2.4 FILTRATION OF WATER

The process of passing the water through beds of sand or other granular materials are known as filtration. For removing bacteria, colour, taste, odours and producing clear and sparkling water, filters are used by sand filtration 95 to 98% suspended impurities are removed.

THEORY OF FILTRATION:

The following are the mechanisms of filtration

1. Mechanical straining – Mechanical straining of suspended particles in the sand pores.
2. Sedimentation – Absorption of colloidal and dissolved inorganic matter in the surface of sand grains in a thin film.
3. Electrolytic action – The electrolytic charges on the surface of the sand particles, which opposite to that of charges of the impurities are responsible for binding them to sand particles.
4. Biological Action – Biological action due to the development of a film of microorganisms layer on the top of filter media, which absorb organic impurities.

Filtration is carries out in three types of filters

1. Slow sand filter
2. Rapid sand filter Gravity filters
3. Pressure filter

1. SLOW SAND FILTER

Slow sand filters are best suited for the filtration of water for small towns. The sand used for the filtration is specified by the effective size and uniformity coefficient. The effective size, D10,which is the sieve in millimeters that permits 10% sand by weight to pass. The uniformity coefficient is calculated by the ratio of D60 and D10.

CONSTRUCTION

Slow sand filter is made up of a top layer of fine sand of effective size 0.2. to 0.3mm and uniformity coefficient 2 to 3 . The thickness of the layer may be 75 to 90 cm. Below the fine sand layer, a layer of coarse sand of such size whose voids do not permit the fine sand to pass through it. The thickness of this layer may be 30cm. The lowermost layer is a graded gravel of size 2 to 45mm and thickness is about 20 to 30cm. The gravel is laid in layers such that the smallest sizes are at the top. The gravel layer is the retains for the coarse sand layer and is laid over the network of open jointed clay pipe or concrete pipes called under drainage. Water collected by the under drainage is passed into the outlet chamber.

OPERATION

The water from sedimentation tanks enters the slow sand filter through a submersible inlet. This water is uniformly spread over a sand bed without causing any disturbances. The water passes through the filter media at an average rate of 2.4 to 3.6 m3/m2/day. This rate of filtration is continued until the difference between the water level on the filter and in the inlet chamber is slightly less than the depth of water above the sand. The difference of water above the sand bed and in the outlet chamber is called the loss of head. During filtration as the filter media gets clogged due to the impurities, which stay in the pores, the resistance to the passage of water and loss of head also increases. When the loss of head reaches 60cm, filtration is stopped and about 2 to 3 cm from the top of bed is scrapped and replaced with clean sand before putting back into service to the filter. The scrapped sand is washed with the water, dried and stored for return to the filter at the time of the next washing. The filter can run for 6 to 8 weeks before it becomes necessary to replace the sand layer.

USES

The slow sand filters are effective in removal of 98 to 99% of bacteria of raw water and completely all suspended impurities and turbidity is reduced to 1

N.T.U. Slow sand filters also removes odours, tastes and colors from the water but not pathogenic bacteria which requires disinfection to safeguard against water-borne diseases. The slow sand filters require large area for their construction and high initial cost for establishment. The rate of filtration is also very slow.

2. RAPID SAND FILTER

Rapid sand filter are replacing the slow sand filters because of high rate of filtration ranging from 100 to 150m3/m2/day and small area of filter required. The main features of rapid sand filter are as follows.

Effective size of sand - 0.45 to 0.70mm Uniformity coefficient of sand - 1.3 to 1.7

Depth of sand - 60 to75cm Filter gravel - 2 to 50mm size (Increase size towards bottom)

Depth of gravel - 45cm

Depth of water over sand during filtration - 1 to 2m

Overall depth of filter including 0.5m free board - 2.6m Area of single filter unit - 100m2 in two parts of each 50m2 Loss of head - Max 1.8 to 2.0m

Turbidity of filtered water - 1 NTU

CONSTRUCTION

Rapid sand filter consists of the following five parts

1. Enclosure tank – A water tight tank is constructed either masony or concrete
2. Under drainage system – may be perforated pipe system or pipe and stracher system
3. Base material – gravel should free from clay, dust, silt and vegetable matter. Should be durable, hard, round and strong and depth 40cm.
4. Filter media of sand – The depth of sand 60 to 75cm
5. Appurtenances – Air compressors useful for washing of filter and wash water troughs for collection of dirty water after washing of filter. Washing process is continued till the sand bed appears clearly. The washing of filter is done generally after 24 hours and it takes 10 minutes and during back washing the sand bed expands by about 50%.Rapid sand filter bring down the turbidity of water to 1 N.T.U. This filter needs constant and skilled supervision to maintain the filter gauge, expansion gauge and rate of flow controller and periodical backwash.

OPERATION

The water from coagulation sedimentation tank enters the filter unit through inlet pipe and uniformly distributed on the whole sand bed. Water after passing through the sand bed is collected through the under drainage system in the filtered water well. The outlet chamber in this filter is also equipped with filter rate controller. In the beginning the loss of head is very small. But as the bed gets clogged, the loss of head increases and the rate of filtration become very low. Therefore the filter bed requires its washing.

3. PRESSURE FILTER

Pressure filter is type of rapid sand filter in closed water tight cylinder through which the water passes through the sand bed under pressure. All the operations of the filter are similar to rapid gravity filter; expect that the coagulated water is directly applied to the filter without mixing and flocculation. These filters are used for industrial plants but these are not economical on large scale. Pressure filters may be vertical pressure filter and horizontal pressure filter. Backwash is carried by reversing the flow with values. The rate of flow is 120 to 300m3/m2/day.

ADVANTAGES

1. It is a compact and automatic operation
2. These are ideal for small estates and small water works
3. These filters requires small area for installation
4. Small number of fittings is required in these filters
5. Filtered water comes out under pressure no further pumping is required.
6. No sedimentation and coagulant tanks are required with these units.

DISADVANTAGES

1. Due to heavy cost on treatment, they cannot be used for treatment large quantity of water at water works
2. Proper quality control and inspection is not possible because of closed tank
3. The efficiency of removal of bacteria & turbidity is poor.
4. Change of filter media, gravel and repair of drainage system is difficult.

2.4.1 WATER SOFTENING

Water softening is the process of removing hardness. Hardness is defined as the water's ability to consume soap. Besides making water more pleasing for washing purposes, softening water can also provide benefits of preventing encrustation and scaling inside boilers, water heaters, hot-water lines, as well as some industrial processes. Hardness is usually expressed in terms of "ppm as $CaCO_3$", or ppm as calcium carbonate.

The home water softener industry usually measures hardness in the form of grains per gallon, of which 1 gpg equals about 17ppm hardness. The terms, "hard water" and "soft water" are used loosely, as there are no accepted standards or "measuring scale" todetermine if water is soft or hard.

The primary constituents in water that cause hardness are calcium (Ca) and magnesium (Mg), especially calcium. Iron (Fe) and manganese (Mn) can also promote to waterhardness, but typically at a much lesser degree. Hardness caused by calcium andmanganese is typically carbonate hardness, for the calcium and manganese exists in the water in the form of calcium bicarbonate, $Ca(HCO_3)_2$, and magnesium bicarbonate, $Mg(HCO_3)_2$. This form of hardness is usually referred to as carbonate hardness, or temporary hardness. On the other hand, the sulfate, chloride and nitrate salts of calcium are usually referred to as permanent hardness, since they cannot be readily precipitated. Water heaters suffer from hard water because when water containing calcium bicarbonate is heated, the insoluble carbonate form of calcium will be precipitated.

It is a property of water, which prevents the lathering of the soap. Hardness is of two types.

1. Temporary hardness: It is caused due to the presence of carbonates and sulphates of calcium and magnesium. It is removed by boiling.
2. Permanent hardness: It is caused due to the presence of chlorides and nitrates of calcium and magnesium. It is removed by zeolite method.

Hardness is usually expressed in gm/liter or p.p.m. of calcium carbonate in water. Hardness of water is determined by EDTA method. For potable water hardness ranges from 5 to 8 degrees.

Temporary hardness removal methods:

Boiling of Water:

Calcium carbonate – slightly soluble in water – present in the form Calcium bicarbonate because, it easily dissolves in water containing CO_2.

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

Addition of Lime (CaO):

Hydrated lime [Ca(OH)2] is added to water

$$MgCO_3 + Ca(OH)_2 \quad Mg(OH)_2 + CaCO_3$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \; Ca(HCO_3)_2 + Mg(OH)_2$$

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

Suitable only for Temporary hardness removal process.

Permanent hardness removal methods

1. Lime-Soda process
2. Base-Exchange process, generally called *Zeolite process*
3. Demineralization process

1. Lime-Soda process

Lime soda process is a method of softening hard water. This process is now obsolete but was very useful for the treatment of large volumes of hard water. In this process Calcium and Magnesium ions are precipitated by the addition of lime (Ca(OH)2) and soda ash (Na2CO3).

Chemistry of Lime Soda Process:

Lime addition removes only magnesium hardness and calcium carbonate hardness. In equation 5 magnesium is precipitated, however, an equivalent amount of calcium is added. The water now contains the original calcium noncarbonate hardness and the calcium non-carbonate hardness produced in equation 5. Soda ash is added to remove calcium non-carbonate hardness:

Na2CO3 + CaSO4 -------- Na2SO4 + CaCO3

Limitations of Lime Soda Process

Lime soda softening cannot produce a water at completely free of hardness because of minute solubility of CaCO3 and Mg (OH)2. Thus the minimum calcium hardness can be achieved is about 30 mg/L as CaCO3, and the magnesium hardness is about 10 mg/L as CaCO3.

We normally tolerate a final total hardness on the order of 75 to 120 mg/L as CaCO3, but the magnesium content should not exceed 40 mg/L as CaCO3.

2. Base-Exchange process, generally called *Zeolite process*

Zeolite or Base-Exchange or Cation exchange process

Zeolites are of two types:

1. Natural zeolite : Natural zeolite are non-porous. for example,natrolite ,Na2O.Al2O3.xSiO2.yH2O.

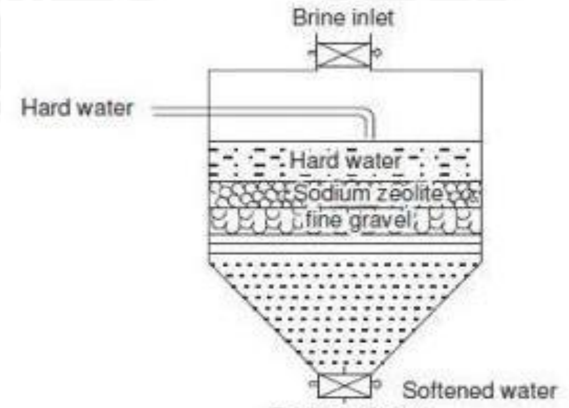
2. Synthtic zeolite : Synthtic zeolite are porous and posses get structure. They are prepared by heating together china clay,feldspar and soda ash. Such zeolites possess higher exchange capacity per unit weight than natural zeolites.

Zeolite – termed as *Green sand* – Na2O Al2O3 x.SiO2 y.H2O

Zeolite or Resins have excellent property of exchanging their cations and hence during softening operation, the sodium ions of the zeolite get replaced by the calcium and magnesium ions present in hard water.

Used as filter media in sand filter (Zeolite sand bed)

- When Sodium is replaced by Calcium & Magnesium – backwashing is done – Again brine is added to regenerated the filter bed – excess brine is removed by back washing with water
- Filters – Gravity or Pressure (more common)
- Rate of filtration: 300 l/m2/min



Zeolite softener

- Zeolite process results in *Zero hardness* – not suitable for public supplies – small amount is processed and mixed with un softened water to obtain standard limits.

2.4.2 REMOVAL OF IRON

Iron and manganese removal:

Iron and manganese control is the most common type of municipal water treatment. Iron and manganese occur naturally in groundwater. These elements are in fact, essential to the human diet. Water containing excessive amounts of iron and manganese can stain clothes, discolor plumbing fixtures, and sometimes add a"rusty" taste and look to the water. Surface water generally does not contain large amounts of iron or manganese, but iron and manganese are found frequently in water systems that use ground water. Iron In drinking water is 0.3 parts per million (ppm) and 0.05 ppm for manganese.

- Iron and manganese minerals are found in soil and rock.
- Iron and manganese can dissolve into groundwater as it percolates through the soil and rock.
- more than 0.3 mg/l of iron will cause yellow to reddish-brown stains of plumbing fixtures or almost anything that it contacts.
- Manganese even at levels as low as 0.1 mg/l, will cause blackish staining of fixtures and anything else it contacts.
- If the water contains both iron and manganese, staining could vary from dark brown to black.
- Iron and manganese in well waters occur as soluble ferrous and manganous bicarbonate.

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Iron and Manganese Removal by Filtration:

Removing iron and manganese from drinking water instead of sequestration it is recommended if the water contains over 0.3 ppm of iron or 0.05 ppm of manganese. These elements can be removed during softening with lime, but most commonly iron and manganese is removed by filtration after oxidation (with air, potassium permanganate, or chlorine).

Gravity and pressure filters are both used, with pressure filters being the more popular. The operator should frequently check to see that all the iron in the water entering the filter has been converted to the ferric (or insoluble particulate) state. The operator collects a water sample, passes it through a filter paper, and runs an iron test on the clean, filtered water (filtrate).

If no iron is present, it has all been oxidized and is being removed in the filtration process. If iron is found in the filtrate, oxidation has not been complete and some of the iron will pass through the filter and end up in the treated water. In this case, the operator should consider adjustments to the oxidation process.

Most iron removal filters are designed so that the filters are backwashed based on head-loss on the filter. If iron breakthrough is a problem, the filters will have to be backwashed more frequently. Accurate records will reveal when breakthrough is expected so that the operator can backwash before it is likely to occur.