Module – 2

Water Treatment

Module:2	Water Treatment	8 hours	SLO:1,14
Water softening methods: - Lime-soda, Zeolite and ion exchange processes and their applications. Specifications of water for domestic use (ICMR and WHO); Unit processes involved in water treatment for municipal supply - Sedimentation with coagulant- Sand Filtration - chlorination; Domestic water purification – Candle filtration- activated carbon filtration; Disinfection methods- Ultrafiltration, UV treatment, Ozonolysis, Reverse Osmosis; Electro dialysis.			

Module – 2: Water Treatment

- Water softening methods: - Lime-soda, Zeolite and ion exchange processes and their applications.
- Specifications of water for domestic use (ICMR and WHO); Unit processes involved in water
- treatment for municipal supply - Sedimentation with coagulant- Sand Filtration - chlorination;
- Domestic water purification – Candle filtration- activated carbon filtration; Disinfection methods-
- Ultrafiltration, UV treatment, Ozonolysis, Reverse Osmosis; Electro dialysis.

Water Treatment – Industrial Applications

Internal conditioning methods

i. Colloidal conditioning

ii. Phosphate conditioning

iii. Carbonate conditioning

iv. Calgon conditioning

v. Treatment with sodium meta aluminate

External conditioning methods

i. Lime Soda Process

ii. Zeolite process

iii. Ion exchange and mixed bed ion exchange process

Internal Conditioning

Ion is prohibited to exhibit its original character by Complexing or converting them into more stable and soluble salts.

i. Colloidal conditioning (*Low pressure boilers*)

Reagents Used - Kerosene, tannin and agar-agar.

- Scale formation can be avoided by adding these substances
- Forms non-sticky loose precipitates → can be easily removed

Internal Conditioning

ii. Phosphate conditioning (*High-Pressure boilers*)

Reagent Used – Sodium Phosphate

$$3CaSO_4 + 2Na_3PO_4 \rightarrow Ca_3(PO_4)_2 \downarrow + 3Na_2SO_4$$

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

NaH_2PO_4 -- Na_2HPO_4 -- Na_3PO_4

(based on pH of the water)

iii. Carbonate Conditioning (*Low-Pressure boilers*)

Reagent Used – Sodium Carbonate

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

Internal Conditioning

iv. Calgon conditioning

Reagent Used – Sodium hexa-meta Phosphate

$$Na_2[Na_4(PO_3)_6] <--> 2Na+ + [Na_4(PO_3)_6]^{2-}$$

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

v. Treatment with Sodium meta aluminate

Reagent Used – Sodium meta aluminate

$$NaAlO_2 + 2H_2O \rightarrow NaOH + Al[OH]_3 \downarrow$$

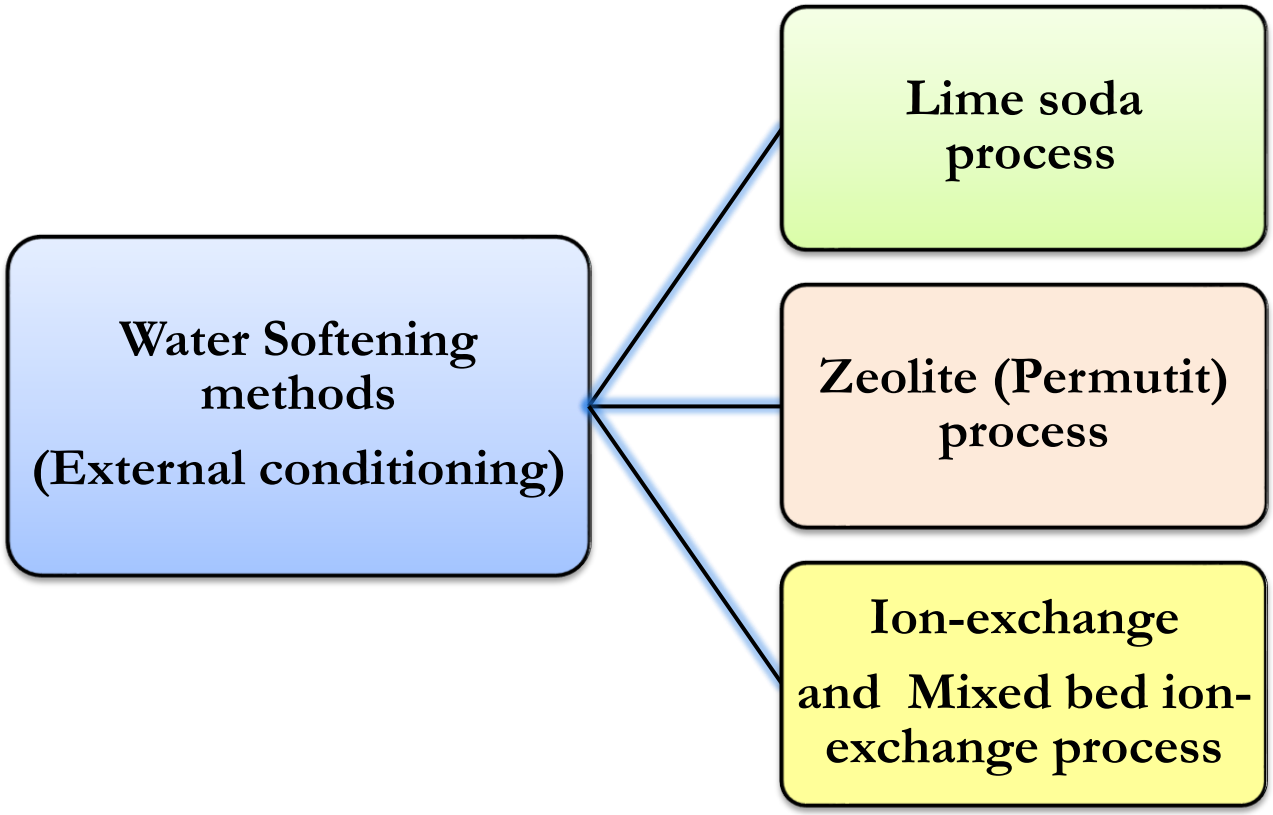
$$MgCl_2 + 2NaOH \rightarrow 2NaCl + Mg(OH)_2 \downarrow$$

Internal Conditioning

Method	Reagents used	Boiler type
Colloidal Conditioning	Kerosene, Agar-Agar, tannin	Low-Pressure
Phosphate Conditioning	Sodium Phosphate	High-Pressure
Carbonate Conditioning	Sodium Carbonate	Low-Pressure
Calgon Conditioning	Sodium hexa-meta Phosphate	
Sodium meta Aluminate treatment	Sodium meta Aluminate	

Water Softening methods: External conditioning

- The process of removing the hardness producing substance from the water is called softening of water
- In Industry three main methods are employed for softening of water



Water softening methods

1. Lime-Soda process

Lime-Soda process

Soluble calcium and magnesium salts in water are chemically converted into insoluble compounds by adding calculated amount of **lime [$Ca(OH)_2$]** and **Soda [Na_2CO_3]**. Calcium carbonate [$CaCO_3$] and Magnesium hydroxide [$Mg(OH)_2$] so precipitated, are filtered off.

1. Lime-soda

I. a) Batch process

b) Continuous process

II. - Cold lime-soda

- Hot lime-soda

Lime Soda Process - Reactions of Lime and Soda

Reaction of Perm. Ca^{2+}

$$Ca^{2+} + Na_2CO_3 \longrightarrow CaCO_3 + 2Na^+$$

Reaction of Perm. Mg^{2+}

$$Mg^{2+} + Ca(OH)_2 \longrightarrow Ca^{2+} + Mg(OH)_2$$

$$Ca^{2+} + Na_2CO_3 \longrightarrow CaCO_3 + 2Na^+$$

Reaction of HCO_3^- (ex. NaH CO_3)

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

Reaction of $Ca(HCO_3)_2$

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

Reaction of $Mg(HCO_3)_2$

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

Lime-Soda process

Reaction of CO_2

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

Reaction of H^+

$$2H^+ + Ca(OH)_2 \longrightarrow Ca^{2+} + 2H_2O$$

$$Ca^{2+} + Na_2CO_3 \longrightarrow CaCO_3 + 2Na^+$$

Lime Soda calculation

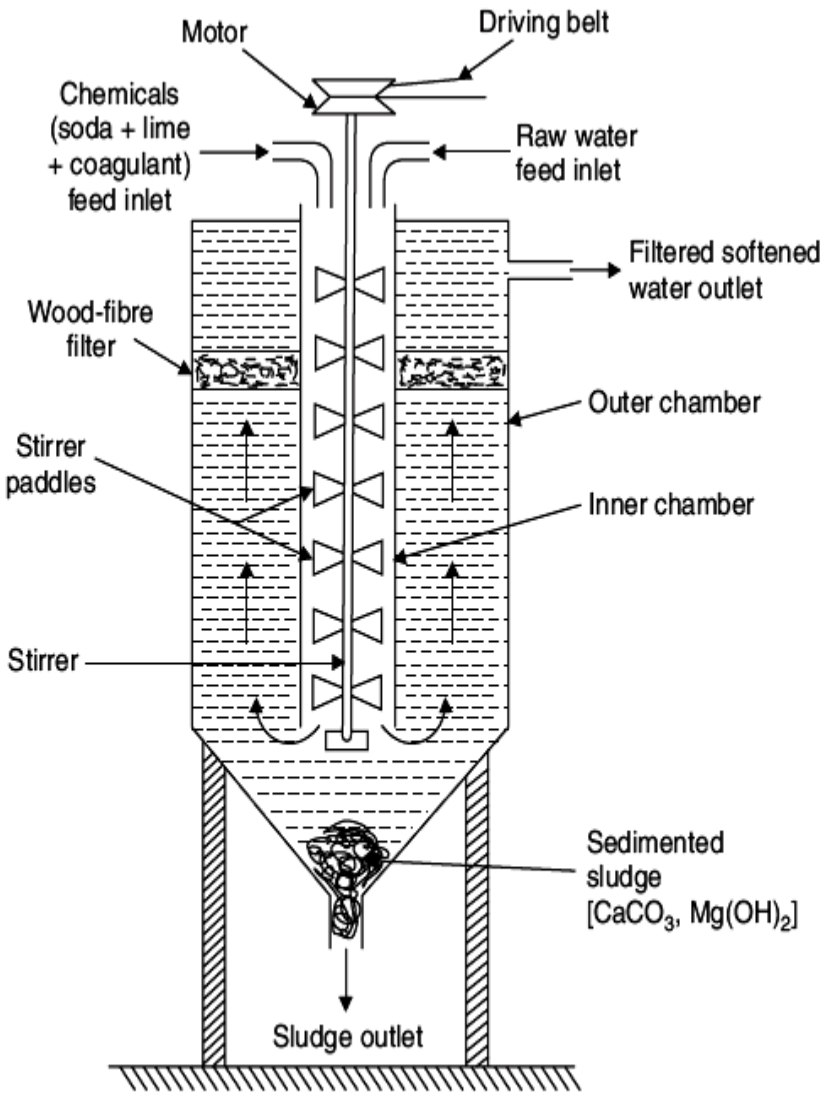
Lime requirement for softening

$$= \frac{74}{100} \left\{ \begin{array}{l} \text{Temp } Ca^{2+} + 2 \text{ X Temp } Mg^{2+} + \text{Perm.}(Mg^{2+} + Fe^{2+} + Al^{3+}) + CO_2 + H^+ \\ + \ HCO_3^- - NaAlO_2 \end{array} \right\}$$

Soda requirement for softening

$$= \frac{106}{100} \left\{ \text{Perm. } (Ca^{2+} + Mg^{2+} + Fe^{2+} + Al^{3+}) + H^+ - HCO_3^- \right\}$$

Continuous cold lime-soda process



Continuous cold lime-soda softener.

- Occurring at room temperature
- precipitate formed are finely divided hence do not settle down easily
- It is essential to add small amount of coagulant (alum, sodium aluminate)
- Coagulant hydrolyze to form gelatinous ppt. and entraps the fine ppt.
- $NaAlO_2 + H_2O \longrightarrow NaOH + Al(OH)_3$
- It provides water with a residual hardness of 50 to 60 ppm

Hot lime-soda process

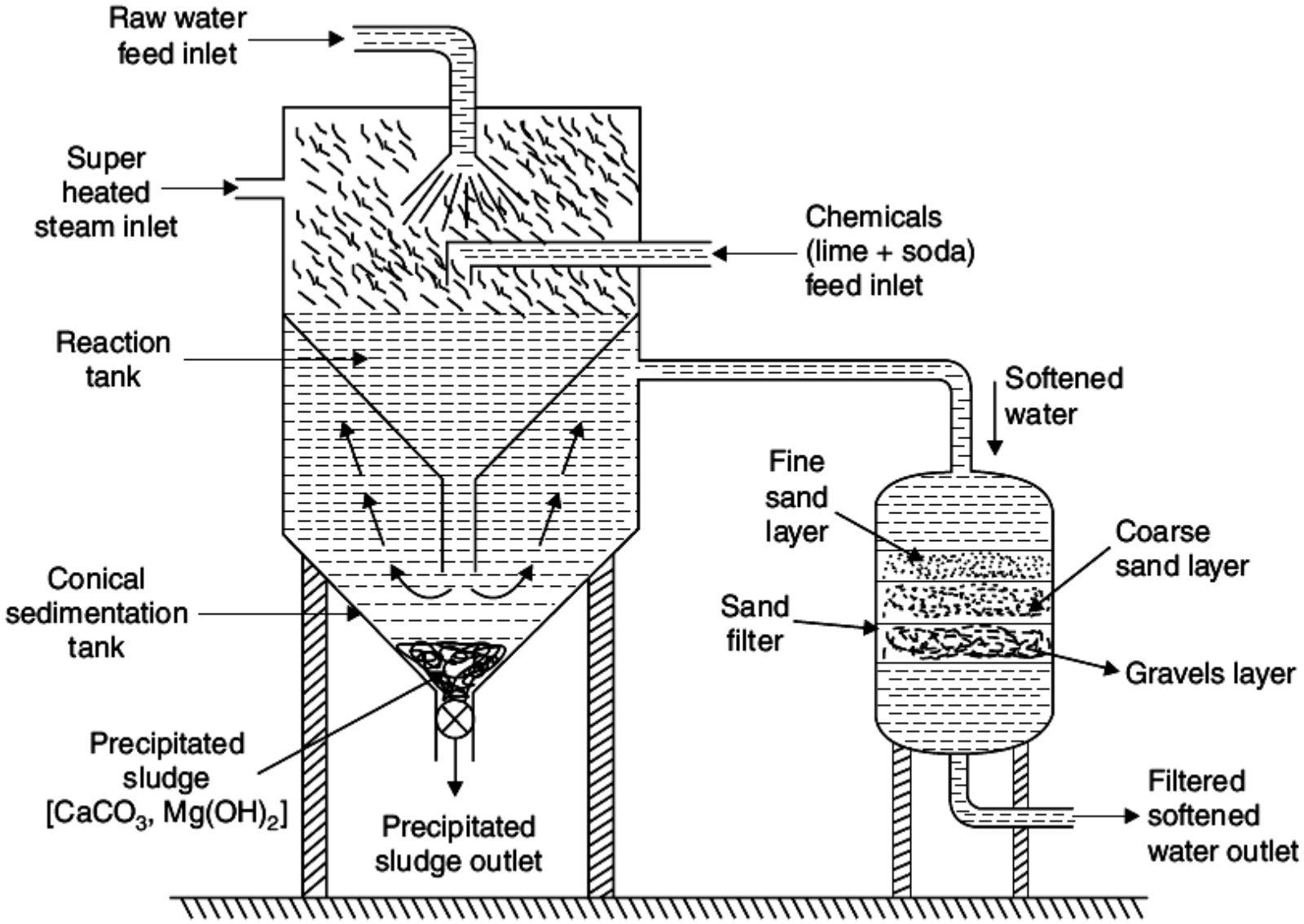
Hot lime-soda process consists of three parts:

a) Reaction tank to mix all ingredients

b) Conical sedimentation vessel where the sludge settles down

c) Sand filter where sludge is completely removed

- **Occurring at 80 to 150 °C close to the boiling point of the solution**
- **Reaction proceed faster**
- **The precipitate and sludge formed settle down rapidly so no coagulant needed**
- **Viscosity of the softened water is lower, so filtration of water becomes much easier**
- **Produce water contain the residual hardness of 15 to 30 ppm**



Continuous hot lime-soda softener.

Hot Lime-Soda Process

Advantages

(*i*) the precipitation reaction becomes almost complete.
(*ii*) the reaction takes place faster.
(*iii*) the sludge settles rapidly.
(*iv*) no coagulant is needed.
(*v*) dissolved gases (which may cause corrosion) are removed.
(*vi*) viscosity of soft water is lower, hence filtered easily.
(*vii*) Residual hardness is low compared to the cold process.

Hot lime-soda process consists of three parts:

(*a*) 'Reaction tank' in which complete mixing of the ingredients takes place.
(*b*) 'Ionical sedimentation vessel' where the sludge settles down and
(*c*) 'Sand filter' where sludge is completely removed.

The soft water from this process is used for feeding the boilers

Hot & cold lime soda process

S. No.	Cold lime soda process	Hot lime soda process
1	It is carried out at room temperature (25-30 °C)	It is carried out at high temperature (80-150 °C)
2	It is a slow process	It is a rapid process
3	Use of coagulant is a necessary	No coagulant required
4	Filtration is not easy	Filtration is easy as viscosity of water is low
5	Residual hardness is 60 ppm	Residual hardness is 15-30 ppm
6	Dissolved gases are not removed	Dissolved gases are removed
7	It has low softening capacity	It has high softening capacity

Advantages & disadvantages of lime-soda process

Advantages of Lime – soda process:

- Economical
- Process improves the corrosion resistance of water
- Mineral content of water is reduced
- pH of water raises thus reducing content of pathogenic bacteria
- No skilled labour is required

Disadvantages of Lime – soda process:

- Huge amount of sludge is formed and its disposal is difficult
- Due to residual hardness, water is not suitable for high pressure boilers