Filtration

Filtration is one of the most important operation followed by sedimentation.

In sedimentation large portion of suspended particles are removed but fine floc materials and micro organisms are not effectively removed.

In filtration turbidity and colloidal matter of non settlable types are removed.

Theory of filtration

The following actions take place in theory of filtration.

(i) Mechanical straining
(ii) Sedimentation.
(iii) Biological Action
(iv) Electrolytic Action.

[Detailed explanation in last sheets]

Rapid sand filteration | Rapid gravity sand filtration.

1. Enclosure tank.
2. Filter media
3. Base material.
4. Underdrainage system.
5. Appurtenances.

1. Enclosure tank :- It is rectangular in shape. Made of concrete or Masonary structure. It is usually coated with water proofing material.

(*) Depth of the tank may vary b/w 2.5m-3.5 Each unit may have a surface area of 20 to 50m². They are arranged in series.

(*) The length and width ratio is normally kept b/w 1.25 to 1.35m

(*) It has a underdrain pipe connected at the bottom of the tank. Along with the underdrain it also has a trough running across the length or width of the walls for distribution of water to be filtered during normal operation and for collection of wash water during cleaning operation.

2) Filter Media

(*) The sand used as filter media should be free from dirt, organic matter and other suspended matter.

(*) When finer suspended particles is to be removed smaller is the sand size. Rapid sand filter will have effective size between 1.2 to 1.7, commonly 1.5.

(*) Due to increase effective size and decreased uniformity of grain size, the void space is increased and results in effective filteration.

(*) The fine sand usually lie at the top of the bed ~~size~~ and coarse grain size lie at the bottom. The depth of the sand media varies b/w 0.6–0.9m

(*) Sometimes crushed antracite ~~has been~~ also will be used as filter media instead of sand. But it is costlier in comparison to sand. The crushed antracite has an effective size of 0.70 to 0.75mm and uniformity co-efficient not over 1.75

Base material :- The filter sand media is supported on base material consisting of graded gravel layer.

The gravel should be hard & durable. ~~And~~

The total depth varies from 45 to 60cm.

<u>under</u> drainage system.

1) It collects the water uniformly over the area of gravel bed.

2) It provides uniform distribution of back-wash water without disturbing or upsetting the gravel bed and filter media.

There are many under drainage system.

1) Perforated pipe system.

2) Pipe & strainer system.

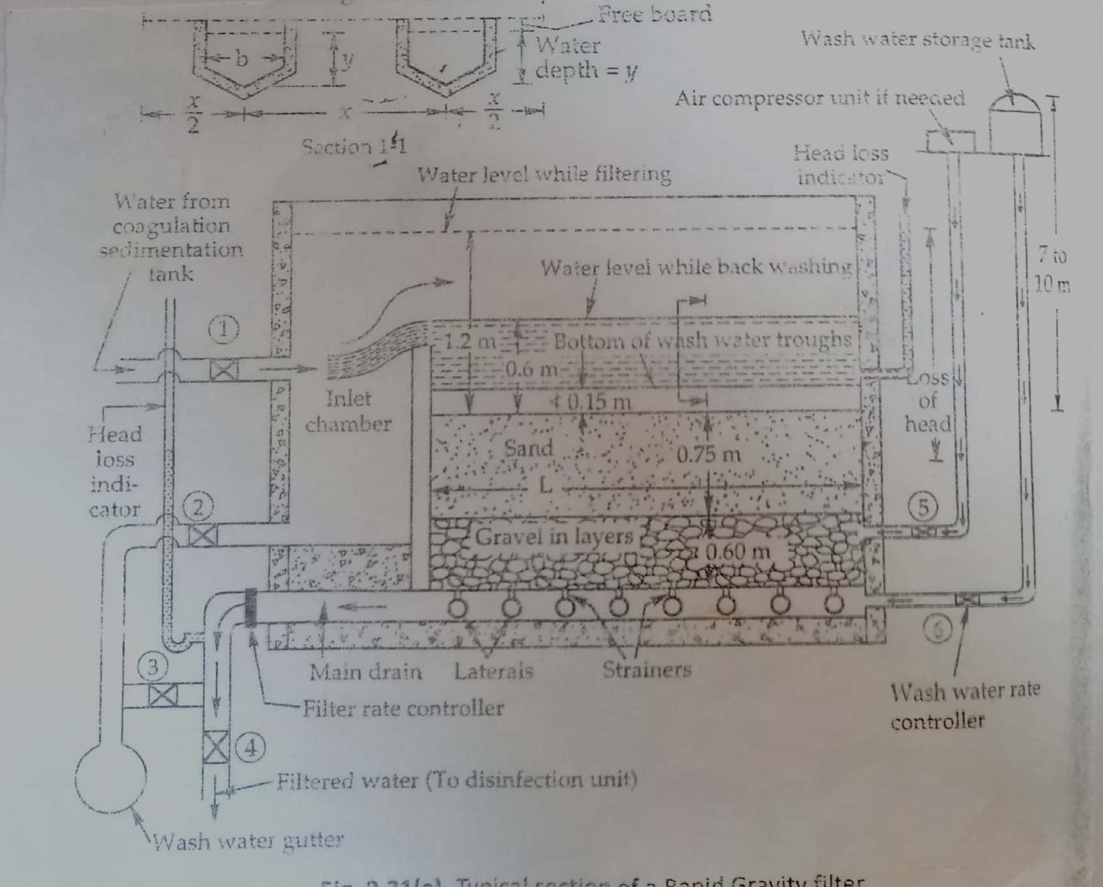

Fig. 9.31(a). Typical section of a Rapid Gravity filter.

Working & cleaning of Rapid Gravity filters

Valve No	Name of Valve
1	Inlet valve
2	waste water valve to drain water from inlet chamber
3	w/w valve to drain water from main drain
4	Filtered water supply valve
5	compressed air valve
6	wash water supply valve.

Valve 1 is opened the effluent to enter into filteration unit and once filtered it has to be taken out of and so valve 4 is kept open.
So when the filter is in working condition valve 1 & 4 are open.

Backwashing

- When sand is dirty its time to wash it. The intake water has to be stopped and so there will be no outlet as well. Thus valve (1) & (4) are closed.
- The wash water is sent backward upward through the filter bed. This forced upward movement of washwater and compressed air will agitate the sand particles thus removing suspended impurities from it. For this process valve 5 & 6 are opened.
- After completing the backwashing process valve 5 & 6 is closed and valve 2 is opened to collect the wash water

Next valve 2 & 6 are closed and valves ① & ③ are opened. This allows free water to enter the filter unit for filtration process and all the remaining washwater still getting drained is removed by valve 3. Finally after all wash water is drained, valve 3 is closed & valve 4 is oped.

- The entire process of backwashing the filters takes about 15 minutes.

Slow Sand Filters

Slow sand filters were the earliest type of filters initially used. Usually water entering a slow sand filter are given only primary settling without any coagulation as pretreat-ment.

A slow sand filter consist of foll parts.

1> Enclosure tank.
2> Filter media
3> Base material
4> Under Drainage System.
5> Appurtenances.

CONSTRUCTION OF Slow Sand Filter.

1> Enclosure Tank :- It is usually rectangular in shape built usually below ground level. The tank is either stone or brick masonary with a coating of water proof material

- The floor has a bed slope of 1 in 100 to 1 in 200 towards the central drains
- The surface area of the tank varies between 50m² to 1000m². The filteration rate varies b/w 100 to 200 ltr of water per square meter.
- The depth of the tank varies from 2.5 to 4m.

2> Filter media :- The filter media consist of sand layer, 90 to 110 cm thick. The effective size of sand varies from 0.20-0.35 with a common value of 0.3 usually

- The co-efficient of uniformity varies from 2 to 3, the common value being 2.5.

- The finer the sand, better will be bacterial removal efficiency but slower will be filteration rate.

when the quality of pretreatment given to water is less, fine sand is more preferable to be used, as it helps in removing better turbidity and bacterial removal.

3> Base material : The filter media is supported on base material consisting of 30 to 75 cm thick gravel bed.

The gravel base is graded and laid in layers of 15cm with topmost layer of finer size and bottommost layer of coarse size.

	Depth	Size.
Top most layer.	15cm	→ 3mm to 6mm
Intermediate layer 1	15 cm	→ 6mm to 20mm
Intermediate layer	15cm	→ 20mm to 40mm
Bottom layer	15cm	→ 40mm to 65mm

4> Under drainage system

The under drainage system placed at the bottom most part of tank collects the filtered water and delivers it to clean water reservoir.

The lateral drains are either earthenware or perforated pipes of 7.5 to 10cm dia.

5> Appurtenances :-

The various appurtenances that are installed for efficient working of filter are devices installed for.

1> Measuring the loss of head to filter media
2> controlling the depth of water above the filter media
3> Maintaining constant rate of flow through the filter.

Working of slow sand filter

Water from the plain sedimentation tank enters the slow sand filter unit through inlet. The depth of water over the filter media is usually equal to the thickness of sand medium. Water passes downwards through sand bed, it works by a combination of both straining and microbiological action.

It has 3 zones of purification - Viz. -

1> The surface coating called 'SCHMUTZDECKE'
2> The autotrophic zone existing few millimeters below the schmutzdecke &
3> The heterotropic zone which may extend some 30cm. in the.

- The partly decomed organic matter along with iron, magnesium & silica form reddish brown sticky deposit called 'SCHMUTZDECKE'. This absorbs organic matter in colloidal state.

- After 2-3 weeks of the start of working of S.S filter it forms also an autotropic layer comprising of algae, bacteria, protozoa, suspended particles and organic matter, it helps in the breakdown of decomposable organic matter by utilising nitrogen, phosphates and carbon-di-oxide and it releas oxygen thus oxiding the filter.

- In the heterotrophic zone which extends to a depth of 30cm, the bacteria multiply in large number, to break down completely remaining organic matter.

- The difference of water level in the filter basin and the outlet chamber is known as filter head. S.S.F works upto a maximu filter head of 75cm

Problem on slow sand filter

1. A city has a population of 20,000 with an average rate of demand as 150 ltr/capita/day. Find the area of slow sand filters

Solution

(1) Assume max daily demand as 1.5 times average daily demand

(2) Assume average rate of filteration as 150 ltr/hr/m^2 of the filter area.

Max daily demand = $1.5 \times 20{,}000 \times 150$

= ~~30,000~~ 4,500,000 ltr.

Area of filteration = $\frac{4500000}{150 \times 24}$ = $1250 m^2$

Provide ~~each~~ 6 filter unit of size

Pressure sand filters -

10.15. PRESSURE FILTERS

The pressure filter is a type of rapid sand filter which is in a closed container and through which the water passes under pressure. The pressure may vary from 3 to 7 kg/cm^2 and may be developed by pumping. It may be either horizontal type or vertical type. The diameter of vertical varies from 2 to 2.5 m and length varies from 2.5 to 8 m. The filter is operated similar to a gravity type rapid filter except that the coagulated water is usually applied directly to the filter without mixing, flocculation or conditioning. Fig. 10.16 (a) shows the diagrammatic sketch of horizontal type pressure filter while Fig. 10.16 (b) shows the vertical type pressure filter.

The uniformity co-efficient and effective size of filter sand is practically the same as that provided for rapid gravity filters, while the thickness of sand bed may vary from 50 to 60 cm. Gravel layers also follow the same practice as in gravity sand filters. The under drainage system may consist of pipe grids or false bottoms. Washing

A = RAW WATER INLET VALVE C = FILTERED WATER VALVE
B = WASH WATER INLET VALVE D = WASH WATER DRAIN VALVE

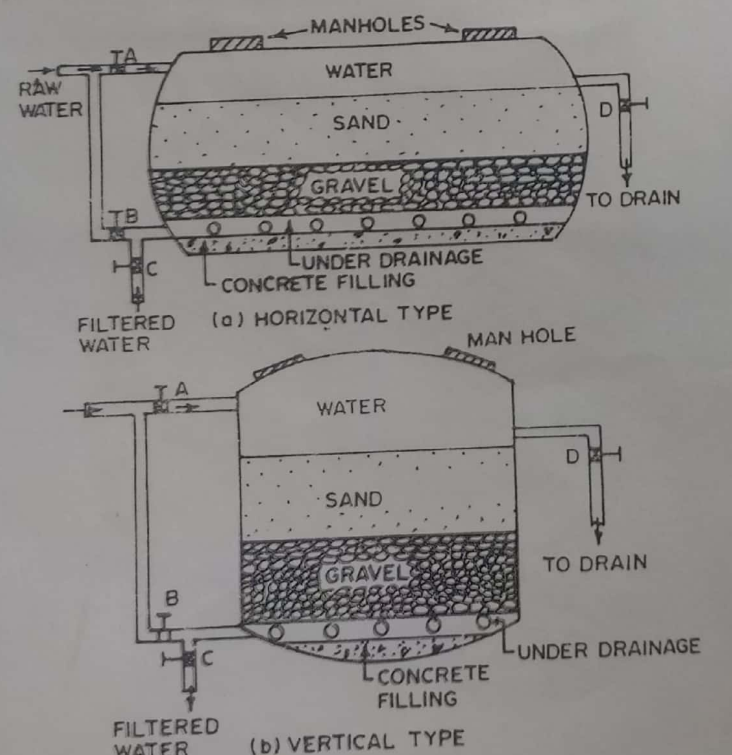

FIG. 10.16. DIAGRAMMATIC SECTIONS OF PRESSURE FILTERS

of filter media is accomplished by reversing the flow by manipulating the valves in the piping. Automatic pressure filters are also available in which backwashing is done automatically after a fixed interval of time or when the head loss has reached a given value.

Pressure filters are particularly advantageous for installations where water is received under pressure, as no pumping after filtration is required. Because the filter container is air tight, this filter may be placed on a pressure line. The only loss of head is that required to force the water through the filter. The filtration rate is much higher than the rapid gravity filter – the rate may vary from 6000 to 15000 litres per hour per m^2 of filter area. Due to this, they are considered as being unreliable in the removal of bacteria. They are, therefore, not used for treating municipal water supplies. They are mostly used in clarifying softened water at industrial plants and in treating swimming pool water that is recirculated.

Operational Problems in Sand Filters

1> Formation of mud balls.
2> Cracking of Filters.
3> Air binding.
4> Sand Incrustation.
5> Jetting and sand boils
6> Sand Leakage.

Formation of mud balls:

1> The mud from the atmosphere usually accumulates on the sand surface, so as to form a dense mat layer. If the filter is not frequently backwashed the mud may sink into deeper layers of sand bed.

2> The mud sticks to the sand grains and other suspended impurities forming mud balls. These mud balls slowly and steadily increase in size and weight and sink down to the layer of gravel and hence interfere with the upward movement of wash water during cleaning

3> The mud balls increase in number thus slowly getting filled up in the larger area of filter.

Control measures to prevent the interference caused by formation of mud balls

1> Mud balls may be broken with mechanical rakes, and hence the mud particles are easily washed

2> mud particles can be broken by water stream. by using a 10mm ϕ pipe which will hit the water with a force so as to break the mud ball

3> compressed air can be passed along with wash water of sand and also simultaneously using mechanical rakes to effectively remove the mud balls.

4> The sand filter ~~sand~~ is washed first then the same water is withdrawn and allowed to stand a depth of 10cm above the sand bed and caustic soda is added. It is allowed to soak for 12hrs and sand is washed again followed by air wash, though the procedure is lengthy it removes the mud balls.

5] Cracking of Filters

The top layer of sand shrinks and develops cracks. The cracks develop more in sand along the walls of sand filter. This increases pressure on sand during filtration process which in the long run reduces the filtration efficiency. ~~of~~

replacement of sand after noticing cracked sand is an option to improve the efficiency of filteration.

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3] Air binding - The condition of air binding is caused by the release of dissolved air and gases from water, to form bubbles. These air bubbles occupy the void space of filter media and drainage pore. This trouble will occur if the water is saturated with air

4] Sand Incrustation :- Sand incrustation occur due to deposition of sticky gelatenous material from influent water or due to filtration of water which is previously treated with lime. Due to this the sand grains enlarge and the effective size of sand changes.

The problem of lime water can be solved by carbonating the limewater before entering the filter.

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5] Sand leakage :- Sand leakage happens when fine grains of sand escape to the bottom as the void spaces get displaced while backwashing.

It can be minimised by properly proportioning the sand and gravel layer.

Theory of filteration

The following actions take place during filteration

1> Mechanical Straining
2> Sedimentation.
3> Biological Action &
4> Electrolytic Action.

1> **Mechanical straining**: When the water passes through the filter media, a simple action takes place. i.e, The suspended particles which are larger than the pore-space of filter media gets trapped, This usually happens in the upper few centimeters of the filter media.

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2> **Sedimentation** :- In mechanical straining, only those particles which are larger than void space get removed, in sedimentation finer suspended particles are trapped which in the continuously formed voids. The continous voids of the filter media act as "tube settlers", All the colloids are thus removed in this action

3> **Biological Action**
When the filter is put to use and the raw water is passed through it, during the first few days, the upper layer of sand grain

become coated with reddish brown sticky deposit of partly decomposed organic matter together with iron, manganese, Aluminium & silica.
After some time, there exist in the upper most layer of sand a film of algae, bacteria & protozoa etc. This film is known as 'Schmutzdecke' or 'dirty skin' which acts as a straining mat. The organic impurities in water become food to different micro organisms

4> Electrolytic Action :- Filter also removes the particulate matter by electrostatic exchange. The charge of the filter medium neutralises the charge of the floc, thereby permitting the floc to be removed.

Classification of Filters

1> Slow sand Filters.

2> Rapid sand filters

(a) Gravity type filter

(b) Pressure sand filter.

Water Softening

The reduction or removal of hardness from water is known as water softening. It is not essentially important to soften the water in order to make water safe for public use.

- The main advantage of softening water is to reduce the usage of soap as hardwater doesnt easily form lather with water and hence usage of soap increases.
- In case of Industrial supplies softening of water is important as it leads to formation of scales on boilers and also interfers in the dyeing system of textile industries

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Types of hardness

1> Temprory hardness or carbonate hardness.
2> Permanent hardness or Non-carbonate hardness.

Carbonate hardness is caused by carbonates & bicarbonates of calcium and Magnesium. It can be removed by boiling or by adding lime.

Permanent or noncarbonate hardness is caused by sulphates, Chlorides and nitrates of calcium and magnesium. It is removed by

Special methods of water softening

Methods of removing temprory hardness

1> Boiling :- Calcium carbonate, being slightly soluble it will be present in water as Calcium bicarbonate.

- It easily dissolves in water c̄ contains CO_2. When such water containing CO_2 is boiled, it expels out CO_2 leading to precipitation of $CaCO_3$. It can be easily removed

$$Ca(HCO_3)_2 + Heat \longrightarrow CaCO_3 \downarrow + CO_2 \uparrow + H_2O$$

Calcium bi-carbonate → Cal-Carbonate [Insoluble]

- Magnesium bicarbonate and Magnesium carbonate cannot be removed by boiling as $MgCO_3$ is easily soluble in water.

  Hence Boiling cannot effectively remove temprory hardness caused by magnesium.

- For large scale water supplies will not opt for boiling method as it is not a feasible method.

- Magnesium Carbonate and Magnesium bicarbona-te are removed by precipitating them as insoluble $Mg(OH)_2$ by treating hard water with lime.

(2) Addition of lime

When hydrated lime [$Ca(OH)_2$] is added to water, the foll reactions take place.

$$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 \downarrow + CaCO_3 \uparrow$$

Mag carbonate, hydrated lime → Mg hydroxide [Insoluble], cal. carbonate

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

Mg. bicarbonate, hydrated lime → Mg. hydroxide

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

Cal bicarbonate

Calcium carbonate and Magnesium hydroxide are precipitated and can be removed.

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Methods of Removing Permanent Hardness

Commonly adopted method for removal of permanent hardness are.

(a) Lime soda process

(b) Base Exchange Process generally called Zeolite Process.

(c) Demineralisation Process.

1. Lime Soda Process

- In this process, lime $Ca(OH)_2$ and soda ash (Na_2CO_3) are added to hardwater. It reacts with calcium & Magnesium salts, to form insoluble precipitate of calcium carbonate and Magnesium hydroxide [$Mg(OH)_2$]

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

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

$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2\downarrow + CaCO_3\downarrow$$

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

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

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

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2NaCl$$

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

- From the above eq'n, It is clear that lime helps in removing carbonate hardness caused by calcium and Magnesium.
- It reacts with non carbonate hardness of Magnesium to convert it into non-carbonate hardness of calcium & is removed by soda.
- Lime also helps in removing free dissolved carbondioxide.

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- The sodium salts formed in the abv reactions are soluble in water and its presence is unobjectionable.

- The calcium carbonate and Magnesium hydroxide formed gets precipitated and can be removed by the process of sedimentation.

- Some of it may remain and can create problems in filter media and in pipes of distribution system. To prevent this water is recarbonated by passing CO_2 gas through it

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- In recarbonation process, the insoluble carbonates combine with carbon-di-oxide to form soluble bi-carbonates

- The carbon-di-oxide gas to be blown in water can be produced by burning coke, gas or oil. In recarbonation process even though water regains some of its hardness yet recarbonation is advisable.

- The amount of lime and soda required for softening depends upon the chemical quality of the water & the extent of hardness removal desired.

- Many a times hardwater may primarily contain carbonate hardness and very low amt of non-carbonate hardness, hence for treating such water lime treatment is most suited.

Zeolite or Base Exchange or cation Exchange Process

* Zeolites are natural salt or clay which are hydrated silicates of sodium and alluminium having general formula

$$Na_2O\,Al_2O_3 \cdot SiO_2 \cdot H_2O$$

* Naturally occuring zeolite like substances can also be manufactured synthetically and are called as <u>Resigns</u>

* The zeolite Resigns have an excellent property of exchanging their cation, ~~and hence~~ during softening process of water, the sodium ions of zeolite get replaced by calcium & Magnesium ions present in hard water.

$$Na_2Z + \begin{matrix} Ca \\ Mg \end{matrix} \begin{cases} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{cases} \longrightarrow Na_2 \begin{cases} (HCO_3)_2 \\ SO_4 \\ Cl_2 \end{cases} + \begin{matrix} Ca \\ Mg \end{matrix} \Big\{ Z$$

* The calcium and Magnesium zeolite can be regenerated into active sodium zeolite by treating it with 5-10 per cent sol'n of sodium chloride

* A zeolite softener resembles a sand filter in C filtering medium is zeolite rather than sand

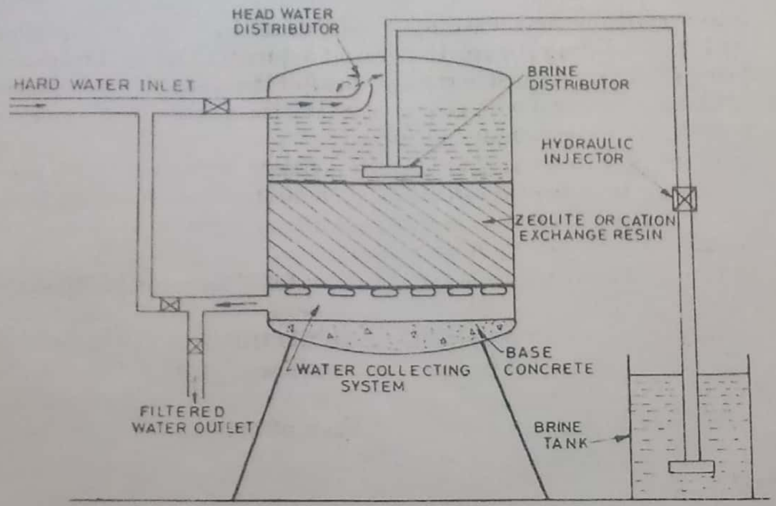
The hard water enters from top and is evenly distri-buted on the entire bed. The softened water is collected through strainers at the base.

* When significant portion of sodium in zeolite has replaced calcium and Magnesium ions, it is regenerated by reverse flow of water and then by treating with 10% brine solution.

* The excess brine solution is also stripped off by passing clean treated water. The regenerated zeolite is now ready to be used again.

* Zeolite softeners may be either gravity filters or pressure filters. usually pressure filters are common among zeolite filters. The rate of filtration is about 300 ltr/m².

* The water treated in a zeolite softener will be free from hardness, it will be 0% hardness which is not suitable for public supplies. Hence a very small portion of unsoftened water is mixed with softened water.



(a) Sectional view

ZEOLITE PROCESS

Advantage of Zeolite process

1) water of zero hardness is Obtained and hence useful for specific uses in textile Industries and boilers etc.

2) The plant is compact, automatic and easy to operate.

3) There is no sludge formation, hence sludge disposal problem is eliminated.

4) The Running, Maintainance and operation [RMO] cost is less hence it is economical.

5) It removes ferrous iron and Manganese from water.

6) water of varying quality of hardness can be treated easily and effective results are Obtained.

There is no problem of incrustation of pipes in distribution system as in case of lime soda process.

Disadvantages of Zeolite process

1> Process is not suitable for highly turbid water, as the suspended impurities get deposited around the Zeolite particle and thus reduce working efficiency reduces.

2> The process leaves sodium bicarbonate as residue which causes problem of foaming in industrial use and in Boilers feed water.

3> It is unsuitable for and coastly for treating water containing Iron and Manganese, though it Zeolite removes it, it forms Iron Zeolite and Manganese Zeolite which Cannot be regenerated during chemical rxn into sodium Zeolite. Thus Zeolite gets wasted.

Demineralisation process for Removing Hardness in

The process

- It removes the minerals from water, It helps in completely removing minerals or reducing the mineral content to any desired levels.

- The Demineralised water also is called as de-Ionised water, It is as pure as distilled water and is very suitable for Industrial purposes, especially for stream raising in high pressure boilers.

- The process is carried out by passing water through cation exchange resigns products, and then through a bed of anion exchange resigns.

- The process of passing water through cation exchange resign produces almost same effect as zeolite process, except that instead of sodium ions like in zeolite process here we have hydrogen ions as exchange metallic ions.

- The cation exchange resigns are phenol aldehyde condensation products c on sulphonation produces resinous mass having base exchange properties

- Their chemical formula is represented by H_2R where H represents hydrogen Ion and R represents organic part of substance.

The chemical reactions are :

$Ca(HCO_3)_2 + H_2R \longrightarrow CaR + H_2O + 2CO_2 \uparrow$

Fresh cation exchange resign — Exhausted resign

$CaCl_2 + H_2R \longrightarrow CaR + 2HCl$.

$MgSO_4 + H_2R \longrightarrow MgR + H_2SO_4$

$2NaCl + H_2R \longrightarrow Na_2R + 2HCl$.

- water coming from cation exchanger will contain diluted carbonic acid, hydrochloric acid, sulphuric acid etc. It is removed by passing the water through a bed of anion exchange resign

- The water coming out from this anion exchanger will then be free from minerals. The extent of removal will depend upon the strength and freshness of the resins used

- The completely demineralised water is sometimes mixed with raw water supplies to obtain the desired mineral content in water

- when the resign is used for longer period of time it needs regeneration & is done as follows

The exhausted cation exchange resigns can be regenerated by treating them with dilute hydrochloric acid or sulphuric acid.

(*) The exhausted anion exchange resigns are regenerated by treating them with sodium carbonate solution.