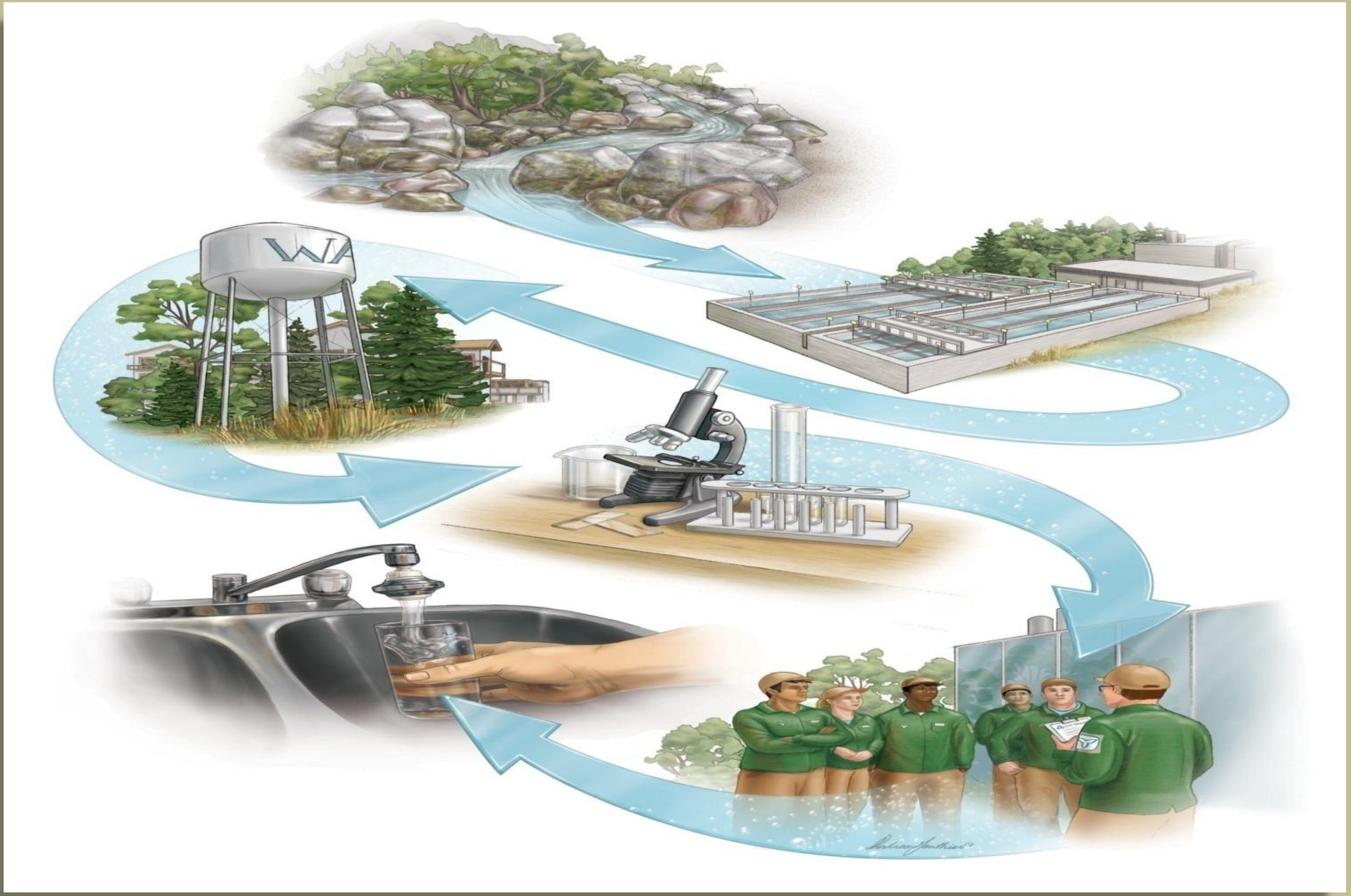
Treatment Processes for Water

Water Treatment Plants

Water Flow



Water Consumption

Water provided for human consumption requires treatment in order to make it

- safe (potable)
- pleasant to taste (palatable)

Modern technology offers remarkable capabilities to accomplish these goals

- introduction of new and different pollutants
- cost of treating to required levels is a challenge for the water supply industry

Water Demand

- Municipal water supplies are treated to be both palatable and potable, regardless of their intended use
- If each person uses about 100 litres of water per day
- Commercial and industrial users may increase that demand by more than 5 times

Drinking Water – Quality

Our water supply comes from two sources

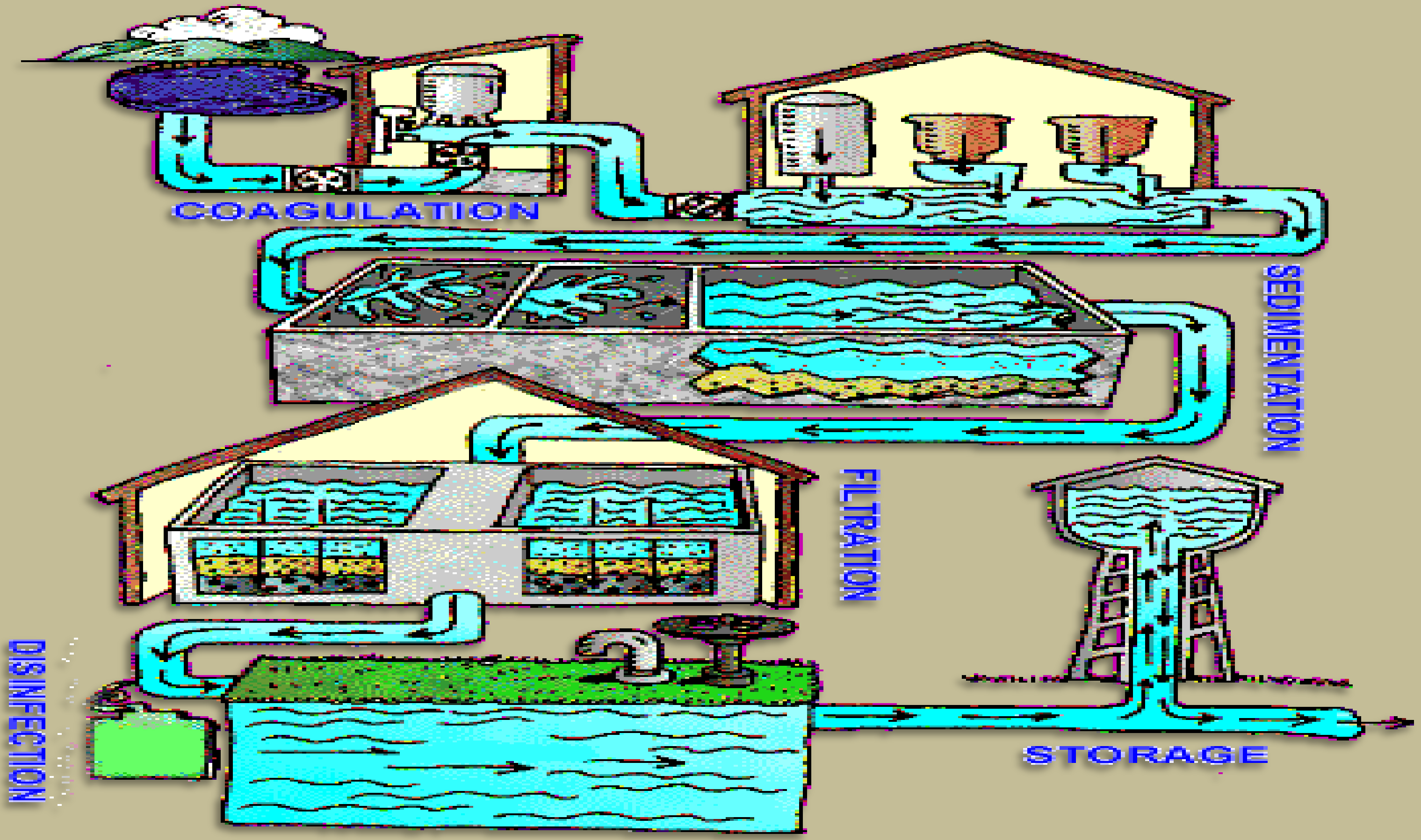
- surface waters i.e. rivers, lakes and reservoirs
- groundwater, which is stored below the earth's surface

Each source presents its own problems

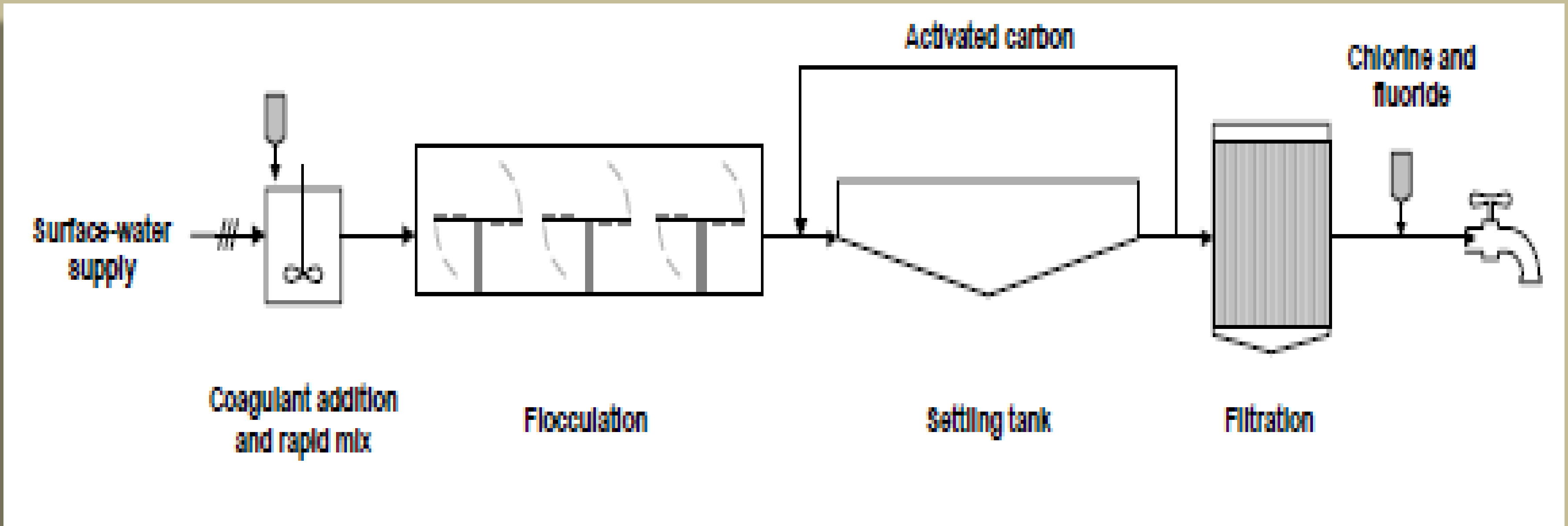
- Surface water has elevated levels of soil particles and algae, making the water turbid
- may contain pathogens

- 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

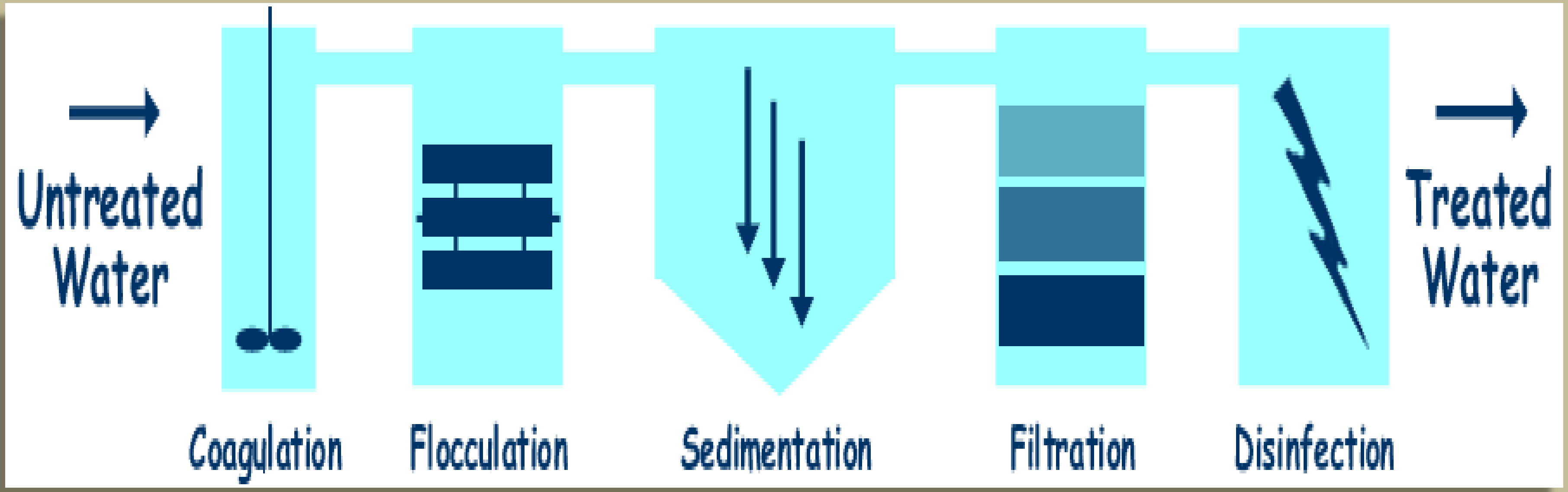
Water Treatment Process



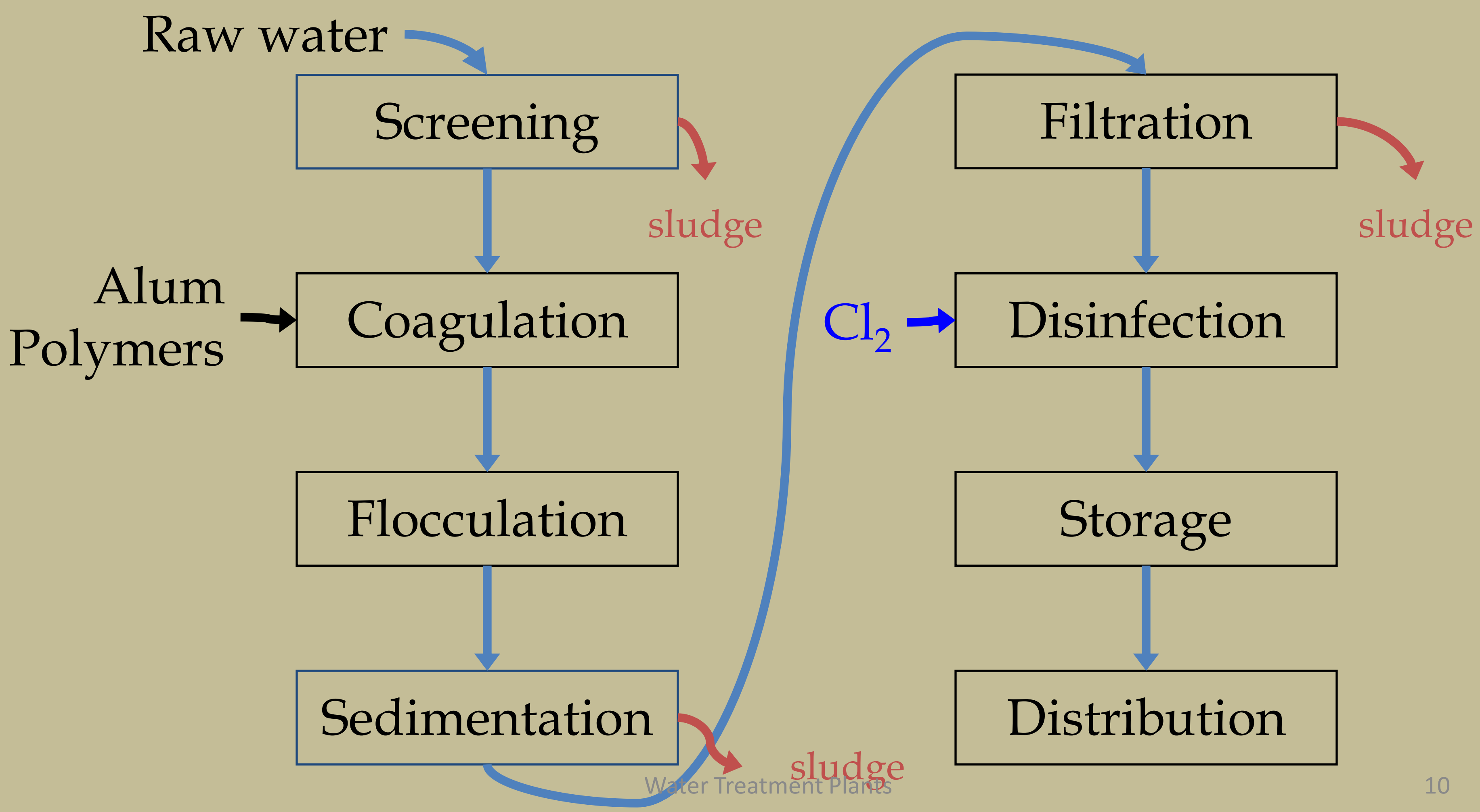
Drinking Water Plant



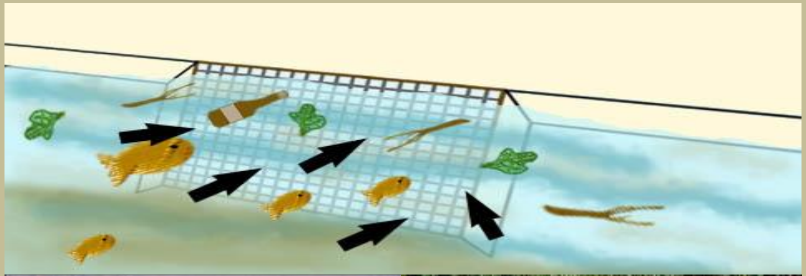
Untreated to Treated Water



Conventional Surface Water Treatment



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

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

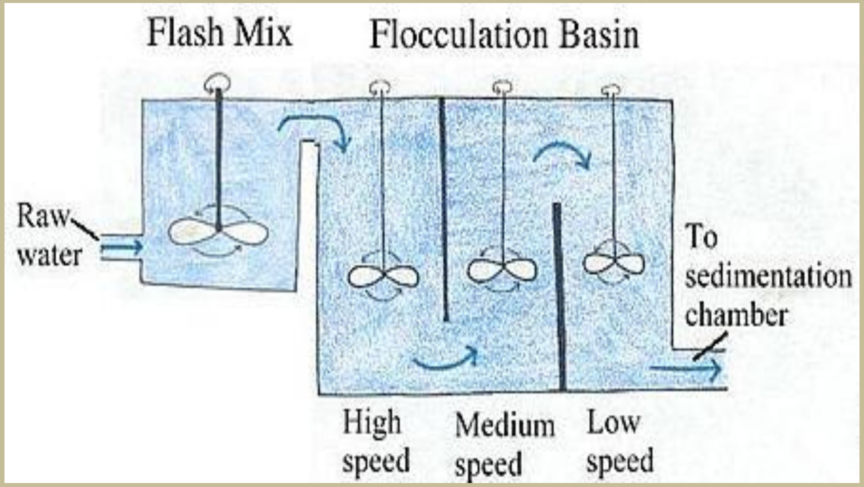
Factors for choosing a coagulant?

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

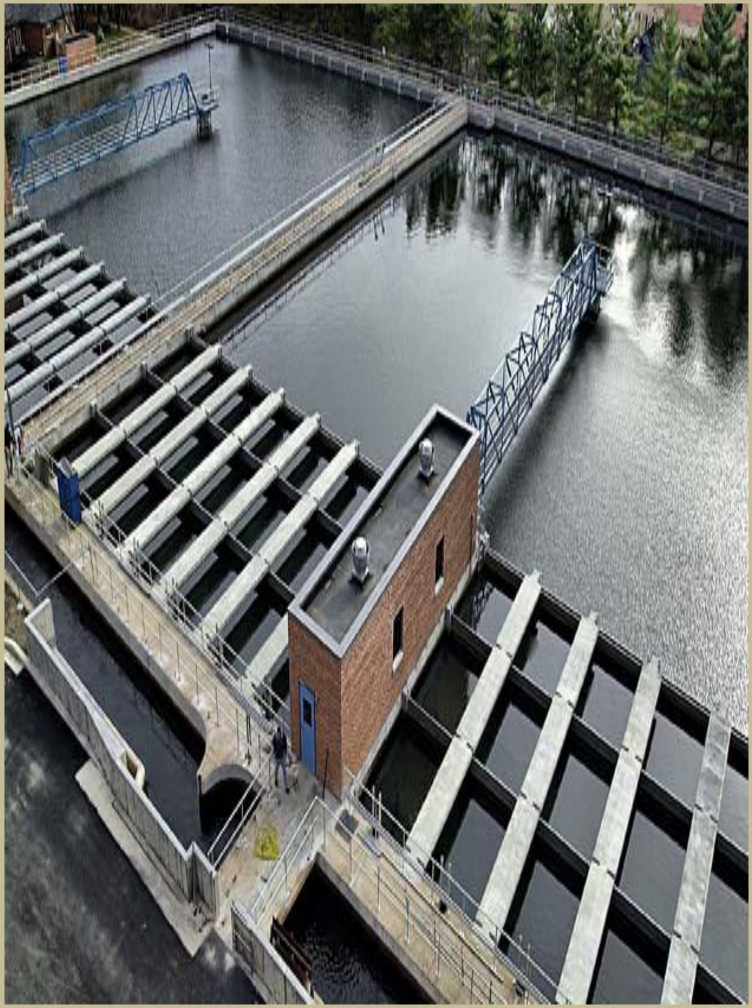
- Now the particles have a neutral charge
- can stick together
- The water flows into a tank with paddles that provide slow mixing
- bring the small particles together to form larger particles called flocs
- Mixing is done quite slowly and gently in the flocculation step

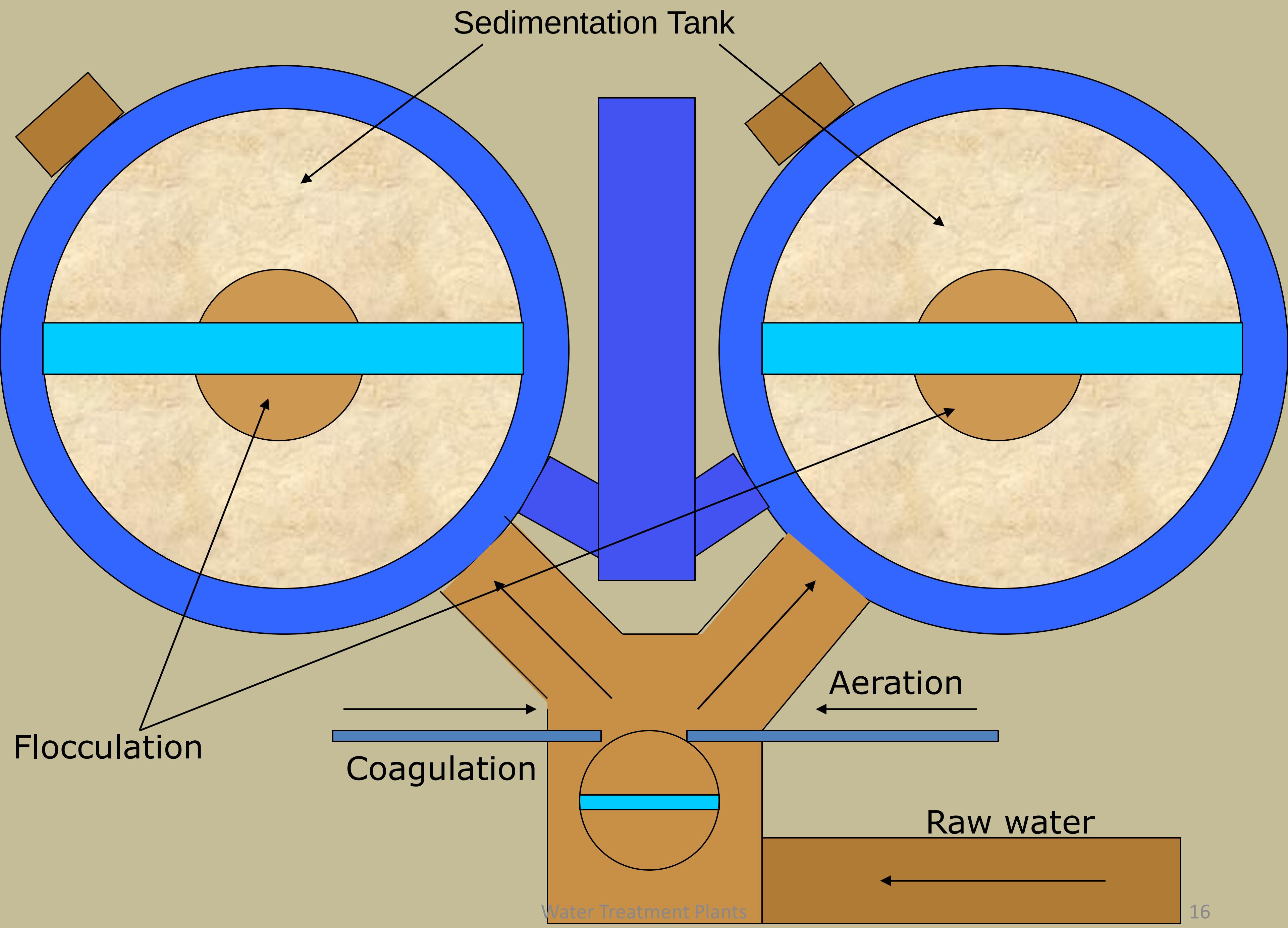
- If the mixing is too fast, the flocs will break apart into small particles that are difficult to remove by sedimentation or filtration.

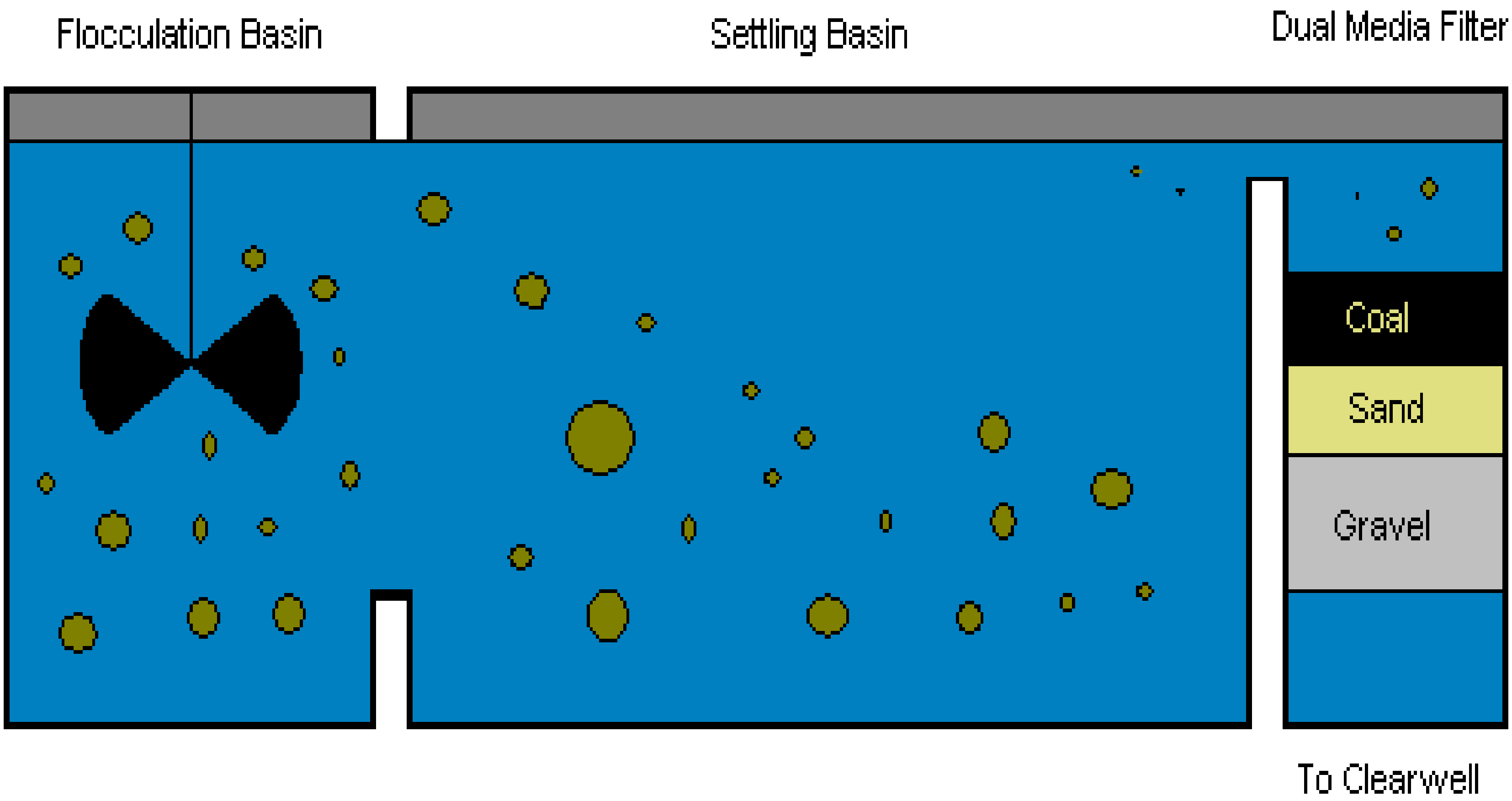


Sedimentation

- 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 Tank
Aeration
Flocculation
Coagulation
Raw water

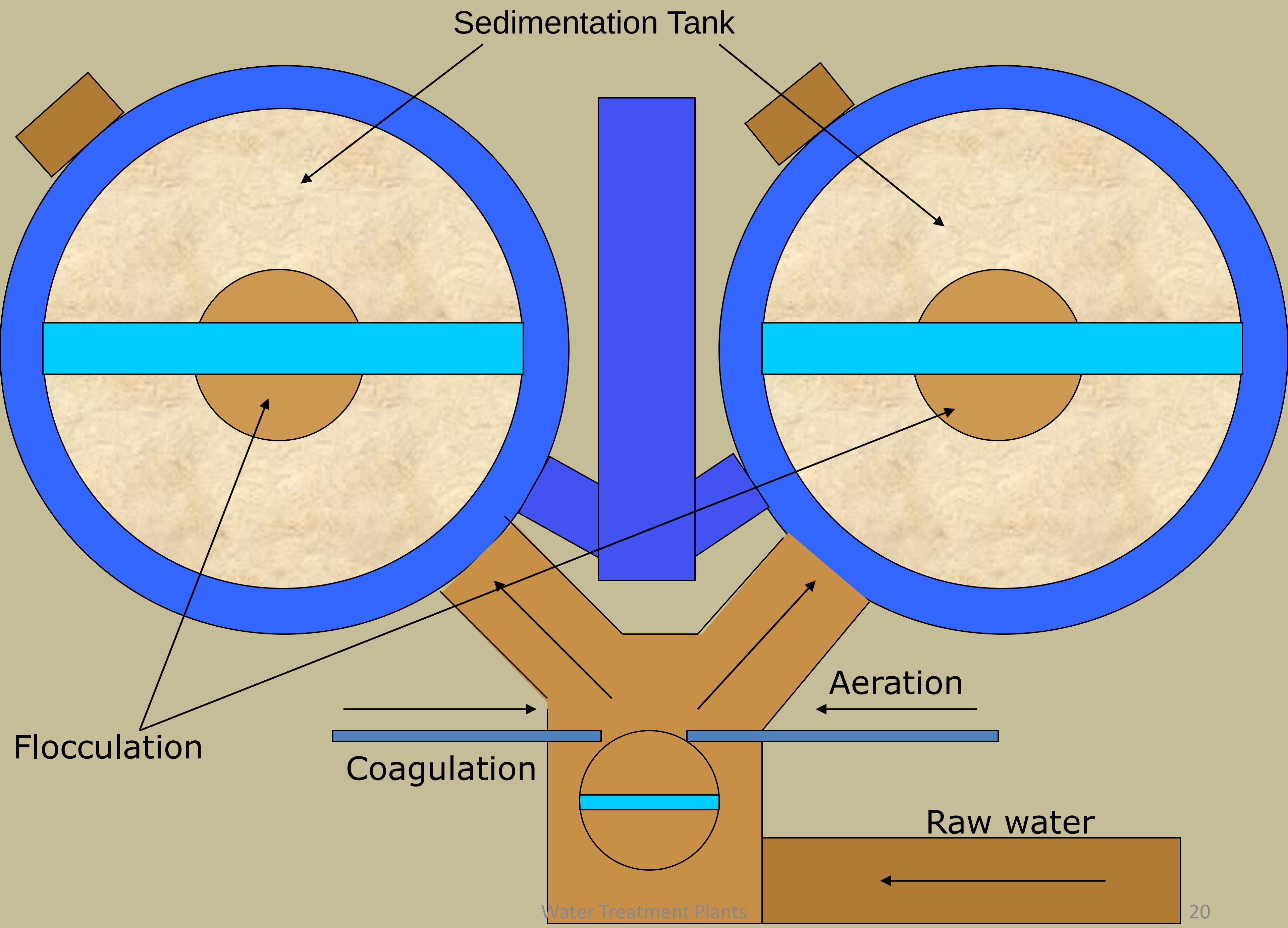

Flocculation Basin
Settling Basin
Dual Media Filter
Coal
Sand
Gravel
To Clearwell

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

Main Components

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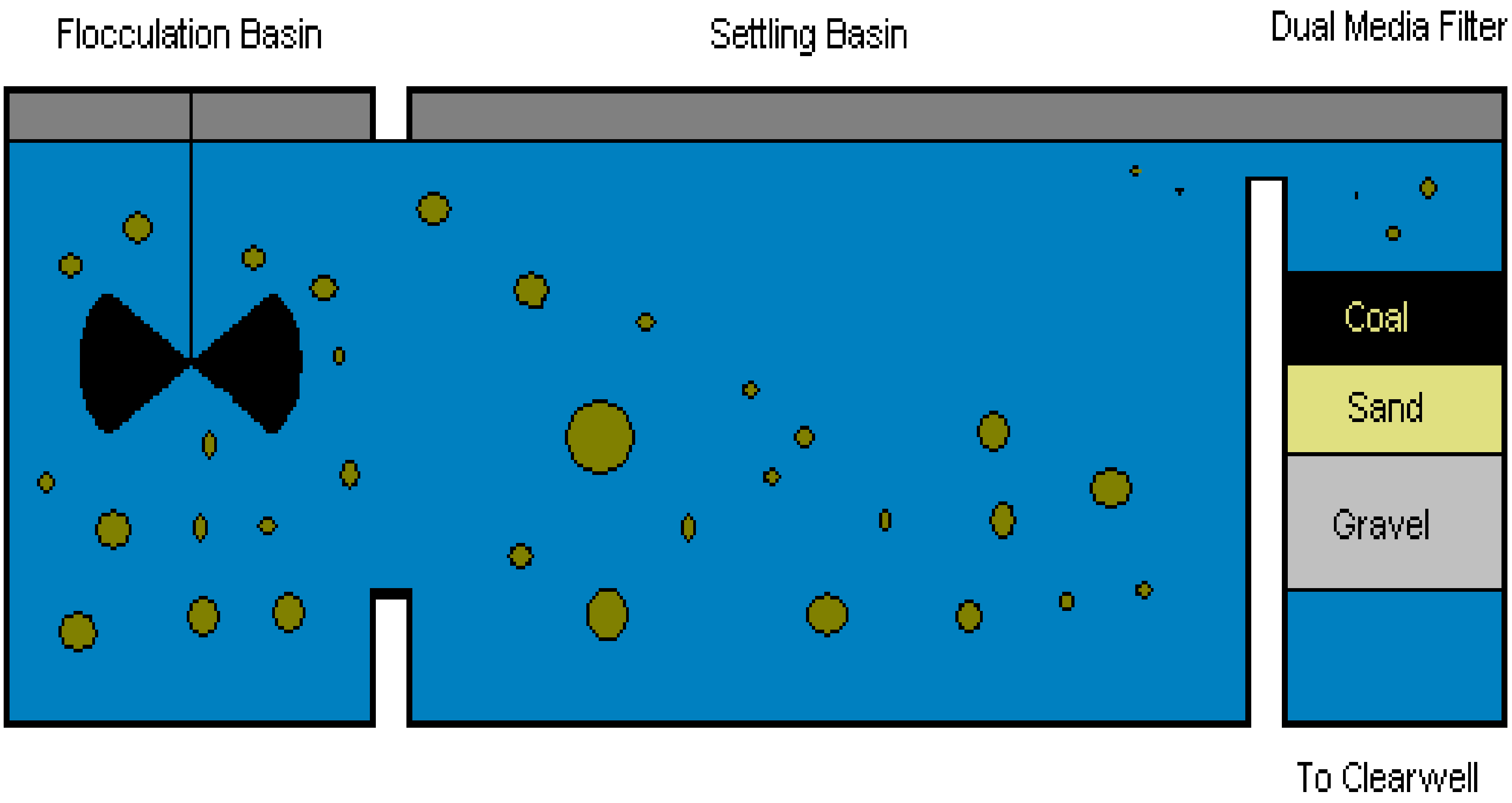
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Unit Operations

- 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.

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.

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.

Water Treatment processes

Aeration

- This is adopted to remove objectionable taste and odour and also to remove dissolved gases such as carbon-dioxide, hydrogen supplied, etc.. The iron & manganese present in water are also oxidized to some extent.

Sedimentation with or without Coagulation

- 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.

Sedimentation with or without Coagulation

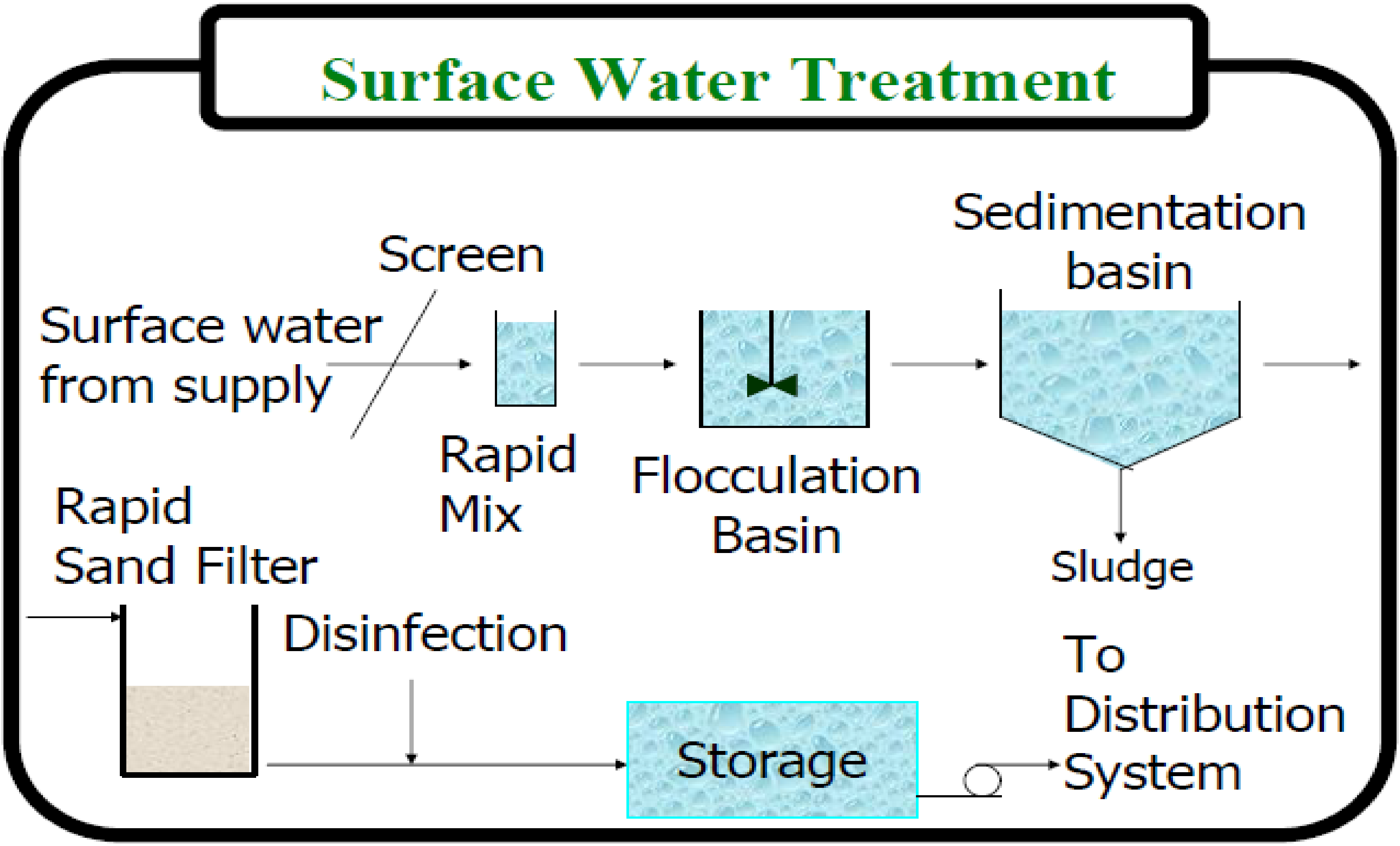
- Filtration
- The process of filtration forms the most important stage in purification of water. Filtration removes very fine suspended impurities and colloidal impurities that may have escaped the sedimentation tanks. In addition the micro-organisms present in water are largely removed.

Sedimentation with or without Coagulation

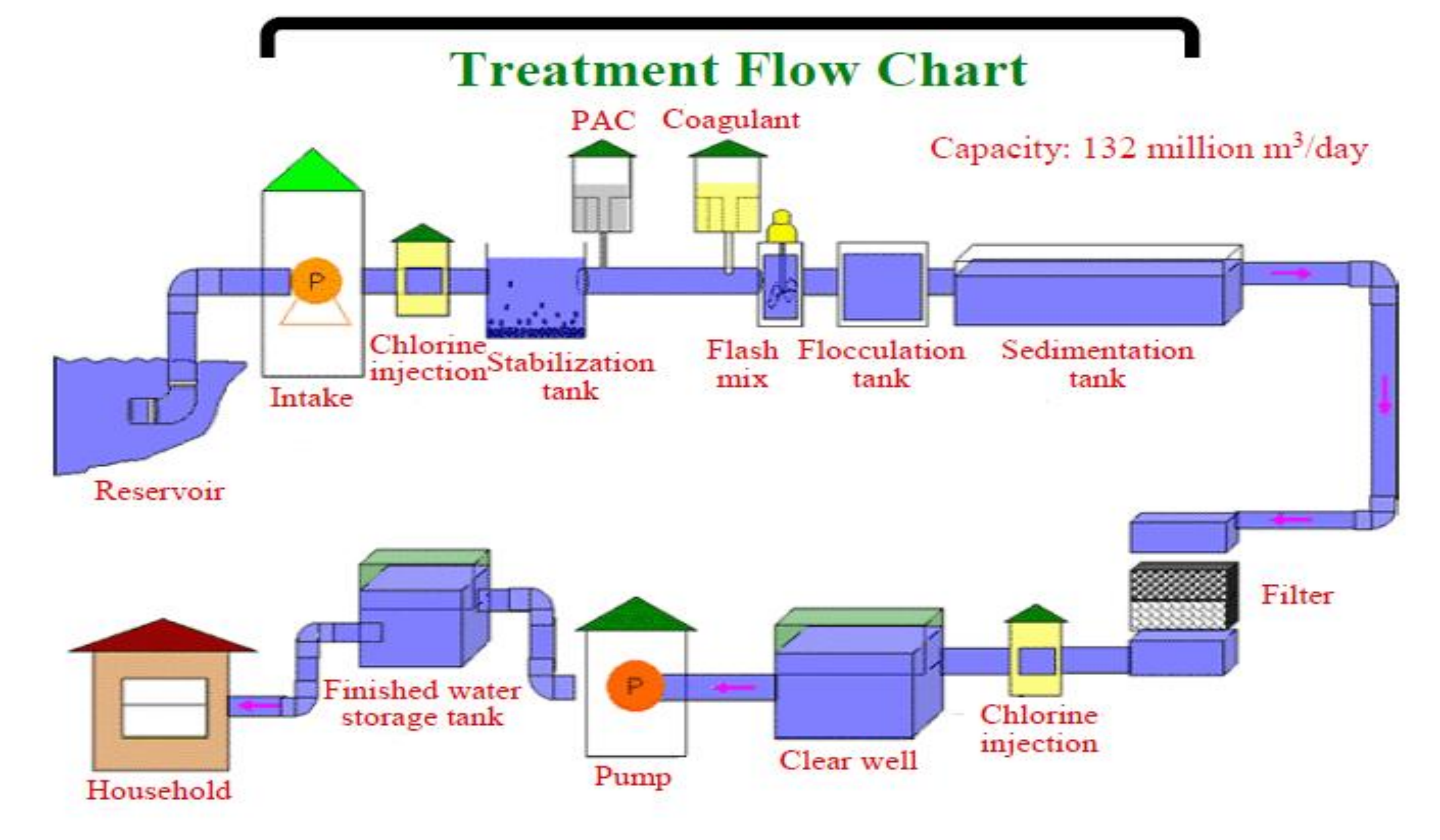
Disinfection

- 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 and to the place of consumption.

Water Treatment Processes



Water Treatment Processes



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.

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.

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.

Water Treatment processes

By permitting water to trickle over cascades

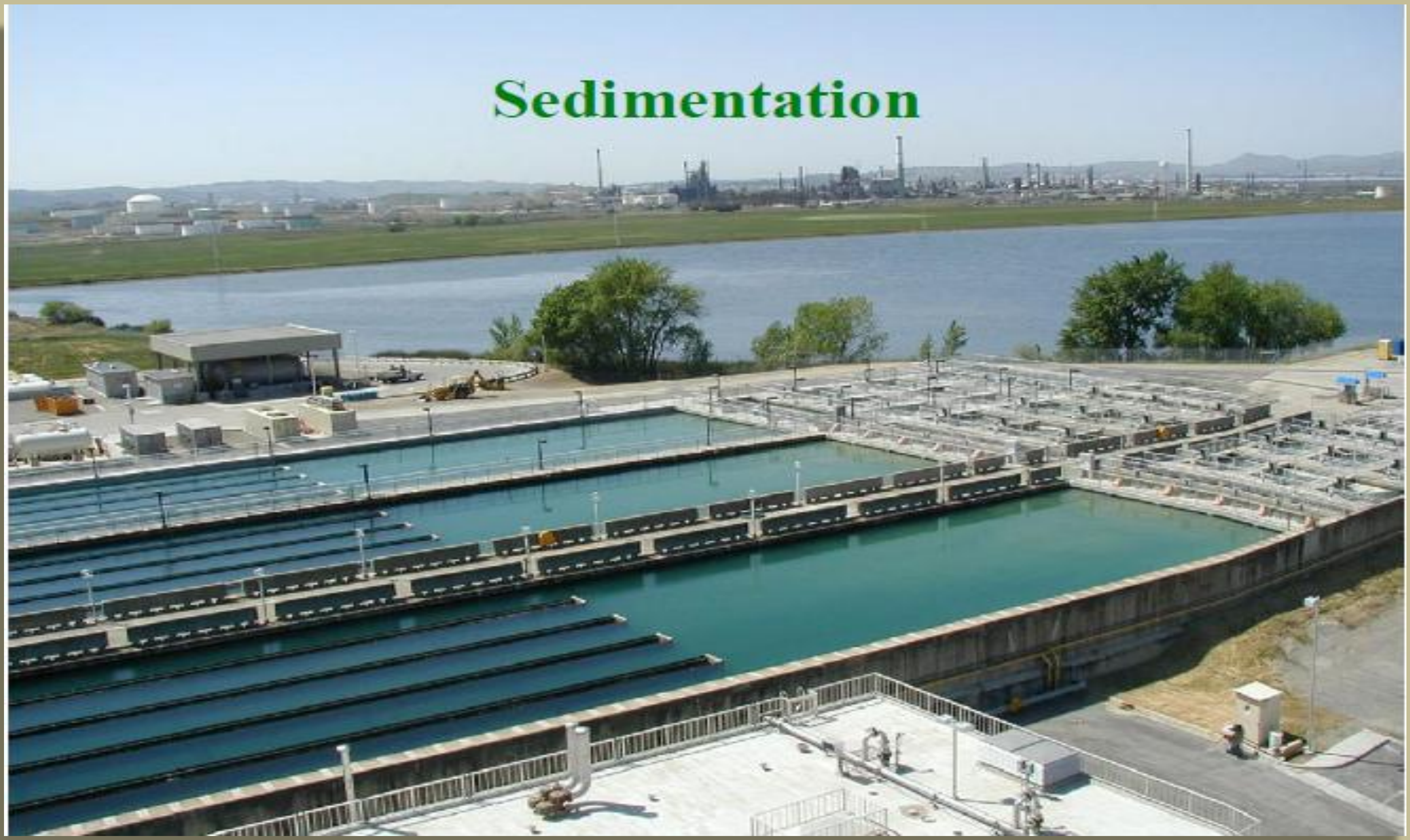
- In this method, compressed air is bubbled through the water, so as to thoroughly mix it with water.
- By Using Trickling Beds
- In this method, the water is allowed to trickle down the beds of coke, supported over perforated trays, and arranged vertically in series.

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



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= $\dfrac{\text{Flow through period}}{\text{Detention Period}}$

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 (m^3/day) / Surface loading rate (m^3/m^2/day)**

$$A = \frac{\text{Rate of flow } (m^3/\text{day})}{\text{Surface loading rate } (m^3/m^2/\text{day})}$$

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

$= 500 \times 5$

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 x 60
- = 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

= 1.6×10^6 lit/day= 66.66 m^3/hr.

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

= 66.66 x 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 x 4 x 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= $\dfrac{Q}{L \times B}$

= $\dfrac{1.6 \times 10^{6}}{36 \times 2.4 \times 24}$ 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
- = $\frac{\text{Volume of tank}}{\text{Length of the tank}}$

= $\frac{2083.30}{60}$

=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

$$SLR = \frac{Q}{A}$$

$$\frac{10 \times 10^{-3}}{60 \times 10}$$

$= 16.66\ m^3/m^2/day$

Within limit so design is O.K.

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