# Unit - I Water and its treatment

## Introduction

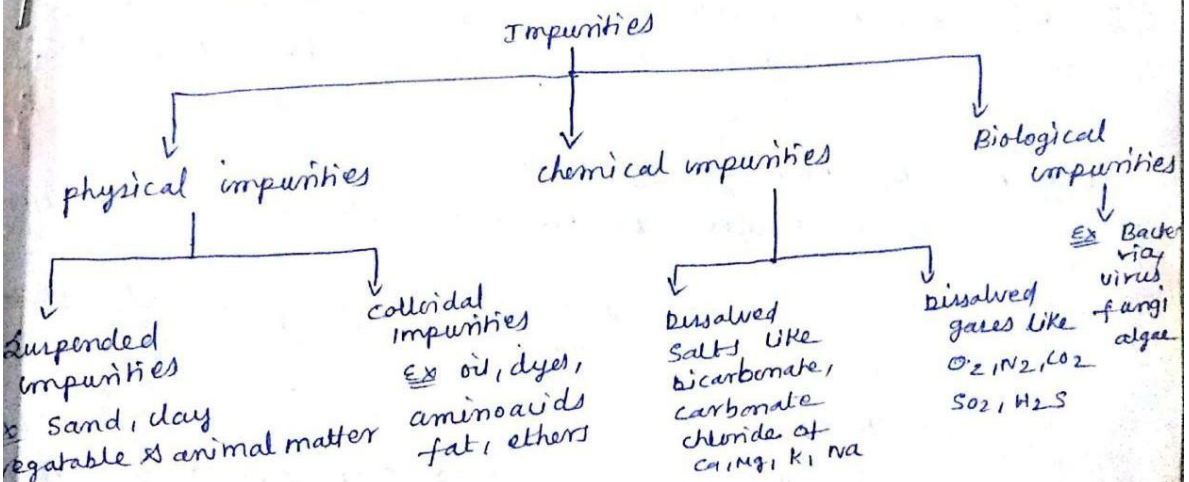
- Water is the most essential for all living beings on the earth.
- Hence without water, there is no life on the earth.

## Sources of water

i) Natural water - Rain water
ii) Surface water - Rain water, river water, lake water & sea water
iii) underground water - spring water and, well water

## Types of impurities

It can divided into three types




## Hardness of water

The presence of dissolved salts like bicarbonates, chlorides and sulphates of calcium and Magnesium.

## Types of water

1. Soft water
2. Hard water

Soft water :.

i) It gives good lather with soap solution is calle
Soft water.

ii) The absence of dissolved salts of ca & Mg

Hard water :.

i) It does not give good lather with soap solutio
is called as hard water.

ii) The presence of dissolved salts of ca & Mg

Difference between Soft water & Hard water

| Soft water | Hard water |
|---|---|
| 1. It gives good lather with soap solution | It does not give good l with soap solution |
| 2. Absence of dissolved salts of ca & Mg | presence of dissolved s of ca & Mg |
| 3. It does not gives wine red colour with Erichrome black-T indicator. | It gives wine red colou with erichrome black-T indicator. |

Detection of hardness of water

It is detected by treating water with soap Solu

$$2\,C_{15}H_{31}COONa + CaCl_2 \rightarrow (C_{15}H_{31}COO)_2Ca + 2$$

Soap (Hard water)

Types of hardness

The types of dissolved salts present in wa
classified into two types.

1. Temporary hardness
2. permanent hardness

Temporary hardness

The presence of bicarbonates salt of ca & Mg called as Temporary hardness of water

carbonate hardness of water (or) alkaline hardness of water.

Removed by

i) boiling the water

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 \downarrow + H_2O + CO_2$$

ii) Adding Lime ($Ca(OH)_2$)

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2 \downarrow + CaCO_3 \downarrow + CO_2 + H_2O$$

permanent hardness of water

The presence of chlorides and sulphates of Ca & Mg called as permanent hardness of water (or) non-carbonate hardness of water (or) non-alkaline hardness of $H_2O$

Removed by

i) Lime soda process → $CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + 2NaCl$

ii) Zeolite process ($Na_2Ze$)

$$MgSO_4 + Na_2Ze \longrightarrow MgZe \downarrow + Na_2SO_4$$

Total Hardness of water = Temporary Hardness + permanent hardness.

Differences between carbonate and non-carbonate hardness of $H_2O$

| carbonate | non-carbonate |
|---|---|
| The presence of bicarbonates of Ca & Mg | The presence of chlorides and sulphates of cas Mg |
| It can be removed by boiling the water | It cannot be removed by boiling the water |
| Another name is alkaline hardness | Another name is non-alkaline hardness. |

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## Expression of hardness of equivalents of $CaCO_3$ Standard

i) Molecular weight is 100 and equivalent weight is 50 are whole number. Hence, the calculations in water simple and easy.

ii) $CaCO_3$ is the most insoluble salt that can be precipitated during water treatment.

iii) The amount equivalent of $CaCO_3$ = $\frac{\text{Amount of hardness producing salt} \times \text{Molecular weight of } CaCO_3}{\text{Molecular weight of hardness producing Salt}}$

| Hardness producing salt | Molecular weight |
|---|---|
| $Mg^{2+}$ | 24 |
| $Mg(HCO_3)_2$ | 146 |
| $Ca^{2+}$ | 40 |
| $Ca(HCO_3)_2$ | 162 |
| $MgCl_2$ | 95 |
| $CaCl_2$ | 111 |

## Units of Hardness

i) Parts per million (PPM)

The number of parts of $CaCO_3$ equivalent hardness per $10^6$ parts of water

ii) Milligrams per Litre (mg/L)

The number of milligrams of $CaCO_3$ equivalent hardness per litre of water

1 mg/L = 1 PPM

iii) Clarkes degree (°Cl)

The number of parts of $CaCO_3$ equivalent hardness per 70,000 parts of water

iv) Degree French ($^0$ Fr)

The number of parts of $CaCO_3$ equivalent hardness per $10^5$ parts of water

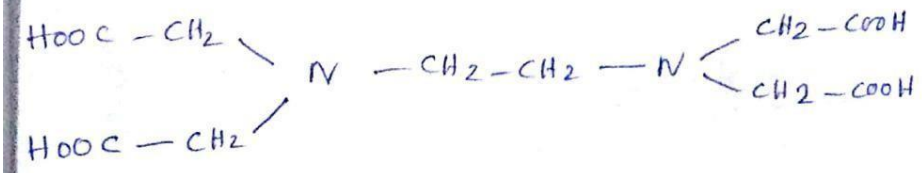
v) Milliequivalent per Litre (meq/L)

The number of milli equivalents of hardness present per Litre.

## Estimation of Hardness of water by EDTA method

* It is a complexometric method.
* It is more accurate, convenient and fast.
* It is widely used for the estimation of hardness of $H_2O$.

EDTA → Ethylene Diamine Tetra Acetic acid.



- EDTA is insoluble in water.
- Disodium Salt ($Na_2$ EDTA) is soluble in water.
- It is used as complexing agent.
- EDTA form stable complexes with $Mg^{2+}$ & $Ca^{2+}$ ions of hard water.

### principle

$M^{2+}$ + EBT ⟶ $M^{2+}$ – EBT + EDTA ⟶

($Ca^{2+}$, $Mg^{2+}$)

↓

Eriochrome black-T (Indicator) pH = 9–10 original colour (steel blue)

unstable wine red complex

Indicator–metal ion complex

$[M^{2+} - EDTA]$ + EBT
(steel blue)

Stable complex

* Buffer solution → Maintain constant pH value
  ↳ Ex: $NH_4Cl - NH_4OH$ mixture is added.

End point ⇒ wine red → steel blue (Indicator colour)

## preparation of solutions

i) Standard hard water → 1g dry $CaCO_3$ + dil HCl + 1000 of $H_2O$

ii) EDTA solution → 4g EDTA + 1000 ml of $H_2O$

iii) EBT indicator → 0.5 g EBT + 100 ml methanol

iv) Buffer solutions → 67.5 g $NH_4Cl$ in 570 ml $NH_4OH$ + 1000 ml of $H_2O$

## procedure

i) Standardization of EDTA solution using standard hard water

Burette solution — EDTA
pipette solution — 50 ml of std. hard water
other solution — 10 ml Buffer solution
Indicator — Eriochrome black-T
End point — Wine red → steel blue colour

## calculation

Volume of EDTA = $V_1$ ml

1 ml of std. Hard water = 1 mg of $CaCO_3$
50 ml of std. " = 50 mg of $CaCO_3$
50 ml of " " requires $V_1$ ml of EDTA
$V_1$ ml of EDTA = 50 mg of $CaCO_3$
1 ml of EDTA = $\frac{50}{V_1}$ mg of $CaCO_3$

i) Estimation of total hardness of water sample using standardised EDTA solution

Burette solution – EDTA
pipette solution – 50 ml of sample water
other solution – 10 ml of Buffer solution
Indicator – Erichrome black-T
End point – Steel blue colour

Calculation.

Volume of EDTA = $V_2$ ml

50 ml of given sample water consumes = $V_2$ ml of EDTA

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

∴ 1000 ml of given sample water = $\frac{V_2}{} \times \frac{50}{V_1} \times \frac{1000}{50}$

$= 1000 \frac{V_2}{V_1}$ mg $CaCO_3$

Total hardness $= 1000 \frac{V_2}{V_1}$ ppM

i) Estimation of permanent hardness of water sample using standardised EDTA solution

a) 100ml sample water in 250ml of Beaker
b) Boiled for temporary hardness cool and filter and make up into 100ml SMF.

a) Burette solution = EDTA
pipette solution = 50 ml Boiled sample water +
other solution to be added = 10 ml of Buffer solution
Indicator = Erichrome black-T
End point = Steel blue colour

calculation

Volume of EDTA = $V_3$ ml

50ml of sample water consumes = $V_3$ ml of EDTA

1 ml of EDTA $= V_3 \times \frac{50}{V_1}$ mg of $CaCO_3$

∴ 1000 ml of given sample water consumes $y = V_3 \times \frac{50}{V_1} \times \frac{1000}{50}$

$= 1000 \frac{V_3}{V_1}$ mg of $CaCO_3$

permanent hardness $= 1000 \frac{V_3}{V_1}$ mg of $CaCO_3$

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

Temporary hardness = Total hardness − permanent hardness

$= 1000 \times \frac{V_2}{V_1} - 1000 \times \frac{V_3}{V_1}$

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

—

## Boiler feed water

**Definition**

The water fed into the boiler for the production of steam is called boiler feed water

The water containing dissolved salts (physical & chemical), gases and suspended impurities are used in boilers the following problems are

1) Scale and Sludge formation
2) boiler corrosion
3) caustic embrittlement
4) priming and foaming

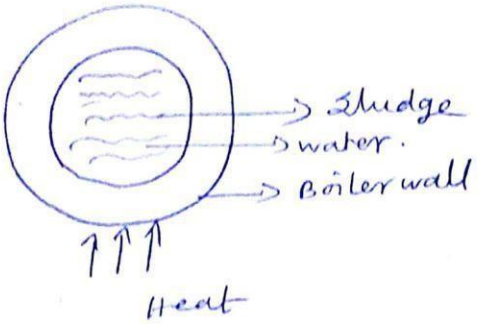
## Boiler troubles (or) Scale and Sludge formation

As water evaporate continuously in boilers for steam production, the salts precipitated

**Sludge** → If the precipitate formed is soft and slimy it is called Sludge.

on the inner walls of the boilers. It is formed by $MgCl_2$, $MgCO_3$, $MgSO_4$ & $CaCl_2$

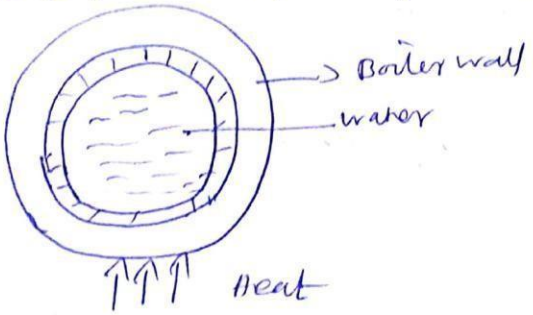
* They have greater solubilities in hot water than cold water




Scale

1. → If the precipitate is hard and adhering on the inner walls it is called scale.

2. → Scales are formed by substances like $Ca(HCO_3)_2$, $CaSO_4$, & $Mg(OH)_2$




Removal of Sludge (or) prevention of Sludge

1. Sludges are poor conductors of heat
2. If formation can be prevented by using soft water
3. They can be removed by blow down operation method.

Properties of Scales

1. Scales are poor thermal conductors, Hence they act as partial heat insulators results wastage of fuels.

2. over heated and produce large amount of steam and high pressure and explosion of boiler.

Removal of Scales

1. Brittle scales may be removed by giving thermal shocks.
2. Loosely sticking scales can be removed by scraping
3. Firmly sticking scales can be removed by chemical reactions.

Comparision of Sludge and scale

| Sludge | Scale |
|---|---|
| 1. It is a soft, loose & slimy precipitated | It is hard and adherent coating. |
| 2. It is formed by substances like $MgCl_2$, $MgCO_3$, $MgSO_4$, $CaCl_2$ | It is formed by substances like $Ca(HCO_3)_2$, $CaSO_4$, $Mg(OH)_2$ |
| 3. It is a poor conductor of heat | It is a thermal insulator |
| 4. Decrease the efficiency of boiler | Decrease the efficiency of boiler and any crack boiler explosion. |
| 5. It can be removed by scrapping off with a wire brush | It may be removed by giving thermal shocks, scrapping, chemical reaction |
| 6. Wastage of fuel is very large | Wastage of fuel is comparatively less. |
| 7. Methods for removal of Sludge<br>i) blow down operation<br>ii) Scraping by wire brush | Methods for removal of Scales<br>i) Internal & external treatment |

# Softening or conditioning processes

**Definition**

Hard water is converted into soft water is called Softening (or conditioning processes.

**Types of process**

1- Internal conditioning processes
2. External " "

**External conditioning process**

1. It is carried out before its entry into the boiler.
2. It is preventive method
3. High pressure boilers require this treatment.
4. It includes lime soda process / zeolite (permutit) process and ion exchange process.

**Internal conditioning process**

1. It is carried out in the boiler it self.
2. It is a corrective method.
3. ~~High~~ Low pressure boilers require this treatment.
4. It includes carbonate conditioning / colloidal conditioning / calgon conditioning / phosphate conditioning.

**Difference between external & internal conditioning process of Softening process.**

(above the points 4 in External & internal conditioning write it)

Internal conditioning process

a) colloidal conditioning

1. In low pressure boilers, scale formation can be avoided by adding organic substances (or) colloidal substances like Kerosene, agar-agar, tan, gelatin etc.

2. colloidal substances coated over the scale forming particles and convert into the loose precipitate called sludge.

3. It can be removed by blow down operation.

b) phosphate conditioning :- 1. In high pressure

1. Scale formation can be avoided by adding Sodium phosphate.

2. The phosphate reacts with $Ca^{2+}$ and $Mg^{2+}$ salts to give soft sludges of Ca & Mg phosphates

$$3\,CaSO_4 + 2\,Na_3PO_4 \longrightarrow Ca_3(PO_4)_2\downarrow + 3\,Na_2$$

$$3\,MgCl_2 + 2\,Na_3PO_4 \longrightarrow Mg_3(PO_4)_2\downarrow + 6\,NaC$$

| No | name of phosphate salt | used in |
|---|---|---|
| 1. | Tri Sodium phosphate ($Na_3PO_4$) | acidic wate |
| 2. | Di Sodium hydrogen phosphate $Na_2HPO_4$ | weakly acid water |
| 3. | Sodium dihydrogen phosphate ($NaH_2PO_4$) | Alkaline w |

c) calgon conditioning

1. calgon is Sodium hexa meta phosphate

$\therefore Na_2[Na_4(PO_3)_6]$

2. It reacts with $Ca^{2+}$ to form highly soluble complex.
3. It prevents the precipitation of scale forming salt.
4. calgon conditioning is better than phosphate conditioning

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

d) Sodium aluminate conditioning

1. Sodium aluminate reacts boiler water to give Sodium hydroxide & gelatinous precipitate of coagulant aluminium hydroxide.

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

2. Sodium hydroxide reacts with $Mg^{2+}$ ions to give magnesium hydroxide

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

3. Aluminium hydroxide & Magnesium hydroxide are produced inside the boiler.
4. Finely suspended & colloidal impurities / oil drops and Silica formed.
5. It can be removed by pre-determined blow down operation.

## External conditioning

Two methods

1. Demineralisation or ion-exchange process (or deionisation process)
2. Zeolite (or) permutit process.

## 1. Demineralisation (or) ion-exchange process (or) de ionisation process

**Definition:**

* Anions and cations are removed from the hard water is called de-ionisation process (or) demineralisation process.

* Soft water is not a demineralised water whereas demineralised water is a soft water.

* Demineralisation process / the ions present in water are removed by ion exchangers.

**process**

### cation exchangers (or) cylinder-I

1. Hard water is passed through the I-cylinder absorbs all the cations like, $Na^+$, $K^+$, $Mg^{2+}$, $Ca^{2+}$ called as cation exchangers
2. It is represented as $RH_2$ (or) RH
3. Examples: Sulphonated coal
   Sulphonated polystyrene
4. Commercially available i) Amberlite IR-120
   ii) Dowex-50

$RH_2 + CaCl_2 \rightarrow RCa + 2HCl$

$2RH + MgCl_2 \rightarrow R_2Mg + 2HCl$

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## Ion-exchange (or) demineralisation process

**Definition**

* Removal of all ions (cations and anions) from the Hard water is called de-ionisation process (or) demineralisation process.
* Soft water is not a demineralised water where as demineralised water is a soft water
* Demineralisation process if the ions present in water are removed by ion-exchangers.

Resins are classified into two types

1. cation exchange resin
2. Anion " "

**cation (or) Acidic exchange Resin ($RH^+$)**

* It is containing acidic functional groups (-COOH, $-SO_3H$, etc).
* It exchange their $H^+$ ions with other cations of hard water

Example Sulphonated (or) carboxylated polystyrene

**rocess**

* Hard water is passed through the cation resin. It removes all the cation like $Ca^{2+}$ & $Mg^{2+}$

$$2R^1H^+ + Ca^{2+} \longrightarrow R^2Ca^{2+} + 2H^+$$

**nion (or) Basic exchange Resins ($R'OH^-$)**

* It is containing basic functional groups (-OH, $-NH_2$ etc.
* It exchange their $OH^-$ ions with other anions of hard water

Ex cross-linked polystyrene containing quaternary ammonium salts.

process

* It Removes all the anions like $SO_4^{2-}$, $Cl^-$ etc.

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

Finally

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

Regeneration

i) cation exchanger is regenerated by passing HCl or $H_2SO_4$ solution.

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

ii) Anion exchanger is regenerated by passing dil. NaOH

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

Advantages

1 It is used to treat highly acidic or alkaline

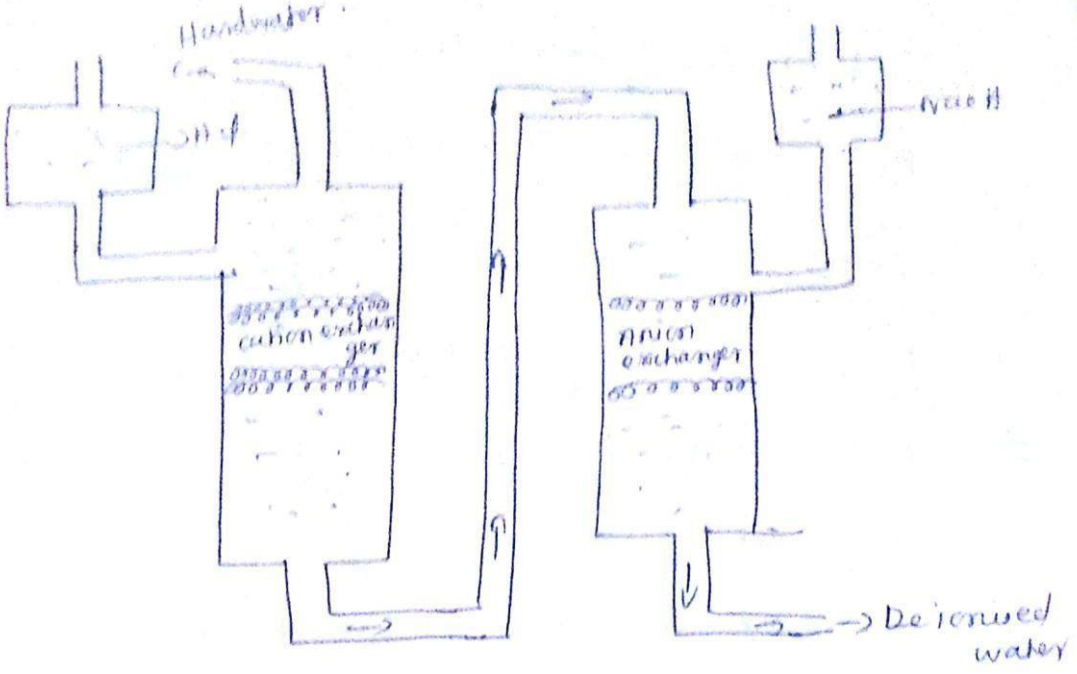
2 It is used in high pressure boilers.

3. It produces water of very low hardness (upto 2 ppm)

Disadvantages

1. the equipment is costly.

2. Turbidity reduces the efficiency of the proce




Anion exchangers (or cylinder - II

1. It absorbs the anions like $Cl^-$, $HCO_3^-$, $SO_4^{2-}$ called as anion exchangers.
2. It is represented as $R(OH)_2$ (or) ROH
3. Examples: i) Urea formaldehyde resin
   ii) Melamine Formaldehyde resin.
4. commercially available in i) Amberlite - 400
   ii) Dowex - 3

Completely free from anions and cations in the water are removed called as deionised water (or) demineralised water.

$$R(OH)_2 + CaCl_2 \longrightarrow RCa + 2OH^-$$

Regeneration

1. cylinder - I passed through the acid

$$RCa + HCl \longrightarrow RH + NaCl$$

2. cylinder – II passed through the base

$RCl_2 + 2NaOH \longrightarrow 2NaCl + R(OH)_2$

resin.

Advantages

1. It is used to treat highly acidic or alkaline water
2. It is used in high pressure boilers

Disadvantages

1. It is costly and more expensive method.
2. Turbidity reduces the efficiency of the proc

Zeolite (or) permutit process

Definition : The process of removing hardness producing salts from ~~hardness~~ ~~zeolites are also known as permutit~~ by using zeolites is called Zeolite process.

* Zeolites are naturally occurring hydrated sod alumino silicate.
* general formula is $Na_2O \cdot Al_2O_3 \cdot x SiO_2 \cdot yH_2$ ($x = 2-10$, $y = 2-6$).

Types : Two Types

1. Natural Zeolites : non-porous & green sand

Ex natralite : $Na_2O\ Al_2O_3 \cdot 4SiO_2 \cdot 2H_2$

2. Synthetic Zeolites : porous & gel structure

* Synthetic form of zeolite is known as permutit.
* It is represented by $Na_2Ze$

Process

* When hard water is passed through a bed of sodium zeolite ($Na_2Ze$), and exchange the sodium ions with $Ca^{2+}$ & $Mg^{2+}$ to form Ca & Mg zeolites.

$$Mg(HCO_3)_2 + Na_2Ze \rightarrow MgZe + 2NaHCO_3$$

$$CaSO_4 + Na_2Ze \rightarrow CaZe + Na_2SO_4$$

$$MgCl_2 + Na_2Ze \rightarrow MgZe + 2NaCl.$$

Regeneration

The exhausted zeolite is again regenerated by treating with 10% solution of NaCl. (or) 10% brine solution.

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

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

Advantages

i) Hardness of water 1 - 2 ppm by this process water obtained.
ii) It can be used again
iii) No sludge is formed
iv) It occupies a small space.
v) It operates easily.

Disadvantages

i) Blocks the pores of the zeolite bed — Turbid water
ii) Decomposes the structure of zeolite — Acidic water

1. colourless and odourless
2. Free from any suspended or colloidal impuri
3. Free from micro organisms and bacteria

untreated water contain pathogens, chemical pollutants and other component like odour, turbidity, algae etc.

Treatment method

i) Heating (or) boiling

a) Heat kills disease causing micro organism.
b) Boiling does not leave any residual protection.

ii) Filtration

Potable pump filters remove most bacteria & protozoa, But they do not kill viruses.

iii) Activated charcoal adsorption

a) It can remove chlorine from treated water.
b) It protects water against pathogens.

iv) chemical disinfection

a) chemical disinfection with $H_2$ & $I_2$ results from oxidation of cellular structures and enzymes.
b) Sodium dichloroisocyanurate (NaDCC) is used for water treatment.
c) Iodine kills many common pathogens in fresh water sources.
d) Ozone finds use in municipal water treatment plants, food processing units and healthcare organisations.

v) Ultra violet purification

· In solar water disinfections (SODIS), microbs are destroyed by temperature and uv radiation provided by the sun.

vi) Solar distillation

There methods are commonly used at household level in developing countries, by recreational enthusiasts, military personnel Survivalists.

## Desalination of Brackish water

### Definition

* The process of removing common salt (NaCl) from the water is known as desalination

* Water containing high concentration of dissolved salts is known as brackish water

Water quality based on dissolved salts as

1. Freshwater — contains < 1000 PPM of dissolved
2. Brackish water — " 1000 – 35000 PPM "
3. Sea water — " > 35000 PPM "

Some techniques are used for desalination of sea water & brackish water

i) Distillation
ii) electrodialysis
iii) reverse osmosis
iv) Distillation
v) Freezing

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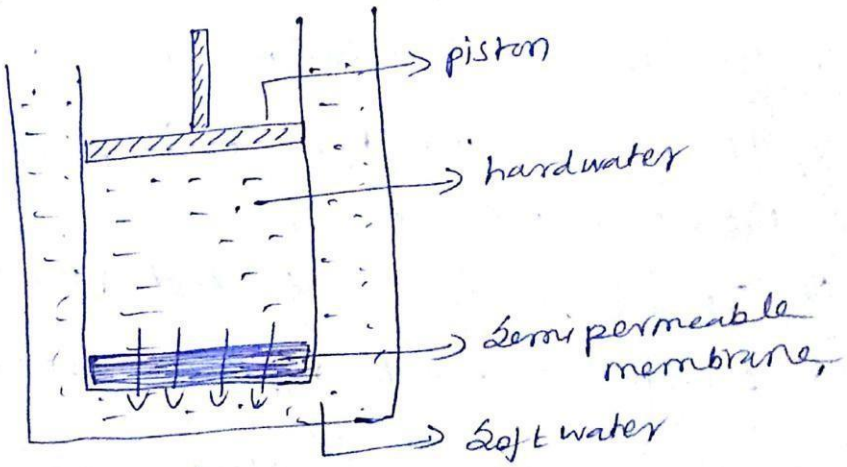
## Reverse osmosis process

**principle :** osmosis

- When two solutions are separated by a semi-permeable membrane, the solvent molecules will move from dilute solution to the concentrated solution.
- This process is known as **osmosis**.
- when a hydrostatic pressure applied on the concentrated side, solvent molecules move from concentrated solution to the dilute solution.
- This process is known as **Reverse osmosis**




**process**

- In this method, hard water is taken in the inner vessel.
- Soft water is taken in the outer vessel.
- Hard & soft water are separated by semi permeable membrane.

* A hydrostatic pressure applied on the hay water side.
* The solvent molecules move from concentrated solution to dilute solution.
* Thus softening of hard water takes place.
* Sulphone, cellulose acetate, polyamide and poly acryle nitrile are used as semi-permeable membranes.

Advantages

* This process is used for purify the sea water for drinking purpose.
* The life time of the membrane is high.
* It removes all types of impurities (ionic, non-ionic, colloidal)
* This prous is used for high pressure boilers
* Membrane can be replaced with in short time
* It is very less expansive method.

Up Flow Anaerobic Sludge Blanket (UASB) process

principle

* In this process waste water enters the reactor from the bottom & flows upward.
* A suspended sludge blanket are filtered.
* It is used for waste water treatment

Process

- UASB is a single tank process.
- It uses a reactor.
- Reactor are constructed using concrete (or) other water tight material.
- It can be designed in a circular (or) rectangular.
- waste water is pumped from the bottom into the reactor.
- Bacteria growth on the sludge.
- A sludge blanket is comprised of microbial granuals of 1 to 3 mm in diameter.
- The microorganisms in the sludge layer degrade organic compounds
- Gases like methane, $CO_2$, biogas are released.
- The rising bubbles mix the sludge.
- Equilibrium forms a stable and suspended sludge blanket
- The effluent is extracted from the top of the tank.
- A gas - liquid - Solid separator (GLSS) Separates the gas from the treated waste water and the sludge

Advantages

- Biogas are produced & used as energy source.
- Sugars dissolved in the liquid waste steam converted into gas quickly.

* High reduction in organics.
* The nutrient rich effluent used as soil fertiliser after composing.

Dis advantages

* Long start up time.
* constant source of electricity is required.
* Difficult to maintain proper hydraulic Condit
* Requires expert design and construction Supe
* Dilute waste water streams with 3%. total suspended solids (TSS) with particle s < 0.75 mm

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Boiler troubles ~~or Boiler feed water~~ or Disadvan

Definition of using hardwater in boilers

* water used in boilers to generate steam known as boiler feed water.
* Hard water is used in boilers many troub will arise. They are
  1. Scale & Sludge formation
  2. corrosion of the boiler metal
  3. caustic embrittlement
  4. Foaming & priming

1. Boiler Scale formation

On heating continuously, the dissolved salts in hard water gets deposited as a coating

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on the boiler surface. This is known as boiler scale.

Disadvantages of Boiler scale

i) Boiler scale is a bad conductor of heat, so the wastage of fuel.

ii) The scales block the safety valves; the boiler explosion.

iii) Corrodes the boiler metal

iv) Boiler metal loses its strength

v) Corrosion of boiler metal

It is due to the presence of

a) Dissolved oxygen
b) Dissolved carbon dioxide
c) dissolved salts.
d) chemical
e) electrochemical
f) environment
g) mineral acids
h

a) Dissolved oxygen → It attacks the boiler metal at high temperature.

$$4Fe + 6H_2O + 3O_2 \longrightarrow 4Fe(OH)_3 \downarrow$$

b) Remedies

Dissolved oxygen can be removed by chemical or mechanical methods by deaeration.

b) Dissolved $CO_2$ → It produces carbonic acid which corrodes the metal.

Remedies

- By removing $CO_2$ using lime
- Removed by mechanical deaeration method

Mineral acids → It attacks the boiler metal and corrode it.

Remedies

By neutralising mineral acids with bases like soda ash.

$HCl + NaOH \longrightarrow NaCl + H_2O$

Caustic embrittlement (Intercrystalline cracki

Definition

* corrosion which occurs at the cracks and ri inside the boiler parts is called caustic embrittl
* This effect is due to the presence of sodium hydroxide in water.
* This problem can be avoided by using lime.

$Fe + 2NaOH \longrightarrow Na_2FeO_2 + H_2\uparrow$

Prevention

It can prevented by

i) using sodium phosphate & sodium carbonate

ii) by adding tannin, lignin to the boiler water

priming & Foaming (carry over)

priming

Definition

* It is the process of production of wet steam
* It is the rapid and violent boiling of $H_2O$

It is caused by

a) High steam velocity
b) very high water level in the boiler
c) Sudden boiling of water
d) very poor design of the boiler

prevention

It can be controlled by

a) control the velocity of steam
b) Keep the water level lower.
c) Good boiler design proper and uniform heating
d) using treated water

Foaming

Definition

* The formation of stable bubbles above the surface of water is called foaming.

* It is caused by
  a) presence of oil & grease
  b) presence of finely divided particles.

prevention

It can be prevented by

a) adding coagulants like sodium aluminate aluminium hydroxide.
b) adding anti-foaming agents like synthetic polyamides.

## 2mark Questions (Additional questions)

1. What are the methods used to prevent scale formation?
   - Scraping & wire brush used.
   - blow down operation.
   - thermal shocks.
   - addding chemicals

2. what are boiler compounds. Give two examples
   Scale forming substances can be removed by addding chemicals directly to the boiler.
   Ex $Na_2CO_3$, $Na_3PO_4$

3. what are the methods used to soften hardwater
   i) External treatment – zeolite process, ion-exchange, Reverse osmosis
   ii) Internal " – carbonate, colloidal, phosphate, sodium aluminiate, calgon.

4. Mention the units used for expressing hardness of water?
   i) PPM ii) Mg/L iii) clarks degree iv) French degree

5. what are ion exchange resins?
   Ion-exchange resins are insoluble, long chain, cross-Linked organic palymers which are permeable due to their micro porous structure

6. Name the salts responsible for scale and sludge.
   Scale: $Ca(HCO_3)_2$, $CaSO_4$
   Sludge: $MgCO_3$, $MgCl_2$

7. what is blow-down operation?
   It is process of removing a portion of concentrated water by freshwater frequently from the boiler durring steam production.

| treatment method | Used in |
|---|---|
| Heating | destroy the micro organism |
| filtration | Remove bacteria & protozoa. |
| Activated charcoal adsorption | pure. Destroy the pathogen |
| . chemical disinfection | purify the water treatment |
| a) Sodium dichloro isocyanurate | Kills the pathogen (or) destroy |
| b) Iodine | municipal water treatment |
| c) Ozone | food processing units |
| . ultraviolet purification. | destroyed the microbes |
| . Solar distillation | purify the water |