CaCO_3$ have negative coefficient of solubility.
- Their solubility decreases as the temperature increases
- These salts are precipitated in hotter regions of the boiler

Hydrolysis of Magnesium Salts

- Dissolved Magnesium salts undergo hydrolysis to form magnesium hydroxide scales (soft)

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

$$MgSO_4 + H_2O \longrightarrow Mg(OH)_2 + H_2SO_4$$

$$Mg(NO_3)_2 + H_2O \longrightarrow Mg(OH)_2 + 2HNO_3$$

Presence of Silica

- Small quantity of silica present in water can react with soluble salts of calcium & Magnesium to form silicate scales
- These are the most troublesome scales in the boilers & are very difficult to remove
- They may be similar to zeolites in composition

Disadvantages of Scale Formation

1. Wastage of fuel
2. Decreases in Efficiency
3. Lowering of boiler safety
4. Danger of Explosion
5. Corrosion

Removal of Scales

1. By scrapping
2. Giving thermal shocks
3. Dissolving by using chemicals e.g. $CaCO_3$ by 5-10% HCl
4. Adding complexing agents e.g. $CaSO_4$ by EDTA
5. Blow down Process

Priming and Foaming

Priming:- It is the carry over of varying amounts of water in the steam(wet steam) e.g. (Foam, mist)

- Leads to deposits of salt crystals in inaccessible areas like turbine blades etc.
- Lowers the energy efficiency

Causes

a) Presence of suspended impurities and dissolved salts
b) High steam velocity and sudden boiling
c) High water levels
d) Faulty boiler design

Preventions

a) Good boiler design
b) Avoid rapid changes in temp.
c) Maintaining low water level
d) Fitting mechanical steam purifier

Priming and Foaming

Foaming: Formation of small but persistent bubbles and forth on the surface of water

Causes

a) Surface tension lowering substances - Oil and grease
b) By high concentration of salts in water

Prevention

a) Adding antifoaming agents e.g. castor oil
b) Removing oily particles using silicic acid and sodium aluminate.

Caustic embrittlement

It is the phenomenon in which the material of boiler becomes brittle due to the accumulation of caustic substances.

- Sodium carbonate is used in softening of water by lime soda process, due to this some sodium carbonate may be left behind in the water.

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

- As Conc. of NaOH increases & water flows into minute hair cracks.
- Water get evaporated and NaOH conc. increases further and reacts with iron of boiler, hence cause embrittlement.
- $2Fe + 2NaOH + O2 \longrightarrow 2NaFeO2 + H2$

Prevention:

1. Addition of sodium sulphate or sodium phosphate for water softening
2. Addition of tannin and lignin to blocks the cracks.
3. Excess of Na_2SO_4 is avoided else it will form $CaSO_4$

Boiler Corrosion

Boiler Corrosion: Decay of material chemically or electrochemically

Causes:

a) Presence of dissolved gases e.g. O_2 , CO_2
b) Caustic Embrittlement
c) Acid formation due to Hydrolysis
d) Presence of free acids.

Boiler Corrosion

- Due to dissolved O_2 : At high temperature O_2 reacts with boiler material
- $2Fe + 2H_2O + O_2 \longrightarrow 2Fe(OH)_2 \downarrow$
- $4Fe(OH)_2 + O_2 \longrightarrow 2[Fe_2O_3.2H_2O] \downarrow$ Rust

Prevention

1. By fitting de-aerator
2. By adding calculated amount of sodium sulphite, Sodium sulphide,hydrazine

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

$$Na_2S + 2O_2 \longrightarrow Na_2SO_4$$

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

Hydrazine is explosive & has to be used carefully

Boiler Corrosion

- Due to dissolved CO_2: It forms carbonic acid, that has a slow corrosive effect on boiler metal
- $CO_2 + H_2O \longrightarrow H_2CO_3$

Prevention

1) By de-aeration
2) By adding calculated amount of liquid ammonia

$$2NH_4OH + CO_2 \longrightarrow (NH_4)_2CO_3 + H_2O$$

Boiler Corrosion

- Due to hydrolysis of Magnesium salts: Hydrolysis results in formation of acids

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

- Liberated acid reacts with boiler metal to form a salt that again hydrolyses to produce more acid resulting in a chain reaction

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2$$

$$FeCl_2 + 2H_2O \longrightarrow Fe(OH)_2 + 2HCl$$

Prevention

1) By maintaining pH of boiler water
2) By removal of Magnesium salts before adding it to boiler

Treatment Methods of Water

A. Internal Treatment : Addition of chemicals directly to water in boiler.

- By adding substances that produces loose precipitate
- Blow down process
- Adding complexing agents: to form water soluble complex

B. External Treatment : Treatment of water before feeding it into boiler

- Removal of Ca, Mg and Silica by Lime-soda process, Zeolite method, demineralization

Internal Treatment Method

1) **Phosphate Conditioning**
2) **Colloidal Conditioning**
3) **Calgon Conditioning**
4) **Sodium Aluminate Conditioning**

Internal Treatment of Water

- Calgon Conditioning
  - Scale forming salts are converted into soluble complexes
  - By Sodium Hexametaphosphate
  - $(NaPO_3)_6 \longrightarrow 2Na^+ + (Na_4P_6O_{18})^{2-}$
  - Calgon
  - $(Na_4P_6O_{18})^{2-} + 2\,CaSO_4 \longrightarrow (Ca_2P_6O_{18})^{2-} + 2Na_2SO_4$
  - water soluble

Internal Treatment of Water

Phosphate Conditioning

- A) Orthophosphate
- Trisodium Phosphate Na_3PO_4 (Alkaline)
- Disodium hydrogen phosphate Na_2HPO_4 (Weakly alkaline)
- Sodium Dihydrogen phosphate NaH_2PO_4 (Acidic)
- Depending on the pH of Boiler water a particular Phosphate is added

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

$2Na_2HPO_4 + 3CaCl_2 \quad Ca_3(PO_4)_2 + 4NaCl + 2HCl$

$2NaH_2PO_4 + 3CaCl_2 \quad Ca_3(PO_4)_2 + 2NaCl + 4HCl$

Phosphate Conditioning

- B) Sodium Pyrophosphate : $Na_4P_2O_7$
- C) Sodium Metaphosphate : $NaPO_3$

They hydrolyse to form orthophosphates that react with scale forming impurities to form sludges that can be removed by Blow Down Operation

$$Na_4P_2O_7 + H_2O \longrightarrow 2Na_2HPO_4$$

$$NaPO_3 + H_2O \longrightarrow NaH_2PO_4$$

External Treatment Method (or) Water softening Method

- Removal of hardness causing substances from water

Methods:

1. Lime-Soda Process
2. Zeolite process
3. Ion Exchange Process

External Treatment Method (or) Water softening Method

- Removal of hardness causing substances from water

Methods:

1. Zeolite process
2. Ion Exchange Process

Zeolite (or Permutit) Process: Hydrated sodium alumino Silicate

$Na_2O.\ Al_2O_3\ \mathbf{X}\ SiO_2\ \mathbf{Y}\ H_2O$ (X= 2-10, Y= 2-6)

Natural Zeolites:

1. Natrolite - $Na_2O.\ Al_2O_3\ 4SiO_2\ .2H_2O$
2. Laumontite - $CaO.\ Al_2O_3\ 4SiO_2\ .4H_2O$
3. Harmotome - $(BaO.K_2O).\ Al_2O_3\ 5SiO_2\ .5H_2O$

- Capable of exchanging its Na ions.

A. **Natural Zeolite**:-

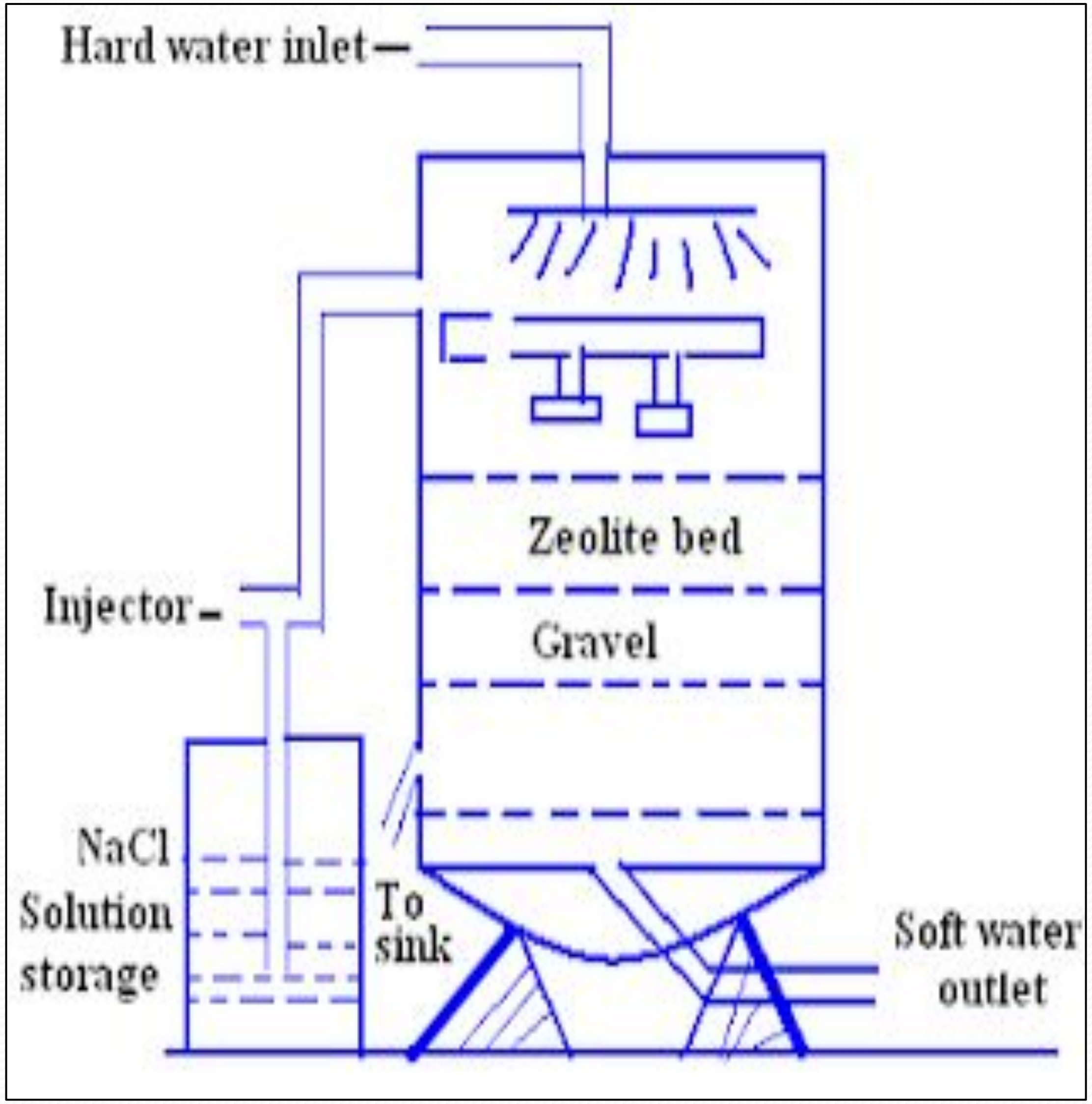
Derived from green sand by washing, Heating, treating with NaOH.

- Non porous in nature.

B. **Synthetic Zeolite**: -

Prepared from solution of Sodium Silicate and Al(OH)3

- Higher exchange capacity and porous in Nature.



- Zeolite exchanger consists of a Steel Tank , Having Thick Layer of Zeolite, fine gravel & coarse gravel and an inlet for hard water on the top , an outlet at the bottom for soft water
- When water passes through it the hardness causing ions (Ca, Mg) are retained by Zeolite and an equivalent amount of Na ions are released in softened water

Chemical Reaction:

$$Ca(HCO_3)_2 + Na_2Ze \rightarrow CaZe + 2\ NaHCO_3$$
$$CaSO_4 + Na_2Ze \rightarrow CaZe + Na_2SO_4$$
$$MgCl_2 + Na_2Ze \rightarrow MgZe + 2NaCl$$
$$Mg(NO_3)_2 + Na_2Ze \rightarrow MgZe + 2NaNO_3$$

- Exchange of Na ions continues until Na ions are exhausted.When all sodium ions are exchanged the zeolite is said to be exhausted
- It can be regenerated by passing calculated amount of brine (NaCl) solution from the top through the zeolite

Regeneration:

$$CaZe + 2NaCl \rightarrow Na_2Ze + CaCl_2$$
$$MgZe + 2NaCl \rightarrow Na_2Ze + MgCl_2$$

- $CaCl_2$ and $MgCl_2$ passes through outlet, these are known as washings & are led to drain and Na_2Ze can be reused.

Advantages

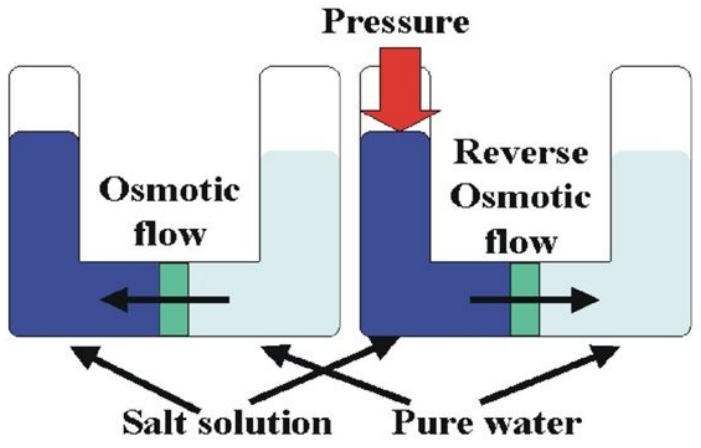
1. Hardness can be completely removed
2. Process can be made automatically
3. Easy operation. No experts required
4. Less time and sludge
5. Small area requires

Disadvantages

1. Only Ca^+ and Mg^+ ions can be removed
2. Large amount of Na ions is present in treated water.
3. Fe^{2+} and Mn^{2+} containing water can not be treated because Fe and Mn Zeolite can not be regenerated
4. Water should be free from suspended impurities to prevent clogging on Zeolite beds.
5. Treated water contains more dissolved solids.

Reverse Osmosis/ Super Filtration / Hyper Filtration

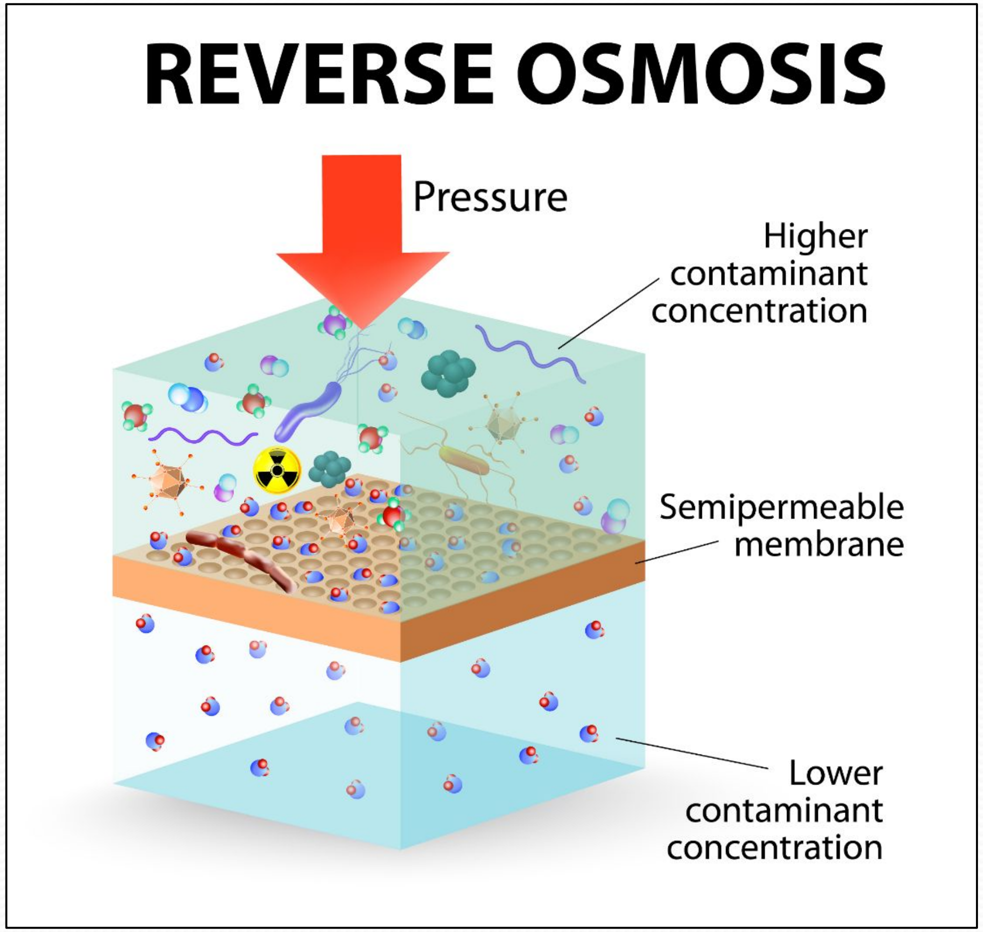
- When a hydrostatic pressure greater than the osmotic pressure is applied on the concentrated side, solvent molecules move from concentrated side to dilute side across the semi-permeable layer, this is called reverse osmosis.
- This principle is used by reverse osmosis plants to soften hard water.

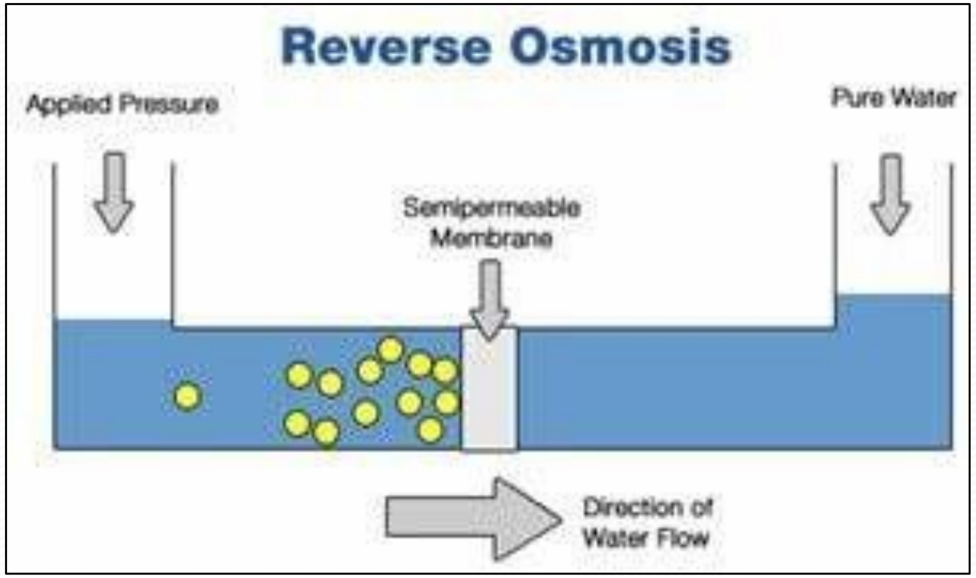


Method of Reverse Osmosis

- In this method hard water & soft water are taken in two different chambers separated by a semi-permeable membrane
- A hydrostatic pressure of greater than the osmotic pressure is applied on the concentrated side, solvent molecules move from concentrated side to dilute side across the semi-permeable layer.
- Thus hard water is converted to soft water by hyper filtration or super filtration
- The membrane used is Cellulose Acetate, Polyamide, Polymethyl methacrylate etc.

  of a thickness: 0.0005 to 0.0000002 μm


REVERSE OSMOSIS
Pressure
Higher contaminant concentration
Semipermeable membrane
Lower contaminant concentration


Reverse Osmosis
Applied Pressure
Pure Water
Semipermeable Membrane
Direction of Water Flow

Advantages of Reverse Osmosis

1. Removes both ionic ,non ionic and colloidal matters

2. Maintenance cost is low

3. Membrane replacement can be done within few minutes

- https://in.video.search.yahoo.com/search/video?fr=mcafee&ei=UTF-8&p=animation+on+water+treatment&type=E211IN1289G0#id=5&vid=daefff4bfb2dc159fc3735dc5f407a7e&action=click

- Animation link – Drinking water treatment

Zeolite Softening

- https://youtu.be/38cgc91aO2I

- Drinking water Treatment
- https://www.youtube.com/watch?v=AF-Sa-OLrb8

Thanks !