

Unit – II

Water quality:

- No water on earth is 100% pure
- Pure water is entirely free from all the three impurities. (Suspended impurities, dissolved impurities, colloidal impurities).
- During precipitation absorbs many impurities from atmosphere such as dust, gases, and floating bacteria.
- When it flows on earth surface, it picks up suspended, dissolved and colloidal organic and inorganic impurities.
- The water used for drinking should be free from these impurities or contain them in permissible limits.

Requirements of Water:

- a. It should be potable – has the following properties
 - It is not contaminated and does not cause water borne diseases.
 - It is free from poisonous substances.
 - It is free from excessive amount of minerals and organic matter.
- b. It should be palatable or aesthetically acceptable – means
 - It is free from excessive temperature, colour, turbidity, taste & odour and it is well aerated.

Water Analysis:

- Various types of impurities present in the water can be determined by water analysis.
- Is done both for raw as well as treated or purified water.
- Is used to classify, prescribe and control the purification process.
- Maintain public supplies of an appropriate standard of quality and palatability.

Characteristics or Properties of Water:

Examination of water may be classified as

Physical characteristics:

1. Colour:

- Colour in water is primarily a concern of water quality for aesthetic reason. Coloured

water give the appearance of being unfit to drink, even though the water may be perfectly safe for public use.

- On the other hand, colour can indicate the presence of organic substances, such as algae or humic compounds.
- More recently, colour has been used as a quantitative assessment of the presence of potentially hazardous or toxic organic materials in water.
- Colour can be measured against various standards of scales such as platinum chloride scale or cobalt scale or the device Lovibond colour comparator.
- For public water supply it should be between 5 to 25 Hazen units.

2. Taste and colour:

- May be due to presence of mineral salts, industrial waste, domestic sewage, certain types of microscopic organisms and chemical compounds such as phenols.
- Odour is measured in terms of odour threshold number.
- For public water supply it should not more than 3.
- This test is conducted at 20°C and carried out by instrument called Osmoscope.

3. Temperature:

- Temperature of water to be supplied should be between 10°C to 20°C.
- Temperature higher than 25°C is objectionable and above 35°C is unfit for public supply.
- It can be measured with ordinary Thermometers range of 0 to 50°C.
- BOD values and biological activities are dependent on temperature of water.

4. Turbidity:

- Is imparted by the suspended and colloidal (may be clay and loam or microscopic organisms)
- Is a measure of light-emitting properties of water that scatters or absorbs light thus prevents its transmission.
- Can be determined in laboratory, either by turbidity rod or Nephelometric turbidity meter and expressed as NTU.
- Desirable and permissible turbidity of domestic water may be 5 to 10 NTU.

Chemical characteristics:

Chemical examination of water means estimation of chemicals parameters which effect parameters.

1. Alkalinity

- Alkalinity of primarily a way of measuring the acid neutralizing capacity of water. In other words, it is ability to maintain a relatively constant pH. Total alkalinity can be approximated by alkalinity as the following expression:

$$\text{Total alkalinity} = [\text{HCO}_3^-] + 2[\text{CO}_3^{2-}] + [\text{OH}^-] - [\text{H}^+]$$

- Total alkalinity includes Hydroxide alkalinity $[\text{OH}^-]$, Bicarbonate alkalinity $[\text{HCO}_3^-]$ and Carbonate alkalinity $[\text{CO}_3^{2-}]$.
- Alkalinity of water can be determined by titrating the water sample with sulphuric acid of known values of pH, volume and concentrations. Based on stoichiometry of the reaction and number of moles of sulphuric acid needed to reach the end point, the concentration of alkalinity in water is calculated.
- Total alkalinity (T) = Phenolphthalein Alkalinity + Methyl orange Alkalinity
- According to IS: 10500–2012, the desirable and permissible limits for mineral total alkalinity for drinking purpose are 200 mg/l and 600 mg/l.

2. pH

- The term pH refers to the measure of hydrogen ion concentration in a solution and defined as the negative log of H^+ ions concentration in water and wastewater.
- The values of pH 0 to a little less than 7 are termed as acidic and the values of pH a little less above 7 to 14 are termed as basic. When the concentration of H^+ and OH^- ions are equal then it is termed as neutral pH (7).
- pH can be determined by using pH strips(colorimetric method), indicators and pH meter(Electrometric method).
- According to IS: 10500–2012, the desirable limits for pH are 6.5 to 8.5 (for drinking purpose).

3. Total Solids:

- Most important characteristic of water is its solid content.

- Gravimetric method is used to measure total solids, generally expressed in mg/l.
 - High solids content indicate either contamination or presence of excessive mineral matters.
 - The amount of total dissolved solids should preferably less than 500 mg/l.
 - Analytically, the total solids content of water is defined as all the matter that remains as residue upon evaporation 103°C to 105°C for 24 hrs.
 - Total solids = Total suspended solids + Total dissolved solids

Dissolved solids:

- Dissolved solids mainly consists of inorganic salts and small amount of organic matter.
- Dissolved solids are determined as the residue left after evaporation and drying of the filtered sample at 103°C to 105°C.

Suspended solids:

- May contain inorganic or organic matter.

Total solids in water are further classified as

a. Volatile solids

- Represents organic matter
- The dish is heated and ignited at 600°C in muffle furnace for 30 minutes
- The loss of weight due to this operation represents volatile solids or nuisance capacity of water.

b. Fixed solids:

- Is generally classified as inorganic.
- Dry residue obtained by evaporating the sample at 105°C for 24 hrs.

Fixed solids = Total solids – Volatile solids

4. Chlorides:

- Chlorides are widely distributed as salts of calcium, sodium and potassium in water and wastewater.
- In potable water, the salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water.

- The major taste producing salts in water are sodium chloride and calcium chloride. The salty taste is due to chloride anions and associated cations in water.
- Natural surface water derive chlorides from oil field wastes, salt water and mineral deposits. Greater amounts arises from geological strata or entry of sewage effluents and wastes.
- Determined in laboratory by Mohr’s method, titration with standard silver nitrate solution, using potassium chromate as indicator and expressed in mg/l.
- According to IS: 10500–2012, the desirable and permissible limits for chlorides for drinking purpose are 250 mg/l and 1000 mg/l.

5. Hardness:

- Water that has high mineral content is known as **Hard Water**. Hard water contains bicarbonates, chlorides and sulphates of calcium and magnesium. Water hardness is a traditional measure of the capacity of water to precipitate soap.
- In fresh water, the principal hardness causing ions are calcium and magnesium.
- Total hardness is defined as the sum of the calcium and magnesium concentration, both expressed as CaCO_3 in mg/L.

There are two types of hardness. They are 1. Temporary hardness

2. Permanent hardness

1. Temporary hardness is due to presence of bicarbonates of calcium and magnesium. This type of hardness can be removed by boiling.

2. Non-carbonate hardness is caused by the association of the hardness-causing cation with sulphate, chloride or nitrate and is referred to as “permanent hardness”. This type of hardness cannot be removed by boiling.

- Hardness is determined by the EDTA method in alkaline condition; EDTA and its sodium salts form a soluble chelated complex with certain metal ions. Calcium and Magnesium ions develop wine red colour with Eriochrome black T in aqueous solution at $\text{pH } 10.0 \pm 0.1$. When EDTA is added as a titrant, Calcium and Magnesium divalent ions get complexed resulting in sharp change from wine red to blue which indicates end-point of the titration.
- According to IS: 10500–2012, the desirable and permissible limits for mineral total alkalinity for drinking purpose are 300 mg/l and 600 mg/l.

Hardness as mg/L CaCO_3	Classification
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0 – 60	Soft
61 – 120	Moderately hard
121 – 180	Hard
>180	Very hard

6. Nitrogen and its compounds:

- Presence of nitrogen in water indicates presence of organic matter.
- Nitrogen appears in the following different forms

a. Free ammonia:

- Is obtained from the decomposition of organic matters indicates the very first stage of decomposition. Indicates recent pollution.
- Presence of free ammonia in water should not exceed 0.15 mg/l.
- Exists in aqueous solution.

b. Organic nitrogen:

- Indicates the quantity of nitrogen present in water before decomposition has started.
- In no case the quantity of albuminoid nitrogen should exceed 0.3 mg/l.

c. Nitrites:

- Arise either directly from biological disruption of organic matter or by the reduction of nitrate.
- Indicate the presence of partly oxidized organic matters, is very dangerous.
- Therefore in no case nitrites should be allowed in the water, their presence must be nil.

d. Nitrates:

- Nitrites are rapidly and easily converted to nitrates by the full oxidation of the organic matters.
- Thus representing old pollution and the presence not so harmful upto certain limits.
- Domestic supplies should be less than 45 mg/l.
- Exceeds cause a disease known as “methemoglobinemia” or blue baby disease in infants.

7. Metals and other chemical substances:

- Iron causes hardness, bad taste, discoloration of cloths and plumbing fixtures.

- Manganese imparts brownish or purplish colour to water and laundered goods and it is also impairs tastes of coffee & tea.
- Other substances are lead, arsenic, fluorides, iodides, cadmium, chromium, sodium, potassium and phenols.

8. Dissolved gases:

Dissolved oxygen:

Surface water get oxygen, dissolved either from atmosphere or due to activities of algae in water.

The amount of oxygen that water can hold depends on temperature.

Determined by 'winkler' method and is expressed as mg/l.

Biochemical Oxygen Method:

Organic matter, in fact is of two types

1. Biologically oxidized and is called biologically active organic matter.
 2. Cannot be oxidized biologically and is called biologically inactive organic matter.
- BOD may be defined as amount of oxygen required for the micro-organisms, to carry out biological decomposition of organic matter present in wastewater under aerobic conditions at standard temperature.
 - BOD test can be performed by dilution method and expressed as mg/l.
 - Unpolluted water should have less than 5ppm.

CO₂:

- Dissolved in water from atmosphere or decomposing organic matter at the earth surface or from underground sources.
- May contribute significantly to some corrosive situations.
- Can be reduced either by aeration or by addition of alkali.

H₂S:

- It is mostly found in ground water and may be produced either by reduction of sulphate by inorganic process or by decomposition of organic waste.
- Gives disagreeable rotten- egg odour.
- Can be reduced by aeration, estimation is made by titration with iodine.

Biological characteristics:

Bacterial examination of water is very important, since it indicates the degree of pollution. Water polluted by sewage contain one or more species of disease producing pathogenic bacteria. Pathogenic organisms cause water borne diseases, and many non pathogenic bacteria such as **E.Coli**, a member of coliform group, also live in the intestinal tract of human beings.

Coliform itself is not a harmful group but it has more resistance to adverse condition than any other group. So, if it is ensured to minimize the number of coliforms, the harmful species will be very less. So, coliform group serves as indicator of contamination of water with sewage and presence of pathogens. The methods to estimate the bacterial quality of water are:

1. Standard Plate Count Test
2. Most Probable Number
3. Membrane Filter Technique

WATER QUALITY STANDARDS:

Indian Standards for drinking water Parameter	Desirable- Tolerable	If no alternative source available, limit extended upto
Physical		
Turbidity (NTU unit)	5	10
Colour (Hazen scale)	5	25
Taste and Odour	Un-objectionable	Un-objectionable
Chemical		
pH	6.5 -8.5	
Total Dissolved Solids mg/l	500	2000
Total Hardness mg/l (as CaCO ₃)	300	600
Chlorides mg/l (as Cl)	250	1000
Sulphates mg/l (as SO ₄)	200	400
Fluorides mg/l (as F)	1	1.5

Nitrates mg/l (as NO ₃)	45	100
Calcium mg/l (as Ca)		200
Iron mg/l (as Fe)	0.3	1
Alkalinity (mg/l as CaCO ₃)	200	600
Acidity(mg/l as CaCO ₃)		
Manganese	0.1	0.3

GENERAL OUTLINE OF CONVENTIONAL WATER TREATMENT UNITS:

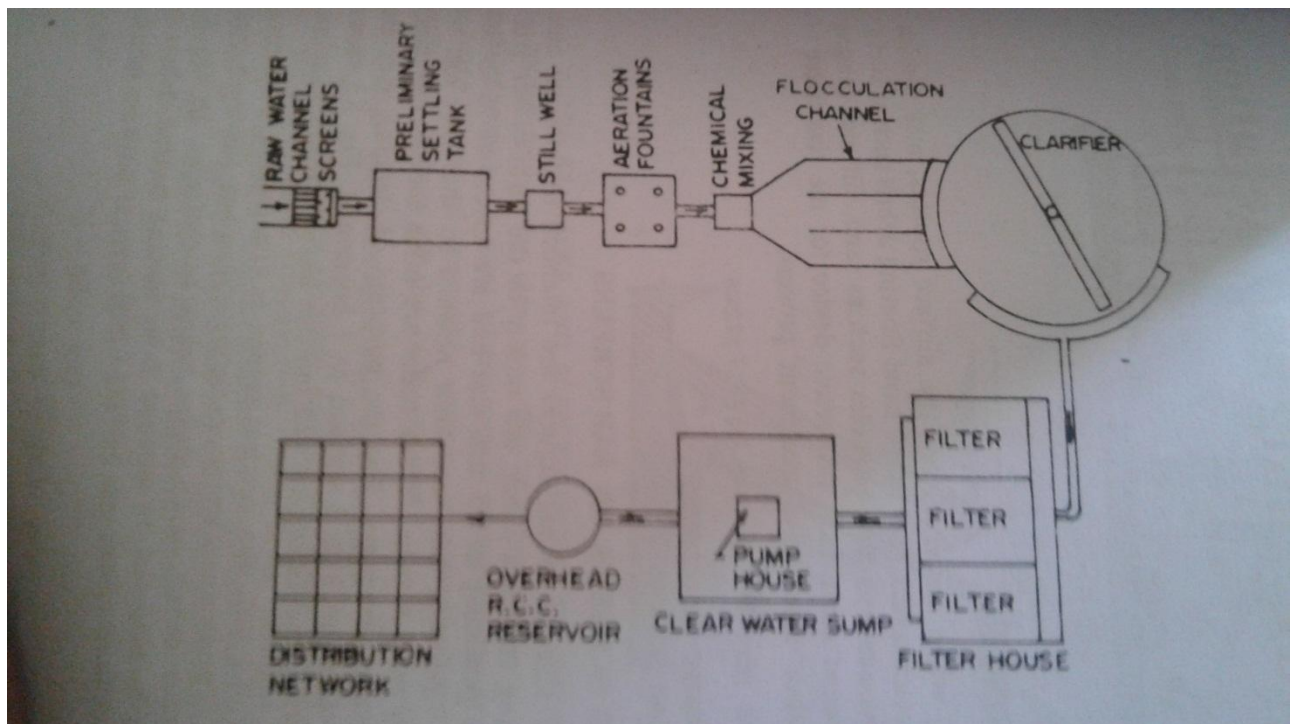


Fig: General outline of water treatment plan

FUNCTIONS OF EACH UNIT:

1. Screening: This is adopted to remove all the floating matter from surface waters. It is generally provided at the intake point.

2. Aeration: This is adopted to remove objectionable taste and odour and also to remove the dissolved gas such as carbon-dioxide, hydrogen sulphide etc. The iron and manganese present in water are also oxidised to some extent. This process is optional and is not adopted in cases where water does not contain objectionable taste and odour.

3. Sedimentation with or without coagulants: The purpose of sedimentation is to remove the suspended impurities. With the help of plain sedimentation, silt, sand etc. can be removed.

However, with the help of sedimentation with coagulants, very fine suspended particles and some bacteria can be removed.

4. Filtration: The process of filtration forms the most important stage in the purification of water. Filtration removes very fine suspended impurities and colloidal impurities that may have escaped the sedimentation tanks, in addition to this, the microorganisms present in water are largely removed.

5. Disinfection: It is carried out to eliminate or reduce to a safe minimum limit, the remaining micro-organisms and to prevent the contamination of water during its transit from the treatment plant to the place of its consumption.

6. Miscellaneous process: These include water softening, desalination, removal of iron, manganese and other harmful constituents.

THEORY OF AERATION:

- Aeration removes odour and tastes due to volatile gases like hydrogen sulphide and due to algae and related organisms.
- Aeration also oxidise iron and manganese, increases dissolved oxygen content in water, removes CO₂ and reduces corrosion and removes methane and other flammable gases.
- Principle of treatment underlines on the fact that volatile gases in water escape into atmosphere from the air-water interface and atmospheric oxygen takes their place in water, provided the water body can expose itself over a vast surface to the atmosphere. This process continues until an equilibrium is reached depending on the partial pressure of each specific gas in the atmosphere.

Types of Aerators:

1. Gravity aerators
2. Fountain aerators
3. Diffused aerators
4. Mechanical aerators.

1. Gravity Aerators (Cascades):

In gravity aerators, water is allowed to fall by gravity such that a large area of water is exposed to atmosphere, sometimes aided by turbulence.

2. Fountain Aerators:

These are also known as spray aerators with special nozzles to produce a fine spray. Each nozzle is 2.5 to 4 cm diameter discharging about 18 to 36 l/h. Nozzle spacing should be such that each m³ of water has aerator area of 0.03 to 0.09 m² for one hour.

3. Injection or Diffused Aerators:

It consists of a tank with perforated pipes, tubes or diffuser plates, fixed at the bottom to release fine air bubbles from compressor unit. The tank depth is kept as 3 to 4 m and tank width is within 1.5 times its depth. If depth is more, the diffusers must be placed at 3 to 4 m depth below water surface. Time of aeration is 10 to 30 min and 0.2 to 0.4 litres of air is required for 1 litre of water.

4. Mechanical Aerators:

Mixing paddles as in flocculation are used. Paddles may be either submerged or at the surface.

PRINCIPLES AND DESIGN OF SEDIMENTATION:

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

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

Purpose of Settling:

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

Principle of Settling:

- Suspended solids present in water having specific gravity greater than that of water tend to settle down by gravity as soon as the turbulence is retarded by offering storage.
- Basin in which the flow is retarded is called *settling tank*.
- Theoretical average time for which the water is detained in the settling tank is called the *detention period*.

Types of Settling:

Type I: **Discrete particle settling** - Particles settle individually without interaction with neighbouring 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.

Type I Settling:

- Size, shape and specific gravity of the particles do not change with time.
- Settling velocity remains constant.

Settling of discrete particles:

$$F_I = (\rho_s - \rho)gV$$

Where ρ_s = Mass density of particle

ρ = Mass density of fluid

V = Volume of particle

F_I = Impelling force

(a). Newton's Law:

The drag force F_D depends upon

1. Dynamic viscosity
2. Mass density of fluid
3. Shape and size of particle

$$F_D = C_D A \frac{\rho v_s^2}{2}$$

Where F_D = Drag Force

C_D = Drag coefficient

= Projected area of particle

$$\text{Settling Velocity } (v_s) = \sqrt{\frac{4}{3} \frac{g}{C_D} (S_s - 1) d}$$

If Reynolds number $R > 10^3$ to 10^4 $C_D = 0.4$

$$\text{Then } v_s = \sqrt{3.33 g \left(\frac{\rho_s - \rho}{\rho} \right) d} \quad (\text{particle size } > 1 \text{ mm dia.})$$

(b). Stoke's Law

$$v_s = \frac{1}{18} \frac{g}{\nu} (S_s - 1) d^2$$

Viscosity of water depends upon temperature, if temperature is 10^0 C,

$$v_s = 418 (S_s - S) d^2$$

at any other temperature, the equation may be modified as

$$v_s = 418 (S_s - S) d^2 \frac{T+10}{60}$$

where v_s = Settling velocity in mm/sec

S_s = Specific gravity of particle

d = Diameter of particle in mm

T = Temperature in $^{\circ}\text{F}$

When T is expressed in t degree centigrade

$$v_s = 418(S_s - S)d^2 \frac{3t+70}{100}$$

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.

1. 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.

Drag of sedimentation tank:

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.

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 up to $300 \text{ m}^3/\text{d}/\text{m}$. 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



Fig: Rectangular Sedimentation Tank

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 centre and is baffled to flow radially towards the perimeter, the horizontal velocity of the water is continuously decreasing as the distance from the centre 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.

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%.

COAGULATION:

General Properties of Colloids

1. Colloidal particles are so small that their **surface area** in relation to mass is very large.
2. **Electrical properties:** All colloidal particles are electrically charged. If electrodes from a D.C. source are placed in a colloidal dispersion, the particles migrate towards the pole of opposite charge.
3. Colloidal particles are in constant motion because of bombardment by molecules of dispersion medium. This motion is called **Brownian motion** (named after Robert Brown who first noticed it).
4. **Tyndall effect:** Colloidal particles have dimensions. These are reversible upon heating. e.g. organics in water.
5. **Adsorption:** Colloids have high surface area and hence have a lot of active surface for adsorption to occur. The stability of colloids is mainly due to preferential adsorption of ions. There are two types of colloids:
 - i. **Lyophobic colloids:** that are solvent hating. These are irreversible upon heating. e.g. inorganic colloids, metal halides.
 - ii. **Lyophilic colloids:** that are solvent loving. These are reversible upon heating. e.g. organics in water.

COAGULATION AND FLOCCULATION:

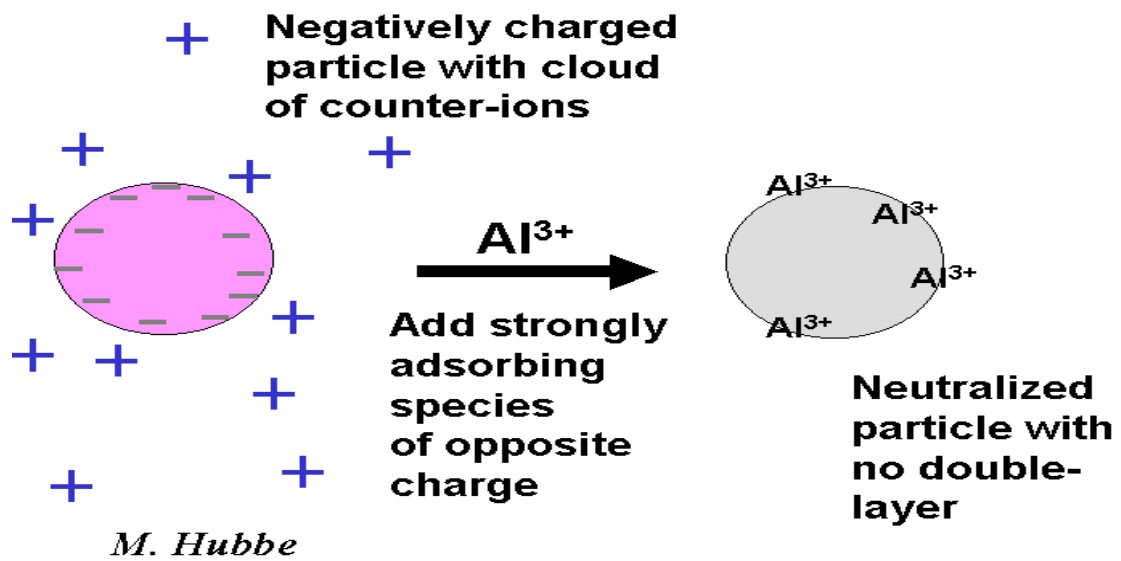
- Colloidal particles are difficult to separate from water because they do not settle by gravity and are so small that they pass through the pores of filtration media.
- To be removed, the individual colloids must aggregate and grow in size.

- The aggregation of colloidal particles can be considered as involving two separate and distinct steps:
 1. Particle transport to effect inter particle collision.
 2. Particle destabilization to permit attachment when contact occurs.
- Transport step is known as **flocculation** whereas **coagulation** is the overall process involving destabilization and transport.

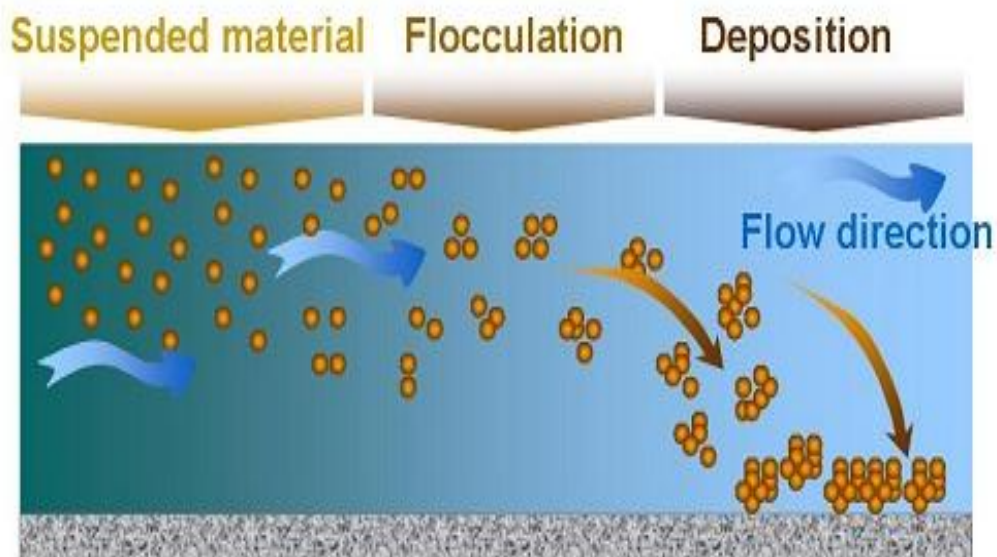
Sedimentation Aided With Coagulation:

- Very fine suspended particles and colloidal matter in water cannot settle down in plain sedimentation of ordinary detention period.
- Particles in water smaller than about 10 microns are difficult to remove by simple settling or by filtration. This is especially true for particles smaller than 1 micron – colloids.
- They can be removed by increasing their size by changing them into flocculant particles.
- For this- certain chemical compounds called coagulants are added to the water, which on through mixing, forms a gelatinous precipitate called “floc”.
- Very fine colloidal particles in water gets attracted and absorbed in these flocs, forming bigger sized flocculated particles.
- Colloidal particles present in water is having negative charge. To neutralize that opposite charge drawn from bulk solution.
- Coagulation is a chemical technique which is directed towards the destabilization of the charged colloidal particles.
- Flocculation is the slow mixing process which promotes the agglomeration of the stabilized particles.
- The entire process of addition of chemicals (coagulants) and mixing (flocculation) is called coagulation.
- The coagulated water – sedimentation tank – flocculated particles settlement – removed.
- Coagulants necessity – turbidity > 30 to 50 mg/l.
- Plain sedimentation is rarely used these days – coagulation before sedimentation is used – followed by rapid sand filtration.
- **Coagulation** is the destabilization of colloids by addition of chemicals that neutralize the negative charges. The chemicals are known as coagulants, usually higher valence cationic salts (Al^{3+} , Fe^{3+} etc.)

- Coagulation is essentially a chemical process.



- **Flocculation** is the agglomeration of destabilized particles into a large size particles known as flocs which can be effectively removed by sedimentation or flotation.



Factors Affecting Coagulation:

1. Type of coagulant
2. Dose of coagulant
3. Characteristics of water
 - a. Type and quantity of suspended water.
 - b. Temperature

c. pH of water

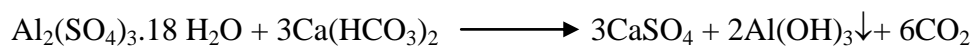
4. Time and method of mixing.

Chemicals Used for Coagulation:

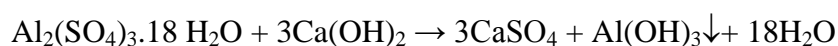
- When coagulant is dissolved in water and thoroughly mixed in it, a gelatinous precipitate – floc is formed.
- The aluminum and ferric ion of the floc contain positive charge. Hence they attract –vely charged colloidal particles of clay, turbidity, colour, thus helping in the removal of these impurities.
- Chemicals are most effective when water is slightly alkaline. In the absence of such an alkalinity in raw water external alkalies like sodium carbonate or lime etc., are added to the water, so as to make slightly alkaline – to increase the effectiveness of coagulants.
- Commonly Used Coagulants are
 1. Aluminium Sulphate
 2. Chlorinated Copperas
 3. Copperas
 4. Sodium Aluminate
 5. Ferric Sulphate and Lime etc.

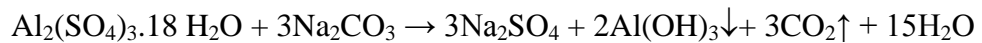
1. **Aluminium Sulphate:** Alum - $\text{Al}_2(\text{SO}_4)_3 \cdot 18 \text{H}_2\text{O}$

- Alum added to water it reacts with the bicarbonate alkalinities present in water, to form gelatinous precipitate (floc) of aluminium hydroxide.
- This flocs attracts other fine particles and suspended matter, and thus grows in size and finally settles down at the bottom of the tank.



- Addition of alum to the water imparts permanent hardness to it, in the form of calcium sulphate. The Carbon dioxide gas evolved causes corrosiveness.
- Amount of alum required for coagulation depends on turbidity, colour of the raw water.
- Optimum dose can be determined by laboratory test (jar test).
- Dose of alum vary from 5mg/l for relatively clear water to 85mg/l for high turbid water.
- Average normal dose is about 17 mg/l
- Chemicals are most effective when water is slightly alkaline. In the absence of such an alkalinity in raw water external alkalies like lime $\text{Ca}(\text{OH})_2$ or Soda ash (Na_2CO_3) are added..the following reactions takes place.



**Disadvantages:**

- Difficult to dewater the sludge with alum.
- Not easy to dispose.
- Unsuitable for filling low lying areas.

Advantages:

- Alum is very effective coagulant and is extensively used. (worldwide).
- Stable floc will forms, cheap, no skilled supervision is required.
- Water is clear, taste, colour reduction is high in addition to turbidity.
- Possible to recover alum from sludge and it can be used for coagulation.
- Cost of recovered alum is 1/4rth of the alum cost.

Jar Test:

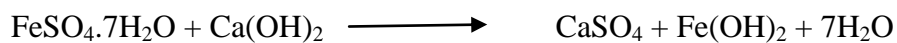
- Take one litre of sample into each of the six beakers.
- Switch on the motors and adjust the speed of paddles to 100 rpm.
- Add varying doses of Alum solution i.e., 1 ml, 2 ml, 3 ml, 4ml, or 6 ml to different beakers simultaneously. (The doses varies with turbidity in water sample)
- Allow flash mix (at 100 rpm) for one minute.
- Reduce the speed of paddles to 40 rpm and continue mixing for 10 minutes.
- Switch off the motor and allow 20 minutes for settling.
- Collect the supernatant without disturbing the sediment and find the turbidity of each.
- Repeat the experiment with high doses of alum, if satisfactory results are not obtained.
- The experiment may be repeated for different pH ranges.
- Note the ideal (optimum) dose of the coagulant for excellent floc formation from the graph.



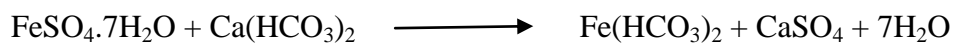
Fig: Jar Test Set Up

2. Copperas: Ferrous Sulphate - $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

- Copperas is added to water in conjunction with lime
- Lime may be added either to copperas or vice-versa.
- When hydrated lime is added first



Alternatively when copperas is added earlier to lime, then



Alkali present

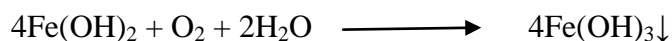
in raw water



Hydrated lime

Ferrous hydroxide

- Ferrous hydroxide formed in either case further gets oxidized, forming ferric hydroxide



- Ferric Hydroxide forms the floc, thus helps in sedimentation
- Copperas – used – raw water which are not coloured.
- Cheaper than alum and functions effectively in the pH range of 8.5 and above.
- Requirement is almost same as alum.

Flocculation Tank or Flocculator:

- After rapid mix, slow mixing in flocculator is required for the formation of flocs.
- Rectangular tanks with paddles operated by electric motors.
- Paddles speed – 2 to 3 rpm
- Detention period – 20 to 60 min. – 30 min is the normal value.
- Velocity gradient ranges – 20 to 80 per second
- Clear distance between the paddles from wall or floor of the tank – 15 to 30 cm.
- Velocity is not required, paddles in revolving motion which prevents flocs to settle.

PROBLEMS

- 1. Determine the quantity of alum required in order to treat 13 million litres of water per day at a treatment plant where 12ppm of alum dose is required. Also determine the amount of carbon dioxide gas which will be released per litre of Water treated.**

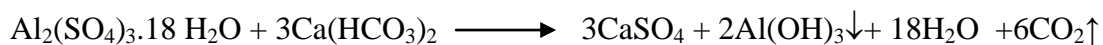
Sol:

Quantity of water to be treated = 13×10^6 litres/day.

Alum dose required = 12 ppm, i.e., 12 mg/l.

Amount of alum reqd. per day = $(13 \times 10^6 \times 12)$ mg. = 156kg

The chemical reaction which is involved in treating water with alum is given by



Now, the molecular weight of alum

$$\begin{aligned} &= 2[26.97] + 3[32.066 + 4 \times 16] + 18[2 \times 1.008 + 16] \\ &= 666.426 \\ &= 666 \end{aligned}$$

The molecular wt. of carbon dioxide

$$= (12.01) + 2(16) = 44.01 = 44$$

Now, it means that 666 mg of alum, if used, will release = 6×44 mg of CO_2

Therefore

$$\begin{aligned} 12 \text{ mg of alum will release} &= \frac{6 \times 44}{666} \times 12 \text{ mg of CO}_2 \\ &= 4.76 \text{ mg.} \end{aligned}$$

Since 12 mg of alum is required for treating 1litre of water, the quantity of CO_2 evolved per litre of water = 4.76mg.

2. 8 mg of copperas is consumed with lime at a coagulation 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:

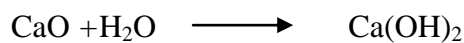
Quantity of copperas required per litre of water = 8 mg

Quantity of copperas required per 10 million litre of water

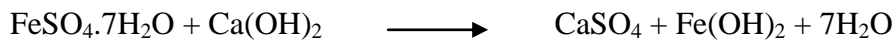
$$= 8 \times 10 \times 10^6 \text{ mg}$$

$$= 80 \text{ kg}$$

The chemical reactions that are involved are



Quick lime or lime Hydrated lime



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

$$= 278.028$$

$$= 278$$

Similarly, molecular wt. of quick lime (CaO)

$$= [40.08 + 16]$$

$$= 56.08$$

$$= 56$$

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

Therefore

278 mg of copperas need = 56 mg quick-lime

or 1mg of copperas needed = $\frac{56}{278}$ mg quick-lime

80kg of copperas need = $\frac{56}{278} \times 80$ kg of quick lime

$$= 16.12 \text{ kg of quick lime}$$

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

3. A coagulation-sedimentation plant clarifies 40 million litre of water every day. The quantity of filter alum required at the plant is 18 mg/l. If the raw water is having an alkalinity equivalent to 5 mg/l of CaCO_3 , determine the quantity of filter alum and the quick lime (containing 85% of CaO) required per year by the plant. Given the molecular weights as :

[Al = 27, S = 32, O = 16, H = 1, Ca = 40, C = 12].