UNIT 3

WATER TREATMENT


Water treatment plants in Coimbatore

Siruvani plant – 87 MLD – Avg supply – 64.15 MLD

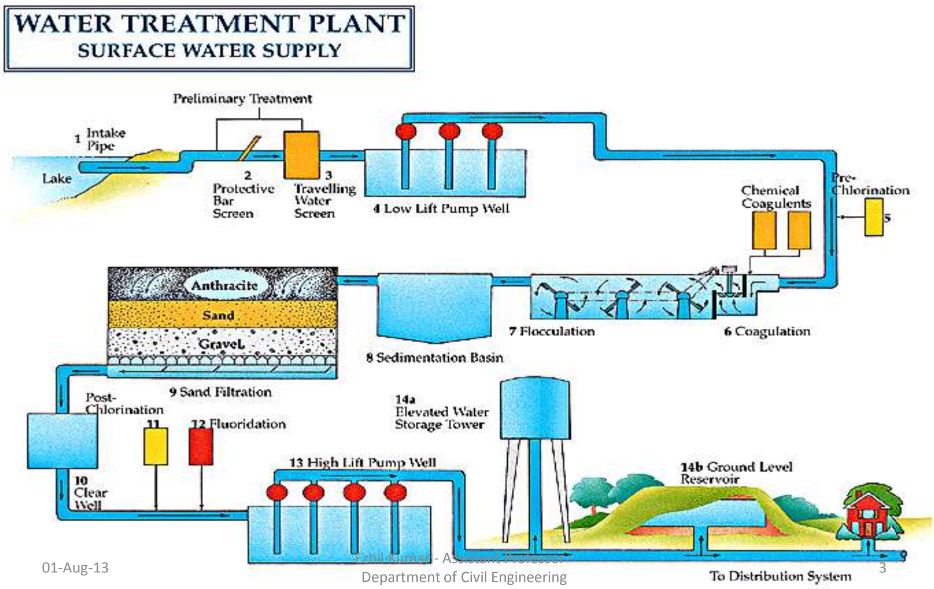
Phase I

Pillur plant – 66 MLD – Avg supply – 65.4 MLD

Phase II

Pillur plant – 30 MLD

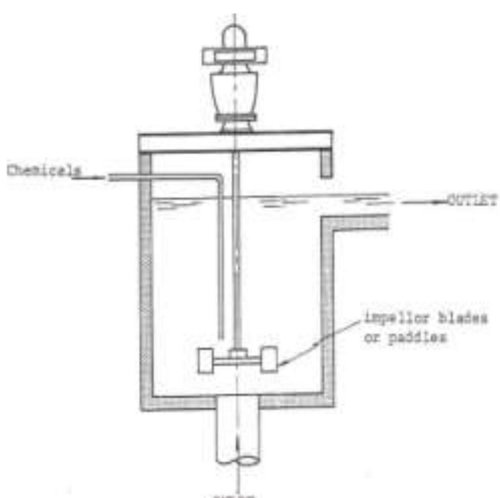
Unit operation

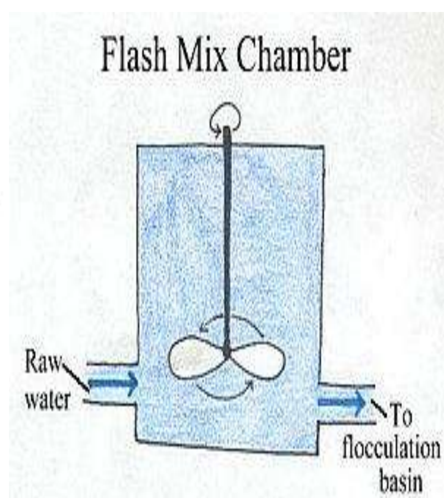


Unit treatment	Functions (Removal)
Aeration, Chemical use	Colour, Odour, Taste
Screening	Floating matter
Chemical methods	Iron, manganese, etc.,
Softening	Hardness
Sedimentation	Suspended matter
Coagulation	Suspended matter, a part of colloidal matter and bacteria
Filtration	Remaining colloidal dissolved matter, bacteria
Disinfection	Pathogenic bacteria, Organic matter and Reducing substances

FLASH MIXER (Coagulation)

- The primary purpose of the coagulation process is the removal of turbidity from the water and also colour.
- **Turbidity** is a cloudy appearance of water caused by small particles suspended therein.
- The maximum allowable level of turbidity in water is 0.5 NTU, while the recommended level is about 0.1 NTU. (Nephelometric Turbidity Unit)





Impellor speed = 100 to 120 r.p.m

Detention period = 0.5 to 2 minutes

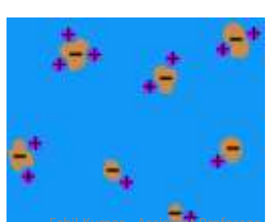
Process

- In the **flash mixer, coagulant chemicals are added to the** water and the water is mixed quickly and violently.
- The purpose of this step is to evenly distribute the chemicals through the water. Flash mixing typically lasts a minute or less.
- After flash mixing, coagulation occurs.
- During **coagulation, the coagulant chemicals neutralize the** electrical charges of the fine particles in the water, allowing the particles to come closer together and form large clumps.

Electrical Charges

The purpose of most coagulant chemicals is to neutralize the negative charges on the colloidal particles to prevent those particles from repelling each other.

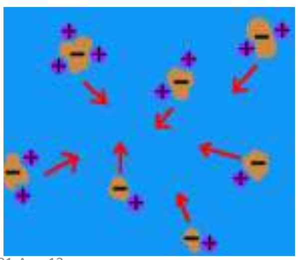
The amount of coagulant which should be added to the water will depend on the **zeta potential, a measurement of the** magnitude of electrical charge surrounding the colloidal particles. If the zeta potential is large, then more coagulants will be needed.

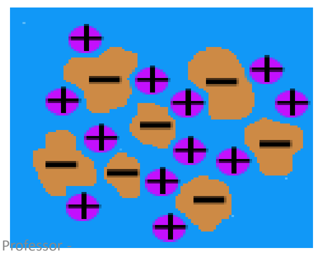


Electrical Charges

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.

The next force which will affect the particles is known as van der Waal's forces. **Van der Waal's forces refer to the** tendency of particles in nature to attract each other if they come close enough.

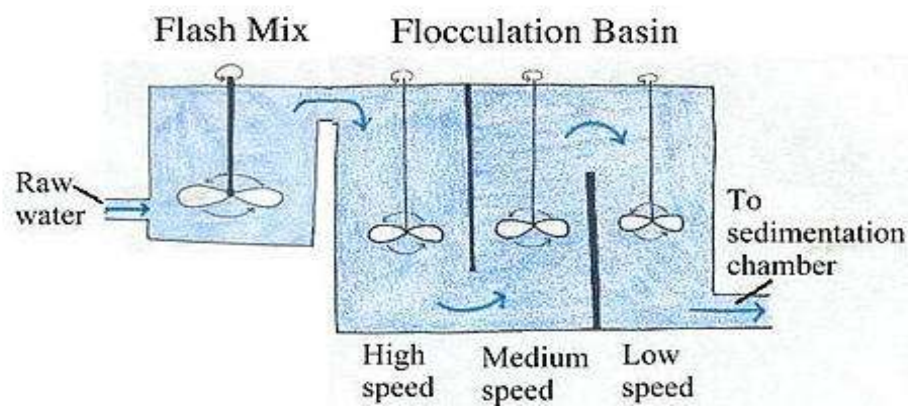




Common Coagulants

- Mainly Aluminium and Iron salts
    - Aluminum sulfate
    - Ferrous sulfate
    - Ferric sulfate
    - Ferric chloride
    - Lime [Ca(OH)2]

FLOCULLATOR



Impellor speed = 2 to 3 r.p.m

Detention period = 20 to 60 minutes

Distance b/w paddle and wall/floor surface = 15 to 30 cm

Working Principle

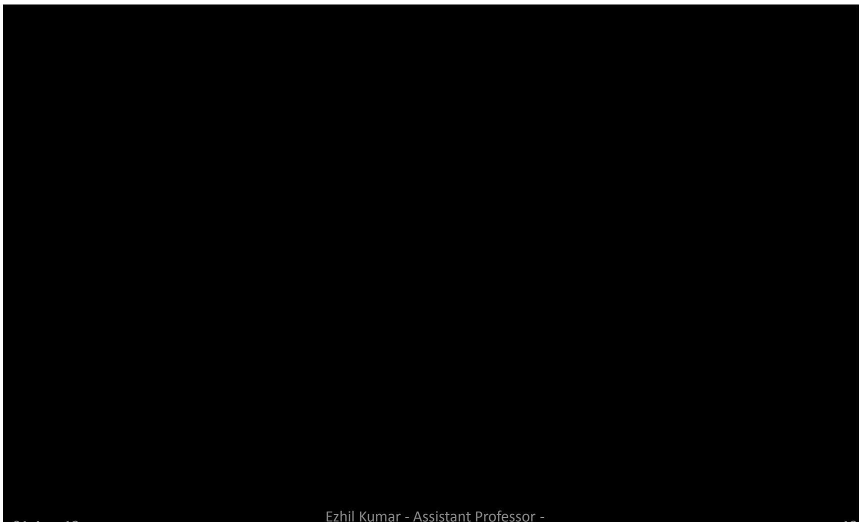
It is a common practice to provide an initial rapid (or) flash mix for the dispersal of the coagulant or other chemicals into the water. Slow mixing is then done, during which the growth of the floc takes place.

Mechanism of Flocculation

Gravitational flocculation: Baffle walls

Mechanical flocculation: Rotating paddles

Coagulation and Flocculation



SEDIMENTATION TANK

Suspended solids present in water having specific gravity greater than that of water tend to settle down by gravity as soon as the turbulence is retarded by offering storage.

Basin in which the flow is retarded is called ***settling tank***.

Theoretical average time for which the water is detained in the settling tank is called the ***detention period***.

Purpose of Settling

To remove coarse dispersed phase.

To remove precipitated impurities after chemical treatment.

To settle the sludge (biomass).

Types of Settling Tanks

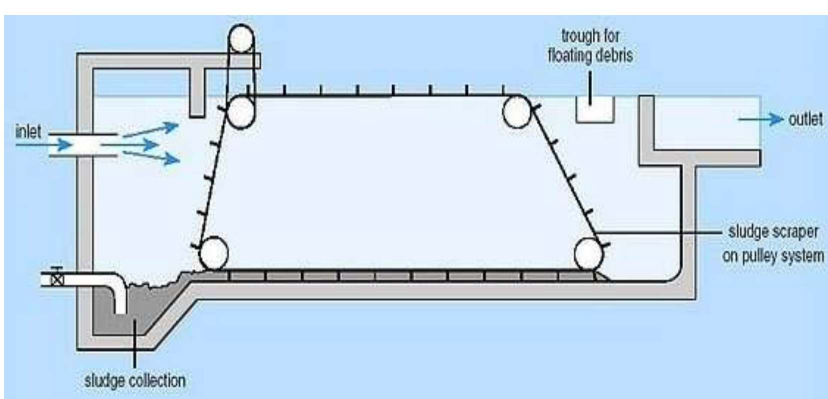
Sedimentation tanks may function either **intermittently or continuously.**

Intermittent tanks / Quiescent type tanks - store water for a certain period and keep it in complete rest.

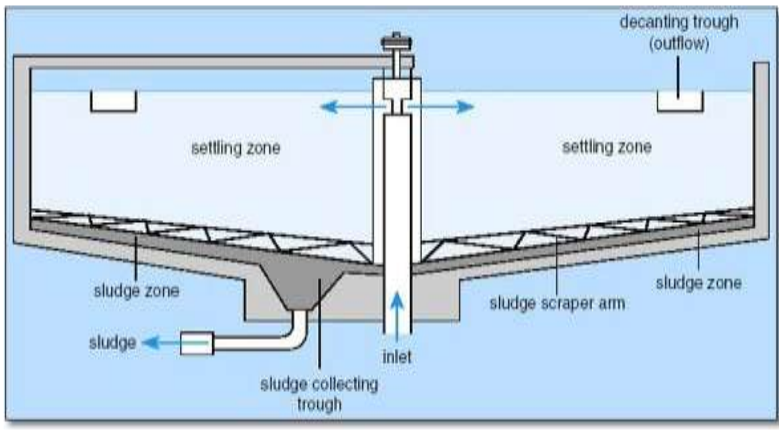
Continuous flow type tank - the flow velocity is only reduced and the water is not brought to complete rest as is done in an intermittent type.

Settling basins may be either long rectangular or circular in plan.

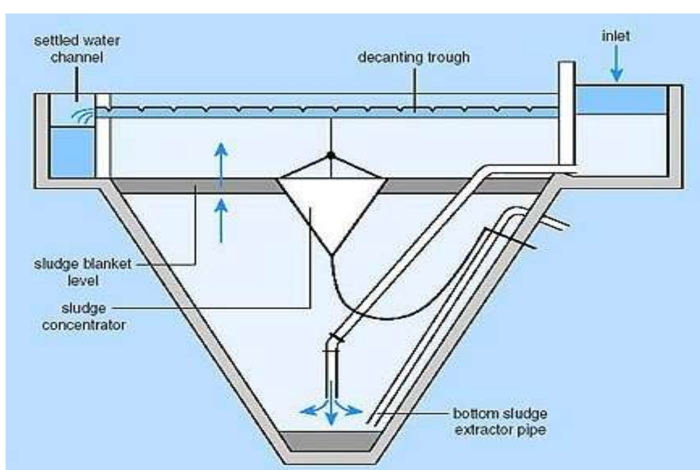
Rectangular



Circular



Up flow



Field View

Design Details

- Detention period: for plain sedimentation: 3 to 4 h, and for coagulated sedimentation: 2 to 2.5 h.
- Velocity of flow: Not greater than 30 cm/min (horizontal flow).
- Tank dimensions: L:B = 3 to 5:1. Generally L= 30 m (common) maximum 100 m. Breadth= 6 m to 10 m. Circular: Diameter not greater than 60 m. generally 20 to 40 m.

- Depth: 2.5 to 5.0 m (3 m).
- Surface Overflow Rate: For plain sedimentation 12000 to 18000 L/d/m2 tank area; for thoroughly flocculated water 24000 to 30000 L/d/m2 tank area.
- Slopes: Rectangular 1% towards inlet and circular 8%.

Problem

Design a rectangular sedimentation tank to treat 2.4 million litres of raw water per day. The detention period may be assumed to be 3 hours.

Solution

- Raw water flow per day is 2.4×10^6 l
- Detention period is 3h
- Volume of tank = Flow x Detention period

  $= (2.4 \times 10^3 \times 3)/24 = 300\ m^3$
- Assume depth of tank = 3.0 m
- Surface area = $300/3 = 100\ m^2$

- L/B = 3 (assumed)
- L = 3B
- $3B^2 = 100\ m^2$ i.e. B = 5.8 m
- L = 3B = 5.8 X 3 = 17.4 m
- Hence surface loading (Overflow rate)

  $= 2.4 \times 10^6 / 100 = 24{,}000\ l/d/m^2 < 30{,}000\ l/d/m^2$

Problem

Two million litres of water per day is passing through a sedimentation tank which is 6m wide, 15m long and having a water depth of 3m. (a) Find the detention time for the tank. (b) What is the average flow velocity through the tank? (c) If 60 ppm is the concentration of suspended solids present in turbid raw water, how much dry solids will be deposited per day in the tank, assuming 70% removal in the basin, and average specific gravity of the deposit as 2. (d) Compute the overflow rate.

Solution

(a) Capacity of tank = L.B.D = 15m x 6m x 3m = **$270 m^3$**

Discharge through the tank = Q

Q = 2 MLD = 2×10^6 l/d = {(2×10^6)/24} l/hr

= 83.33×10^3 l/hr = **83.33 cu.m/hr**

Detention time = Tank Capacity/Discharge

= 270/83.33 = **3.24 hours**

(b) Average velocity of flow in tank = Discharge/Cross-sectional area

= Q/BH = (83.33)/(6x3) m/hr = (4.629 x 100) / 60 cm/min

= **7.72 cm/min**

(c) Quantity of water passing per day

= 2 ML = **2×10^6 litres**

Concentration of suspended solids = 60 ppm

Quantity of SS entering the tank = $2 \times 10^6 \times (60/ 10^6)$ l

= 120 l = **0.12 cu.m**

Average specific gravity of material is 2 (given)

Density = 2000 kg/m^3

Mass of SS deposited (70% removal) per day

= (0.12 x 0.7) (2000) kg = **168 kg**

(d) Overflow rate = Discharge per unit plan area

$$= Q / B.L$$

$$= \frac{(83.33 \times 10^3) \text{ litres/hr}}{6 \times 15 \text{ m}^2}$$

= **926 litres/hr/m²**

FILTRATION

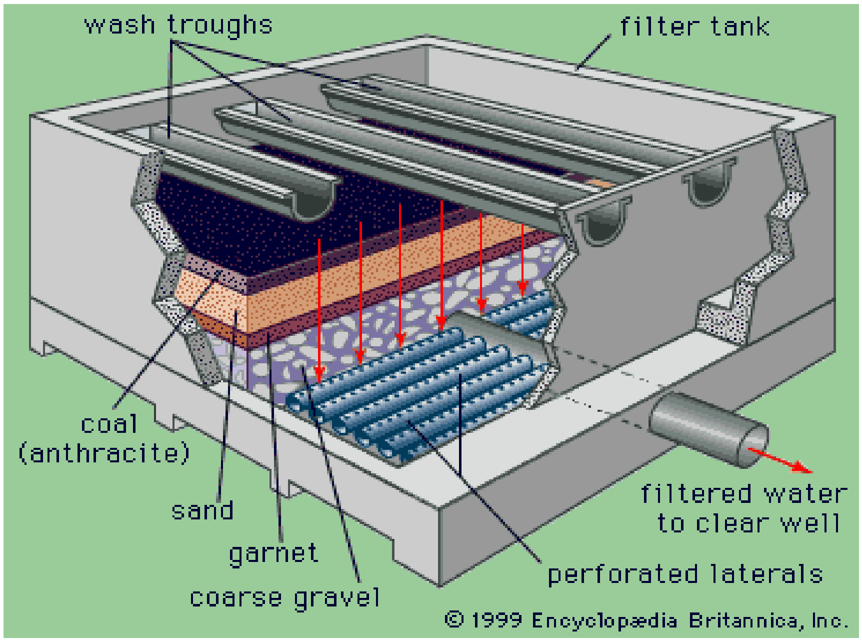
- The resultant water after sedimentation will not be pure, and may contain some very fine suspended particles and bacteria in it.
- To remove or to reduce the remaining impurities still further, the water is filtered through the beds of fine granular material, such as sand, gravel etc.
- The process of passing the water through the beds of such granular materials is known as **Filtration**.

Types of Filters

1. Slow sand gravity filter
2. Rapid sand gravity filter
3. Pressure filter

SLOW SAND FILTER

- James Simpson – England – 1829.
- Used till 19^{th} century – later became obsolete.
- They consist of fine sand, supported by gravel. They capture particles near the surface of the bed and are usually cleaned by scraping away the top layer of sand that contains the particles.



Enclosure tank:
- Water tight rectangular tank
- Masonry or concrete
- Bed slope 1 in 100 towards central drain
- Tank depth – 2.5 to 3.5 m
- Tank area – 100 to 2000 m^2 or even more

Filter media:
- Uniform sand size - Sand layer – 90 to 110 cm depth
- Effective size (D_{10}) – 0.2 to 0.4 mm
- Uniformity coefficient (D_{60}/D_{10}) – 1.8 to 2.5 or 3.0

Base material:
- Gravel – 30 to 75 cm thick – different size
- 3 to 4 layers – each 15 to 20 cm depth
- Coarse material @ bottom – fine material @ top
- Size of gravel - @ bottom 40 to 65 mm - @ middle 20 to 40 mm - @ top 6 to 20 mm

Cleaning of slow sand filter

- No backwashing is done
- Top layer of sand is scrapped and removed – 1.5 to 3 cm
- System is washed with good water
- Amount of wash water – 0.2 to 0.6 % of total water filtered
- Cleaning is repeated – sand depth reduces by 40 cm
- Then sand is laid by labour manually
- Next filtration starts only after 24 or 36 hrs – for bio film formation
- Cleaning interval – 1 to 3 months

Rate of filtration: 100 to 200 l/hr/m^2

Efficiency and performance of SSF:

- Removing bacteria and other suspended solids
- 98% to 99%
- Removes odour and taste
- Less efficient in removing colour
- Turbidity upto 50mg/l and not suitable if higher in turbidity

Uses:

- Best suited for small scale
- Raw water with low turbidity, low colour, low bacterial content
- Small rate of filtration – huge surface area – large volume of filter media is required
- Costly – Uneconomical

Problem

Design six slow sand filter beds from the following data

population to be served = 50,000 persons

per capita demand = 150 l/h/d

Rate of filtration = 180 l/hr/sq. m

length of each bed = twice the breadth

Assume max demand as 1.8 times the average daily demand. Also assume that one unit, out of six will be kept as stand-by.

Solution

Average daily demand = Population x Per capita demand

= 50,000 x 150 l/d

= **7.5×10^6 l/d**

Max daily demand = $1.8 \times 7.5 \times 10^6$ = **13.5×10^6 l/d**

Rate of filtration per day = (180 x 24) l/m^2/day

Total surface area of filters required

= Max daily demand / Rate of filtration per day

= 13.5×10^6 / 180 x 24 = **3125 sq m**

Now six units are to be used, out which one is made stand by and we design area of filtration for 5 units.

The area of each filter unit = Total area required / 5

= 3125 / 5

= **625 m^2**

Given L=2B,

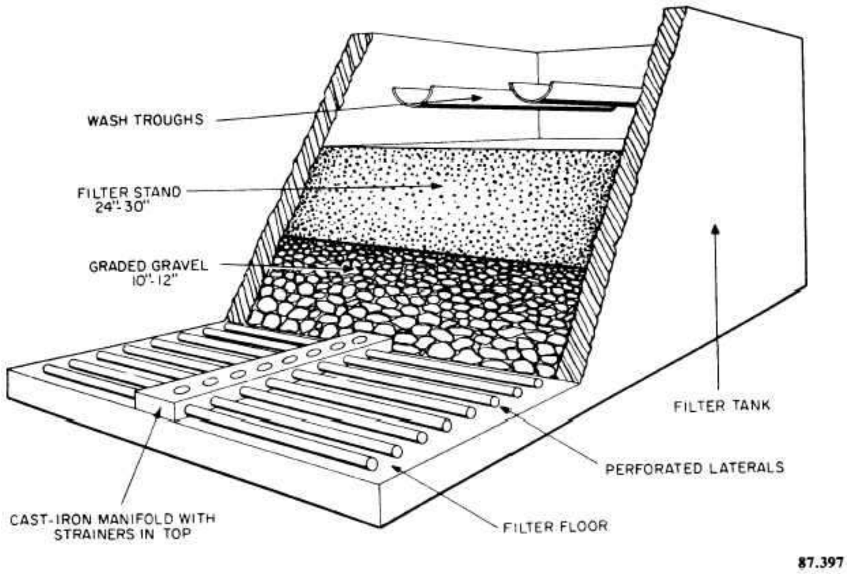
A = L.B 625 = $2.B^2$

B = 18m L = 36m

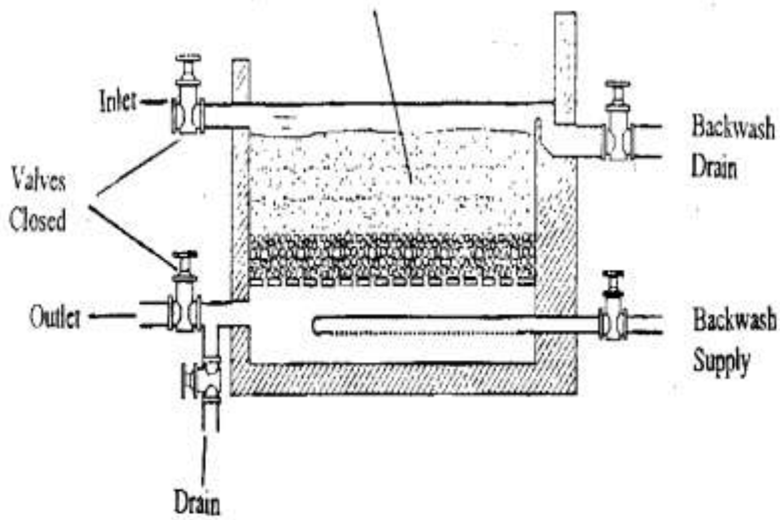
Make 6 units of SSF bed with size 36 m x 18 m. Place them in series with 3 units on either side.

RAPID SAND FILTER

- G.W. Fuller – Louisville U.S.A – 1829.
- Developed after 19^{th} century.
- They consist of Coarser sand, supported by gravel.
- 30 times effective than SSF.
- Water from coagulation-sedimentation tank are used in this filter.
- Filtered water is treated with *disinfectants*.


WASH TROUGHS
FILTER STAND
24"-30"
GRADED GRAVEL
10"-12"
FILTER TANK
PERFORATED LATERALS
CAST-IRON MANIFOLD WITH
STRAINERS IN TOP
FILTER FLOOR
87.397


EM-9
RAPID SAND FILTER



Enclosure tank:
- Water tight rectangular tank
- Masonry or concrete
- Bed slope 1 in 100 towards central drain
- Tank depth – 2.5 to 3.5 m
- Tank area – not more than 10 to 80 m^2 for each unit – min 2 units

Filter media:
- Uniform sand size - Sand layer – 60 to 90 cm depth
- Effective size (D_{10}) – 0.35 to 0.55 mm
- Uniformity coefficient (D_{60}/D_{10}) – 1.3 to 1.7

Base material:
- Gravel – 60 to 90 cm thick – different size
- 5 to 6 layers – each 10 to 15 cm depth
- Coarse material @ bottom – fine material @ top
- Size of gravel - @ bottom 20 to 40 mm - @ middle 12 to 20 mm - @ top 3 to 6 mm

Cleaning of Rapid sand filter

- Backwashing is done – 3 to 5 minutes
- Wash water pressure – 40 kN/m^2
- System is washed with good water
- Amount of wash water – 2 to 5 % of total water filtered
- Next filtration starts only after 15 minutes
- Cleaning interval – 24 to 48 hours

Operation troubles:

- Formation of mud balls
- Cracking of filters

Rate of filtration: 3000 to 6000 $l/hr/m^2$

Efficiency and performance of RSF:

- Less efficient in removing bacteria and turbidity
- 80% to 90% - remaining by *Disinfection* process
- Turbidity – upto 35 to 40 mg/l
- But water before entering RSF – pre-treatment is done coagulation sedimentation tank where turbidity is reduced
- Efficient colour removal – reduce to 10 TCU

Uses:

- Best suited for large scale
- Most economical
- Even after filtration not safe for drinking – further treatment is necessary

Points that are to be considered and kept in mind while designing the size of pipes in RSF system,

1) Total C/S area of perforation should be 0.2% of the total filter area
2) C/S area of each lateral should be 2 to 4 times of C/S area of perforations, diameter of perforations 13 mm and 6 mm
3) C/S area of manifold should be *Twice* the C/S area of lateral drains
4) (Length of each lateral / Diameter of the lateral) < 60
5) Max permissible velocity in manifold for wash water flow is about 1.8 to 2.4 m/sec

Problem

Design a rapid sand filter unit for 4 million litres per day of supply, with all it principal components.

Solution

Water required per day = 4 MLD

Assuming that 4% of filtered water is required for washing of the filter, every day, we have

Total filtered water req per day = **4.16 ML/d**

Now assuming that 0.5 hours is lost everyday in washing the filter,

= 4.16/23.5 = **0.177 ML/hr**

Now assuming the rate of filtration to be 5000 l/hr/sq m,

Area of filter = 0.177 x 10^6 / 5000 = **35.4 m^2**

Now assuming the length of the filter bed (L) as 1.5 times the width of filter bed (B), L = 1.5B with two beds

2 x (L.B) = 35.4

2 x (1.5B) (B) = 35.4

B = 3.4 m; L = 5.2 m;

Hence provide 2 filter unit, each by **5.2 m x 3.4 m.**

Design of under-drainage system

Manifold and laterals systems are provided below filter bed

To design the system we assume that the area of perforations is 0.2% of the total filter area,

Total area of perforation = 0.2% x filter area

= (0.2/100) x (5.2 x 3.4) = **0.035 m^2**

Assuming the area of each lateral = 2 times the area of perforation

Total area of laterals = 2 x total area of perforation

= 2 x 0.035 = **0.070 m^2**

Assuming the area of manifold = 2 times the area of lateral

Total area of manifold = 2 x total area of lateral

= 2 x 0.070 = **0.14 m^2**

Dia of manifold (d), A = (3.14 x d^2) / 4

d = 0.42 m

Hence use 45cm manifold pipe, laid along the centre of the filter bed. Laterals laid perpendicular to manifold with 15cm spacing.

Number of laterals = 5.2 x 100 / 15 = 34.6 i.e. **35 nos**

Lay them on either side, so use **70 laterals**.

Length of each lateral = (width of filter/2) – (Dia of manifold/2)

= (3.4/2) – (0.45/2) = **1.475 m**

Adopting 13mm dia perforations in laterals,

Total area of perforation = 0.035 m^2 = 350 cm^2

350 cm^2 = (X). (3.14 x 1.3^2 / 4)

X = Total no of perforations in all 70 laterals

X = 264

No of perforations in each lateral = 264 / 70 = **4 nos**

Area of perforations per lateral

= 4 x {(3.14 x $(1.3)^2$ / 4} = **5.30 cm^2**

Area of each lateral = 2 x Area of perforations per lateral

= 2 x 5.30 = **10.60 cm^2**

Dia of each lateral = √ 10.60 x 4 / 3.14 = **3.7 cm**

Hence, use 70 laterals each of 3.7 cm dia, @ 15 cm c/c, each having 4 perforations of 13 mm size, with 45 cm dia manifold. (Check = L / D < 60)

Let us assume that the rate of washing of the filter be 45 cm rise/minute or 0.45 m/minute

Wash water discharge = 0.45 x 5.2 x 3.4 / 60 = **0.133 m^3/sec**

Velocity of flow in the lateral for wash water,

= (0.133) / {70 x (A)}

A = 3.14 x $(3.7/100)^2$ / 4

= (0.133 x 10000) / (70 x 10.75) m/sec

= **1.77 m/sec**

Velocity of flow in manifold,

= Q / A

= 0.133 / (3.14 x 0.45^2 / 4) = **0.84 m/sec**

(Check: 0.84 m/sec < 1.8 to 2.4 m/sec)

Design of Wash water troughs

Wash water troughs are kept 1.5 – 2 m apart.

With length of 5.2 m filter bed, we provide 3 troughs @ 5.2/3 = 1.73 m apart.

Total wash water discharge of 0.133 m^3/sec in 3 troughs,

Discharge in each trough = 0.133 / 3 = **0.044 m^3/sec**

Dimension of flat bottom trough is designed by ***empirical formula***

$$Q = 1.376 \cdot b \cdot y^{3/2}$$

Q = discharge, m^3/s

b = width of trough in m (0.2 m)

y = water depth in the trough, m

$$0.044 = 1.376 \times 0.2 \times y^{3/2}$$

***y* = 0.3 m = 30 cm**

Keeping 5 cm as freeboard,

adopt the depth of trough = (30+5) = **35 cm**

Hence, 3 nos of wash water troughs of size 35 cm x 20 cm may be used.

DISINFECTION / STERILISATION

The filtered water may normally contain some harmful disease producing bacteria in it. These bacteria must be killed in order to make the water safe for drinking. The process of killing these bacteria is known as *Disinfection or Sterilization.*

Boiling of water

Treatment with excess *lime*

Treatment with *Ozone*

Treatment with *ultra-violet rays*

Treatment with *iodine & bromine*

CHLORINATION

The germicidal action of chlorine is explained by the recent theory of *Enzymatic hypothesis*, according to which the chlorine enters the cell walls of bacteria and kill the enzymes which are essential for the metabolic processes of living organisms.

Disinfection action of chlorine

Chlorine is added to the water supply in different ways.

- Liquid chlorine or Chlorine gas
- Hypochlorites (HOCl) or Bleaching powder
- Chloramines (ammonia + chlorine)
- Chlorine dioxide

$$Cl_{2(g)} \longrightarrow Cl_{2(aq)}$$

$$Cl_{2(aq)} + H_2O \longrightarrow HOCl + H^+ + Cl^-$$

$$HOCl \longrightarrow OCl^- + H^+$$

5 < pH > 7

Chlorine reacts readily with ammonia present in water and forms various chloramines,

NH_3 + HOCL ⟶ NH_2Cl + H_2O	pH > 7.5
NH_2Cl + HOCL ⟶ $NHCl_2$ + H_2O	5 < pH > 6.5
$NHCl_2$ + HOCL ⟶ NCl_3 + H_2O	pH < 4.4

❖ Ensure proper dosage – DPD test must be done – Residual chlorine level should be 0.2 mg/l after 10 min from contact time.

❖ Chlorine – higher dose – rainy season and epidemic.

❖ First consumer must receive chlorinated water only after 30 minutes from the reaction time.

Merits

- Cheap, reliable, easy to handle
- Easily measurable
- Provides disinfectant for long period
- Removes odour to a certain amount

De-merits

- When used in greater – make water bad in taste

Types of chlorination

1. Plain chlorination
2. Pre – chlorination
3. Post – chlorination
4. Double chlorination
5. Break point chlorination
6. Super chlorination
7. Dechlorination

Plain Chlorination

Only chlorination process – can treat water with turbidity in range 20 to 30 mg/l – used in emergency period – Chlorine required ≥ 0.5 mg/l.

Pre Chlorination

Chlorine added to water before filtration (sedimentation) – improves coagulation – Reduces odour, taste, algae and other microbes – dosage limit 5 to 10 mg/l.

Post Chlorination

Applying chlorine at end of process – residual chlorine (0.1 to 0.2 mg/l) – after the contact period of 20 minutes.

Double Chlorination

Combination of Pre and Post chlorination

Break point Chlorination

BPC is excess chlorine dose added beyond the limit where additional chlorine will appear as free residual chlorine.

Super Chlorination

Chlorine dosage beyond BPC – used when water is highly polluted – later excess residual chlorine is removed by *Dechlorination.*

De Chlorination

Used when super chlorination is practiced – Done simply by aeration or using chemicals.

Dechlorination agents

- Sulphur dioxide gas
- Activated carbon
- Sodium thiosulphate
- Sodium metabisulphate
- Ammonia as NH_4OH

RESIDUAL MANAGEMENT

In all biological waste treatment processes some surplus sludge is produced.

objective of residual management

- Reduction of water content.
- Stabilization of sludge solids.
- Reduction in sludge solids volume.

Sludge Dewatering Methods

Natural: sludge drying beds, sludge lagoons

Mechanical: sludge thickeners, centrifuges, vacuum filters, filter press

Physical: heat drying, incineration

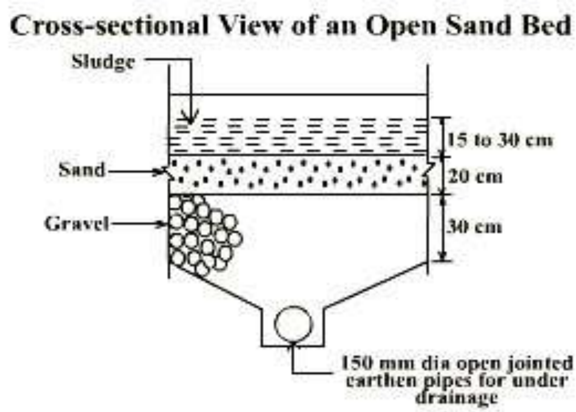
Disposal of Sludge

Final disposal of sludge is to land and sometimes to the sea, in one of the following ways:

- Agricultural use of dried or wet sludge.
- Use of dried sludge as landfill in absence of agricultural demand.
- Spreading wet sludge on eroded or waste land, contouring the field, so as to gradually build up a top soil of agricultural value.
- Disposing off wet sludge along with solid wastes for (i) composting, or (ii) sanitary landfill.
- Transporting and dumping into the sea.

Sand Beds for Sludge Drying

Sand beds are generally constructed as shown in the typical cross-sectional view.



- Sludge is generally spread over the sand which is supported on a gravel bed.
- Open-joint earthen pipe 15 cm in diameter spaced about 3 m apart and sloping at a gradient of 1 in 150 towards the filtrate sump.
- The drying beds are often subdivided into smaller units, each bed 5-8 m wide and 15-50 m long.
- The drying time averages about 1-2 weeks in warmer climates, and 3-6 or even more in unfavourable ones.


Filtration
Distillation
Bottled Water
Reverse Osmosis
?
thank you
Raw Water
+ Treatment =
Drinking Water