

SCI1210 ENVIRONMENTAL ENGINEERING – I

UNIT IV

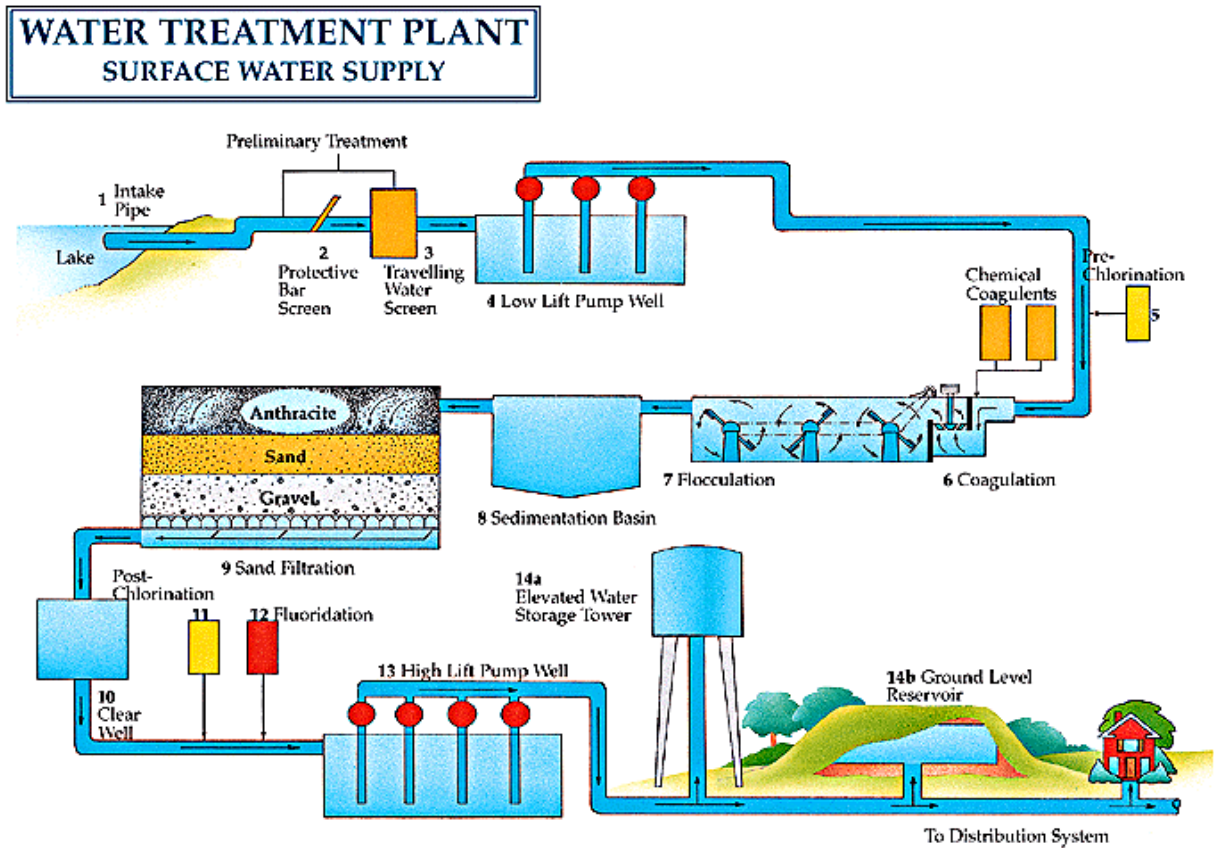
TREATMENT OF WATER

OBJECTIVES:

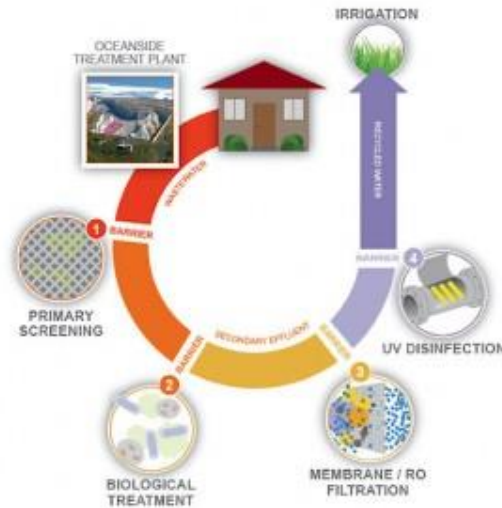
In general, Water contains many impurities, such as trace minerals, metals, chemicals etc.

The following are the objectives of water treatment:

- To eradicate the contaminants that are contained in water as found in nature.
- To control the impurities from scale formation.
- Pure water quality is required to minimize the corrosion, radiation levels and fouling of heat transfer surfaces in reactor facility systems.
- To provide safe potable water to the public.
- To reduce the physical, chemical and biological contaminants in water.
- Water treatment is required for surface waters and some ground waters for drinking purposes.
- Water treatments involves the removal of pollutants generated from different sources and to produce water that is pure and suitable for human consumption without causing any long term or short term adverse health effects.
- To improve the quality of water for several purposes, water treatment is required.
- To provide appropriate treatment technology to the contaminated water, which will be useful to all populations groups.

LAYOUT OF TREATMENT PLANTS :**Water Treatment Process Principle**

Objective or principle of water treatment process are to remove the different impurities in the raw water, to render the water safe and clean and to ensure the treated water quality meets the drinking water standards. The types of treatment required depends on the characteristics of the raw water.



The characteristics of the raw water is assessed by taking sample of water from source during different seasons of the year and analyzing for physical, chemical and bacteriological quality parameters.

SEDIMENTATION::

THEORY:

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

- i) The velocity of flow
- ii) The viscosity of water
- iii) The size shape and specific gravity of the particle.

The settling velocity of a spherical particle is expressed by stoke's law, which takes the above three factors into account. This final stokes equation is expressed as

$$V_s = g/18 [(G-1)] d^2/v \quad \text{for } d < 0.1 \text{ mm}$$

[for viscous flow and small sized particles, represented by $Re < 0.5$]

Where v_s = velocity of settlement of particle (assumed to be spherical) in m/sec

D = diameter of the particle in m

G = Sp.gravity of the particle

= density of the particle / density of water

v = kinematic viscosity of water in m^2/sec

PRINCIPLES:

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.

Types of Settling Tanks

- Sedimentation tanks may function either intermittently or continuously. The intermittent tanks also called quiescent type tanks are those which store water for a certain period and keep it in complete rest. In a continuous flow type tank, the flow velocity is only reduced and the water is not brought to complete rest as is done in an intermittent type.

- Settling basins may be either long rectangular or circular in plan. Long narrow rectangular tanks with horizontal flow are generally preferred to the circular tanks with radial or spiral flow.

Long Rectangular Settling Basin

- Long rectangular basins are hydraulically more stable, and flow control for large volumes is easier with this configuration.
- A typical long rectangular tank have length ranging from 2 to 4 times their width. The bottom is slightly sloped to facilitate sludge scraping. A slow moving mechanical sludge scraper continuously pulls the settled material into a sludge hopper from where it is pumped out periodically.

A long rectangular settling tank can be divided into four different functional zones:

Inlet zone: Region in which the flow is uniformly distributed over the cross section such that the flow through settling zone follows horizontal path.

Settling zone: Settling occurs under quiescent conditions.

Outlet zone: Clarified effluent is collected and discharge through outlet weir.

Sludge zone: For collection of sludge below settling zone.

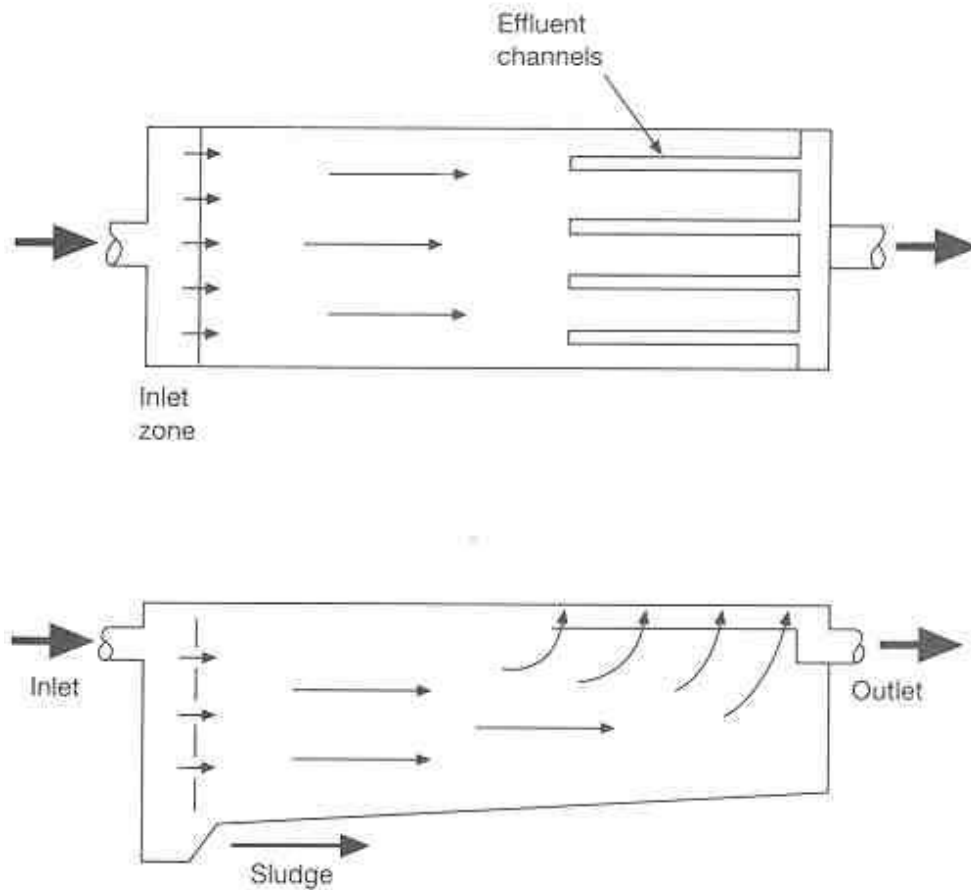


Fig: Rectangular Basin

Inlet and Outlet Arrangement

- **Inlet devices:** Inlets shall be designed to distribute the water equally and at uniform velocities. A baffle should be constructed across the basin close to the inlet and should project several feet below the water surface to dissipate inlet velocities and provide uniform flow;
- **Outlet Devices:** Outlet weirs or submerged orifices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank. However, peripheral weirs are not acceptable as they tend to cause excessive short-circuiting.

Weir Overflow Rates

- Large weir overflow rates result in excessive velocities at the outlet. These velocities extend backward into the settling zone, causing particles and flocs to be drawn into the outlet. Weir loadings are generally used upto $300 \text{ m}^3/\text{d}/\text{m}$. It may be necessary to provide special inboard weir designs as shown to lower the weir overflow rates.

Inboard Weir Arrangement to Increase Weir Length



Circular Basins

- Circular settling basins have the same functional zones as the long rectangular basin, but the flow regime is different. When the flow enters at the center and is baffled to flow radially towards the perimeter, the horizontal velocity of the water is continuously decreasing as the distance from the center increases. Thus, the particle path in a circular basin is a parabola as opposed

to the straight line path in the long rectangular tank.

- Sludge removal mechanisms in circular tanks are simpler and require less maintenance.

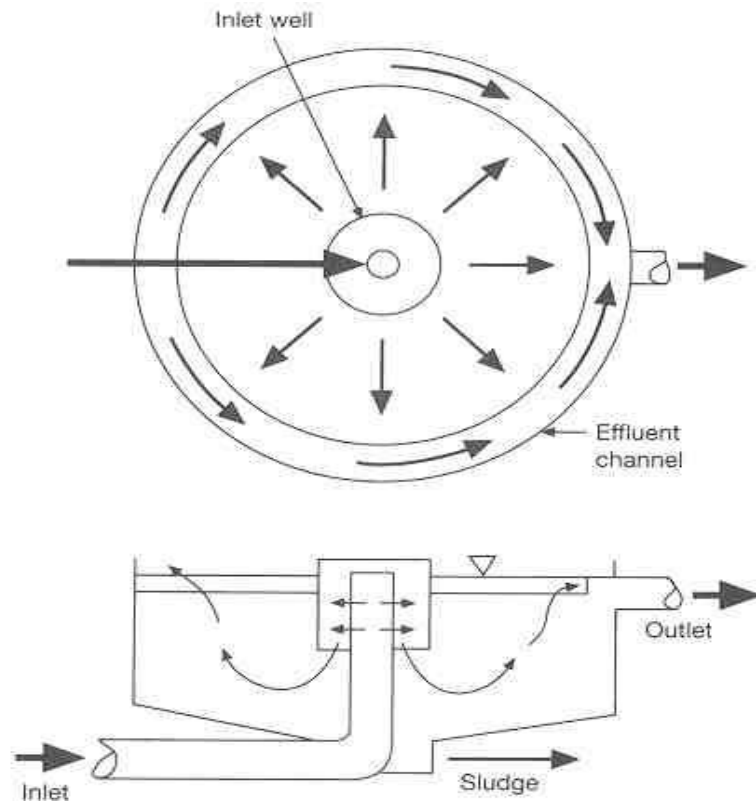


Fig: Circular Basin

Settling Operations

- Particles falling through the settling basin have two components of velocity:

1) Vertical component:

$$v_t = \left\{ \frac{(\rho_p - \rho)gd^2}{18\mu} \right\}$$

2) Horizontal component: $v_h = Q/A$

The path of the particle is given by the vector sum of horizontal velocity v_h and vertical settling velocity v_t .

- Assume that a settling column is suspended in the flow of the settling zone and that the column travels with the flow across the settling zone. Consider the particle in the batch analysis for type-1 settling which was initially at the surface and settled through the depth of the column Z_0 , in the time t_0 . If t_0 also corresponds to the time required for the column to be carried horizontally across the settling zone, then the particle will fall into the sludge zone and be removed from the suspension at the point at which the column reaches the end of the settling zone. All particles with $v_t > v_0$ will be removed from suspension at some point along the settling zone.
- Now consider the particle with settling velocity $< v_0$. If the initial depth of this particle was such that $Z_p/v_t = t_0$, this particle will also be removed. Therefore, the removal of suspended particles passing through the settling zone will be in proportion to the ratio of the individual settling velocities to the settling velocity v_0 .
The time t_0 corresponds to the retention time in the settling zone.
- $t = V/Q = LZ_0W / Q$

$$\text{Also, } t_0 = Z_0/v_0$$

$$\text{Therefore, } Z_0/v_0 = LZ_0W / Q \text{ and } v_0 = Q/LW$$

or

$$v_0 = \frac{Q}{A_s}$$

Thus, the depth of the basin is not a factor in determining the size particle that can be removed completely in the settling zone. The determining factor is the quantity Q/A_s , which has the units of velocity and is referred to as the overflow rate q_0 . This overflow rate is the design factor for settling basins and corresponds to the terminal setting velocity of the particle that is 100% removed.

Design Details

1. Detention period: for plain sedimentation: 3 to 4 h, and for coagulated sedimentation: 2 to 2.5 h.
2. Velocity of flow: Not greater than 30 cm/min (horizontal flow).
3. Tank dimensions: L:B = 3 to 5:1. Generally L= 30 m (common) maximum 100 m. Breadth= 6 m to 10 m. Circular: Diameter not greater than 60 m. generally 20 to 40 m.
4. Depth 2.5 to 5.0 m (3 m).
5. Surface Overflow Rate: For plain sedimentation 12000 to 18000 L/d/m² tank area; for thoroughly flocculated water 24000 to 30000 L/d/m² tank area.
6. Slopes: Rectangular 1% towards inlet and circular 8%.

Table 1 Typical Dimensions of Sedimentation Tanks

Description	Dimensions	
	Range	Typical
Rectangular		
Depth, m	3-5	3.5
Length, m	15-90	25-40
Width, m	3-24	6-10
Circular		
Diameter, m	4-60	12-45
Depth, m	3-5	4.5
Bottom Slope, mm/m	60-160	80

Example:

- A water treatment plant has a flow rate of 0.6 m³/sec. The settling basin at the plant has an effective settling volume that is 20 m long, 3 m tall and 6 m wide. Will particles that have a settling velocity of 0.004 m/sec be completely removed? If not, what percent of the particles will be removed?

Solution : $v_0 = Q/A = 0.6 \text{ m/sec} / (20 \text{ m} \times 6 \text{ m}) = 0.005 \text{ m/sec}$

Since v_0 is greater than the settling velocity of the particle of interest, they will not be completely removed.

The percent of particles which will be removed may be found using the following formula:

$$\begin{aligned} \text{Percent removed} &= (v_p / v_0) 100 \\ &= (0.004/0.005) 100 = 80 \% \end{aligned}$$

Applications in Water Treatment:

1. settling of coagulated and flocculated waters prior to filtration
2. settling settling of coagulated coagulated and flocculated flocculated waters in a softening softening plant
3. settling of treated waters in an iron and manganese removal plant

TYPES SEDIMENTATION:

The sedimentation tanks can basically be divided into two types:

- 1) Horizontal flow tanks
- 2) Vertical or up flow tanks

Design Examples on Sedimentation Tanks

Example: The Maximum daily demand at a water purification plant has been estimated as 12 million litres per day. Design the dimensions of a suitable sedimentation tank (fitted with mechanical sludge removal arrangements) for the raw supplies, assuming a detention period of 6 hours and the velocity of flow as 20 cm per minute.

Solution: Quantity of water to be treated in 24 hours = 12×10^6 litres

Quantity of water to be treated during the detention period of 6 hours

$$\begin{aligned} &= [(12 \times 10^6) / 24] \times 6 \text{ litres} \\ &= 3 \times 10^6 \text{ litres} \\ &= 3 \times 10^3 \text{ cubic metres} \\ &= 3000 \text{ cu.m} \end{aligned}$$

The capacity of the tank required = 3000 cu.m

Velocity of flow to be maintained through the tank

$$= 20 \text{ cm/minute}$$

$$= 0.2 \text{ m/minute}$$

$$\begin{aligned} \text{The length of the tank required} &= \text{Velocity of flow} \times \text{Detention period} \\ &= 0.2 \times (6 \times 60) = 72 \text{ m} \end{aligned}$$

Cross-sectional area of the tank required

$$= [\text{Capacity of the tank} / \text{Length of the tank}]$$

$$= 3000 / 72 \text{ m}^2$$

$$= 41.67 \text{ m}^2, \text{ say } 41.7 \text{ m}^2$$

Assuming the water depth in the tank as 4 m, the width of the tank required

$$= 41.7 / 4$$

$$= 10.42 \text{ m}, \text{ say } 10.5 \text{ m}$$

Using a free board of 0.5m, the overall depth = 0.5 + 4.0 = 4.5

Hence, a rectangular sedimentation tank with an overall size of 72m x 10.5m x 4.5m can be used.

Example: A rectangular settling tank without mechanical equipment is to treat 1.8 million litres per day of raw water. The sedimentation period is to be 4 hours, the velocity of flow 8cm/minute, and the depth of the water and sediment 4.2m. If an allowance of 1.2 m for sediment is made, what should be (a) the length of the basin (b) the width of the basin.

Solution: Supply of water to be treated per day = 1.8×10^6 litres

Supply of water to be treated during the detention period of 4 hours, i.e the capacity of the tank = $[(1.8 \times 10^6) / 24] \times 4$

$$= 0.3 \times 10^6 \text{ litres}$$

$$= 300 \text{ cu.m}$$

Flow velocity = 8 cm/minute

Length of the tank = Flow velocity x Detention time

$$= 8 \times (4 \times 60) \text{ cm}$$

$$= 1920$$

$$= 19.2 \text{ m}$$

The cross-sectional area of the tank = (Capacity of the tank / Length of the tank)

$$= 300/19.2 \text{ m}^2$$

$$= 15.63 \text{ m}^2$$

The depth of the sediment and water = 4.2 m

The depth of sediment = 1.2 m

The water depth = 3 m

The width of the tank = [Cross sectional area/ water depth]

$$= 15.63/3$$

$$= 5.21 \text{ m}$$

Example : A circular sedimentation tank fitted with standard mechanical sludge removal equipment is to handle 3.5 million litres per day of raw water. If the detention period of the tank is 5 hours, and the depth of the tank is 3 m, what should be the diameter of the tank ?

Solution: Quantity of the raw water to be treated per day = 3.5×10^6 litres

Quantity of the raw water to be treated during the detention period of 5 hours

i.e the capacity of the tank = $[(3.5 \times 10^6 \times 5) / 24]$ litres

$$= 728 \times 10^3 \text{ litres}$$

$$= 728 \text{ cu.m}$$

The capacity of a circular tank of depth H and dia d is given by

$$\text{Volume} = d^2 [0.011d + 0.785H]$$

Here H = 3 m (given)

$$728 = d^2 (0.011d + 0.785 \times 3)$$

$$= d^2(0.011d + 2.255)$$

Solving this equation by Hit and trial, we get $d = 17.3 \text{ m}$

THEORY ON COAGULATION AND FLOCCULATION:

Coagulation and flocculation occur in successive steps intended to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc. If step one is incomplete, the following step will be unsuccessful.

COAGULATION

The first step destabilizes the particle's charges. Coagulants with charges opposite those of the suspended solids are added to the water to neutralize the negative

charges on dispersed nonsettling solids such as clay and color-producing organic substances. Once the charge is neutralized, the small suspended particles are capable of sticking together. The slightly larger particles, formed through this process and called microflocs, are not visible to the naked eye. The water surrounding the newly formed microflocs should be clear. If it is not, all the particles' charges have not been neutralized, and coagulation has not been carried to completion. More coagulant may need to be added. A high-energy, rapid-mix to properly disperse the coagulant and promote particle collisions is needed to achieve good coagulation. Over-mixing does not affect coagulation, but insufficient mixing will leave this step incomplete. Coagulants should be added where sufficient mixing will occur. Proper contact time in the rapid-mix chamber is typically 1 to 3 minutes.

FLOCCULATION

Following the first step of coagulation, a second process called flocculation occurs. Flocculation, a gentle mixing stage, increases the particle size from submicroscopic microfloc to visible suspended particles. The microflocs are brought into contact with each other through the process of slow mixing. Collisions of the microfloc particles cause them to bond to produce larger, visible flocs called pinflocs. The floc size continues to build through additional collisions and interaction with inorganic polymers formed by the coagulant or with organic polymers added. Macroflocs are formed. High molecular weight polymers, called coagulant aids, may be added during this step to help bridge, bind, and strengthen the floc, add weight, and increase settling rate. Once the floc has reached its optimum size and strength, the water is ready for the sedimentation process. Design contact times for flocculation range from 15 or 20 minutes to an hour or more.

Operational Considerations

Flocculation requires careful attention to the mixing velocity and amount of mix energy. To prevent the floc from tearing apart or shearing, the mixing velocity and energy input are usually tapered off as the size of the floc increases. Once flocs are torn apart, it is difficult to get them to reform to their optimum size and strength. The amount of operator control available in flocculation is highly dependent upon the type and design of the equipment.

COAGULANT SELECTION

The choice of coagulant chemical depends upon the nature of the suspended solid to be removed, the raw water conditions, the facility design, and the cost of the amount of chemical necessary to produce the desired result. Final selection of the coagulant (or coagulants) should be made following thorough jar testing and plant scale evaluation. Considerations must be given to required effluent quality, effect upon downstream treatment process performance, cost, method and cost of sludge handling and disposal, and net overall cost at the dose required for effective treatment.

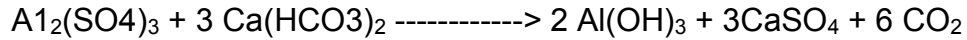
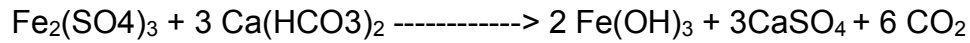
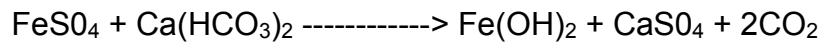
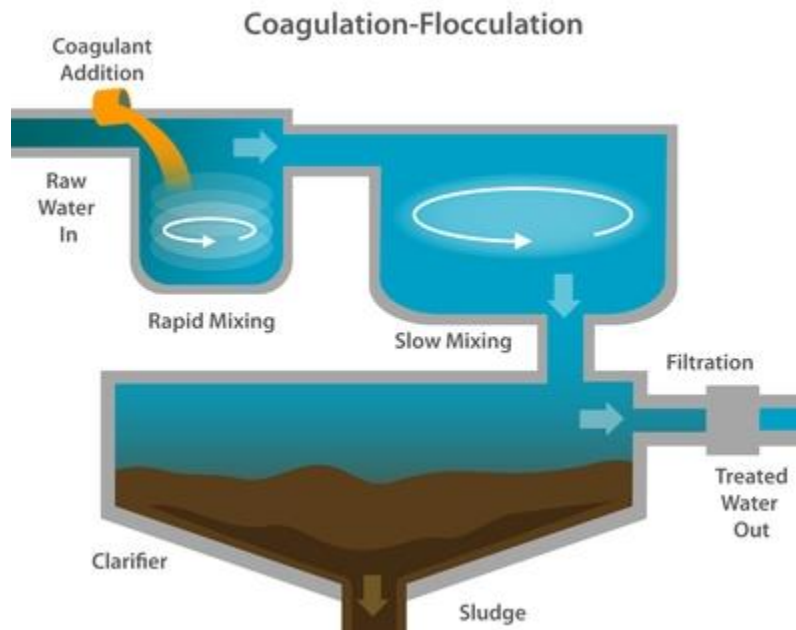
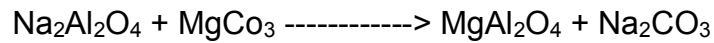
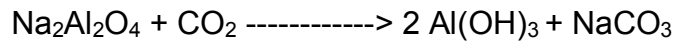
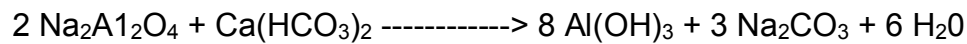
Inorganic Coagulants

Inorganic coagulants such as aluminum and iron salts are the most commonly used. When added to the water, they furnish highly charged ions to neutralize the suspended particles. The inorganic hydroxides formed produce short polymer chains which enhance microfloc formation. Inorganic coagulants usually offer the lowest price per pound, are widely available, and, when properly applied, are quite effective in removing most suspended solids. They are also capable of removing a portion of the organic precursors which may combine with chlorine to form disinfection by-products. They produce large volumes of floc which can entrap bacteria as they settle. However, they may alter the pH of the water since they consume alkalinity. When applied in a lime soda ash softening process, alum and iron salts generate demand for lime and soda ash. They require corrosion-resistant storage and feed equipment. The large volumes of settled floc must be disposed of in an environmentally acceptable manner.

Inorganic Coagulant Reactions

Common coagulant chemicals used are alum, ferric sulfate, ferric chloride, ferrous sulfate, and sodium aluminate. The first four will lower the alkalinity and pH of the solution while the sodium aluminate will add alkalinity and raise the pH. The reactions of each follow:

ALUM

**FERRIC SULFATE****FERRIC CHLORIDE****FERROUS SULFATE****SODIUM ALUMINATE**

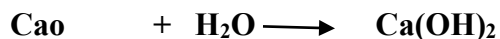


Example: 8 mg of copperas is consumed with lime at a coagulation basin, per litre water. Determine the quantity of copperas and the quick lime required to treat 10 million litres of water.

Solution: Quantity of copperas required per litre of water = 8 mg

Quantity of copperas required per 10 million litre of water = $8 \times 10 \times 10^6 \text{ mg} = 80 \text{ kg}$

The chemical reactions that are involved are



(Quick lime)

(Hydrated lime)

(or)

lime



(Copperas) (Hydrated lime)

Now, molecular weight of copperas = $[55.85 + 32.066 + 4 \times 16 + 7(2 \times 1.008 + 16)]$

$$= 278.028$$

$$= 278 \text{ (say)}$$

Similarly, molecular weight of quick lime (CaO) = $[40.08 + 16]$

$$= 56.08$$

$$= 56 \text{ (say)}$$

Since one molecule of copperas requires one molecule of lime, 278 mg of copperas will require 56mg of quick lime.

$$278\text{mg of copperas need} = 56\text{mg quick lime}$$

$$\text{Or } 1 \text{ mg of copperas need} = 56/278 \text{ mg quick lime}$$

$$\begin{aligned} \text{Or } 80 \text{ kg of copperas need} &= 56/278 \times 80 \text{ kg of quick lime} \\ &= 16.12 \text{ kg of quick lime} \end{aligned}$$

Hence, the quantity of quick lime required at the plant = 16.12 kg

Example: A rectangular sedimentation tank following coagulation – flocculation is to treat a flow of 3000 m³/day with a detention time of 6 hours. It is to be hand cleaned of sludge at 6 week intervals. The suspended solids concentration of the water is reduced from 250mg/l to 5 mg/l by coagulation – flocculation. The settled sludge includes 40mg/l (based on water flow) of metallic precipitate and has a moisture content of 85% and specific gravity of 1.24. Determine the volume of sludge produced between cleanings and the basic dimensions of the tank if the water depth just before cleaning is 3m and its length is twice its width.

Solution: Initial suspended solids concentration of water = 250 mg/l

Final suspended solids concentration of water = 5 mg/l

$$\begin{aligned} \text{Suspended solids removed in the tank} &= 250 \text{ mg/l} - 5 \text{ mg/l} \\ &= 245 \text{ mg/l} \end{aligned}$$

These removed suspended solids will settle down as sludge along with the metallic precipitates formed during coagulation. The concentration of such metallic precipitates in sludge is given as 40 mg/l.

$$\text{Hence, the total solids concentration in sludge} = 245 \text{ mg/l} + 40 \text{ mg/l} = 285 \text{ mg/l}$$

$$\text{Discharge or water flow in the tank} = 3000 \text{ m}^3 / \text{day}$$

$$\begin{aligned} \text{Total solids removed as sludge per day} &= 285 \text{ mg/l} \times 3000 \text{ m}^3 / \text{day} \\ &= 285 \text{ mg/l} \times [(3000 \times 1000) \text{ L}] / \text{day} \\ &= 285/10^6 \times (3000 \times 1000) \text{ kg/day} \\ &= 855 \text{ kg/day} \end{aligned}$$

Total solids removed in 6 weeks (i.e 6x7 days)

$$= 855 \times (6 \times 7) \text{ kg}$$

$$=35,910 \text{ kg}$$

Since the produced sludge has a m.c of 85% we have:

15 kg of solids (dry sludge) will make

$$= 100 \text{ kg of wet sludge}$$

35910 kg of solids (dry sludge) will make

$$= (100/15) \times 35,910 \text{ kg of wet sludge}$$

$$= 2,39,400 \text{ kg of wet sludge}$$

$$= 239.4 \text{ tonne of wet sludge}$$

Volume of wet sludge produced per 6 week interval

$$=(\text{Mass of wet sludge})/(\text{Density of set sludge})$$

Where density of wet sludge

$$= \text{sp.gr.of wet sludge} \times \text{density of water}$$

$$= 1.24 \times 1 \text{ t/m}^3$$

$$= 1.24 \text{ t/m}^3$$

$$= [239.4\text{t}] / [1.24 \text{ t/m}^3]$$

$$= 193.06 \text{ m}^3$$

Dimensions of the Tank

L= Length of the tank = 2 B, where B is width of the tank (given)

D_w = Water depth = 3 m (assuming that the given “water depth just before cleaning” is only the water depth, and does not include the sludge depth)

$$Q = \text{Flow in the tank} = 3000 \text{ m}^3 / \text{day}$$

t = detention time = 6 hrs

Capacity of the tank required i.e Qty of water to be treated per 6 hr.

$$= 3000 \times [6/24] \text{ m}^3$$

$$= 750 \text{ m}^3$$

But capacity = L x B x D_w = (2 B) (B) (3) = 750

$$B = \sqrt{(750/6)}$$

$$= 11.2 \text{ m (say)}$$

$$L = 22.4 \text{ m}$$

$$B = 11.2 \text{ m}$$

$D = D_w + \text{Sludge depth (av.)} + \text{Free board; Where}$

$$\begin{aligned}\text{Sludge depth (av)} &= (\text{Sludge volume}) / (\text{Plan area of the tank}) \\ &= 193.06 \text{ m}^3 / (22.4 \times 11.2 \text{ m}) \\ &= 0.77 \text{ m ; say } 0.8 \text{ m}\end{aligned}$$

Assuming that a free-board of 0.5 m is provided, we have the total depth of the tank

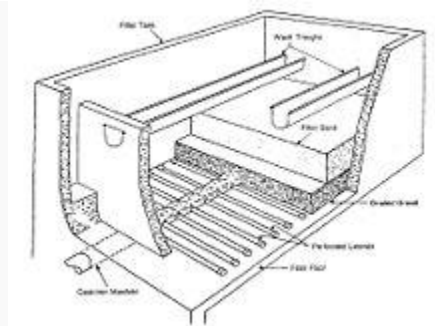
$$= D = 3 + 0.8 + 0.5 = 4.3 \text{ m}$$

Hence, the tank size to be used shall be 22.4m x 11.2m x 4.3m

THEORY ON FILTRATION:

The filtration apparatus is a concrete box which contains sand (which does the filtering), gravel (which keeps the sand from getting out) and an underdrain (where the filtered water exits). After the filter is operated for a while, the sand becomes clogged with particles and must be backwashed. Flow through the filter is reversed and the sand and particles are suspended. The particles are lighter than the sand, so they rise up and are flushed from the system. When backwashing is complete, the sand settles down onto the gravel, flow is reversed and the process begins again.

Rapid sand filters



Cutaway view of a typical rapid sand filter

The most common type of filter is a rapid sand filter. Water moves vertically through sand which often has a layer of activated carbon or anthracite coal above the sand. The top layer removes organic compounds, which contribute to taste and odour. The space between sand particles is larger than the smallest suspended particles, so simple filtration is not enough. Most particles pass through surface layers but are trapped in pore spaces or adhere to sand particles. Effective filtration extends into the

depth of the filter. This property of the filter is key to its operation: if the top layer of sand were to block all the particles, the filter would quickly clog.

To clean the filter, water is passed quickly upward through the filter, opposite the normal direction (called *backflushing* or *backwashing*) to remove embedded particles. Prior to this step, compressed air may be blown up through the bottom of the filter to break up the compacted filter media to aid the backwashing process; this is known as *air scouring*. This contaminated water can be disposed of, along with the sludge from the sedimentation basin, or it can be recycled by mixing with the raw water entering the plant although this is often considered poor practice since it re-introduces an elevated concentration of bacteria into the raw water.

Some water treatment plants employ pressure filters. These work on the same principle as rapid gravity filters, differing in that the filter medium is enclosed in a steel vessel and the water is forced through it under pressure.

Advantages:

- Filters out much smaller particles than paper and sand filters can.
- Filters out virtually all particles larger than their specified pore sizes.
- They are quite thin and so liquids flow through them fairly rapidly.
- They are reasonably strong and so can withstand pressure differences across them of typically 2–5 atmospheres.
- They can be cleaned (back flushed) and reused.

Slow sand filters

Slow sand filters may be used where there is sufficient land and space, as the water must be passed very slowly through the filters. These filters rely on biological treatment processes for their action rather than physical filtration. The filters are carefully constructed using graded layers of sand, with the coarsest sand, along with some gravel, at the bottom and finest sand at the top. Drains at the base convey treated water away for disinfection. Filtration depends on the development of a thin biological layer, called the zoogeal layer or Schmutzdecke, on the surface of the filter. An effective slow sand filter may remain in service for many weeks or even months if

the pre-treatment is well designed and produces water with a very low available nutrient level which physical methods of treatment rarely achieve. Very low nutrient levels allow water to be safely sent through distribution systems with very low disinfectant levels, thereby reducing consumer irritation over offensive levels of chlorine and chlorine by-products. Slow sand filters are not backwashed; they are maintained by having the top layer of sand scraped off when flow is eventually obstructed by biological growth.

A specific "large-scale" form of slow sand filter is the process of bank filtration, in

which natural sediments in a riverbank are used to provide a first stage of contaminant filtration. While typically not clean enough to be used directly for drinking water, the water gained from the associated extraction wells is much less problematic than river water taken directly from the major streams where bank filtration is often used.

Pressure Sand Filters:

Pressure filters are just like small rapid gravity filters placed in closed vessels, and through which water to be treated is passed under pressure. Since water is forced through such filters at a pressure greater than the atmospheric pressure, it is necessary that these filters are located in air tight vessels. The raw water is pumped into the vessels by means of pumps, The pressure so developed may normally vary between 30 to 70 metre head of water i.e 300 to 700 KN/m²

Pressure Sand Filter is highly recommended for the removal of suspended solids & undissolved impurities like dust particles & heavy metals etc. PSF reduces turbidity. Pressure Sand Filter is an ideal solution for the systems with high sediment, silt, sand, and turbidity. The sand filters are specially designed to take care of the range of suspended impurities.

Sand filtration is frequently used and very robust method to remove suspended solids from water. The filtration medium consists of a multiple layer of sand with a variety in

size and specific gravity. Sand filters can be supplied in different sizes and materials both hand operated or fully automatically. Raw water pump is used for generating necessary operating pressure in the pressure sand filter. Raw water is passed through CHEMTRONICS Multigrade Sand Filter at a pressure of 3.5 kg / cm² to reduce the suspended solids present in the raw water.

The filter will effectively remove up to 30 – 50 micron of the suspended solids to less than 5 ppm. The filter will have to be washed with raw water for 20 to 30 minutes daily. To filter the partials below 30 – 50 micron cartridge filter is used.

Applications For Sand Filtration :

- > Preparation of cooling water
- > Treatment of waste water
- > Production of Drinking water
- > Pre filtration for RO (membrane) systems
 - > Filtration of gray or surface water
 - > Filtration in swimming pools
 - > Pre filtration for membrane system
 - > Filtration of gray or surface water
 - >

Multi Grade Sand Filter:

The Multigrade Sand Filter is a depth filter that makes use of coarse and fine media mixed together in a fixed proportion. This arrangement produces a filter bed with adequate pore dimensions for retaining both large and small suspended particles. Multigrade sand filter is highly recommended for the removal of suspended solids & undissolved impurities like dust particles & heavy metals etc. doing so it reduces turbidity. Pressure sand filters is an ideal solution for the systems with high sediment, silt, sand, and turbidity. Our sand filters are well established in media filtration technology. The sand filters are specially designed to take care of the range of suspended impurities. Chemtronics filtration series multigrade sand filter include vessel complete with

pipings & valves sand media and gravel support bed.

Applications:

The Multigrade sand filter is an ideal choice for all applications where a conventional sand filter is used.

- It is extensively used in side stream filtration of cooling water.
- Drinking Water
- It is ideal for filtration of clarified water.
- Water used in chemical processes.
- Filtration process in Industries
- Used for pre – treatment for membrane systems.
- Swimming Pool Water Filtration.
- Filtration in Tertiary waste water treatment.
- Pharmaceutical Production processes

Pressure Sand Water Filter FR Series:

Fiber Glass Reinforced Plastic (FGRP) composite vessels are 1/3 the weight of carbon steel, strengths are directly comparable to steel, no maintenance & high aesthetic appearance.

Multigrade Sand Filter FRP Series:

- The non corrosive, cost effective solution for commercial /industrial water treatment and storage
- FRP vessels are used for residential, large commercial and Industrial applications.
- Vessel is made up of Natural fiberglass shell never fades or changes color, colored shells recommended for UV protection.
- 100% Corrosion –resistant both inside and out.
- Physical Properties: Operating Pressure – Min 0 bar and Max. 10 bar.
- Factory Test Pressure – 11 bar.
- Operating Temp – Min. 1°C and Max. 50 °C
- The light weight of composites can lead to cost saving like lower installation

costs easier handling.

- Top & Bottom Opening Vessel.
- Low Pressure drop across the vessel.
- Multiport valve MOC is ABS.
- Manual, Semi automatic and automatic features are provided
- High Filtration efficiencies Standard and effective multigrade sand media
- Efficient Turbidity and TSS Removal

Pressure Sand Water Filter SS Series:

- Stainless steel pressure sand filters are widely used in following applications :
- Pharmaceutical product water
- Dairy & food products.
- Beverages
- Package drinking water
- Cosmetics

Pressure Sand Water Filter MS:

Mild Steel(MS) pressure sand filters are commonly used across the world for following applications:

- Filter high quantity of water.
- Thermoelectric power plants.
- Irrigation & farming
- Aquaculture

Example: Design a six slow sand filter beds from the following data:

Population to be served = 50000 persons

Per capita demand = 150 litres /head/day

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

Length of each bed = Twice the breadth

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

Solution :

$$\begin{aligned}\text{Average daily demand} &= \text{Population} \times \text{Per capita demand} \\ &= 50,000 \times 150 \text{ litres/day} \\ &= 7.5 \times 10^6 \text{ litres/day}\end{aligned}$$

$$\text{Max.daily demand} = 1.8 \times 7.5 \times 10^6 = 13.5 \times 10^6 \text{ litres/day}$$

$$\text{Rate of filtration per day} = (180 \times 24) \text{ litres/sq.m/day}$$

$$\begin{aligned}\text{Total surface area of filters required} &= (\text{Max.daily demand}) / (\text{Rate of filtration per day}) \\ &= [(13.5 \times 10^6) / (180 \times 24)] \text{ sq.m} \\ &= 3125 \text{ sq.m}\end{aligned}$$

Now, six units are to be used, out of them, one is to be kept as stand-by, and hence only 5 units should provide the necessary area of filter required.

$$\begin{aligned}\text{The area of each filter unit} &= 1/5 \times \text{Total area reqd.} \\ &= 1/5 \times 3125 \\ &= 625 \text{ sq.m}\end{aligned}$$

Now, if L is the length and B is the breadth of each unit, then $L=2B$ (given)

$$2 B \cdot B = 625 \text{ sq.m}$$

$$\text{Or } B^2 = 312.5 \text{ sq.m}$$

$$\text{Or } B = 17.7 \text{ m say } 18 \text{ m}$$

$$\begin{aligned}L &= 2(17.75) \\ &= 36 \text{ m}\end{aligned}$$

Hence, use filter units with one unit as stand by, each unit of size 36m x 18m, arranged in series with 3 units on either side.

Example: A filter unit is 4.5 m by 9.0 m. After filtering 10,000 cubic metre per day in 24 hour period , the filter is back washed at a rate of 10 l/sq.m/sec for 15 min. Compute the average filtration rate, quantity, and percentage of treated water used in washing, and the rate of wash water flow in each trough. Assume 4 troughs.

Solution:

$$\text{Area of filter} = 4.5 \times 9.0 \text{ m}^2 = 40.5 \text{ m}^2$$

$$\text{Filtered qty. in 24 hours} = 10,000 \text{ cum/day}$$

$$\text{Area of filter} = (\text{Water filtered}) / (\text{Rate of filtration})$$

Rate of filtration in 1/hr/sq.m

$$= [(10,000 \times 1000) / (24 \times 40.5)] \text{ l/hr/m}^2$$

$$= 10,288 \text{ l/hr/m}^2$$

Av. rate of filtration (by counting ½ hr. lost in cleaning)

$$= [10,288 / 24.5] \times 24$$

$$= 10,078 \text{ l/hr/m}^2$$

Amount of water used in cleaning @ 10 l/m²/sec for 15 min

$$= 10 \times (4.5 \times 9.0) \times (15 \times 60) \text{ l}$$

$$= 364500 \text{ litres}$$

$$= 364.5 \text{ cum.}$$

Qty. of wash water expressed as percentage of total filtered water

$$= [364.5 \times 100] / 10,000$$

$$= 3.645 \%$$

Wash water discharge through each trough

$$= (\text{Total wash water discharge through the filter}) / (\text{No. of troughs})$$

$$= [10 \text{ l/m}^2/\text{sec} \times (4.5 \times 9) \text{ m}^2] / 4$$

$$= 101.25 \text{ l/sec}$$

DISINFECTION:

Disinfection is accomplished both by filtering out harmful micro-organisms and also by adding disinfectant chemicals. Water is disinfected to kill any pathogens which pass through the filters and to provide a residual dose of disinfectant to kill or inactivate potentially harmful micro-organisms in the storage and distribution systems. Possible pathogens include viruses, bacteria, including Salmonella, Cholera, Campylobacter and Shigella, and protozoa, including Giardia lamblia and other cryptosporidia. Following the introduction of any chemical disinfecting agent, the water is usually held in temporary storage – often called a contact tank or clear well to allow the disinfecting action to complete.

Chlorine disinfection

The most common disinfection method involves some form of chlorine or its compounds such as chloramine or chlorine dioxide. Chlorine is a strong oxidant that

rapidly kills many harmful micro-organisms. Because chlorine is a toxic gas, there is a danger of a release associated with its use. This problem is avoided by the use of sodium hypochlorite, which is a relatively inexpensive solution used in household bleach that releases free chlorine when dissolved in water. Chlorine solutions can be generated on site by electrolyzing common salt solutions. A solid form, calcium hypochlorite, releases chlorine on contact with water. Handling the solid, however, requires greater routine human contact through opening bags and pouring than the use of gas cylinders or bleach which are more easily automated. The generation of liquid sodium hypochlorite is both inexpensive and safer than the use of gas or solid chlorine.

All forms of chlorine are widely used, despite their respective drawbacks. One drawback is that chlorine from any source reacts with natural organic compounds in the water to form potentially harmful chemical by-products. These by-products, trihalomethanes (THMs) and haloacetic acids (HAAs), are both carcinogenic in large quantities and are regulated by the United States Environmental Protection Agency (EPA) and the Drinking Water Inspectorate in the UK. The formation of THMs and haloacetic acids may be minimized by effective removal of as many organics from the water as possible prior to chlorine addition. Although chlorine is effective in killing bacteria, it has limited effectiveness against protozoa that form cysts in water (*Giardia lamblia* and *Cryptosporidium*, both of which are pathogenic).

Chlorine dioxide disinfection

Chlorine dioxide is a faster-acting disinfectant than elemental chlorine. It is relatively rarely used, because in some circumstances it may create excessive amounts of chlorite, which is a by-product regulated to low allowable levels in the United States. Chlorine dioxide can be supplied as an aqueous solution and added to water to avoid gas handling problems; chlorine dioxide gas accumulations may spontaneously detonate.

Chloramine disinfection

The use of chloramine is becoming more common as a disinfectant. Although

chloramine is not as strong an oxidant, it does provide a longer-lasting residual than free chlorine and it will not readily form THMs or haloacetic acids. It is possible to convert chlorine to chloramine by adding ammonia to the water after addition of chlorine. The chlorine and ammonia react to form chloramine. Water distribution systems disinfected with chloramines may experience nitrification, as ammonia is a nutrient for bacterial growth, with nitrates being generated as a by-product.

Ozone disinfection

Ozone is an unstable molecule which readily gives up one atom of oxygen providing a powerful oxidizing agent which is toxic to most waterborne organisms. It is a very strong, broad spectrum disinfectant that is widely used in Europe. It is an effective method to inactivate harmful protozoa that form cysts. It also works well against almost all other pathogens. Ozone is made by passing oxygen through ultraviolet light or a "cold" electrical discharge. To use ozone as a disinfectant, it must be created on-site and added to the water by bubble contact. Some of the advantages of ozone include the production of fewer dangerous by-products and the absence of taste and odour problems (in comparison to chlorination). Another advantage of ozone is that it leaves no residual disinfectant in the water. Ozone has been used in drinking water plants since 1906 where the first industrial ozonation plant was built in Nice, France. The U.S. Food and Drug Administration has accepted ozone as being safe; and it is applied as an anti-microbiological agent for the treatment, storage, and processing of foods. However, although fewer by-products are formed by ozonation, it has been discovered that ozone reacts with bromide ions in water to produce concentrations of the suspected carcinogen bromate. Bromide can be found in fresh water supplies in sufficient concentrations to produce (after ozonation) more than 10 parts per billion (ppb) of bromate — the maximum contaminant level established by the USEPA.

Ultraviolet disinfection

Ultraviolet light (UV) is very effective at inactivating cysts, in low turbidity water. UV light's disinfection effectiveness decreases as turbidity increases, a result of the absorption, scattering, and shadowing caused by the suspended solids. The main

disadvantage to the use of UV radiation is that, like ozone treatment, it leaves no residual disinfectant in the water; therefore, it is sometimes necessary to add a residual disinfectant after the primary disinfection process. This is often done through the addition of chloramines, discussed above as a primary disinfectant. When used in this manner, chloramines provide an effective residual disinfectant with very few of the negative effects of chlorination.

MISCELLANEOUS METHODS:

IRON AND MANGANESE REMOVAL:

Problems caused by iron and manganese:

Small amounts of iron are often found in water because of the large amount of iron present in the soil and because corrosive water will pick up iron from pipes. Clothing washed in water containing excessive iron may become stained a brownish color. The taste of beverages, such as tea and coffee, may also be affected by iron. Manganese produces a brownish color in laundered clothing, leaves black particles on fixtures, and—as with iron—affects the taste of beverages, including coffee and tea. Well water from the faucet or tap is usually clear and colorless. However, when water containing colorless, dissolved iron is allowed to stand in a cooking container or comes in contact with a sink or bathtub, the iron combines with oxygen from the air to form reddish-brown particles (commonly called rust). Manganese forms brownish-black particles. These impurities can give a metallic taste to water or to food. The rusty or brown stains on plumbing fixtures, fabrics, dishes, and utensils cannot be removed by soaps or detergents. Bleaches and alkaline builders (often sodium phosphate) can make the stains worse. Over time, iron deposits can build up in pressure tanks, water heaters, and pipelines, reducing the quantity and pressure of the water supply. Iron and/or manganese in water creates problems common to many water supply systems. When both are present beyond recommended levels, special attention should be paid to the problem. How iron and manganese are removed depends on the type and concentration and this helps determine the best procedure and (possible) equipment to use.

Chemistry of iron and manganese in water systems:

Iron (Fe) and manganese (Mn) can be present in water in one of three basic forms:

1. Dissolved: ferrous (Fe^{2+}) and manganous (Mn^{2+})
2. Particulate: ferric (Fe^{3+}) and manganic (Mn^{4+}) states
3. Colloidal: very small particles (difficult to settle and filter).

The predominance of one form over another is dependent on the pH, Eh (redox potential), and temperature of the water. Knowledge of the forms or states of iron and manganese can help finetune a given treatment practice for these metals

Most common treatment processes:

The majority of iron and manganese treatment systems employ the processes of oxidation/ filtration. The oxidant chemically oxidizes the iron or manganese (forming a particle), and kills iron bacteria and any other disease-causing bacteria that may be present. The filter then removes the iron or manganese particles. Oxidation followed by filtration is a relatively simple process. The source water must be monitored to determine proper oxidant dosage, and the treated water should be monitored to determine if the oxidation process was successful

Oxidation

Before iron and manganese can be filtered, they need to be oxidized to a state in which they can form insoluble complexes. Oxidation involves the transfer of electrons from the iron, manganese, or other chemicals being treated to the oxidizing agent. Ferrous iron (Fe^{2+}) is oxidized to ferric iron (Fe^{3+}), which readily forms the insoluble iron hydroxide complex $\text{Fe}(\text{OH})_3$. Reduced manganese (Mn^{2+}) is oxidized to (Mn^{4+}), which forms insoluble (MnO_2). The most common chemical oxidants in water treatment are chlorine, chlorine dioxide, potassium permanganate, and ozone. Oxidation using chlorine or potassium permanganate is frequently applied in small groundwater systems. The dosing is relatively easy, requires simple equipment, and is fairly inexpensive. Chlorination is widely used for oxidation of divalent iron and manganese. However, the formation of trihalomethanes (THMs) in highly colored

waters may be a problem. Chlorine feed rates and contact time requirements can be determined by simple jar tests.

As an oxidant, potassium permanganate (KMnO_4) is normally more expensive than chlorine and ozone, but for iron and manganese removal, it has been reported to be as efficient and it requires considerably less equipment and capital investment. The dose of potassium permanganate, however, must be carefully controlled. Too little permanganate will not oxidize all the iron and manganese, and too much will allow permanganate to enter the distribution system and cause a pink color. Permanganate can also form precipitates that cause mudball formations on filters. These are difficult to remove and compromise filter performance. Ozone may be used for iron and manganese oxidation. Ozone may not be effective for oxidation in the presence of humic or fulvic materials. If not dosed carefully, ozone can oxidize reduced manganese to permanganate and result in pink water formation as well. Manganese dioxide particles, also formed by oxidation of reduced manganese, must be carefully coagulated to ensure their removal. A low-cost method of providing oxidation is to use the oxygen in air as the oxidizing agent in a tray aerator. Water is simply passed down a series of porous trays to provide contact between air and water. No chemical dosing is required, which allows for unattended operation. This method is not effective for water in which the iron is complexed with humic materials or other large organic molecules. Oxygen is not a strong enough oxidizing agent to break the strong complexes formed between iron and manganese and large organic molecules. Furthermore, the rate of reaction between oxygen and manganese is very slow below pH values of 9.5. The presence of other oxidizable species in water hinders oxidation of the desired reduced compounds. Volatile organic chemicals, other organic compounds, or taste- and odor-causing compounds may result in an oxidant demand. This additional oxidant demand must be accounted for when dosing the oxidant. The expense of operation derives from the chemical use in most cases, and therefore is directly related to the source water quality.

Filtration

In general, manganese oxidation is more difficult than iron oxidation because the reaction rate is slower. A longer detention time (10 to 30 minutes) following chemical addition is needed prior to filtration to allow the reaction to take place. There are different filtration media for the removal of iron and manganese, including manganese greensand, anthra/sand or ironman sand, electromedia, and ceramic. Manganese greensand is by far the most common medium in use for removal of iron and manganese through pressure filtration. Greensand is a processed material consisting of nodular grains of the zeolite mineral glauconite. The material is coated with manganese oxide. The ion exchange properties of the glauconite facilitates the bonding of the coating. This treatment gives the media a catalytic effect in the chemical oxidation reduction reactions necessary for iron and manganese removal. This coating is maintained through either continuous or intermittent feed of potassium permanganate. Anthra/sand (also iron-man sand) are other types of media available for removal of iron and manganese. They consist of select anthracite and sand with a chemically bonded manganese oxide coating. Unlike manganese greensand, these media are conditioned in the filter after media installation. Electromedia provides a slightly different option from the manganese oxide coated media. This is a proprietary multi-media formulation which uses a naturally occurring zeolite and does not require potassium permanganate regeneration. Finally, macrolite, unlike the other media discussed so far, is not a naturally occurring material which then undergoes processing for iron and manganese removal purposes. It is a manufactured ceramic material with a spherical shape and a rough, textured surface. The principal removal mechanism is physical straining rather than contact oxidation or adsorption. Each medium has its advantages and disadvantages. Selection of a medium and oxidant should be based on pilot testing in which all necessary design criteria can be determined. Pressure filtration system manufacturers who offer the indicated media also offer fully automated systems.

Alternative treatments:**Sequestration**

Sequestration is the addition of chemicals to groundwater aimed at controlling

problems caused by iron and manganese without removing them. These chemicals are added to groundwater at the well head or at the pump intake before the water has a chance to come in contact with air or chlorine. This ensures that the iron and manganese stays in a soluble form. If the water contains less than 1.0 mg/L iron and less than 0.3 mg/L manganese, using polyphosphates followed by chlorination can be an effective and inexpensive method for mitigating iron and manganese problems. No sludge is generated in this method. Below these concentrations, the polyphosphates combine with the iron and manganese preventing them from being oxidized. Any of the three polyphosphates (pyrophosphate, tripolyphosphate, or metaphosphate) can be used. To determine the best polyphosphate to use and the correct dosage, a series of samples at different concentrations may be prepared. Chlorine is added, and the samples are observed daily against a white background. The right polyphosphate dose is the lowest dose that does not noticeably discolor the water samples for four days. Applying sodium silicate and chlorine simultaneously has also been used to sequester iron and manganese. However, while this technique is reliable in the case of iron treatment, it has not been found to be effective in manganese control.

Ion Exchange

Ion exchange should be considered only for the removal of small quantities of iron and manganese because there is a risk of rapid clogging. Ion exchange involves the use of synthetic resins where a pre-saturant ion on the solid phase (the “adsorbent,” usually sodium) is exchanged for the unwanted ions in the water . One of the major difficulties in using this method for controlling iron and manganese is that if any oxidation occurs during the process, the resulting precipitate can coat and foul the media. Cleaning would then be required using acid or sodium bisulfate.

Other

Systems that have a lime-soda ash softening plant do not need a separate iron and manganese removal plant. The high pH during softening allows rapid oxidation and precipitation of the iron and manganese as well as incorporation in the calcium and magnesium precipitates. Similarly, surface water treatment plants using coagulation, flocculation, sedimentation, and filtration also will remove iron and manganese as long as they make certain the iron and manganese get oxidized. Oxidation is sometimes a

problem because of the presence of organic matter. Finally, biological treatment methods are being pilot tested at different locations. Biological treatment methods are used extensively in European countries, such as the Netherlands, France, and Germany, and are advantageous primarily when water simultaneously contains iron, manganese, and ammonia.

How can iron and manganese problems be minimized in distribution mains?

Problems due to iron and manganese in distribution mains may be minimized by:

- prior removal by appropriate treatment,
- protecting iron/steel mains with bituminous linings, or using noncorrosive materials,
- avoiding dead-end mains,
- avoiding disturbances in the water flow, and
- flushing periodically.

DE-FLUORIDATION:

Defluoridation refers to methods of water treatment that reduce the concentration of fluoride in the water, normally, in order to make it safe for human consumption. Some water treatments that have the capacity of reducing the fluoride concentration along with most other anions, or anions and cations, in the water, are not considered as defluoridation methods. Thus general demineralising methods like distillation, reverse osmosis, electrodialysis and resin de-anionisation, which are able to remove fluoride fully or partly from the water, are not considered as defluoridation methods. On the other hand methods that only remove fluoride without any addition or reduction of other parameters are not yet discovered. That's why the expression "fluoride removal" lacks precision. Defluoridation is used to characterise methods that reduce the fluoride ion specifically, without *major* other changes to the quality of the treated water.

Defluoridation of water differs from normal piped water treatments:

- Because fluoride does not deteriorate the piped water quality neither technically nor organoleptically, it is normally only required for the small part of the water that is used for drinking and cooking.
- Defluoridation of large quantities of water, out of which only small part is used for human consumption, is environmentally unsound. This is because of

accumulation of correspondingly large quantities of toxic sludge that would create a new problem, more severe to deal with.

- Most large cities and towns do not need defluoridation, because they are historically built in sites privileged to have good water resources.
- Defluoridation is easily avoided in industrialised countries, as they have no difficulties in prospecting and transporting low fluoride water.

The objective of defluoridation is to prevent or to mitigate **endemic fluorosis**.

WATER SOFTENING:

Water softening is the removal of calcium, magnesium, and certain other metal cations in hard water. The resulting soft water is more compatible with soap and extends the lifetime of plumbing. Water softening is usually achieved using lime softening or ion-exchange resins.

Problems with hard water

The presence of certain metal ions like calcium and magnesium principally as bicarbonates, chlorides, and sulfates in water causes a variety of problems.

Limescale formation

Hard water leads to the buildup of limescale, which can foul plumbing, and promote galvanic corrosion. In industrial scale water softening plants, the effluent flow from the re-generation process can precipitate scale that can interfere with sewage systems.

Soap scum

The slippery feeling experienced when using soap with soft water occurs because soaps tend to bind to fats in the surface layers of skin, making soap molecules difficult to remove by simple dilution. In contrast, in hard-water areas the rinse water contains calcium or magnesium ions which form insoluble salts, effectively removing the residual soap from the skin but potentially leaving a coating of insoluble stearates on tub and shower surfaces, commonly called soap scum

Which of these effects is considered more or less desirable varies from person to person, and those who dislike the sliminess and difficulty of washing off soap caused by soft water may harden the water by adding chemicals such as baking soda, calcium chloride or magnesium sulphate.

Water softening methods

The most common means for removing water hardness rely on ion-exchange polymers or reverse osmosis. Other approaches include precipitation methods and sequestration by the addition of chelating agents.

Ion-exchange resin devices

Conventional water-softening appliances intended for household use depend on an ion-exchange resin in which "hardness ions" - mainly Ca^{2+} and Mg^{2+} - are exchanged for sodium ions. As described by NSF/ANSI Standard 44, ion-exchange devices reduce the hardness by replacing magnesium and calcium (Mg^{2+} and Ca^{2+}) with sodium or potassium ions (Na^+ and K^+).

Types of ion-exchange materials

Ion exchange resins are organic polymers containing anionic functional groups to which the divalent cations (Ca^{++}) bind more strongly than monovalent cations (Na^+). Inorganic materials called zeolites also exhibit ion-exchange properties. These minerals are widely used in laundry detergents. Resins are also available to remove carbonate, bi-carbonate and sulphate ions which are absorbed and hydroxide ions released from the resin.

Regeneration of ion-exchange resins

When all the available Na^+ ions have been replaced with calcium or magnesium ions, the resin must be re-charged by eluting the Ca^{2+} and Mg^{2+} ions using a solution of sodium chloride or sodium hydroxide depending on the type of resin used..For anionic resins, regeneration typically uses a solution of sodium hydroxide (lye) or potassium hydroxide. The waste waters eluted from the ion-exchange column containing the unwanted calcium and magnesium salts are typically discharged to the sewage system.



Fig: Ion exchange resins, in the form of beads, are a functional component of domestic water softening units.

Lime softening

Lime softening is the process in which lime is added to hard water to make it softer.

Chelating agents

Chelators are used in chemical analysis, as water softeners, and are ingredients in many commercial products such as shampoos and food preservatives. Citric acid is used to soften water in soaps and laundry detergents. A commonly used synthetic chelator is ethylenediaminetetraacetic acid (EDTA).

Distillation and rain water

Since Ca^{2+} and Mg^{2+} exist as nonvolatile salts, they can be removed by distilling the water. Distillation is too expensive in most cases. Rainwater is soft because it is naturally distilled during the water cycle of evaporation, condensation and precipitation.

Reverse osmosis

Reverse osmosis (RO) takes advantage of hydrostatic pressure gradients across a special membrane. The membrane has pores large enough to admit water molecules for passage; hardness ions such as Ca^{2+} and Mg^{2+} remain behind and are flushed away by excess water into a drain. The resulting soft water supply is free of hardness ions without any other ions being added. Membranes have a limited capacity, requiring regular replacement.

DESALINATION:

Desalination – is a process by which saline water (generally sea water) is converted to fresh water. The most common desalination processes are distillation and reverse osmosis. Desalination is currently expensive compared to most alternative sources of water, and only a very small fraction of total human use is satisfied by desalination. It is only economically practical for high-valued uses (such as household and industrial uses) in arid areas.

MEMBRANE FILTRATION:

Membrane filters are widely used for filtering both drinking water and sewage. For drinking water, membrane filters can remove virtually all particles larger than 0.2 μm —including giardia and cryptosporidium. Membrane filters are an effective form of tertiary treatment when it is desired to reuse the water for industry, for limited domestic purposes, or before discharging the water into a river that is used by towns further downstream. They are widely used in industry, particularly for beverage preparation (including bottled water). However no filtration can remove substances that are actually dissolved in the water such as phosphorus, nitrates and heavy metal ions.