Urban Utilities Planning: Water Supply, Sanitation and Drainage
Prof. Debapratim Pandit
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Module - 06
Water quality, testing, treatment
Lecture - 29
Water Treatment Part II

Welcome back. In lecture 29, Water treatment (2nd part) will be discussed.

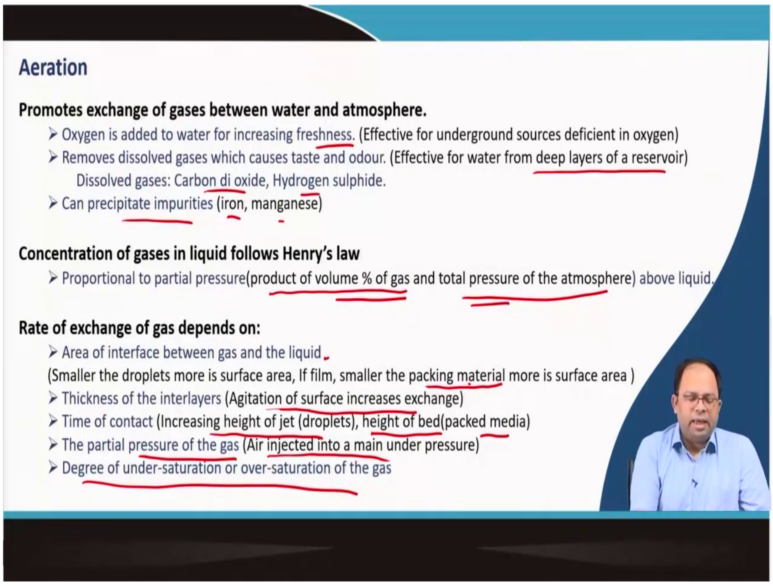
(Refer Slide Time: 00:32)

The concepts covered in this lecture include

- Aeration
- Plain sedimentation, and
- Coagulation, flocculation and clarification.

Aeration

(Refer Slide Time: 00:45)



Aeration is the process that promotes the exchange of gases between water and the atmosphere.

- Oxygen is added to water to increase its freshness - it is effective when it is extracted from underground sources which are deficient in oxygen as it is not in contact with the atmosphere.

- Removal of dissolved gases such as carbon dioxide and hydrogen sulphide, which causes taste and odour – This is effective for water from deep layers of a reservoir.

- Aeration can precipitate impurities - such as iron and manganese by the formation of certain oxides.

Henry's law - Concentration of gases in liquid follows Henry's law which states that gas concentration is proportional to the partial pressure above the liquid. Partial pressure means the product of the volume of percent of gas and the total pressure of the atmosphere. This principle is used in the process of aeration.

The rate of exchange of gas depends on many factors, and these are utilized to design different aerators for the water treatment process.

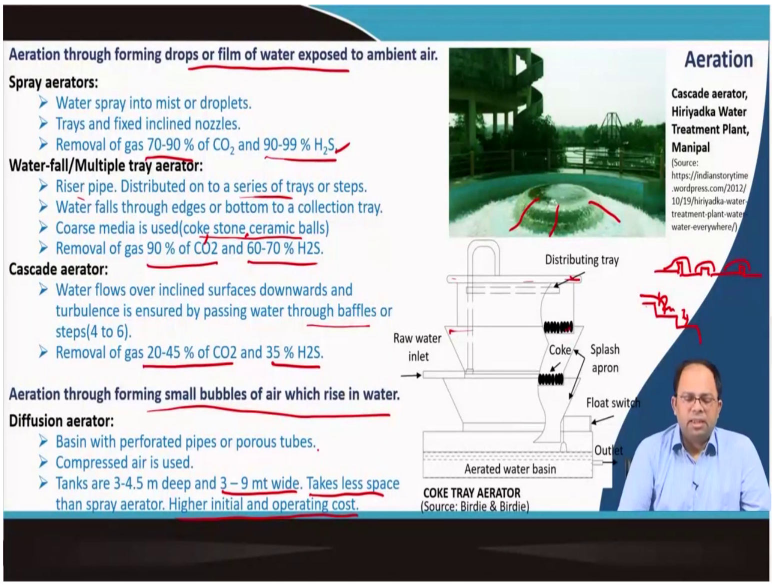
Area of interface between gas and liquid - More area results in more exchange. The smaller the droplets, the more is the surface area and hence more is the exchange. If the water is applied as a film or a layer over packing material or a filtered media such as activated carbon/coke/brickbats; the smaller the packing material, the more the surface area, which results in more exchange.

The thickness of the interlayers - Agitation of the surface increases the exchange. Increasing the height of the jet or droplets from which it is sprayed, allows it to remain in contact with air for a longer time, and hence more exchange happens. Similarly, if it comes in contact with other packed media, more exchange would happen if there is more time of contact.

The partial pressure of the gas - Air injected into a main under pressure as more pressure would increase exchange.

Degree of under-saturation or over-saturation of the gas - The existing percentage of gas in the liquid determines the rate of this aeration. As stated in Henrys law, there is a percentage volume of gas as well as the total pressure that play a role in determining the exchange of gas.

(Refer Slide Time: 04:37)



Aeration is achieved through the formation of drops or films of water exposed to ambient air. This is achieved with various kinds of aerators.

Spray aerator – Water is sprayed in the form of mist or droplets. It consists of trays and fixed inclined nozzles. The inclined nozzles spray water downwards, and the tray collects the water as it comes down. This system helps remove gas to 70 to 90 percent of CO_2 and 90 to 99 percent of H_2S. This system is adopted based on the constituents to be removed.

Waterfall or multiple tray aerators – The sprayed water is collected in multiple trays. Water is raised up with the riser pipe and sprayed and distributed to multiple trays. The figure shows the multiple trays and the filter media over which water is passed through. Water comes in contact with air, and different gases also get removed. The bottom basin collects the water as it falls down. Water falls through the edges or bottom to a collection tray at the bottom. Coarse media is used, such as coke, stone, and ceramic balls etc. are employed. Removal of gas 90 percent of CO_2 and 60 to 70 percent of H_2S.

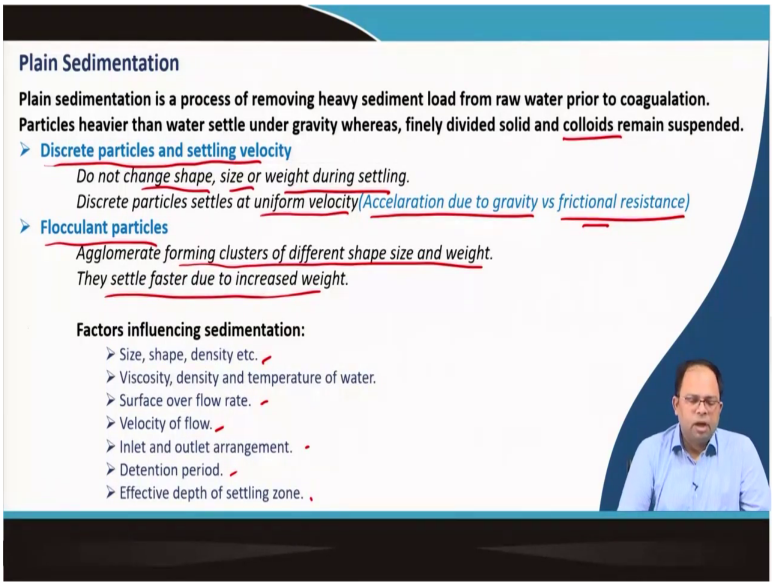
Cascade aerators - Water flows over inclined surfaces downwards, and turbulence is ensured by passing water through baffles or steps (4 to 6). Turbulence is caused by the flow of water, which helps in the mixing of water with air. Steps or baffles could be adopted to achieve this.

Removal of gas is 20 to 45 percent of CO_2 and 35 percent of H_2S. The effectiveness is less, but the system is easier to construct. Example: Hiriyadka Water Treatment Plant in Manipal

Diffusion aerators – consists of a basin with perforated or porous pipes. Aeration is achieved by allowing compressed air through perforated pipes inside water, resulting in bubbles that rise through the water and help in the mixing of water with air. The tanks are 3 to 4.5 meters deep and 3 to 9 meters wide and occupy less space than the spray aerator. Based on the capacity of the aerator and the determined flow rates, the required number of units can be known. This system requires higher initial and operating costs.

<u>Plain Sedimentation</u>

(Refer Slide Time: 08:42)



Plain sedimentation is the process of removing heavy sediment load from raw water prior to coagulation. Particles heavier than water settle under gravity whereas finely divided solid and colloids remain suspended. Coagulants are mixed with water and the sediments are removed with clarifiers. Sedimentation is employed in both plain sedimentation as well as coagulation with sedimentation.

<u>Discrete particles and settling velocity</u> – Discrete particles doesn't change shape, size, or weight during settling and settle at uniform velocity. Understanding the velocity is important because it determines the amount of time that will be taken for sedimentation. Settling

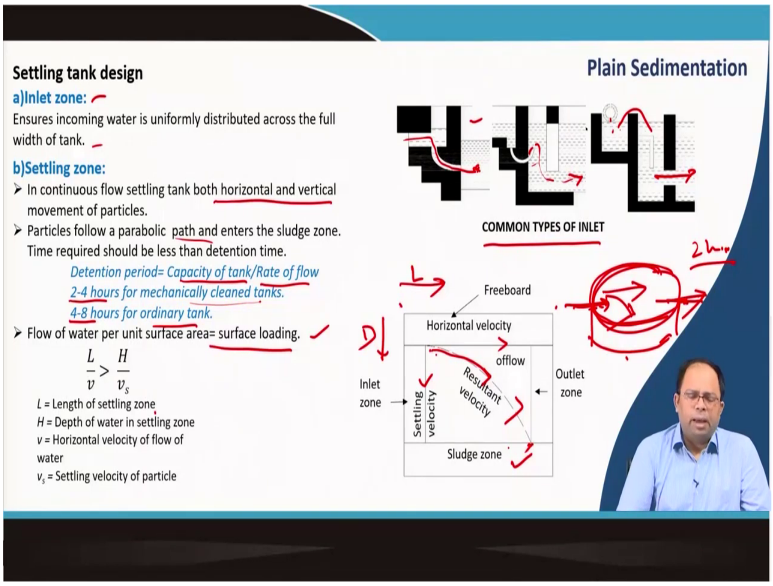
velocity is determined by both the acceleration due to gravity as well as the frictional resistance corresponding to the particular liquid.

<u>Flocculant Particles</u> - Whereas, in the case of flocculant particles, agglomerates form clusters of different shape, size, and weight. Thus, the weight increases making the settling faster. The factors that influences the process of sedimentation includes:

- The size, shape, density etc.
- Viscosity, density, and temperature of water because it influences the frictional resistance.
- Surface overflow rate – the rate at which water is flowing into a particular chamber.
- The velocity of flow.
- Inlet and outlet arrangement.
- The detention period – the period for which water is to be retained.
- The effective depth of the settling zone – refers to the depth of a particular tank.

Settling tank design

(Refer Slide Time: 11:54)



Sedimentation tank consists of an inlet zone, settling zone, sludge zone and the outlet zone.

− Inlet zone: Inlet ensures incoming water to get uniformly distributed across the entire width of the tank. The common types of inlets and the flow of water are shown in the figure. It is important to ensure that water gets uniformly spread across the tank.

− Settling zone: In a continuous flow settling tank, water continuously flows. So, The volume of the tank depends on the time up to which the water has to be retained. In a continuous-flow settling tank, both horizontal and vertical movement of particles happen. It moves from the inlet zone to the outlet zone; Along with this, the gravitational effect causes the resultant velocity as represented in the above figure. So, the particles follow a parabolic path and enter the sludge zone, the size of the sludge zone in a particular tank should also be carefully determined. The time for the particle to start from the inlet zone and to move towards the sludge zone should be less than the detention time.

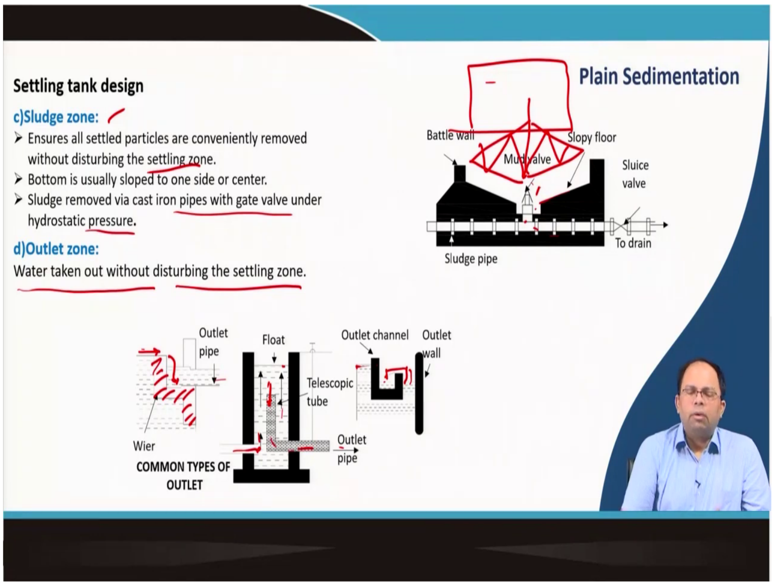
Detention period = Capacity of the tank / rate of flow.

For mechanically cleaned tanks where the sludge is removed mechanically after certain intervals, 2 to 4 hours of time is taken. For normal tanks, where mechanical cleaning is not employed, it takes 4 to 8 hours. This determines the tank sizes. The flow of water per unit surface area is the surface loading, i.e., the amount of water to load per square meter of the surface. Surface loading rates have to be considered depending on the tank type because water spreads all over the tank's surface before it starts to fall down. The following relationship is as follows:

$$\frac{L}{v} > \frac{H}{v_s}$$

Where L is the length of the settling zone, H is depth of water in the settling zone, v is the horizontal velocity of flow of water, and v_s is the settling velocity of particles.

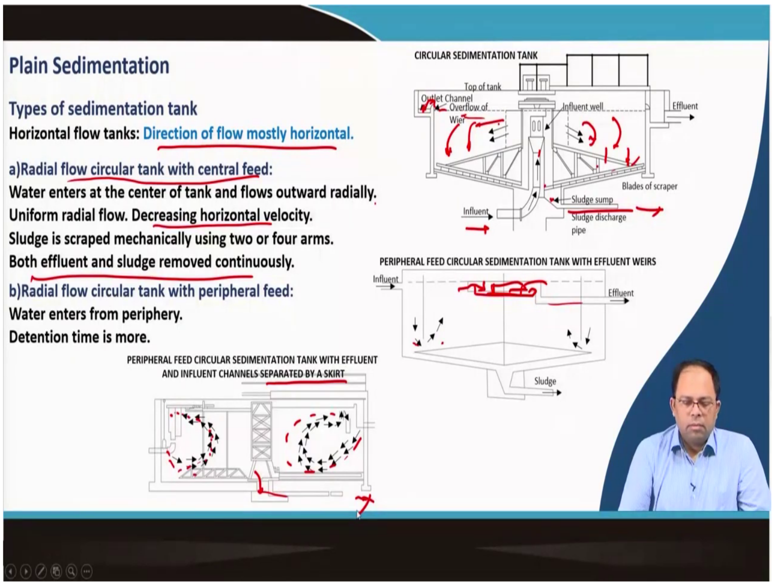
(Refer Slide Time: 16:05)



- <u>Sludge zone</u> ensures that all the settled particles are conveniently removed without disturbing the settling zone. The inclined surface is given at the bottom, and the sludge gradually moves downwards; there are mechanical means for scrapping the sludge. This is done by employing rotating arms which moves the sludge towards the centre. The system also consists of a mud valve which is a sort of gate valve which could be operated by electricity which opens at certain intervals. The pressure conduit sucks the sludge in and allows mechanical cleaning. Sludge is removed via cast iron pipes with a gate valve under hydrostatic pressure.

- <u>Outlet zone:</u> The water that is treated at the top is taken out via outlet without disturbing the settling zone. Different outlet designs and the water flow inside them are shown in the above figure.

(Refer Slide Time: 18:17)



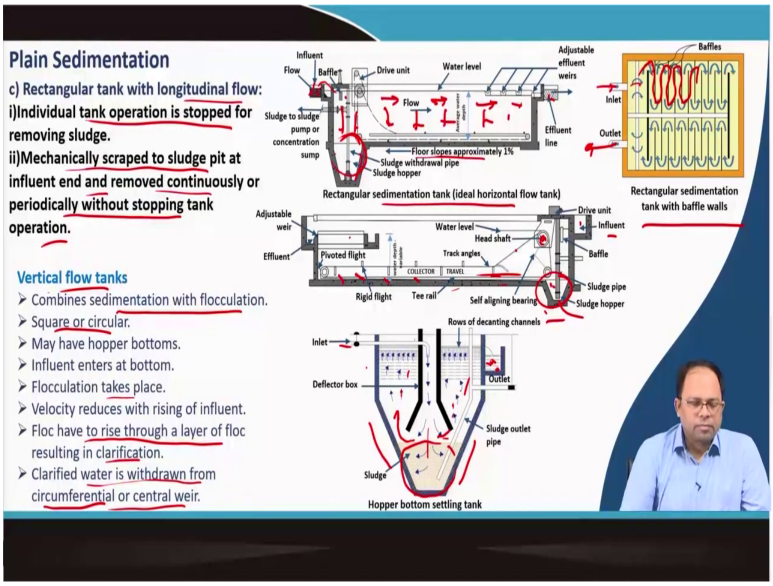
Types of sedimentation tank

<u>Horizontal flow tanks</u> - where the direction of flow is mostly horizontal. Horizontal flow tanks are also of multiple types.

a). *Radial flow circular tank with central feed* – Influent is fed from the bottom centre. The circulation corresponding to the influent flow and how it settles and moves out is given in the above figure. Two or four mechanical arms operated by a motor moves in circular motion and scraps the sludge getting settled, and direct it towards the centre where the sludge sump is located. The sludge is discharged via the sludge discharge pipe. The water gets collected in the outlet channel and is removed. Uniform radial flow and decreasing horizontal velocity are other characteristic features.

b). *Radial flow circular tank with peripheral feed* - Here, the influent gets inside the tank from the bottom periphery and gets circulated upwards and clean water gets collected in a central channel as shown in the figure above (peripheral feed circular sedimentation tank with effluent weirs). In a peripheral feed circular sedimentation tank with effluent and influent channels separated by a skirt, the influent enters from the bottom periphery and gets circulated. The clean water moves out at the top periphery, as shown in the figure. The movement of water results in the sedimentation process. Skirt separates the influent and effluent channels. A scrapper over continuously rotates, leading to the sludge movement to the centre from where pipes remove it.

(Refer Slide Time: 21:11)

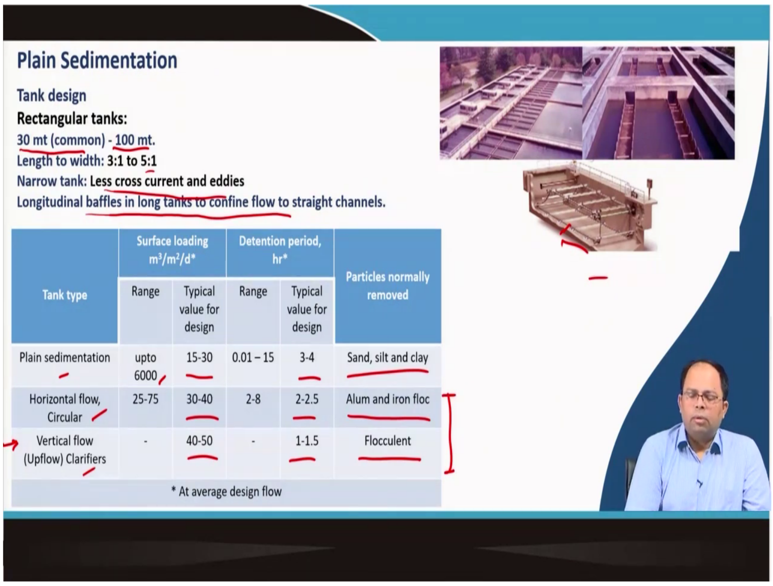


c). <u>Rectangular tanks with longitudinal flows</u> – Rectangular sedimentation tank with the longitudinal flow has multiple baffle walls. Water is conveyed continuously to pass through the baffles, as shown in the figure above (right-top). It flows out through the outlet zone. The speed of the water determines the detention time of water through the baffles. Sedimentation happens during the process. The figure of a rectangular sedimentation tank with ideal horizontal flow shows the water flow in a longitudinal direction. The effluent water is collected with the adjustable effluent weirs to the effluent line by adjusting the height of the weir in such a way that water can flow into that. Sedimentation occurs during this process, and a mechanical scrapper/belt scrapes off the sludge from the bottom to enable its collection inside the sludge hopper from where the sludge is removed. The sludge is taken back near the influent zone in the first design (refer to the above figure). Having the sludge hopper and the influent zone towards one side makes it easier for the heavier particles to settle in the sludge hopper, eliminating the movement to the tank's end and then returning to the hopper. Another design works in a similar manner as shown in the figure. A slope of 1 percent is given for the floor. The inflow of the influent and the sludge removal can be done simultaneously or otherwise. If it is done simultaneously, tank operation has to be stopped for removal of sludge when required. There are vertical flow tanks; the inflow of the influent from the top is first conveyed towards the bottom centre and is then circulated towards the top, where the water moves across multiple layers, and the clean water flows out of the outlet. In such systems, as the water rises up, the velocity decreases, and the sedimentation increases, resulting in the collection of the sludge at the bottom.

- Vertical flow tanks employ a combination of sedimentation and flocculation.
- The tank shape can be square or circular.
- The tanks can have hopper bottoms.
- Influent enters at the bottom.
- Velocity reduces with the rising of influent.
- Floc have to rise through the layer of floc resulting in clarification
- Clarified water is withdrawn from the circumferential or the central wheel.

<u>Tank design:</u>

(Refer Slide Time: 27:58)



Rectangular tanks:

- 30 mt (common) - 100 mt.
- Length to width: 3:1 to 5:1
- Narrow tank to maintain less cross current and eddies

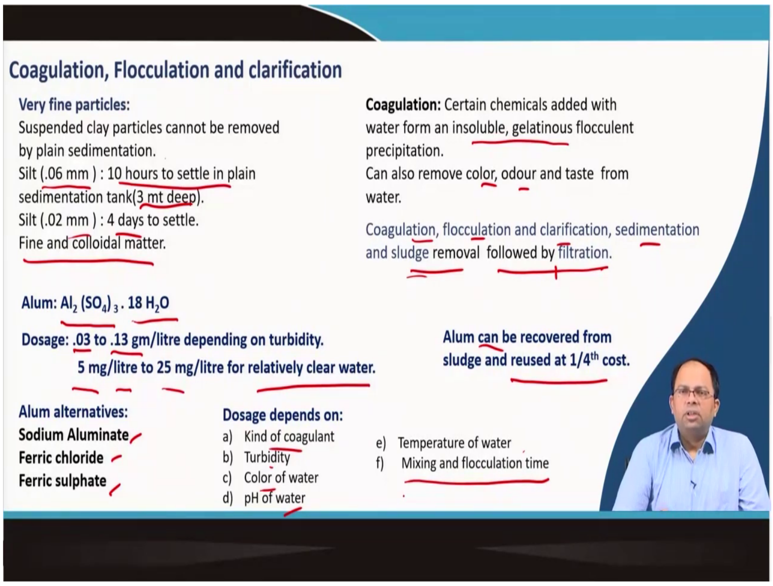
– Longitudinal baffles in long tanks to confine flow to straight channels

The above image shows the longitudinal flow tank and the mechanical scrapping component.

Tank type	**Surface loading $m^3/m^2/d$***		**Detention period, hr***		**Particles normally removed**
	Range	Typical value for design	Range	Typical value for design	
Plain sedimentation	upto 6000	15-30	0.01 – 15	3-4	Sand, silt and clay
Horizontal flow, Circular	25-75	30-40	2-8	2-2.5	Alum and iron floc
Vertical flow (Upflow) Clarifiers	-	40-50	-	1-1.5	Flocculent
* At average design flow					

Coagulation, flocculation, and clarification

(Refer Slide Time: 29:57)



Very fine particles such as suspended clay particles cannot be removed by plain sedimentation. Other particles involve silt, fine and colloidal matter etc. Silt takes different time to settle based on its size, such as:

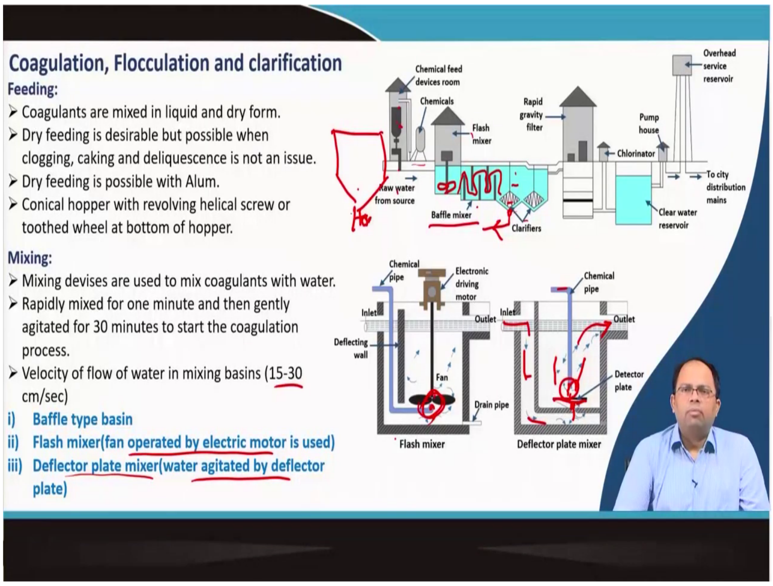
Silt (.06 mm): 10 hours to settle in a plain sedimentation tank (3 mt. deep).

Silt (.02 mm): 4 days to settle, which is not feasible owing to the requirement of time as well as such a large tank size.

Similar is the case for the fine and colloidal matter.

In order to achieve the removal of all these, certain chemicals (ALUM) are mixed with the water, which forms an insoluble, gelatinous flocculant precipitation and thereby removes colour, odour and taste from water to a certain extent. The entire process will involve coagulation, flocculation, clarification, sedimentation and sludge removal followed by filtration because the water doesn't become clear after clarification. $Al_2(SO_4)_3$ and $18H_2O$ are the other chemical involved. Huge tanks may be required to store such chemicals. Dosage is .03 to .13 gm/litre depending on turbidity and 5 mg/litre to 25 mg/litre for relatively clear water. Alum can also be recovered from sludge and could be used at one-fourth of the cost. This helps save costs but requires additional systems. Alternatives to Alum, sodium aluminate, ferric chloride, and ferric sulphate can be used. The dosage depends on turbidity, kind of coagulant, colour and pH of water, and temperature of water mixing and flocculation time.

(Refer Slide Time: 33:26)



The process of coagulation, flocculation, and clarification starts with the process of feeding.

Feeding:

- Coagulants are mixed in liquid and dry form.
- Dry feeding is desirable but possible when clogging, caking and deliquescence is not an issue.
- Dry feeding is possible with Alum.
- Conical hopper with revolving helical screw or toothed wheel at bottom of hopper. Valves can be used to release the chemicals.

Mixing:

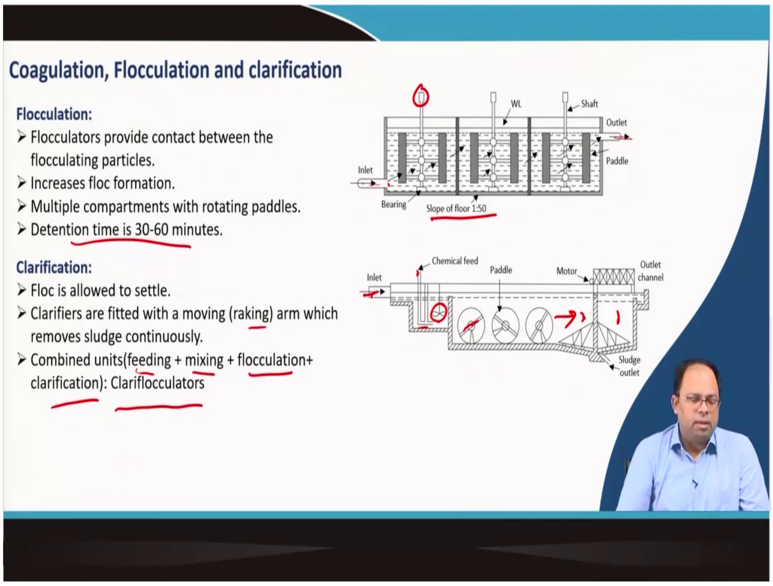
- Mixing devices are used to mix coagulants with water and rapidly mix for 1 minute and then gently agitated for 30 minutes to start the coagulation process.
- The velocity of flow of water in the mixing basin is around 15 to 30 centimeters per second.

Mixing can happen in different ways:

The figure (right top) shows the different components involved, such as the influent line, chemical storage tank, hopper, flash mixer (which has a fan-operated by an electric motor to mix the chemicals with water in a rapid manner), baffle walls resulting in slow mixing, clarifiers allowing the flocs which settle via sedimentation. The sludge can be removed, and the clear water moves to the rapid gravity filter.

Deflector plate mixer - deflector plate agitates water. The circulation of water is shown in the figure (bottom right). The up and down movement of the deflector plate results in mixing. The mixed water moves to the next chamber

(Refer Slide Time: 36:25)



<u>Coagulation, Flocculation and Clarification</u>

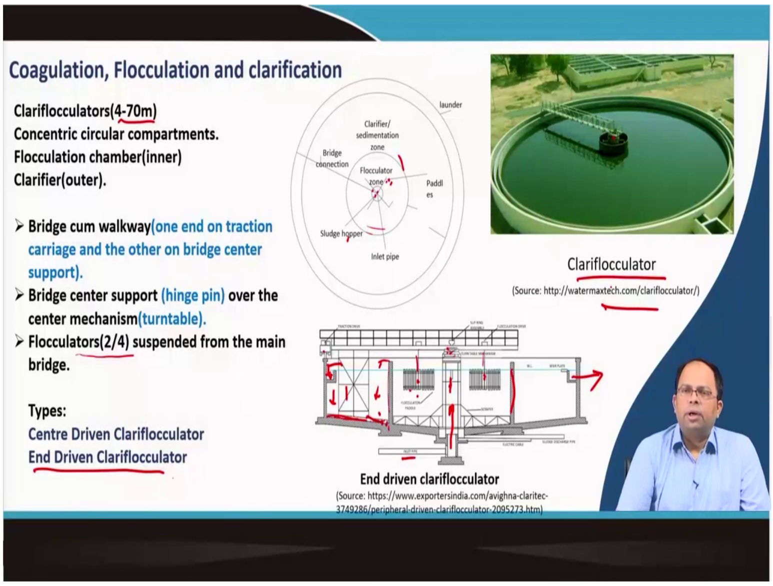
Flocculation

Flocculation is the continuous mixing of the liquid and the chemical to form further coagulants helping the process of coagulation. Flocculators provide contact between the flocculating particles, increasing the floc formation because more particles join together. Such systems consist of multiple compartments consisting of rotating paddles operated by motors to keep on churning the water to help in further mixing. The detention time is 30 to 60 minutes. The slope of the flow is around 1 to 150. The figure shows that the inlet is from the bottom, and the outlet is from the top.

Clarification

This is the final process where the floc is allowed to settle. Clarifiers are fitted with a moving or raking arm, which removes sludge continuously. Combined units called clariflocculators are employed, which do feeding, mixing, flocculation, and clarification. As shown in the figure (right bottom), the inlet, chemical feed, flash mixer (to mix the chemical), rotating paddles (to help to mix of the chemical) can be observed. The clarifier helps in removing the sludge after sedimentation. The entire unit is called a clariflocculator. These processes can occur in separate units as well.

(Refer Slide Time: 38:19)

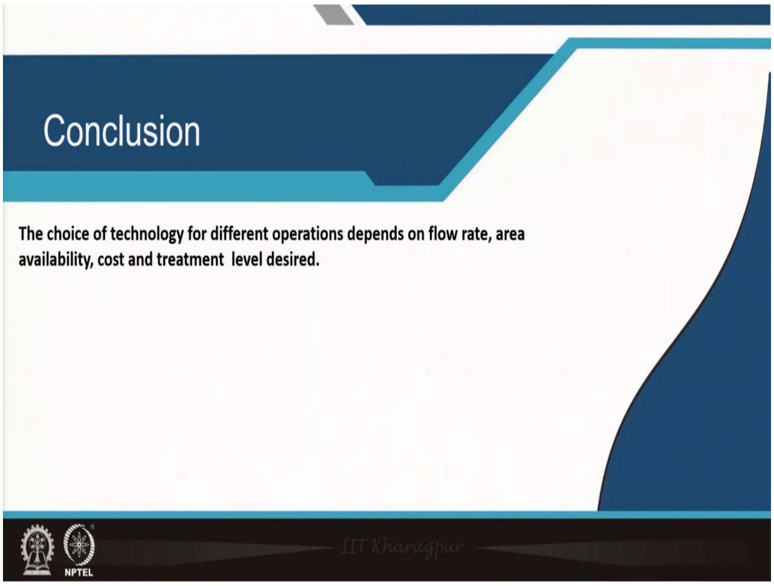


Clariflocculators are of different designs. The above figure shows a circular clariflocculator. A bridge is fitted at the centre (hinge pin and is loosely fitted to allow the rotating movement), which is in the flocculation zone. The bridges can rotate and are fitted with paddles which helps in mixing and floc formation. The sectional elevation shown in the figure shows the inlet, which is at the bottom. The circulation pattern of influent is shown in the figure. The water settles towards the periphery, and a clarifier scrapes the settled sludge. The sludge is collected from the bottom. The clean water goes into the peripheral channel, and the effluent can be collected in the outlet zone. Clariflocculators can be of different sizes ranging from 4 meters to 70 meters. 70 metres could be in the form of concentric circular compartments.

In the clariflocculator unit shown in the figure, the inner zone is the flocculator zone, the outer zone is the clarifier or the sedimentation zone, the sludge hopper is fitted below, inlet pipe at the centre, and the bridge attached with paddles. Bridge cum walkway has its one end on traction carriage and the other on bridge centre support. Around 2 to 4 flocculators paddles are suspended from the main bridge to allow mixing. The different types of such combined units are center driven clariflocculators (as shown in the figure), and end driven clariflocculator i.e., a system where rotation is from the side.

Conclusion:

(Refer Slide Time: 41:25)



The choice of technology for different operations depend on flow rate, area availability, cost, and desired treatment level.

References

(Refer Slide Time: 41:48)