



East Central Railway

Office of the
General Manager (Engg)
Hajipur

PCE's CIRCULAR No- 26/2008/WORKS

Sub- FILTRATION OF WATER

Water to be supplied for public use must be potable i.e., satisfactory for drinking purposes from the standpoint of its chemical, physical and biological characteristics. Drinking water should, preferably, be obtained from a source free from pollution. The raw water normally available from surface water sources is, however, not directly suitable for drinking purposes. The objective of water treatment is to produce safe and potable drinking water.

Filtration is a very important process in water treatment. The purpose of filtration is the removal of suspended and colloidal impurities from water by passage through a porous media. Filtration helps in removing turbidity (e.g. silts & clay), colour, odour and pathogenic bacteria from water.

Depending upon the flow rates two types of filters are commonly used for treating public water supply. These are (a) Slow Sand Filters & (b) Rapid Sand Filters.

A third type of filters which works under pressure known as pressure filters are also used for individual industrial needs and swimming pools and isolated colonies.

Thus in general there are three types of filters commonly used for treating public water supply and these are (a) Slow Sand Filters (b) Rapid Sand Filters and (c) Pressure Filters. The differences between these types of filters are brought out together in following tables.

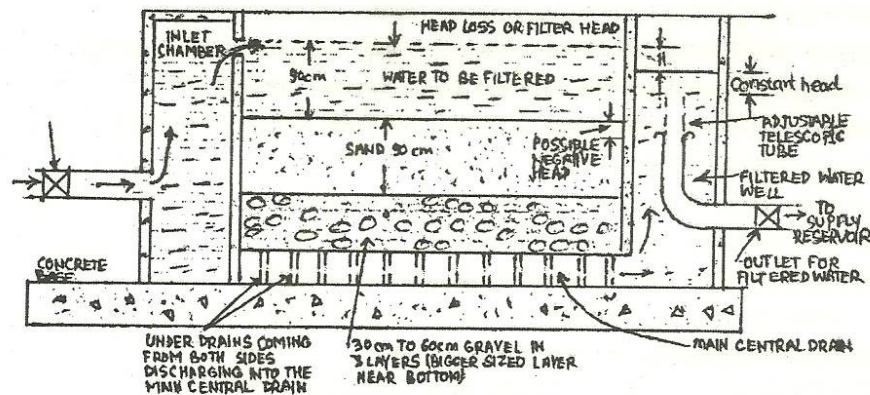
S.No	Item	Slow Sand Filters	Rapid Gravity Filters	Pressure Filters
1	Filtration rate (lit/m ² .h)	100-200	3000-6000	6000-15000
2	Economy	High initial cost of both land materials, but low cost of operation and maintenance.	Low initial cost, but higher cost of operation and maintenance. Overall, it is cheaper and economical.	Very economical for isolated colonies where water demand is not much high.
3	Efficiency	Very efficient in removing bacteria but less efficient in removing colour. Overall turbidity removal in these filters is also low. They can not handle turbid waters containing turbidities more than 50 mg/l.	Less efficient in removing bacteria but very efficient in removing colour. Overall turbidity removal in these filters is high. They can, therefore, handle very turbid waters.	Less efficient than rapid gravity filter.
4	Flexibility	Not flexible for meeting variations in demand	Quite flexible for meeting reasonable variations in demand.	Same as rapid filters

S.No	Item	Slow Sand Filters	Rapid Gravity Filters	Pressure Filters
5	Suitability and adaptability	May be adopted for smaller demand. These filters have become obsolete now a day.	They are widely and almost universally adopted for treating public water supply.	May be adopted for remote & isolated locations, swimming pools etc.

A. SLOW SAND FILTERS

(1) DESCRIPTION

Slow Sand filter can provide a single step treatment for polluted surface water of low turbidity [Less than 20 NTU (Nephelometric Turbidity Unit)] when land, labour and filter sand are readily available at low cost, chemicals and equipments are difficult to procure and skilled personnel to operate and maintain are not available. Crosssectional detail of a slow sand filter is shown in Fig-1 below.



Typical section of slow sand filter.

Fig-1

A slow sand filter consists of an open box about 3.0 m deep rectangular or circular in shape and made of concrete or masonry. The box contains a supernatant water layer, a bed of filter medium, an under drainage system and a set of control valves and appurtenances.

The supernatant provides the driving force for the water to flow through the sand bed and to overcome frictional resistance in other parts of the system. It can also provide a storage of several hours to the incoming water before it reaches the sand surface.

The filter bed consists of natural sand with an effective size of 0.25 mm to 0.35 mm and uniformity coefficient of 3 to 5. For best efficiency, the thickness of filter bed should not be less than 0.4 to 0.5 m. As a layer of 20-30 mm sand will be removed every time the filter is cleaned, a new filter should be provided with an initial sand depth of about 1.0 m. Resanding will then become necessary only once in 2-3 years.

The under drainage system supports the sand bed and provides unobstructed passage for filtered water to leave the underside of the filter.

A system of control valves facilitates regulation of filter rate and adjustments of water level in the filter at the time of cleaning and backfilling when the filter is put back into operation after cleaning.

In a slow sand filter, water is subject to various purifying influences as it percolates through the sand bed. Impurities are removed by a combination of straining, sedimentation, bio-chemical and biological processes. Starting with an average quality of raw water, a properly designed and operated filter can produce a filtrate satisfying normal drinking water standards. Nevertheless, the filtrate should be disinfected to render it safe.

(2) Maintenance of Slow Sand Filter

(a) Filter Cleaning-When the filter has attained the maximum permissible headloss, it is taken out of service for cleaning. The inlet is closed and the supernatant is drained out by opening its drain out valve. When the supernatant is drained out, the water level is lowered to 10-15 cm below the top of the sand bed by opening the scour valve. Without allowing the bed to dry up, the filter is cleaned manually by removing the top layer of 20-30 mm of sand along with the filter skin. The filter is returned to service by admitting through bottom filtered water from the adjacent filter to a level of a few cm above the sand bed before allowing raw water from top. The removed sand is washed, dried and stored for future use.

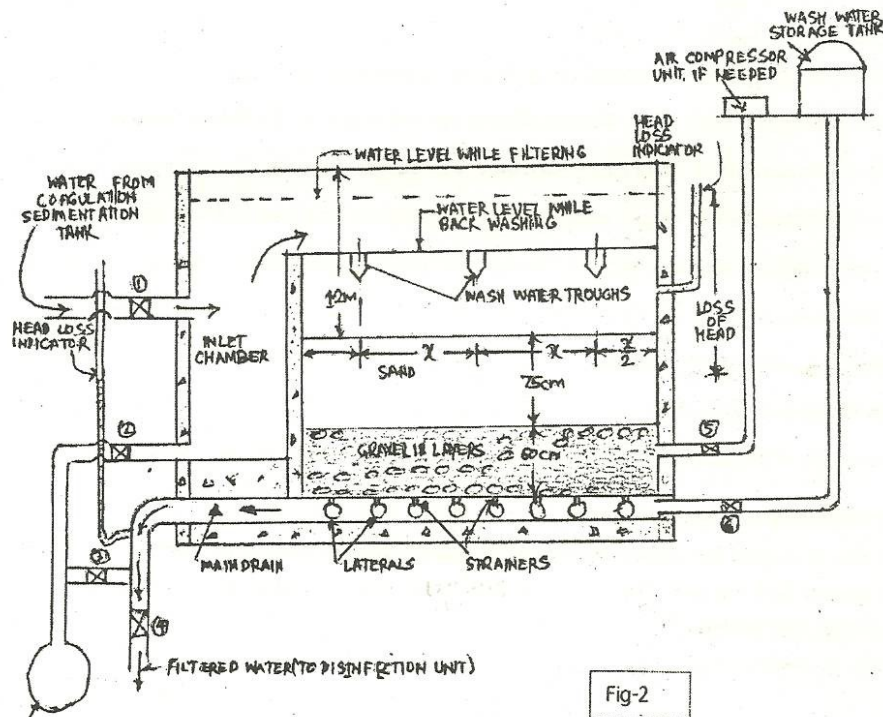
(b) Resanding-Due to periodical cleaning, when the sand depth is reduced to a maximum of 0.4m, it is necessary to make up the sand depth to the original level. This is done by replenishing with a fresh lot of sand, taking care to see that the remaining old sand is placed on top of the new sand. This avoids accumulation of dirt in the deeper layers of filter bed and helps in quick ripening after resanding.

(3) Efficiency and Performance-

The slow sand filters are useful in the sense that they can remove much larger percentage of impurities and bacteria from the water. However, slow sand filters yield a very slow rate of filtration and require large areas, and are costly.

B. RAPID SAND FILTERS

The Rapid Sand Filter comprises of a bed of sand serving as a single medium granular matrix supported on gravel overlying an underdrainage system. The distinctive features of rapid sand filtration as compared to slow sand filtration include careful pretreatment of a raw water to effectively flocculate the colloidal particles, use of higher filtration rates and coarser but uniform filter media to utilize greater depths of filter media to trap influent solids without excessive head loss and backwashing of filter bed by reversing the flow direction to clean the entire depth of filter. Crosssectional detail of a Rapid Sand Filter is shown below in Fig-2



(1) Component of Rapid Sand Filters.

It can be briefly divided into two main components:

(a) The Pretreatment units & (b) Filter Units

(a) The Pretreatment units- The pretreatment units which form essential parts of a Rapid sand filtration unit include

- (i) Coagulation and flocculation with rapid mixing facilities and
- (ii) Sedimentation units.

(i) COAGULATION AND FLOCCULATION

The purpose of coagulation and flocculation is to remove particulate impurities, especially non-settleable solids (particularly colloids) and colour from the water being treated. Non-settleable particles in water are removed by the use of coagulating chemicals. The most commonly used coagulant is ferric alum. However, Poly Aluminum Chloride (PAC) is also used as a coagulant. Coagulation is a physical and chemical reaction occurring between the alkalinity of the water and the coagulant added to the water, which results in the formation of insoluble flocs. The most important consideration is the selection of the proper type and amount of coagulant chemical to be added to the water to be treated. Overdosing as well as underdosing of coagulants may lead to reduced solids removal efficiency.

(ii) SEDIMENTATION

The purpose of sedimentation process is to remove suspended particles so as to reduce load on filters. If adequate detention time and basin surface area are provided in the sedimentation basins, solids removal efficiencies greater than 95% can be achieved. However, high sedimentation basin removal efficiencies may not always be the most cost effective way to remove suspended solids.

(b) Filter units.

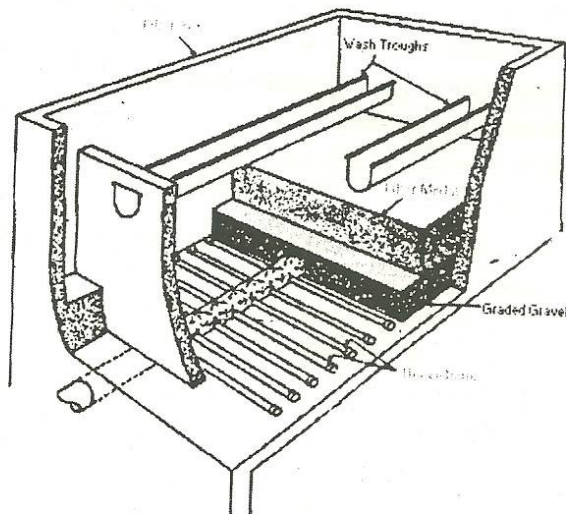


Fig-3

Fig-3 Showing various parts of Rapid Sand Filters

(i) Enclosure Tanks or Filter Box-

- i. It consists of open water tight rectangular tank made of masonry or concrete with length and breadth in ratio of in the range of 1.25 to 1.33.[Figure-3]
- ii. A minimum overall depth of 2.60m including a free board of 0.50m is adopted.

- iii. The depth of the tank may vary from 2.60m to 3.50m.
- iv. The area of the filter units is limited to 10-80 Sq.M for each unit.
- v. The numbers of units of a filter plant may be calculated as

$$N = 1.22 \times \text{Sq root of } (Q)$$
 Where N= No of filter unit and Q= Plant capacity in million liters per day.
- vi. There should be at least 2 filter units in any plants.
- vii. For a plant of more than 9 million liters per day capacity, no single unit should have capacity greater than 1/4 th of the capacity of that plant.

(ii) Filter Media.

- i. The filtering media consists of sand layers about 600-750 mm in depth and placed over a gravel support.
- ii. Sand shall be of hard and resistant quartz or quartzite and free of clay, fine particles, soft grains and dirt of every description.
- iii. Effective size(D₁₀) shall be 0.45 to 0.70 mm
- iv. Uniformity co-efficient (D₆₀/D₁₀) shall not be more than 1.7 nor less than 1.3
- v. Ignition loss should not exceed 0.7% by weight.
- vi. Soluble fraction in hydrochloric acid shall not exceed 5% by weight.
- vii. Silica content should not be less than 90%.
- viii. Specific gravity shall be in the range of 2.55-2.65
- ix. Wearing loss shall not exceed 3%
- x. The sand must be laid in layers. the finer variety should be used towards the top and coarser variety towards the bottom [IS: 8419(Part I) -1977]

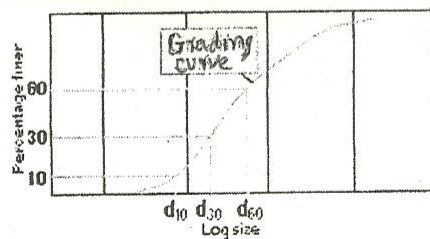


Fig-4

(iii) Base Materials

- i. Gravels are being used as base materials and is placed between sand and the under drainage system to prevent sand from entering the under drains and to aid in uniform distribution of wash water.
- ii. The filter gravel shall be as spherical as possible, hard, clean and uniform in quality and also shall not contain such impurities as dirt and clay.
- iii. For strainer or wheeler type under drain system, gravel shall be of 2mm minimum size, 50mm maximum size and 300-500 mm deep.

- iv. For perforated pipe under drain system gravel shall be 2mm minimum size, 25mm maximum size and 500mm in depth.
- v. Generally gravels are placed in layers of about 100mm thick. The coarsest gravels are used in bottom layers and finest gravels are used in top layers. [IS: 8419(Part I) -1977]

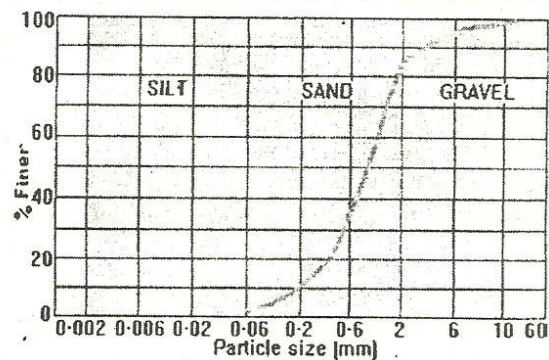


Fig-5

(iii) Under Drainage System

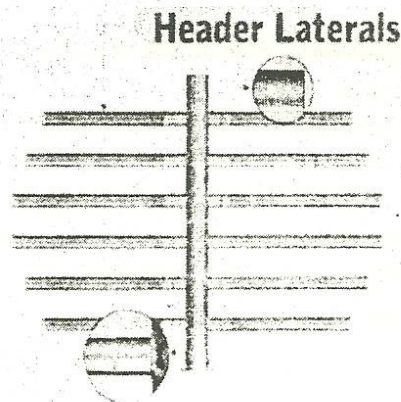


Fig-6

The under drainage system [Fig-6] of the filter is intended to

- (i) Collect the filtered water
- (ii) To distribute the wash water in such a fashion that all portions of the bed may perform nearly the same amount of work and when washed, receive nearly the same amount of cleaning. Since the rate of wash is several times higher than the rate of filtration, the former is the governing factor in the hydraulic design of the filters which are cleaned by the back washing.

The most common type of under-drain is a central manifold with laterals either perforated on the bottom or having umbrella type strainers on top.

In the case of central manifold with lateral system [Fig-7] the manifold, headers and laterals are of cast iron, plastic, asbestos cement, concrete or other materials. The following values, may be used in design of an under drain system consisting of central manifold and laterals

- (i) The perforations vary from 5-12 mm in diameter and should be staggered at a slight angle from the vertical axis of the pipe.
- (ii) Spacing of perforations along the laterals may vary from 80 mm for perforations of 5 mm to 200 mm for perforation of 12 mm.
- (iii) Ratio of total area of perforation in the under drain system to total cross sectional area of lateral should not exceed 0.5 for perforations of 12 mm and should decrease to 0.25 for perforations of 5 mm.
- (iv) Total area of perforation may be taken as 0.3% of the entire filter area.
- (v) The ratio of length to diameter of the lateral should not exceed 60.
- (vi) The spacing of laterals closely approximate the spacing of the orifices and shall be max 300 mm.
- (vii) The cross sectional area of the manifold should be preferably 1.5 to 2 times the total area of the laterals to minimize the frictional losses and to give the best distribution.
- (viii) The laterals drains are supported on concrete blocks of about 40-50 mm thickness, and placed on the floor of the filter.
- (ix) The maximum permissible velocity in the manifold to provide the required amount of wash water is about 1.80 to 2.40 m/sec
- (x) In perforated pipe type of this system lateral drains are provided with holes at the bottom side. These holes are at an angle of 30 degree with the vertical.
- (xi) In pipe and strainer type of this system, the laterals are attached to the manifold as in the perforated pipe system, but holes are not drilled into laterals. Instead of drilling holes, strainers are placed on the lateral drains. A strainer, in its simplest form, is a small brass pipe closed at its top by a perforated cap.

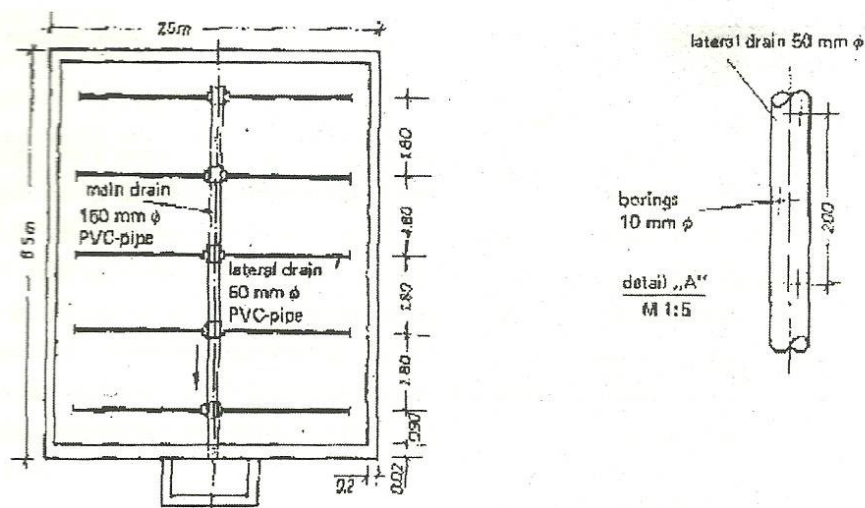


Fig-7

(v) Wash Water Gutters

The dirty wash water, which comes out of the filter after cleaning is collected in wash water gutters and carried to the main gutter.

- (i) These gutters may be either of square shaped or semi circular. They may be of cast irons, concrete, steel or wrought iron.
- (ii) The top of the gutters are kept at least above the sand bed by a distance of about half the depth of the sand.
- (iii) The bottoms of the gutter should clear the top of the expanded sand by 50 mm or more.
- (iv) These gutters are generally spaced at about 1.50- 2.00 m
- (v) For efficient working, these gutters should be sufficiently large enough and should be laid at suitable slopes. These are designed as free falling weirs or spillways.
- (vi) For free falling rectangular gutter with level invert the discharge capacity Q in cum/sec may be computed by the formula

$$Q = 1.376 \cdot B \cdot (H)^{3/2}$$

Where B & H is the width & depth of the gutter in m respectively

(vi) System for High Rate Back Wash

Back wash should be arranged at such a pressure that sand should expand to about 130-150% of its undisturbed volume. The pressure at which the wash water is applied is about 6-8 m head of water as measured in under drains with the wash water requirement being 40-50 Cum/hour/per Sq.M for duration of 6-10 minutes.

The supply of wash water can be made through an over head tank or by direct pumping or by tapping the rising main of the treated water if the clear water motors are not over loaded. The capacity of storage

tank must be sufficient to supply wash water to two filter units, at a time, where the units are four or more.

(vii) System for Surface Wash

The rapid gravity filters are conventionally cleaned by back washing. However it has been found that there is lack of abrasion during water backwash and therefore a backwashing with water alone is inherently a weak cleaning. The upper layer of the filter bed becomes the dirtiest and any inadequate washing will lead to the formation of mud balls, cracks and clogged spots in the filters. For effective cleaning, abrasion resulting from collision, between grains is achieved by auxiliary process like surface wash. Surface wash may be used to supplement the back wash. Adequate surface wash can be accomplished by stirring the expanded filter bed mechanically by rakes, hydraulically with jets of water directed into the suspended sand or pneumatically with air. The latter two methods being common are as below.

a. Hydraulic System

The fixed type surface wash system shall consists of pipes not less than 25 mm diameter arranged vertically at intervals of 0.60 m to 0.90 m. The lower ends of the pipes are to be situated to 0.10m approx over the sand surface and nozzles shall be located on the lower ends of pipes. An alternate fixed type may consist of piping horizontally arranged at intervals of 0.60 m approximately at a height of 50-100 mm over the sand surface. The horizontal pipe shall be perforated at intervals of 300 mm approximately and provided with non clogging orifice units to prevent entry of filter media

The rotary type shall consist of rotating units suspended at a height of 50 mm to 75 mm at adequate intervals over the bed to provide complete coverage. Jet nozzles shall be located on side and bottom of arms and jet action of water causes the arms to rotate at a rate of 7-10 RPM.

b. Air Wash System

In the Air wash system compressed air are being forced through the under drain before the wash water is forced through a separate piping system placed between the gravel and the sand layer. Though the former results in better washing, the gravel is likely to be disturbed. With the former procedure, free air of about 36-45 m³/hr (600-900 lpm/Sq.m of the filter area) at 0.35 Kg/Sq.Cm is forced through the under drains until the sand is thoroughly agitated, for a duration of 5 minutes, following which wash water is introduced through the same under drains at a rate of 24-36 m³/hr (400-600 lpm/Sq.m of area). On the other hand with the latter procedure while water is forced through the under drains, about the same volume of air is forced simultaneously through a separate piping. In the practice of back washing employing conjunctive air and water wash, air is usually applied at a rate of 45-50 m³/hr and water at 12-15 m³/hr. This system is used when pipe and strainer system is being used in under drainage.

(viii) Appurtenances

Filter appurtenances includes manually, hydraulically or electrically operated sluice valves on the influent, effluent, drain and wash water lines, measuring devices such as venturimeters, rate controllers activated by measuring devices, loss of head and rate of flow gauges, sand expansion indicators, wash water controllers and indicators, operating tables and water sampling devices, ejectors and sand washers, wash water tank and pumps.

(i) Rate of flow Controllers

The primary function of rate of flow controller is to regulate the flows of liquid in the lines and specifically in filter plant to maintain at all times a uniform rate of filtration through each filter unit. Without these control features in the filter effluent lines, raw water will pass through the sand bed at different velocities, higher when the sand bed is clean and lower when the coagulated deposit has accumulated on its surface.

Sudden change of rate of flow also must be avoided if the filter medium is to be maintained in an unbroken and efficient condition. Any change in rate must be gradual and predetermined maximum must not exceeded. Such unfavorable operating conditions may be eliminated by the use of rate of flow controller.

The most commonly used type of a controller is a venturi- rate controller which works on the principle of venturimeter. The flow can also be controlled by means of a V-notch or a rectangular weir.

(ii) Filter Gauges.

Filter gauges are essential for the operation of the modern filter plant in order to measure accurately the rate of flow through each filter box and to determine the loss of head occurring at any governing time during the filter run. These gauges use the float and mercury principle for the conversion of differential pressure into measurement of loss of head or rate of flow.

(iii) Sand Expansion Gauges

Properly designed sand expansion gauges accurately determine the correct % of sand expansion and the proper washing cycle for each filter bed. In some plant the expansion of sand is not given emphasis and the fluidization is checked by means of probing with a vertical rod during the backwash cycle to see whether the probe will easily go down to the gravel.

(ix) Pipe Gallery

The influent, effluent, wash and waste water pipes together with rate controllers and appurtenances are placed in pipe gallery. Galleries should be well designed to provide adequate space, ventilation drainage and easy accessibility to all pipe work and other fittings.

2. OPERATION OF RAPID SAND FILTERS

OPERATIONAL TROUBLES

A filter is usually operated until just before clogging or breakthrough occurs or a specified time period has passed (generally 24 hours). Followings are the common troubles which are generally encountered during the operation of rapid gravity filters

- a) Air Binding
- b) Formation of mud balls
- c) Cracking of filters

a) Air Binding

The water percolating through the filter moves downward under the force of gravity. The motion is opposed by the resistance offered by the sand grains and the impurities arrested in them. The percolating water, therefore, loses some of its head. When the filter is newly commissioned the loss of head is generally small and is of the order of 15 cm to 30 Cm. However loss of head goes on increasing as the time passes, and as more and more impurities get trapped into it. A stage is finally reached when the frictional resistance offered by the filter media exceeds the static head of water above sand bed. Most of this resistance is caused by the top 10 to 15 cm of sand layer. The bottom sand then acts like more or less a vacuum, and water is sucked through the filter media rather than getting filtered through it. The fall of mercury level in the piezometer inserted in the outlet pipe below the centre line of pipe indicates the presence and extent of the negative pressure. The negative pressure so developed, tends to release the dissolved air and other gases present in the water. The formation of bubbles takes place which sticks to the sand grains, and thereby seriously affecting the working of the filter. The phenomenon is known as **Air Binding**, as the air binds the filters and stops its functioning, thereby reducing the rate of filtration considerably.

In order to avoid such troubles, the filters are cleaned as soon as the loss of head exceeds the optimum allowable values. On an average loss of head is generally limited to 2.5 to 3.5 m and the negative head to about 1.2 m

b) Formation of mud balls

The mud from the atmosphere generally accumulates on the sand surface, so as to form a dense mat. During inadequate washing of the filter, this mud may sink down into the sand bed. This mud then sticks to the sand grains and other arrested impurities, thereby forming mud balls. These mud balls slowly and steadily go on increasing in size and weight. They may then sink down into the gravel, thus interfering with the upward movement of wash water during cleaning. They cause turbulence around them and thus hinder with the uniform application of wash water. The high velocities created around the edges of these balls, also displace the gravels, and thereby forming mounds. When these balls moves during washing the sand around these balls gets improperly washed and further mud accumulates. Thus when once the mud ball formation starts, they go on increasing in number, until the entire space in the filter box gets filled up with them.

The surface washing is very successful in eliminating mud ball formation. They may otherwise reduced or removed by

- Breaking them up with rakes or such equipments and then washing off the particles.
- Washing the filter with a solution of caustic soda or some other such chemicals.
- Removing, cleaning and replacing the damaged sand.

c) Cracking of Filters

The fine sand contained in the top layers of the filter bed shrinks and causes the development of shrinkage cracks in the sand bed. These cracks are more prominent near the wall junctions. With the use of filter there is loss of head and, therefore, the pressure on the sand bed goes on increasing, which further goes on widening these cracks. The flocks, mud and other impurities arrested in the filter, penetrate deep into the filter through these cracks and thus impairing both the washing of the filter and efficiency of filtration.

The remedial measures for these consequent troubles are same as are adopted for preventing mud ball formation.

3. EFFICIENCY & PERFORMANCE OF RAPID SAND FILTERS

Rapid sand filters as compared to slow sand filters are less efficient in removing bacteria (80-90%) but very efficient in removing colour. The overall turbidity removal in these filters using coagulation sedimentation is also high. They can, therefore, handle very turbid waters. These filters are almost universally adopted for treating public water supplies. The treated water are, however not so much safe as those obtained from slow sand filters and need further treatment (Disinfection) before they can be supplied to general public.

(i) The indicators of Normal Operating Conditions

The filter influent and effluent turbidities should be closely watched with a turbid meter. Filter Influent turbidity levels (settled turbidity) can be checked on a periodic basis at the filter or from the laboratory sample tap. However, the filter effluent turbidity is best monitored and recorded on a continuous basis by an on-line turbidimeter.

(ii) Important process activities and Precautions.

- a) Monitoring process performance is an ongoing activity. One should look for and attempt to anticipate any treatment process changes or other problems that might affect filtered water quality, such as a chemical feed system failure.
- b) Measurement of head loss built up in the filter media will give a good indication of how well the solids removal process is performing. The total designed head loss from the filter influent to the effluent in a gravity filter is usually about 3 meters. At the beginning of the filtration cycle the actual measured head loss due to clean media and other hydraulic losses is about 0.9m. This would permit an additional head loss of about 2.1m due to solid accumulation in the filter.
- c) The rate of head loss built up is an important indication of process performance. Sudden increase in head loss might be an indication of surface sealing of the filter media (lack of depth

penetration). Early detection of this condition may permit to make appropriate process changes such as adjustment of chemical filter and feed rate or adjustment of filtration rate.

- d) Monitoring of filter turbidity on a continuous basis with an on-line turbidimeter is highly recommended. This will provide continuous feed back on the performance of the filtration process. In most instances it is desirable to cut off (terminate) filter at a predetermined effluent turbidity level. Preset the filter cutoff control at a point where it is experienced and tests show that breakthrough will soon occur.
- e) In the normal operation of the filter process, it is best to calculate when the filter cycle will be completed on the basis of the (a) Head loss (b) Effluent turbidity level (c) Elapsed run time. A predetermined value is established for each guideline as a cut off point for filter operation. When any of these levels is reached, the filter is removed from service and backwashed.
- f) At least once a year one must examine the filter media and evaluate its overall condition. Measure the filter media thickness for an indication of media loss during the backwashing process. Measure mud ball accumulation in the filter media to evaluate the effectiveness of the overall backwashing operation.
- g) Routinely observe the backwash process to qualitatively assess process performance. Watch for media boils (uneven flow distribution) during backwashing, media carry over into the wash water trough, and clarity of the waste wash-water near the end of the backwash cycle.
- h) Upon completion of the backwash cycle, observe the condition of the media surface and check for filter sidewall or media surface cracks. One should routinely inspect physical facilities and equipment as part of good housekeeping and maintenance practice. Correct or report the abnormal equipment conditions to the appropriate maintenance personnel.
- i) Never bump up a filter to avoid backwashing. Bumping is the act of opening the backwash valve during the course of a filter run to dislodge the trapped solids and increase the length of filter run. This is not a good practice.
- j) Before starting a filter it is backwashed at increasing rates until the sand bed has been stratified vertically by the wash water which carries various sizes of sand to different levels. The filter run of rapid gravity filters depends on several attendant factors. It is necessary to calculate the total loss of head in backwashing to arrive at the pump capacity and staging height of back wash water reservoir. The total loss of head includes loss due to expansion of sand, loss in orifices or under drainage system, loss in incoming pipe and height of wash water gutter with respect to under drainage system. The loss of head immediately after washing should not exceed 0.3 m. The finer the sand or the greater the rate of filtration, the greater the initial loss. The head loss builds as the filter grows dirty during a run. It is usual to allow

a filter head loss of 1.8m to 2.0 M before cleaning such filters. Under no circumstances, a build up of negative head within the filter media be allowed.

- k) The duration of the washing process varies for different conditions of cleaning of the filter, sizes and character of the filter media, rate of wash and the desired quality of filtrate. It should not normally exceed 10 minutes
- l) In a properly operated plant, the quantity of wash water used should not exceed 2% of the total amount of water filtered. Following the washing process, it is usually advisable to waste first few minutes of flow through the filter, unless the quality of the filter effluent immediately following the wash may make this unnecessary. A turbidity of 1.0 NTU or less is the best criteria of the stability of effluent of a freshly washed filter.
- m) The water standing on the bed at the close of wash should be clear with a turbidity not exceeding 10 NTU. In a well designed and operated filter, there should be no air binding either during filtration or during washing, there should be no carry away of sand with the washed water and the sand bed should settle down fairly uniformly without undulations. Formation of mud balls and their retention in the bed even after washing indicates poor performance.

Design Example

Design of a rapid sand filter unit for 2 lakh gallons per day supply with its entire principal component.

Water required per day = 200000 gallon

$$= 200000 \times 4.546 = 909200 \text{ liters}$$

Add water requirement per day for filtration (Back washing etc) = $0.05 \times 909200 = 45460$ liters

Total filtered water required per day = $909200 + 45460 = 954660$ liter

Assuming that 0.5 hr is lost every day in washing out of 8 pumping hours

Filtered water required per hour = $954660 / 7.5 = 127288$ l/hr

Now assuming rate of filtration as 5000 litre/Hr/Sq.M

The area of filter required = $127288 / 5000 = 25.4576$ Sq.M

Assuming $L = 1.33B$ and two filter unit

$$2 \times B \times 1.33B = 25.4576$$

$$B = 3.09 \text{ m} \quad \text{Say } 3.00 \text{ M}$$

$$L = 4.25 \text{ M}$$

Hence provide two filter units each of $4.25 \text{ m} \times 3.00 \text{ M}$

Design of Under Drainage system

Provide manifold and lateral system below the filter bed for receiving the filtered water

Assuming Area of perforation is equal to 0.3% of filter area.

$$\text{Total area of perforations} = 0.3 \times (4.25 \times 3.00) / 100 \text{ Sq.M} = 0.03825 \text{ Sq.M}$$

Assuming the area of each lateral = $2 \times \text{area of perforation}$ (12mm dia)

$$\text{Total Area of laterals} = 2 \times 0.03825 \text{ Sq.M} = 0.0765 \text{ Sq.M}$$

Assuming area of Manifold = $2 \times \text{Area of laterals} = 2 \times 0.0765 \text{ Sq M}$

If D is the dia of manifold then

$$\pi/4 D^2 = 2 \times 0.0765$$

$$D = 0.441 \text{ m} \quad \text{Say } 0.45 \text{ M}$$

Hence use 450 mm dia manifold pipe laid length wise along the central line of the filter bottom. Laterals running perpendicular to the manifold emanating from the manifold may be laid at a spacing of 200 mm (Max spacing 300 mm).

Hence number of laterals is then given by $4.25 \times 1000 / 200 = 21.25$

Say 22 on either side of the manifold. Hence use 44 laterals in all in each unit.

Now length of each lateral = $\text{Width of filter} / 2 - \text{Dia of Manifold} / 2$

$$= 3000 / 2 - 450 / 2 = 1275 \text{ mm}$$

Now adopting 12 mm dia perforations in the laterals we have total area of perforations = 0.03825 Sq M

If X is the total number of perforation in all laterals then

$$X \times \pi/4 \times 0.012^2 = 0.03825$$

$$X = 338.2 \quad \text{Say } 340$$

Hence Number of perforation in each laterals = $340/44 = 7.72$ Say 8

Area of perforation in each laterals = $\pi/4 \times 12^2 \times 8 = 904.778 \text{ Sq.mm}$

Now area of each lateral = $2 \times \text{Area of perforation per lateral}$
 $= 2 \times 904.778 \text{ Sq.M}$

If d is the dia of each lateral Then d = 48 mm Say 50 mm

Hence use 44 laterals of 50 mm dia @ 200 mm c/c each having 8 perforations of 12 mm size with 450mm dia manifold.

Length of each laterals/Dia of lateral = $1325/50 = 26.50 < 60$ (O.K)

Now let us assuming that the rate of washing of the filter be 0.45 M rise /Minutes

Hence the wash water discharge = $0.45 \times 4.25 \times 3.00/60 \text{ cum/sec}$
 $= 0.095625 \text{ cum/Sec}$

Velocity of flow in laterals = $0.095625/44 \times [\pi/4 \times 0.05^2 \times 0.05]$
 $= 1.107 \text{ M/sec}$

- Similarly velocity in manifold = Discharge/Area
 $= 0.095625/[\pi/4 \times 0.45^2 \times 0.45]$
 $= 0.60 \text{ M/sec}$ which is less than 1.8-2.4 m/sec (Max permissible) hence

OK

Design of wash water gutters

Spacing 1.5-2.0 m apart

So in a length of 4.25 m let us provide 3 gutter at $4.25/3 = 1.416 \text{ m}$ apart

Now the total wash water discharge of 0.095625 cum/sec enters in 3 troughs

Hence Discharge in each trough = $0.095625/3 = 0.032 \text{ cum/sec}$

The dimension of flat bottom trough may be calculated by formula

Take B = 200 MM

$$Q = 1.376 \times B \times H^{3/2}$$

$$0.032 = 1.376 \times 0.20 \times H^{3/2}$$

$$H = 0.238 = 240 \text{ mm}$$

Keeping 60 mm free board H = $240 + 60 = 300 \text{ mm}$

- Hence 3 No wash water gutter of size 300 mm x 200 mm may be used.

C. PRESSURE FILTERS

Pressure filters are just like small rapid gravity filters placed in a closed vessel working on the same principle as that of rapid gravity filters and through which water to be treated is passed under pressure. Since water is forced through such filters at a pressure greater than the atmospheric pressure (normally vary between 3 to 7 Kg/cm²), it is necessary that these filters are located in air tight vessels, usually made of steel or cast iron, wherein the underdrain, gravel and sand are placed. They are compact and can be prefabricated and moved to site.

The vessel may be installed either in a horizontal or in a vertical position depending upon which they may be classified as Horizontal pressure filters or Vertical Pressure filters. Generally steel cylinders are being used and may be riveted or welded. Their diameters generally vary between 1.5 to 3.0 m and their lengths or height may vary from 3.5 to 8.0 m. Inspection windows are provided at top for inspection purposes. Crosssectional detail of a pressure filter is shown in Fig-8 below.

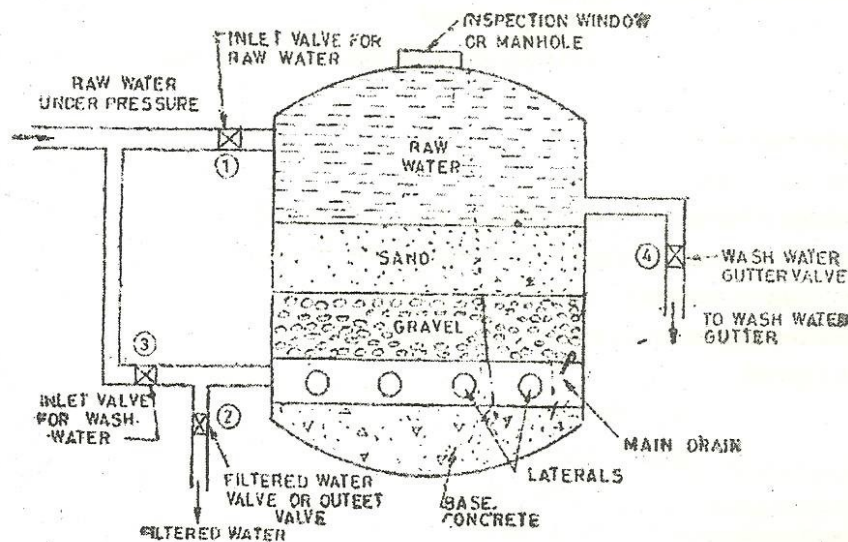


Fig-8

Vertical pressure filter.

(a) Working and Operation

The pressure filters are operated like an ordinary rapid gravity filter except that the raw coagulated water is neither flocculated nor sedimented before it enters the filter. The flocculation takes place inside the pressure filter itself. A general arrangement is shown in Fig-9 below. The commonly used coagulant is alum and is kept in a pressure container connected to the influent line to the filter. Little time is thus available for this coagulant to get mixed properly or to form flock outside the filter vessel

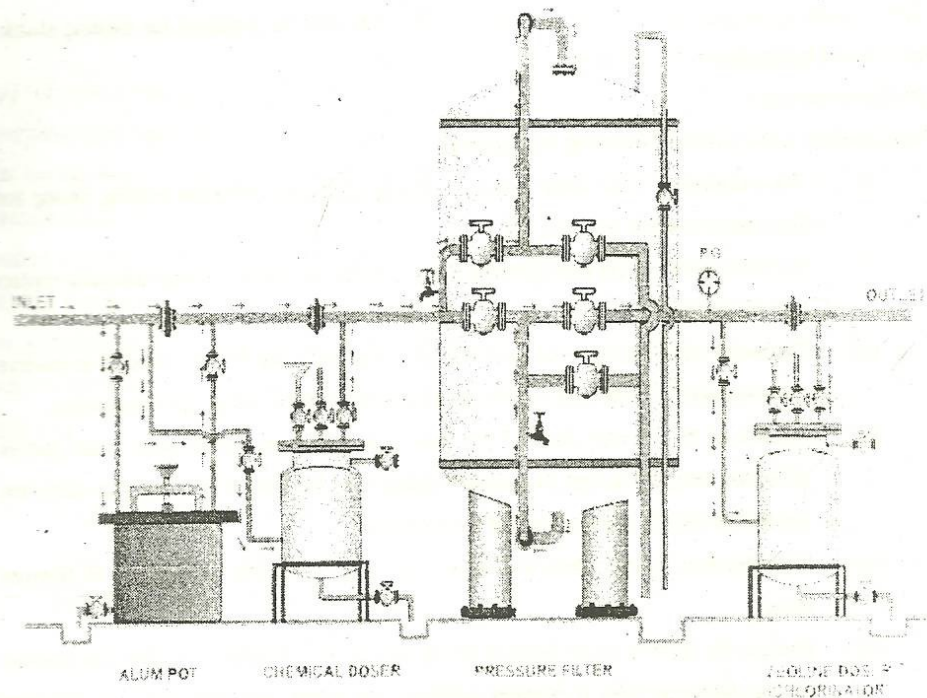


Fig-9

The cleaning of the filter may be carried out by back washing as is done in a normal rapid gravity filter. Pressure filter may require a slightly more frequent cleaning as compared to that required by ordinary rapid gravity filters, because the impurities, which are removed in the sedimentation tank in case of rapid gravity filters, are also removed by the filters in case of pressure filters. Compact automatic pressure filters in which the cleaning is done automatically at a predetermined interval of time or loss of head are now a days available.

(b) Rate of Filtration

The pressure filters can yield filtered water at a rate 2 to 5 times than what can be obtained by ordinary rapid gravity filters. Their rates of filtration normally range from 6000 to 15000 liters per hour per sq.m of filter area. The lower rates are used for domestic supply, medium rates for industrial supplies and higher rates for recirculating swimming pool supplies.

(c) Efficiency & Suitability

The pressure filters are less efficient than rapid gravity filters in removing bacterias and turbidities. The quality of their effluent is poorer and they are generally not used for public supplies. But since a pressure

filter provides a compact and an easy handling machine they may be preferred for treating smaller quantities of comparatively clearer water.

(d) Disadvantages

Pressure filters suffers from the following disadvantages:

- (i) The treatment of water under pressure seriously complicates effective feeding, mixing and flocculation of water to be filtered.
- (ii) In case of direct supply from pressure filters, it is not possible to provide adequate contact time for chlorine.
- (iii) The water under filtration and sand bed are out of sight and it is not possible to observe the effectiveness of the back wash or the degree of agitation during washing process.
- (iv) Because of the inherent shape of the filters it is difficult to provide wash water gutters effectively designed so that the material washed from the sand is discharged to waste and not flushed back to other portions of the sand bed.
- (v) It is difficult to inspect, clean and replace the sand, gravel and under drains of pressure filters.
- (vi) Because the water is under pressure at the delivery end, on occasions when the pressure on the discharge main is released suddenly, the entire sand bed might be disturbed violently with disastrous results to the filter effluent.

In view of these disadvantages pressure filters are not recommended for large scale community water supplies. They may be used for industrial needs, isolated small colonies and swimming pools.

CONCLUSIONS

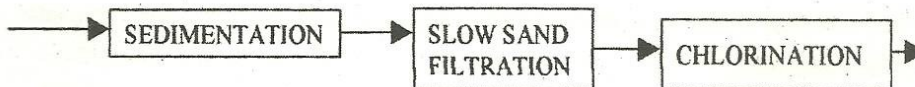
(a) From the details as elucidated in respect of slow sand filter, rapid gravity filter and pressure filter it is concluded that rapid gravity filter is most suited among three types of filtration system. Moreover with the advancement of disinfection techniques, the necessity of too much purification and that of 100% removal of bacteria has decreased, and, therefore, slow sand filters are becoming obsolete these days. In modern treatment plant rapid gravity filters are now a days almost universally adopted.

(b) The flow diagram showing different unit operation of water treatment is shown below. The choice of any particular sequence of treatment units will depend not only on the qualities of the raw water available and treated water desired but also on the comparative economics of alternative treatment steps applicable.

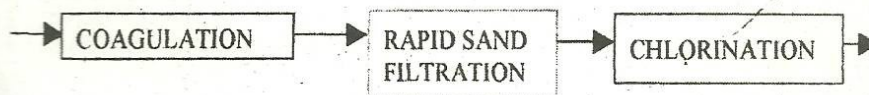
- i. In case of ground water and surface water with storage which is well protected, and in case water has turbidity below 10 NTU and also they are free from odour and colour, only plain disinfection by chlorination should be adopted as shown below.



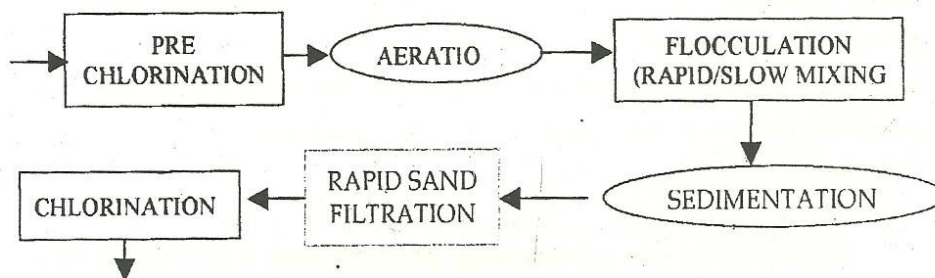
- ii. If sufficient area is available and turbidity of surface water not exceeding 50 NTU plain sedimentation followed by slow sand filtration and disinfection are practised.



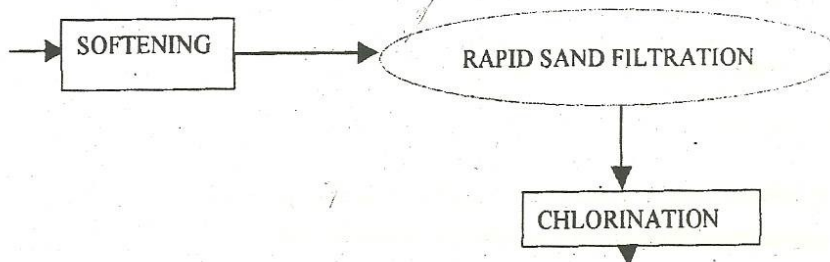
- iii. If the water turbidity is low (less than 10-15 NTU) but it contains low concentration of suspended matter (less than 50 mg/l) raw water should be treated with rapid sand filters along with coagulation as shown below.



iv. In case of highly polluted surface water with algae or other microorganisms prechlorination, aeration, flocculation, sedimentation, rapid gravity filtration and post chlorination should be as shown below.



v. Water with excessive hardness needs softening.



vi. For removal of dissolved solids, demineralization by ion exchange may form a part of the water treatment unit.

