Water and Waste Water Treatment

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Lecture -27
Secondary Clarifiers and Attached Growth System

Hello everyone welcome back to the latest lecture session. In the past 10 or 15 sessions we have been looking at removing one set of compounds or the other from the water, grit, coarse screens and then headworks, preliminary treatment. Primary treatment we looked at suspended solids. In secondary treatment we oxidized most of the organic content S or BOD and what do we have after the secondary treatment or after part of the aeration.

We have still a lot of microbes but they are relatively floc forming or microbes that can form flocs and can settle out. So still you have water which is relatively free of soluble organics or soluble COD but you have microbes so you need to remove that or those microbes by settling them down. So in the case of settling our friend is gravity and we looked at Stokes law. We looked at sedimentation earlier when we are talking about wastewater treatment in the context of preliminary or mostly primary treatment.

So, here same principles, so we will not go into detail. What do we have? we have the secondary clarifier or secondary sedimentation tank. The first segmentation tank we looked at removal of suspended solids here we are trying to remove the suspended what is it now microbes or such which have formed flocs. So that is the aspect out here.

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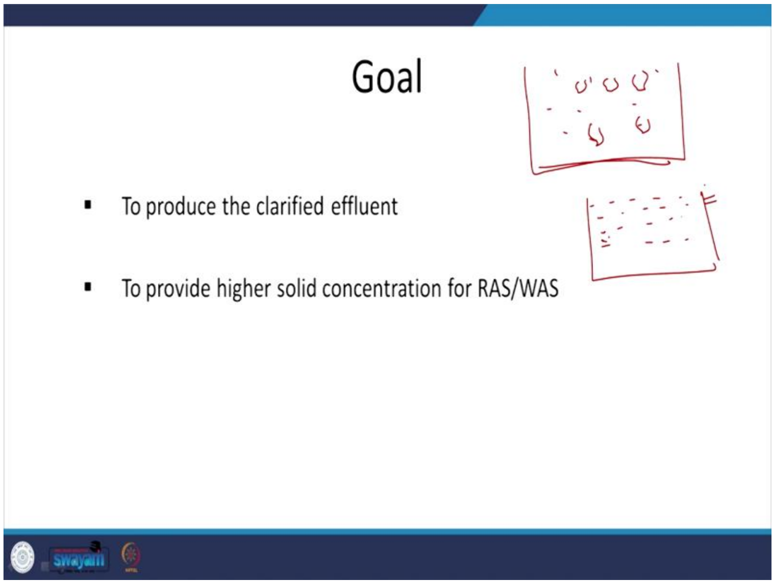

Goal let me write it in this way so I have the relevant flocs out here and this is my water. Now I cannot use this but given enough time what is going to happen I am going to have clarification I will have water that is relatively clarified and this as we saw in the video is the supernatant decantation we looked at that. So we are going to have clarification one aspect is clarification. What will this lead to it? will lead to water that has rest suspended solids.

Otherwise all my microbes will come up as suspended solids and then all the flocs would have settled down. So this is what I want but I am not just concerned about this I also need to look at this part of it will be recycled part of it will be wasted. So even the cost of recycle and treatment after wasting this is recycle this is sludge treatment or wasting. What do I do I need to transport it somewhere or look at anaerobic direction .

If the volume is high or the mass is high the cost will be high so there I want to see to it that thickening of sludge happens such that most of the water within these particular flocs is removed. So, two aspects; clarification of the water or supernatant above and good thickening of the sludge, so, that the water is coming out of this particular sludge. So what are the relevant processes involved.

Let me see what else I have here to produce the clarified effluent and to provide higher solid concentration in return activated sludge or such how will we provide higher solid concentration?

By removing the water if I have more water in the sludge the solid concentration is going to be less.

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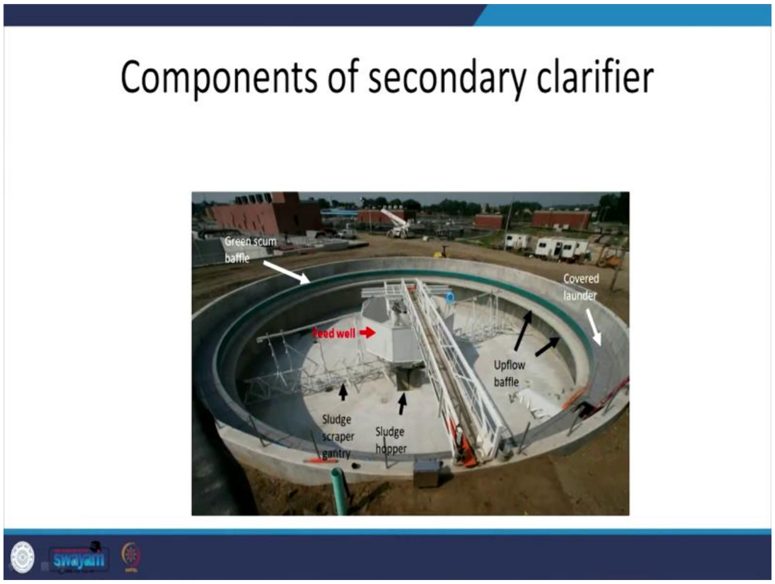

So this is what a clarification tank looks like so we looked at this. This is a circular one relatively easy to build and maintain that is what we already know. You have the sludge scraper here this is how sludge will be scraped and this is in this kind of a shape this is the side view. It will collect or the sludge will collect here sludge hopper and where is the water going to come from? From the center here.

You can see the center top flow and then it will flow radially and the covered launders are such here upflow baffles. Yes you have the baffles out here. So that you have the cuisine or laminar flow conditions yes that is what you are going to have. Yes and this is the green baffle scum yes and you can walk here and for maintenance . The MLSS is going to come from the bottom go up and then it is going to go out here.

And during that time the flocs will settle down to the bottom. Once they settle down to the bottom they will be scraped by the sludge scraper into this hopper. So that is what do we, say working if I may say so.

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And how does it look like this is what it looks like. So you can see in the internal basin the quality of the water and by the time it goes out here this is where your effluent will be the treated effluent and that is where you see it is relatively better. And depending upon the maintenance of such you can have scum or even sometimes nocardia foaming but forming typically in the aeration tank not here but you can see this scum being removed by this scum scraper or such here. So you see the baffles and then the treated water this is the treated water here.

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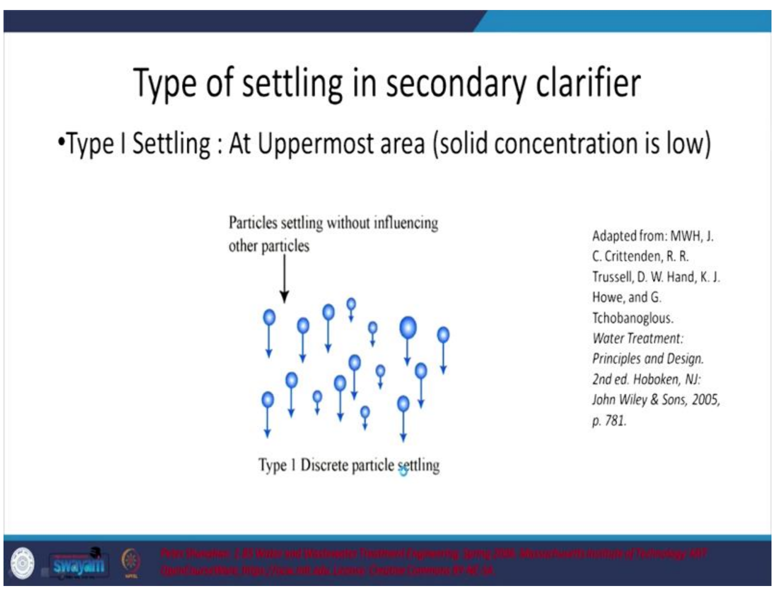

So what else we have what are the types of settling we will encounter. In general if you look at it holistically. So in the top zone how is the clarification occurring you have solids coming down.

So you can say it is maybe zone settling because we saw this in our video where I just took out the MLSS put the put it there and it settled within 30, 40 seconds thickening we did not see that there.

But it is not so straightforward where else or what other kinds of settling we take look at. Type one settling discrete each particle does not influence the other or interfere the settling of the other particle. This occurs in the topmost layer not much but topmost layer and solid concentration where solid concentration is relatively low.

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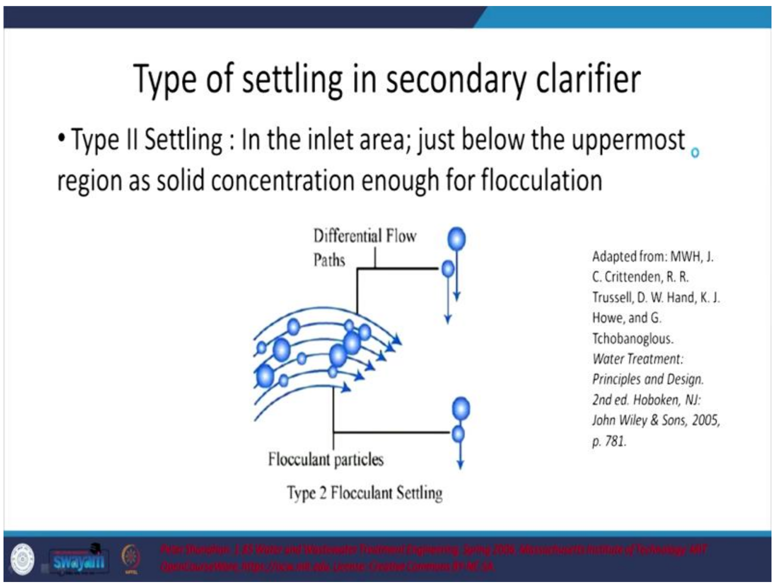

And type two settling this typically occurs in the inlet area. If it is rectangular or even if it is up flow during that inlet area you will have the solid particles flocs coming in contact with each other bigger flocs being formed. So just below the upper most regions as solid concentration is high enough for flocs being formed. So that is when you are going to have here you are going to have or inlet area type 2 and where the concentration is less at the upper most reaches it is going to be type 1 settling.

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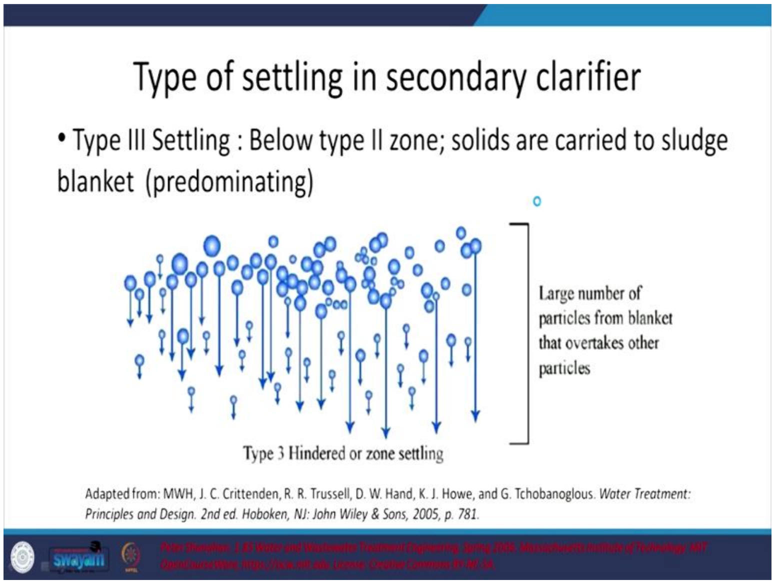

And below type two zone solids are carried to sludge blanket type three settling zone settling that is what we see. So it is zone settling here. And one aspect here is there is going initially there is going to be the velocity is going to be relatively constant but as the solid concentration in this zone increases the water will find it difficult to find space to move out. The water has to move out, yes so that will take as the concentration increases that will be difficult.

So the velocity at which this zone comes down will decrease with increasing concentration within this zone. So, large number of particles forms from blanket form blanket that overtakes other particles. It more or less traps and take it down so this is what you would see beneath that zone two.

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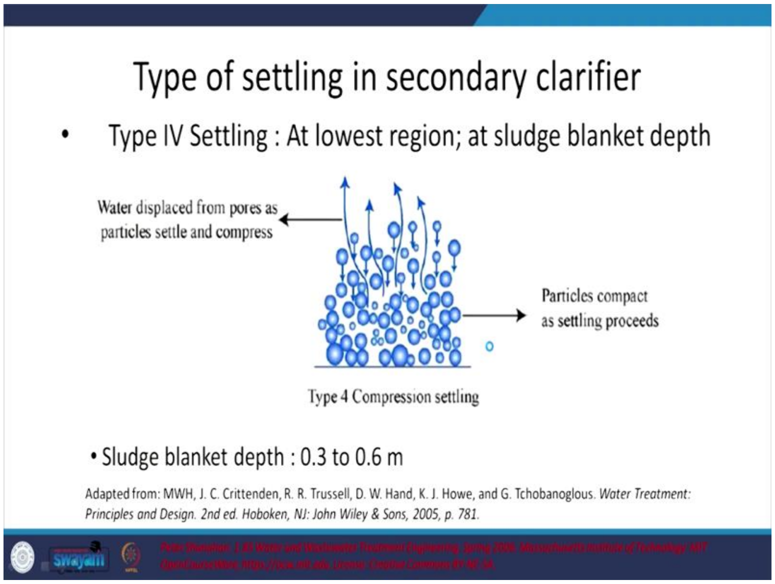

And in the lowest region where it is we are talking about thickening. So this one, two and primarily three primarily three will look at clarification, yes. And with respect to thickening what is happening here type four settling at low earth region and at sludge blanket depth. Water is displaced from the pores because the particles settle down and compress the lower regions. So due to that weight if I may say so or mass the water is squeezed out.

So that is the type 4 settling so compaction occurs in a way. Particles compact as settling occurs typical sludge bank at depth is 0.3 to 0.6 meters. So that is another aspect you do not have want to have a very thick sludge blanket because then you are going to start having anaerobic conditions and relevant issues.

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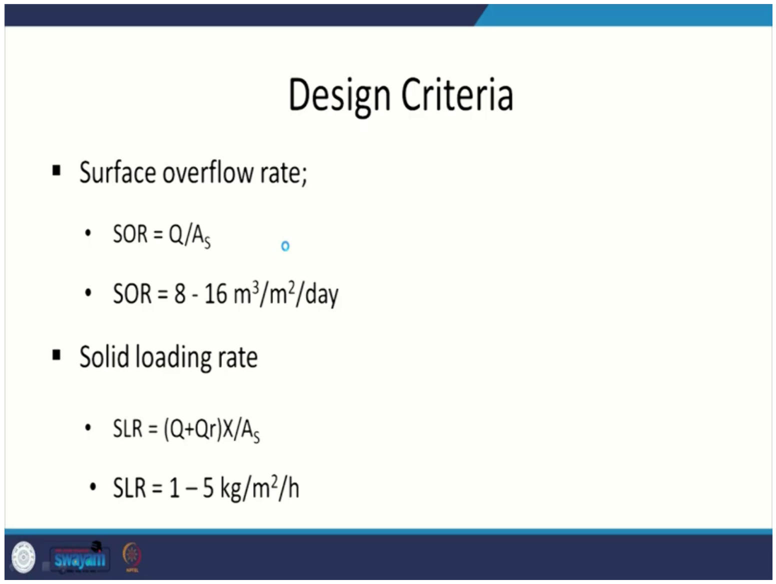

So design criteria what is it that I am concerned about here it is sedimentation. So surface overflow rate is an issue Q by the; what is it plant surface area so that is what we have. And typically we want surface overflow rate to be between 8 to 16 m^3/m^2/day. Meter cube per day (m^3/day) is the unit of Q, meter square (m^2) is the unit of the surface area. And solid loading rate why is this important?

Solid loading rate is when you have this and water is coming in here. So Q is coming from here and Q_R is coming here. So what will also be here Q + Q_R and we know that the microbial concentration here is X so (Q + Q_R) x X will give me an idea about the mass of the microbes coming into my sedimentation tank and divide that by area I get this sludge loading rate per unit area.

So I want that to be looks like 1 to 5 kg/m^2/hr. Why is that looks like if I increase it further the sludge blanket depth will increase. And if that increases what is going to happen you are going to have septic conditions and relevant decomposition there you do not want that to happen within your secondary settling tank. So that is something to keep in mind with respect to solid loading rate. So my PhD student Bharat informed me about this.

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So thanks to Bharat, so design criteria as I mentioned depth is also relevant because it plays considerable role that is what people saw empirically too. And 3m if the surface area is greater than 28 m^2 less than this these are typical thumb rules .

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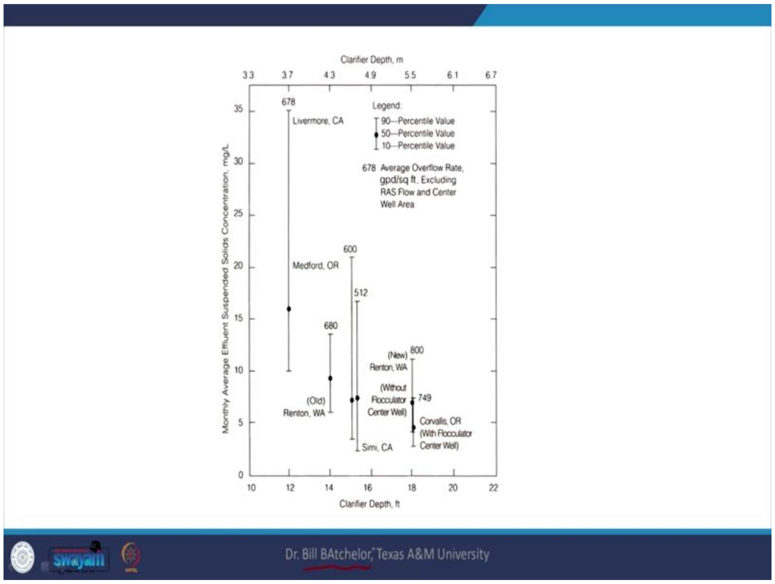

And here is where we see one graph which I got from Dr. Bill Bachelor my PhD advisor whom I learned everything from rather not just this particular graph . So what do we have out here monthly average effluent suspended solids concentration? So here I have the suspended solids concentration in the treated wastewater and here I have the clarifier depth but this is in feet. As you see with even 12 feet I think 3 feet is equal to approximately equal to 1 meter.

So 4 meter here as such but for these kinds of plants we do not know how they are maintaining it. At relatively higher depth around 16 or 18 m, depth that is when you saw very low suspended solid concentration. So you see that here we have it in meters 3.7 meters to 5 meters. So around 4 to 5 meters looks like was this sweet spot for most of these plants. And what was the average overflow rate it is 678 gallons/day/ft^2.

So that is one aspect that you can use to compare. So what else do we have to look at. Until now we looked at suspended what we say systems the microbes were suspended in the water. We have microbes that were suspended in the water and mostly it is because we were providing air from the bottom in the video you would have seen a fine bubble diffuser that I held in my hand water goes in and very fine bubbles come in.

So you are going to have a suspended system that is what we saw until now sequential batch reactor or activated such process or such. Another such type of system is the attached growth system. So here it is not suspended for example for an example of attached growth so when drains or such are places which are frequented by what we say water or which frequently come in contact with water with organic content you see green or slimy layer.

So that is attached growth you have a media or a surface onto which your microorganisms attach and you have a biofilm developing. So that is an attached growth system.

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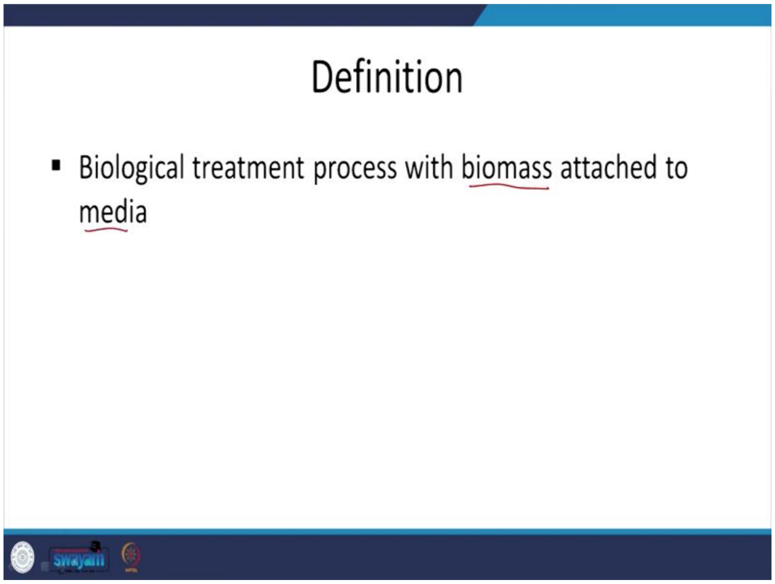

So not one for definitions you do not need to mark this up just to understand that process where the biomass is attached to a particular media. The media can be different forms for example here I have it for MBBR process moving bed biofilm reactors.

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I just have it here my son always messes around with this in my office so I am going to hold this up and in different directions relatively hollow. So inert media why do they prefer this because you have this as a combined system. You have microbes thriving on this and you can also having had this as a moving bed moving bed biological reactor.

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So here I have this suspended in the water and with aeration I am going to have what is it these being suspended water. But these will provide surface area for the microbes to grow. But if I do not keep them suspended and just leave them but then we will not use this different kind of media. So what is going to happen we are going to call that as the attached growth system. These materials provide the surface area for the microbes to attach onto or grow on so that is the relevant aspect.

So attached media but MBBR it is not a typical attached growth system it is neither here nor there but I wanted to mention that here what else we have.

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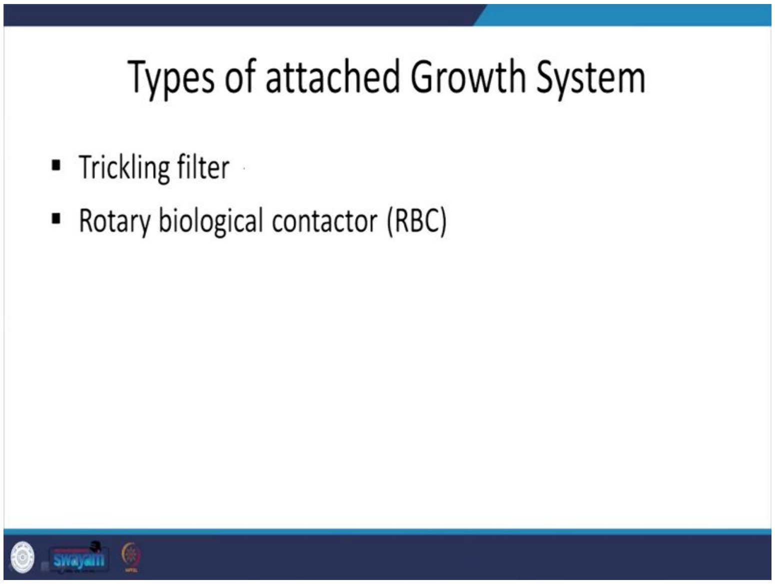

Types of attached growth so one is trickling filter and other is rotating biological contactor. So as the name indicators indicate pardon me it is a rotary or rotating biological contactor. So it is self-explanatory you have a contactor which keeps rotating we will look at that. Another one is trickling filter but when we think of filter we think of activated carbon or sand filter .

But then the; head loss will be too high and you will have clogging way too often it is not a filter but it is only different kind of media that give a surface for the microbes to thrive upon. But let us look at these aspects and move on.

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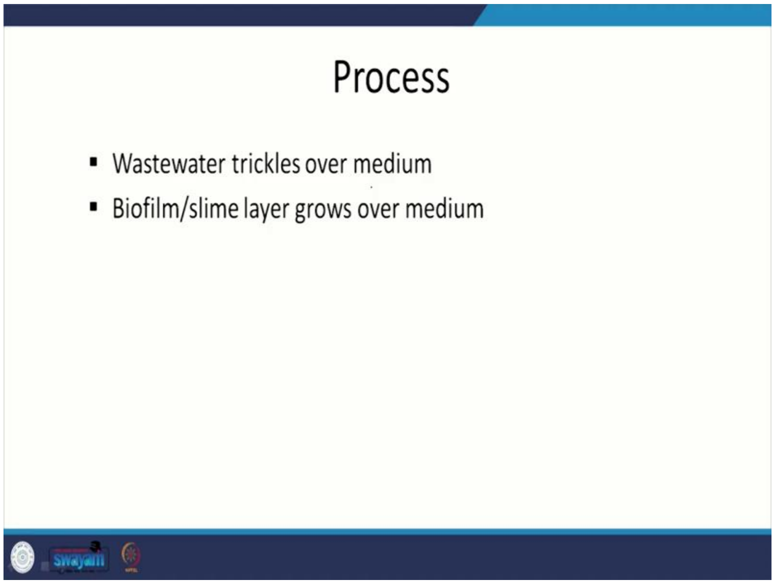

So trickling filter wastewater trickles over the medium and to use the organics or to degrade the organics in the presence of oxygen and the nutrients you are going to have a biofilm developing over the medium.

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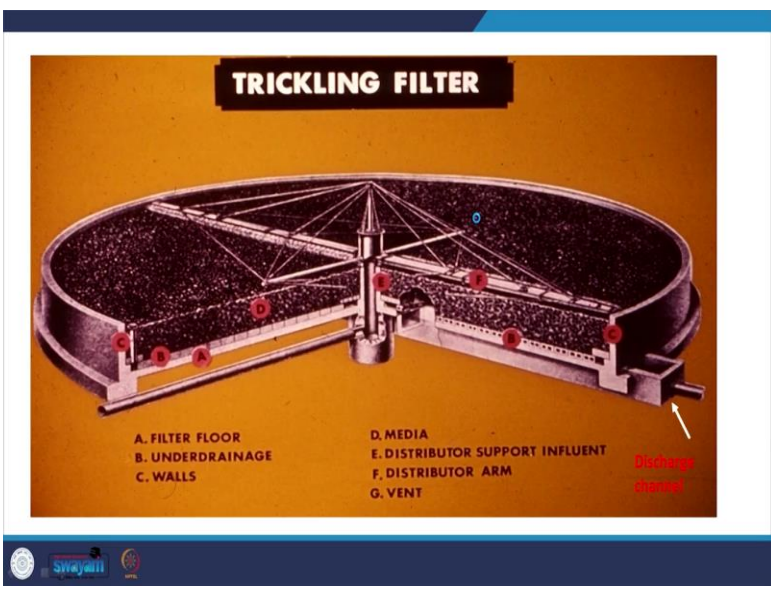

So trickling filter what is it that you have this is a typical schematic we will look at one later. So from this particular what are they calling that F distributor arm you see that water will be distributed and this will keep rotating like this and what else do we have we have the filter floor. We have the under drainage water has to drain out we have the walls, we have the media this is the media on which the microbes will grow we will look at the picture soon.

And we have the distributor support of influent where is that E, distributor support influence distributor arm and then G is the vent. So I am unable to find G out here and then the discharge tunnel.

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Let us look at this is the trickling filter that you can see. You can see various trickling filters in the background but here you can see the distributor arm and you can see the filter media. So it is not per se filter but we call that a trickling filters though. So here it is not when we say filter we talk about it in terms of physical separation of the relevant particle from the water. I have a cloth and I put in water that has a lot of sand I am filtering it out. But here it is not filtration it is actually degradation but we still call that a trickling filter.

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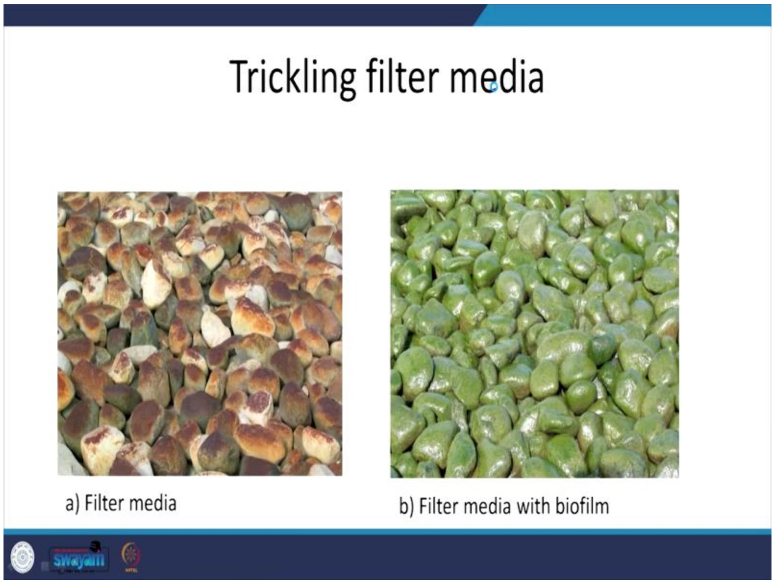

Let us look at the close-up so here you have the filtered media and after what we say the biofilm has developed due to what we say the organic content available there and the oxygen content this is what we have filtered media with a biofilm.

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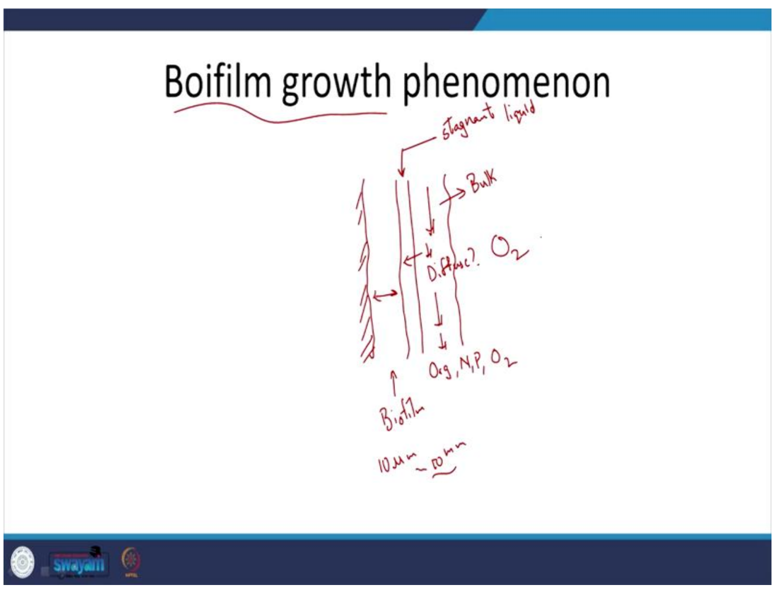

So let us just look at how the biofilm grows or such. So I have this media or the surface this is my media and on this over time the biofilm will develop. This is my biofilm and MIT open courseware tells me that it can be anywhere between 10 micrometer to even a few mm or 10 mm. So you can see that there can be a wide variation but what else will you have you will have a stagnant liquid layer here.

Stagnant liquid layer here liquid and so through this what needs to go in or what needs to diffuse through. So this is where the degradation takes place within the relevant biofilm but what has to be degraded your organic matter has to degrade and it needs your nutrients and it needs oxygen. So that is what you have these needs to diffuse through this particular stagnant liquid film here. And here you will have the bulk liquid the water that is flowing or trickling over this particular layer.

This is your bulk liquid and here you have your oxygen or the air. So that is what you have out here so that is how the biofilm looks from the side view if I may say so.

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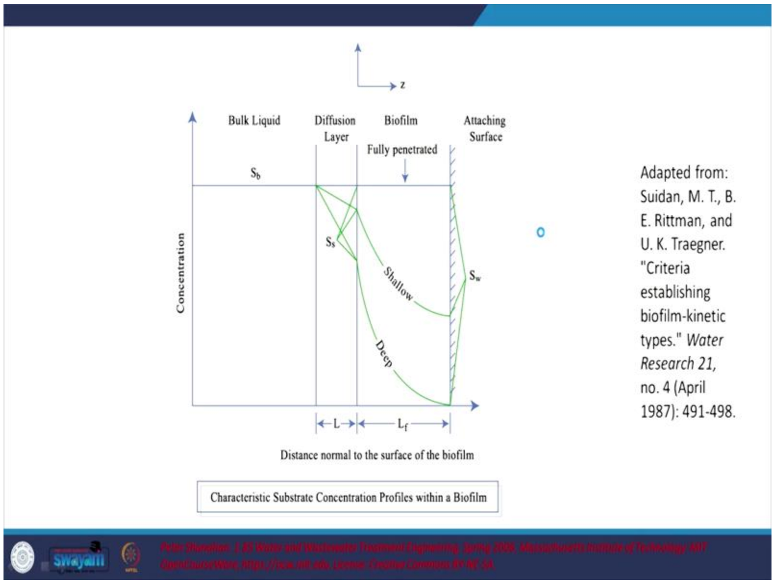

So, let us look at other data here characteristic substrate concentration profiles within a biofilm. So we are sweeping this or swapping that picture from left to here. So here is the attaching surface or the media so this is the biofilm this is the stagnant layer or the diffusion layer this is the bulk liquid. So in the bulk the surface not surface the concentration of the relevant organic matter or the substrate is going to be high.

So through the diffusion when will why will it go through the diffusion layer or why will it diffuse as we know only if there is a concentration gradient. If the gradient is concentration or such anyway varying so that is the relevant aspect. So we have shallow and we have deep let us just look at the shallow. So we have this diffusion due to concentration gradient and then you have the substrate penetrating further fully penetrated.

And with that case you are going to have degradation of the organic content within the biofilm the organic content in the biofilm will be degrading it. So that is why the concentration here will be less than what it is in the bulk liquid or bulk layer.

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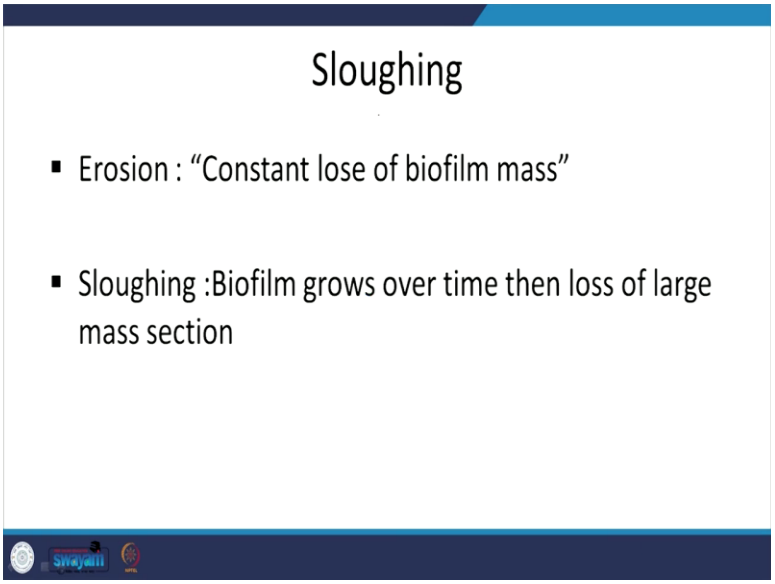

So, biofilm profile and sloughing, you have two aspects that can lead to loss of this biofilm you will have decay that is something we always know but in general you will have erosion in general you will always have this constant loss of biofilm mass. So that is what we have sloughing. Though biofilm grows over time then sometimes you see sections itself falling down. So that is called sloughing.

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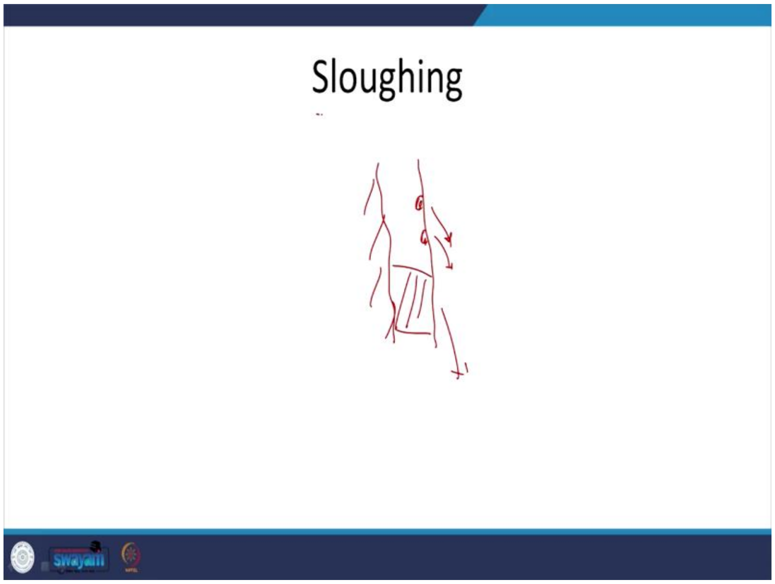

So, just a picture so if this is the media and this is my biofilm. Erosion sometimes looks like small particles .

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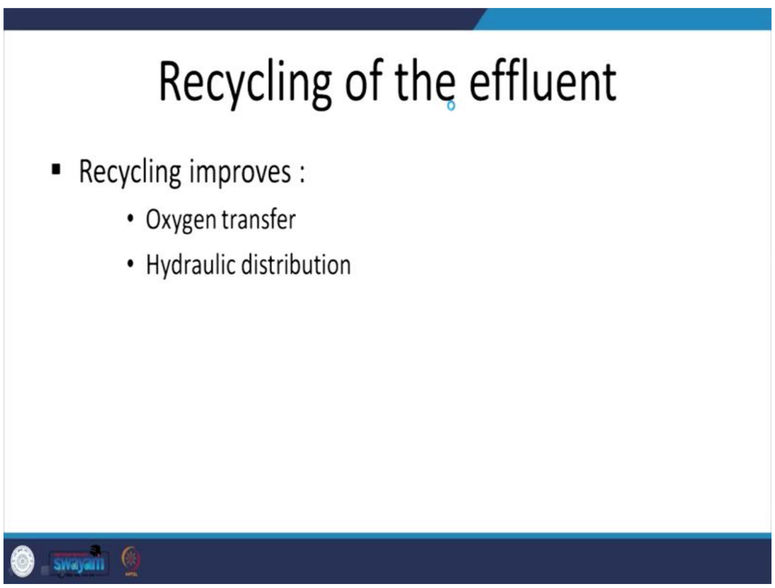

due to various reasons will be eroded but sometimes whole sections. well fall off this is slowing so this can happen and you need to look at the loading rate . So recycling of the effluent why do we need it because it improves the oxygen transfer and more importantly the hydraulic distribution. You have to recycle this effluent and typically you would do it before the settling.

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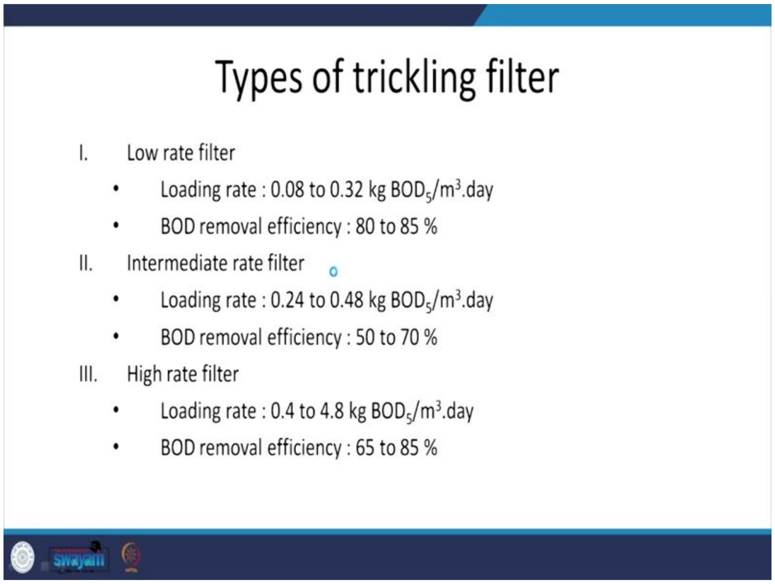

And here we have different types of trickling filter low rate intermediate and high rate. As you can see the loading rate varies 0.08, 0.24 and 0.4 and removal efficiency also is slightly depend upon your what this rate of loading. Relatively low loading rate the highest efficiency why is that because now I am what we say distributing the water at a very slow pace. So the rate at which the water is going through the filter is less meaning the microbes not microbes pardon me the organic content has more time or it can diffuse into the stagnant layer and the biofilm.

And the microbes thus can have greater access if I may say so to the organic content. But if I am sending the water through fast not enough time for diffusion into the relevant biofilm so relatively less efficiency out here. So that is one aspect to understand.

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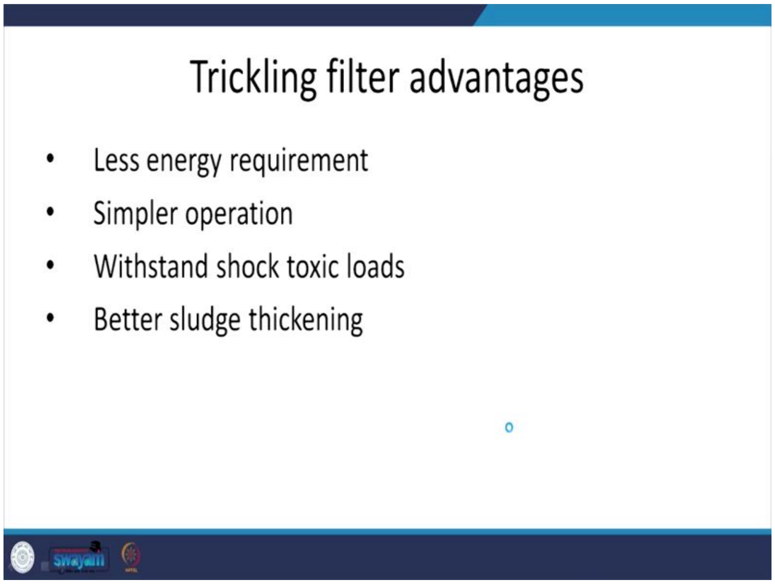

Why is it advantageous here I am not pumping in air I am just using air that is present in the atmosphere and thus less energy requirement pretty simple operation and depending on how I can recycle it can withstand shock and toxic loads and looks like it depending upon how I maintain it and recycle the sludge thickening is better. But every time it comes down to money and so as you see the operation is pretty simple.

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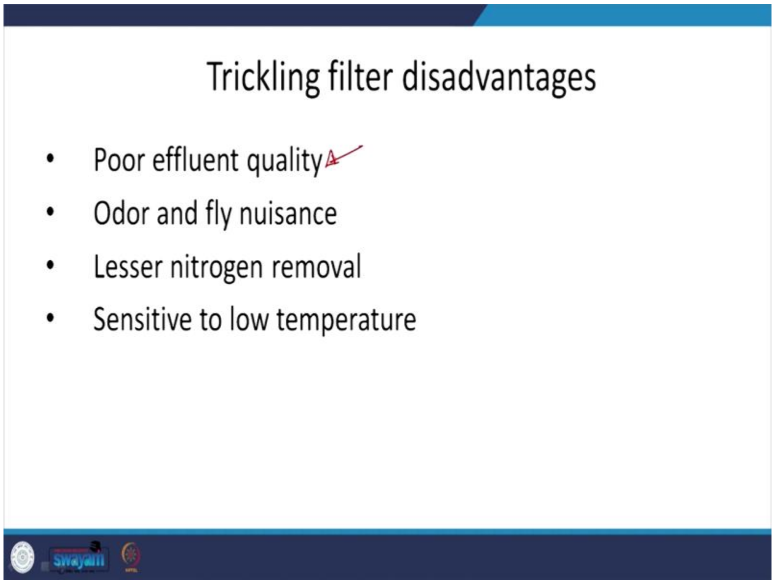

What are the disadvantages depending upon how tightly or not how tightly within a unit volume how much biomass I have that will allow for or tell me how efficient the process of degradation of organics will be. So due to that I am assuming relatively less biomass or microorganisms per unit volume you are going to have poor relatively poor effluent quality.

odor will be an issue sometimes you can have inorganic removal especially within not inorganic anaerobic removal especially within the relevant biofilm. So odor can be an issue and fly nuisance lesser nitrogen removal depending on the thickness of the biofilm and because it is exposed it is pretty sensitive to low temperature. So these are the aspects but primary aspect is odor and poor effluent quality.

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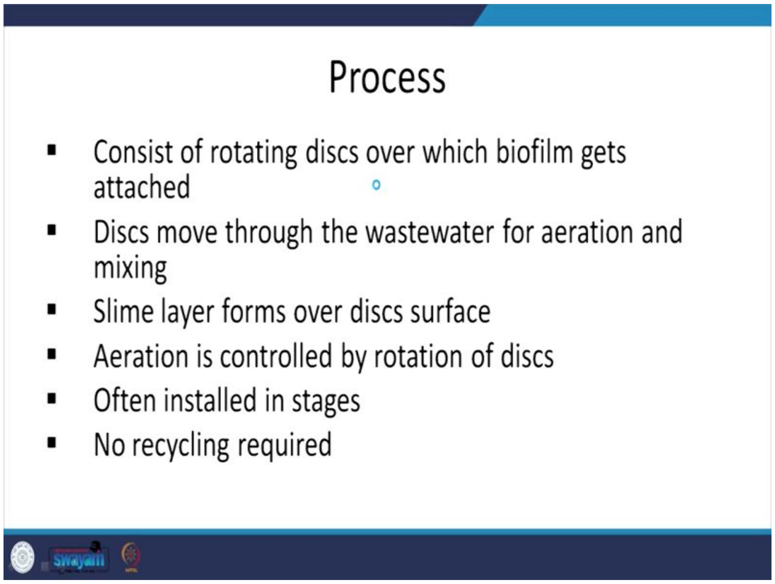

So rotary biological contact so it consists as is obvious from the name rotating this or which biofilm gets attached thus it is called attached growth system. Discs rotate or move through the wastewater for aeration and mixing. You have water here and the disc here and this rotates. So when it is underneath the biofilm comes in contact with it and also when it is on it you have bringing in air you are circulating air.

Slime layer forms over the disc surface aeration is controlled by the rate of rotation of the disks and no recycling is required but effluent quality will be less.

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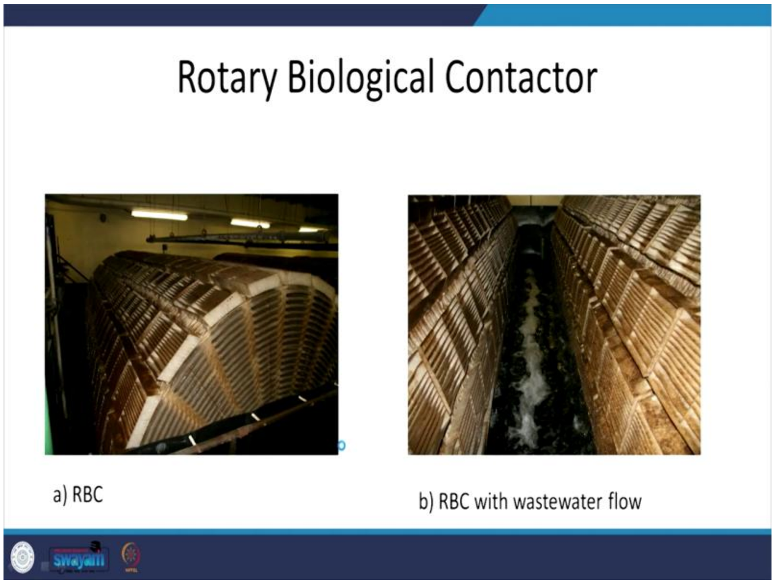

So here you see the rotating biological contactors RBC with the wastewater flow typically it will be in this direction these are the discs.

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And you can see the slime layer that has grown or the attached biofilm all over. Some cases relatively less and some places relatively more.

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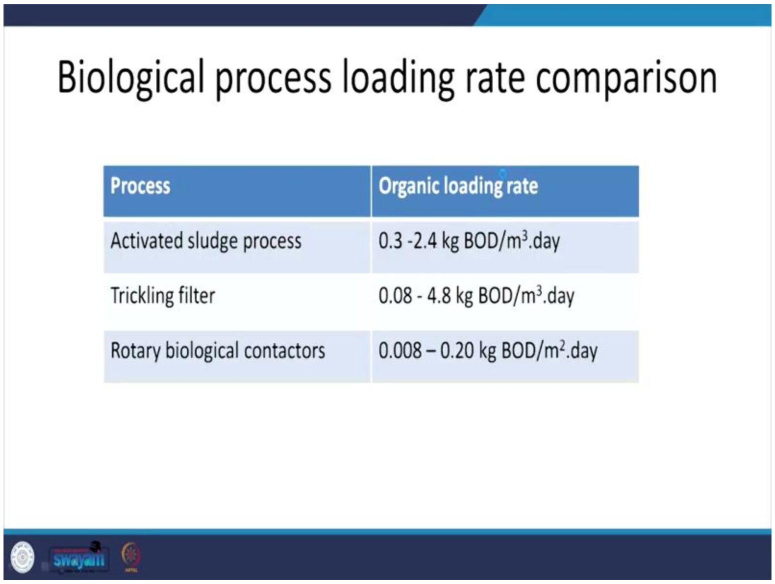

So MBBR that is something I already discussed and now we will move on to another aspect but let me finish this up. So biological process loading rate let us just compare the three different cases one is the activated sludge which is the suspended process. And two attached growth which is which are trickling filter and rotary biological contactors. as you see organic loading rate is relatively much higher in the case of the suspended process when compared to the trickling filter and more specifically with respect to the RBC.

But simpler operation and relatively less flow rates coming in then you can go for trickling filter but space is an issue or area has to be available. If not you will have to go with accurate search process. As I mentioned and that is why I had the reminder with respect to MBBR. So you can have both suspended and attached some people have looked at providing media and the media can be these kinds of MBBR moving bed biofilm reactor.

So you can have both attached, so this will be pumped in this is air coming in and this is my media upon which the microbes will grow. So that is MBBR system.

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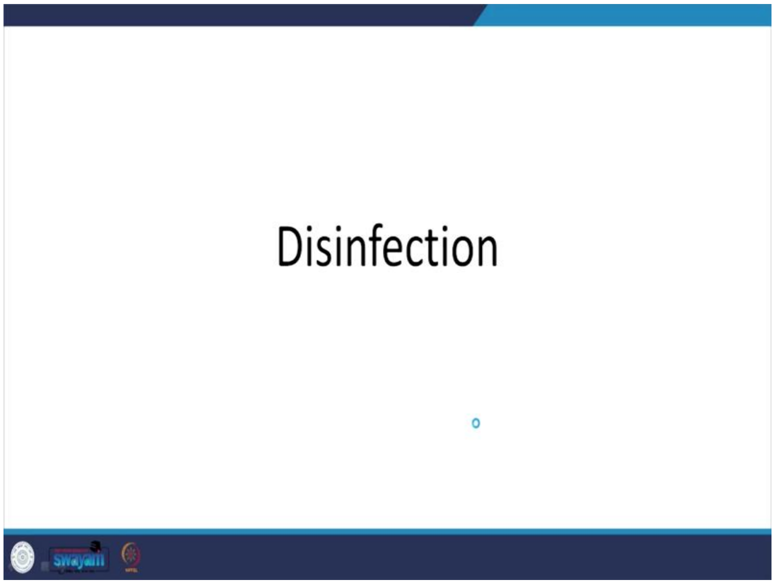

So next what do we have disinfection. Until now I have removed organic content suspended solids, grit different plastics or such that might come through with the coarse screens. And I removed the microorganisms in the secondary clarifier what else am I left with. Most of the pathogens or enteric organisms that come in with the infinite wastewater are killed during the activated sludge process or this biological process why is that?

They cannot withstand this thriving microbial community but still you will have some pathogenic organisms and typically you do not want to release that into the environment or the water thus you want to disinfect it. And we will look at this in the next session but disinfection there are different ways how they do it in India. And what are the better ways but with that I will end today's session and thank you.