Unit-4
Water Analysis
Hard & Soft Water

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Hard and Soft Water

Water, that does not give lather with soap,
Hard Water.

Water, that gives lather with soap easily, is called as
Soft Water.

Cause of Hardness of Water

Soap is a sodium or potassium salt of higher fatty acids , such as sodium stearate.
Water contains certain soluble salts of Calcium, Magnesium and other Heavy metal ions. These ions react with soap to form an insoluble compound called as Scum which hinders the formation of lather.

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

Sodium stearate — Calcium stearate — sodium ion

Soap — **Insoluble Scum**

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

Sodium stearate — Magnesium stearate — sodium ion

Thus, the cause of hardness of water is presence of Ca^{++}, Mg^{++} and other heavy metal ions like Fe^{++}, Zn^{++}, Ni^{++} etc.

Types of Hardness of Water

There are two types of harness

1. **Temporary Hardness or Carbonate Hardness**

   The hardness of water which can be removed by boiling of water.

   It is due to presence of soluble
   Calcium bicarbonate $Ca(HCO_3)_2$ and Magnesium bicarbonate $Mg(HCO_3)_2$

2. **Permanent Hardness or Non-Carbonate Hardness**

   The hardness of water that can not be removed by simple boiling but some chemical treatment is required for its removal then it is called as Permanent Hardness.

   It is due the the presence of sulphates, chlorides and nitrates of Ca^{++} and Mg^{++}.
   For example
   $CaSO_4$, $CaCl_2$, $Ca(NO_3)_2$, $MgSO_4$, $MgCl_2$, $Mg(NO_3)_2$,

$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-COO^- Na^+$

Q. How can temporary hardness be removed by boiling of water?

A. Cause of temporary hardness is

soluble Calcium bicarbonate $Ca(HCO_3)_2$ and Magnesium bicarbonate $Mg(HCO_3)_2$

When these compounds are heated, they get converted to insoluble compounds which can be removed by filtration.

Calcium removal

$$2Ca(HCO_3)_2 \xrightarrow{\text{Heat}} CaCO_3 \downarrow + CO_2 + H_2O$$

Soluble   Heat   Insoluble

Magnesium removal

(i) $$Mg(HCO_3)_2 \xrightarrow{\text{Heat}} MgCO_3 + CO_2 + H_2O$$

Soluble   Heat

(ii) $$MgCO_3 + H_2O \rightarrow Mg(OH)_2 \downarrow + CO_2$$

$$Mg(HCO_3)_2 \xrightarrow{\text{Heat}} Mg(OH)_2 + \downarrow + 2CO_2$$

Soluble   Heat   Insoluble

Units of Hardness

Hardness of water is expressed in following terms

1. **Parts per million (ppm) of $CaCO_3$**
2. **Degree French °Fr**
3. **Degree Clarke°Cl**

ppm of $CaCO_3$

1 ppm = 1part $CaCO_3$ equivalent hardness present in 10^6 parts (1 million parts) of water.

= 1 part $CaCO_3$ equivalent/ 10^6 parts water

Degree French °Fr

1 °Fr = 1part $CaCO_3$ equivalent hardness present in 10^5 parts (1 Lakh parts) of water.

= 1 part $CaCO_3$ equivalent/ 10^5 parts water

Degree Clark °Cl

1 °Cl = 1part $CaCO_3$ equivalent hardness present in 1 Gallon (70000 parts) of water.

= 1 part $CaCO_3$ equivalent/ 70000 parts water

Thus, 1ppm = 0.1 °Fr = 0.07 °Cl

Q. Hardness of Water is expressed in terms of CaCO3 equivalent. Why?

A. Because of

1. $CaCO_3$ is the most insoluble salt that can be precipitated in water.
2. The molecular weight of CaCO3 is 100 and Equivalent weight is 50 that makes the calculation simple.

Q.1 A water sample contains hardness of

$CaSO_4$ = 20 ppm of $CaCO_3$
$Ca(HCO_3)_2$ = 30 ,,
$MgCl_2$ = 40 ,,
$Mg(HCO_3)_2$ = 20 ,,
$Ca(NO_3)_2$ = 10 ,,

Calculate Temporary and permanent and Total hardness and express in ppm, °Fr and °Cl.

Temporary Hardness		Ppm of CaCO3	**°Fr** × 0.1	**°Cl** × 0.07
1	$Ca(HCO_3)_2$	30	3.0	2.1
2	$Mg(HCO_3)_2$	20	2.0	1.4
Total Temporary Hardness		**50**	**5.0**	**3.5**
Permanent Hardness				
1	$CaSO_4$	20	2.0	1.4
2	$MgCl_2$	40	4.0	2.8
3	$Ca(NO_3)_2$	10	1.0	0.7
Total Permanent Hardness		**70**	**7.0**	**4.9**
Total Hardness = Temporary hardness + Permanent Hardness		**50 + 70=120**	**5.0 +7.0 = 12.0**	**3.5 + 4.9 = 8.4**

Equivalents of Calcium Carbonate $CaCO_3$

As we know that the hardness of water is expressed in terms of $CaCO_3$ equivalent, so how to convert the concentration in terms of $CaCO_3$

The equivalent of $CaCO_3$ =

(Mass of Hardness producing substance)×(Chemical equivalent of $CaCO_3$)/ Chemical equivalent of hardness producing substance

Equivalent Weight of $CaCO_3$		=100/2=50	or
,,	Ca(HCO3)$_2$	=162/2=81	
,,	$Mg(HCO_3)_2$	= 146/2=73	
,,	$CaSO_4$	= 136/2=68	

And so on.....

Thus, If a water sample contains $CaSO_4$ 340 ppm or (mg/L)

The $CaCO_3$ equivalent =Mass of $CaSO_4$ × Eq. Wt. of $CaCO_3$/Eq. Wt. of $CaSO_4$

= 340×50/68

If we multiply by 2, Then, =340× 100/136

The figure enclosed in circle is called as **Multiplication Factor** for conversion into $CaCO_3$ Equivalent

Dissolved Salt/Ion	**Molecular Wt.**	**Equivalent. Wt.**	**Multiplication Factor**
$CaCO_3$	**100**	**50**	**100/100**
$Ca(HCO_3)_2$	162	81	100/162
$Mg(HCO_3)_2$	146	73	100/146
$CaSO_4$	136	68	100/136
$CaCl_2$	111	55.5	100/111
$MgSO_4$	120	60	100/120
$MgCl_2$	95	47.5	100/95
$MgCO_3$	84	42	100/84
CO_2	44	22	100/44
$Ca(NO_3)_2$	164	82	100/164
$Mg(NO_3)_2$	148	74	100/148
HCO_3^{-}	61	61	100/122
OH^{-}	17	17	100/34
CO_3^{--}	60	30	100/60
$NaAlO_2$	82	82	100/164
$Al_2(SO_4)_3$	342	57	100/114
$FeSO_4.7H_2O$	278	139	100/278
H^{+}	1	1	100/2
HCl	36.5	36.5	100/73

Q. Show that, 1ppm = 1mg/L

A. Let's take

1mg/L	**=**	**1mg/kg**	**(1 L weighs 1 kg at 4°C)**
	=	**1 mg/1000 g**	**(1 kg = 1000g)**
	=	**1 mg/1000×1000 mg**	**(1 g = 1000 mg)**
	=	**1 mg/ 10^6 mg**	
	=	**1 part substance/ 10^6 parts water**	
	=	**1 ppm**	

Q. Calculate the temporary and permanent hardness of water sample containing $Mg(HCO_3)_2$= 7.3mg/L, $Ca(HCO_3)_2$= 16.2mg/L, $MgCl_2$= 9.5mg/L, $CaSO_4$=13.6mg/L).

Solution: conversion into $CaCO_3$ equivalents:

A.

Constituent	Multiplication factor	$CaCO_3$ equivalent	
$Mg(HCO_3)_2$= 7.3mg/L	100/146	7.3X100/146	= 5ppm
$Ca(HCO_3)_2$= 16.2mg/L	100/162	16.2X100/162	=10ppm
$MgCl_2$= 9.5mg/L	100/95	9.5X100/95	= 10ppm
$CaSO_4$=13.6mg/L	100/136	13.6X100/136	= 10ppm

Therefore,

Temporary hardness of water due to

$Mg(HCO_3)_2$ and $Ca(HCO_3)_2$ = 5+10 = 15ppm of $CaCO_3$.

Permanent hardness due to

$MgCl_2$ and $CaSO_4$ = 10+10 = 20ppm of $CaCO_3$.

Lime-Soda Process

Lime-Soda process:

In this process, lime [($Ca(OH)_2$)] and soda [Na_2CO_3] are the reagents used to precipitate the dissolved salts of Ca^{+2} and Mg^{+2} as $CaCO_3$ and $Mg(OH)_2$ which are later on filtered off.

Types of L-S Process

1. Cold Lime Soda Process
2. Hot Lime Soda Process

The process may be carried out in

a. Batch Method
b. Continuous Method

Role of Lime $Ca(OH)_2$

1. Lime removes all temporary hardness

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

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

2. Removes Mg -permanent hardness

   $MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaCl_2$

   $MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaSO_4$

3. Removes CO_2

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

4. Removes mineral acids (H^+)

   $Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

5. Bicarbonates (NaHCO3)

   $2HCO_3^- + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O + CO_3^{--}$

Role of Soda Na_2CO_3

1. Soda removes all permanent hardness

   $Na_2CO_3 + CaSO_4 \rightarrow Na_2SO_4 + CaCO_3\downarrow$

   $Na_2CO_3 + CaCl_2 \rightarrow 2NaCl + CaCO_3$

Cold Lime -Soda Process:

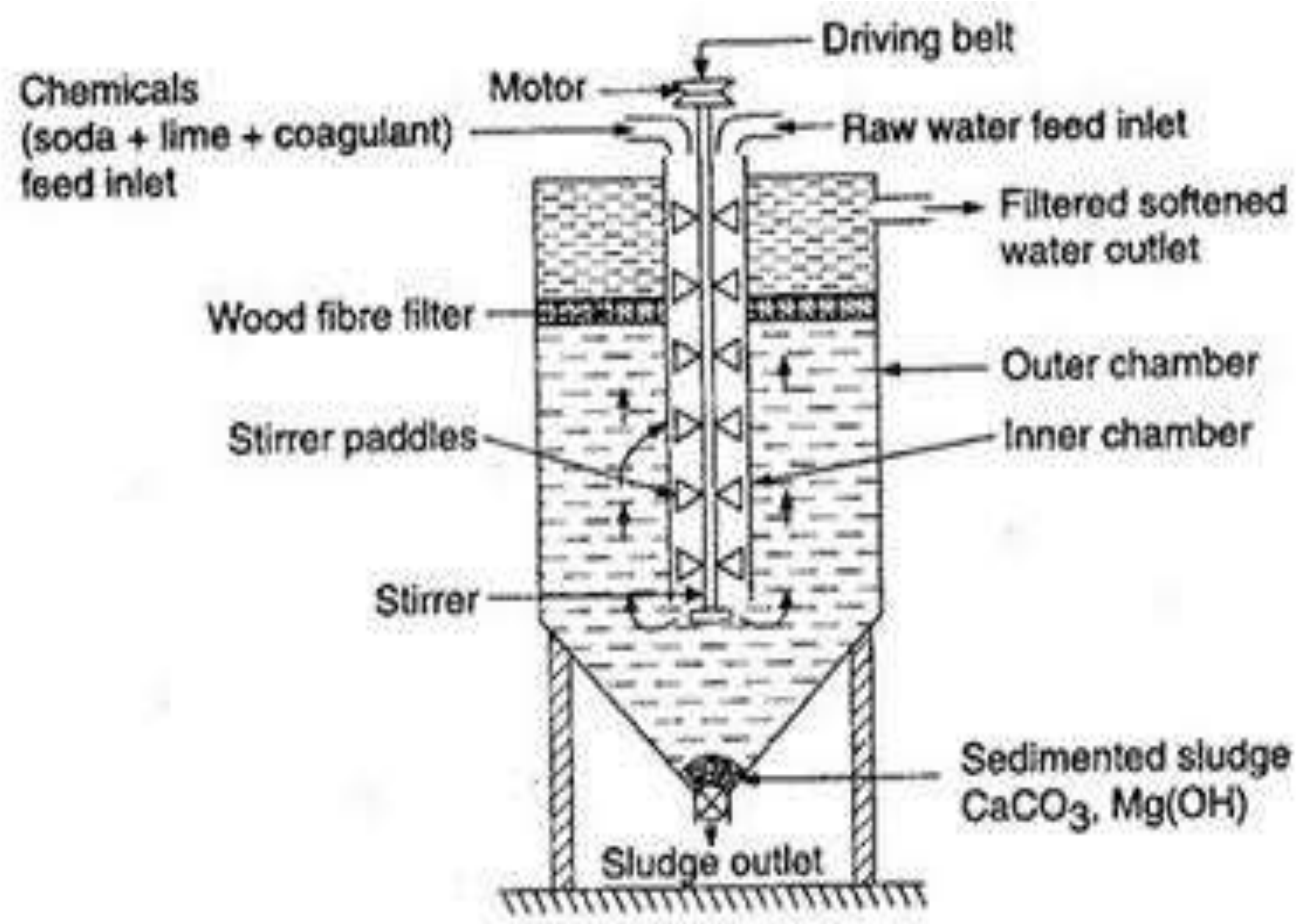
Calculated amounts of lime and Soda are mixed with water at room temperature.

For rapid precipitation of fine particles, it is essential to add small amounts of coagulants.
(like Alum, Aluminium Sulphate, Sodium Aluminate etc.)
which hydrolyses to flocculent, gelatinous precipitate of $Al(OH)_3$.

Use of sodium aluminate as **Coagulant also helps in the removal of silica as well as oil present in the water.**
Cold lime soda process provides water containing residual hardness of 50-60 ppm.

$$\mathbf{NaAlO_2 + 2H_2O \rightarrow NaOH + Al(OH)_3 \downarrow}$$
$$\mathbf{Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 \downarrow + 3CaSO_4 + 6CO_2 \uparrow}$$

Cold Lime Soda Process



Hot Lime Soda Process:

It involves treating water with softening chemicals (Lime+Soda) at a temperature of 80°C-100°C. Since hot process is operated at a temperature close to the boiling point of the solution, so

a) The reaction proceeds faster,

b) Softening capacity of hot process is increased,

c) The precipitate and sludge formed settle down rapidly and hence no coagulants are needed,

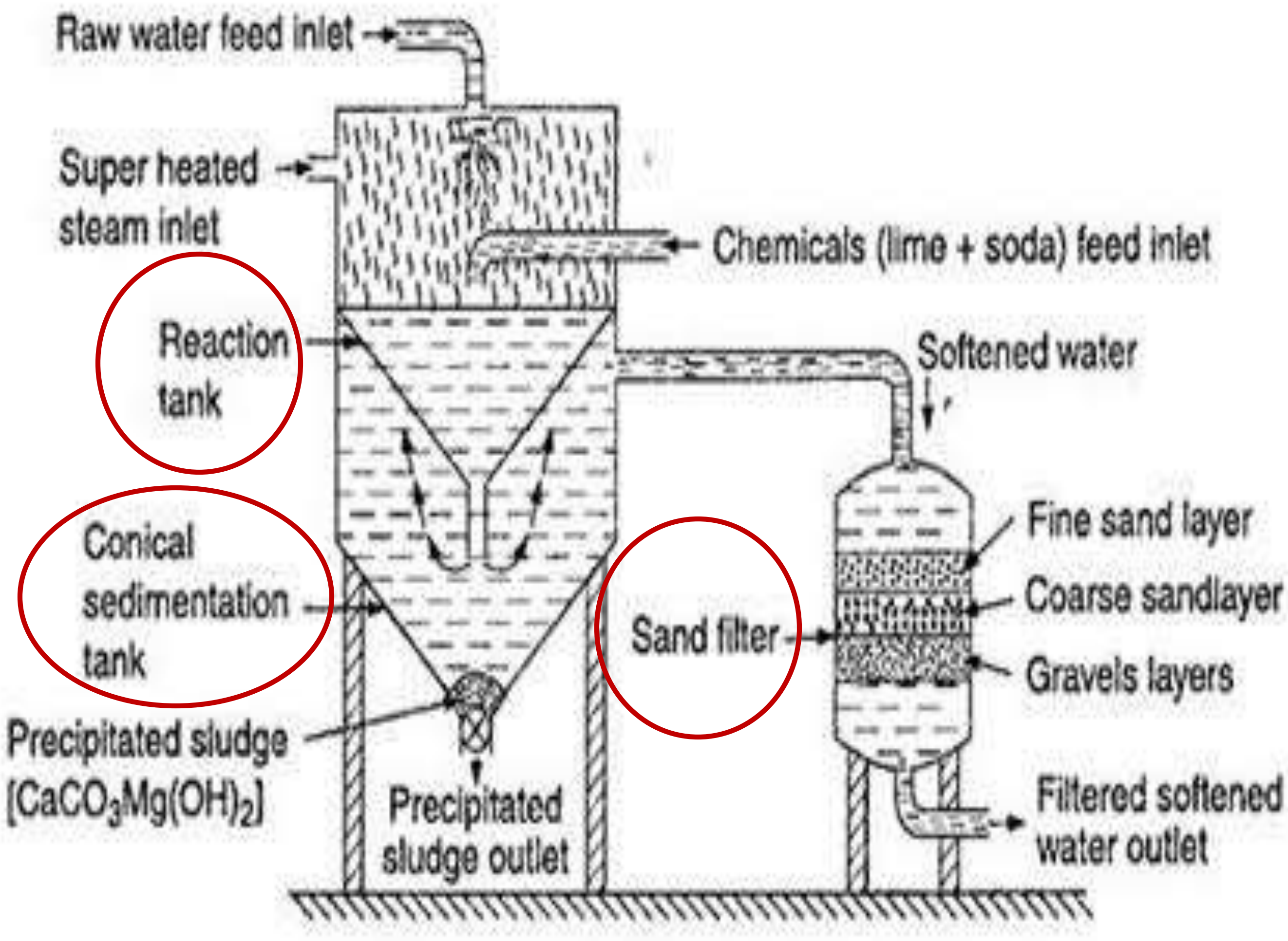
d) Much of the dissolved gases (CO_2) are driven out,

e) Viscosity of softened water is lower so filtration of water becomes much easier.

Process:

It contains essentially three parts

1) A reaction tank in which water, chemical and steam are thoroughly mixed.
2) A conical sedimentation vessel in which sludge settle down.
3) A sand filter which ensures complete removal of sludge from the softened water.



Advantages of Lime-Soda process:

1) It is very economical.
2) The process increases the pH value of treated water thereby corrosion of distribution pipes is reduced.
3) Besides removal of hardness causing salts, minerals, iron and manganese present in water is removed.
4) Due to alkaline nature, amount of pathogenic bacteria in water is considerably reduced.

Disadvantages of Lime-Soda Process:

1) Skilled supervision is required for efficient and economical softening.
2) Disposal of large amounts of sludge poses a problem.
3) This can remove hardness only up to 15ppm, which is not good for boilers.

Differences between cold and hot lime soda process:-

S.No	Cold Lime Soda Process	Hot Lime Soda Process
1.	It is done at room temperature.	It is done at elevated temperatures (84-100 ^{0}C).
2.	It is slow process.	It is rapid process.
3.	Use of coagulants is must.	Coagulants are not needed.
4.	Filtration is not easy.	Filtration is easy as viscosity of water becomes low at elevated temperatures.
5.	Softened water has residual hardness around 60 ppm.	Softened water has residual hardness around 15-30 ppm.
6.	Dissolved gases are not removed.	Dissolved gases such as CO_2 are removed to some extent.
7.	It has low softening capacity.	It has high softening capacity.

Calculation on Requirement of Lime & Soda

Lime & Soda Requirement

$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O$ (L)

$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow Mg(OH)_2 + 2H_2O$ (2L)

$\mathbf{MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCl_2}$ **(L+S)**

$\mathbf{CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl}$

$NaHCO_3 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O + NaOH$ (L–S)

$NaAlO_2 + 2H_2O \rightarrow Al(OH)_3 + NaOH$ $(2NaOH \cong Ca(OH)_2)$ (–L)

$\mathbf{Al_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2\,Al(OH)_3 + 3CaSO_4}$ **(L+S)**

$\mathbf{3(CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4)3}$

$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$

$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$ (L+S)

Formula for Lime & Soda Requirement

∴ Lime requirement for softening =

74/100[Mg^{2+}+Ca-Temp. + 2xMg-Temp.+Perm(Mg^{+2})+CO_2 +H^+ (HCl or H_2SO_4)+HCO_3^- + $Al_2(SO_4)_3$+$FeSO_4$–$NaAlO_2$]×Vol. of Water (L)× (100/ purity %) mg

all in terms of $CaCO_3$ equivalents (Mol. Wt. of Lime = 74).

∴ Soda requirement for softening =

106/100 [Ca^{2+} + Mg^{2+}+Permanent (Ca^{+2}+ Mg^{+2})+ H^+(HCl or H_2SO_4) – HCO_3^- + $Al_2(SO_4)_3$+$FeSO_4$–$NaAlO_2$] × Volume of Water (in L)× (100/ purity %) mg

all in terms of $CaCO_3$ equivalents (Mol. Wt. of Soda = 106).

Q. Calculate quantities of lime and soda required for softening of 20,000 litres of water containing following salts in ppm (16.4 ppm $NaAlO_2$ used as a coagulant).

Ca^{+2} = 160 ppm Mg^{+2} = 72 ppm HCO_3^- = 73.2 ppm

CO_2 = 44 ppm $Al_2(SO_4)_3$ = 34.2 ppm HCl = 36.5 ppm

Conversion into $CaCO_3$ equivalents.

Solution

Iron or salt	Amount present (ppm)	Conversion (MF)	$CaCO_3$ equivalent (ppm)	
Ca^{+2}	160	100/ 40	$160 \times 100/40$	= 400
Mg^{+2}	72	100/ 24	$72 \times 100/24$	= 300
HCO_3^-	73.2	100 /122	$73.2 \times 100/122$	= 60
CO_2	44	100 /44	$44 \times 100/44$	= 100
$NaAlO_2$	16.4	100 /164	$16.4 \times 100/164$	= 10
$Al_2(SO_4)_3$	34.2	100 /114	$34.2 \times 100/114$	= 30
HCl	36.5	100 /73	$36.5 \times 100/73$	= 50

∴ Lime requirement for softening

= 74/100[Mg^{2+}+Ca-Temp. + 2x Mg-Temp. + Perm(Mg^{+2})+ CO_2 +H^+(HCl or H_2SO_4) + HCO_3^-+$FeSO_4$–$NaAlO_2$ + $Al_2(SO_4)_3$]×Volume of Water (in L)× 100/% purity all in terms of $CaCO_3$ equivalents (Mol. Wt. of Lime = 74).

= **74 /100 [300+ 0 +0+0 + 100 + 50 + 60 + 0 – 10 + 30]×20000**

= 74/100 [530] × 20000

= 7844000 mg = 7.844 kg

∴ Soda requirement for softening

= $106/100\ [Ca^{2+} + Mg^{2+} + \text{Permanent}\ (Ca^{+2} + Mg^{+2}) + H^{+}(HCl$ or $H_2SO_4) + FeSO_4 + Al_2(SO_4)_3 - HCO_3^{-} - NaAlO_2] \times$ Volume of Water (in L) $\times$ (100/ purity %) mg

all in terms of $CaCO_3$ equivalents (Mol. Wt. of Soda = 106).

= $106/100[\ 400 + 300 + 0 + 50 + 0 + 30 - 60 - 10] \times 20000$ mg

= $106/100[710] \times 20000$ mg

= 15052000 mg

= 15.052 kg

Therefore, Lime Required = 7.844 Kg

Soda Required = 15.052 Kg

Zeolite or Permutit Method

Zeolite Process of Softening of Water (Permutit Method)

Zeolites are naturally occurring (hydrated) sodium aluminium silicates, having different amounts of water of crystallization. They are represented as $Na_2O.\ Al_2O_3.\ x\ SiO_2.\ y.H_2O$, where x varies from 2 to 10 and y from 2 to 6.

Zeolite is an inorganic compound with a property of exchanging Na^+ with hardness causing ions Ca^{++} and Mg^{++}.

The naturally occurring mineral though more durable, is non-porous and has lower exchange capacity. Synthetic zeolites, on the other hand, are porous and have more exchange capacity per unit weight.

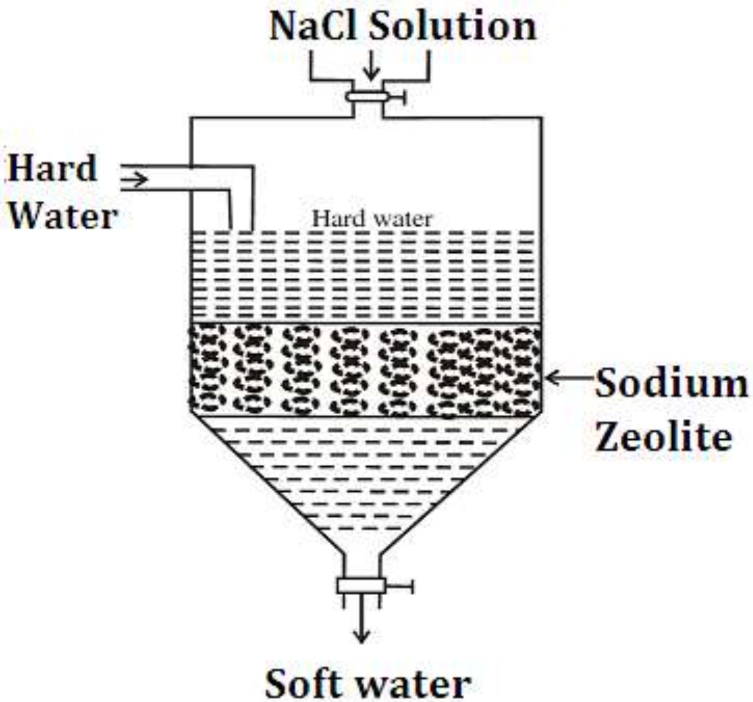
Whether natural or synthetic, zeolites have the property of exchanging their Na^+ ions for hardness causing ions like Ca++and Mg++.

Method

The reactions taking place during the process of softening are presented below:

For convenience sodium zeolite can be written as Na_2Ze, where Ze represents

($Na_2O.\ A1_2O_3.\ x\,SiO_2.\ y\,H_2O$) zeolite.



$$Ca(HCO_3)_2 + Na_2Ze \rightarrow CaZe + 2NaHCO_3$$

$$MgSO_4 + Na_2Ze \rightarrow MgZe + Na_2SO_4$$

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

Regeneration of Exhausted Zeolite

The zeolite mineral gets exhausted when all the Na^{+} ions are replaced by $Ca^{++}$and Mg^{++} ions.

This indicates such an exhausted zeolite no longer has the capacity to exchange any more Ca^{++} and Mg^{++} ions. Under such situation, the hardness of incoming water will not be removed. The discharged Zeolite can be regenerated by passing NaCl solution (Brine).

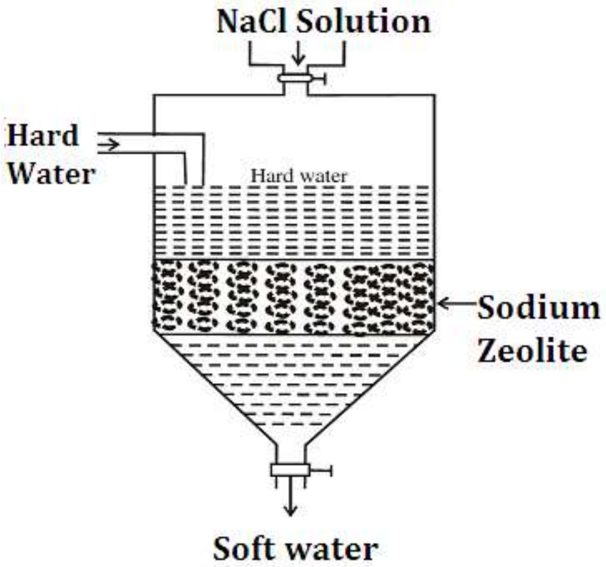
Calcium and magnesium zeolite on treatment with a solution of NaCl can replace Ca^{++} and Mg^{++} ion with Na^{+} ions, thereby regenerating the zeolite.

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

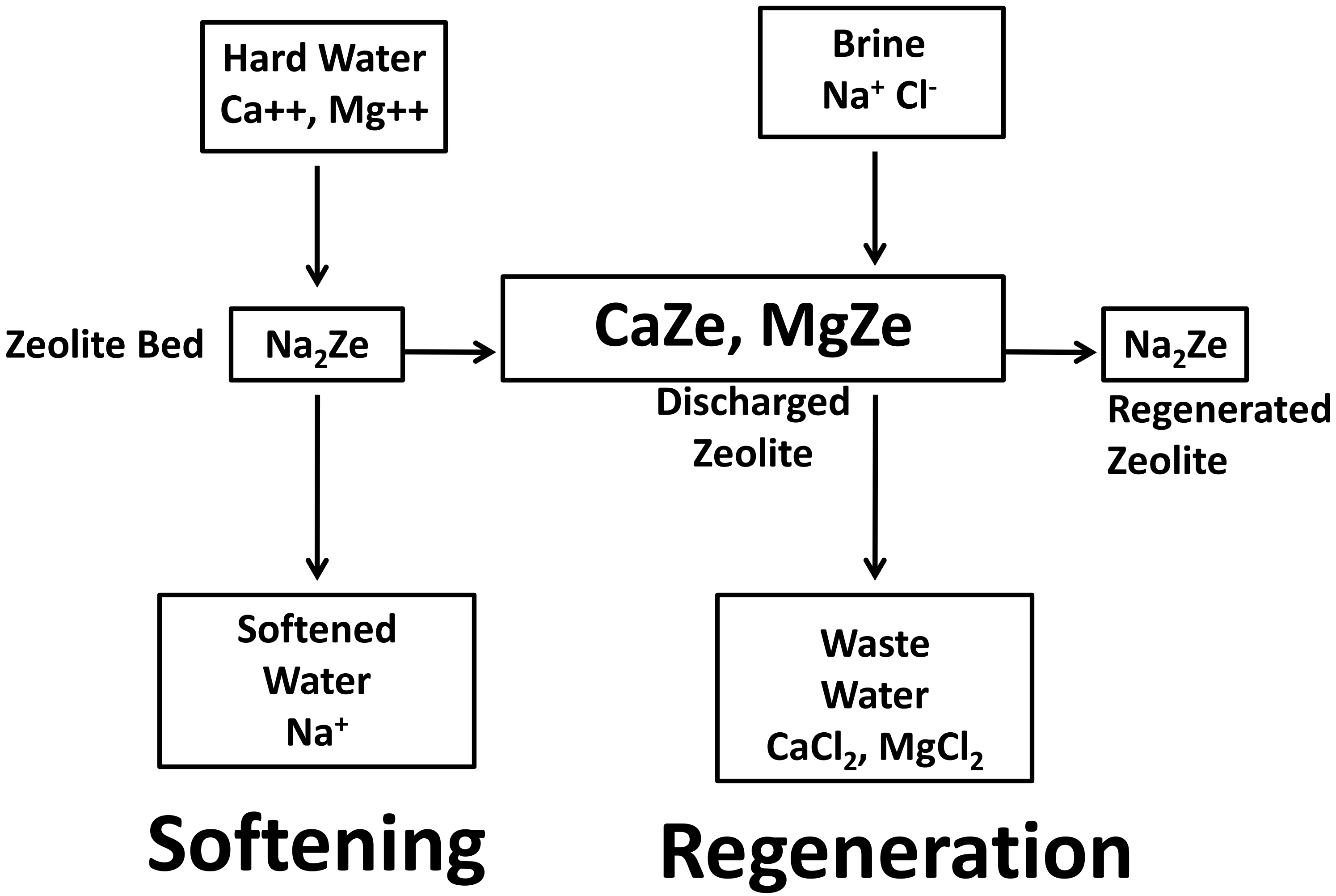
Exhausted Zeolite → **Regenerated Zeolite**

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

Exhusted Zeolite → **Regenerated Zeolite**



Zeolite Process



Advantages of Zeolite Process

1. Hardness is almost completely removed. Soft Water upto 5 ppm hardness can be obtained.
2. Equipment occupies less space.
3. It automatically adjust itself to waters of different hardness.
4. The equipment can be used as many as times needed.
3. The materials used are cheap and easily available.
4. The process can be operated under pressure also.
5. Since the reaction involves only replacement of Ca++ and Mg++ ions with Na+ ions, there is no chance of sludge formation after precipitation at later stage.

Limitations of Zeolite Process

1. Water should be free from supended impurities and turbidity otherwise pores of the zeolite bed will be blocked.
2. Water should be treated at room temperature as zeolite is soluble in hot water.
3. Water should not contain acidic impurities as zeolite being basic can react with the acid.
4. Water should not contain heavy metal ions (Fe^{++}, Mn^{++} etc.) because regeneration of zeolite is not possible after being exhausted.
5. Soft water obtained by this process contain Na^{+} which needs to be removed.

Calculations based on Zeolite method

For convenience sodium zeolite can be written as Na_2**Ze**, where Ze represents ($Na_2O.\ A1_2O_3.\ x\,SiO_2.\ y\,H_2O$) **zeolite**.

$$MgSO_4 + Na_2Ze \rightarrow MgZe + Na_2SO_4$$

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

Regeneration of Exhausted Zeolite

$$\underset{\text{Exhausted Zeolite}}{CaZe} + 2NaCl \rightarrow \underset{\text{Regenerated Zeolite}}{Na_2Ze} + CaCl_2$$

$$\underset{\text{Exhusted Zeolite}}{MgZe} + 2NaCl \rightarrow \underset{\text{Regenerated Zeolite}}{Na_2Ze} + MgCl_2$$

Key Points:

1. NaCl as $CaCO_3$ equivalent = Amount of NaCl × M. F.

$$= W_{NaCl} \times \text{Eq. Wt. of } CaCO_3/\text{Eq. Wt of NaCl}$$

$$= W_{NaCl} \times 50/58.5$$

$$= W_{NaCl} \times 100/117$$

2. For Regeneration
Amount of NaCl used as mg/L of $CaCO_3$ =
Hardness of water (ppm of $CaCO_3$)

3. Calculation of volume of water softened:
Amount of NaCl used as mg of $CaCO_3$ =
Hardness of Water × Volume of water

4. Conc. of NaCl (mg/L as $CaCO_3$)× its Volume =
Hardness × Vol. of hard water

Q.1 1000 litres of hard water is softened by zeolite process. The zeolite was regenerated by passing 20 litres of sodium chloride solution containing 1500 mg/lit. of NaCl. Calculate hardness of water.

Solution: *Key Point:* Amount of NaCl used as mg/L of $CaCO_3$ for regeneration is equivalent to Hardness of water.

1500 mg/L NaCl means,

1 Lit. NaCl solution contains 1500 mg of NaCl

20 litres of NaCl contain $= 1500 \times 20 = 30000$ mg of NaCl

We have to convert it in terms of $CaCO_3$ equivalent.

Thus, 30000 mg of NaCl $= 30000 \times MF = 30000 \times 100/117$ mg of $CaCO_3$

Since, 1000 litres of water required $30000 \times 100/117$ mg of NaCl as $CaCO_3$

$\therefore$ 1 ltr. of water required $(30000 \times 100/117)/1000$ mg of NaCl as $CaCO_3$

$= 25.641$mg of NaCl as $CaCO_3$/L

Therefore,

Amount of NaCl in terms of $CaCO_3$ required for regeneration= 25.641 mg/L

Thus, Hardness of water is 25.64 ppm of $CaCO_3$ (mg/L = ppm)

Q.2 **By passing 100 litres of NaCl solution containing 125 gm/litre of NaCl, a exhaust zeolite softener bed was regenerated. Calculate the volume of hard water sample (hardness equal to 100 ppm as $CaCO_3$) which can be softened by regenerated bed of zeolite softener.**

Conversion of NaCl used for regeneration in terms of $CaCO_3$

for the regeneration of zeolite 100 litres of NaCl

$= 100 \times 125$ gm of NaCl

$= 12,500$ gm of NaCl

$= 12500 \times MF \quad = 12500 \times 100/117$ gm as $CaCO_3$

$= \ 10683.76$ gm as $CaCO_3$

Suppose V Lit. of hard water needed NaCl = 10683.76 gm in terms of $CaCO_3$

Therfore per liter NaCl required (as $CaCO_3$) $= \ 10683.76/V$ gm/L

$= 10683760/V$ mg/L (or ppm)

Key Point:

Amount of NaCl used as mg/L of $CaCO_3$ for regeneration = Hardness of water.

Thus, $\quad 10683760/V = 100$ ppm

$V = 10683760/100$

$= \ 106837.6$ L **Ans.**

Thank You

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