Water treatment - unit III

Objectives of water treatment:

(i) To remove the different impurities present in raw water.
(ii) The treated water should meet the water quality standard for which purpose (drinking, agricultural, industrial purposes), it is used.
(iii) Reduction of the corrosive properties of water which affect the carrying capacity and life of pipe conduits.

Selection of treatment process:

(i) Ability to meet the water quality objectives, satisfying the water standards considering both seasonal and long-term changes in raw water quality.
(ii) Topography and site condition, land area available, hydraulic requirement.
(iii) Flexibility and simplicity in operation.
(iv) Availability of skilled operation and maintenance personnel, major equipment & chemicals.
(v) Ease of construction facilities.
(vi) Economics of construction & operation.

**Methods of Purification of Water:**

The various methods or the techniques which may be adopted for purifying the public water supplies are:

(i) Screens.
(ii) Plain sedimentation.
(iii) Sedimentation aided with coagulation.
(iv) Filtration.
(v) Disinfection.
(vi) Aeration.
(vii) Softening.
(viii) Other advanced treatment such as fluoridation, re-carbonation, liming desalination, etc.

Aeration:

It is a process of inducing oxygen for the raw water.

Due to aerobic process, the microbes, pathogens will decrease in the water.
Screening (Coarse + Fine Screens).

Screens are generally provided in front of pumps or intake works so as to exclude large sized particles such as debris, animals, branches, bugs, etc. Coarse screens are placed in front of fine screens. Coarse screen consist of parallel iron rods placed vertically or at a slight slope at about 2 to 10 cm to centre. The fine screens are made up of fine wire or perforated metal with openings less than 1 cm wide.

The coarse screen first remove big bigger floating bodies and the organic solids and the fine screens remove fine suspended solids.

The fine screen normally get clogged and are to be cleaned frequently so these are avoided now a days by fine, test house are avoided now a days) the fine particles are removed by sedimentation.
The coarse screens are also now normally kept inclined at about 45-60° to the horizontal, so as to increase the opening area to reduce the flow velocity and thus make the screening more effective. While designing the screen, clean openings should have sufficient total area so the velocity through them is not more than 0.4 to 1 m/s.

The material which collects on the upstream of screen is removed either manually or mechanically.
plain sedimentation.

Principle:

most of the suspended impurities present in water do have a specific gravity greater than that of water (1.0), so water being denser will cause them to settle down under the influence of gravity, although in normal supplies they may remain in suspension. Because of the turbulence is retarded by offering storage to the water.

These impurities tend to settle down at the bottom of the tank.

At offering such storage. This is the principle behind sedimentation.

The basin in which the flow of water is retarded is called the settling tank or sedimentation tank or clarifier.
Theory of Sedimentation.

The settlement of a particle in water brought to rest is opposed by the following factors.

(i) The velocity of flow which carries the particle horizontally. The greater the flow area, the lesser is the velocity and hence more easily the particle will settle down.

(ii) The viscosity of water in which the particle is travelling. The viscosity varies inversely with temperature.

(iii) Warm water is less viscous and hence offers less resistance to settlement.

However, the temperature of water cannot be controlled to any appreciable extent in water purification processes, hence this factor is generally ignored.

(iv) The size, shape and specific gravity of the particle. The greater is the specific gravity, and the more easily the particle will settle. The size and shape of the particle also play a significant role in the settling process.
the particle also affect the settling rate.

Hence, very small sized particles will settle very slowly. It has been clearly shown that the shape and size of the particle do affect their settling velocities.

The settling velocity of the spherical particle is expressed by Stoke's law which take the above three factors into account. The final stoke's equation is expressed as:

\[ V_s = \frac{g}{18} \left( \frac{S_s - 1}{S_s} \right) \frac{d^2}{v} \quad \text{for} \; d < 0.1 \text{mm}. \]

where,

- \( V_s \) = velocity of settlement of particle in m/sec.
- \( d \) = diameter of the particle in m,
- \( S_s \) = specific gravity of the particle
- \( v \) = kinematic viscosity of water in m²/sec.

\[ Re = \text{Reynold Number} = \frac{V_s d}{v}. \]
Derivation of Stoke's Law:

When a solid particle settles down in water, its downward settlement is opposed by the drag force offered by the water.

The effective weight of the particle, causing the particle to accelerate in the beginning, till it attains a sufficient velocity (vs) at which the drag force becomes equal to effective weight of the particle.

After attaining that velocity, the particle falls down with that constant velocity (vs), now the drag force offered by the fluid is given by Newton's Law as,

\[
\text{Drag force} = C_D \cdot A \cdot \rho \cdot \frac{v^2}{2}
\]

where,

- \( C_D \): Drag coefficient
- \( A \): Area of particle
- \( \rho \): Density of water
- \( v \): Velocity of fluid
The effective weight of the particle

- Total wt - Buoyancy

\[ \frac{1}{2} \pi r^2 y_s - \frac{1}{2} \pi r^2 y_w \]

\( y_s \rightarrow \) wt. of particle.

\( y_w \rightarrow \) wt. of water.

\[ \frac{1}{2} \pi r^2 (y_s - y_w) \]

\( \text{Eqn } 1 + 2 \) will become equal when \( y \)

becomes equal to \( y_s \) in \( \text{Eqn } 1 \)

\[ C_D \rho_w \frac{v_s^2}{2} = \frac{1}{2} \pi r^2 [y_s - y_w] \]

\[ \theta = \pi r^2 \]

\[ C_D \pi r^2 \rho_w \frac{v_s^2}{2} = \frac{1}{2} \pi r^2 \sum (y_s - y_w) \]

\[ V_s^2 = \frac{1}{2} \frac{y (y_s - y_w)}{\rho_w} \cdot 2 \]

\[ V_s^2 = \frac{1}{5} \frac{(y_s - y_w)}{\rho_w} \cdot d \]

\[ \rho_w \cdot C_D \]
\[ v_s = c \cdot \rho_w \cdot \eta \]
\[ v_s - \eta = \eta (\frac{\rho_s - \rho_w}{\rho_w}) \]
\[ = \eta \rho_w \left( \frac{\rho_s}{\rho_w} - 1 \right) \]

\[ v_s = 4/3 \cdot \eta \cdot \rho_w (s_s - 1) d \]

\[ \frac{v_s}{\rho_w \cdot C_D} \]

\( C_D \) drag coefficient \((C_D)\) has been found for viscous flow + small particle to be equal to \( \frac{24}{Re} \)

\( Re \) is particle Reynolds number \( \left( \frac{v_s \cdot d}{v} \right) \)

\[ v_s = 4/3 \cdot \eta \cdot \rho_w (s_s - 1) d \]

\[ = \frac{4/3 \cdot \eta \cdot \rho_w (s_s - 1) d}{24 \cdot Re} \]

\[ v_s = \frac{4}{15} \cdot \eta \left( s_s - 1 \right) d \cdot \frac{Re}{24 \cdot \sigma} \]
Find the settling velocity of a discrete particle in water under conditions when Reynolds number is less than 0.5. The diameter and specific gravity of the particle is \( \leq 10^{-3} \text{ cm} \) and 2.65 respectively. Water temperature is 20°C (kinematic viscosity \( \nu \) of water at 20°C = \( 1.01 \times 10^{-2} \) cm²/sec).

\[
V_s = \frac{g}{18} (S_s - 1) \frac{d^2}{\nu}
\]

when \( d \leq 0.1 \text{ mm} \),

where,

- \( S_s \rightarrow \) (specific gravity)
- \( d = \leq 10^{-3} \text{ cm} \)
- \( \nu = 1.01 \times 10^{-2} \) cm²/sec.

\[
V_s = \frac{981}{18} (2.65 - 1) \frac{0.005}{1.01 \times 10^{-2}} \text{ cm/sec.}
\]

\[
= \frac{981}{18} \frac{1.65 \times 25 \times 10^{-6}}{1.01 \times 10^{-2}} \text{ cm/sec.}
\]
\[ V_s = \frac{418 \left( S_s - 1 \right) d^2 (2T + 70)}{100} \]

\[ = \frac{418 \left( 2.65 - 1 \right) \left( 5 \times 10^{-4} \right)^3 \left( \frac{2 \times 20 + 70}{100} \right)}{100} \]

\[ = 418 \times 1.65 \times 2.5 \times 10^{-4} \times 1.8. \]

\[ V_s = 0.224 \text{ cm/sec}. \]

Type of sedimentation or settling:

Type I - Discrete settling:

This describes the sedimentation of low concentrations of particles that settle on individual entities.

Type I settling in water treatment plants is the settling of silt, grit, etc., from river water being applied to the slow sand filter.

Type II - Flocculant settling:

This describes sedimentation of larger concentrations of solids that aggregate as they settle.

Sedimentation or coagulated wastewater prior to rapid sand filters is an example of flocculant settling. This type of settling is for pre-classification.
Type III: Hindered settling or zone settling

This describes sedimentation of a suspension with solids concentration sufficiently high to cause the particles to settle as a smooth layer. An example of this settling is the upper portion of the sludge blanket in sludge thickeners.

Type IV: Compression settling

This describes sedimentation of a suspension with solids concentration so high that the particles are in contact with one another and further sedimentation can only occur by compression of the mass.

The lower portion of a sludge thickener is an example of compression settling.

Sedimentation with coagulation

The efficiency of plain sedimentation is generally very low, especially when water contains very fine suspended matter and colloidal matter.
The coagulants neutralize the negative protective charge on the colloidal particles and allow them to coagulate.

The chemically assisted sedimentation process comprises several separate processes which make up the treatment system known as clarification. It is achieved in 3 stages.

(i) Addition of measured quantity of chemicals to water and thorough mixing

(ii) Formation of precipitate which coagulates and forms a floc.

(iii) Sedimentation.

Characteristics of colloids:

The principle phenomena that control the behaviour of the colloids are zeta potential (electrostatic force), Van der Waals force and Brownian motion. The amount of coagulant added to water will depend on the zeta potential.
a measurement of the magnitude of electrical charge, which keeps the particles in water.

If zeta potential is large, then reutureres of coagulation is essential. Vahder wall's forces refers to the tendency of particles in nature to attract each other weakly is they have no charge.

once the particles in water are not repelling each other, vander wall's forces makes the particles drift toward each other and join together into a group.

Colloids have a sufficiently small mass that collisions with molecular size particles in water will cause constant movements of the colloids. The phenomenon of constant random movement of colloids is known as brownian motion.

The combination of positive and negative charge results in a neutral or lack of charge. As a result the particles no longer repel each other.
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negative charge results in a neutral or
lack of charge. As a result the particles
no longer repel each other.
When enough particles have joined together, they become floc and will settle out of the water.

Types of coagulants:

Alum:

One of the earliest and still and most extensively used coagulant, is aluminium sulphate \((\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O})\) also known as alum.

Alum is acidic with light tan to grey in colour and available in blocks, lumps and powder with a density of 1000 - 1100 kg/m³. It is readily soluble in water.

When alum is added to water, it reacts with the water and results in positively charged ions.

The ions can have charges as high as +4 but are typically bivalent (+2).

The bivalent resulting from alum mainly serves as very effective primary coagulant.
$\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O} + 3\text{Ca}(\text{HCO}_3)_2 \leftrightarrow$ 

$2\text{Mg} + \text{SO}_4^{2-} + 6\text{CO}_3^{2-} + 14\text{H}_2\text{O}$

For best result pH range b/w 6.5-8.5.

Ferric sulphate or copper is

Hydrated ferric sulphate ($\text{Fe}_2\text{SO}_4$) is traditionally referred to as copper 4$\text{H}_2\text{O}$ is added to water. It first oxidised to ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$) and ferric chloride ($\text{FeCl}_3$) by mixing it with feed for a chlorinator before administering to the bulk of water.

Both of these are immediately available for the formation of ferric hydroxide $\text{Fe}_3(\text{OH})_3$.

$\text{Fe}_2(\text{SO}_4)_3 \cup \text{Ca} + 3\text{Ca}(\text{OH})_2 \rightarrow 3\text{CaSO}_4 + 2\text{Fe}(\text{OH})_3$

$2\text{FeCl}_3$

act as removing colour.

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1. Ferrous sulphate + lime:

Copper can react with natural calcium bicarbonate alkalinity in water, but there is very much a delayed one, hence lime is used with copper as following reaction:

$$\text{FeSO}_4 \cdot 7\text{H}_2\text{O} + \text{Ca(OH)}_2 \rightarrow \text{Fe(OH)}_2 + \text{CaSO}_4 + 7\text{H}_2\text{O}$$

Oxidised with Do in water to form ferric hydroxide:

$$4\text{Fe(OH)}_2 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{Fe(OH)}_3,$$

2) Magnesium carbonate and lime:

When magnesium carbonate and lime are dissolved in water to form magnesium hydroxide and calcium carbonate. Both are soluble in water, resulting in the formation of sludge which is in the slurry form, so these are not used commonly.

3) Polyelectrolyte:

These are high molecular weight water soluble polymers. They are classified as anionic, cationic and non-ionic depending on the charge they carry.
Cationic poly electrolytes can be used independently as effective coagulants while other are used as coagulant aids along with alum etc.

Sodium aluminate:

\[ \text{Na}_2\text{Al}_2\text{O}_4 \text{ is alkaline in reaction and is used very much less often than alum because of its cost. It react with the salts of calcium and magnesium as follows.} \]

\[ \text{Na}_2\text{Al}_2\text{O}_4 + \text{Ca} (\text{HCO}_3)_2 \rightarrow \text{Ca}\text{Al}_2\text{O}_4 + \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}. \]

\[ \text{Na}_2\text{Al}_2\text{O}_4 + 6\text{CaCl}_2 \rightarrow 3\text{Ca}\text{Al}_2\text{O}_4 + 2\text{NaCl}. \]

\[ \text{Na}_2\text{Al}_2\text{O}_4 + \text{CaSO}_4 \rightarrow \text{Ca}\text{Al}_2\text{O}_4 + \text{Na}_2\text{SO}_4. \]

It helps to remove both temporary and permanent hardness and is effective for a pH of 6 to 8.5.
The constituents of a coagulation sedimentation plant (clarifier) contain the following four units:

1. Feeding device.
2. Mixing device or mixing basin.
3. Flocculation tank or flocculator.
4. Settling or sedimentation tank.

Feeding device:

The chemical coagulant may be fed into the raw water either in a powdered form or in a solution form.

The former is known as dry feeding, and the latter is known as wet feeding. The choice between the two types depends on the following factors:

1. The characteristics of the coagulant.
2. The convenience with which it can be applied.
3. The amount of the coagulant to be used.
4. The cost of the coagulant and its source.
1. **Wet Feeding Devices**

   In this, the solution of required strength of coagulant is prepared and stored in a tank, from where it is allowed to trickle down into the mixing tank through an outlet.

   The level of coagulant solution in the coagulant feeding tank is maintained constant by means of a float controlled valve in order to ensure a constant rate of discharge for a certain fixed rate of flow in the mixing basin.

   When the rate of inflow of water changes. In order to make these two flows in proportion to each other, a conical plug type arrangement was used.

   The mixing basin and float chamber are interconnected together, so that the water level remains the same in both of them. As the flow of raw water increases, the depth of water & therefore its level increases in mixing tank.
11) **Dry Feeding Devices**

The common devices used are in the form of a tank with a hopper bottom. Agitating plates are placed inside the tank, so as to prevent arching of the coagulant. The coagulant, in the powdered form is filled in the tank and allowed to fall in the mixing basin.

Its dose is regulated by the speed of a bevelled wheel or a helical screw. The speed of both is controlled by connecting it to a venturi device installed in the raw water pipes bringing water to mixing basin.
The water in the float chamber increases here by increasing & lifting the float of float chamber. As the float rises, the pinion and pulley rotates in the same direction, here by lifting the conical plug and allowing more quantity of corrosulent solution to fall into the mixing basin.
mixing Devices:

After the addition of the coagulant in the raw water, the mixture is thoroughly and vigorously mixed, so that the coagulant gets fully dispersed into the entire mass of water.

The violent or mixing devices such as centrifugal pumps, compressed air, mixing basin etc. are most important and normally adopted.

There are two types of mixing basin, such as:

(i) Mixing basins with battle walls.
(ii) Mixing basins equipped with mechanical devices.

There are two types of mixing basin with baffles. In the horizontal or round the basin will turn.
The water flows horizontally for a short distance make a complete turn, continues back and forth around the ends of the baffles.

This causes turbulence and hence mixing. Another type known as vertical or mixing, another type used in smaller plants over and under type used in smaller plants, has vertically hanging baffle walls due to which water flows up and down.

Mixing basins with baffle walls are not used now because of high head losses and variation in the velocities.

(1) Round the end type.

Inlet → outlet
mixing basins with mechanical devices.

Most of the modern water treatment plants now have mixing basin with mechanical devices.

Fig. 1 shows a typical flash mixer in which the raw water and the coagulant are agitated vigorously by a paddle operated by a variable speed motor.

The intensity of mixing is dependent upon the temporal mean velocity gradient. Flash mixers have high revolving speeds ranging from 1400 to 1400 rpm.

A detention time of 30-60 sec is provided in the flash mixer which are deep circular or square tanks with the ratio of height to diameter or side of 1:1 to 1:2.5 kept as 300 s⁻¹ or more per rev. from 1 to 3 w/m³/hr of flow. The usual ratio of impeller diameter to tank diameter...
Mixing basins with mechanical devices.

Most of the modern water treatment plants now have mixing basins with mechanical devices.

Fig. shows a typical flash mixer in which the raw water + the coagulant are agitated vigorously by a paddle operated by a variable speed motor.

The intensity of mixing is dependent upon the temporal mean velocity gradient. Flash mixers have high revolving speeds ranging from 400-1400 rpm.

A detention time of 30-60 sec is provided in the flash mixer which are deep circular or square tanks with the ratio of height to diameter or side of 1:1 to 1:3. 'Q1' kept at 300 sec⁻¹ or more per cm². From 1 to 3 m³/hr of flow. The usual ratio of impeller diameter to tank diameter...
Flocculation tank or Flocculator

The best floc will form when the mixture of water and coagulant are violently agitated followed by a relatively slow and gentle stirring to permit build up of an agglomerate of the floc particles.

From the mixing basin, the water is taken to a flocculation tank called a flocculator, where it is given a slow stirring motion. Rectangular tanks fitted with paddles or a slow-by-electric-motors can best serve this purpose, although even plain flocculators with controlled flow velocities are also possible. Various patented flocculators are now a days available in the market.

The water coming out from the flocculators is taken to a sedimentation tank.
Design Criteria for Flash Mixers:

1. detention period = 0.5 to 2 min.
2. speed of impeller = 100 - 120 rpm.
3. Depth of tank = 1 to 3 m.
4. Power required = 0.5 kw/m³/min.
5. velocity gradient \( G_t = \left( \frac{P}{\mu V} \right)^{\frac{1}{3}} \) (per sec)

where,
- \( P \): Power dissipated in watt (Nm/s).
- \( \mu \): Dynamic viscosity of raw water (Ns/m²).
- \( V \): Volume of raw water to which \( P \) is applied in m³.
- \( G_t \): 30000 to 60000 (written?)

The motor power of the mixer is the power to drive the speed reduction gears. The power imparted to the water by a mixer is calculated by the equation

\[
P = \frac{2\pi n T}{n_t}
\]

\( n \) = Impeller speed, rpm
\( T \) = Impeller shaft to remix N.m
Filtration:

Screening and sedimentation removes a large percentage of the suspended solids and organic matter present in raw supplies. The percentage of SS removal of the fine colloidal matter increases when coagulants are added before sedimentation. But however, the resultant water will be pure and may contain some very fine suspended discrete or flocculated when coagulation is used or bacteria present in it.

To remove or to reduce the remaining impurities still further a to provide potable water, the water is filtered through the beds of sand granular material such as sands etc. known as filtration. The process of passing the water through the beds of such granular materials is known as filtration.

This may help in removing colour, odour, turbidity and pathogenic bacteria from the water.

Two types of filters are commonly used for treating municipal water supplies -

1. Rapid sand filters.
A third type of rapid sand filters works under pressure and is known as pressure filter. This type of filters is generally used for small plants, such as for individual supplies or for swimming pools and are generally not adopted for treating large scale municipal supplies.

Filter materials:

Sand either fine or coarse 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 & allows the wash water to move uniformly upward.

Sand:

The filter sand should generally be obtained from rocks like quartzite and should contain the following properties:

1. It should be free from dirt & other impurities
2. It should be uniform in nature & size
3. It should be hard and resistant
4. It should be such as not to lose being placed in soil
Granular:

The granular which may be used below the sand should be hard, durable, free from impurities, properly rounded and should have a density of about \( 1600 \text{ kg/m}^3 \).

Other materials:

Instead of using sand, sometimes anthracite is used as filter media. Anthracite is made from anthracite, which is a type of coal—stone that without smoke or fumes.

The use of anthracite as filter media in two or multi-layers have proved very successful in foreign countries. It is cheaper and has been able to give a high rate of filtration. However, this type of coal is not available in India. Types of filters and their classification:

- Filters
  - Gravity filters
    - Slow sand filters
  - Pressure filters
    - Rapid sand filters
Pressure filters are like small rapid filters placed in closed vessels and gravity. Water to be treated is pumped under pressure. Since water is forced through such filters at a pressure greater than the atmospheric pressure, it is necessary that these filters are located in air-free vessels.

The raw water is pumped into vessels by means of pumps. The pressure so developed may normally vary from 30 to 70 cm head of water (W) 300 to 700 mm.

Design criteria for slow sand filters

- Design life → 10-15 years.
- Period of operation → 16-24 hr/day.
- Filtration rate → 100-200 L/h/m².
- Filter bed area → 50-200 m²/ha.
- No. of HAU → minimum 2.
- Initial sand bed h → 0.9-1.2 m.
- Minimum sand bed h → 0.5-0.6 m.
Pressure filters.

Pressure filters are like small rapid filters placed in closed vessels and gravity. When water to be treated is pumped under pressure. Since water is forced through such filters at a pressure greater than the atmospheric pressure, it is recognized that these filters are located in air-free vessels.

The raw water is pumped into vessels by means of pumps. The pressure so developed may normally vary between 300 to 700 mm head or water (W) 200 to 700 m/s.

**Design Criteria for Slow Sand Filters**

- **Design Life** → 10 - 15 years.
- **Period of operation** → 16 - 24 hr/day.
- **Filtration rate** → 100 - 200 L/hr/m²
- **Filter bed area** → 50 - 200 m²/h filter.
- **No. of filters** → Minimum 2

- Initial sand bed h₁ → 0.9 - 1.2 m
- Final sand bed h₂ → 0.5 - 0.6 m.
Filter Sand:

Effective Size \( \rightarrow 0.15 \text{ to } 0.2 \text{ mm} \).

Uniformity Coefficient \( \rightarrow 3 \).

Supporting Gravel Layer \( \rightarrow 0.3 \text{ to } 0.5 \text{ m} \).

Superficial Water Depth \( \rightarrow 1 \text{ m} \).

Cleaning Interval \( \rightarrow 2 \text{ to } 4 \text{ hours} \).

Length to Width Ratio of Filter Bed \( \rightarrow 1.25 \text{ to } 1.35 : 1 \).

Depth of Water Above Sand \( \rightarrow 1200 \text{ to } 1500 \text{ mm} \).

Depth of Sand \( \rightarrow 600 \text{ to } 900 \text{ mm} \).

Depth of Gravel \( \rightarrow 300 \text{ to } 600 \text{ mm} \).

Free Board \( \rightarrow 0.2 \text{ to } 0.3 \text{ m} \).

Effective Size \( \rightarrow 0.2 \text{ to } 0.4 \text{ mm} \).

Uniformity Coefficient \( \rightarrow 2 \text{ to } 3 \).

Velocity of Flow in Under Drain \( \rightarrow 25 \text{ cm/sec} \).

No Under Drain should be provided within 600 mm of the side wall.
Design criteria for rapid sand filters.

Design Life — 20-30 years.

Period of operation — 20 to 24 hr/day.

Filtration rate — 80 to 120 lpm/m²

(31800 – 7200 lph/m²)

Filter bed area — 10 – 100 m²/filter.

Length to breadth ratio — 1:25 to 1:33

Dimensions of filter beds — Length 5-12 m

Breadth 2.5 to 9 m

Initial sand bed thickness — 60-75 cm

Filter sand eff. size — 0.41 – 0.7 mm

Uniformity coefficient — 1.2 – 1.7

Thickness of gravel support — 45 to 50 cm

Superimposed water depth — 1 m to 1.25 m.

Under drainage system — Any one of these: control manifolds, perforated laterals, false floor, porous plate, or strain nozzles.

Cleaning Intervals — 24-48 hrs.