UNIT OPERATIONS AND UNIT PROCESSES OF WATER TREATMENT:

Unit operations are the physical operations to remove the impurities present in the water and waste water where as the unit processes are the chemical and biological conversion on the status of the impurities that they will be converted to a form that can be easily separated. Both are applied especially to make the fine colloidal particles to coalesce and grow in size to be removed from the water or waste water. There is no impurity that can be categorized as inorganic, it is named so for it takes time to disintegrate and had been to this hard form, free from decomposable matter with the ecological factors. We can find metal eating bacteria these days that makes the accelerated form to human use get decelerated to favor nature accommodate effectively as indigenous.

Screens are in use from the intake structure where they prevent the floating matter to enter into the pumping units, and fine and coarse screens are in use to treat waste water to prevent the entry of floating wastes and coarse solids into the treatment.

Sedimentation is simply detaining water for a sufficient time mostly in stagnant or relatively stagnant position to make the flow velocity of water less than the settling velocity of the solid particles that they without being driven by horizontal force settles down by gravity. The efficiency of the process depends on the detention time, how long the waste water remains within the sedimentation tank. When applied to individual units we need not reduce the flow velocity but make it stagnant as fill and draw type that the efficiency will be more. In the continuous flow type the flow velocity is reduced to the level of the minimum velocity which will not carry the particles with it according to stokes law that the vertical velocity, which is the settling velocity of the particle will be more than the horizontal drag velocity and the particle settles down. Mostly the tanks will be rectangular and we also have circular tanks where the flow will be from centre to periphery. Whatever may be the shape of the tank, it is the surface area which makes the travel of particles independent of others which makes the settling efficient that the depth has to be considered taking into effect the sludge accumulation and to prevent the reentry of particles back to flow.

Filtration is to the removal of fine particle sand dissolved solids where the fine sand layer and coarse sand layer below serves as the media to remove colloidal solids and the water remains completely free of solids. In trickling filters the waste water that trickles down gets oxidized that the organic matter grows in size and retained over the sand medium and bacteria assimilate on the organic matter to form layer on the surface which grows thicker and thicker to give more bacterial mass to act upon the organic solids. The bottom most layer becomes deprived of oxygen in due course of time that it sloughs and the same reaches the secondary settling tank where the same gets settled for its increased density.

Odour and colour present in water and waste water are removed by aeration and adsorption process.The odour and colour causing elements are adsorbed and aerated that the water is free from impurities for use and waste water for reuse and recycling. Toxic chemicals and metals too get adsorbed with suitable media for adsorption.

Unit processes:

Flocculation is a water treatment process where solids form larger clusters, or flocs, to be removed from water. This process can happen spontaneously, or with the help of chemical agents.

Coagulation is the chemical water treatment process used to remove solids from water, by manipulating electrostatic charges of particles suspended in water. This process introduces small, highly charged molecules into water to destabilize the charges on particles, colloids, or oily materials in suspension.

Coagulants are added to the water that the flocculent particles grow bigger in size which is by chemical reaction by rapid mixing and slow mixing and the coalescent particles which grew in size gets removed by settling. The coagulant we add changes the quality of water and the sludge volume too, and some of the coagulants add to bulking of sludge where the removal of moisture is difficult. Lime water instead of lime reduces the volume of sludge which is to all the solid coagulants. Liquid coagulants have more influence readily on coagulant particles than the solid coagulants which itself will take time to dissolve and react with the particles.

Chlorination is the process of adding chlorine or chlorine compounds such as sodium hypochlorite to water. This method is used to kill bacteria, viruses and other microbes in water. In particular, chlorination is used to prevent the spread of waterborne diseases such as cholera, dysentery, and typhoid.

The unit operations and processes can be applied in individual units of houses, colonies and industries that it gives fewer problems to the environment and handled with more efficiency. The entire process of sedimentation, filtration and hardness removal can be done at home, for removal of hardness we need not go for reverse osmosis which is much expensive on installation and maintenance but the simple lime soda process or boiling serve the purpose of both disinfection and hardness removal as the water from the top stratum of aquifer will not be saline in nature with chlorides and sulphates of calcium and magnesium as is seen common with river water discharged with domestic and industrial wastes. The lime soda solution can be sold commercially to separate salts in the tank and that can be removed very frequently. There are plant extracts that helps removing salinity too.

SEDIMENTATION TANK:

It is the process in which the suspended solids are made to settle by gravity under still water conditions is called plain sedimentation.

PLAIN SEDIMENTATION

By plain sedimentation the following are the advantages.

- Plain sedimentation lightens the load on the subsequent process.
- The operation of subsequent purification process can be controlled in better way.
- The cost of cleaning the chemical coagulation basins is reduced.
- No chemical is lost with sludge discharged from the plain settling basin.
- Less quantity of chemicals are required in the subsequent treatment processes.

The amount of matter removed by sedimentation tank depends upon the factors.

- Velocity of flow
- size and shape of particles
- Viscosity of water

The particles which do not change in size, shape or mass during settling are known as the discrete particles. The velocity of descrete particles with dia less than 0.1 mm is given by

V = 418 (S - S1) d2 (3T + 70) -------------------------- (1)

Where V → Velocity of settlement in mm/sec

S → Specific gravity of the particle

S1 → Specific gravity of water

D → dia of the particle in mm

T → Temperature in °C

If the dia of the particle is greater than 0.1mm then the velocity is measured by

V = 418 (S - S1) d (3T + 70) ---------------------------(2)

In practice settling of the particles governed by the resultant of horizontal velocity of water and the vertical downward velocity of the particle.

DESIGN ASPECTS OF SEDIMENTATION TANKS

The design aspects of sedimentary tanks are

- Velocity of flow
- Capacity of tank
- Inlet and outlet arrangements
- Shapes of tanks
- Miscellaneous considerations.

(1) Velocity of flow: The velocity of flow of water in sedimentation tanks should be sufficient enough to cause the hydraulic subsidence of suspended impurities. It should remain uniform throughout the tank and it is generally not allowed to exceed 150mm to 300mm per minute.

(2) Capacity of tank: capacity of tank is calculated by

i) Detention period

ii) Overflow rate

(i) Detention period: The theoretical time taken by a particle of water to pass between entry and exit of a settling tank is known as the known as the detention period. The capacity of tank is calculated by

C = Q x T where C → Capacity of tank

Q → Discharge or rate of flow

T → Detention period in hours

The detention period depends on the quality of suspended impurities present in water. For plain sedimentation tanks, the detention period is found to vary from 4 to 8 hours.

(ii) Overflow Rate: in this method it is assumed that the settlement of a particle at the bottom of the settlement of a particle at the bottom of the tank does not depend on the depth of tank and depends upon the surface area of the tank.

Distance of descend D

Surface overflow rate, V

C L x B x D L x B

Where L → Length of tank

B → Breadth of tank

D → Depth of tank = Side water depth = S.W.D

C → Capacity of tank

T → Detention period

U → Discharge or rate of flow

V → Velocity of descend of a particle to the bottom of tank

Surface overflow rate = S.O.R

(3) INLET AND OUTLET ARRANGEMENTS

The inlet is a device, which is provided to distribute the water inside a tank, and the outlet is a device, which is meant to collect outgoing water. These arrangements should be properly designed and located in such a way that they do not form any obstruction or cause any disturbance to the flowing water.

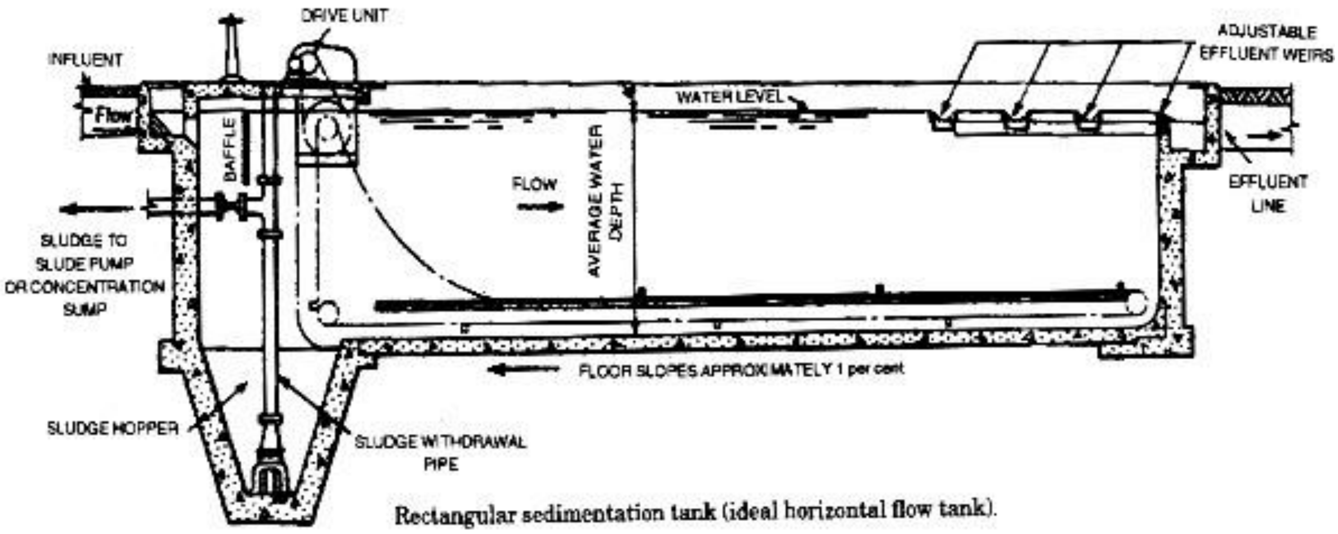
(4) SHAPES OF TANKS

Following are the three shapes of settling tank.

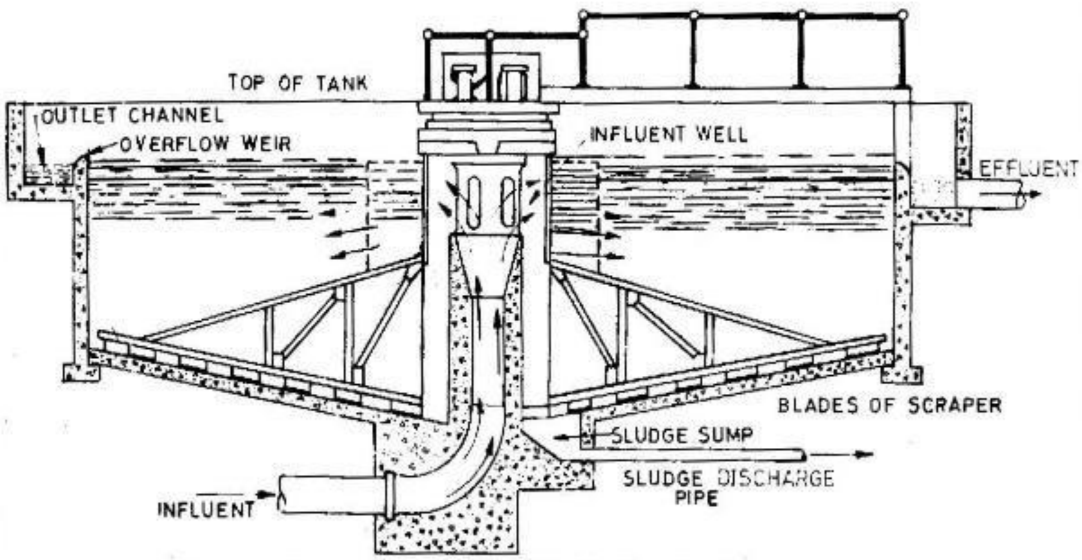
(i) Rectangular tanks with horizontal flow

(ii) Circular tanks with radial or spiral flow

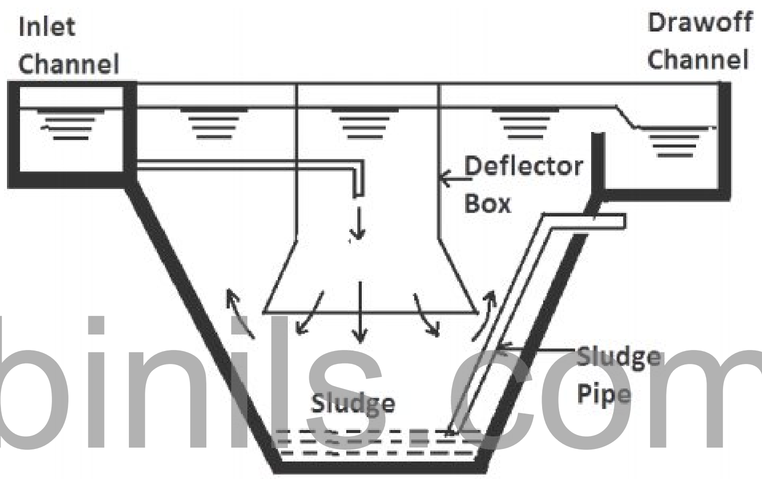
(iii) Hopper bottom tanks with vertical flow



Rectangular sedimentation tank (ideal horizontal flow tank).



Circular sedimentation tank (central feed) with radial flow.



Hopper Bottom Tank

The following are the parameters for satisfactory performance.

- Detention period ….. 3 to 4 hours for plain settling.
  2 to 21/2 hours for coagulant settling
  1 to 11/2 hours for up flow type
- Overflow rate ……… 30 – 40 m3/m2/day for horizontal flow
  40-50m3/m2/day for up flow
- Velocity of flow ....0.5 to 1.0 cm/sec
- Weir loading................300m3/m/day
- L:B ....1:3 to 1:4
- Breadth of tank…...... (10 to 12m) to 30 to 50m
- Depth of tank…..........21/2 – 4m
- Diameter of circular tank…. upto 60m
- Solids removal efficiency… ..50%
- Turbidity of water after sedimentation – 15 to 20 N.T.U.
- Inlet and Outlet zones ....0.75 to 1.0m

- Free board… 0.5m
- Sludge Zone 0.5m

Settling Solid liquid separation process in which a suspension is separated into two phases:

- Clarified supernatant leaving the top of the sedimentation tank (overflow).
- Concentrated sludge leaving the bottom of the sedimentation tank (underflow).

Purpose of Settling:

- To remove coarse dispersed phase.
- To remove coagulated and flocculated impurities.
- To remove precipitated impurities after chemical treatment.
- To settle the sludge (biomass) after activated sludge process / tricking filters.

Principle of Settling:

- 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.

Types of Settling:

Type I: Discrete particle settling - Particles settle individually without interaction with neighboring particles.

Type II: Flocculent Particles – Flocculation causes the particles to increase in mass and settle at a faster rate.

Type III: Hindered or Zone settling –The mass of particles tends to settle as a unit with individual particles remaining in fixed positions with respect to each other.

Type IV: Compression – The concentration of particles is so high that sedimentation can only occur through compaction of the structure.

SEDIMENTATION AIDED WITH COAGULATION:

When water contains fine clay and colloidal impurities which are electrically charged are continually in motion and never settle down due to gravitational force. Certain chemicals are added to the water so as to remove such impurities which are not removed by plain sedimentation. The chemical form insoluble, gelatinous, flocculent precipitates absorb and entangle very fine suspended matter and colloidal impurities during its formation and descent through water. These coagulants further have an advantage of removing colour, odour and taste from the water. Turbidity of water reduced upto 5-10 ppm and bacteria removes up to 65%. The following are the mostly used Coagulants with normal dose and PH values required for best floc formation . Coagulant PH Range Dosage mg/l

1. Aluminium sulphate Al2(SO4)3, 18 H2O 5.5 – 8.0 5 – 85

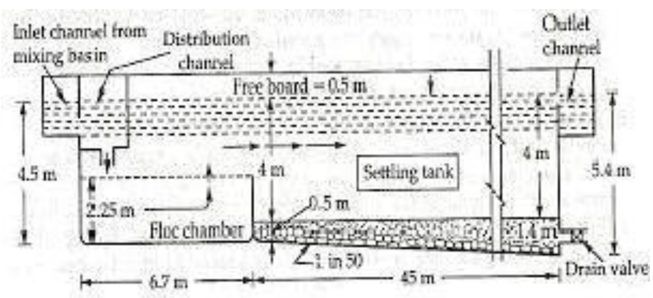
2. Sodium Aluminate, Na2Al2O4 5.5 – 8.0 3.4 – 34

3. Ferric Chloride (Fecl3) 5.5 – 11.0 8.5 – 51

4. Ferric Sulphate Fe2 (SO4)3 5.5 – 11.0 8.5 – 51

5. Ferric Sulphate FeSO47H2O 5.5 – 11.0 8.5 - 51

Coagulants are chosen depending upon the PH of water. Alum or Aluminium sulphate is normally used in all treatment plants because of the low cost and ease of storage as solid crystals over long periods. The dosage of coagulants, which should be added to the water, depends upon kind of coagulant, turbidity of water, colour of water, PH of water, temperature of water and temperature of water and mixing & flocculation time. The optimum dose of coagulant required for a water treatment plant is determined by a Jar test. For starting the experiment first of all the sample of water is taken in every jar and added the coagulant in a jar in varying amounts. The quantity of coagulant added in each jar is noted. Then with the help of electric motor all the paddles are rotated at a speed of 30-40 R.P.M. for about 10 minutes. After this the speed is reduced and paddles are rotated for about 20-30 minutes. The rotation of paddles is stopped and the floc formed in each Jar is noted and is allowed to settle. The dose of coagulant which gives the best floc is the optimum dose of coagulants.



Dimensions of the Coagulation-cum-Sedimentation tank

The coagulants may be fed or allowed to enter either in powder form called dry feeding or in solution form called wet feeding. The mixing of coagulant with the water to form the floc by the following methods.

1. Centrifugal pump
2. Compressed air
3. Hydraulic jump
4. Mixing channel
5. Mixing basins with buffle walls
6. Mixing basins with mechanical means

Now a day's some firms manufacture combined unit comprising of feeding, mixing, flocculator and clarifier device.

Sedimention with Caogulation:

Water enters in this tank through central inlet pipe placed inside the deflector box. The deflector box deflects the water downwards and then it goes out through the holes provided sides of the deflector box. The water flows radially from the deflector box towards the circumference of the tank, where outlet is provided on the full periphery. All the suspended particles along with floc settle down on the slopy floor and clear water goes through outlet. The sludge is removed by scrapper which continuously moves around the floor with very small velocity. Disinfection and repainting is to be carried out once in a year before monsoon. Sludge pipes are to be flushed and kept clean. Bleaching powder may be used to control the growth of algae on the weirs. Scraper mechanism should be oiled and greased periodically.

FILTRATIONOF WATER:

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

THEORY OF FILTRATION:

The following are the mechanisms of filtration

1. Mechanical straining – Mechanical straining of suspended particles in the sand pores.

2. Sedimentation – Absorption of colloidal and dissolved inorganic matter in the surface of sand grains in a thin film.

3. Electrolytic action – The electrolytic charges on the surface of the sand particles, which opposite to that of charges of the impurities are responsible for binding them to sand particles.

4. Biological Action – Biological action due to the development of a film of microorganisms layer on the top of filter media, which absorb organic impurities.

Filtration is carries out in three types of filters

1. Slow sand filter

2. Rapid sand filter Gravity filters

3. Pressure filter

1. SLOW SAND FILTER

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

CONSTRUCTION

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

OPERATION

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

USES

The slow sand filters are effective in removal of 98 to 99% of bacteria of raw water and completely all suspended impurities and turbidity is reduced to 1 N.T.U. Slow sand filters also removes odours, tastes and colors from the water but not pathogenic bacteria which requires disinfection to safeguard against water-borne diseases. The slow sand filters require large area for their construction and high initial cost for establishment. The rate of filtration is also very slow.

2. RAPID SAND FILTER

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

Effective size of sand - 0.45 to 0.70mm

Uniformity coefficient of sand - 1.3 to 1.7

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

Depth of gravel - 45cm

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

Overall depth of filter including 0.5m free board - 2.6m

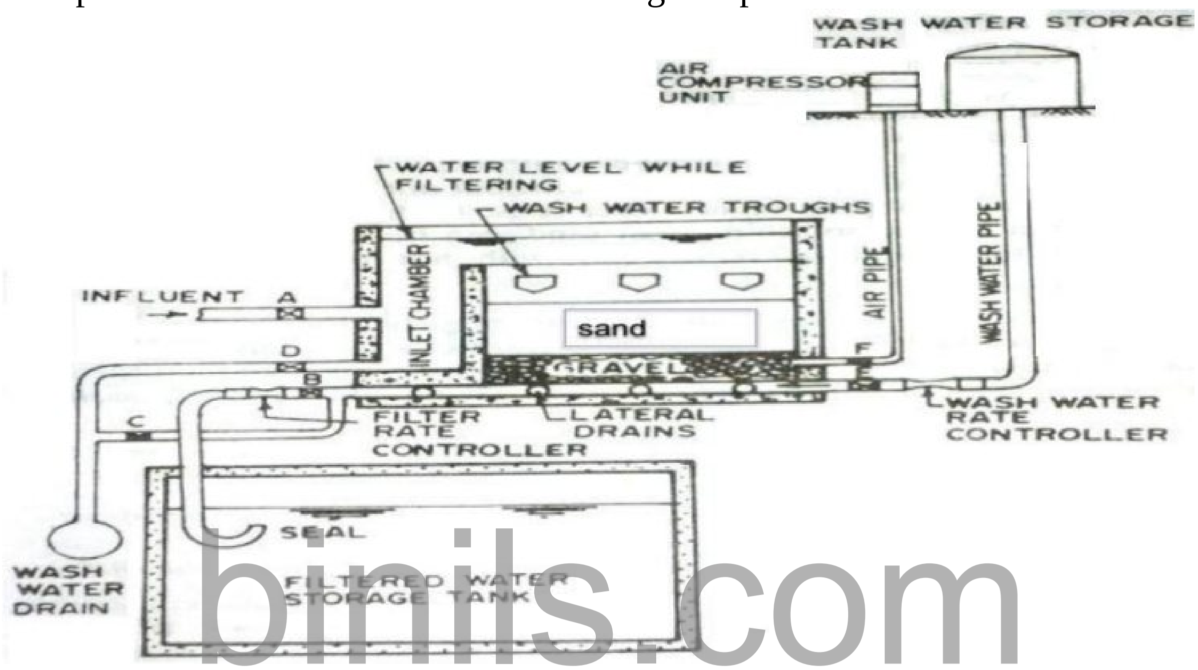
Area of single filter unit - 100m^2 in two parts of each 50m^2

Loss of head - Max 1.8 to 2.0m

Turbidity of filtered water - 1 NTU

CONSTRUCTION

Rapid sand filter cons ists of the following five parts



1. Enclosure tank – A water tight tank is constructed either masony or concrete

2. Under drainage system – may be perforated pipe system or pipe and stracher system

3. Base material – gravel should free from clay, dust, silt and vegetable matter. Should be durable, hard, round and strong and depth 40cm.

4. Filter media of sand – The depth of sand 60 to 75cm

5. Appurtenances – Air compressors useful for washing of filter and wash water troughs for collection of dirty water after washing of filter. Washing process is continued till the sand bed appears clearly. The washing of filter is done generally after 24 hours and it takes 10 minutes and during back washing the sand bed expands by about 50%.Rapid sand filter bring down the turbidity of water to 1 N.T.U. This filter needs constant and skilled supervision to maintain the filter gauge, expansion gauge and rate of flow controller and periodical backwash.

OPERATION

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

3. **PRESSURE FILTER**

Pressure filter is type of rapid sand filter in closed water tight cylinder through which the water passes through the sand bed under pressure. All the operations of the filter are similar to rapid gravity filter; expect that the coagulated water is directly applied to the filter without mixing and flocculation. These filters are used for industrial plants but these are not economical on large scale. Pressure filters may be vertical pressure filter and horizontal pressure filter. Backwash is carried by reversing the flow with values. The rate of flow is 120 to 300m^3/m^2/day.

ADVANTAGES

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

DISADVATAGES

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

DISINFECTION OF WATER:

The process of killing the infective bacteria from the water and making it safe to the user is called disinfection. The water which comes out from the filter may contain some disease – causing bacteria in addition to the useful bacteria. Before the water is supplied to the public it is utmost necessary to kill all the disease causing bacteria. The chemicals or substances which are used for killing the bacteria are known as disinfectants.

REQUIREMENTS OF GOOD DISINFECTANTS

1. They should destroy all the harmful pathogens and make it safe for use.
2. They should not take more time in killing bacteria.
3. They should be economical and easily available.
4. They should not require high skill for their application.
5. After treatment the water should not become toxic and objectionable to the user.
6. The concentration should be determined by simply and quickly.

METHODS OF DISINFECTION

Disinfection of water by different physical and chemical methods

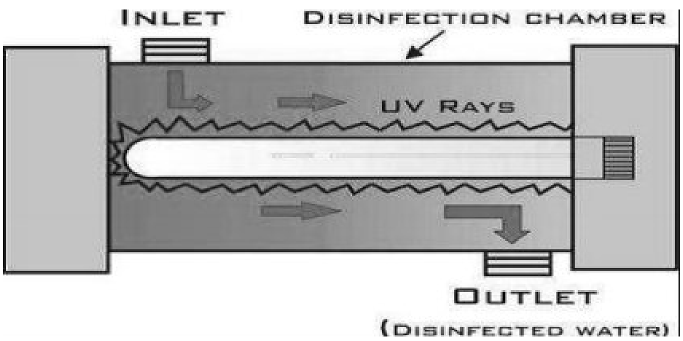
I. PHYSICAL METHODS

1. Boiling:

Boil the water for 15 to 20 minutes and kills the disease causing bacteria. This process is applicable for individual homes.

2. Ultra-violet rays:

Water is allowed to pass about 10cm thickness by ultraviolet rays. This process is very costly and not used at water works. Suitable for institutions.



II. CHEMICAL METHODS

1. Treatment with Excess Lime:

Lime is used in water treatment plant for softening. But if excess lime is added to the water, it can in addition, kill the bacteria also. Lime when added raises the pH value of water making it extremely alkaline. This extreme alkalinity has been found detrimental to the survival of bacteria. This method needs the removal of excess lime from the water before it can be supplied to the general public. Treatment like recarbonation for lime removal should be used after disinfection.

2. 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.

3. Bromine and Iodine:

Use of iodine or bromine is limited to small water supplies such as swimming pools, troops of army, private plants, etc.

- Dosage of iodine or bromine is about 8 p.p.m.
- Contact period with water is 5 minutes.
- Available in the form of pellets or small pills.

4. POTASSIUM PERMANGANATE TREATMENT ($KMnO_4$)

- It is a powerful oxidising agent, effective in killing cholera bacteria
- Restricted to disinfection of water of village wells and ponds
- Dosage is about 2.1 ppm
- Contact period of 3 to 4 hours
- The treated water produces a dark brown coating on porcelain vessels and this is difficult to remove except with scratching or rubbing

5. **SILVER TREATMENT**

- Colloidal silver is used to preserve the quality of water stored in jars.
- Metallic silver is placed as filter media. Water get purified while passing through these filters.
- Dosage of silver varies from 0.05 to 1 p.p.m.
- Contact period is about 15 minutes to 3 hours.
- It is costly and limited to private individual houses only.

CHLORINATION:

Chlorination is the addition of chlorine to kill the bacteria Chlorination is very widely adopted in all developing countries for treatment of water for public supply. Chlorine is available in gas, liquid or solid form (bleaching powder)

ADVANTAGES OF CHLORINE

1. Chlorine is manufactured easily by electrolytes of common salts (NaCl).
2. It is powerful oxidant and can penetrate the cell wall of organism and its contents.
3. Dosage can be controlled precisely.
4. Can be easily detected by simple orthotolidine test.
5. Does not form harmful constituents on reaction with organics of inorganic in water.

RESIDUAL CHLORINE AND CHLORINE DEMAND

When chlorine is applied in water some of it is consumed in killing the pathogens, some react organs & inorganic substances and the balance is detected as “Residual Chlorine”. The difference between the quantity applied per liter and the residual is called “Chlorine Demand”. Polluted waters exert more chlorine demand. If water is pre-treated by sedimentation and aeration, chlorine demand may be reduced. Normally residual chlorine of 0.2 mg/liter is required.

DOSAGE OF CHLORINE

(A) PLAIN CHLORINATION

Plain chlorination is the process of addition of chlorine only when the surface water with no other treatment is required. The water of lakes and springs is pure and can be used after plain chlorination. A rate of 0.8 mg/lit/hour at 15N/cm^2 pressure is the normal dosage so as to maintain in resided chlorine of 0.2 mg/lit.

(B) SUPER CHLORINATION

Super chlorination is defined as administration of a dose considerably in excess of that necessary for the adequate bacterial purification of water. About 10 to 15 mg/lit is applied with a contact time of 10 to 30 minutes under the circumstances such as during epidemic breakout water is to be dechlorinated before supply to the distribution system.

(C) BRAKE POINT CHLORINATION

When chlorine is applied to water containing organics, micro organisms and ammonia the residual chlorine levels fluctuate with increase in dosage Upto the point B it is obsorbed by reducing agents in water (like nitrates, Iron etc) further increases forms chloramines with ammonia in water. Chloramines are effective as CL and OCL formed. When the free chlorine content increases it reacts with the chloramines and reducing the available chlorine. At the point „D‟ all the chloramines are converted to effective N2, N2O and NCl3. Beyond point „D‟ free residual chlorine appear again. This point „D‟ is called break point chlorination. Dosage beyond this point is the same as super chlorination. In super chlorination no such rational measurement is made and the dosage is taken at random.

(D) DECHLORINATION

Removal of excess chlorine resulting from super chlorination in part or completely is called „Dechlorination". Excess chlorine in water gives pungent smell and corrodes the pipe lines. Hence excess chlorine is to be removed before supply. Physical methods like aeration, heating and absorption on charcoal may be adopted. Chemical methods like sulphurdioxide(SO2) , Sodium Bi-sulphate (NaHSO3),Sodium Thiosulphate(Na2S2O8) are used.

POINTS OF CHLORINATION

Chlorine applied at various stages of treatment and distribution accordingly they are known as pre, post and Re-chlorination.

a) PRE-CHLORINATION

Chlorine applied prior to the sedimentation and filtration process is known as Prechlorination.This is practiced when the water is heavily polluted and to remove taste, odour, color and growth of algae on treatment units. Pre-chlorination improves coagulation and post chlorination dosage may be reduced.

b) POST CHLORINATION

When the chlorine is added in the water after all the treatment is known as Postchlorination.

c) RE-CHLORINATION

In long distribution systems, chlorine residual may fall tendering the water unsafe. Application of excess chlorine to compensate for this may lead to unpleasant smell to consumers at the points nearer to treatment point in such cases chlorine is applied again that is rechlorinated at intermediate points generally at service reservoirs and booster pumping stations.