Water and Waste Water Treatment

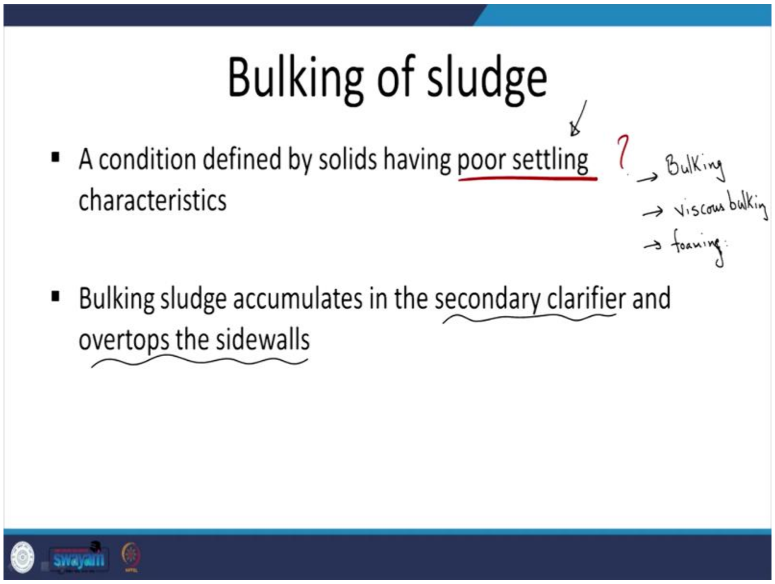
Prof. Bhanu Prakash
Department of Civil Engineering
Indian Institute of Technology- Roorkee

Lecture -22
Sludge Bulking and Activated Sludge Variations

Hello everyone welcome back to the latest lecture session. In the last session we looked at activated sludge process relevant variables such as substrate, microbial concentration and so forth. And we looked at how to design a plant if I understand the level of this effluent wastewater strength or effluent that I want I can design the plant given a cell retention time or such.

In that context or in that same session we also discussed bulking of sludge. And as I mentioned bulking off sludge there are various aspects and depending on which source you look at there is overlap of some aspects.

(Refer Slide Time: 01:10)



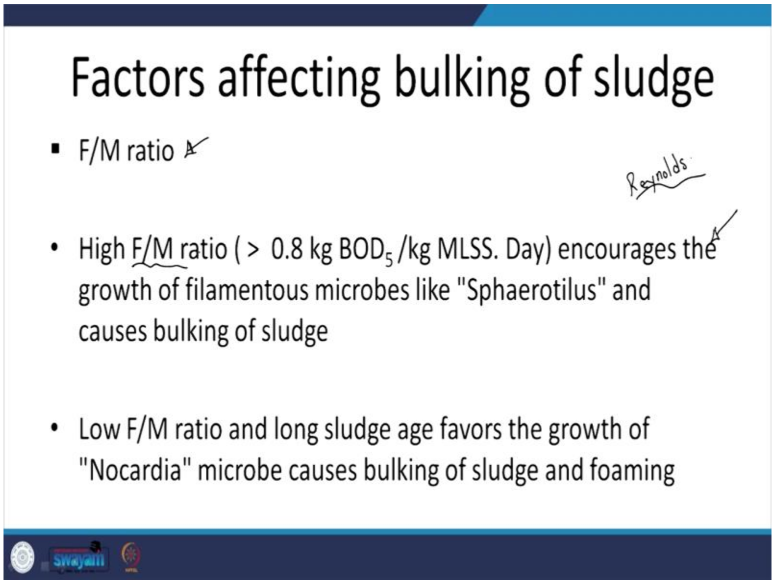
Let us just take a quick recap of bulking of sludge and then move on to relevant aspects. So bulking of sludge what is it that we have we have poor settling and why is that because of the different kinds of microbes that thrive. The microbes that I want are typically Floc forming microbes that have lower surface area per unit mass. But if I have microbes like filamentous microbes which have greater surface area per unit mass they are not going to settle down.

In general you want to have a good mix or not good mix good ratio of filamentous to Floc forming. If you have just Floc forming a pin Floc that is going to be an issue if you have too many filamentous microbes due to various conditions you are going to have higher surface area per unit mass and they are not going to settle down. A quick recap of what we have been up to.

So poor settling characteristics and what is it where do we typically see that in the secondary clarifier or the secondary sedimentation tank and sometimes the situation is so severe that it can overflow. there are different kinds but as I mentioned looks like different sources makes different aspects one is sludge bulking and in the way that we looked at it we encompass most of the kinds of issues with sludge settling within bulking.

But different sources distinguish between bulking and viscous bulking and then foaming so let us just have a quick recap of these aspects.

(Refer Slide Time: 02:58)

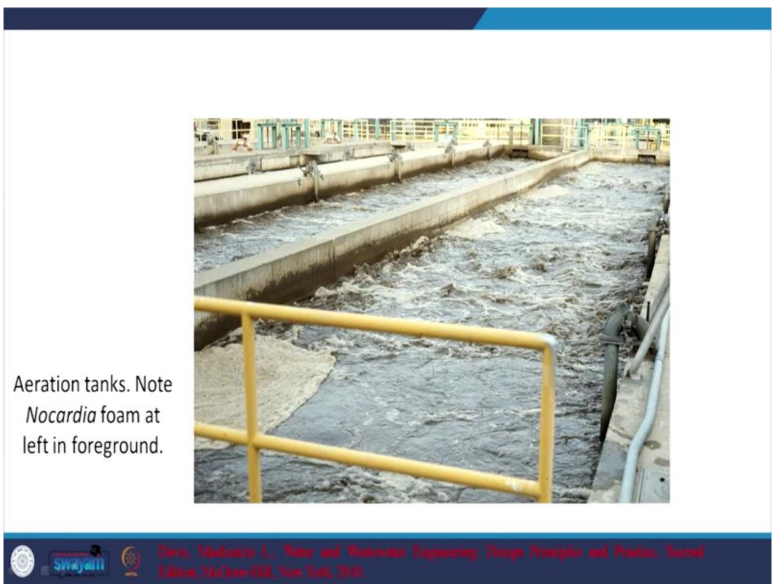


So F/M ratio food to microorganism and this is from MIT open courseware but the reference they looked at was Reynolds. And this seems to be a relatively unique reference in the sense that typically we understand that at low F/M ratio when the microbes are starving you typically have filamentous microbes. But here this reference tells us that even at high F/M ratio it does encourage the growth of a certain kind of filamentous microbe that can lead to bulking of sludge.

, but this seems to be a one-off reference. In general low F/M ratio leads to filamentous growth and that will lead to what we say poor settling characteristics and thus you are going to have higher microbial concentration being suspended in the secondary clarifier. So you are not going to get just treated wastewater you are also going to get considerable microbial concentration out of your settled sludge not settle sludge out of your secondary clarifier.

If the sludge does not settle down you are going to have microbes out here and they are going to leave with the water and the other one is with respect to foaming. So typically nocardia that causes foaming here we talked about bulking of sludge and foaming.

(Refer Slide Time: 04:18)

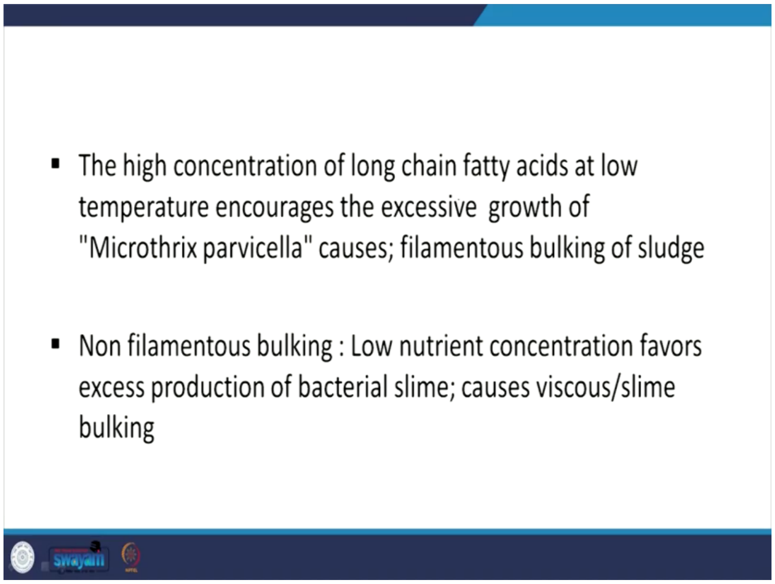


But typically it leads to foaming this is the kind and this seems to be prevalent when we have fine diffusers or the conditions are described in different ways and different sources but one aspect of the principle here seems to be that you have air and nocardia type of microbes which are the which are relatively hydrophobic. Hydrophobic means they do not want to stay in water so they want to change phase into or would like to stay in this maybe gaseous bubble.

And they will lift up and this is what you see here. So severe cases you will have a lot of such what we say nocardia growth and you will have foaming that is going to go out of your secondary sedimentation tank and another aspect is because they are going to stay afloat here.

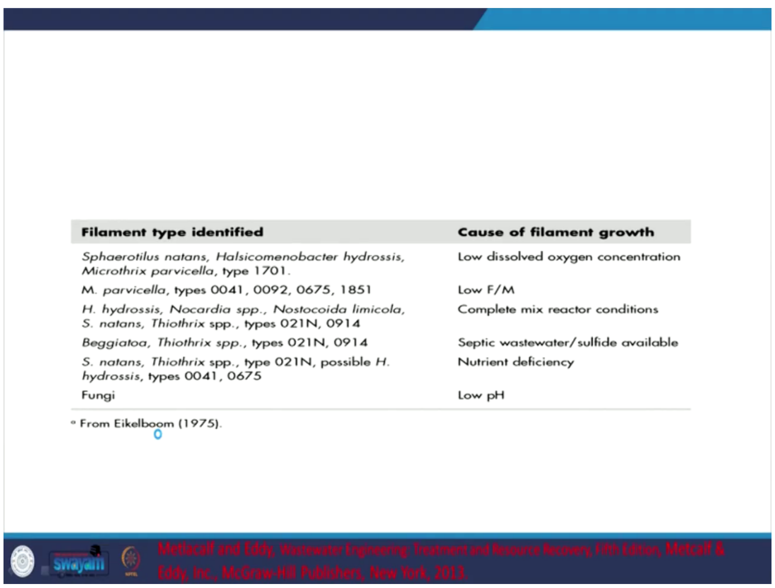
They are going to spend more time in the tank. So that means that these kinds of microbes typically have greater cell resistance time and so that can lead to some issues.

(Refer Slide Time: 05:24)



And different kinds low long chain fatty acids at low temperature we discuss this. Another one which is viscous bulking but which is non-filamentous bulking low nutrient concentration leads to production of bacterial slime and this slime is remarkably hydrophilic. So you have greater water retention within the cells and thus it will not settle down. That leads to viscous or slime bulking.

(Refer Slide Time: 05:57)



Filament type identified	Cause of filament growth
Sphaerotilus natans, Halsicomenobacter hydrossis, Microthrix parvicella, type 1701.	Low dissolved oxygen concentration
M. parvicella, types 0041, 0092, 0675, 1851	Low F/M
H. hydrossis, Nocardia spp., Nostocoida limicola, S. natans, Thiothrix spp., types 021N, 0914	Complete mix reactor conditions
Beggiatoa, Thiothrix spp., types 021N, 0914	Septic wastewater/sulfide available
S. natans, Thiothrix spp., type 021N, possible *H. hydrossis*, types 0041, 0675	Nutrient deficiency
Fungi	Low pH

[a] From Eikelboom (1975).

Metlacalf and Eddy, Wastewater Engineering: Treatment and Resource Recovery, Fifth Edition, Metcalf & Eddy, Inc., McGraw-Hill Publishers, New York, 2013.

And let us look at some aspects this is from Metcalf and Eddie. As I mentioned different sources different aspects but there are some aspects where more or less there is considerable agreement. So here we are looking at causes of filament growth. So most often we look at low F/M pretty low F/M that leads to the formation of a kind of filament or filament bacteria.

And then low devo typically 0.5 milligrams or so cases also you will see kind of filamentous growth. And low F/M and thus come and also completely mix reactor conditions that is what will typically lead to low F/M when do you want to have low F when your effluent quality is to be low effluent quality low meaning our waste in that effluent has to be low meaning low food for the relevant microbes especially if it is a continuously stirred tank reactor.

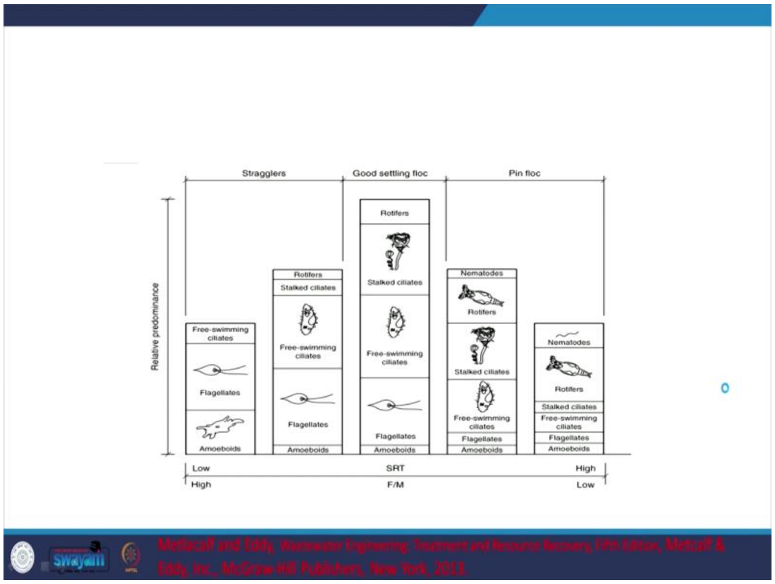
If it is continuously stirred whatever goes to has to go out will be the same concentration within; so if I have low F/M because I want to have low waste or 10 milligram per liter BOD in my effluent. So well this is an extreme case. So I will have low F/M in my completely mixed reactor system. And another case is when we have sulfide content or sulfide available and some septic waste water coming in at different times of the day then you can have different kind of filament growth.

And nutrient deficiency leads to different kind of filament nutrient deficiency when will you see that typically in industrial wastewaters where there is not enough nitrogen and that is one case typically indicative of industrial wastewaters. Then you might need to add nitrogen. Low pH you have fungi the predominant in typical conditions fungi cannot predominate but in conditions where the pH is 6.5 or so bacteria are less affected or pardon me more affected than fungi.

And fungi can predominate but in sewage or human sewage, sewage treatment plants you typically do not come across this condition that can be a case when we are looking at industrial wastewaters. As you see different kinds of bacteria can thrive depending upon the different conditions different kinds of filamentous bacteria. Before we go about rectifying an issue in general it would always be good to identify the kind of bacteria that is thriving in that sludge which is bulking or which is not settling down.

And then try to rectify the scenario. If not you can misdiagnose the issue and does exactly bear the problem so that is one aspect.

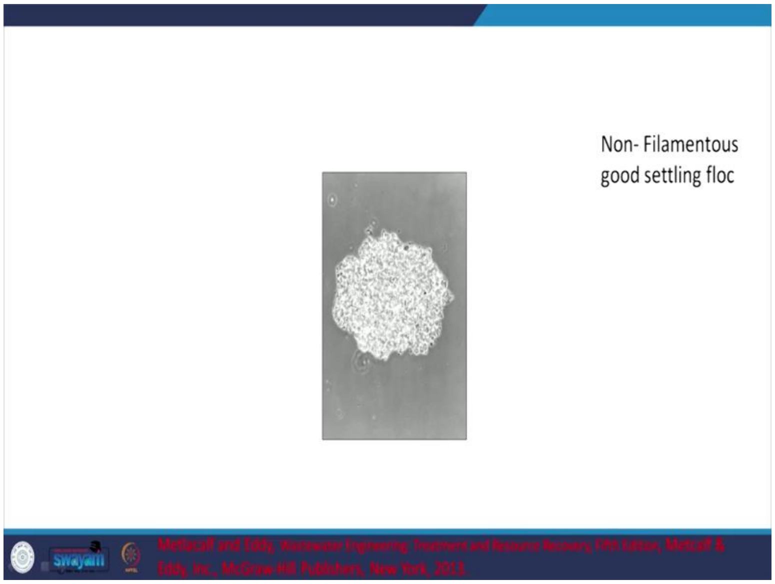
(Refer Slide Time: 08:56)



And here we have one decent figure from Metcalf and Eddie. I think we saw some equation earlier where we had I mean I think k d here but let me not go to that efficiency and F/M and other variables here . So higher F/M means lower θ_C high F/M means low cell retention time. So as we discussed if the cell retention time is pretty high   you are going to have a different kind of Floc. So you do not want to have very high or very low what is it now SRT or F/M you have a specific range.

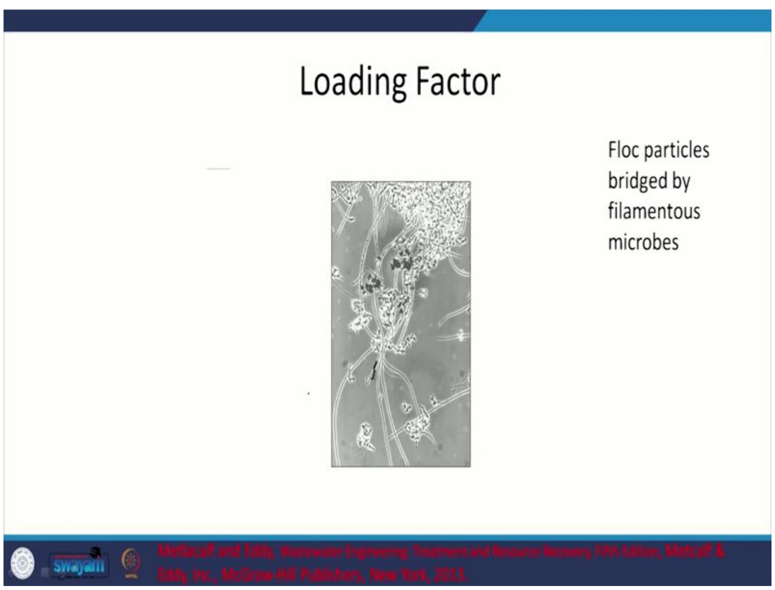
Because you want to more or less have a certain kind of filamentous microbes and also considerable ratio of the Floc forming microbes. So that is something to keep in mind. So, let us move on.

(Refer Slide Time: 09:59)



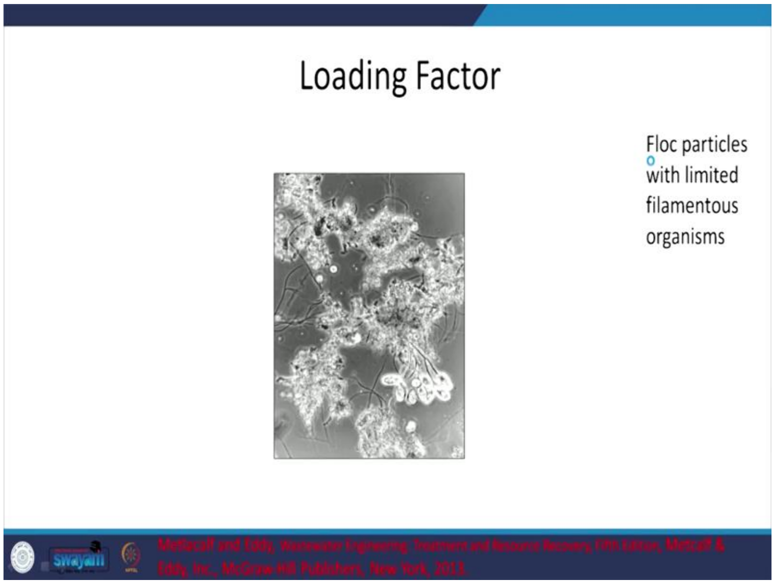
So some pictures non-filamentous good settling flocs but here there are relatively less what is it, filamentous microbes. But in general we do not want flocs only Floc forming microbes thriving why is that because if it is the small floc or pin Floc they will not settle but there are some flocs that can settle even in the absence of or complete absence of filamentous growth

(Refer Slide Time: 10:31)



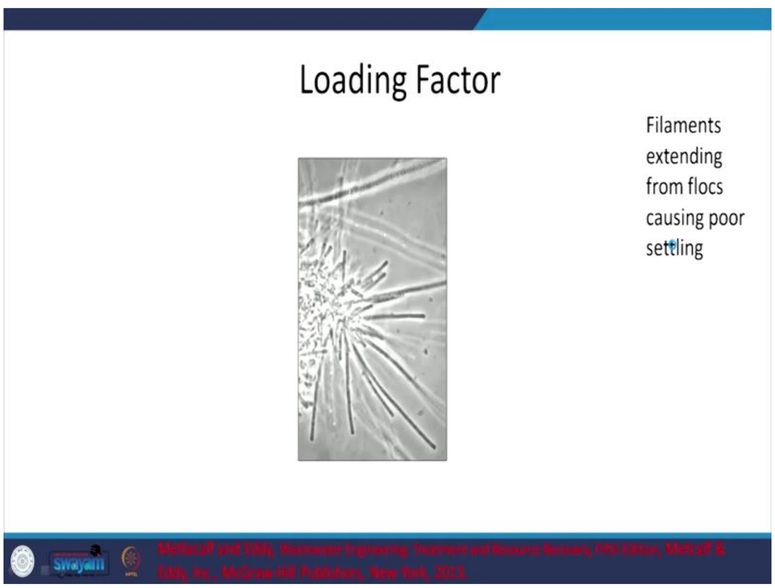
And then this is what you typically see you have some filamentous microbes and you have the Floc forming microbes in the relevant proportion or ratio. Filamentous and floc forming. So these flocs act as bridges or sometimes as the backbone.

(Refer Slide Time: 10:51)



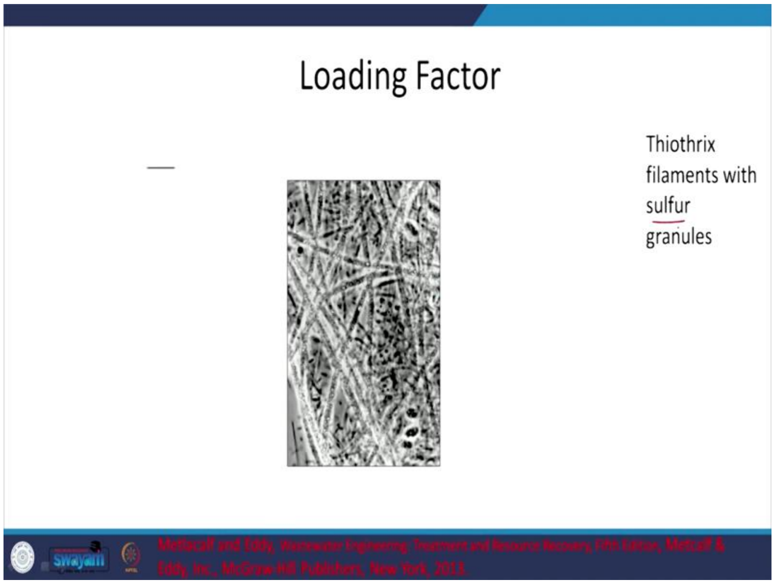
And thus you have good settling characteristics Floc particles with limited filamentous growth which is what we want.

(Refer Slide Time: 10:57)



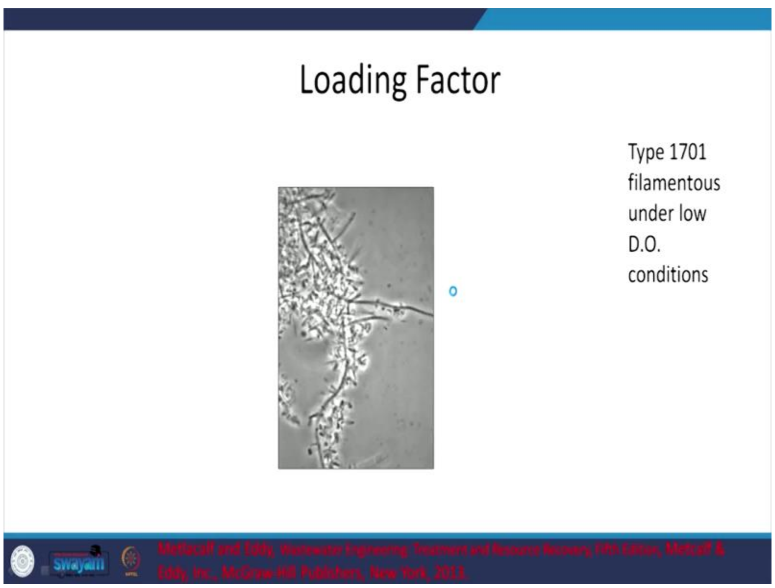
And here we have excessive filamentous growth the filaments extending from Flocs causing poor settling characteristics. Why do they or why do not they settle well with respect to filaments as you can see greater surface area per unit mass and thus they will not settle down easily.

(Refer Slide Time: 11:17)



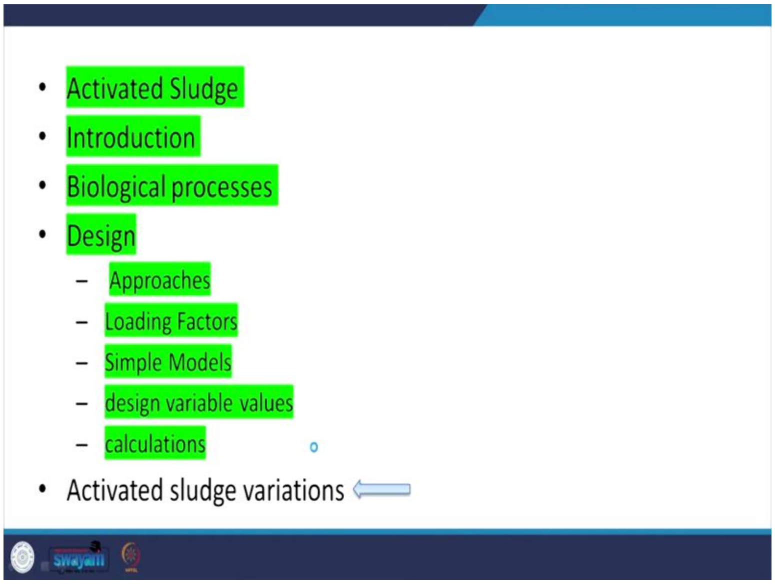
So when we have sulphide the kind of filaments that you have

(Refer Slide Time: 11:23)



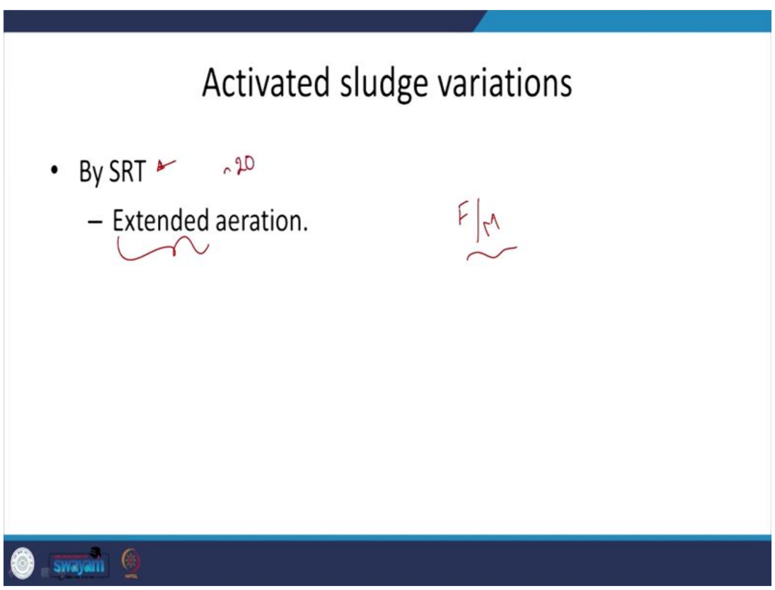
please note that the organic content will be decreased in the aeration tank or such because both the filamentous and the Floc forming microbes will degrade it but in the secondary settling tank we will not be able to separate the water from the microbes and that does not serve our purpose that is what we need to consider. And under low DO conditions a different kind of filamentous microbes thriving.

(Refer Slide Time: 11:53)



So let us move on we looked at these aspects yes design we looked at that we will look at a sample example later and approaches as such. Now let us look at some of the variations of activated sludge process. In India a lot of people or many people or many plants typically use only activated sludge process. Only now are people moving on to are more open to looking at variations of activated sludge process to suit their needs. We will not go into detail because this is a UG class.

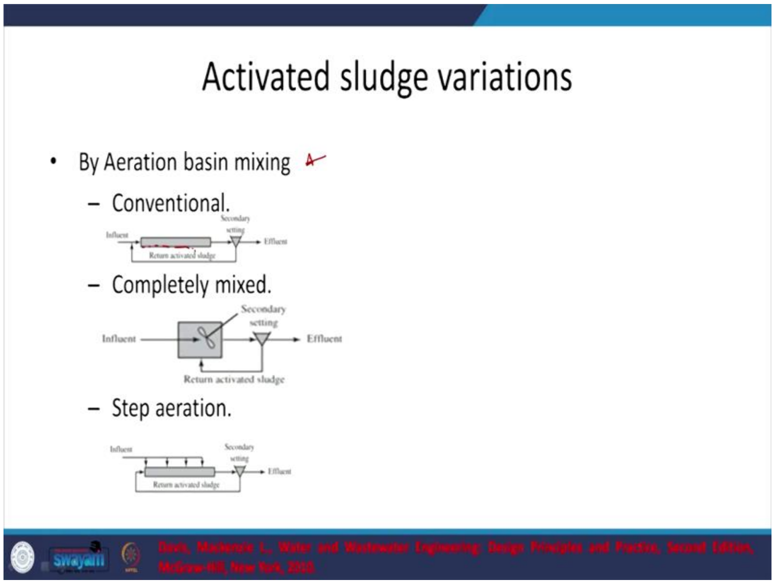
(Refer Slide Time: 12:31)



there are different variations by SRT extended aeration. So the key is an extended aeration. So typically low F/M and with respect to low incoming load and also the key aspect as we mentioned was with respect to SRT solid retention time or cell resting retention time can be around 20 days while for typical or the usual ASP process it will be around five days late. So you can see that SRT is are the cells or microbes are spending more time in the relevant system.

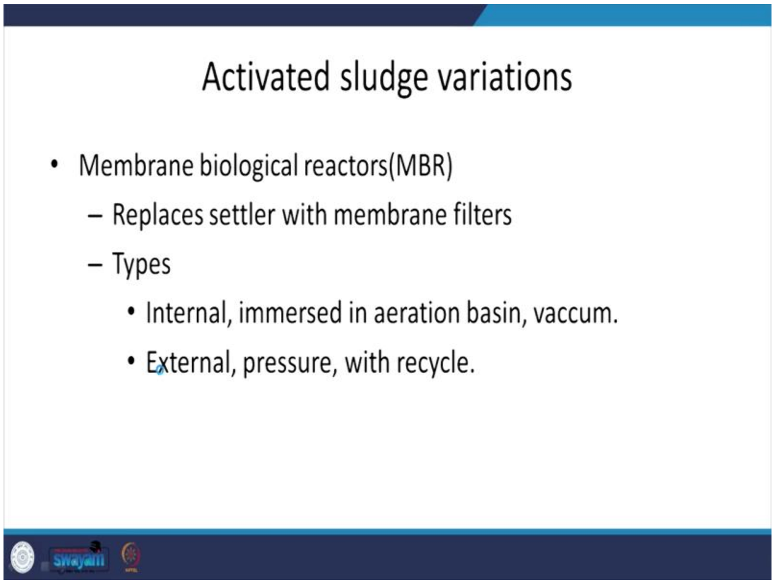
extended aeration and thus low F/M we are not going into that in detail.

(Refer Slide Time: 13:14)



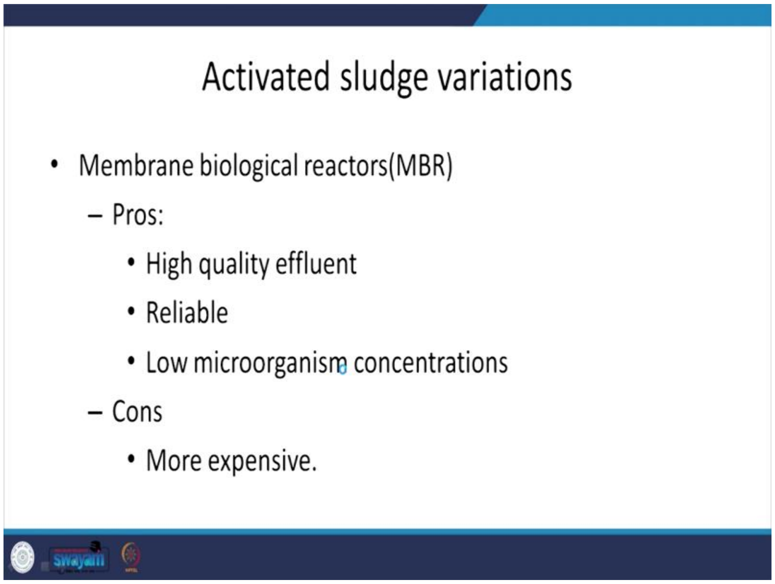
So by the kind of mixing conventional type where you want to more or less try to achieve plug flow but you cannot achieve what is it ideal plug flow. Completely mixed but this will have its own issues and step aeration. So this is sometimes practice but we will not go into that in detail only aspect that we need to know is the kind of mixing and the kind of aeration we are providing will depend upon the kind of system that we are trying to promote. Let us move on.

(Refer Slide Time: 13:48)



Another variation which is used because it leads to remarkable good effluent water quality is the MBR system which is the membrane biological reactor. So in general what do we have we have this aeration tank where we supply air and mixing and then we have the secondary settling tank where the microbes settle down to the bottom. And this relatively clear water is removed. Yes so this replaces the settler and these meaning the membrane filters replace the settler. So you have different types internal immersed in aeration basin vacuum and depending on whether we are applying the pressure or is it by gravity

(Refer Slide Time: 14:37)



What we have, so why do we want it first because the quality of the effluent is high. These membranes which can be nano or ultra filtration membranes will not let the microbes pass through the membrane and thus you will only have water or relatively clear water free of most suspended solids passing through this MBR and then that is going to leave the system that is your treated wastewater and the microbes are going to stay in the system itself.

So high quality effluent relatively reliable and low microorganism concentrations because you are not really wasting them they are staying in the system but compared to what we say the conventional ASP process MBR is relatively more expensive depending upon what you say the maintenance of MBR. You can have falling of the membranes over time you are going to have following you have this nano membranes or ultra filtration membranes size of the pores is very less.

Due to different kinds of either precipitation or microbial growth you are going to have falling not enough what we say pore space if I message or poor area for the water to go through. And thus you are going to have to apply pressure which means higher cost or less flow rate so maintenance is an issue depending on how well you are running the plant. But one other aspect which I should have mentioned here is that it requires lesser area when compared to the traditional ASP process.

Why is that? why do we need lesser area well it was obvious we have the aeration tank and then the secondary settling tank. here we do not need the secondary settling tank we just need the membranes here these membranes can also be placed within the aeration tank itself so that is another advantage depending upon the kind of system that you are going for so usually it has or the area requirements are up to 60% lesser compared to the ASP.

(Refer Slide Time: 16:36)

So typical MBR membrane biological reactor modules membrane modules this is what they look like so the water has to pass through this this is a kind of MBR or membrane we have the hollow fiber the water has to pass through these fibers, yes that you can see out here. This is a hollow fiber. And what do we have membrane module which is to be installed in a rack or cassette and an individual hollow fiber.

And one other aspect is sometimes you will also have attached growth not only suspended growth but that varies depending on the kind of system that you want to have.

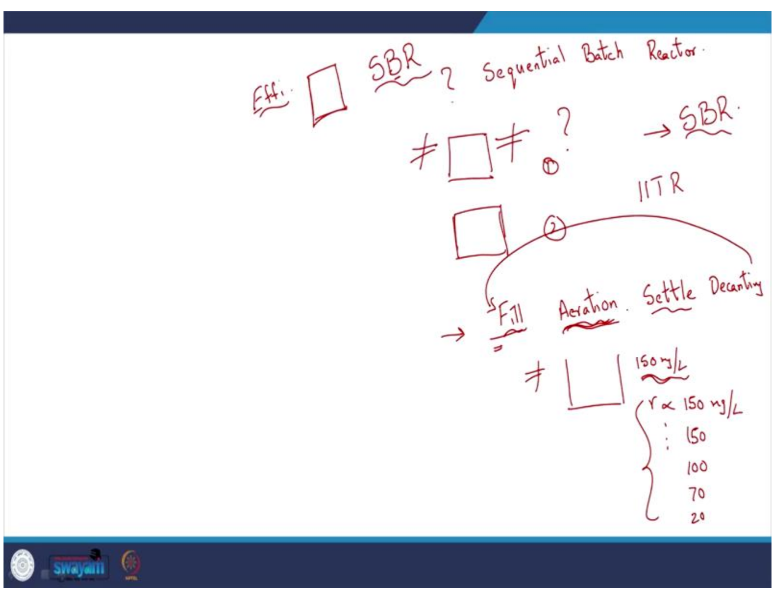
(Refer Slide Time: 17:17)

Here you see this membranes being lowered into the relevant tank. , as we mentioned the water will throw a flow around it and then we will have to flow through this membrane thus the microbes will not be able to pass through the membrane and the clear water will move out of the system. let us move on.

(Refer Slide Time: 17:37)

So air bubbles in an MBR as you can see model MBR where you have the membranes and the aeration occurring together different kinds of aeration. So we talked about different kinds of aeration or activated Sledge process.

(Refer Slide Time: 17:52)



But one that is pretty widely used or very much coming up within the at least within India is the sequential batch reactor. Why, if the first case efficiency will be greater because if we look at the way that it is going to be run or operated you will see that the rates are going to be similar to what you would expect in a completely not completely mixed in a plug flow system. And also you will see that the area requirements are much, much lesser.

Let us try to understand how the biological processes are taken care of within this batch reactor. When we say batch reactor what does it mean there is no continuous flow coming in no continuous flow going out. So what is going to happen or how do we treat the continuous flow coming in from the distribution network or sewerage network pardon me. So you typically have more than one SBR sequential batch reactors at a minimum of two if not more.

And then you can have an equalization tank and then you will have biosectors depending on how advanced it is but we will discuss that later. So this tank will be in a different cycle tank one and this tank will be in a different cycle. So we will look at the case where we have two tanks because we will be looking at a video of a sewage treatment plant in IIT Roorkee that is based on SBR sequential batch reactor. So let us try to understand the system and then move on to looking at the relevant video.

So what is it that we have first the waste water is coming in so you have filling here you have filling and then after the tank is full or depending upon the relevant scenario what do you have you are going to have aeration. Aeration where you are going to provide the relevant oxygen for the microbes to degrade your waste. So, one aspect during aeration is that unlike the complete limbic system note that this is a batch system.

Once it is filled there is no more inflow. So now we have waste water at 150 milligram per liter and the rate of this substrate utilization or the rate of degradation of the microbes will certainly be not microbes rate of degradation of our waste will be depend upon the strength of the waste water. So it is going to be depending upon the concentration over time this 150 will keep coming down 100, 70 or 20 or so on and so forth.

So rate will come down but if we look at the r average it is certainly going to be much better than a completely mixed system which will always try to maintain a much lower concentration inside the system. that is one aspect to keep in mind. So first what do we have we have we are filling the tank and then we have the aeration and then you will have the settling when you stop the air.

If you have continuous aeration you are going to have turbulence the Flocs that have formed or the kind of microbes that have formed will not be able to settle down. So you will have wanted to have stop aeration and have settling. And after these microbes have settled down you want to remove the clear water from the top so that is called decanting. So after decanting now the tank is empty.

So what is going to happen, the next batch of wastewater is going to come in you are going to have a new set of wastewater coming into the tank which is filling aeration settling decanting and then the cycle repeats. So these are the four cycles. So some aspects that we need to discuss before we go ead and look at the video is that with respect to aeration I know that we have not yet talked about nitrogen removal or such in great detail.

But we know that for nitrification and denitrification to occur at least at some conditions you want to have anoxic conditions and even for phosphorus removal you will have certain conditions that need to be maintained. So in SBR you have greater control about the kind of aeration and also the level of aeration that you want to achieve or can achieve and thus you can achieve nutrient removal during SBR process.

we will look at that later but this is something that we are going to look at in a video. So but I see that I am almost out of time I will end this session for today in the next session we are going to look at the SBR system or process or the SBR sewage treatment plant at IIT Roorkee. the crux of the issue is you are going to fill up this batch reactor meaning no flow coming in no flow going out.

And after you fill it up you are going to pump air in aeration and then after the relevant time which you design you are going to stop this aeration and then you are going to let the plant the reactor have quiescent conditions such that it settles down and then you are going to decant the clear water. So with that I will end today's session, thank you.