Ganesh Institute of Engineering and Technology

SCTE &VT, BHUBANESWAR, ODISHA

By

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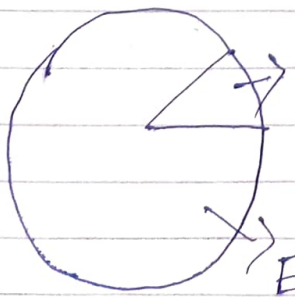
Unit - 2

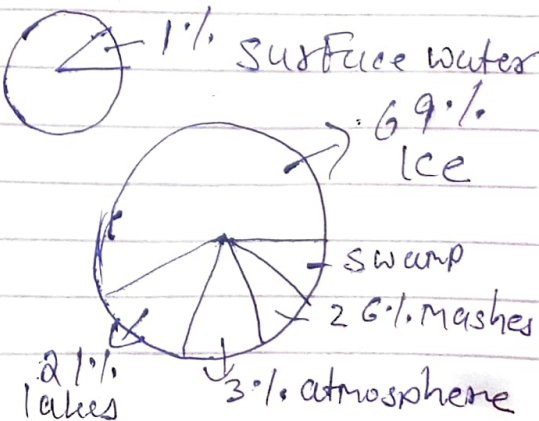
Water

→ Water is an extremly crucial resource for the proper functioning of living organisms.
→ About 60% of human body is a made up of water while blood consists of 90% water.
→ Water on earth is cycled continuosly through evaporation, transporation condensation, precipitation and other means.

* Graphical Representation of Water distribution on earth

→ Out of total existing water only 3% is Fresh water while remaining 97% is Saline or sea water.
→ Almost 99% of Freshwater is lockedup in the glesious on under grounel.
→ less than 1% of Freshwater is present on the earth surface.
→ 69% of Surface water is locked in Form of eyels while 21% is Found in lakes and rivers.
→ Soil moisture contains 3.8% water the atmosphere contains 3% and swamp and marshes have 2.6% of wcater.
→ River accounts for a small % of Fresh water that is 0.49%.





SOFT And HARD Water

→ Water that produces lather easily by shak with show solution is called SOFT water.

→ Water that does not produce lather easily but Forms a white curd or whites scum is called harder water.

→ Soap is sodium or pottassium salt of higher Fatty acid when Soap is mixed with water the lather is produced due to stearic acid and Sodium Stearate.

$$C_{17}H_{35}COONa + H_2O \longrightarrow C_{17}H_{35}COOH + NaO$$

Soap — Stearic acid

The Hardness in water is mainly due to the Presence OF diFFerent salts in dissolve state.

Types OF Hardness :

Temporary hardness - Hardness that can be removed by more boiling is called Temparary hardness.

- Such hardness is caused by the presence of dissolve by bicarbonates OF Mg, Ca and other metal.

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

Calcium carbonate

Permanent Hardness

- It is a type of hardness that cannot be removed by more boiling.
- This type of hardness is caused by the presence of Chlorides and Sulphides of Mg and Ca.

	Soft Water	Hard Water
①	It has less mineral content.	It has high mineral content.
②	It contents sodium ion	It contents calcium and magnesium ion
③	It reacts with soap to form lather	It reacts with soap to form scum or curd
④	It is sweetable for industrial application.	It is not sweetable for industrial application.
⑤	It is sweetable for human conjuction.	It is not sweetable for human conjuction

Units of hardness

It is expressed in terms of parts by weight of Calcium carbonate ($CaCO_3$). There are different systems to describe the hardness of water.

→ **Parts Per million (PPM)**

The no of parts by weight of $CaCO_3$ present per million parts by weight of water (H_2O)

Formula

$$PPM = \frac{1 \text{ Part of } CaCO_3}{10^6 \text{ parts of Weight of } H_2O}$$

b) French degree of hardness.
The no of parts by weight of $CaCO_3$ present in 10^5 parts by weight of water.

1 French = $\frac{1 \text{ Part of } CaCO_3}{10^5 \text{ parts by weight of Water.}}$

c) Degree clark
No of Parts by weight of $CaCO_3$ in 70,000 parts by weight of water.

10 Clark = $\frac{1 \text{ Parts of } CaCO_3}{70{,}000 \text{ parts by weight of } H_2O}$

d) Milligram Per Metre (MPM)
The no of Milligrams of $CaCO_3$ equivalent hardness present per liter of H_2O.

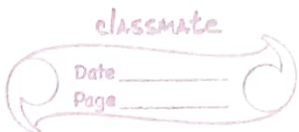
1mg/ltr = 1mg of $CaCO_3$ equivalent present per liter.

1 Liter = 1kg = 10^6mg = 1PPM

e) Milliequivalent per liter
The no of milliequivalent of hardness present per liter

1meq/ltr = 1meq of $CaCO_3$ present per liter
= 50×10^6 = 50PPM

→ Cause of hard water
When waters containing chlorides and sulphides of Mg and Ca upon reaction with soap they form in soluble salt of Mg and Ca sterate. Precipitate stearate that appears as scum and curd.



$C_{17}H_{35}COONa + MgCl_2 \rightarrow H_{35}C_{17}C(=O)-O-Mg + 2NaCl$

$H_{35}C_{17}C(=O)O-Mg$

$C_{17}H_{35}COONa + MgSO_4 \rightarrow H_{35}C_{17}C(=O)-O-Mg + NaSO_4$

$H_{35}C_{17}C(=O)O-Mg$

→ Problems caused by the use of hardwater in boilers

- Water containing dissolve salts of SO_4 CO_3 Cl of Ca, Mg and Iron have an adhesive impact on steam boilers.
- Water for reasing steam in boilers must be soft and must not contain dissolve matter to avoid slause and foaming problems in the boiler.

Sluge

Due to continuous boiling of H_2O the concentration of dissolve salt inside the boiler is increased when salt concentration reaches a saturation point salts are thrownout of the H_2O, precipitating on the inner wall of the boiler. This sluge sets on the region of poor water circulation such as pipe connections there by choceling the pipes.

→ Properties of Sluge

- Sluge are soft and less formable precipitation
- Sluge are poor conductors of heat.
- These are formed are comparatively pulles portion of the boiler.
- Sluges are formed by substances that have greater solibilatey in hot water
  Ex - Magnessium Co_3 ($MgCo_3$), $MgCl_2$ / $CaCl_2$ etc.

→ Prevention of Slauge Formations

- We can decrease slauge formation by using well softer water.
- Frequency blow down operation by drawing by portion of be concentrated water.
- Mechanical means by screeping of these sluge with a wire box.
- Giving thermal shock.

SCAL

- The hard adhering coating deposited on inner wall of boiler is known as scal.
- There formed due to the presence of sulphates and sillicate of calcium and magnessium.

→ Properties of Scal

- Scal is very hard and formly adher to the boiler.
- It is difficult to remove them.
- It is bad conduction on heat.

→ Prevention of Scal Formation

- The Form precipitate can be removed by thermal sluge.
- Internal conditioning with different chemicals such as phosphati, Co_3, EDTA etc.

Priming

- Priming is cover of variable amounts of droplets of water in the stell.
- When the boiler is being stream rapidly some liquid water particles are mixed with the steel.

Foaming

- It is the Production of Persistance Foam and bubbles in boilers.
- Bubbles do not break easily Foaming is Formed generally due to presence of substances like oils.

→ Causes of Priming and Foaming

- Presence of large amount of dissolved solids
- High steam velocity
- Sudden boiling
- Improper boiler design
- Sudden increase in steam production rate.

→ Prevention of Priming Foaming

- Heating mechanical steam purifier.
- Avoiding rapid change in steam rate
- Maintaining low water level in boiler.
- Efficient softing and Filtration of boiler Field water.

- Adding Anti Foaming chemicals like castor oil.
- Removing oil from boiling water by adding components like Sodium alluminate.

→ Problems For Priming and Foaming
- Choking of outlets
- Reducing velocity of steam due to the presence of foam.

→ Effects of Priming and Foaming
- It occurs together because the actual height of the water column cannot be accurately judged their by making maintanence difficult.
- Dissolved salts are carried by wet steam to different machinery parts were they evaporate.
- life of Machine decreases.

→ Corrosion

Boiler corrosion is the decay or destruction of boiler material by chemical or electrochemical environment.

Causes

Dissolved oxygen interacts with boiler act steaming temperature to form Ferrous hydroxide.

Ferrous hydroxide continues to react with the dissolved oxygen to form Ferric oxide.

dissolved O_2

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

Ferrous hydroxide

$4Fe(OH)_2 + O_2 \rightarrow 2(Fe_2O_3\ 2H_2O)\downarrow$
Rust Ferric hydroxide

→ Removal of dissolved Oxygen by

a) Chemicals

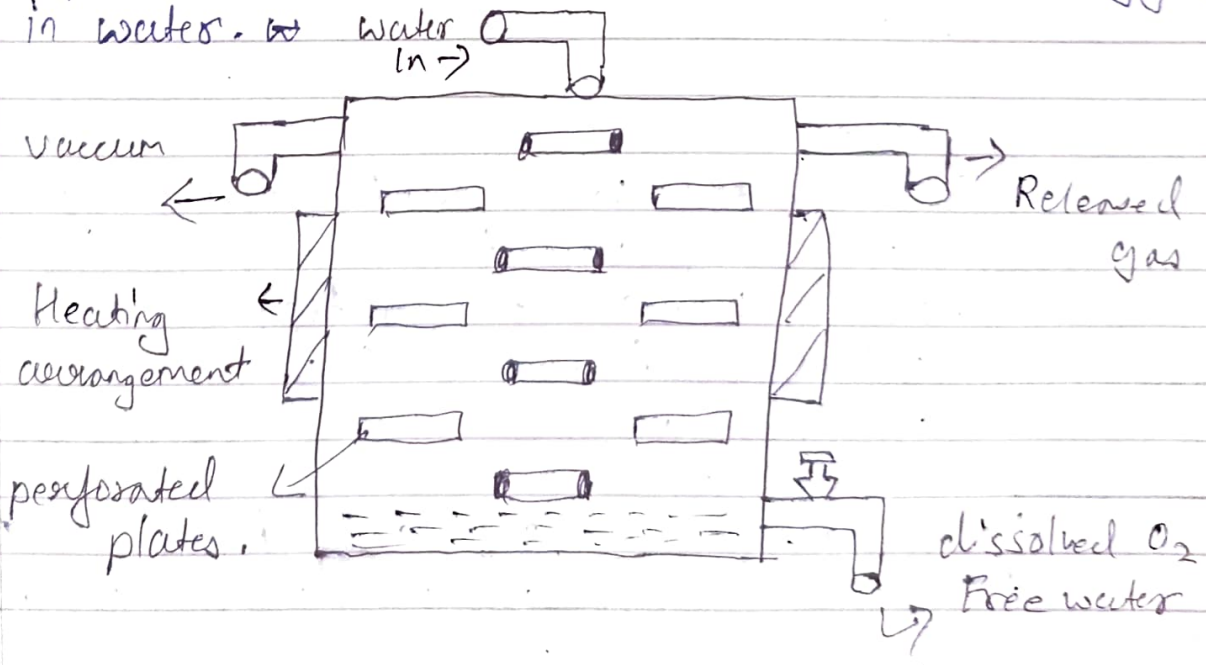
Chemicals like hydrazine sodium sulphate tanning can be used to remove the dissolved oxygen from boiler feed water.

When hydrazine reacts with oxygen it forms nitrogen gas and water. The dissolved nitrogen is harmless as it doesn't contribute to the change in Percentage of dissolved solids.

$$\begin{matrix} H \\ H \end{matrix}\!\!>\!N\text{-}N\!<\!\!\begin{matrix} H \\ H \end{matrix} + O_2 \longrightarrow \underset{\text{hydrazine}}{N_2} + H_2O$$

b) Heating

Water is passed through the tower which contains perforated plates, Heating arrangement from the sides and vaccum pump arrangement High temperature low pressure and large exposure surface reduced the dissolved oxygen in water.



ii) Dissolved Co_2

Water associated with dissolved Co_2 Forms Carbonic acid which has low Corrosive effect on the boiler material Water Containing by carbonates is also the source of Co_2

(1) $Co_2 + H_2O \longrightarrow H_2CO_3$
Carbonic acid

(2) $Mg(HCO_3)_2 \longrightarrow MgCO_3 + H_2O + CO_3 \uparrow$
Magnesium bicarbonate

Removal OF Carbondioxide by ammonia

When a small quantity OF ammonia is added to the water it Forms aluminium hydroxide. Further it reacts with the dissolved Co_2 to Form ammonium carbonate and water and Hence Co_2 is removed.

$H_2O + NH_3 \longrightarrow NH_4OH$

$NH_4OH + Co_2 \longrightarrow (NH_4)_2CO_3 + H_2O$
Ammonia

By Heating

H_2O associated with different types OF gases is required to be removed by heating the water at high temperature and low pressure to reduce Co_2.

→ Dissolved salt

Magnesium chloride dissolved in water Forms Magnesium hydroxide and hydrochloric acid at h

temp. This HCl reacts with Iron to Form Ferrous chloride and hydrogen gas this initiates a chain reaction in which HCl is produced in every step which results in boiler & Material Decay.

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

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$
$$FeCl_2 + 2H_2O \rightarrow Fe(OH)_2 + 2HCl$$

During water Supporing process a small quantity of Sodium carbonate is added on high temperature and pressure it decomposes to Sodium hydroxide and carbon dioxide.

$$Na_2CO_3 + H_2O \longrightarrow NaOH + CO_2 \uparrow$$

Due to the Formation of Sodium hydroxide water becomes alkaline. The number of minute cracks observed on the inner walls of the boiler. This alkaline water flows into such minute cracks by capillary actions. Here due to water evaporation the dissolved sodium hydroxide is left behind. The amount of Sodium hydroxide goes on increasing due to progressive evaporation. The alkaline action of Sodium hydroxide attack the surrounding areas of cracks their by dissolving the Iron material of the boiler.

→ Precaution to avoid corrosion due to salt
- Supply water free from magnesium chloride
- use sodium phosphate instead of Sodium Carbonate.
- Internal Conditioning by tanning
- Adjusting water alkanative

b) Quantitative determination of Water hardness and Total dissolved solid.
For determination of residue on evaporation or total dissolved solid measure out volume of the Filtered sample required for the main analysis and evaporates to dryness Dried the Filtered contained for 1/2 hr at 1800°C and weight. The weight obtained is often refer to as TDS.

c) Quantitative determination of Water hardness by alkalinity ST Mesher.
Alkanity is defined as the measure of the acid neutralizing capacity of waters. The alkanity of water is attributed to the presence of
① Costic alkanity (OH^-), (CO_3^{2-})
② Temporary hardness (HCO_3^-)
③ These can be estimated separately by titration against Standard Sulphuric acid using phenolphthalein thaleen and methyl orange as indicators.
The determination is based on the following reaction.

i) $[OH^-] + [H^+] \rightarrow H_2O$
ii) $[CO_3^{2-}] + [H^+] \rightarrow [HCO_3^-]$ (M.O)
iii) $[HCO_3^-] + [H^+] \rightarrow H_2O + CO_2$

The titration OF water Sample against a standard acid upto Phenolphalene end point mass completion OF reaction one and two. This amount OF acid used thus corresponds to hydroxide and 1 half OF normal carbonate Present on the other hand titration OF Water sample against standard acid to methyl-Orange end point, Mass completion OF reaction (1), (2), (3) Hence amount OF acid used after Phenophthalyne corresponds to 1 half OF carbonate and bicarbonate while total acid used represents the total alkalinity.

OH- The possible combination OF ions causing alkanity in water are.

i) OH^- only
ii) CO_3^{2-} only
iii) HCO_3^{2-} together
iv) CO_3^{2-} together
v) OH^-

The possibility OF OH^- and HCO_3^- is ruled out because they Form CO_3^{2-}

OH^-, HCO_3^- and CO_3^{2-} cannot exist together

$OH^- + HCO_3^- \longrightarrow CO_3^{2-} + H_2O$

$$\text{Molarity} = \frac{W}{m} \times \frac{1000}{V}$$

1) The molecular mass of oxalic acid is 126 gF 0.63g of oxalic acid is dissolved 200 ml of distilled water then what is the molarity of the solution.

$$= \frac{0.63}{126} \times \frac{1000}{200}$$

$$= 0.025\ m$$

2) Prepare 0.1 M OF Oxalic acid.

$$0.1 = \frac{W}{0.1} \times \frac{1000}{250} \qquad \frac{W}{0.2} \times \frac{1000}{250}$$

$$W = \frac{1}{10} \times 4 \qquad = \frac{2}{10}$$

$$W = 40 \qquad = 20$$

$$W = \frac{2}{10} \times \frac{126}{4} = \frac{63}{10}$$

$$= 6.3$$

3) Prepare 500 ml 0.1 M oxalic acid solution.

$$M = \frac{W}{m} \times \frac{1000}{V}$$

$$0.1 = \frac{W}{126} \times \frac{1000}{500}$$

$$W = \frac{0.1}{126} \times 2 \qquad \frac{1}{10} \times \frac{1260}{2} = 630$$

Molality

$$\text{Molality} = \frac{w}{M} \times \frac{1000}{W}$$

1) The Molality of a solution containing 200g of water is 0.1M Calculate the weight of Oxalic acid.

$$\frac{w}{M} \times \frac{1000}{W}$$

$$M = \frac{0.1}{10} \times \frac{1000}{200} \cdot 5$$

$$= \frac{5}{10} = 0.5$$

$$\frac{0.1}{10} = \frac{w}{126} \times \frac{1000}{200}$$

$$w = \frac{1 \times 126}{10 \times 5}$$

$$= \frac{126 \times 2.053}{50 \times 2} \quad \frac{053}{100}$$

$$= 2.52$$

$(C_2H_2O_4)$ oxalic acid

Normality

$$\frac{w}{E} \times \frac{1000}{V}$$

Equivalent Mass For acid = Molecular mass / basicity

Basicity = H^+ ions $C_2H_2O_4$

Equivalent Mass of base = Molecular Mass / acidity

acidity = OH^-

$NaOH = \frac{23+16+1}{1} = 40$

$Ca(OH)_2 = \frac{39+16+1}{2} = 28$

Eq Mass of Salt = Molecular Mass / Charge on Metal atom

NaCl

$Na^+ Cl^-$ NaCl = $\frac{23+35}{1} = 58$

Prepare 0.5N OF 250 ML OF NaOH solution.

$$N = \frac{W}{E} \times \frac{1000}{V}$$

$$0.5 = \frac{W}{40} \times \frac{1000}{250}$$

$$W = \frac{0.5}{40} \times 4 = \frac{5}{10} \times \cancel{4} \times \frac{4}{\cancel{10}}$$

$$= \frac{5}{10 \times 40} \times 4 = 5$$

$$= \frac{5}{400} \times 4$$

$$= \frac{20}{80} =$$

→ Removal OF hardness

Water Softning is the process OF removal OF dissolved Ca, Mg salt that causes hardness in water.

→ Removal OF temporary hardness

When temporary hardwater is boiled the soluble bicarbonate present in water decompases to give insoluble carbonates. which settle down easily then the soft water is Filtered.

$$Ca(HCO_3)_2 \xrightarrow{\text{boil}} CaCO_3 + H_2O + CO_2$$

→ Removal OF Permanent hardness

lime soda process - In this process water is treated with a calculated quantity OF lime and soda converts the soluble hardness in to insoluble substances called slouges. which is removed by Filteration to get soFt water.

$CaCl_3 + Na_2CO_3 \longrightarrow CaCO_3 + NaCl.$

Lime soda process is of two types

1. Cold soda process
2. hot lime soda process

a) Cold lime Soda

When hard water is treated with calculated amount of lime $Ca(OH_2)$ and soda Na_2CO_3 at room temperature that is 25°C the insoluble calcium and Magnessium salt present in hard water are chemically converted into precipitate OF Calcium carbonate and Magnesium hydroxide. These precipitate are removed by Filteration thus soFt water is obtained

→ Disadvantages OF Cold lime Soda process

i) It is a slow process because reaction during water SuFFning takes place in very dilute solution at room temperature

ii) It requires coagulants For Setting particles OF precipitate Formed during reaction OF water SuFFning.

iii) SuFFning Capacity in this process is less.

iv) SOFt water obtained by this process consists

of dissolved gases.

b) Hot lime soda process

This process involves treatment of hardness with lime and soda at 80° to 100°C

Advantage

i) It is most economical
ii) The reaction is completed within a short period
iii) The reaction proceeds faster Hence, Softening Capacity is increased
iv) No coagulant is required as the sludge settles down easily.
v) Dissolved gases like carbon dioxide, air etc are removed.

Disadvantages

i) For efficient and economic softening careful operation and skilled supervision is required.
ii) Disposal of large amount of sludge creates problem.
iii) This can remove hardness only upto 15 ppm which is not suitable for high pressure boilers.

2 → Zeolite Process / Permutet process

This process involves softening of water by natural or artificial Zeolite. Zeoline is hydrated sodium aluminosilicate. Zeolines are insoluble in water and can act as a base exchanger when placed in contact with water containing carbon

Zeolites are commercially known as Permutet and these are of two types
- Natural
- Synthetic

→ Natural Zealite - These are non porous, durable and can be derived from green sand.
Ex- Natrolite [$Na_2O.Al_2O_3.3SiO_2.2H_2O$]

→ Synthetic Zeolite - These are porous, possess a gel like structure and have a higher exchange capacity per unit weight. This can be prepared from the solution of sodium silicate and aluminium hydroxide.
Ex- china clay

Advantages of Zeolite
1. Equipment used in this process occupies small space and also easy to operate.
2. Zero hardness water can be produced through this method.
3. No sluge Formation occurs during this Process.
4. This method is Cheap as permutet can be regenerated.
5. Automatically adjust water to different hardness.
6. The plant can be insert in water supply line itself avoiding double pumping.

Limitations
1. The Feed water must be free from suspended particles otherwise Permutet will get clogged
2. Excess of alkali or acid present in water must

be neutralised to prevent the burning of Zeolite. Thus Ph of the solution should be maintained to around 7.

3. Regeneration of Permutite is very hard where it is associated with Fe^{2+} and Mn^{2+} salt
4. Water treated by zeolite process contains about 25% more dissolved solids than that treated by soda lime.
5. The treated water contains more sodium salt.
6. All acidic ions such as bio carbonates and carbonates are left in suffering water.
7. High turbidity water cannot be treated by this method.

3) Ion exchange process

In this method ion responsible for hardness are exchanged with other ions which don't make water hard

→ Organic ion exchanger (ion exchange resigns)

These are organic polymers having

(1) High molecular weight
(2) open and permeable molecular structure.
(3) Acidic or basic groups attached with them.

Ion exchange resins are of two types

(1) Cation exchange resins
(2) Anion exchange resins

a) Cation exchange resins ($R \cdot H^+$)

If the active ion in ion exchanger is a cation generally acidic functional group, the resin

is called cation exchange resin. $-COOH$

$-\overset{O}{\overset{\|}{C}}-O^- + H^+$

b) Anion exchange resin ($R-OH^-$)

If active ion in ion exchanger is an anion, basic functional group the resin is called Anion exchange resin.

$CaCl_2$

$2R-H + Ca \rightarrow R_2Ca + OH^+$

$R-OH + Cl^- \rightarrow RCl + OH^-$

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

Process :-

The hard water is passed through a column of cation exchange resin called Zero cat. All the cations present in hard water get exchanged with H^+ ion of the resin. Then the hard water is passed through the column of anion exchange resin. All with OH^- ion of the resin.

$MgCl_2$

$2R-H + Mg^{+2} \longrightarrow R_2Mg + 2H^+$

$2R-OH + 2Cl^- \rightarrow 2RCl + 2OH^-$

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

The H^+ and OH^- ion combine to form water molecule.

Regeneration of Resin

When all the H^+ and OH^- ions of the resins are exchanged by the cations and anions present in hard water then the resins are said to be exausted and regeneration can be done. The cation exchange resin can be regenerated by treatment with dilute acides like HCl or H_2SO_4

$$R_2Ca + 2HCl \longrightarrow R-H + CaCl_2$$

Similarly, anion exchange resin can be regenerated by treatment with dilute alkali like sodium hydroxide

$$RCl + NaOH \longrightarrow R-OH + NaCl$$

The regenerated resins may be used again.

Advantages :-

→ This process can be used to soften highly acidic or alkaline water.

→ It produces water of very low hardness upto 2 PPM. So, it is good for treating high pressure boilers.

Disadvantages :-

→ The equipments are costly and expensive chemicals are needed.

→ If water contains turbidity then output of the process is reduced.

Municipal Water treatment

Municipal water supply is the most challenging and much needed to be addressed to remove undesirable components that are harmful for human health. Depending upon the type of impurity different methods are employed for purification of water.

→ Sedimentation - is a process of removing suspended impurities suspended particles settle down due to force of gravity. This process takes two to Eight hours and removes 75% of suspended impurities. It is done in large settlement ~~tank~~ tanks or reservoir.

→ Coagulation - is the process by which the fine, suspended and colloidal impurities are removed from the water by the addition of suitable chemicals called Coagulants. Finly divided suspended Inorganic materials do not settle down easily so, these small particles are converted into larger ones which have higher settling velocity.

$Al_2(SO_4)_3$, $FeSO_4.7H_2O$, $NaAlO_2$

$[K_2SO_4.Al_2(SO_4)_3.24H_2O]$ - potash alum

The commonly used coagulants

These Coagulants react with water to form Zelatinous precipitate in the form of hydroxide known as Flacks that absorbs the finly

suspended colloidal particles which settle down rapidly. It is the most effective and economical means to remove impurities.

$$Al_2(SO_4)_3 + H_2O \rightarrow Al(OH)_3 \downarrow + H_2SO_4$$

→ Filtration

In this method suspended impurities, all types of Insoluble Colloidal bacterial impurities are removed by passing water through a bed of proper sized material through Filtration.

→ Sterilization / Disinfection

It is the means of Complete destruction of all living microorganisms such as bacteria, virus etc present in water. Water after passing through different process such as sedimentation, coagulation and Filtration still contained a small percentage of pathogenic bacteria therefore it is necessary to remove these bacteria and microorganisms from water. The chemicals used for sterilization are known as sterilizers or disinfectorse.

$[Na^+]$: $1s^2\ 2s^2\ 2p^6\ 3s^0$
11

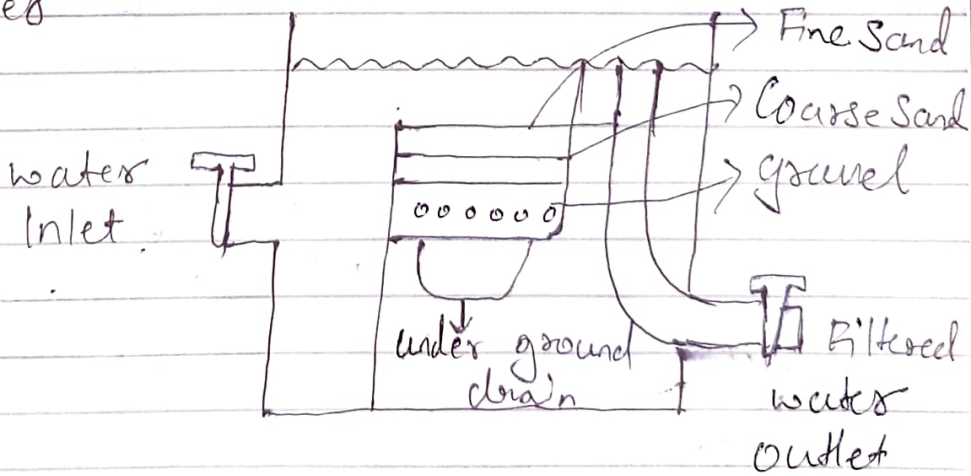
$[Fe^{2+}] = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^4$

ES stable = $4s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$

Types of Filtration

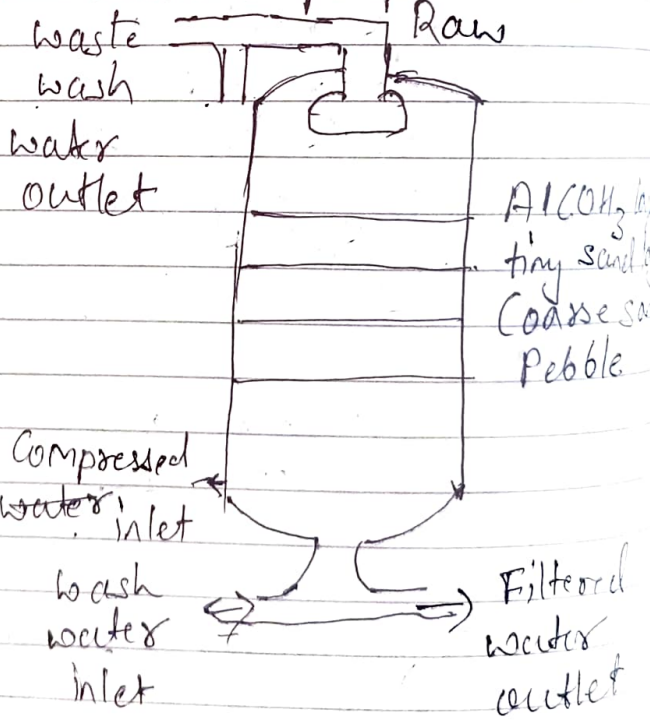
Gravity sand Filter

It consists of a large rectangular tank made of concreet and a process medium known as filter medium which retains solid particles but allows the passage of water. It consists of three layers the upper layer is made up of fine sand. (50cm) the middle layer consists of course sand (20 cm) and the buttom layer contains gravels (30 cm). It is provided with an inlet for sedimentad water and an under drain channel at the buttom for the exit of filtered water. Sedimented water enters the sand filter from the top and is uniformly distributed over the fine sand layer



→ Pressure Filter

It consists of a cylindrical tank with three layers of filtering material. The bottom layer consists of pebbles (10 to 35 mm) the middle layer consists of coarse sand (5 to and the top layer consists of Fine sand (1 The impure sedimented water is ~~mixed~~ with passed through filtered bed under pressure while a small amount of alum solution added to it. Alum forms the slimy layer on the filtered bed this helps in the removal of colloidal and bacterial impuri The function OF deflector plate which is provide at the top is to distribute the slimy laye uniformly over the top of the filter bed. Filtered water comes out From the bottom OF the Filtered is under pressure and can be pumped directly. These filters are widely used for Industrial purpose.



Several methods have been adopted for sterilization of water Some of them are.

a) Boiling
Water For domestic purpose may be sterilized by simple boilling For 20 to 30 min. This method kills haarmful disease causing bacteria and germs.

b) Chlorination
It can be done by using
i) Chlorine gas or Concentrated aqueous solution
ii) Bleaching powder
iii) Chloramine

→ Chlorine gas
It is used directly as a gas or as chlorine water it reacts with water to Form hypochlorous acid and nacent oxygen both of which are powerful germicides

$$Cl_2 + H_2O \longrightarrow HOCl + HCl$$
$$HOCl \longrightarrow [O] + HCl$$