UNIT –IV

Treatment of water

The raw water which is found in various natural sources cannot be directly used by the public for various purposes, before removing the impurities. For palability the water must be free from unpleasant tastes, odours and must have sparkling appearance and free from disease spreading germs. To obtain the quality standards the treatment of water is necessary.

- ***Objectives of treatment:*** The main objective is to remove the unwanted impurities and increase the water quality to the standards. The main objectives are:
  1. To remove dissolved gases, murkiness and colour of water.
  2. To remove unpleasant odours and tastes
  3. To kill disease causing pathogenic organisms.
  4. To make water useful for different purposes.
- ***Treatment Process:*** The selection of treatment process depends upon the impurities present in the water. The treatment process should be selected in such a way that maximum removal of impurities can be achieved. The characteristics and degree of treatment directly depends upon the nature of water. Different treatment processes employed are:
  1. Screening: Removal of floating matter.
  2. Plain Sedimentation: Removal of suspended matter.
  3. Coagulation: Removal of colloidal matter.
  4. Filtration: Removal of suspended matter.
  5. Disinfection: Removal of pathogenic bacteria
  6. Aeration and chemical treatment: Removal of dissolved gases, tastes and odours.
  7. Water softening: Removal of hardness of water.

  When treating large amounts of water all the above process are employed in order to attain wholesome water.

❖ ***Sequence or Flow chart of a treatment plant process:***

Intake

↓

Screening

(Usually provided at the intake)

↓

Plain Sedimentation

↓

Coagulation

↓

Filtration

↓

Disinfection

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Water Softening

↓

Miscellaneous treatments

↓

Clean water reservoir

↓

Pumping stations

↓

Service Reservoirs

❖ ***Design considerations while designing the layout of a treatment plant:***

1. All the plants treatment units should be located in sequence, so that overall load on the treatment plant is reduced.
2. All treatment units should be located in such a way that water flows from one unit to another under gravity only.
3. Treatment units are arranged in such a way that they should occupy less or minimum space, hence being economical.
4. Staff quarters and office is to be provided near the treatment plant, so that the treatment process is constantly supervised.

- ***Sedimentation:***

It is a process in which water is kept in a rectangular tank for a certain period of time so that the heavier particles settle at the bottom of the tank. In plain sedimentation after settlement of the particles, water is drained out without disturbing the settled particles. There are two different types of process that are employed in sedimentation:

1. Drag and fill
2. Uniform rate flow

- ***Drag and fill:*** It is an ancient process of sedimentation practice. In this method the water is filled in the tank first and then it was allowed to remain quiescent so that the suspended impurities may settle down. After the settlement the water is drawn out and sludge is disposed off.
- ***Uniform Flow rate:*** This is also known as continuous flow rate. It is the process in which the rate of water entering the tank is kept uniform throughout the process. This process is mostly adopted now-a-days. By keeping the velocity to the minimum settling of the particle is allowed. All the particles with high mass density are settled at the bottom of the tank.
- ***Principle of Sedimentation:*** Refer to notes.
- ***Design for continuous flow settling tank***

  The continuous flow settling tank is designed by dividing it into four zones

  1. An inlet zone
  2. A settling zone
  3. Sludge zone
  4. Outlet zone

  - ***Assumptions:*** Before starting the design process the following assumptions are made.
    1. The water in the settling zone is quiescent and the sedimentation takes place as a quiescent container of the same depth.
    2. The flow of water is steady and all suspended particles are uniformly distributed across the cross section at right angles to the flow just after entering the settling zone.
    3. Any particle that enters the sludge zone settles and stays till removed.

- ***Design of an inlet zone:*** It is designed in such a way that the incoming water is uniformly distributed on full width of the tank and enters into the settling Zone without any disturbance to the settling particles.

- ***Design of settling zone:*** When a particle enters the settling zone in a continuous flow settling tank it is acted upon by 2 forces i.e.; horizontal force due to water flow and vertical force due to gravitational force. Due to these forces it traces a parabolic path. If it reaches the sludge zone it is removed or else it goes out through outlet zone.

  The condition for entering the sludge zone is

$$\frac{L}{Vh} > \frac{H}{Vs}$$

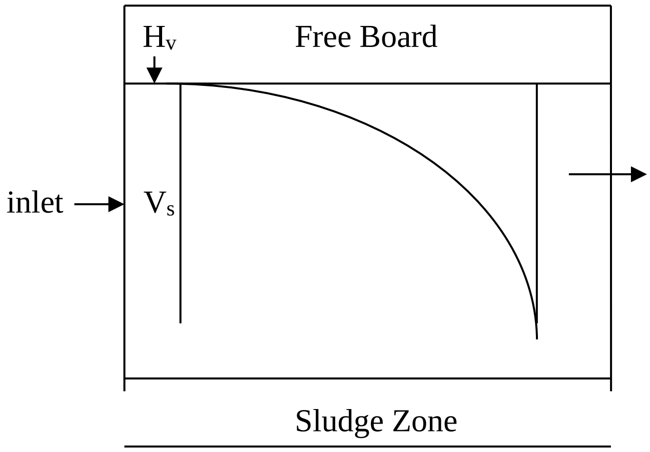
Where L= Length of the tank

V_h = Horizontal velocity

H= Height of the tank

V_s= Settling velocity

Out let



To attain maximum removal of suspended particles the water is to be detained for a period of time and that period is called “Detention Period”

$$\text{Detentioin Period (Dt)} = \frac{Capacity\ of\ the\ tank}{Rate\ of\ flow}$$

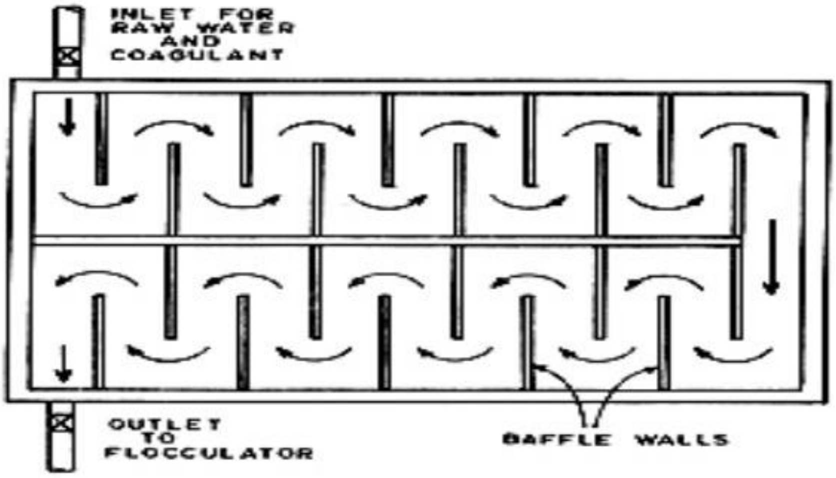
In continuous flow process the water inters through inlet and exists through outlet due to short-circuiting. So for design purpose if it is a mechanically cleaned tank we take D_t as 2 -4 hours and for ordinary settling tank it is 4-8 hours. The settling velocity of the particle is always equal to the “Surface Loading” (It is the flow of water for unit surface area of the settling tank).

- ***Design of Sludge Zone:*** The settling zone is designed in such a way that all the suspended particles are collected at the bottom of the tank without causing any disturbance to the water. It is designed in such a way that one side is sloped or both sides sloped to the centre. Cast iron pipes with gate valves are provided at the lowest bottom and the sludge is removed by hydrostatic pressure.
- ***Design of an outlet zone:*** It is designed in a way that the water is removed from the tank without causing any disturbance to the sludge.

❖ ***Types of sedimentation tanks:*** There are three types of sedimentation tanks.

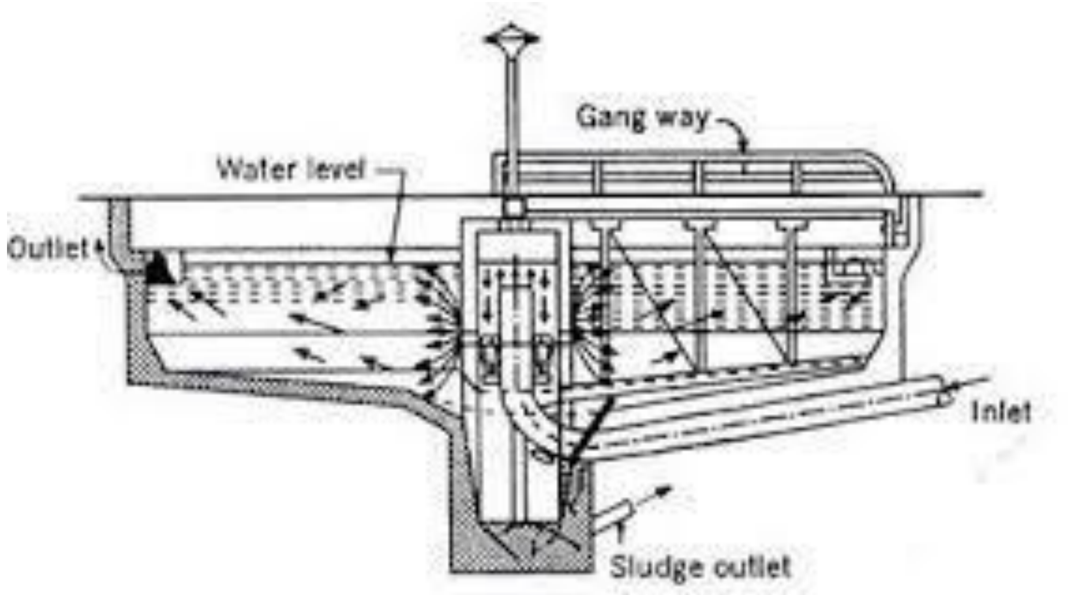
1. Rectangular tanks
2. Circular Tanks
3. Hopper bottom tank

1. ***Rectangular tank:*** Rectangular in plan and consists of a large number of baffle walls the function of baffle walls id to reduce the velocity of the incoming water and to increase the effective length of travelling to prevent short circuiting. These have channel type inlet and outlet extending on the full width. The floor between the two baffles is made like a hopper sloping towards centre where sludge pipe is provided and the sludge is taken out through sludge outlet under hydrostatic force by operating the gate valve.



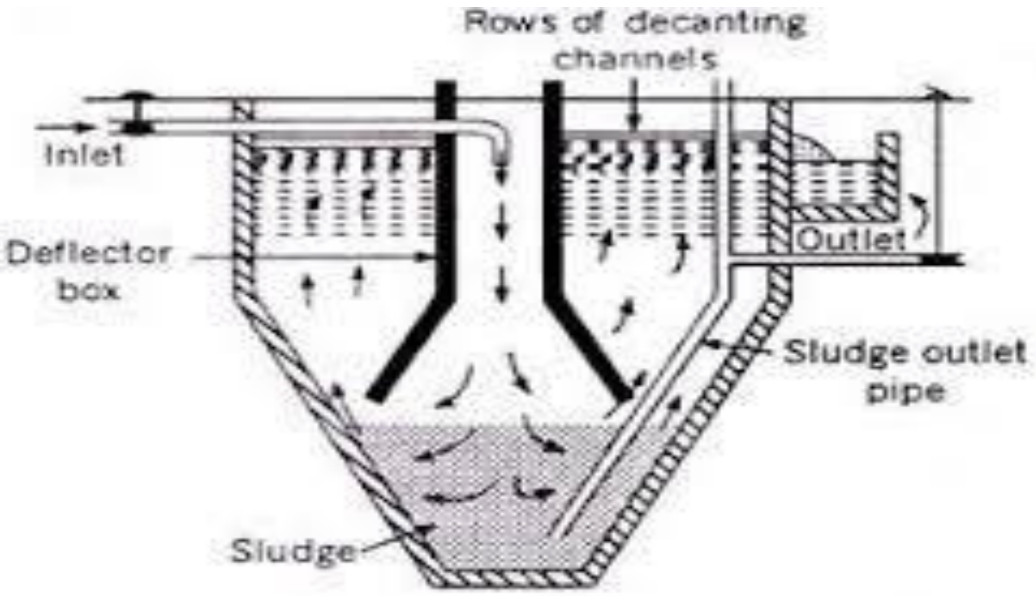
2. ***Circular tanks:*** It is of two types

   i. ***Radial flow circular tank:*** In this model the water enters through the central inlet pipe placed in a deflector box. This deflector box deflects the water downwards through the holes present at the sides of the box. The water flows radially from the deflector box to the circumference where an outlet is provided. All suspended particles settle downward towards the sloppy centre and cleaned by an mechanical scraper called “raking arm” and it does not exceed a maximum velocity of 4.5 m/hr.



ii. ***Circumferential flow circular tank:*** Water enters the tank through 2-3 vertical slits and the rotating arm present in the tank allows the water to flow along the circumference of the tank. As the water mocing with a very low velocity allows the suspended particles to settle in the tank where the water is removed from a small weir type outlet and sludge is removed from the sludge outlet.

3. ***Hopper bottom tanks:*** It is a vertical flow tank because the water flows upwards and downwards in these tanks. The water enters in these tanks from the top into the deflector box and from there it flows downwards and then the water reverses its direction and flows upwards thus letting the particles with higher mass density to settle at he bottom of the tank which are removed from the sludge outlet under hydrostatic pressure. A row of decanting channels is provided at the top to collect the water.



❖ ***Design of sedimentation tank:*** A continuous flow type sedimentation tanks are widely used at present types. The following are the design aspects for the construction of sedimentation tanks:

1. ***Velocity of flow:*** The velocity in the tank should be sufficient to cause hydraulic subsidence of suspended impurities and should be uniform through the tank and it is generally not allowed to exceed 15 cm/min – 30 cm/min (9m/s – 18 m/s).
2. ***Capacity of tank:*** the capacity of tank is determined based on
   a. ***Detention period:*** It is the time taken by the settling tank and can be determined by capacity of the tank (C) and 0the rate of flow (Q)

$$\boldsymbol{Dt = \frac{C}{Q}}$$

   D_t depends upon the quality of water. For plain sedimentation it is 4-8 hrs and when coagulants are used it is 3-4 hrs. In this type of tanks the depth of the tank usually varies from 3 – 6m.

   b. ***Over flow rate:*** It is calculated by assuming that the settlement of particles does not depend upon the depth but depends upon the surface area of the tank.

$$\boldsymbol{T = \frac{LXBXD}{Q}}$$

But $T = \frac{\boldsymbol{Disatance\ (D)}}{\boldsymbol{Velocity\ (V)}}$

$$\boldsymbol{\frac{LXBX\cancel{D}}{Q} = \frac{\cancel{D}}{V}}$$

$$V = \frac{Q}{LXB}$$

Velocity of surface over flow rate (S.O.R)

S.O.R is the quantity of water flowing per hr per unit area of the settling tank. For plain sedimentation it is 500-750 $l/hr/m^2$ and when coagulants are used it is 3-4 hrs. In this type of tanks the depth of the tank usually varies from 1000 -1250 $l/hr/m^2$ of plan area.

3. ***Inlet and outlet arrangements:*** Discussed above
4. ***Shape of tanks:*** Discussed above
5. In addition to the above for the construction of tanks some other aspects are also considered.
   - ***a. Construction:*** If the water is to be supplied directly for consumption the ranks should be water tight.
   - ***b. Free board:*** The distance between top wall and the water level is call free board. A free board of about 30-60 cm is to be provided.
   - ***c. Sludge capacity:*** A depth of 50-60 cm is provided at the bottom of the tank for the collection of sludge.
   - d. ***Sludge removal:*** It is removed by gravity or by pumping compressed air. In general the tanks are cleaned at an interval of 1-3 months.

❖ ***Coagulation:***

When certain chemicals are added to water it forms an insoluble, gelatinous flocculent precipitation is formed. This formation descents through water through and entrap very fine suspended and colloidal impurities. The coagulants can also remove colour, odour and taste.

❖ ***Chemical coagulants:*** The common coagulants used are

1. Aluminium sulphate (ALUM): $Al_2 (SO_4)_3 . 18 H_2O$
2. Sodium Aluminate:
3. Ferric coagulant

4. Chlorinated copperas

5. Ferrous sulphate and lime

1. Aluminium sulphate (ALUM): $Al_2 (SO_4)_3 . 18 H_2O$:

Chemical formula: $Al_2 (SO_4)_3 . 18 H_2O$

Availability: widely available and is commonly known as ALUM. It is dirty grey solid in the form of lumps containing about 17% of Aluminium Sulphate.

Reaction: Reacts in the presence of alkalinity. If natural alkalinity is absent lime is added.

$$Al_2 (SO_4)_3 . 18 H_2O + 3Na_2CO_3 \longrightarrow 2Al (OH)_3 + 3Na2SO4 + 2 CO_2 + 15 H_2O$$

$$Al_2(SO_4)_3 . 18 H_2O + 3Ca_2 (OH)_2 \longrightarrow 2Al(OH)_3 + 3CaSO_4 + 18 H_2O$$

$$Al_2 (SO_4)_3 . 18 H_2O + 3Ca (HCO_3)_2 \longrightarrow 2Al (OH)_3 + 2CaSO4 + 6 Co_2 + 18 H_2O$$

Dosage: The quantity of dosage depends upon the colour and turbidity of water. Usually dosage varies from 5 mg/L for relatively clear water to 25 mg/L for very turbid water, average dosage is 19 mg/L and pH is 6.5 to 8.5

Advantages:

1. It's cheap and forms stable floc.
2. Doesn't require skilled supervision and extensively used in water treatment.
3. The water obtained after the treatment is very clear.

Disadvantages: Posses problem in removing of floc and its disposal.

Recovery: Alum is recovered from the sludge and can be reused in coagulation process. This is also reducing the sludge disposal problems. The cost of recovery is about ¼ the cost of alum.

2. Sodium Aluminate: $Na_2Al_2O_3$:

Chemical formula: $Na_2Al_2O_3$

Availability: The best grade contains 55% Al2O3, 34 % Na_2O_3, 4.5% $Na_{2C}O_3$, and 6.3% Na (OH).

Reaction: This is used to treat water which is having no alkalinity. It reacts quickly and forms aluminium hydroxide.

$Na_2Al_2O_3 + CaSO_4 \longrightarrow CaAl_2O_3 + Na_2SO_4$

$Na_2Al_2O_3 + CaCl_2 \longrightarrow CaAl_2O_3 + Na_2Cl$

$Na_2Al_2O_3 + Ca(HCO_3)_2 \longrightarrow CaAl_2O_3 + Na_2CO_3 + Co_2 + H_2O$

$CaAl_2O_3$ forms floc and can be removed by sedimentation.

Dosage: $Na_2Al_2O_3$ does not increase the non carbonate hardness and can easily be mixed with lime and soda ash solutions.

Advantages: Removes corrosive quality of water.

Disadvantages: It is costly and hence not used in water treatment.

3. ***Ferric coagulant:***

The general ferric coagulants used for coagulation purpose are

a) Ferric Chloride : $FeCl_3$
b) Ferric Sulphate : $Fe_2(SO_4)_3$

Chemical reactions:

$2FeCl_3 + 3Ca(OH)_2 \longrightarrow 2Fe(OH)_3 + 3CaCl_2$

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

4. ***Chlorinated Copperas:***

It is a mixture of ferric chloride & ferric sulphate prepared by adding chlorine to the solution of ferric sulphate in the ratio of 1:7.9 (i.e.; 1 parts of chlorine to 7.9 parts of coppears).

Chemical Reaction:

$6FeSO_4 + 3Cl_2 \longrightarrow 2Fe_2(SO_4)_3 + 2FeCl_3$

Advantages:

- A very good coagulant and requires less alkalinity.
- Forms tough floc which can settle easily at the bottom.
- It removes colour very well.

5. ***Ferrous sulphate and lime: $FeSO_4 . 7 H_2O$***

***Chemical formula*:** $FeSO_4 . 7 H_2O$

Dosage: It is most commonly used coagulant. It is used in the treatment of sewage. The quantity required is more or less the same as that of alum.

Chemical reaction:

$$FeSO_4 . 7 H2O + Ca (OH)_2 (OH)_2 \longrightarrow Fe (OH)_2 + Ca SO_4$$

$$Fe (OH)_2 + 2 H_2O + O_2 \longrightarrow 4Fe (OH)_3$$

$Fe (OH)_3$ forms the floc which causes sedimentation.

Dosage: The quantity required is more or less the same as that of the alum. Satisfactory results are achieved at a pH of 8.5.

Advantages:

a. These are good oxidizing agents.
b. Removes hydrogen sulphate tastes and odours from waters.

❖ ***Comparison of alum and other Iron salt coagulants:***

Alum	Iron Salts
Cannot be used for wide range of pH	Can be used for wide range of pH
Causes less corrosion	Causes more corrosion
Removes comparatively less suspended solids	Forms heavy floc and more % of solids can be removed.
Removes only suspended solids.	It also removes hydrogen sulphide & its odour and taste
Biologically non reactive.	Promotes bacteria growth
Easy to handle and operate	Require skilled workers
Non corrosive in nature	Corrosive and deliquescent in nature

❖ ***Dosage of Coagulants:***

The amount or dosage of coagulants to be added into the water depends upon

1. Kind of coagulant
2. Turbidity of water
3. Colour of water
4. pH of water
5. Temperature of water
6. Mixing and Flocculation time.

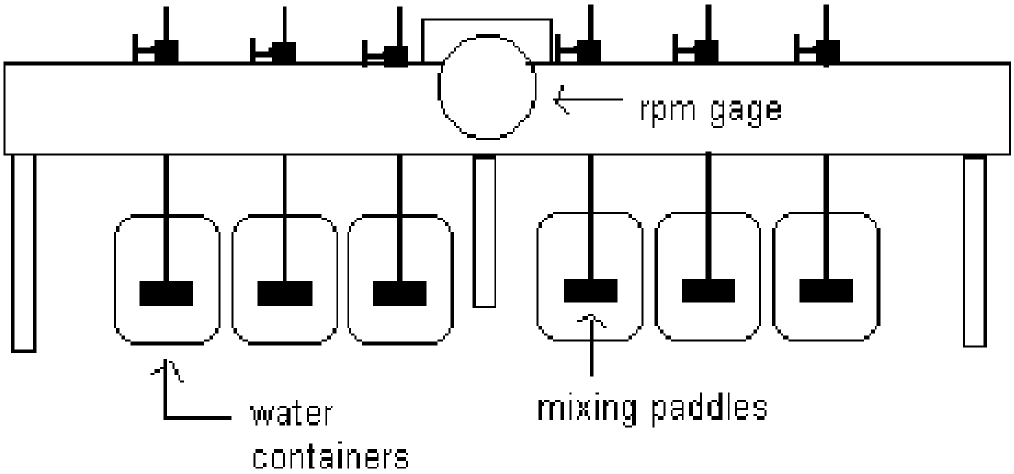
❖ ***Determination of optimum dosage:***

The optimum dosage can be determined by “Jar Test Apparatus”. It contains four or more large sized beakers of 1-2 litres capacity. Stirring paddles are fixed in each beaker which can be rotated at any speed by gear and spindle system.

- Procedure:

1. The water sample which is to be tested is taken in equal quantity in all the beakers.
2. Coagulant in varying amounts is added and noted.
3. With the help of electric motor all the paddles are rotated at a speed of 30-40 rpm for about 10 minutes.
4. After that the speed is reduced and the paddles are rotated for about 20-30 minutes.
5. After 30 minutes the rotation is stopped and the floc formed is allowed to settle.
6. The dosage of coagulant at which the formation of floc is more gives the optimum dosage.

In water works this test should be done frequently to determine the optimum dosage and to economically use the coagulants.



- ***Dose of chemicals:*** the dose of chemicals mainly depends upon the turbidity, pH and the standard purity required. The quantity of coagulant which is to be added for better floc formation is determined based on the Jar Test are

Coagulant	Quantity required
Alum	
1. Lime as CaO	55 mg/l
2. Lime as Ca $(OH)_2$	74 mg/l
3. Soda Ash Na_2CO_3	104 mg/l
4. Natural alkalinity CaCO3	99 mg/l
Ferrous sulphate	
1. Lime as CaO	44 mg/l
2. Lime as Ca $(OH)_2$	58 mg/l
3. Chlorine as Cl_2	27 mg/l

- ***Handling and storage:***

Generally stored in paper bags, paper lined boxes and paper lined wooden barrels during transportation to the treatment plant. At treatment plant it is stored in dry place where deliquescence or cracking doesn't take place. These should be stored in the room above the coagulant preparation room so that during the solution preparation it moves under gravity. Storage containers: concrete, steel, wood, lead, rubber, stainless steel, acid resistant bronze material.

- ***Feeding devices:***

The type of feeding devices to be adopted is based on the nature of the coagulant, water quality and economy. Coagulants are either in dry form or wet form.

- ***Dry feed:*** It is desirable as they are simple and requires less installation space. Keeps neatness and free from corrosion

Characteristics: The coagulant should have uniformity in size, consistency in composition, should be free from hygroscopic or efflorescent and should remain dry under various temperatures and pressures. Aluminum sulphate can be fed in dry condition. Coagulants which are corrosive in nature and create difficulties in solution are fed in dry state.

- ***Dry feed devices:*** It works on the principle of volumetric or gravimetric displacement of dry chemicals.

Process:

1. The chemicals are placed in a hopper and required amount of coagulant is fed.
2. The feeding is done by revolving a helical screw or toothed wheel fixed at the bottom of the hopper.
3. The speed of rotation is controlled with the help of venturi device.
4. When the quantity of water increases the spee4d of rotation also increases thus by increasing the feed.

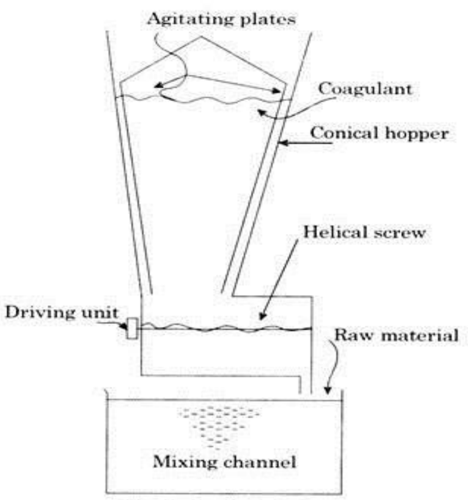


Fig. 1. Dry fed device.

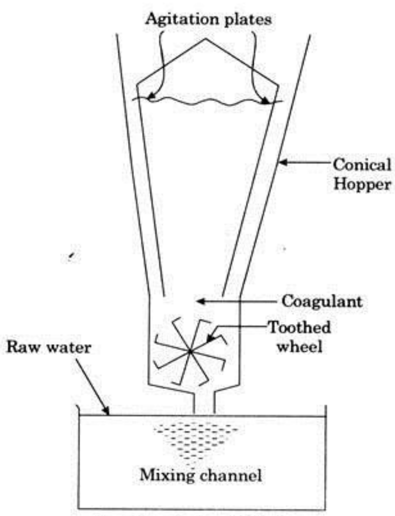


Fig. 2. Anode dry fed device

- ***Wet feed:***

All coagulants may not be fed in dry feed as some may cause clogging, cracking, deliquescence & caking. Ferrous sulphate is fed in wet form as its crystallization changes with temperature; therefore it becomes difficult to be fed in dry form as the powder may change to solid. Similarly hydrated lime cannot be easily fed in dry form as it absorbs moisture from atmosphere and becomes slaked lime.

- ***Wet feed devices:***

Process:

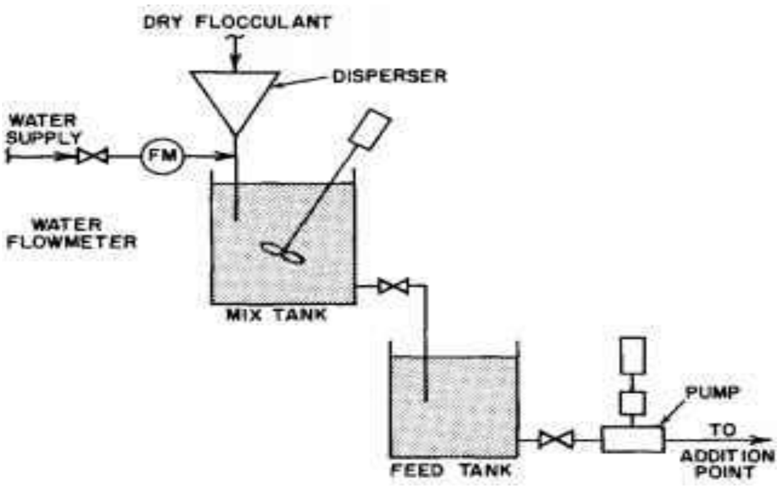
1. The coagulant is first placed in a metal box or perforated concrete or wooden box and warm water is sprayed over it.
2. The most satisfactory method is pot method.
3. Coagulant is placed in a pot and water flows through the pot which is proportional to the rate of flow of water in the main channel.
4. It has two types of devices:

   a) Conical plug type &

   b) Adjustable weir type

   Both works on the principle that with the increase in flow the dosage of coagulant is directly proportional.

i. The solution is kept in a level tank with a tapperd hole at the bottom which is connected by a conical plug controlled by rod and pulley.
ii. A small float chamber is connected to the raw water and the float is operated with the help of race and pinion.
iii. When the water level increase the float increases, the float raises and it lifts the conical plug thus providing a large opening through which the solution reaches the raw water.
iv. The float and conical plug are connected through pulley, shaft, and rack and pinion arrangement.



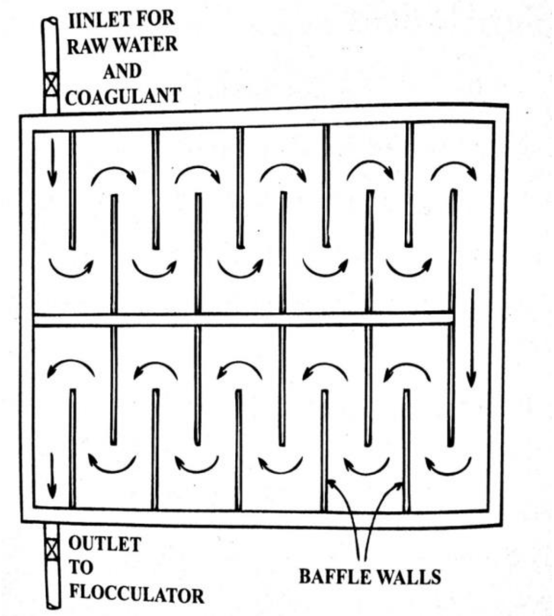
- ***Mixing Devices:*** These are used to thoroughly mix the added coagulants in water. First the coagulants are rigorously mixed for about 1 minute and gently agitated for about half an hour so that the coagulants may react and start to flocculate. The flow velocity in the basin is kept between 15- 30 cm, the velocity should not be less than 10 cm/sec and more than 75 cm/sec. different types of mixing devices are used.

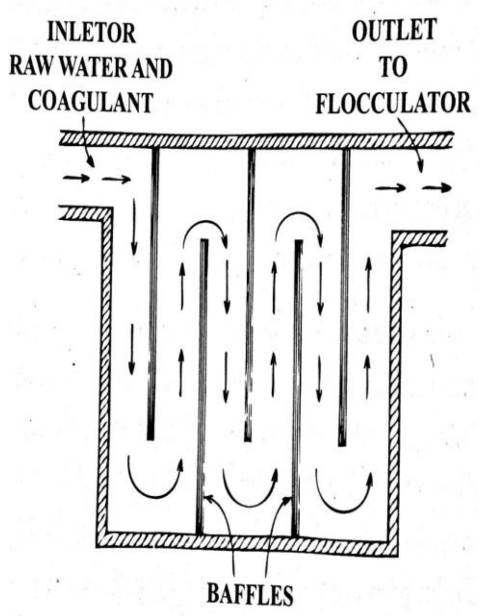
1. **Baffle type basin**

Two types of flow patterns up & down, past under & over & under baffles. Baffles plates are paced 60-100 cm apart with having a flow velocity b/w 15-3 cm/sec and detention time 20-50 minutes.

Disadvantages:

1. Not suitable for small plants because of high construction cost
2. Have less flexibility of control
3. Greater head loss.





2. Flash mixers:

The coagulant is mixed thoroughly in the water by means of fan operated by electric motor. The water enters through inlet & the deflecting wall deflects the water towards the fan where chemicals also reach through chemical pipe.

b. Mixing basin with mechanical means

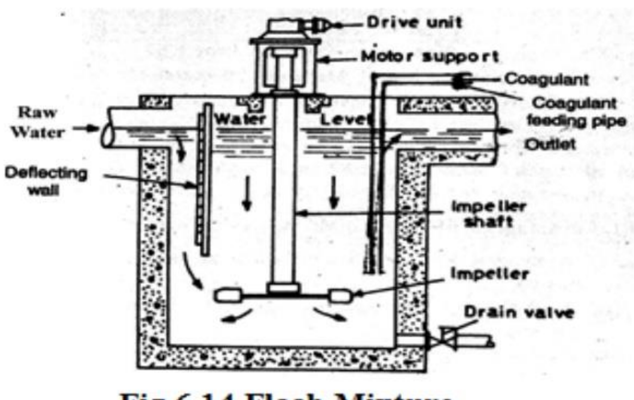
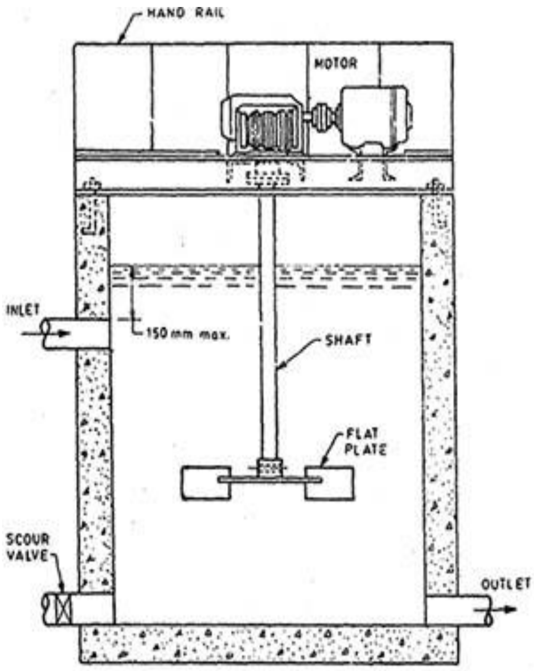


Fig 6.14 Flash Mixture
(Source: Upadhayay, 2002)

3. Deflector plate mixing:

The mixing is done by diffusing water through deflector plate. Chemicals enter the tank near the deflector plate. The water enters through the holes provided at the bottom of a plate. Through mixing of chemicals & water is done by diffusion.


HAND RAIL
MOTOR
INLET
150 mm max.
SHAFT
FLAT PLATE
SCOUR VALVE
OUTLET

- ***Filtration:***

  Filtration is often used for the removal of small floc or precipitation particles which are not removed by settling. Filter beds are used for removing bacteria, colour, taste, odours & producing clear and sparking waters. Precoat filtration is a process in which a thin sheet of diatomaceous earth or other very fine media combine to form filter media which is used for filtration. The most commonly used filtration process involves passing of water through a stationary bed of granular medium.

- ***Types of filtration:*** The phenomena on which filtration process removes bacteria, colour, taste, odours, manganese, and iron can be explained on the basis of four actions.
  1. ***Mechanical straining:*** suspended particles which are larger than the pore spaces are removed.
  2. ***Sedimentation:*** the voids between sand beds acts as settling basins where small particles, bacteria etc settles.
  3. ***Biological action:*** Organic matter present in water acts as food for micro organisms, this organic mater matter forms a layer known as “Schmutzdecke” or “dirty skin”
  4. ***Electrolytic action:*** the sand particles of filter media and ionized matter carry opposite charges, thus the attract each other and gets removed.

- ***Classification of filters:*** Filters may be classifies as
  1. Gravity filters
  2. Pressure filters
  3. Which are further classified into sub categories

     Slow sand filters → Gravity filters
     Rapid gravity filters → Gravity filters

     Horizontal pressure filters → Pressure filters
     Vertical pressure filters → Pressure filters

- ***Slow sand filters***

  a) Construction:

  1. These are water tight and shallow tanks about 2.5 m – 4.0 m deep having surface area 100 sq. m – 2000 sq. m in plan.
  2. These tanks contain 60 -90 cm tick sand bed supported on 30 – 60 cm thick gravel bed.
  3. The effective size of filter media is 0.3 – 0.35 mm and its uniformity coefficient is 1.75
  4. Generally 3- 4 layers of gravel having thickness 15 – 20 cm.

5. The coarsest gravel is placed at bottom and finest size is paced at top.
6. The size of the bottom layer is 40-60mm thick, intermediate layers 20 – 40mm & 6 – 20 mm and top most layer 3 – 6 mm thick.
7. The gravel is supported on a bed of concrete sloping towards longitudinal drains connected by a system of open jointed drains.

b) Appurtenances

i. ***Inlet chamber***: It is fitted with a sluice valve. Inlet pipe is carried vertically in the body of the filter with the mouth of the inlet flush with the water level.
ii. ***Filter box:*** It is a Container or box like structure constructed with RCC where filter media is constructed. It must be strong enough to support the weight of under drain system, filter medium and water column. Usually square or rectangular in shape. The filter boxes are arranged facing each other across an access corridor containing common piping and other appurtenances. These are commonly known as filter galleries.
iii. ***Under drain system:*** These are used to collect and remove filtered water & to disperse the backwash water. Under drain systems in filters may consists of a built in main pipe along with laterals placing 3.5 m apart on the bottom.
iv. ***Depth of water:*** there is no rule in fixing the depth of water. It varies depending on the country. In India the depth = thickness of filter media provided.

Miscellaneous appurtenances

1. Flow rate controller: designed to automatically control the flow rate / rate of flow. A venturi controller is usually employed.
2. Head loss guages: used to measure head loss by means of a simple guage consisting of two glass tubes one connected to inlet and the other to outlet. The difference is transmitted through a float arranged to dial guage which gives reading.
3. Compressed air: before allowing back washing compressed air is sent to agitate the sand grains. Air compressor should supply air 600 – 800 l/min/sq. m for atleast 5 mins.
4. Wash water troughs: the back wash water is collected in a V shaped wash water troughs or gutters. Usually placed 1.5 – 2.0 m apart.

Washing of filter: it is done by back flow of water through the sand bed.

Process:

1. Inlet valve is closed and the water is drained leaving a few centimeters
2. Keeping all valves closed compressed air is sent for 2-3 mins, for loosening up of sand particles.
3. Now the valves are opened and wash water is slowly sent from the bottom
4. Due to back flow sand expands and all impurities are released. Process is continued till the sand appears clear.
5. Generally washing of filters is done after 24 hrs for 10 mins and sand expands 50% during back washing.

Slow sand filters

Operation.

1. Water from sedimentation enters into the filters and gets uniformly distributed.
2. The water passes through filter media @ 100 – 200 l/sq. m/hr.
3. Rate if filtration is continued till the difference of water level between the water level and oulet chamber is slightly less than the water above the sand bed.
4. The difference of water above the sand bed and outlet chamber is called “loss of head”.
5. During the process the filter media gets clogged and the loss of increases.
6. When it reaches permissible limit the operation is stopped and back washing is done.
7. 2-3 cm of top sand is scrapped and clean sand is placed and the operation is re started.
8. The scrapped layer is washed and dried and stored until future use.
9. Results : the results using slow sand filter are

1. Bacterial efficiency is high = 98-99%
2. It also removes odours, taste & colour.

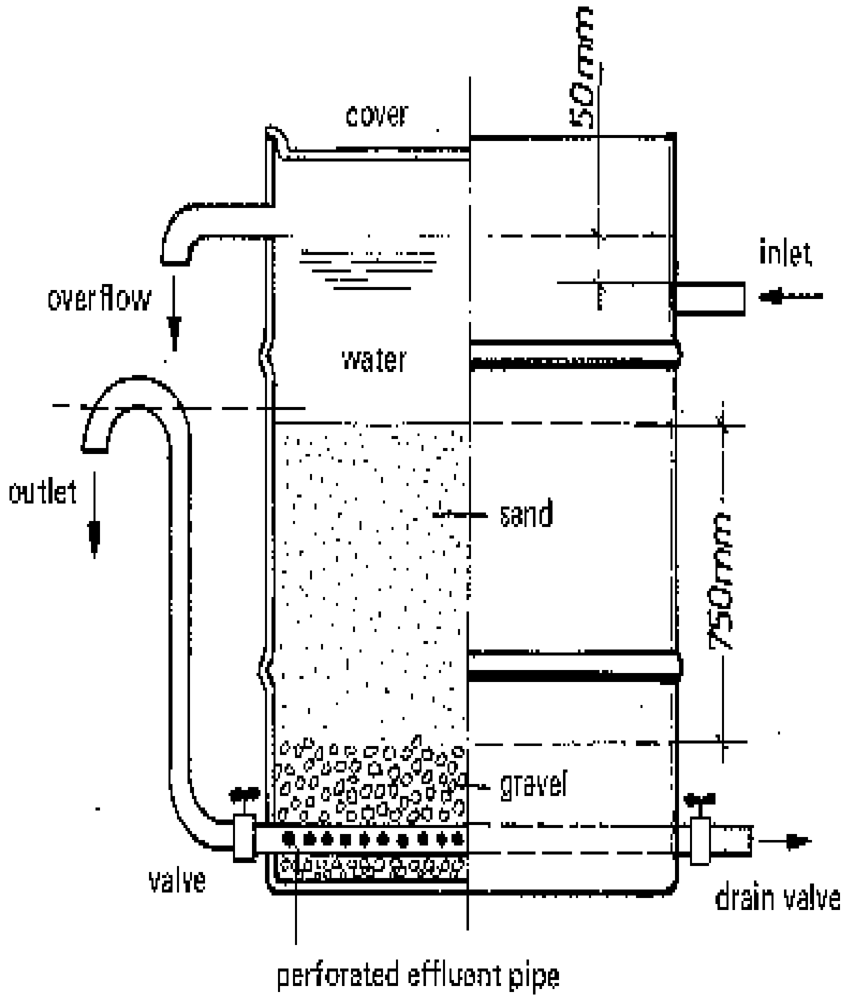
- Advantages:

1. Best suitable for small plants and small towns.

2. Removes turbidity (removes upto 50ppm), bacteria (98-99%), low colour(20-25%) and taste very effectively

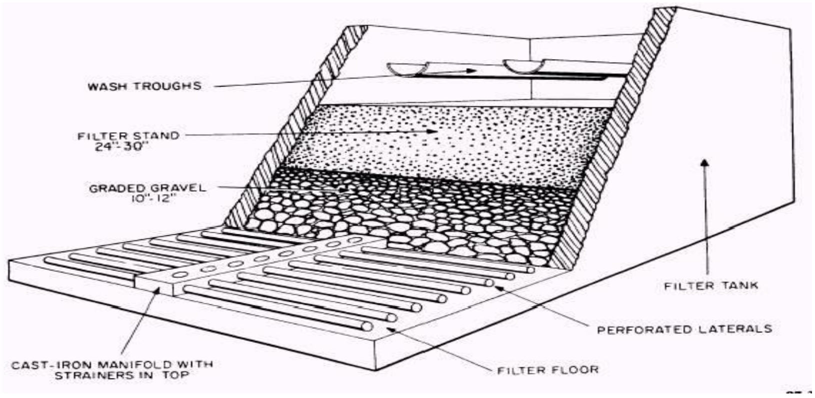
- Disadvantages:

1. Disinfection of filtered water is necessary to assure complete safety from water borne diseases.
2. Rate of filtration is low.
3. Requires large area for construction.
4. High initial cost.
5. Not suitable for waters having turbidity greater than 50 ppm.



Rapid gravity filters/ Rapid sand filters

- It is a water tight masonry or concrete basin 33.5 m deep. The under drainage system of cast iron along with laterals are placed. Under drainage system is embedded in 60-70cm thick gravel whose size varies form 2.5 cm at bottom to 0.5 cm at top. The laterals are placed 15-20cm apart & about 1.75-2.5 m of water depth.



Construction:

1. Consists of water tight rectangular tank with depth varying from 2.5-3.5 m.
2. The surface area of each filter is kept between 10-80 sq. m
3. The approximate number of filter units to be provided is determined using

$$N = 1.22\sqrt{Q}$$

no: of units quantity of water MLD

Every treatment plant must have at least 2 filter units.

4. Effective size varying from 0.35-0.55mm and uniformity coefficient ranging from 1.2-1.8 &thickness of 60-90 cm.

Operation:

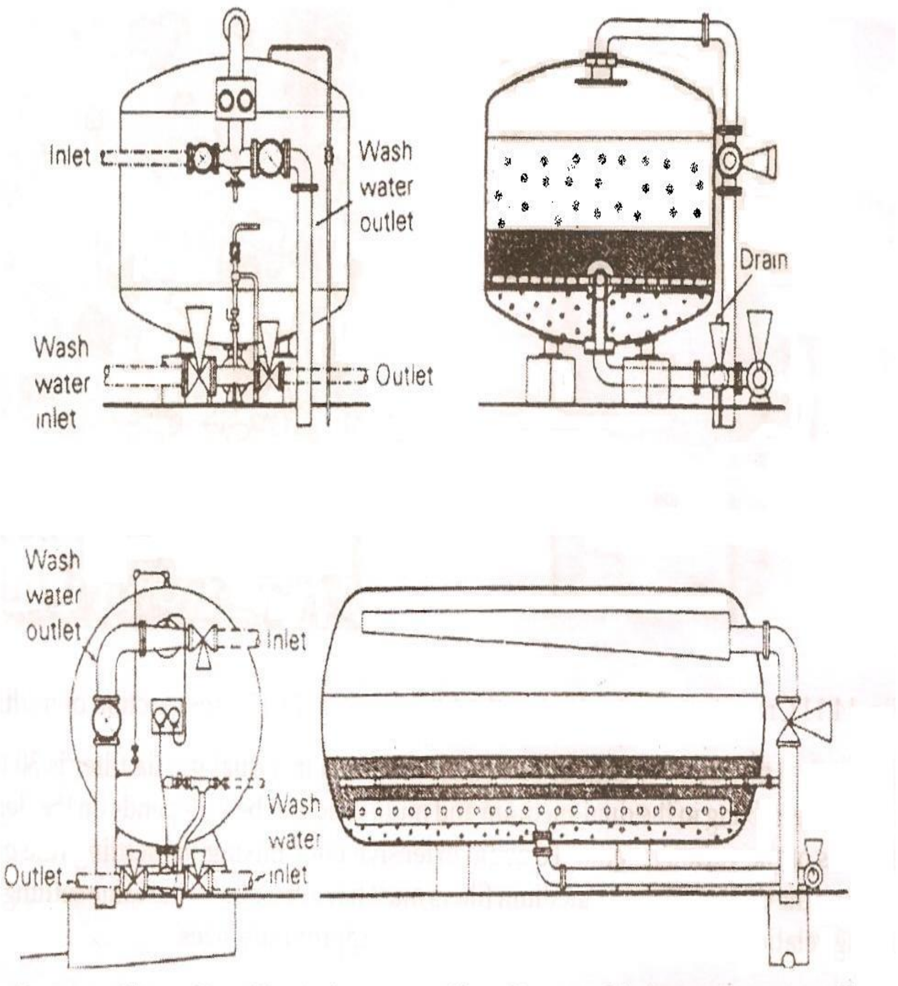
1. Water from sedimentation enters into the filters and gets uniformly distributed.
2. Water passing from filter media is collected through the under drainage system.
3. Outlet in this filter is fitted with filter rate control.
4. Loss id head is small in the beginning but increases as the process continuous..
5. When the bed reaches saturation point, the process is stopped and filter bed is washed.

Results of rapid gravity filters:

1. Removes suspended matter, odour & bacteria from water.
2. The treated water must be pretreated before passing through rapid sand filters.
3. Max. turbidity should not be more than 35-40 ppm.
4. Cannot remove bacteria completely.
5. Rate of filtration is usually 3000-6000 l/sq.m/hr.
6. Wash water should not exceed 10m.

Pressure filters:

1. It is a rapid sand filter placed with in a closed water tight steel cylinder.
2. The sand bed is 45-90 cm thick .
3. The water passes through the sand filter under a pressure greater then atmospheric pressure.
4. All operations are similar to rapid sand filters, except that the coagulant water is directly applied with out mixing and flocculation
5. Mostly used for industrial plants as they are not suited for large scale usage.
6. The cylindrical shell containing filter media can either be kept horizontally or vertically.
7. The size of vertical filter varies from 0.3-2.75m in diameter and height 2-2.5m.
8. The horizontal filters are generally 2-3m in dia. and length upto 9m.
9. The rate of filtration is 6000-15000 l/sq.m/hr area of filter bed.
10. Cleaning of filter bed is similar to that of rapid gravity filters



Pressure filters. Top: Vertical pressure filter, Bottom: Horizontal pressure filter

- **Disinfection**
  - **Definition:** The process of killing the infective bacteria from the water and making it safe to the user is called disinfection.

The filters are unable to remove all the disease bacteria. Therefore the water comes out of the filters contain some disease causing bacteria. Before water is supplied to the consumers it is necessary to destroy all the pathogenic bacteria. The chemicals used in this process are called disinfectants.

- **Requirements of good disinfectants:** The following are the requirements of a good disinfectant:

1. Should all the pathogenic bacteria and make it useful for drinking.
2. Should not take more time in killing the bacteria.
3. Do their task at required time in normal temperature.

4. Should be economical and easily available.
5. Should not require high skill and costly equipment.
6. After treatment the water should not be objectionable and toxic to the users.
7. They should be in such a way that their strength can be quickly determined
8. Their dosage should be such that it should leave some residual concentration to protect against contamination during conveyance.

- **Methods of disinfection:** The disinfection can be done by the following common methods

1. **By boiling of water**: Boiling of water for 15-20 mins will kill all the existing bacteria but doesn't protect from future contamination.
    - This method is costly and can be used individually in case of emergencies.
    - Impossible to employ in water works.
2. **By ultra violet rays**: It is highly disinfectant and kills all bacteria but requires costly equipment and skilled personnel.
    - UV rays are invisible rays of light having a wavelength of 1000-4000m.
    - UV rays are allowed to pass through the water after removing its turbidity and colour.
    - As no chemicals are used, no taste or odour is added
3. **By the use of iodine and bromine**: kills bacteria with a min. contact period of 5 mins, but its conc. Should not be more than 8ppm
4. **By the use of ozone**: Excellent disinfectant and is used in gaseous form.

$3O_2 \longrightarrow 2O_3$ (forms by passing through high electric voltage)

$O_3 \longrightarrow O_2 + O$ (highly unstable and breaks down to oxygen and nascent oxygen)

- Nascent oxygen is very powerful oxidizing agent and it kills all bacteria.

5. **By the use of excess of lime**: lime is added to remove hardness but it is also observed that it will also disinfect water while removing the hardness. At pH 9.5 all bacteria is killed.
6. **By using potassium permanganate**: this is most common method used in villages for disinfecting dug well, pond or private source of water. In addition to killing of bacteria it also reduces the organic matter present.
7. **By the treatment of silver**: It is a very costly method and is not used in water works. Metallic silver ions are introduced into the water which is highly disinfectant.

- **Disinfection by chlorine:** The most commonly used disinfectant. Several theories are developed to explain the working.

  Theory I: The nascent oxygen liberated from the hypochlorous acid oxidizes some essential constituents of the bacterial cell, thus destroying them.

  Theory II: The germicidal action of chlorine is not only due to the nascent oxygen, but the destruction of the bacteria is due to the direct chemical combination of chlorine with the protoplasm.

  Theory III: The death of bacteria is due to the chemical reaction of hypochlorous acid with the enzyme system of the cell which is essential for the metabolism of the organism.

- **Factors affecting the bacterial efficiency of chlorine /** ***Chlorine Demand***

1. **Time of contact**: The no. of organisms destroyed per unit time is proportional to the no. of organism remaining. The death rate decreases with time.

2. **Concentration of disinfectant**: The time required by any disinfectant to work efficiently depends upon its concentration.

   Eg: 2 different disinfectants which are equally potent at one concentration may have quite different efficiencies at different concentrations.

3. **Number of organisms**: The higher the number of organisms the greater the destruction.

4. **Temperature of water**: The rate of reaction increases with temperature. That is the destruction rate increases with increase in temperature.

5. **pH value of water:** The change in pH also changes the efficiency of chlorine. At lower pH value smaller contact period is required for the same % of kill.

6. **Presence of various chemicals:** Various chemicals present in the water reacts with chlorine, which is added as disinfectant and will reduce the concentration of chlorine available for direct disinfection

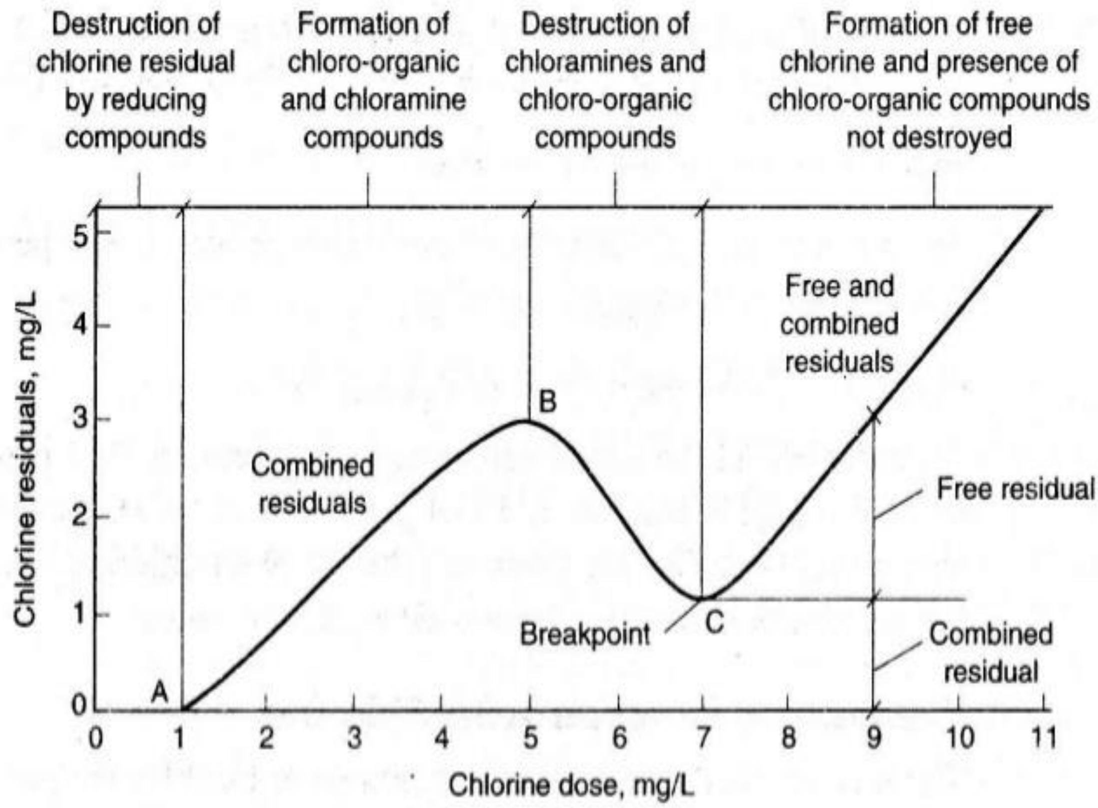
❖ **Chlorine Compounds:**

Various chlorine compounds which are used as disinfectants are

1. Hypochlorides of calcium & sodium,
2. The chloromines,
3. Chlorine dioxide and
4. Complex chlorine compounds.

❖ Break point chlorination

- When chlorine is added to water it reacts with organic & in organic matter and forms common compounds.
- Some portion remains as residual which is not sufficient for disinfection but if the chlorine dosage is increased then the residual chlorine content also increases.
- When the chlorine dose is increased the compounds gets oxidized and the substances which are newly formed do not react with orthotolodine to show any residual.
- If more chlorine is added the reaction is shown in the graph.
- The residual chlorine in the beginning increases with the applied chlorine dose, but after point C it suddenly drops up to point D and then increases.
- Portion OC shows formation of chloromines and portion CD shows their oxidation.
- Point D at which residual chlorine starts to increase is known as “Break-Point Chlorination”.
- After reaching this point the chlorine further added will remain as free residual chlorine and the curve becomes a straight line.



Chlorine reacts with reduced materials (Fe^{2+}, Mn^{2+}, H_2S, organics, NH_3, etc.)

Breakpoint Chlorination

❖ **Types of chlorination**

1. **Super chlorination**: defined as the administration of dosage in excess of that necessary for bacterial purification, usually done during epidemics to prevent water borne diseases.

2. **Plain chlorination**: it is used when good surface water is available where no other treatment process is employed.

3. **Post chlorination**: when chlorine is added when all the treatment is done, generally this is done after filtration process.

4. **Pre chlorination**: When chlorine is added to raw water

5. **Double chlorination**: when chlorine is added to raw at more than one point.

6. **Dechlorination:** It is defined as the partial or complete reduction of residual chlorine from the water

   There are several methods of dechlorination, but most common methods are:

a) **Sulphur dioxide**: mostly used for larger plants.
b) **Sodium bi-sulphate**: it is used for smaller treatment plants. It is cheaper and more suitable
c) **Sodium thio sulphate:** used to dechlorinate samples that are collected for bacteriological analysis.

❖ **Forms of chlorine:**

- Chlorine is generally available in the following forms:

1. Liquid chlorine
2. Gaseous chlorine
3. In the form of chlorine di oxide
4. Chloramines

❖ **Disinfection using chloromines**

- It is name given to the compound which contains chlorine and ammonia.
- These are stable compounds and are good disinfectants.
- They can remain in water for longer period, which provides greater safety against future contamination.
- They do not cause bad taste or odours even when they are present in residual form.
- Chlorimines are produced by adding ammonia to water before adding chlorine.
- The quantity of ammonia and chlorine depends upon the quality of water available.

  ➢ **Reactions** are

$H_2O + Cl_2 \longrightarrow HCl + HOCl$

$NH_3 + HOCl \longrightarrow H_2O + NH_2Cl$ (Monochloromine)

$NH_2Cl + HOCl \longrightarrow H_2O + NHCl_2$ (Dichloromine)

$NHCl_2 + HOCl \longrightarrow H_2O + NCl_3$ (Nitrogen Trichloride)

- **Precaution:**

a) After the treatment is completed the water has to be supplied after 20-60 minutes.

b) High dosage requires longer contact periods.

- **Testing of residual chlorine:**

1. Starch iodine test: Mostly used of all three tests
2. Orthotolodine test
3. Ortho arsinate test

- ***Removal of Tastes and Odours:*** The tastes and odours in water supplies may be caused due to the presence in water of any of the following:

I. Decaying organic matter resulting from algae and other microorganisms

II. Industrial wastes Such as phenols

III. Chlorophenol compounds resulting from combination of residual chlorine with phenol, iv. Dissolved gases like H_2S, CO_2, v. excess amount of chlorine

Methods for the control of tastes and odours , therefore, amount to treating the aforesaid causes of trouble and may be listed as below:

1. Copper sulphate treatment
2. ammonia – chlorine process,
3. use of activated carbon,
4. use of chlorine dioxide,
5. aeration
6. perchlorination
7. super chlorination followed by dichlorination and
8. ozonisation

1. **Copper sulphate treatment:** used to control algae and organic matter
2. **Ammonia chlorine process :** addition of ammonia results in the formation of chloromines which are inert in taste and odours
3. **Use of activated carbon**: most important method which removes taste and odour which helps in adsorption of organic materials.

❖ **Water softening process:** There are three general methods used for water softening:

(i). Lime Process ,

(ii). Lime and Soda Ash Process and

(iii). Base – exchange process

1. **Lime Process** reduces only the carbonate hardness. The principle involved is to neutralize the CO_2 with milk of lime i.e., Ca $(OH)_2$, forming normal carbonates which precipitate out when present in excess and are removed by settlement and filtration. the process is also known as the Clark process. Chemical reactions involved are:

$$CO_2 + Ca(OH)_2 = CaCo_3 + H_2O$$

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCo_3 + 2H_2O$$

$$Mg(HCO_3)_2 + Ca\ (OH)_2 = CaCo_3 + MgCo_3 + 2H_2O$$

2. ***Lime and soda ash process:*** Lime has no effect on sulphates of calcium and magnesium, which are responsible for causing most of the non – carbonate hardness found in natural waters. However, by the use of soda ash (sodium carbonate) , the non – carbonate hardness can be removed. The reactions are:

(i). $CaSO_4 + Na_2\,CO_3 = CaCO_3 + Na_2\,SO_4$

(ii). $MgSO_4 + Ca(OH)_2 = Mg\ (OH)_2 + CaSO_4$

$CaSO_4 + Na_2\,CO_3 = CaCO_3 + Na_2SO_4$

Most of the insoluble compounds, which precipitate out in the above mentioned methods, will settle out if the treated water is passed through a settling basin. As, however, some of the insoluble material tends to remain in a finely – divided state and may be found to be later depositing on the filter sand or in the distribution mains, service pipes and metres, this difficulty may be overcome by treating the partially clarified water from settling basin with carbon dioxide, before it reaches the filters. This process, called recarbonization, has the effect of converting any unprecipitated carbonates back into the soluble carbonate form.

3.Base exchange process: in this process, hard water is passed through a bed of zeolite sand (complex silicates of aluminium and sodium) whereby it exchanges its Ca and Mg for the sodium (Na) in the zeolite until Na becomes exhausted. The sodium is then restored by regenerating the zeolite with a solution of common salt(NaCl) resulting in the reversal of ionic reactions viz., Ca and Mg taking the place of Na and being washed out as chlorides while the Na remains in the zeolite so that it is again ready to act as a softening agent.

$$\left(\begin{array}{l} CaSO_4 \\ MgSO_4 \\ MgCO_3 \\ CaCO_3 \\ CaCl_2 \\ \text{Etc.} \end{array}\right) + Na_2\,Al\,(SiO_3)_2 = \left[\begin{array}{l} Ca \\ Mg \end{array}\right] Al\,(SiO_3)_2 + \left[\begin{array}{l} Na_2CO_3 \\ Na2SO_4 \\ 2NaCl \end{array}\right]$$

For regeneration:

$$\left[\begin{array}{l} Ca \\ Mg \end{array}\right] Al(SiO_3)_2 + 2NaCl = Na_2Al(SiO_3)_2 + \left[\begin{array}{l} CaCl_2 \\ MgCl_2 \end{array}\right]$$

Zeolites are artificial products in granular form with size varying between 0.5 mm to 0.25 mm. in diameter. Its trade names are Permutit, Verdite etc. the zeolite softeners are very much similar to the rapid gravity filter with the difference that the zeolite layer is thicker 1.2 to 1.8 mm and the flow of water may be either upwards of downwards. The treated effluent can show water of zero hardness. The zeolite or the base – exchange process of water softening is applicable only to clear water since the presence of turbidity causes clogging of the zeolite material. Its use is, therefore, limited to ground waters.

❖ DEFLOURIODATION OF WATER

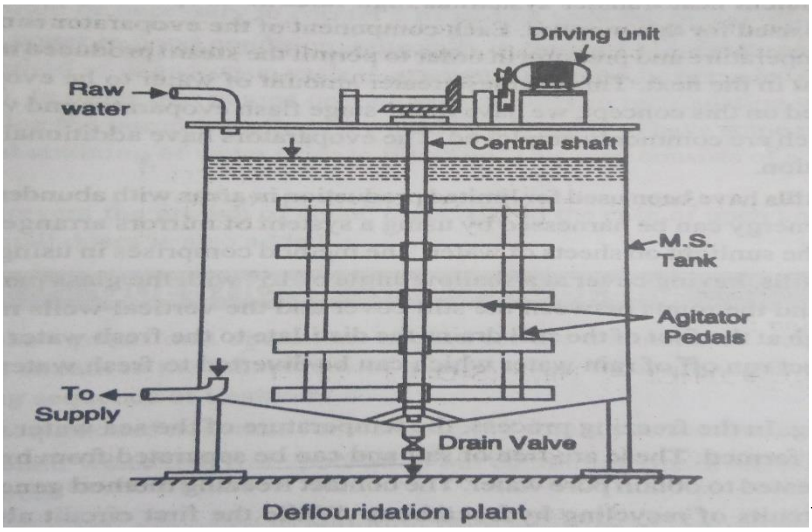
When concentration of fluorides in water is more than 1.5 mg/l, mottling of teeth or dental flourosis occurs. This results in unsightly staining and chipping of the teeth leading to their delay. In children, it is most severe. At high fluoride concentration (6 mg./l and above) , bone flourosis involving deleterious skeletal changes and bone crippling have been observed. These are highly prevalent amongst people of states like Rajasthan, Punjab, Haryana, Andhra Pradesh, Bihar, Gujrat and Tamil Nadu , where ground water containing high concentrations of fluorides is used for household consumption.

Defluorination is the removal of excessive fluorides from public or individual water supplies. Defluorination methods are basically of two types – those based upon exchange process or adsorption and those based upon addition of chemicals water during treatment.

In the first category we have Fluoride Exchangers which use bone charcoal or activated carbon treated with alkali phosphate, with spent material being regenerated. Besides anion exchange resins have also been used.

The second category includes the use of lime either alone or with magnesium salts and aluminum salts with or without coagulant aid. Other methods include addition to fluoride water of materials like magnesia, calcium phosphate, fuller's earth, bentonite and diatomaceous earth. However, all these methods suffer from one or more of the drawbacks of high initial cost, inefficient fluoride removal capacity, separation problem and expensive regeneration.

A simple method of defluorination which has been popularly used for domestic as well as community water supply schemes is the Nalgonda Technique developed by NEERI. This involves the addition of two readily available chemicals – lime and alum. The process employs the sequence precipitation, settling and filtration, if necessary. A fill and draw type defluorination plant is shown



The defluorination system comprises of a tank of suitable design capacity (@ 40 Ipcd) having a hopper bottom and fitted with agitator peddles moving on a central shaft driven by an electric motor fitted on top of the tank. Raw water is pumped into the tank and the required amounts of lime or sodium carbonate, bleaching powder and alum (depending upon alkalinity and fluoride content of water), are added. The contents are stirred slowly for ten minutes and then allowed to settle for 1 -2 hours. The supernatant defluorinated water is withdrawn for supply and the settled sludge is disposed of separately. The Nalgonda technique of deflouridation is easy to operate and maintain. It employs chemicals which are readily available. Besides, it does not involve regeneration of used media. It largely offsets the drawbacks of the earlier method and is therefore widely used for water supply to small communities and for rural water supply.

Salient features of Nalgonda technique

1. No regeneration of media
2. No handling of caustic acids and alkalis
3. Readily available chemicals used in conventional municipal water treatment are only required
4. Adaptable to domestic use
5. Flexible up to several thousand m3 / d
6. Applicable in batch as well as in continuous operation to suit needs simplicity of design, construction, operation and maintenance
7. Local skills could be readily employed

8. Highly efficient removal of fluorides from 1.5 to 20 mg/L to desirable levels