Water Treatment And Mangement

Book Name: Water Supply & Sanitary Engg

UNIT-I - Internal treatment water

Impurities in water

all the impurities of water can be listed boardly as follows:- a) suspended impurities :- it includes clay, algae, fungi, organic matters and mineral matter etc... These impurities are macroscopic and cause turbidity in the water. The size of the suspended impurities ranges from $0-10^3$ mm as diameter.

b) colloidal impurities :- It is very finally divided dispersion of particles in water. These particles are so small that this cannot be removed by ordinary filters and are not visible to the naked eye. The size of the colloidal particles are in b/w 10^{-3} mm and 10^{-6} mm.

c) Dissolved impurities - Some impurities are dissolved into water when moves over drops and soil etc, solids liquids, and gaseous are dissolved in natural water. This dissolved impurities may contain organic compounds inorganic salt and gaseous etc. The concentration of total dissolved solid its usually expressed in ppm

Causes of different impurities

i) suspended impurities - Bacteria causes sudden deases.

Algae, protozoa etc will produce odour, turbidity and colour.

Presence of clay and silt will cause turbidity

Dissolved impurities

Calcium & Magnesium → causes hardness, alkalinity

fluoride → Mottled enamle, enamle of teeth

Sodium → taste change, produce alkalinity

Manganese → Black or Brown colour

lead & orgganic - poisoning

CO_2 - acidity, corrosiveness

H_2S - Bootten egg odour

Water treatment process

The rock water which is found in various natural sources cannot be directly used by the public for the various purpose, before removing the impurities. The amount and type of treatment process will dependent on the quality of rock water and std of quality to be required after treatment.

Objectives of Treatment

The main objective of the treatment process is to remove the impurities of rock water and bring the quality of water to the required std the other objectives are

1. To remove the dissolved gases and colour of water
2. To remove the unpleasent and objectives taste and odour.
3. To kill the all the pathogenic germs which are hoarmful to the human health
4. To make the water fit for domestic use as cooking and washing and various industrial purpose as dying, steel generation etc..
5. To eliminate corrosive properties of water.

Treatment process

The treatment process directly depend on the impurities present in water. For removing various types of impurities, the following treatment process are use.

Sl.No	Impurity	Process used for removal
1.	floating matters such as leaves dead animals etc.	Screening
2.	Suspended impurities such as silt, clay, sand etc.	plain sedimentation
3.	Fine suspended Matter	Sedimentation with Coagulation
4.	Micro-organism and colloidal matter	Filteration
5.	Dissolved gases, taste and odour	Aeration and Chemical treatment
6.	Hardness	Water softening
7.	pathogenic Bacteria	Disinfection

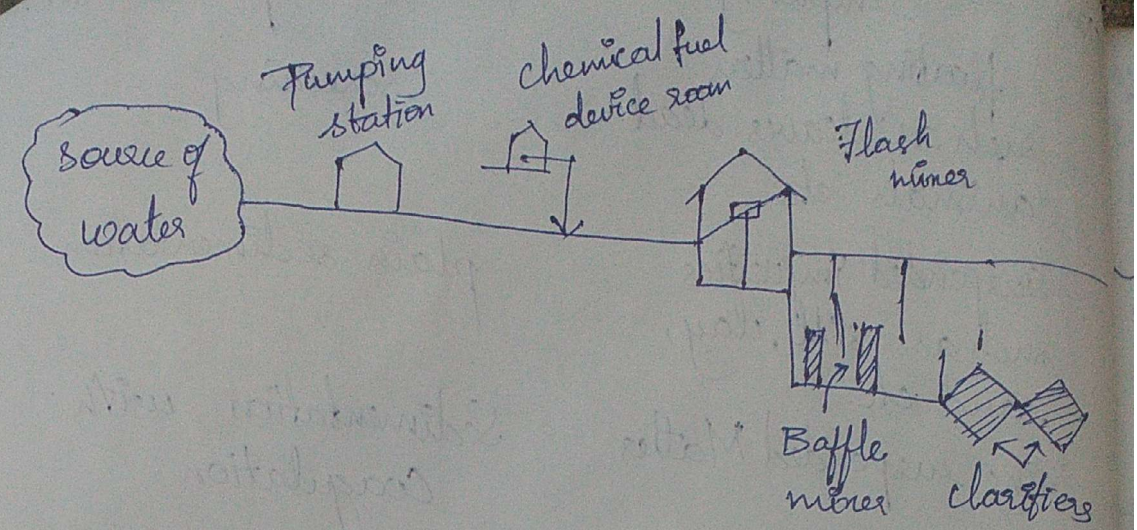
Location of the treatment plants and layout of the time:-

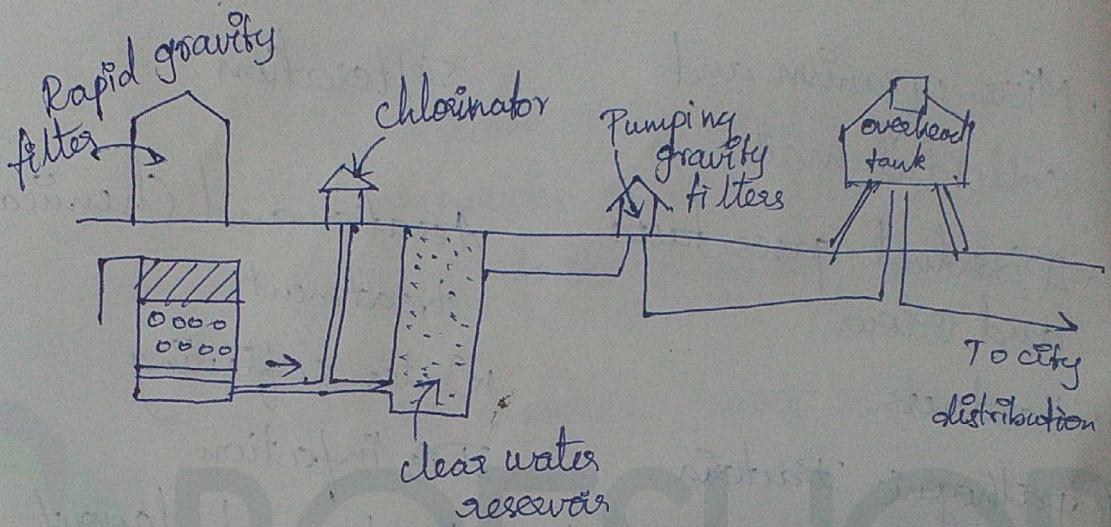
The water treatment plant should be located as near to the towns/Industry as possible.

One complete water treatment plant requires the following process starting from the source of water upto the distribution zone in order of sequence.

i) pumping station ii) plain sedimentation iii) sedimentation with coagulation iv) filteration v) Water softening plant vi) miscilianous treatment plant vii) Disinfection viii) clear water reservoir

A typical sequence of water treatment plant is as given below





Laboratory.

A well equiped laboratory should be provided with treatment plant to check the quality of raw material and treated water according to the variations in impurities, the treatment process should be changed.

Type of test

1. physical test
   i) pH ii) TDS - Total dissolved salts
2. chemical Test
   i) Hardness ii) Alkality iii) free carbondioxide iv) Nitrogen as Nitrade, Nitrite and free ammonia v) Active chlorine

3. Biological test

i) presence of B. coli group ii) plate counts

plain Sedimentation

It is a process of removing suspended matters from the water by keeping it quiescent (Motion less) in tanks so that suspended matter stelled down in the bottom due to the force of gravity

Advantages of plain sedimentation

It lighten the load on the subsequent process.

The cost of cleaning the clemical coagulation basin is reduced.

No chemical is lost with sludge

Less quantity of chemicals are required in the subsequent treatment process.

Process

In the process of treating water by sedimentation, the water is retained in a basin so that the suspended particles may settled down due to force of gravity only. After the settlement of suspended particles, the water is taken out from the basin without causing any disturbance to the suspended impurities.

Principle of sedimentation

Any particle which does not changed its size, shape and weight while settling any fluid is called discred particles. All the particles having more specific gravity than the liquid will move vertically downward due to gravitational force. when any discred particles is falling

through a quiescent fluid. it will accelerate until the frictional resistance or drag force becomes equal to the gravitational force acting upon the particles. At such stage, the particle will settled at uniform velocity. These uniform velocity is called settling velocity

Design of continious flow settling tanks

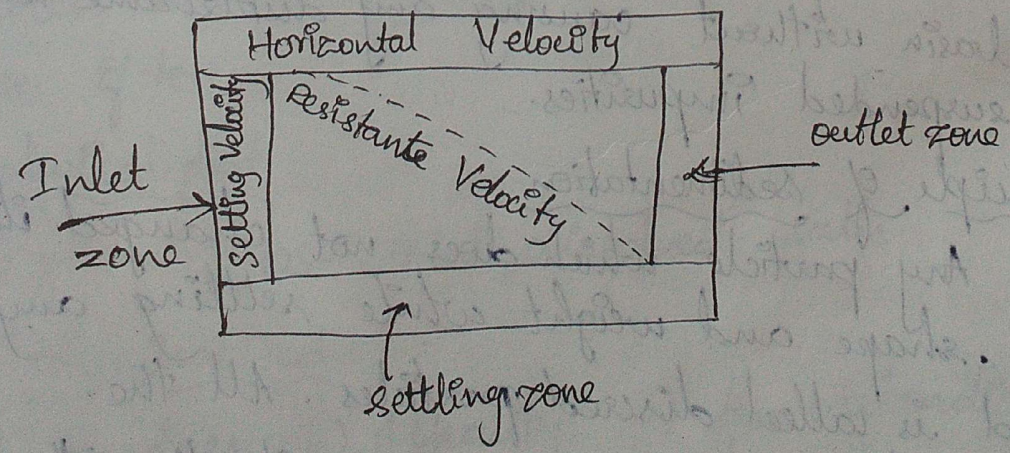
For the purpose of desinging the continous flow basin may be divided into four zones
i) An inlet zone ii) settling zone iii) sludge
v) outlet zone.

Design of inlet zone

The inlet zone should be desigued in such a way that in coming water is uniformly distributed on the full width of the time and it enters the settling zone without causing any distribance to the velocity particles.

Plain Sedimentation

Settling zone Designing



when any particle enters the settling zone in a continous flow settling tanks it is acted upon by the two forces

i) The horizontal flow of water gives it horizontal movement, while

ii) Gravitational force causes it to move downward

The particles moves under the influence of both this forces and traces out a parabolic path as shown in the figure.

Water should be detained in the settling time such a period all the desired suspended particles may reach the sludge zone & are removed.

The time for which a water is detained in the settling time is called detention time.

$$\text{Theoretical detention time} = \frac{\text{capacity of the tank}}{\text{Rate of flow of water}}$$

Generally detention period of 2 hours - 4 hours is adopted for mechanically clean tanks and 4 - 8 hours for ordinary settling tanks.

Design of sludge zone

sludge zone of the settling sedimentation tank is design in such way time all the settled may be collected and can be conviently removed whenever desired without causing disturbance to the water of settling zone.

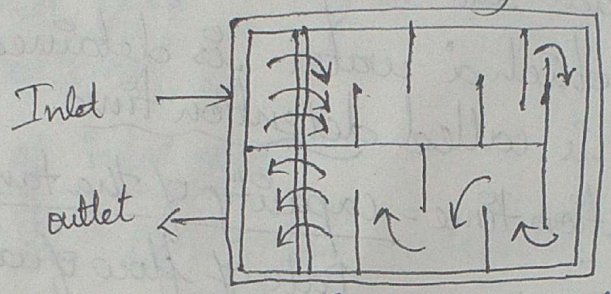
Generally the bottom flow of the tanks are made slopping towards one side or towards centre of the tank

Cast irons pipe with gate wall are provided at the lowest point of the flow where sludge is removed under hydrostatic pressure.

Types of Sedimentation tank

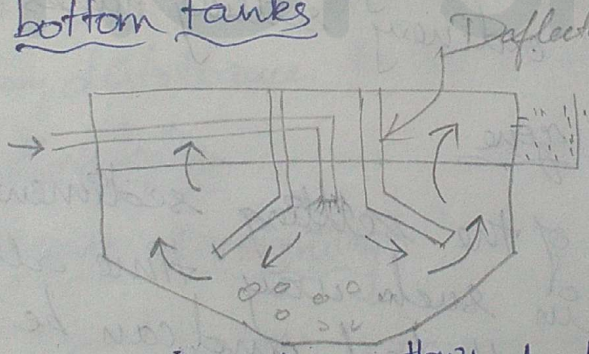
In practice three types of sedimentation tanks are used i) rectangular tanks ii) circular tanks ii) hopper bottom tanks.

i) Rectangular tank - These are rectangular in plan and consist of large no. of baffle walls. The function of the baffle wall is to reduce the velocity of incoming water, to increase the effective length of travel of the particle, to prevent the short circuiting.



ii) Circular tank - Generally not used in sedimentation with coagulation

Hopper bottom tanks



These are vertical flow tank because water flows upward and downward in tanks.

After flowing downward inside the deflector box the water reverses its direction and start flowing upward around the deflector box as shown by the arrow marks this is called Hopper bottom tanks.

Sedimentation with Coagulation

Very fine suspended clay particle are not removed by plain sedimentation since requires more settling time with ranges to 4 days.

In addition to the fine suspended matter, water also contain electrically charged colloidal matter which are continously in motion and never settled down due to the gravitational force. After long experiment it has found that such impurities can be removed by sedimentation with coagulation process

It has been found that certain chemicals are added insoluble, gelatenous flocculent precipitation is formed. This gelatinous precipitate absorbed and entangled very fine suspended matter and colloidal matter. Thus the gelatinous precipitate as the property of removing fine and colloidal particles quickly and completly than the plain sedimentation. These coagulants have further, have the advantages of removing colour, odour and taste from the water.

First the coagulants are mixed in water to produce required precipitate then the water sent in sedimentation basin where the sedimentation of fine and colloidal particle take place.

Most commonly used coagulants are 1. alum (aluminium sulfate) 2. sodium aluminate 3. ferric coagulants 4. chlorinated coppears 5. ferrous sulfate and lime

Aluminium sulfate $(Al_2(SO_4)_3 \cdot 18H_2O)$

It is also called as alum. alum reacts in water in the presence of alkalinity $[CO_3^{2-}, OH^- \& HCO_3^-]$ If alkalinity is not present, sufficient lime is added. The following chemical reactions take place with the various types of alkalinity.

$$Al_2(SO_4)_3 \cdot 18H_2O + 3Na_2CO_3 \rightarrow 2Al(OH)_3 + 3Na_2SO_4 + 2CO_2 + 15H_2O$$

$$Al_2(SO_4)_3 \cdot 18H_2O + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 2CaSO_4 + 18H_2O$$

$$Al_2(SO_4)_3 \cdot 18H_2O + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 2CaSO_4 + 6CO_2 + 18H_2O$$

The insoluble and colloidal $Al(OH)_3$ forms the floc which removes the fine suspended colloidal impurities for

best result the pH of water should be b/w 6.5 & 8.5
The doses of alum should 0.03 to 0.18 gm/litre depending upon the turbinity of water. Sodium aluminate ($Na_2Al_2O_3$). This is an alkaline compound this can be used for treatment very easily in the water have keen no alkalinity. It reacts very quickly and form precipitate of calcium aluminate ($CaAl_2O_3$)

$$Na_2Al_2O_3 + CaSO_4 \rightarrow CaAl_2O_3 + Na_2SO_4 \text{ flox}$$

$$Na_2Al_2O_3 + CaCl_2 \rightarrow CaAl_2O_3 + 2NaCl \text{ flox}$$

$$Na_2Al_2O_3 + Ca(HCO_3)_2 \xrightarrow{H_2O} CaAl_2O_3 + Na_2CO_3 + CO_2 \uparrow$$

Calcium aluminate is the sequired flox which causes sedimentation which has advantages of removing corrosive qualities of the water but it is costly.

Ferric Coagulants

Generally Ferric $Fe_2(SO_4)_3$ or mixture of both is used for coagulation purpose

$$2FeCl_3 + 3Ca(OH)_2 \rightarrow 2Fe(OH)_3 + 3CaCl_2 \text{ flox}$$

$$Fe_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Fe(OH)_3 + 3CaSO_4$$

Ferrous sulphate & lime:

$$FeSO_4 7H_2O + Ca(OH)_2 \rightarrow Fe(OH)_2 + CaSO_4$$

$$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3 \text{ (floc)}$$

Ferric hydroxide is a floc which causes sedimentation ferric coagulants are good oxidising agent due to which this also removed hydrogen sulphide, taste, odour from water.

This coagulants are generally used in the treatment of sewage. Ferrous sulphate is commonly used in coagulation it is cheaper than alum and gives that good result above pH value of 8.5

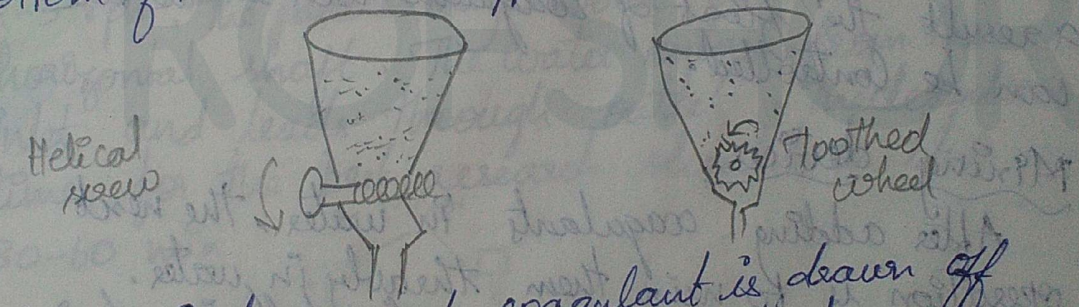
Feeding devices

Coagulants can be feed in dry or liquid form dry feed devices are desirable because they are simple require small space for installation, keep neatness, free from corrosion and economical but all coagulants can't be fed by dry feed devices because some coagulants have characteristics of clogging, caking and deliquescence

∴ The choice of feeding device depends on the types of coagulant and the economy the total cost of the plant

Dry feed devices

These devices are designed on volumetric or gravimetric displacement of drying chemicals. The chemicals are kept in hoppers required amount of coagulant is feed by the revolving the helical screw or toothed wheel fixed at the bottom of the conical hopper.



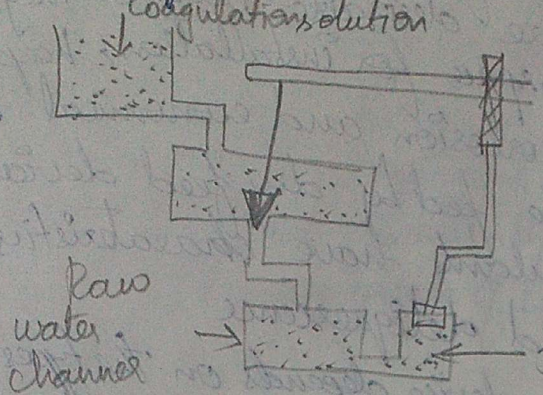
Only required amount coagulant is drawn off continously. The speed of rotation of helical screw or toothed wheel is control by means of venturey devices installed in raw water channels are pipes through which raw water flows to the treatment plants when the quantity of water increases automatically the speed of rotation is increased and required amount of coagulant is feed in water every time.

Solution feed devices

The chemicals, which can be easily prepared are suitable to feed by this method

1. solution is prepared by placing the coagulants in a metal basket, Perforated wooden box & then

spine water over it. The solution so prepared is kept in large tanks.



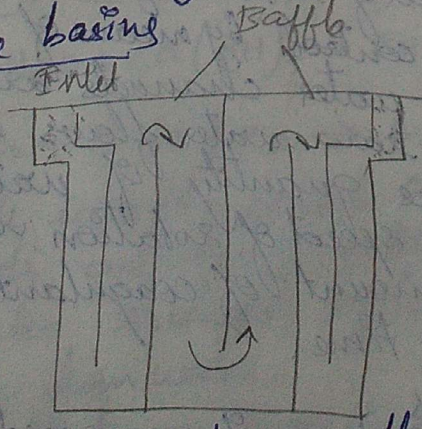
The chemical moves is kept in a constant level tank, having tapered hole in the bottom which is controlled by a conical plug operated by a rod connected to the pulley.

A float chamber is constructed and connected to the raw water channel by means of a pipe, when the quantity of raw water increases, the water level in the float chamber also increases and left the float. The lifting of float operates the pulley and the conical plug is also shifted the position as a result the flow of coagulant into the tank can be controlled.

Mixing devices

After adding coagulants in water, the next operation is to mix them thearly in water. Mixing can be done by one of the following devices

1) Baffle type basins

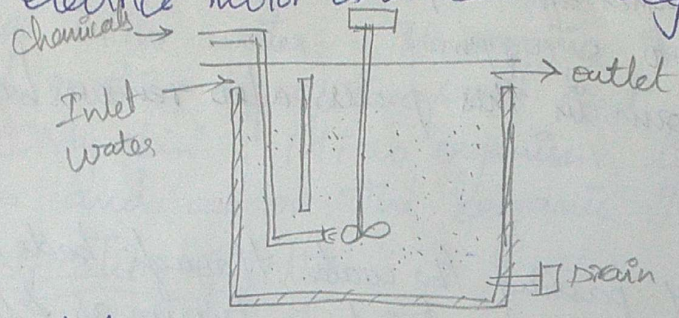


In this basin water may flow up and down and over baffles. The baffils walls are placed 60 to 100 cm apart, the velocity of water is kept b/w 1.5-30 cm/s.

the detention period in this basins is kept 20-30 min this are non-suitable for small

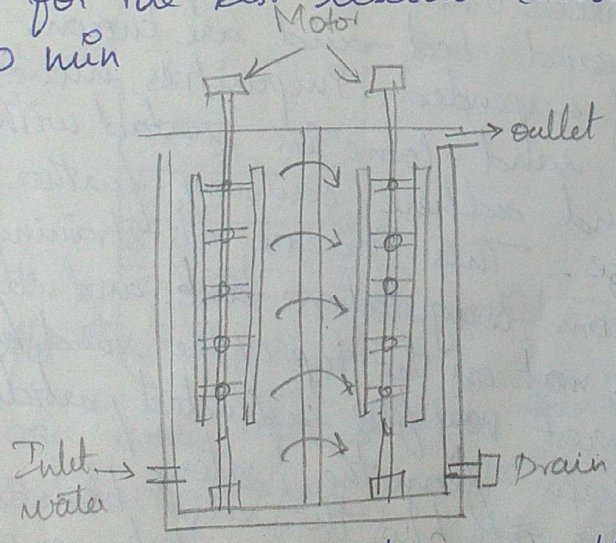
ii) Flash mixer

In this device the solution of coagulants is mixed thoroughly in the water by means of a fan operated by electric motor and suitable ~~dog~~ drive.



Floculation

After thoroughly mixing of coagulation in water, the next operation is floculation. Floculation are slow stirring mechanism, which forms floc. The floculator mostly consist of paddles which are revolving at very slow speed about 2-3 rpm. The paddes may revolve on a vertical are horizontal shaft. The water entas from the inlet and leads through outlet. The detention time for the best research should be b/w 30-60 min



Clarifiers :- In this operation, the floc which has been found is allowed to settled and is separated from water. This is done by keeping the water in sedimentation tanks which are also known as coagulation basin. The design of clarifiers is similar to the top plain sedimentation tanks.

Limitation of the process

1. The coagulation process removes the suspended impurities of and considerable reduces the load on the filteration process.

2. The toxicity of water can be removed less than 20 ppm and if the process is properly controlled it can grow upto 5-10 ppm

3. The floc form in this process also removes bacteria upto 65%.

Filteration

The process of passing the water through beds of sand or other granular material is known as filteration Broadly speaking filters essentially consist of a thick layer of sand and the water is aloud to pass through it.

Theory of filteration

The phenomenon on which filteration process removes bacteria, colour, taste, odour, iron, magnese etc... can be explained on the basis of following four action

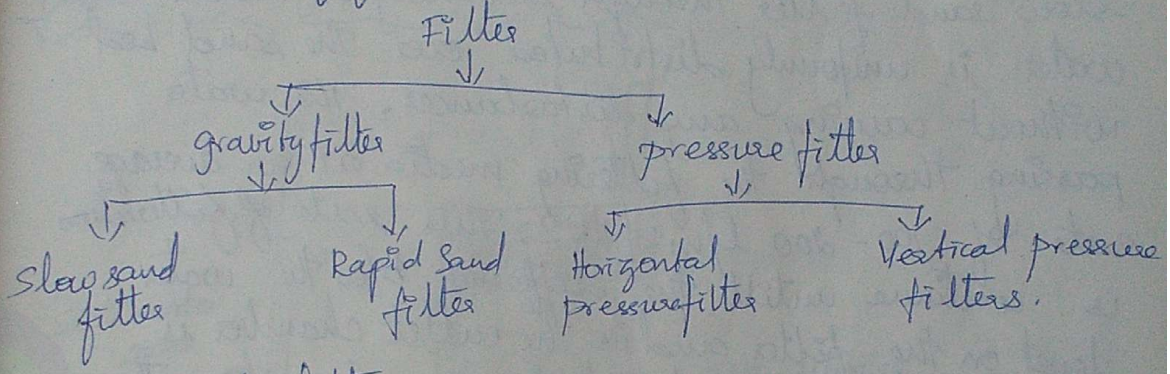
a) Mechanical straining - Sand consist of small pores, ∴ The suspended particles which are large in size can't pass through the sand bed and are known. Small particles of suspended impurities move through the pores in the sand come in contact with the sand surfaces and adhere causing further reduction in the pores size. This increase its straining action, unsettled floc from coagulation tank and settled particles form a mat on the top of the sand bed which further arrest very fine suspended particles and removes them from the water.

b) Sedimentation - The voids b/w the sand bed act as small settling basin Very small particles are suspended matter, colloidal particles and some bacteria settled in these small setting basin and adhere to the sand particle. Due to the physical attraction b/w the two particles of matter and because of the presence of gelatinous coating formed on the sand grains.

by previously deposited suspended matter.

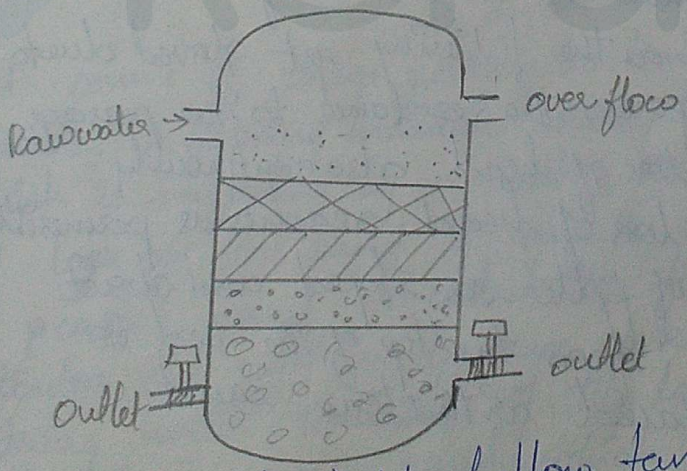
c) Biological Action - Suspended impurities contain some portion of organic impurities such as algae, plankton etc... which are food of various types of microorganism. These organism act on the organic matter and cause the chemical and biological change in the water. The organic impurities form a layer on the top of the sand bed which is known as "Dirty skin". Micro organism live in the dirty skin and act on the organic impurities of water.

classification of filter



Slow sand filters

Construction of slow sand filter tank



These are water tight shallow tanks about 2.5 m to 4m deep and having surface area 100^2 m to 2000^2 m is the surface area. These tank contain thick bed of sand filtering media. Supported on thick gravel bed. Generally 3 to 4 layers of gravel of having thickness 15 to 20 cm are used. The coarse gravel "40-60 mm" is played in the bottom and the smallest size "3 to 6 mm" gravel is used in the top most layer

The intermediate layer 20-40mm can be used. The gravel is supported on a bed of concrete sloping towards a central longitudinal drain connected by a system of open jointed under drains. The sand bed "filtering media" consist of graded sand in various layers for slow sand filter sand of having effective size b/w 0.3 and 0.35 mm is used in Indian practise.

Operation of filter

The water from sedimentation tanks enter the slow sand filter through submergible inlet. This water is uniformly distributed over the sand bed without causing any disturbances. The water passing through the filtering media at an average rate of 100 - 200 l/m²/hr. This rate of filteration is continue until the difference b/w the water level on the filter and in the outlet chamber is slightly less than the depth of water above the sand. The difference b/w water above the sand and in the outlet chamber is called loss of head.

During filtering as the filtering get gloved due to which stay in the pores, the resistance to the passage of the water and loss of head also continously increased. When loss of head reaches is permesible limit the working of filter is stoped and about 2 to 3 cm sand from the top of the bed is scraped and replaced with clean sand

Results

1. slow sand filters are very efficient in the removal of bacteria 95 to 98% of the raw water and completely all the suspended matter which cannot be removed by sedimentation process
2. It also removes the odour, taste & colour from the water

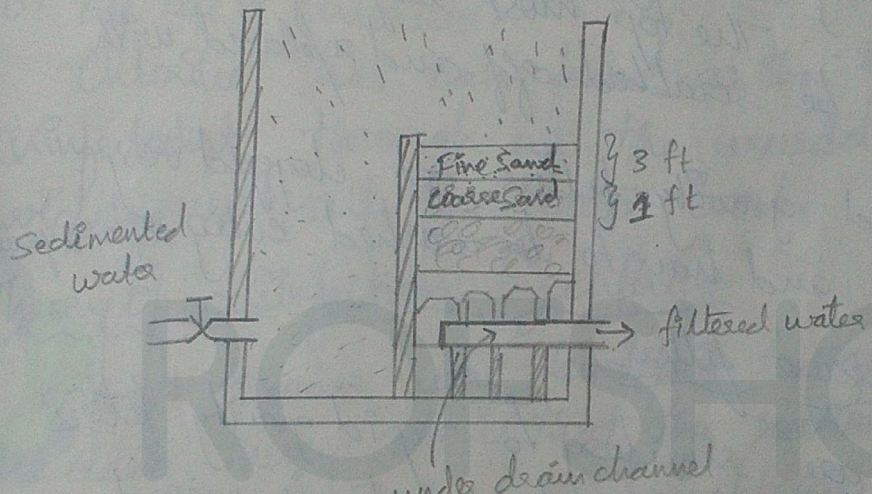
Merits

1. Best suited for filteration of small plants & for small team.
2. Removes turbidity, bacteria, colour and taste very efficiently.

Demerits

1. Requires large area for their construction
2. As a result increases their initial cost
3. cannot remove pathogenic bacteria completely.

Rapid Sand [Gravity] filters



It consits of large rectangular tank made up of concrete. A filtering medium easier layer of coarser sand which is supported by a bed of graded gravel.

A layer of fine sand is carefully seived at the top of coarse sand to collect the filter water steel cylindors are used as pressure vessels containing filtering media consisting of the layers of fine sand followed by coarse sand which intern turn supported on gravel.

The water enters the vessel through inlet wall under pressure often coagulants are added to the incoming water, after it enters the filter vessel. This helps to form slimy layer over the filter bed so that the colloidal and bacteriological impurities are removed, the cleaning of filter is carried out by backwashing as is done in gravity filter

before backwashing compressed air is passed to agitated the sand water trains provides at the bottom.

sedimented water entering the sand filter is uniformly distributed over the entire fine sand bed after passing through filter beds. The filtered water is taken out from the drying system provided at the system. When the filter bed is clogged by the particles removed from the water it as to cleaned. When the rate of filteration becomes slow. The working of filter is stop. The filter bed is cleaned by back washing by reversing the flow of water through the filter. The top most layer of sand can also be scrabbed off and replaced with sand.

The rapid gravity filters get clogged very frequently and have to be washed every 24 to 48 hours

Rapid pressure filters

These are similary to rapid gravity filters placed in closed vessel. Water is passed through pressure filters at a pressure greater than atmospheric pressure (filter should be located in air tight vessel).

Disinfection

The process of killing the pathogenic bacteria and microorganisms is known as sterilization or disinfection the chemicals and ~~usage~~ substances used for disinfection is called disinfectant

eg :- UV rays, Iodine and Bromine

necessity for disinfection

The filters are unable to remove all disease cause bacteria they can remove one day few types of bacteria. Water which comes out from the filters may contain some deases cause bacteria in addition to the useful bacteria, before the water is supplied to the public it is the most necessary add to kill all the bacteria.

Methods of disinfection

1. Boiling 2. By UV rays 3. use of iodine and chromin 4. By ozone 5. KMNO4
6. By use of chlorine.

Chlorine has been found as the most ideal disinfectant through out the world and its widely used all the water works.

Theory of disinfection by chlorine

several theories were developed to explain it. The oldest theory of it is that the nascent oxygen is liberated from hypochlorous oxide. oxidises some essential constituent of the bacterial cell, thus destroying them

$$Cl_2 + H_2O \rightarrow HCl + HOCl$$

Hypochlorous acid

$$HOCl \underset{}{\overset{pH_{7-8}}{\rightleftharpoons}} H^+ + OCl^-$$

all the three forms by HOCl, OCl^- and Cl_2 existing in a sample water are called as free chlorine.

Out of these three form the HOCl is found to be most destructive according to enzymatic hypothesis given by Gleen & stump for this reason, the pH value of water during chlorination

is generally maintained slightly less than 7 so has to prevent the dissociation of HOCl.

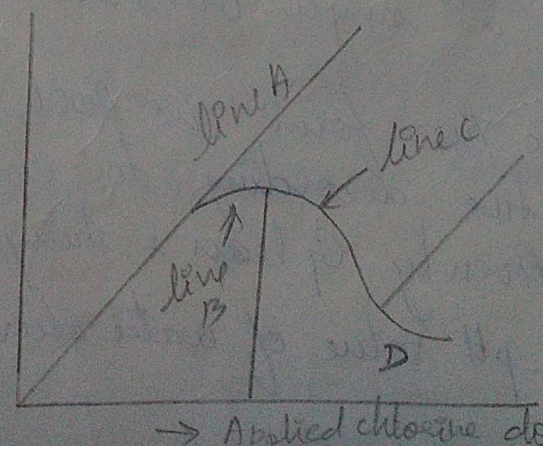
According to enzymatic hypothesis HOCl reacts with enzymes in the cells of bacteria which are essential for the growth and other metabolic process HOCl is about 80 times more destructive to bacteria than OCl⁻

Factors affecting the efficiency of chlorine

1) time of contact 2) concentration of disinfected 3) the no. of organisms 4) temperature of water 5) pH value 6) presence of various chemicals.

Break point chlorination

When chlorination added to water it react with organic and inorganic matter and forms common compounds. Some portions of chlorine remains as residual chlorine "combined residual, which is much weak in disinfection action now the chlorine dose is increased the combined available residual chlorine also increases when the chlorine those is so increased, the compound gets oxidised to form new substance which do not react with ortho toledine. If the addition of the chloride continue and graph is plotted b/w chlorine those and residual chlorine, a curve is obtained as shown in the figure.



on study in the curve it will be noticed that the residual chlorine being increases with the applied chlorine, after the point C is suddenly drops upto the point D and then increases. point BC indicate the formation of chloramines and the portion CD indicate their oxidation.

Point D at with residual chlorine again starts increased the is known as break point Chlorination.

Super Chlorination

The addition of chlorine is excess is called superchlorination which gives a strong odour and taste of Cl in the treated water, which can be removed by dechlorination.

Dechlorination

The residual chlorine can be removed by the addition of following chemicals

1. SO_2
2. $NaHSO_3$
3. $Na_2S_2O_3$
4. Activated carbon
5. Ammonia