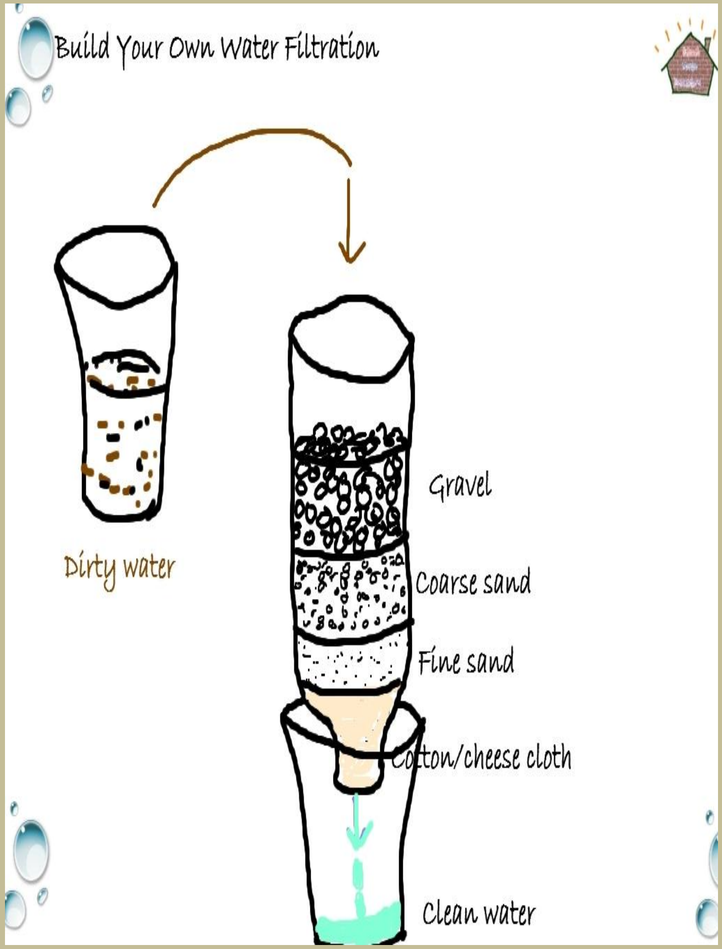
Treatment Processes for Water

Filtration

- The filtration apparatus is a concrete box which contains sand (which does the filtering), gravel (which keeps the sand from getting out) and underdrain (where the filtered water exits)
- After the filter is operated for a while, the sand becomes clogged with particles and must be backwashed
- Flow through the filter is reversed and the sand and particles are suspended
- The particles are lighter than the sand, so they rise up and are flushed from the system. When backwashing is complete, the sand settles down onto the gravel, flow is reversed and the process begins again



Water Treatment processes

By Air Diffusing Method

- In this method supplying ozone treats water. The gas contains oxygen, and it helps in removing carbon dioxide from water.

Example

Surface overflow rate

$$SLR = \frac{Q}{A}$$

$$\frac{10 \times 10^{-3}}{60 \times 10}$$

$= 16.66\ m^3/m^2/day$

Within limit so design is O.K.

Filtration

- Sedimentation removes a large percentage of settleble solids, suspended solids, organic matter and small percentage of bacteria. If coagulation is used more percentage of fine colloidal particles will be removed. But water still contains fine suspended particles, micro-organisms and color. To remove these impurities still further and to produce potable and palatable water, the water is filtered through beds of granular material like sand and gravel. This process of passing the water through the beds of such granular materials is known as filtration.

Filtration

Theory of Filtration

- When water is filtered through the beds of filter media, usually consisting of clean sand, the following action takes place:
- Mechanical Straining
- Sedimentation
- Biological action
- Electrolytic action

Filtration

Mechanical Straining

- Sand contains small pores, the suspended particles which are bigger than the size of the voids in the sand layer cannot pass through these voids and get arrested in them as the water passes through the filter media (sand). Most of the particles are removed in the upper few centimeters of the filter media, these arrested particles forms a mat on the top of the bed which further helps in straining out impurities.

Filtration

Sedimentation

- In mechanical Straining, only those particles which are coarser than the void size are arrested. Finer particles are removed by sedimentation. The voids between grains of filters act like small sedimentation tanks. The colloidal matter arrested in the voids is a gelatinous mass and therefore, attract other finer particle. These finer particle thus settle down in the voids and get removed.

Filtration

Biological action

- When a filter is put into operation and the water is passed through it, during the first few days, the upper layer of sand grain become coated with sticky deposit of decomposed organic matter together with iron, manganese aluminum and silica. After some time there exists a upper most layer of sand a film of algae, bacteria and protozoa etc. this film is called schmutzdecke or dirty skin which acts as an extremely fine messed straining mat. This layer further helps in absorbing and straining out the impurities. The organic impurities present in water become food for micro-organisms residing in the film. Bacteria breakdown the organic matter and convert them into harmless compounds.

Filtration

Electrolytic action

- The sand particles of filter media and the impurities in water carry electric charge of opposite nature, therefore they attract each other and neutralize the charge of each other. After long use the electric charge of filter sand is exhausted, which is renewed by washing the filter bed.

Filter Material

- Sand either coarse or fine, is generally used as filter media. The layers of sand may be supported on gravel, which permits the filtered water to move freely to the under drains and allow the wash water to move uniformly upward.
- **Sand**
- The filter sand should generally be obtained from rock like quartzite and should have following properties:
- It should be free from dirt and other impurities
- It should be of uniform size
- It should be hard
- If placed in hydrochloric acid for 24 hrs., it should not lose more than 5 % of weight.

Filter Material

- Effective size of sand shall be
- (a) 0.2 to 0.3 mm for slow sand filters
- (b) 0.35 to 0.6 mm for rapid sand filter
- Uniformity of Sand
- It is specified by the uniformity coefficient which is defined as the ratio between the sieve size in mm through which 60 % of the sample sand will pass to the effective size of the sand.
- Uniformity coefficient for slow sand filter
- = 2 to 3
- 1.3 to 1.7 for rapid sand filters

Filter Material

Gravel

- The sand beds are supported on the gravel bed. The gravel used should be hard, durable, free from impurities, properly rounded and should have a density of about 1600 kg/ m^3
- The gravel is placed in 5-6 layers having finest size on top.
- Other material
- Other material which can be used are anthracite, Garnet, Sand or local material like coconut husks, rice husks.

Types of Filters

- Filters are mainly classified based upon the rate of filtration as
- Slow Sand Filter
- Rapid Sand Filter
- (a) Rapid sand gravity filter
- (b) Pressure Filter

Types of Filters

Slow Sand Filter

- Slow Sand filter was the earliest type , they were called slow sand filter because the rate of filtration through them is about 1/20th or less of the rate of filtration through rapid gravity filter. Du to low filtration rate, slow sand filters require large area of land and are costly to install. They are expensive to operate due to laborious method of bed cleaning by surface scrapping Due to this slow Sand filters are not used these days.

Types of Filters

- A slow sand filter unit consists of the following parts
- Enclosure tank
- Filter media
- Base Material
- Under drainage system
- Inlet & Outlet arrangement
- Other appurtenances

Types of Filters

Enclosure Tank

- It consist of an open water tight rectangular tank made of concrete or masonary. The bed slope is 1 in 100 to 1 in 200 towards the central drain. The depth of tank varies from 2.5 to 4 m. The plan area may vary from 100 to 200 sq.m. depending upon the quantity of water treated.

Types of Filters

Filter Media

- The filter media consist of sand layers about 90 to 110 cm in depth and placed over a gravel support. The effective size varies from 0.2 to 0.35 and uniformity coefficient varies from 2 to 3. Finer is the sand better is the quality of water.

Types of Filters

Base Material

- The filter media is supported on base size material consisting of 30 to 75 cm thick gravel of different sizes, placed in layers, generally 3 to 4 layers of 15 to 20 cm depth are used.

Types of Filters

Under Drainage System

- The base material are supported over the under drainage system which centrally collects the filter water. The water drainage system consists of a central drain collecting water from a number of lateral drains. The lateral drains are open jointed pipe drains or perforated pipes of 7.5 to 10 cm dia spaced at 2 to 4 m centre to centre.

Types of Filters

Inlet & Outlet

- An inlet chamber, is constructed for admitting the effluent from the plain sedimentation tank without disturbing the sand layer of filter and to distribute it uniformly over filter bed

Types of Filters

Other appurtenances

- Various appurtenances that are generally installed for efficient working are the device for
- Measuring loss of head through filter media
- Controlling depth of water above the filter media.
- Maintaining constant rate of flow through filter.

Filters

Efficiency of Slow Sand Filters

- **Bacterial Load**
- The slow sand filter are highly efficient in removal of bacterial load from water. They remove about 98 to 99 % of bacterial Load from raw water.
- **Color**
- The slow sand filter are less efficient in the removal of color of raw water. They remove about 20 to 25 % color of water.
- **Turbidity**
- The slow sand filter are not very effective in removing colloidal turbidity. They can remove turbidity to the extent of about 50 ppm

Example

- Find the area of slow sand filter required for a town having a population of 15000 with average rate of demand as 160 lpcd.

Example

- Maximum daily demand = 15000 x 160 x 1.5
- = 3600000 lit
- Assume the rate of filtration as 150 lit/hr./m^2, the filter area required will be.
- $= \frac{3600000}{150 \times 24} = 1000\ m^2$

Let the size of each unit of 20 x 10 = 200 m^2

Then total number of unit required would be 5

Provided one unit as stand by, so provide 6 unit of 20 x 10 m

Rapid Sand Filter

- Rapid sand filters were first developed in last decade of 19th century, on an average these filters may yield as high as 30 times the yield given by the slow sand filter. These filters employ coarser sand with effective size around 0.5 mm. Water from the coagulation sedimentation tank are used in these filters.

Rapid Sand Filter

- A gravity type of rapid sand filters consists of following units
- Enclosure tank
- Filter Media
- Base Material
- Under Drainage System
- Other appurtenances

Rapid Sand Filter

Enclosure tank

- It is generally rectangular in plan, constructed either of masonary or of concrete, coated with water proof material. The depth of the tank varies from 2.5 to 3.5 m. Each unit may have a surface area of 10 to 50 m^2. They are arranged in series. The length to width ratio is kept between 1.25 to 1.35.

Rapid Sand Filter

- Following formula is used to get approximately the number of filter unit beds required
- $N = \frac{\sqrt{Q}}{4.69}$

Where N is the number of units or beds and Q is quantity of water in m^3/ hr…. There should be at least 2 units in each plant.

Rapid Sand Filter

Filter media

- The filtering media consists of sand layer, about 60 to 90 cm in depth and placed over a gravel support. The effective size of sand varies from 0.35 to 0.6 mm and the uniformity coefficient ranges between 1.3 to 1.7.

Rapid Sand Filter

Base Material

- The filter sand media is supported on the base material consisting of gravel . In addition to supporting the sand, it distributes the wash water. It total depth varies from 45 to 60 cm. It may be divided into 4 to 5 layers.

Rapid Sand Filter

Under Drainage System

- The under drainage system serves the two purpose
- It collects the filter water uniformly over the area of gravel bed.
- It provides uniform distribution of backwash water without disturbing or upsetting the gravel bed and filter media.

Rapid Sand Filter

- Under drainage should be capable of passing the wash water at a rate of about 300 to 900 lit.min/m^2 . Since the rate application of wash water is much higher then filtration rate, the design of under drainage system is governed by the consideration of even and uniform distribution of wash water.

Rapid Sand Filter

- There are various types of Under drainage System Such as
- Manifold and Lateral
- (a) Perforated & Pipe System
- (b) Pipe and Straining System
- Wheeler System
- Leopald System

Rapid Sand Filter

Manifold and Lateral

- It consist of a manifold running lengthwise along the centre of the filter bottom. Several pipe called laterals taken off in both the direction at right angle to the manifold. The laterals are placed at a distance of 15 to 30 cm centre to centre.

Rapid Sand Filter

- In perforated pipe type of this system, the laterals are provided with holes at the bottom side. These holes are 6 to 12 mm in dia and make an angle 30 0
- Following thumb rules are use in the design of Under drainage System
- Ratio of the total area of the orifice
- Perforation or holes in lateral
- : 0. 15 to 0.5 % perferable about 0.3 %
- Ratio of C/s area of lateral to the area of orifice served 2 to 4:1
- Dia of Orifice : 6 mm to 18 mm
- Ratio of area of manifold to that of the area of lateral served
- 1.5 to 3:1 preferably
- Spacing of Orifices: 7.5 cm for 6 mm dia
- Spacing of lateral 15 to 30 cm
- Length of lateral: not more than 60 times
- Length of lateral > 60
- Dia of lateral

Rapid Sand Filter

Back Washing

- When the clean filter bed is put in to operation, in the beginning the loss of head is very small, but as the bed gets clogged, the loss of head increases, When the head losses becomes excessive, the filtration rate decreases and the filter bed must be washed
- Rapid gravity filters are washed by sending air and water upward through the bed the reverse flow through the underdrainage system

Efficiency and performance of Rapid Sand Filter

Turbidity

- If the influent water does not have turbidity of more than 35 to 40 mg/lit. Since Coagulation and sedimentation always precedes filtration the turbidity of water applied to filter is always less than 35 to 40 mg/lit.

Bacterial Load

- The rapid sand filter are less effective in removal of bacterial load as compare to slow sand filter. They can remove 80 to 90 % of bacterial load

Color

- Rapid sand filter are very efficient in color removal. The intensity of color can be brought down below 3 on cobalt scale.

Iron & Manganese

- Rapid sand filter remove oxidized or oxidizing iron through it is less efficient in removing manganese

Taste & Odor

- Unless special treatment such as activated carbon or pre chlorination is provided, rapid sand filters will not ordinarily remove taste and odor,

Loss of Head & Negative Head

- When a cleaned bed is put into operation, the loss of head through it will be small usually 15 to 30 cm. as the water is filtered through it, impurities arrested by the filter media, due to which the loss of head goes on increasing. A stage comes when the frictional resistance exceeds the static head above the sand bed, at this stage, the lower portion of media and the under drainage system are under partial vacuum or negative head.
- Due to the formation of negative head, dissolved gases and air are released filling the pores of the filter and the under drainage system.
- In rapid sand filter permissible head loss will be 2.5 m to 3.5 m

Comparison of Slow Sand Filter & Rapid Sand Filter

Item	Slow Sand Filter	Rapid Sand Filter
Rate of filtration	100 to 200 lit/ hr./m^2	3000 to 6000 lit/hr./m^2
Loss of head	15 cm to 100 cm	30 cm to 3 m
Area	Requires Larger Area	Requires smaller area
Coagulation	Not Required	Essential
Filter media	Effective Size 0.2 to 0.35 mm Depth 90 to 110cm	Effective size 0.35 to 0.6 mm Depth 60 to 90 cm
Base material	Size 3 to 65 mm Depth 30 to 75 cm	Size: 3 to 40 mm Depth 40 to 65 mm
Method of cleaning	Scrapping the top layer	Agitation and back washing

Comparison of Slow Sand Filter & Rapid Sand Filter

Item	Slow Sand Filter	Rapid Sand Filter
Amount of wash water required	0.2 to 0.6 % of water filtered	2 to 4 % water filtered
Efficiency	Very efficient in the removal of bacteria less efficient in removal of color and turbidity.	Less efficient in removal of bacteria more efficient in the removal of color & turbidity.
Cost	High initial cost	Cheap & economical
Cost of maintenance	Less	More
Skilled Supervision	Not essential	Essential
Depreciation Cost	Relatively low	Relatively high,

Example

- A City has population of 50,000 with an average rate of demand of 160 lpcd find area of rapid sand filters. Also find number of units or beds required.

Example

- Population= 50,000
- Rate of water supply= 160
- Maximum daily demand per day= 1.5 x 160 x 50000
- = 12×10^{6} lit /day
- Assume rate of filtration = 4500 lit /hr./sq.m
- Area of filter beds required= $\dfrac{12 \times 10^{6}}{24 \times 4500}$

= $111.11\ m^{2}$

Example

- Number of filter beds can be found out by
- (i) assuming area of one bed/ unit and then finding out the number of beds/ units required.
- (ii) By using the following eel
- $N = \frac{\sqrt{Q}}{4.69}$

Where, N= No of beds

Q= Quantity of water to be filtered in m^3 /hr…

Example

- $Q = 12$ MLD
- $= \dfrac{12 \times 10^{6} \times 10^{-3}}{24}$

$= 500 \ m^{3}/hr$…

$N = \dfrac{\sqrt{Q}}{4.69}$

$= \dfrac{\sqrt{500}}{4.69}$

= 5 units

Area of each unit = $\dfrac{111.11}{5}$

= 22.22

Example

Assume L:B ratio as 1.3

L= 1.3 B

A= 1,3 B x B

= 22.22= 1.3 B x B

B= 4.13 m

L= 1.3 x 4.13

= 5.369 m

Provide B= 4.2 m and L= 5.4 m

Provide 6 such units one as stand by

Example

- Design a rapid sand filter Unit for supplying 10 MLD to a town with all its principle components

Example

Step-I Design of filter Units

- Water Required per day= 10 MLD
- Assuming that 3 % of filtered water is used for washing of filter every day
- Therefore total filter water required per day
- = 1.03 x 10
- = 10.3 MLD
- $\frac{10.3}{24-0.5}$ = 0.438 ML/hr
- Assuming the rate of filtration as 5000 lit /hr./m ^{2}
- Area of filter required= $\frac{0.438 \times 10^6}{5000}$

= 87.6 sq.

Example

- No of Unis Required
- $N = \frac{\sqrt{Q}}{4.69}$

$= \frac{\sqrt{438}}{4.69}$

= 4.46

= 5

Area of each Unit $= \frac{87.6}{5}$

= 17.52

Assume L/B= 1.3

1.3 B x B= 17.52

B= 3.67= 3.7 m

L= 3.67 x 1.3 = 4.771= 4.8m

Say provide total 6 units of 4.8 m x 3.7 m

Design of Under drainage System

- Laterals & manifold system is used for Underdrainage System
- Let us assume that the total area of perforations in the underdrainage system as 0.3 % of area of filter bed/ unit.
- $\frac{0.3 \times 4.8 \times 3.7}{100} = 0.533\ m^2 = 533\ cm^2$
- Total Area of Laterals= 2 time the area of perforation
- = 2 x 533
- = 1066 cm^2= 0.1066 m^2
- Assume the area of manifold as twice the total area of laterals we have
- Area of manifold= 2 x 0.1066
- = 0,2132 m^2
- = 0.52 m
- Let us provide manifold of 0.55 or 55 cm let the spacing of lateral as 15 cm

Design of Under drainage System

- Hence number of laterals= $\frac{4.8 \times 100}{15}$

= 32 laterals

Hence provide 32 laterals on either side of the manifold

Hence total no of lateral in each filter unit

= 2 x 32 = 64

Length of each lateral=

$\frac{\text{width of filter- dia of manifold}}{2}$

= $\frac{3.7 - 0.55}{2}$

= 1.575 m

Let n be the total no of perforation, each of 12 mm dia in all 64 laterals

Design of Under drainage System

- Total area of perforations= 533 cm^2
- $n \times \frac{\prod (1.2)^2}{4} = 533$

n= 472

No of perforations = $\frac{472}{64}$

= 7.8

Hence provide 8 perforation per lateral

Area of perforation per lateral = $8 \times \frac{\prod \times (1.2)^2}{4}$

= 9.04 x 2 = 18.08 cm^2

Therefore dia of lateral = $\left(\frac{18.8 \times 4}{\prod}\right)^{1/2}$ = 4.8 cm

Hence provide 64 laterals each of 4.8 cm at 15 cm c/c spacing and having 8 perforations of 12 mm dia

Design of Under drainage System

$$\frac{\text{Length of Lateral}}{\text{Dia of Lateral}} = \frac{1.575 \times 100}{4.8} = 32.81 < 60$$

- Also spacing of perforation = $\frac{1.575}{8}$ = 20
-
- Therefore O.K.