ENVIRONMENTAL ENGINEERING

(Course code-011618)

UNIT-3RD & 4TH

6TH SEMESTER

CIVIL ENGINEERING DEPARTMENT

DCE DARBHANGA

Water Treatment Plants

Drinking Water - Quality

Our water supply comes from two sources

- surface waters i.e. rivers, lakes and reservoirs
- groundwater, which is stored below the earth's surface

Each source presents its own problems

- Surface water has elevated levels of soil particles and algae, making the water turbid
- may contain pathogens
- Groundwater has higher levels of dissolved organic matter (yellow color) and minerals such as iron
- Both sources may have high levels of calcium and magnesium (hardness)
- both can be contaminated by toxic chemicals

Ground- vs. Surface Water

Groundwater

- constant composition
- high mineral content
- low turbidity
- low color
- low or no D.O.
- high hardness
- high Fe, Mn

Surface water

- variable composition
- low mineral content
- high turbidity
- colored
- D.O. present
- low hardness
- taste and odor

History of Water Treatment

Ancient Greek and Indians treated drinking water (charcoal filtration, sunlight exposure, boiling, straining) to improve taste & odor

Filtration widely used to remove particles (turbidity) but the degree of clarity was not measured

Discovered both turbidity and pathogens in drinking water in US - Filtration & disinfection

4000 B.C. | **1500 B.C.** | **1700s** | **1800s** | **1900s** | **1960s**

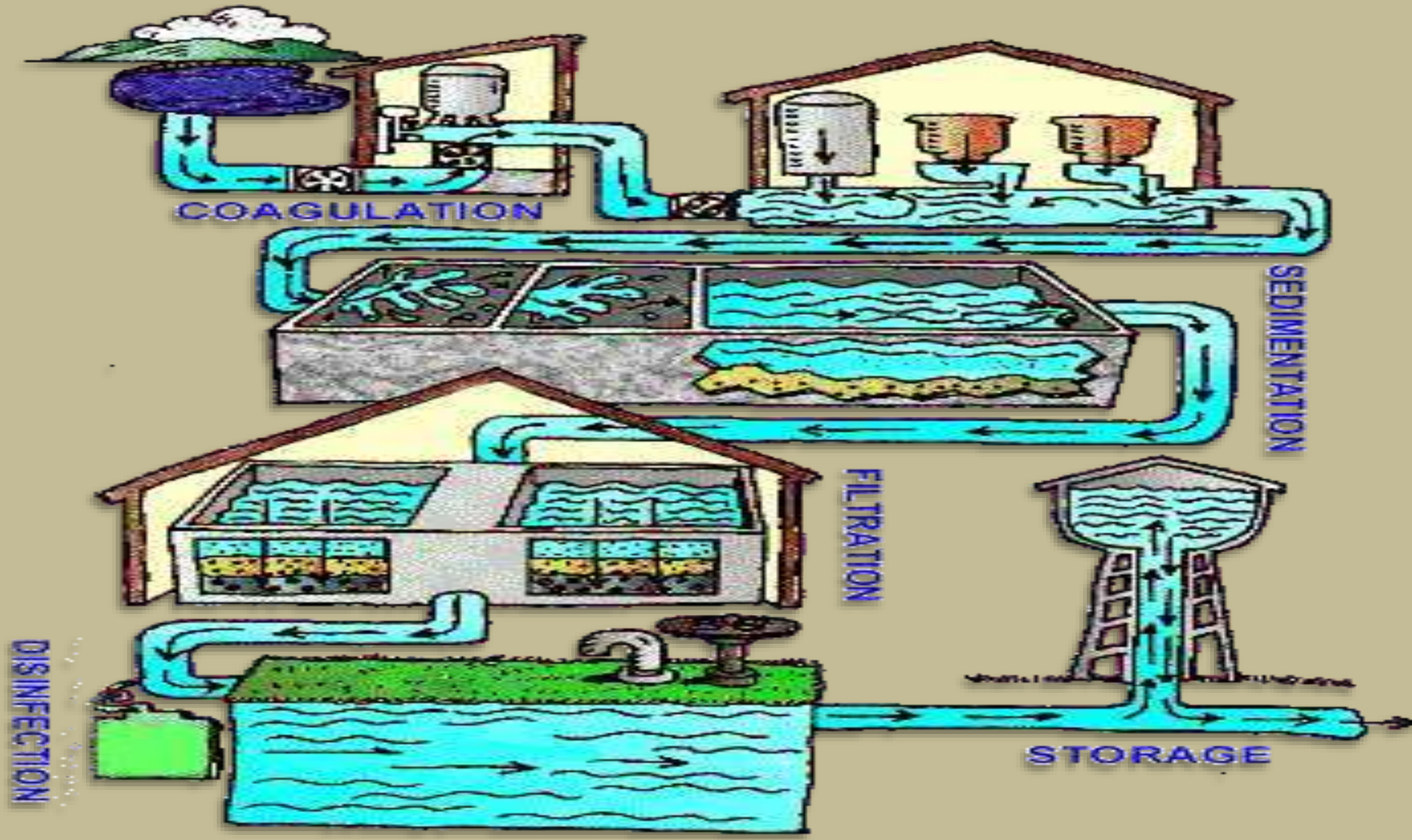
Ancient Egyptians used chemical alum to caused suspended particles to settle in water

•Sources and effects of drinking water contaminants were identified
•Identification of waterborne disease (chlorela)

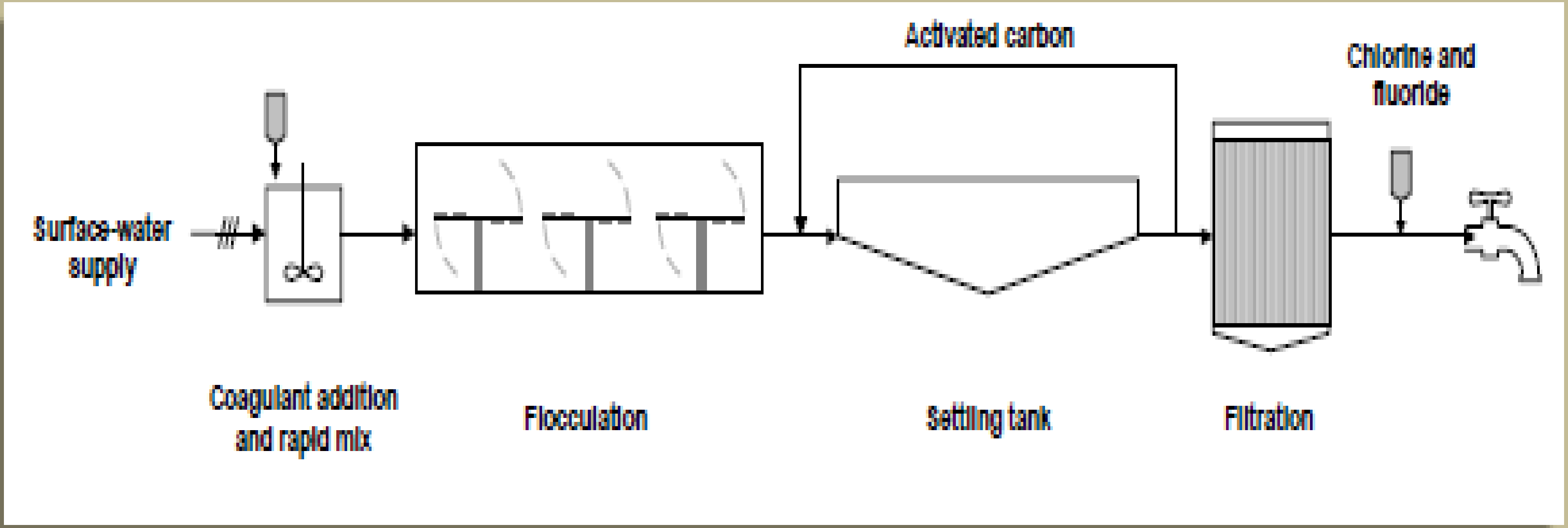
Advancement in industrial and agricultural sector – man-made chemicals found in water sources (pesticides, volatile organic chemicals, pharmaceuticals, etc)

OBJECTIVE:
To supply **clean** and **safe** water for public demand
Clean – colourless, odourless, tasteless and no suspended solids
Safe – no pathogen, no dangerous organic/inorganic and less mineral substances

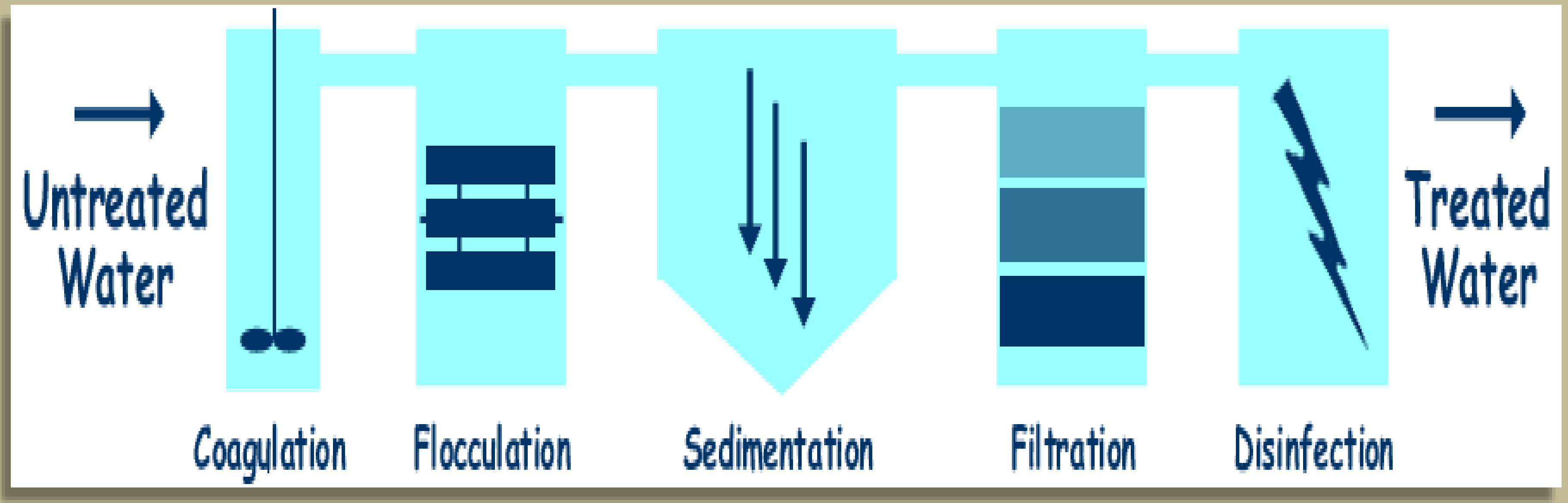
Water Treatment Process



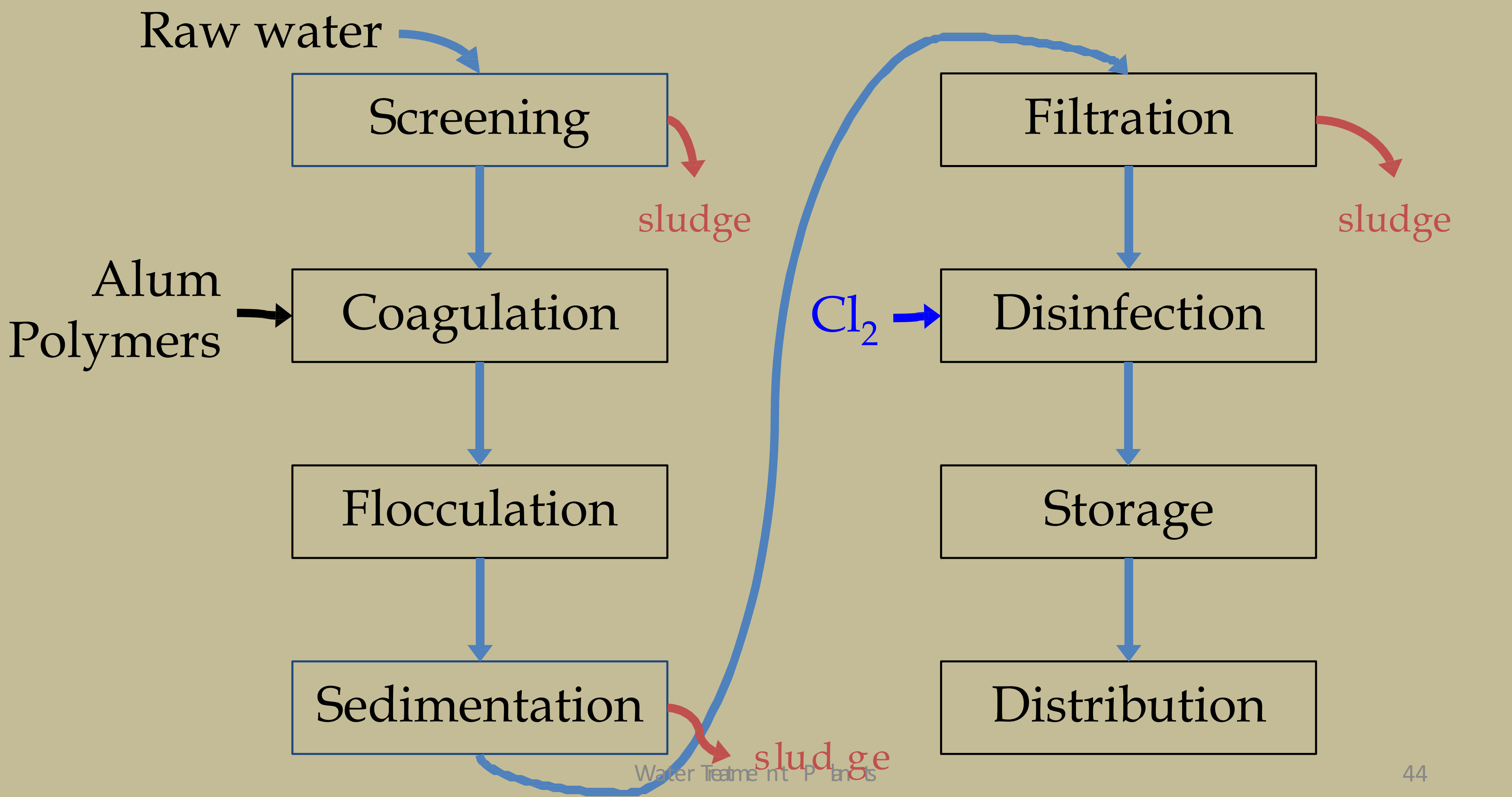
Drinking Water Plant



Untreated to Treated Water



Conventional Surface Water Treatment



Unit Operations

- Unit operations and Unit processes water treatment plants utilize many treatment processes to produce water of a desired quality.
- These processes fall into two broad divisions:-

A) Unit operations: (UO)

- Removal of contaminants is achieved by physical forces such as gravity and screening.

B) Unit processes (UP)

- Removal is achieved by chemical and biological reactions.

Physical Unit Operations

- Screening
- Mixing
- Flocculation
- Sedimentation

Chemical Unit Processes

- Chemical Precipitation
- Adsorption
- Disinfection
- Ion Exchange
- Electro dialysis

Biological Unit Processes

- Biological processes are classified by the oxygen dependence of the primary micro-organisms responsible for waste treatment.
- Unit Processes are:

1. Aerobic Processes
2. Anaerobic Processes
3. Facultative Processes

- Generally these are used in the treatment of waste water.

Water Treatment processes

- Raw water may contain suspended, colloidal and dissolved impurities. The purpose of water treatment is to remove all those impurities which are objectionable either from taste and odour point of view or from health or public point of view.

Water Treatment processes

- Following are the purpose of Water treatment
- To remove color, dissolved gases and turbidity.
- To remove taste and odour
- To remove disease causing microorganisms so that water is safe for drinking purposes.
- To remove hardness of water.
- To make it suitable for a wide variety of industrial purpose such as steam generation, dyeing etc.

A Typical Water Treatment Plant

Water Intake
(Lakes, rivers)

→

Aeration/Air Stripping (optional)
- To remove volatile organic chemicals, taste & odor
- To add O_2 for oxidation of iron, manganese & organic matter

→

Coagulation/Flocculation
- To remove dirt and particles in water
- Alum/chemicals are added in water to form sticky particles that can attached to other particles – known as "floc"

↓

Sedimentation
- The floc settles to the bottom and the settable solids are removed.
- Also known as clarification process

←

Filtration
- To remove suspended solids
- Made of layers of sand, gravel, and charcoal

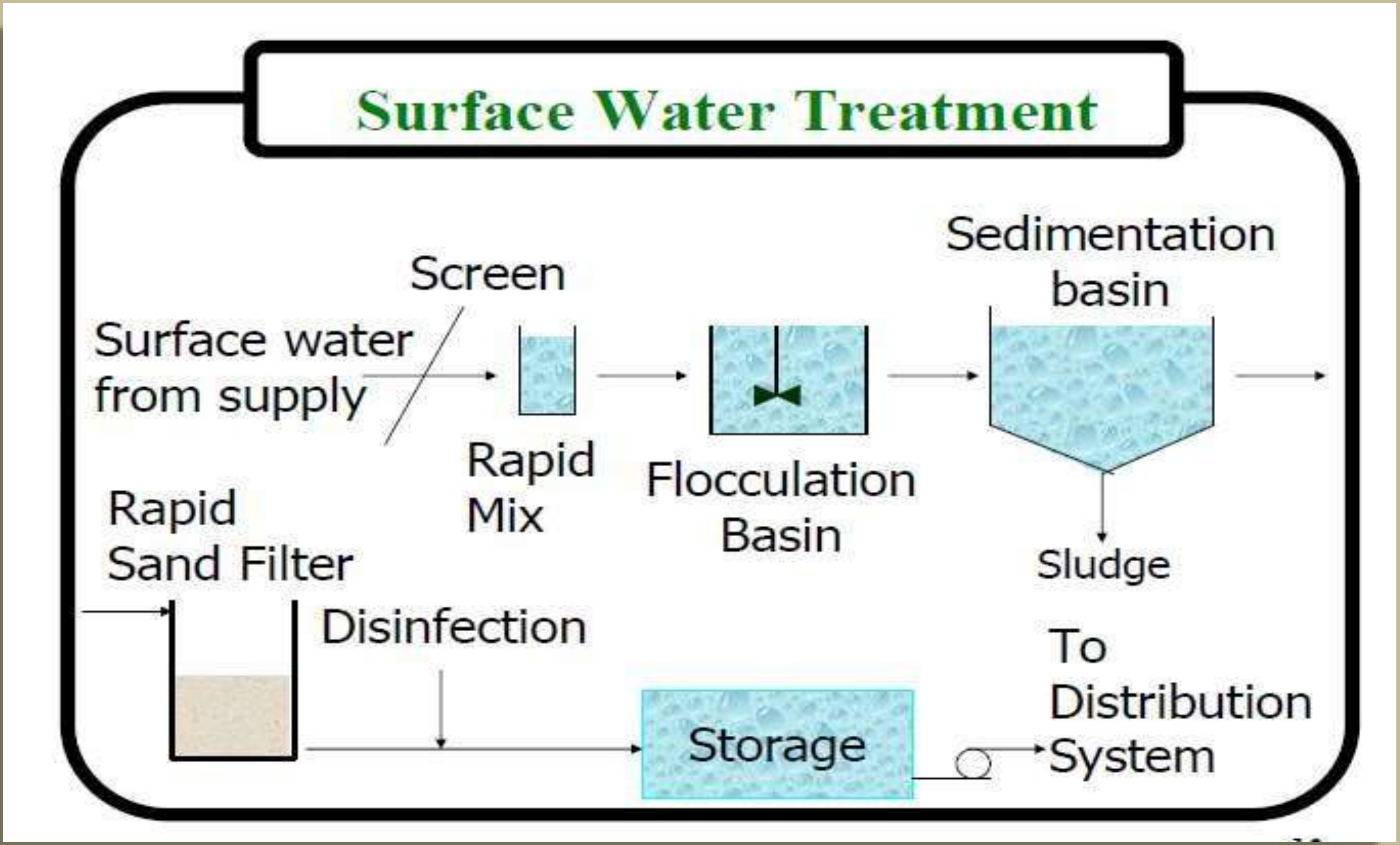
←

Disinfection
- To remove waterborne pathogens (bacteria, viruses, etc)
- Types of disinfection: Chlorine, chloramine, monochloramine, UV, ozone

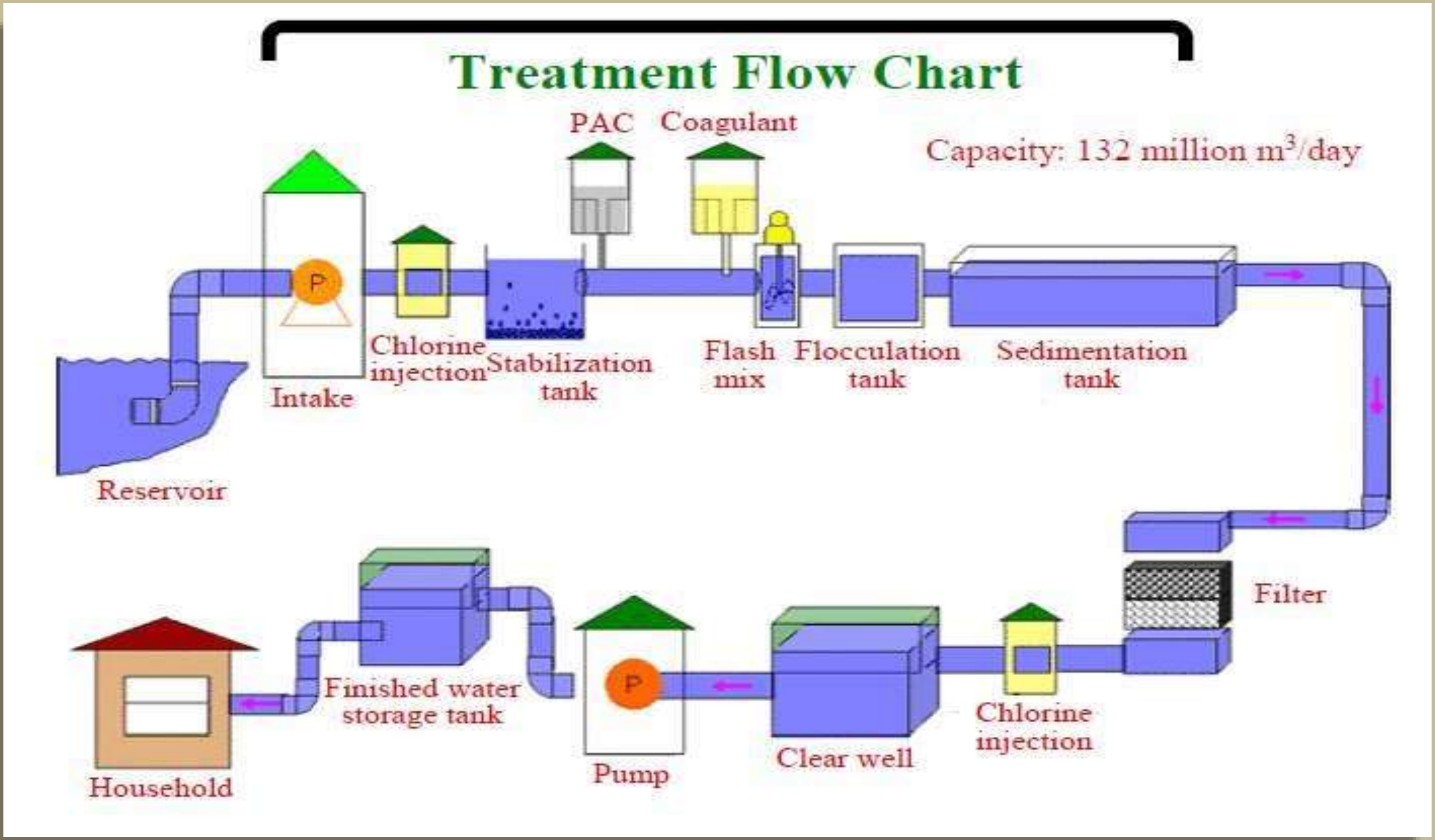
↓

Water Distribution System

Water Treatment Processes



Water Treatment Processes



Main Components

- Screening
- Coagulation
- Aeration
- Flocculation
- Sedimentation
- Filtration
- Disinfection or Chlorination
- Lime Dosing

Water Treatment processes

- For the surface water following are the treatment processes that are generally adopted.

Screening

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

Screening

- Removes large solids
  - logs
  - branches
  - rags
  - fish
- Simple process
  - may incorporate a mechanized trash removal system
- Protects pumps and pipes in Water Treatment Plants
- Velocity through them should not more than 0.8 to 1.0 m/sec.

Screening: To remove floating matter of large size which will choke up small pipes.

1. According to size of openings:

a. Coarse screens

b. Medium screens

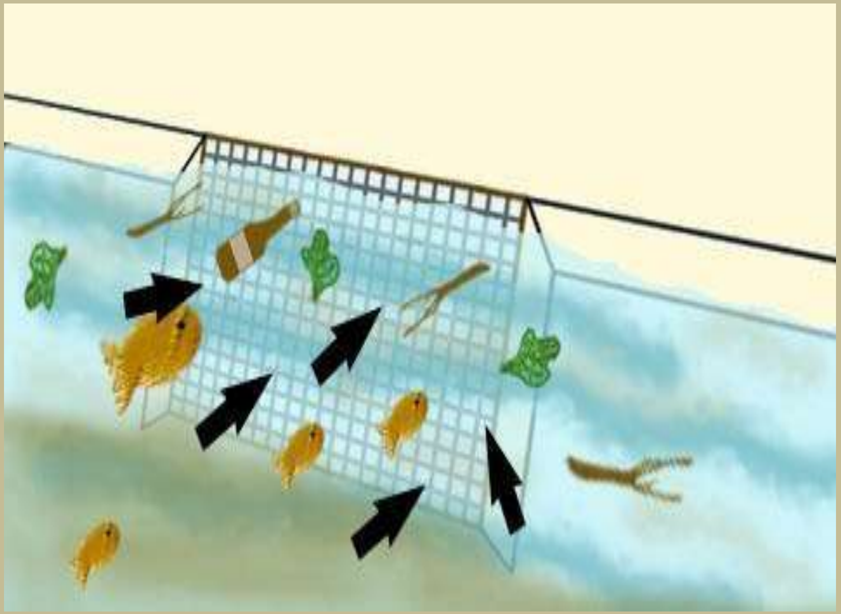
c. Fine screens

2. According to condition of screens:

a. Fixed screens

b. Movable screens

c. Moving screens



Water Treatment processes

Screening

- Screens are generally provided in front of the pump or the intake works so as to exclude the large sized particles, such as debris, animals, trees, branches, bushes, ice, etc.. Coarse screens are placed in front of the fine screens. Coarse screens consist of parallel iron rods placed vertically or at a slight slope at about 2 to 10 cm Centre to Centre. The fine screens are made up of fine wire or perforated metal with opening less than 1 cm wide.

Water Treatment processes

- Thee coarse screen first remove the bigger floating bodies and the organic solids; and the fine screen removes the fine suspended solids.
- The coarse screens are also kept inclined at about 450 to 600 to the horizontal. While designing the screens, clear opening should have sufficient total area, so that the velocity is not more than 0.8 to 1 m/sec

Water Treatment processes

Aeration

- It is the type of treatment given for removing colours, odours, and taste from water. Under this process of aeration, water is brought in intimate contact with air, so as to absorb oxygen and to remove carbon-dioxide gas. It may also help in killing bacteria to a certain extent.
- Object of aeration
- To kill bacteria up to some extent
- To have less corrosion to pipes
- To oxidize iron &manganese present in water.

Aeration: Exposing large surface of water to atmospheric air.

- Objects:

1. To remove volatile substances & gases causing bad taste & odour.
2. To increase oxygen level in water for imparting freshness.
3. To oxidize Fe & Mn so that these can be precipitated & agitated.
4. To destroy bacteria to some extent by agitaton.

Methods of aeration

a. Gravity or free fall aerators:

- Cascade aerators:

Circular type

Straight type

Methods of aeration

a. Gravity or free fall aerators:

- Inclined apron aerators:

Water Treatment Processes

- Methods of Aeration
- By Using Spray Nozzles
- In this method water is sprinkled in air or atmosphere through special nozzles. Carbon-dioxide gas is thus considerable removed upto 90 %in this process.

Methods of aeration

a. By using fountains, spray nozzles





Spray Aerators: Nozzles

Water Treatment processes

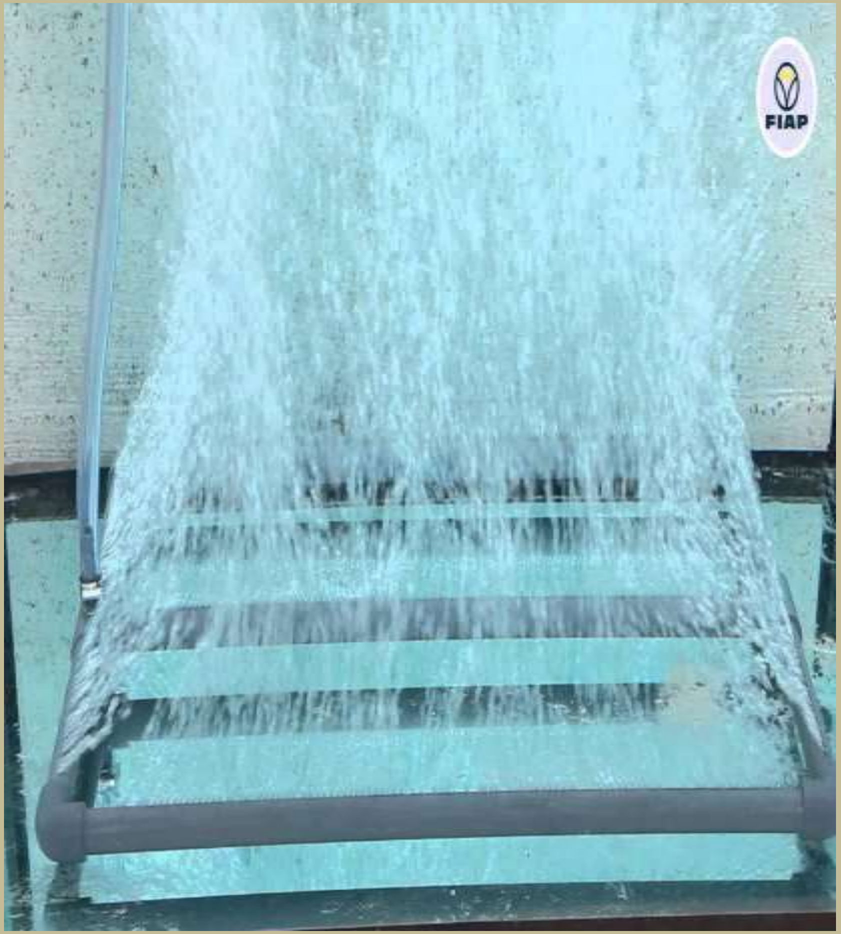
By Air Diffusing Method

- In this method supplying ozone treats water. The gas contains oxygen, and it helps in removing carbon dioxide from water.

Methods of aeration

a. Gravity or free fall aerators:

- By air diffusion:



Water Treatment processes

By permitting water to trickle over cascades

- In this method, compressed air is bubbled through the water, so as to thoroughly mix it with water.
- By Using Trickling Beds
- In this method, the water is allowed to trickle down the beds of coke, supported over perforated trays, and arranged vertically in series.

Methods of aeration

a. Gravity or free fall aerators:

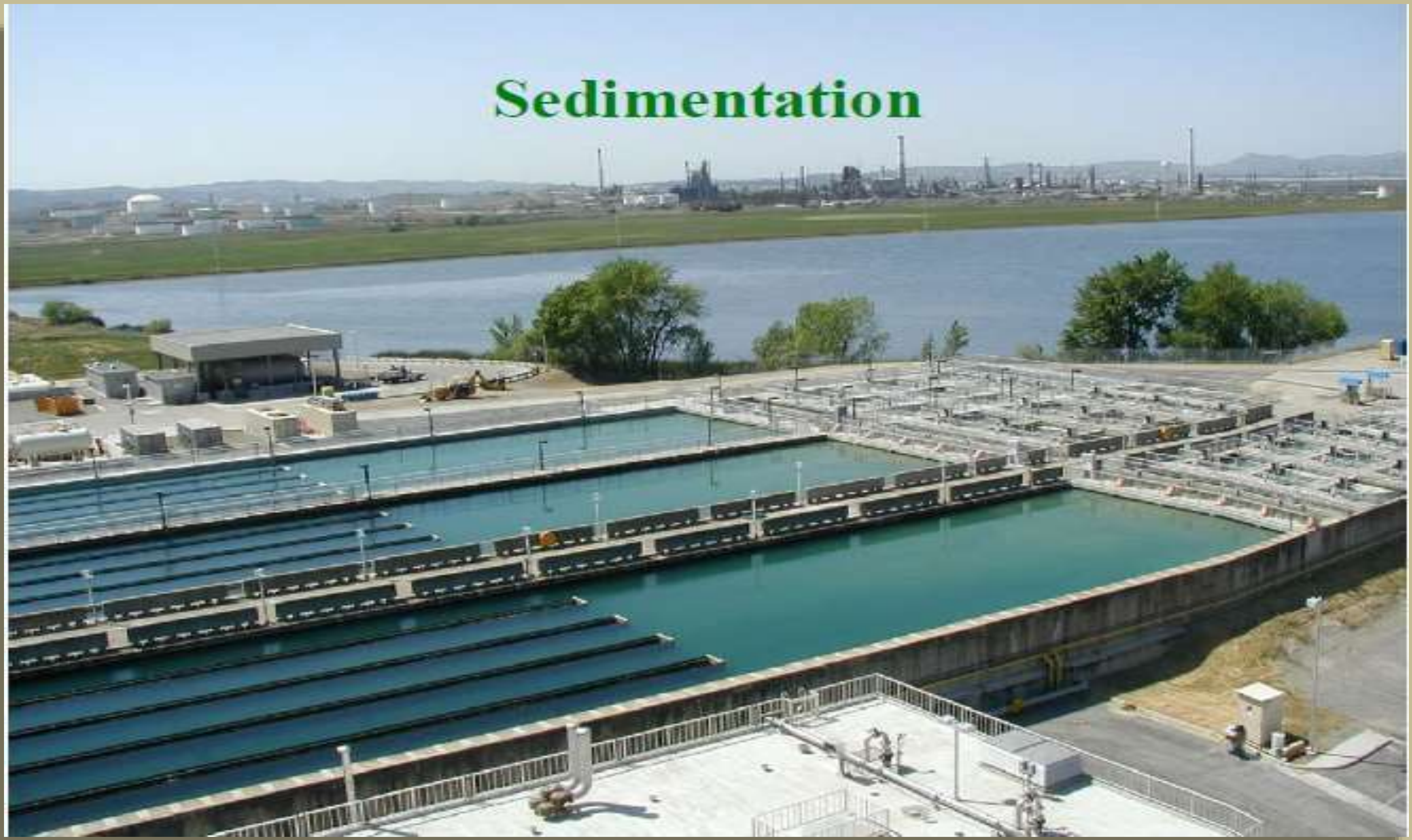
- Trickling beds or multiple trays:

Water Treatment processes

Sedimentation

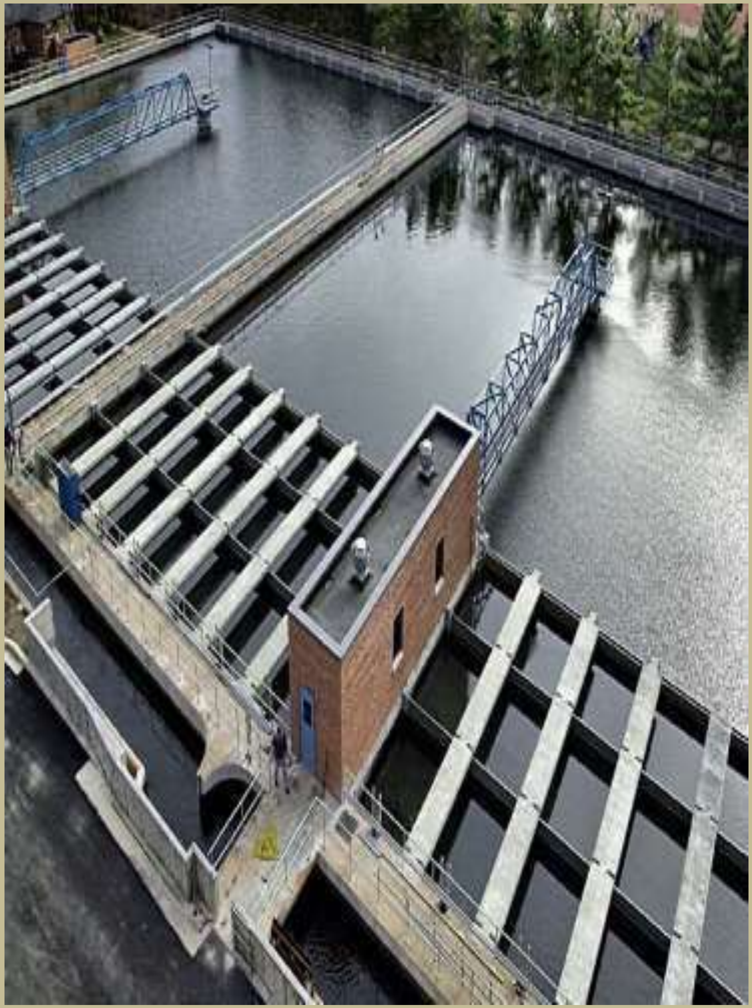
- Plain Sedimentation
- **Most of the suspended impurities present in water tend to settle down under gravity, so that the water is allowed to still in basin, and this process is called plain sedimentation**. The basin in which water is detained is **called settling tank** or sedimentation tank or clarifier, and the theoretical average time for which the **water is detained in the tank is called detention time.**

Water Treatment processes



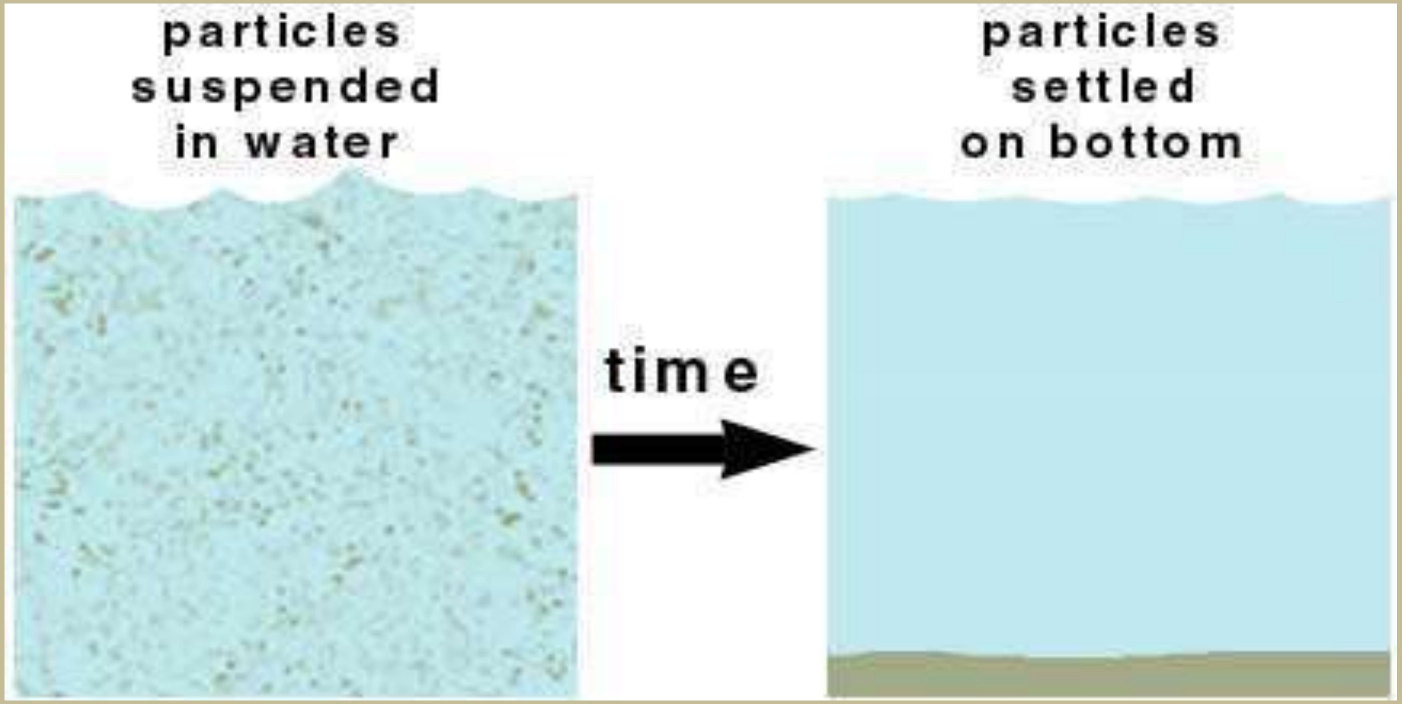
Sedimentation

- water flows to a tank called a sedimentation basin
- gravity causes the flocs to settle to the bottom
- Large particles settle more rapidly than small particles
- It would take a very long time for all particles to settle out and that would mean we would need a very large sedimentation basin.
- So the clarified water, with most of the particles removed, moves on to the filtration step where the finer particles are removed

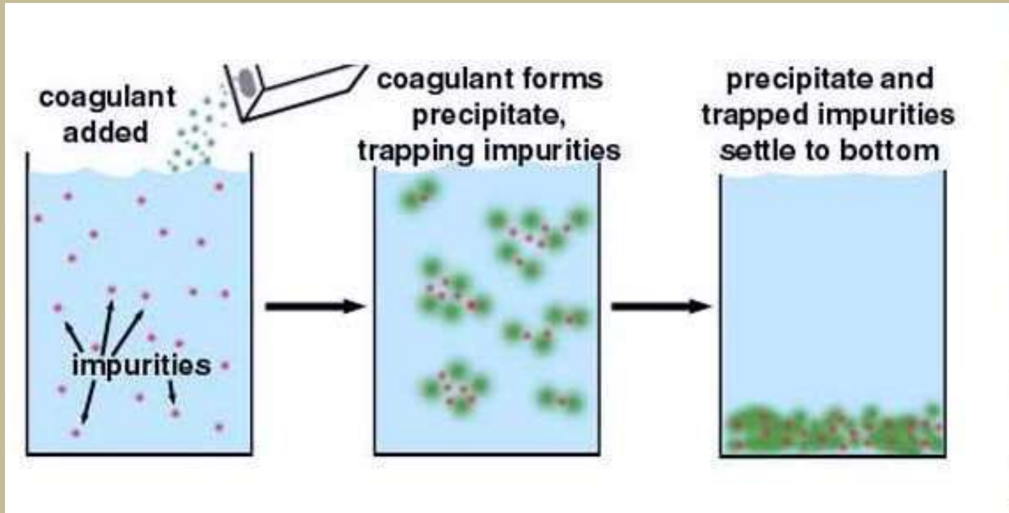


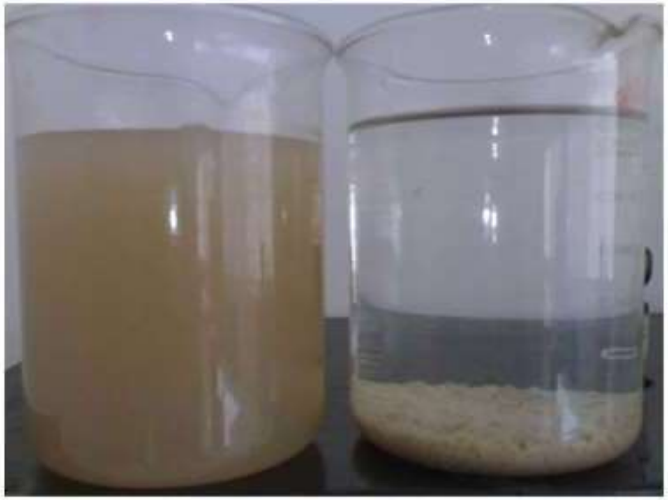
Sedimentation: suspended particles settle down under the action of gravity

- Plain sedimentation:



Sedimentation with coagulation





JAR TEST APPARATUS

Coagulation

- Small particles are not removed efficiently by sedimentation because they settle too slowly
- they may also pass through filters
- easier to remove if they are clumped together
- Coagulated to form larger particles, **but they don't** because they have a negative charge
- repel each other (like two north poles of a magnet)

- In coagulation
- we add a chemical such as alum which produces positive charges to neutralize the negative charges on the particles
- particles can stick together
- forming larger particles
- more easily removed
- process involves addition of chemical (e.g. alum)
- rapid mixing to dissolve the chemical
- distribute it evenly throughout water

Coagulants

- Aluminum Sulfate $Al_2(SO_4)_3$
- Ferrous Sulfate $FeSO_4$
- Ferric Sulfate $Fe_2(SO_4)_3$
- Ferric Chloride $FeCl_3$
- Lime $Ca(OH)_2$

Aluminum salts are cheaper but iron salts are more effective over wider pH range

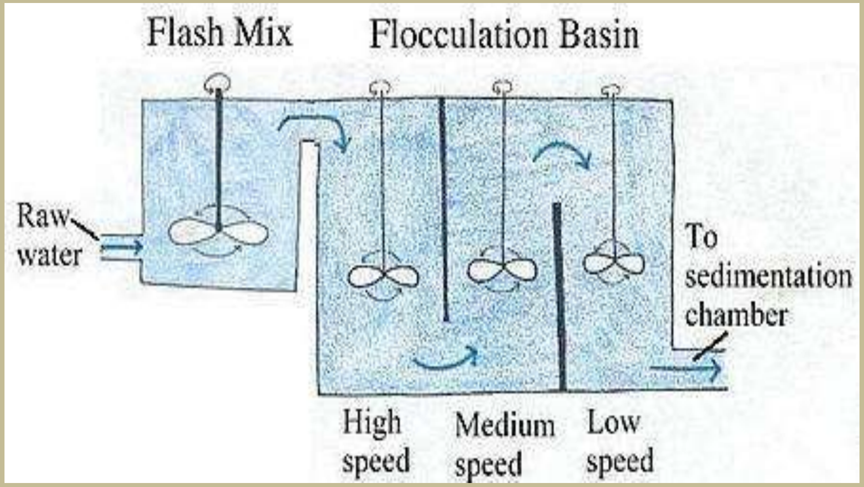
Factors for choosing a coagulant?

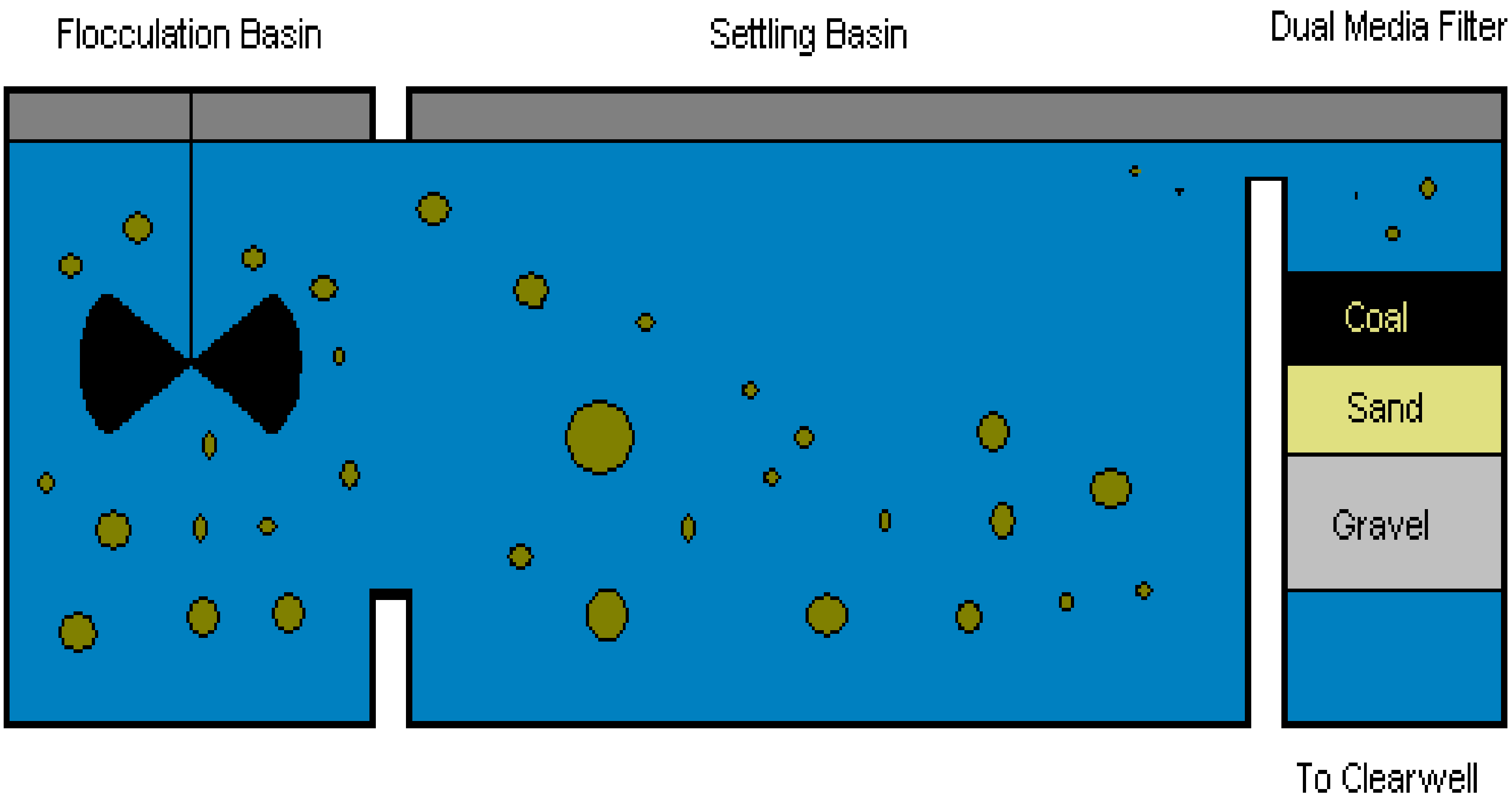
1. Easily available in all dry and liquid forms
2. Economical
3. Effective over wide range of pH
4. Produces less sludges
5. Less harmful for environment
6. Fast

Flocculation

- Now the particles have a neutral charge
- can stick together
- The water flows into a tank with paddles that provide slow mixing
- bring the small particles together to form larger particles called flocs
- Mixing is done quite slowly and gently in the flocculation step

- If the mixing is too fast, the flocs will break apart into small particles that are difficult to remove by sedimentation or filtration.




Flocculation Basin
Settling Basin
Dual Media Filter
Coal
Sand
Gravel
To Clearwell

Water Treatment processes

- Sedimentation basins are generally made of reinforced concrete, and may be rectangular or circular in plan. A plain sedimentation under normal condition may remove as much as 70 % of the suspended impurities present in the water.

Water Treatment processes

Object of Sedimentation

- Plain sedimentation is adopted to settle the suspended impurities in water. When water is stored, particles with specific gravity more then one try to settle down, **the forces, which resists the settlement of particles are viscosity, velocity, shape and size of the particles**. When the particles to be removed are bigger in size, so that by reducing the turbulence of water, they can settle, plain sedimentation is recommended.

Water Treatment processes

Design of Sedimentation Tank

- **Surface Loading or Overflow Velocity**
- The discharge per unit area Q/ BL is known as overflow velocity. Normal velocities range from between 500- 750 lit/hr/m^2 of plan area for sedimentation tanks using coagulants.

Water Treatment processes

Water Treatment processes

Detention Time

- Detention time (t) of settling tank may be defined as the average theoretical time required for the water to flow through the tank. It is the time that would be required for the flow of water to fill the water if there will be no overflow. Hence it is the ratio of Volume of the basin to the rate of flow through the basin.

Water Treatment processes

For Rectangular tank.

- Detention Time (t) = $\frac{\text{Volume of Tank}}{\text{Rate of flow}}$

$$= \frac{BLH}{Q}$$

Where,

H= Water depth or Height

L=Length of Tank

B= Width

Q= Discharge

Detention time usually ranges between 4 to 8 hours for plain sedimentation, it is 2 to 4 hrs... as coagulant get used.

Water Treatment processes

Short Circuiting

- For the efficient removal of sediment in sedimentation tank, it is necessary that flow through period uniformly distributed throughout the tank. If current permit a substantial portion of water to pass directly through the tank without being detained for intended time, the flow is said to be short circuited.

Water Treatment processes

Inlet &Out let Zone

- Inlet & Outlet zone near the entrance and exit should be designed which may reduce the short-circuiting tendencies and in such a way distribute the flow uniformly. The size and shape of particle also affect the settling rate. The greater is the specific gravity more readily the particle will settle.

Water Treatment processes

Displacement Efficiency

- The actual average time, which a batch of water takes in passing through a settling tank is called the flowing through period it is always less than the detention period. Which is the corresponding theoretical time. The ratio of the flowing through period to detention time is called ‘displacement efficiency’
- Therefore,
- Displacement efficiency= $\frac{\text{Flow through period}}{\text{Detention Period}}$

It generally varies between 0.25 to 0.5 in normal sedimentation tank.

Water Treatment processes

- Types of Sedimentation Tanks
- The Sedimentation tanks can be divided into two types
- Horizontal flow tanks
- Vertical or up-flow tanks

Water Treatment Processes

- Among the horizontal flow tanks, we may have different types of designs, such as.
- Rectangular tanks with longitudinal flow
- Circular tank with radial flow, with central feed.

Water Treatment Processes

- Vertical or Up-flow Tanks
- Vertical tanks usually combine with sedimentation with flocculation, although they may be used for plain sedimentation. They may be square or circular in plan and may have hopper bottoms.
- When used with coagulants, the flocculation takes place in the bottom of the tank leading to the formation of blanket of floc through which the rising floc must pass. Because of this phenomenon, these tanks are called the Up-flow sludge blanket clarifiers.

Types of Settling

- Particles may settle out of a sedimentation tank in the following four ways:
- Type:- I Discrete Settling
- This corresponds to the sedimentation of discrete particles in a suspension of low solid concentration. This is also known as free settling since the particle have tendency to flocculate or coalesce upon contact with each other.

Types of Settling

Discrete Particle

A particle that does not alter its shape, size and weight while settling or rising in water is known as discrete particle.

Type-II

Hindered Settling

This type of settling refers to rather dilute suspension of particles that coalesce or flocculate during sedimentation process. Due to flocculation, particles increase in mass and settle at a faster rate.

Types of Settling

Type-III

- Zone Settling
- This type of settling refer to flocculent suspension of intermediate concentration. Inter particle forces hold the particle to-gather and mass of particle subside as a whole.

Types of Settling

Type IV

- Compression Settling
- This refers to flocculent suspension of so high concentration that particles actually comes in contact with each other resulting in formation of a structure. Further settling can occur only by compression of the structure brought about due to weight of particles which are constantly being added to the structure.

Types of Sedimentation Tank

Fill and Draw type

- As the name indicates the sedimentation tank is first filled with incoming water, and is allowed to rest for a certain time, under this quiescent condition the suspended particles settle down at the bottom of the tank. Generally a detention time of 24 hrs.. is allowed. At the end of the period the clear water is drawn off through the outlet valve without causing any disturbance to the settling mass. This method is obsolete and not in use in recent times.

Types of Sedimentation Tank

Continuous flow type tank

- In this type of tank water after entering through the inlet, keeps on moving continuously with small uniform velocity. Before the water is reached outlet, the suspended particles settles at the bottom, and the clear water is collected from the outlet.
- There are two types
- Horizontal flow tank
- Vertical flow tank

Types of Sedimentation Tank

Horizontal flow Sedimentation Tank

- In the design of a horizontal flow settling tank, the aim is to achieve as nearly as possible the ideal condition of equal velocity at all points lying on each vertical in the settling zone.

Sedimentation Tank

Design aspect of continuous flow type sedimentation tank

- **Detention Period**
- Detention Period
- Detention time or period is the theoretical time taken by a particle of water to pass between entry and exit of a settling tank.
- Detention time to is given by
- $t_o = \frac{\text{Volume of the tank}}{\text{Rate of flow}} = \frac{V}{Q} = \frac{LBH}{Q}$

Detention time for a plain sedimentation tank varies from 4 to 8 hrs.. and for 2 to 4 hrs.. when coagulant are used.

Sedimentation Tank

Flow through period

- Flowing through period
- It is the average time required for a batch of water to pass through the settling tank. It is always less than detention period.
- Displacement efficiency
- It is the ratio of $\frac{\text{Flow through period}}{\text{Detention time}}$

It varies from 0.25 to 0.5 in plain sedimentation tanks

Sedimentation Tank

Overflow Rate

- The quantity of water passing per hour per unit plan area is known as flow rate. This term is also referred to as surface loading rate, because its unit is $m^3/d/m^2$, the unit m^3/d represents discharge or flow of water in tank and m^2 is the surface area of the tank.

Sedimentation Tank

- The normally adopted values varies between 12 – 18 m^3/m^2/day (500 to 750 lit per hour per m^2) for plain sedimentation tank and between 24 – 30 m^3/m^2/day (1000 to 1250 lit per hour per m^2) for sedimentation tank using coagulation.

Sedimentation Tank

Basin Dimension

- The surface area of the tank is determined on the basis of overflow rate or surface loading rate
- **Surface Area A = Rate of flow (m³/day)**

Surface loading rate (m³/m²/day)

The length to width ratio of rectangle tank should preferably be 3:1 to 5:1 Width of tank should not exceed 12 m. The depth is kept between 3 to 6 m. For a circular tank the diameter is limited to 60 m

C/s area is such that to provide a horizontal velocity of flow of 0.2 to 0.4 m/min, normally about 0.3 m/min..

Bottom slope is taken as 1 % in rectangular tank to about 8% in circular tank.

Sedimentation Tank

Weir Loading Rate

- It is ratio of flow rate divided by length of the outlet weir over which the water will flow
- Weir loading rate= $\frac{\text{flow rate}}{\text{perimeter}}$

Circular tank usually ranges 300 m3/m/day

Sedimentation Tank

Maximum velocity to prevent scour

- It is very essential that once the particle has settled and reach the sludge zone it should not be scoured or lifted up by velocity of flow of water over the bed.
- $V_d = \left(\frac{8\,\beta(S_s-1)\,d}{f} \right)^{1/2}$

B= 0.04 for uni-granular sand and 0.06 or more for non uniform sand.

f= Darcy Weisbach friction factor

=0.025 to 0.03 for settling velocity.

d= diameter of particle

Ss= Specific Gravity of particles

Sedimentation Tank

Inlet &Outlet arrangement

- Inlet & outlet arrangement for sedimentation tank are made such that minimum disturbance is caused due to inflow and effluent streams. If this disturbance is not overcome by inlet & outlet arrangement, the effective detention period will be reduced.
- An ideal structure is that which
- Distribute the water uniformly across the width and depth.
- Reduce turbulence
- Initiates the longitudinal or radial flow so as to achieve high removal efficiency.
- Mix it with the water already in the tank to prevent density currents.

Sedimentation Tank

Sludge Removal

- The particles settled in the basin constitutes the sludge which can be removed either manually or mechanically. In manual process the tank has to be put out of service, drained and sludge has to be dug out from the bottom manually. This method is used when the quantity of matter is small. However when quantity is large, mechanical or hydraulic methods are used for sludge removal.

Sedimentation Tank

- Design a suitable sedimentation tank for a town whose daily demand is 12 million lit per day. Tank is fitted with a mechanical scrapper for sludge removal. Assume detention period as 5 hr..... and velocity of flow as 20 cm/sec

Sedimentation Tank

- Quantity of water to be treated
- $=12 \times 10^{6}$ lit/day
- $=12 \times 10^{3}$ m^3/day
- $\frac{12 \times 10^{3}}{24} = 500\ m^3/hr$

Capacity of tank= Q x detention time

=500 x 5

2500 m^3

Sedimentation Tank

- Velocity of flow= 20 cm /min
- =0.2 m/min
- The length of the tank required= Velocity of flow x Detention time
- =0.2 x 5 x60
- =60 m
- The c/s area of the tank required
- $= \dfrac{\text{Volume of tank}}{\text{Length of the tank}}$
- $= \dfrac{2500}{60}$

$=41.66\ m^2$

Sedimentation Tank

- Assume water depth of 3.5 m
- Width of tank required = $\frac{41.66}{3.5}$

=11.9 m

=12 m

Using free board of 0.5 m the overall depth =3.5 +0.5 =4.0 m

So provide a tank of 60 x 12 x 4 m

Surface loading rate= $\frac{Q}{L \times B}$

$= \frac{12 \times 10^3}{60 \times 12} = 16.66\ m^3/m^2/day$ (Within limits)

O.K.

Example

- Design a sedimentation tank for a water works which supplies 1.6 MLD to the town. The sedimentation period is 4 hrs.. The velocity of flow is 0.15 m/min and the depth of water in the tank is 4.0 m. Assume an allowance for sludge as 80 cm. Also find the overflow rate.

Example

- Quantity of water to be treated

$=1.6 \times 10^{6}$ lit/day= 66.66 m^3/hr.

- Volume of tank or capacity of tank
- =Q x detention time

$=66.66 \times 4 = 266.64\ m^3$

- The velocity of horizontal flow= 0.15 m/min
- The required length of the tank= Velocity of flow x detention time

$=0.15 \times 4 \times 60$

=36 m

Example

- Cross-Sectional area of the tank= $\frac{\text{Capacity}}{\text{Length}}$

$= \frac{266.64}{36}\ m^3$

$= 7.4\ m^2$

Depth of tank= 4.0 m

Therefore width of the tank

$= \frac{\text{Cross – Sectional area}}{\text{depth of water}}$

Here total depth of water including sludge= 4.0 m

Sludge depth= 0.8 m

Therefore Water depth= 4-0.8 =3.2 m

Therefore width of tank = $\frac{7.4}{3.2}$ m

=2.31= 2.4 m

Example

Provide a free board of 0.5 m the size of the tank

=36 x 2.4 x 4.5 m

Overflow rate= $\frac{Q}{L \times B}$

= $\frac{1.6 \times 10^{6}}{36 \times 2.4 \times 24}$ lit/hr./m ^{2}

=771.6 lit/hr./m2 or 18.51 m^3/m^2/day

Example

- Design a plain sedimentation tank for water supply scheme having capacity to treat water= 10 MLD

Example

- Design a Continuous horizontal flow Rectangle tank
- Assume detention time= 5 hrs. (4 to 8 hrs.)
- Velocity of flow= 0.2 m/sec (0.15 to 0.30 m/sec)
- Water depth= 3.5 m (3 to 6 m)
- Freeboard= 0.5 m

Example

- Quantity of water to be treated= 10 MLD
- $=10 \times 10^6$ lit/day
- $= \dfrac{10 \times 10^6 \times 10^{-3}}{24}$

$=416.66\ m^3/hr.$

Volume of tank= Q x Detention time

$=416.66 \times 5$

$=2083.3\ m^3$

Example

- Length of tank required= Velocity of flow x Detention time
- =0.2 x 5 x 60
- =60 m
- Cross-Sectional area of the tank
- = $\dfrac{\text{Volume of tank}}{\text{Length of the tank}}$

= $\dfrac{2083.30}{60}$

=34.72 sq.

Example

- Water depth is assumed as 3.5 m
- So required width of the tank = $\frac{34.72}{3.5}$

=9.92 m

Say 10 m

Provide a free board of 0.5 m total depth

=3.5 +0.5 =4.0 m

Therefore the dimensions of the tank

=60 x 10 x 4 m

Example

Surface overflow rate

SLR= Q

A 10

x 10 $^{-3}$

60 x 10

=16.66 m^3/m^2/day

Within limit so design is O.K.

Filtration

- Sedimentation removes a large percentage of settleble solids, suspended solids, organic matter and small percentage of bacteria. If coagulation is used more percentage of fine colloidal particles will be removed. But water still contains fine suspended particles, micro-organisms and color. To remove these impurities still further and to produce potable and palatable water, the water is filtered through beds of granular material like sand and gravel. This process of passing the water through the beds of such granular materials is known as filtration.

Filtration

Theory of Filtration

- When water is filtered through the beds of filter media, usually consisting of clean sand, the following action takes place:
- Mechanical Straining
- Sedimentation
- Biological action
- Electrolytic action

Filtration

Mechanical Straining

- Sand contains small pores, the suspended particles which are bigger than the size of the voids in the sand layer cannot pass through these voids and get arrested in them as the water passes through the filter media (sand). Most of the particles are removed in the upper few centimeters of the filter media, these arrested particles forms a mat on the top of the bed which further helps in straining out impurities.

Filtration

Sedimentation

- In mechanical Straining, only those particles which are coarser than the void size are arrested. Finer particles are removed by sedimentation. The voids between grains of filters act like small sedimentation tanks. The colloidal matter arrested in the voids is a gelatinous mass and therefore, attract other finer particle. These finer particle thus settle down in the voids and get removed.

Filtration

Biological action

- When a filter is put into operation and the water is passed through it, during the first few days, the upper layer of sand grain become coated with sticky deposit of decomposed organic matter together with iron, manganese aluminum and silica. After some time there exists a upper most layer of sand a film of algae, bacteria and protozoa etc. this film is called schmutzdecke or dirty skin which acts as an extremely fine messed straining mat. This layer further helps in absorbing and straining out the impurities. The organic impurities present in water become food for micro-organisms residing in the film. Bacteria breakdown the organic matter and convert them into harmless compounds.

Filtration

Electrolytic action

- The sand particles of filter media and the impurities in water carry electric charge of opposite nature, therefore they attract each other and neutralize the charge of each other. After long use the electric charge of filter sand is exhausted, which is renewed by washing the filter bed.

Filter Material

- Sand either coarse or fine, is generally used as filter media. The layers of sand may be supported on gravel, which permits the filtered water to move freely to the under drains and allow the wash water to move uniformly upward.
- **Sand**
- The filter sand should generally be obtained from rock like quartzite and should have following properties:
- It should be free from dirt and other impurities
- It should be of uniform size
- It should be hard
- If placed in hydrochloric acid for 24 hrs., it should not lose more than 5 % of weight.

Filter Material

- Effective size of sand shall be
- (a) 0.2 to 0.3 mm for slow sand filters
- (b) 0.35 to 0.6 mm for rapid sand filter
- Uniformity of Sand
- It is specified by the uniformity coefficient which is defined as the ratio between the sieve size in mm through which 60 % of the sample sand will pass to the effective size of the sand.
- Uniformity coefficient for slow sand filter
- =2 to 3
- 1.3 to 1.7 for rapid sand filters

Filter Material

Gravel

- The sand beds are supported on the gravel bed. The gravel used should be hard, durable, free from impurities, properly rounded and should have a density of about 1600 kg/ m^3
- The gravel is placed in 5-6 layers having finest size on top.
- Other material
- Other material which can be used are anthracite, Garnet, Sand or local material like coconut husks, rice husks.

Types of Filters

- Filters are mainly classified based upon the rate of filtration as
- Slow Sand Filter
- Rapid Sand Filter
- (a) Rapid sand gravity filter
- (b) Pressure Filter

Types of Filters

Slow Sand Filter

- Slow Sand filter was the earliest type , they were called slow sand filter because the rate of filtration through them is about 1/20th or less of the rate of filtration through rapid gravity filter. Du to low filtration rate, slow sand filters require large area of land and are costly to install. They are expensive to operate due to laborious method of bed cleaning by surface scrapping Due to this slow Sand filters are not used these days.

Types of Filters

- A slow sand filter unit consists of the following parts
- Enclosure tank
- Filter media
- Base Material
- Under drainage system
- Inlet &Outlet arrangement
- Other appurtenances

Types of Filters

Enclosure Tank

- It consist of an open water tight rectangular tank made of concrete or masonary. The bed slope is 1 in 100 to 1 in 200 towards the central drain. The depth of tank varies from 2.5 to 4 m. The plan area may vary from 100 to 200 sq.m. depending upon the quantity of water treated.

Types of Filters

Filter Media

- The filter media consist of sand layers about 90 to 110 cm in depth and placed over a gravel support. The effective size varies from 0.2 to 0.35 and uniformity coefficient varies from 2 to 3. Finer is the sand better is the quality of water.

Types of Filters

Base Material

- The filter media is supported on base size material consisting of 30 to 75 cm thick gravel of different sizes, placed in layers, generally 3 to 4 layers of 15 to 20 cm depth are used.

Types of Filters

Under Drainage System

- The base material are supported over the under drainage system which centrally collects the filter water. The water drainage system consists of a central drain collecting water from a number of lateral drains. The lateral drains are open jointed pipe drains or perforated pipes of 7.5 to 10 cm dia spaced at 2 to 4 m centre to centre.

Types of Filters

Inlet &Outlet

- An inlet chamber, is constructed for admitting the effluent from the plain sedimentation tank without disturbing the sand layer of filter and to distribute it uniformly over filter bed

Types of Filters

Other appurtenances

- Various appurtenances that are generally installed for efficient working are the device for
- Measuring loss of head through filter media
- Controlling depth of water above the filter media.
- Maintaining constant rate of flow through filter.

Filters

Efficiency of Slow Sand Filters

- **Bacterial Load**
- The slow sand filter are highly efficient in removal of bacterial load from water. They remove about 98 to 99 %of bacterial Load from raw water.
- **Color**
- The slow sand filter are less efficient in the removal of color of raw water. They remove about 20 to 25 % color of water.
- **Turbidity**
- The slow sand filter are not very effective in removing colloidal turbidity. They can remove turbidity to the extent of about 50 ppm

Example

- Find the area of slow sand filter required for a town having a population of 15000 with average rate of demand as 160 lpcd.

Example

- Maximum daily demand =15000 x 160 x 1.5
- =3600000 lit
- Assume the rate of filtration as 150 lit/hr./m^2, the filter area required will be.
- $= \frac{3600000}{150 \times 24} = 1000\ m^2$

Let the size of each unit of 20 x 10 =200 m^2

Then total number of unit required would be 5

Provided one unit as stand by, so provide 6 unit of 20 x 10 m

Rapid Sand Filter

- Rapid sand filters were first developed in last decade of 19th century, on an average these filters may yield as high as 30 times the yield given by the slow sand filter. These filters employ coarser sand with effective size around 0.5 mm. Water from the coagulation sedimentation tank are used in these filters.

Rapid Sand Filter

- Agravity type of rapid sand filters consists of following units
- Enclosure tank
- Filter Media
- Base Material
- Under Drainage System
- Other appurtenances

Rapid Sand Filter

Enclosure tank

- It is generally rectangular in plan, constructed either of masonary or of concrete, coated with water proof material. The depth of the tank varies from 2.5 to 3.5 m. Each unit may have a surface area of 10 to 50 m^2. They are arranged in series. The length to width ratio is kept between 1.25 to 1.35.

Rapid Sand Filter

- Following formula is used to get approximately the number of filter unit beds required
- $$N = \frac{\sqrt{Q}}{4.69}$$

Where N is the number of units or beds and Q is quantity of water in m^3/ hr.... There should be at least 2 units in each plant.

Rapid Sand Filter

Filter media

- The filtering media consists of sand layer, about 60 to 90 cm in depth and placed over a gravel support. The effective size of sand varies from 0.35 to 0.6 mm and the uniformity coefficient ranges between 1.3 to 1.7.

Rapid Sand Filter

Base Material

- The filter sand media is supported on the base material consisting of gravel . In addition to supporting the sand, it distributes the wash water. It total depth varies from 45 to 60 cm. It may be divided into 4 to 5 layers.

Rapid Sand Filter

Under Drainage System

- The under drainage system serves the two purpose
- It collects the filter water uniformly over the area of gravel bed.
- It provides uniform distribution of backwash water without disturbing or upsetting the gravel bed and filter media.

Rapid Sand Filter

- Under drainage should be capable of passing the wash water at a rate of about 300 to 900 lit.min/m^2 . Since the rate application of wash water is much higher then filtration rate, the design of under drainage system is governed by the consideration of even and uniform distribution of wash water.

Rapid Sand Filter

- There are various types of Under drainage System Such as
- Manifold and Lateral
- (a) Perforated &Pipe System
- (b) Pipe and Straining System
- Wheeler System
- Leopald System

Rapid Sand Filter

Manifold and Lateral

- It consist of a manifold running lengthwise along the centre of the filter bottom. Several pipe called laterals taken off in both the direction at right angle to the manifold. The laterals are placed at a distance of 15 to 30 cm centre to centre.

Rapid Sand Filter

- In perforated pipe type of this system, the laterals are provided with holes at the bottom side. These holes are 6 to 12 mm in dia and make an angle 30 0
- Following thumb rules are use in the design of Under drainage System
- Ratio of the total area of the orifice
- Perforation or holes in lateral
- :0. 15 to 0.5 %perferable about 0.3%
- Ratio of C/s area of lateral to the area of orifice served 2 to 4:1
- Dia of Orifice :6 mm to 18 mm
- Ratio of area of manifold to that of the area of lateral served
- 1.5 to 3:1 preferably
- Spacing of Orifices: 7.5 cm for 6 mm dia
- Spacing of lateral 15 to 30 cm
- Length of lateral: not more than 60 times
- Length of lateral > 60
- Dia of lateral

Rapid Sand Filter

Back Washing

- When the clean filter bed is put in to operation, in the beginning the loss of head is very small, but as the bed gets clogged, the loss of head increases, When the head losses becomes excessive, the filtration rate decreases and the filter bed must be washed
- Rapid gravity filters are washed by sending air and water upward through the bed the reverse flow through the underdrainage system

Efficiency and performance of Rapid Sand Filter

Turbidity

- If the influent water does not have turbidity of more than 35 to 40 mg/lit. Since Coagulation and sedimentation always precedes filtration the turbidity of water applied to filter is always less than 35 to 40 mg/lit.

Bacterial Load

- The rapid sand filter are less effective in removal of bacterial load as compare to slow sand filter. They can remove 80 to 90 % of bacterial load

Color

- Rapid sand filter are very efficient in color removal. The intensity of color can be brought down below 3 on cobalt scale.

Iron &Manganese

- Rapid sand filter remove oxidized or oxidizing iron through it is less efficient in removing manganese

Taste &Odor

- Unless special treatment such as activated carbon or pre chlorination is provided, rapid sand filters will not ordinarily remove taste and odor,

Loss of Head &Negative Head

- When a cleaned bed is put into operation, the loss of head through it will be small usually 15 to 30 cm. as the water is filtered through it, impurities arrested by the filter media, due to which the loss of head goes on increasing. A stage comes when the frictional resistance exceeds the static head above the sand bed, at this stage, the lower portion of media and the under drainage system are under partial vacuum or negative head.
- Due to the formation of negative head, dissolved gases and air are released filling the pores of the filter and the under drainage system.
- In rapid sand filter permissible head loss will be 2.5 m to 3.5 m

Comparison of Slow Sand Filter & Rapid Sand Filter

Item	Slow Sand Filter	Rapid Sand Filter
Rate of filtration	100 to 200 lit/hr./m^2	3000 to 6000 lit/hr./m^2
Loss of head	15 cm to 100 cm	30 cm to 3 m
Area	Requires Larger Area	Requires smaller area
Coagulation	Not Required	Essential
Filter media	Effective Size 0.2 to 0.35 mm Depth 90 to 110cm	Effective size 0.35 to 0.6 mm Depth 60 to 90 cm
Base material	Size 3 to 65 mm Depth 30 to 75 cm	Size: 3 to 40 mm Depth 40 to 65 mm
Method of cleaning	Scrapping the top layer	Agitation and back washing

Comparison of Slow Sand Filter &Rapid Sand Filter

Item	Slow Sand Filter	Rapid Sand Filter
Amount of wash water required	0.2 to 0.6 % of water filtered	2 to 4 %water filtered
Efficiency	Very efficient in the removal of bacteria less efficient in removal of color and turbidity.	Less efficient in removal of bacteria more efficient in the removal of color & turbidity.
Cost	High initial cost	Cheap &economical
Cost of maintenance	Less	More
Skilled Supervision	Not essential	Essential
Depreciation Cost	Relatively low	Relatively high,

Example

- A City has population of 50,000 with an average rate of demand of 160 lpcd find area of rapid sand filters. Also find number of units or beds required.

Example

- Population= 50,000
- Rate of water supply= 160
- Maximum daily demand per day= 1.5 x 160 x 50000
- $=12 \times 10^{6}$ lit/day
- Assume rate of filtration =4500 lit/hr./sq.m
- Area of filter beds required= $\frac{12 \times 10^{6}}{24 \times 4500}$

$=111.11\ m^{2}$

Example

- Number of filter beds can be found out by
- (i) assuming area of one bed/ unit and then finding out the number of beds/ units required.
- (ii) By using the following eel
- $N = \frac{\sqrt{Q}}{4.69}$

Where, N= No of beds

Q= Quantity of water to be filtered in m^3 /hr...

Example

- Q= 12 MLD
- $= \frac{12 \times 10^{6} \times 10^{-3}}{24}$

$=500\ m^{3}/hr...$

$N = \frac{\sqrt{Q}}{4.69}$

$= \frac{\sqrt{500}}{4.69}$

= 5 units

Area of each unit $= \frac{111.11}{5}$

= 22.22

Example

Assume L:B ratio as 1.3

L=1.3 B

A=1,3 Bx B

=22.22= 1.3 Bx B

B=4.13 m

L=1.3 x 4.13

=5.369 m

Provide B=4.2 m and L=5.4 m

Provide 6 such units one as stand by

Example

- Design a rapid sand filter Unit for supplying 10 MLD to a town with all its principle components

Example

Step-I Design of filter Units

- Water Required per day= 10 MLD
- Assuming that 3 %of filtered water is used for washing of filter every day
- Therefore total filter water required per day
- =1.03 x 10
- =10.3 MLD
- $\frac{10.3}{24-0.5}$ =0.438 ML/hr
- Assuming the rate of filtration as 5000 lit /hr./m ^{2}
- Area of filter required= $\frac{0.438 \times 10^6}{5000}$

=87.6 sq.

Example

- No of Unis Required
- $N = \frac{\sqrt{Q}}{4.69}$

$= \frac{\sqrt{438}}{4.69}$

$= 4.46$

$= 5$

Area of each Unit $= \frac{87.6}{5}$

$= 17.52$

Assume L/B= 1.3

1.3 B x B=17.52

B=3.67= 3.7 m

L=3.67 x 1.3 =4.771= 4.8m

Say provide total 6 units of 4.8 m x 3.7 m

Design of Under drainage System

- Laterals &manifold system is used for Underdrainage System
- Let us assume that the total area of perforations in the underdrainage system as 0.3 %of area of filter bed/ unit.
- $\frac{0.3 \times 4.8 \times 3.7}{100} = 0.533\ m^2 = 533\ cm^2$
- Total Area of Laterals= 2 time the area of perforation
- =2 x 533
- $=1066\ cm^2 = 0.1066\ m^2$
- Assume the area of manifold as twice the total area of laterals we have
- Area of manifold= 2 x 0.1066
- $=0,2132\ m^2$
- =0.52 m
- Let us provide manifold of 0.55 or 55 cm let the spacing of lateral as 15 cm

Design of Under drainage System

- Hence number of laterals= $\frac{4.8 \times 100}{15}$

=32 laterals

Hence provide 32 laterals on either side of the manifold

Hence total no of lateral in each filter unit

=2 x 32 =64

Length of each lateral=

$\frac{\text{width of filter- dia of manifold}}{2}$

$= \frac{3.7 - 0.55}{2}$

=1.575 m

Let n be the total no of perforation, each of 12 mm dia in all 64 laterals

Design of Under drainage System

- Total area of perforations= 533 cm^2
- $n \times \frac{\prod (1.2)^2}{4} = 533$

n= 472

No of perforations = $\frac{472}{64}$

= 7.8

Hence provide 8 perforation per lateral

Area of perforation per lateral =8 x $\frac{\prod \times (1.2)^2}{4}$

=9.04 x 2 =18.08 cm^2

Therefore dia of lateral $= \left(\frac{18.8 \times 4}{\prod}\right)^{1/2} = 4.8$ cm

Hence provide 64 laterals each of 4.8 cm at 15 cm c/c spacing and having 8 perforations of 12 mm dia

Design of Under drainage System

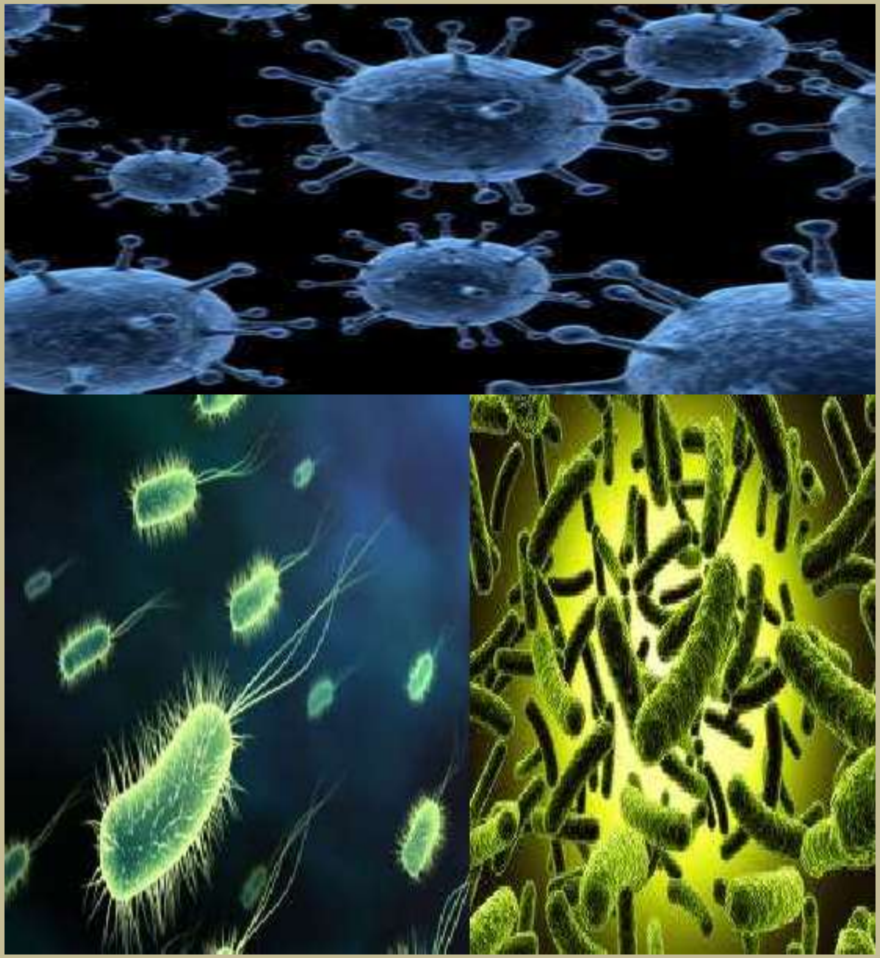
Length of Lateral = 1.575 x 100 = 32.81 <60

Dia of Lateral 4.8

- Also spacing of perforation = 1.575 = 20
- 8
- Therefore O.K.

Disinfection

- With particles removed, it only remains to provide disinfection, so that no pathogens remain in the water
- Protozoan pathogens are large in size and have been removed with other particles
- Bacteria and viruses are now destroyed by addition of a disinfectant



Chlorination

- Enough chlorine is added so that some remains to go out in the water distribution system, protecting the public once the water leaves the plant

Disinfection: killing pathogenic bacteria from water

DISINFECTANTS USED FOR WATER

- For **Chemical Disinfection** of water the following disinfectants can be used:

- - Chlorine (Cl_2)
  - Chlorine dioxide (ClO_2)
  - Hypo chlorite (OCl^-)
  - Ozone (O_3)
  - Halogens: bromine (Br_2), iodene (I)
  - Bromine chloride (BrCl)
  - Metals: copper (Cu^{2+}), silver (Ag^+)
  - Potassium Permanganate ($KMnO_4$)
  - Fenols
  - Alcohols
  - Soaps and detergents
  - Hydrogen peroxide
  - Several acids and bases

- For **Physical Disinfection** of water the following disinfectants can be used:

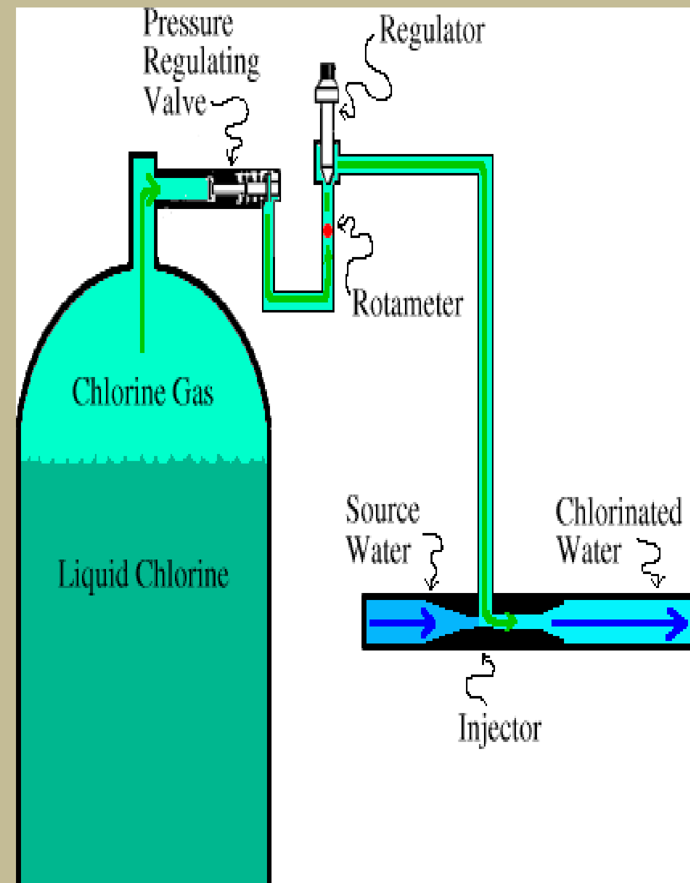
  - Ultraviolet light (UV)
  - Electronic radiation
  - Gamma rays
  - Sounds
  - Heat

Chlorination

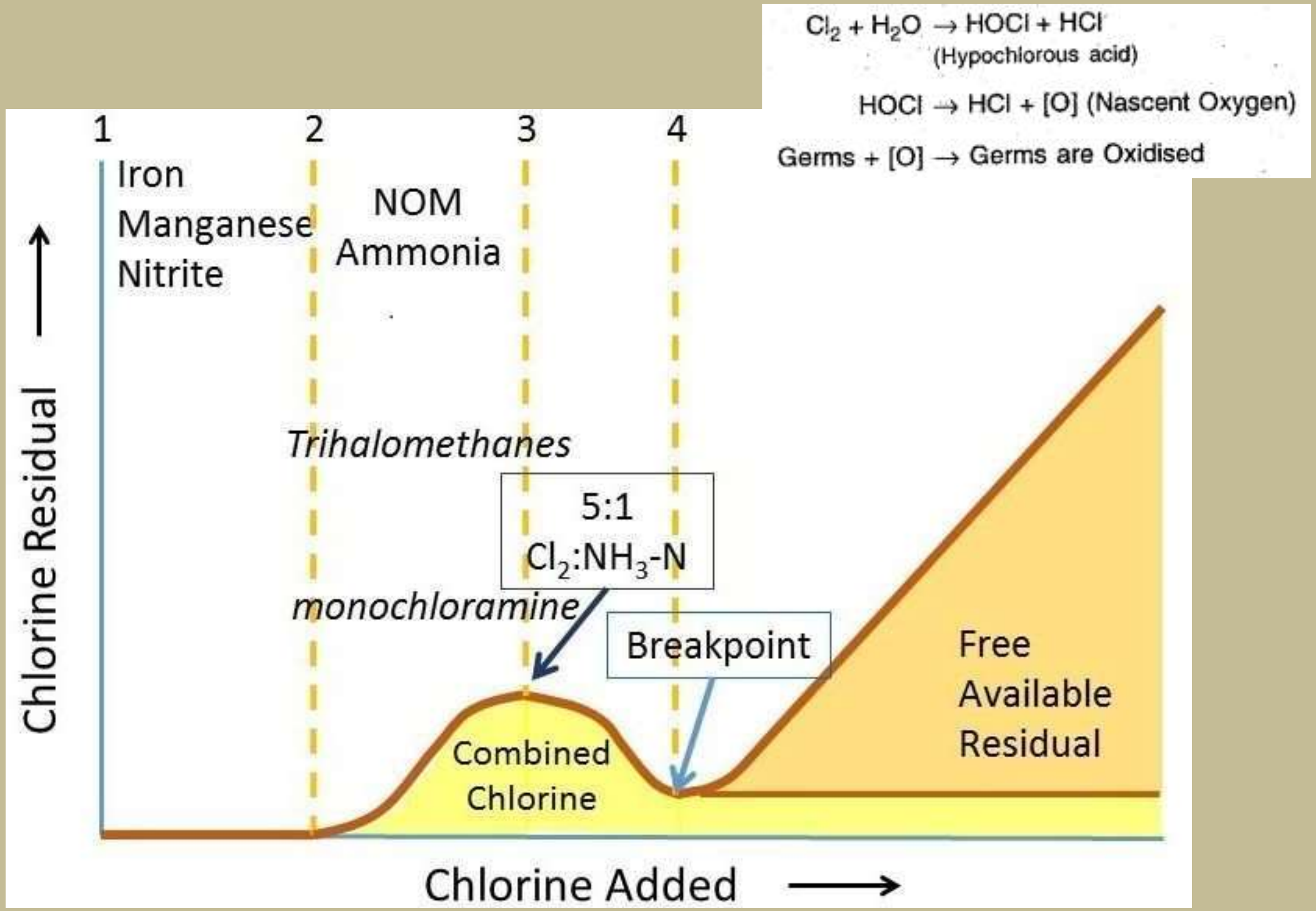
FORMS OF CHLORINATION

1. Plain chlorination or simple chlorination:
   To raw water
2. Pre-chlorination:
   Before treatment
3. Post chlorination:
   After treatment
4. Double or multiple chlorination:
   Two or more point
5. Super chlorination:
   Application beyond break point
6. De-chlorination
   Removing chlorine
7. Break point chlorination or free residual chlorination:

26



Break point chlorination



Softening

- Areas where water comes into contact with limestone, there may be high levels of calcium and magnesium present
- these chemicals make the water "hard"
- Hardness is removed by a process called softening
- Two chemicals (lime, CaO and soda ash, Na_2CO_3) are added to water
- causing the calcium and magnesium to form precipitates
- solid substance is then removed with the other particles by sedimentation and filtration

Distribution

- Pumping of the clean water produced at the treatment plant to the community is called distribution
- This can be done directly or by first pumping the water to reservoirs or water storage tanks

Onsite Treatment
Color, Taste and Odor

- The activated carbon technology used in municipal drinking water treatment can be applied in homes as well
- the carbon is contained in a "household-sized" column
- water passes through the carbon removing organic matter (which can cause a yellow color) and also compounds which cause unpleasant taste and odor

Onsite Treatment At The Tap

- Home water treatment systems may also be installed at the tap
- Although the technologies vary somewhat among products, they typically include pre-filtration
- hardness and metals removal by ion exchange
- organic matter removal with activated carbon
- post-filtration

Thank You