Water Quality Management Practices

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Week-08

Lecture-40

Membrane Bioreactor (MBR)

Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Dhar Bhowmick. I am from the Department of Agriculture and Food Engineering of Indian Institute of Technology, Kharagpur. So, in this last lecture of module 8, we will be discussing about a very interesting technology which we call membrane bioreactor or MBR in short. So, the concept that we will be covering in this particular lecture module, lecture video are the type of different process description, the types of membrane bioreactor, different membrane fouling phenomena, what is the occurrence, what is the consequences and how we can control those biofouling phenomena, how we can mitigate those phenomenon as well. And we will also discuss about the performance of MBR in different case studies happened like you know in domestic wastewater treatment systems as well as industrial wastewater treatment systems.

To start with a membrane bioreactor or membrane biological reactor in some cases, it is also known as a membrane biological reactor in short MBR. It consists of a of an aeration tank in a in general and then just like the activated sludge process which will be called as bio reactor with a suspended active aerobic microbial sludge for the oxidation of organic matter present in incoming wastewater followed by one membrane filtration systems ok. So, just try to understand. So, first we have one activated sludge process, just like the same we have we designed in the in this module in the beginning of this module the same thing, but along with along with this activated sludge process where the microorganisms are growing in suspension, we introduce one mechanical filter as well just inside the say aeration tank itself.

Otherwise what will happen in case of ASP what we do? In case of ASP first we have aeration tank, then we have a secondary clarifier. We treat the biological or the organic matter inside this aeration tank, then the effluent goes to the secondary sedimentation tank, there thus clarification or the sedimentation occurs we have to leave it for some time and then we after sedimentation the sludge is being carried out for the handling purposes or for sometimes the return sludge can also be come out to the aeration tank. And then from there from the effluent we get rid of the effluent from the top of it from the supernatant part of it. So, in case of ASP we have a aeration tank, then we have a separate secondary sedimentation tank. In case of membrane bioreactor we do not have that though that additional secondary sedimentation tank, we do not need that clarifier because the aeration tank itself can act as the aeration unit plus the clarification unit.

Why? Because we introduce some membrane in it, some ultrafiltration, microfiltration or nanofiltration membrane inside the aeration tank itself and then we provide some vacuum suction, we provide some pressure like to let the water pass through from outside in or inside in different inside out different mechanisms are there by which we are collecting the water fresh water from the aeration tank itself. And we let the membrane to do the job of filtration and get rid of all the suspended solid possibly based on the type of the pore size of your membrane and based on the type of membrane that you are going to use and the pressure that you are going to apply based on that your performance will vary, but in general the concept is the same. Aeration tank inside you put the membrane, you have the aeration anyway the suspended microorganisms are growing there, they will consume the organic matter, then you suck the water through this membrane and the membrane will filter all the only the filter in only the water only the fresh water devoid of any suspended solid and all the rest of the stuff will keep on collecting there only ok. In general in secondary clarifier instead of secondary clarifier in MBR we use this microfiltration in some cases ultrafiltration or nanofiltration can also be used. The membrane module can be flat sheet or hollow fibre membrane.

What is a flat sheet? It is like you know it is like it is more like a flat screen ok. There will be a flat screen like structure in the screen itself we have a multiple pore. So, because of this pore what will happen when the suction pressure is applied from the top from certain area. So, say it is like a 2 number of small flat sheets are you know attached ok. In between in between there is a small space between there is like you know it is like a sandwich like structure.

So, in between this spaces we have like certain small small like you know fibres. In those fibres we have small pore in inside inside this in on the body of this this fibres are made

of a like a very tiny tiny pores. So, whenever there is a pressure that you applied from the vacuum you you apply you suck the air what will happen the water will try to fill up that void. So, water will try to fill up that void and it will pass the membrane because of this pressure transmembrane pressure that you are applying and it will pass it will either come in or either come out based on the design there are different type of membrane design as well. So, you get the water only the fresh water out of it.

So, please remember one thing that MBR can be aerobic as well as anaerobic as well ok. In the beginning as I was mentioning it can be kind of a ASP like structure rather it can be anaerobic filter like structure as well. What do I mean by anaerobic filter? Suppose you have a membrane bioreactor in that membrane bioreactor what you are doing in the in the bottom you are supplying you there is no aeration external means of aeration ok. There is only a tiny tiny bit of movement in the some aeration biological means I mean like mechanical means by which you can keep on rotating the surface that the water body I would say and because of that there are all the microorganisms will be in suspension. But because of the non availability of oxygen it will convert into it will actually be acting as an anoxic or anaerobic zone.

Because it is acting as an anaerobic or anoxic zone it will be acting like a anaerobic reactor only and those anaerobic microorganisms will consume the pollutant present in the wastewater and then when you applied the pressure through this membrane. So, then again the same same filtering function will happen. In case of effluent quality wise MBR effluent is far more superior in terms of BOD and suspended soil removal compared to any conventional activities sludge process or conventional anaerobic treatment systems because you literally filter the membrane filter the water inside that system itself. Performance of MBR is also depending on the sludge volume index of the sludge developed because the biomass is retained in the reactor by membrane and sludge recirculation is not involved. So, MBR performance is quite good amount of like it is influenced by the by the SBI as well.

In general the mixed liquor suspended solid concentration maintained in MBR is higher than the conventional activated sludge process. Hence higher volumetric loading rate can be applied and so which will reduce the required volume of the reactor and because otherwise in for the same amount of wastewater to be treated in the ASP you need a much higher size reactor ok, but here thus MLSS can be easily controlled like you can maintain a very high MLSS value. Due to the retention of biomass by membrane higher SRT is also provided in the reactor resulting in lesser sludge production and simultaneous nitrification denitrification can be achieved if operated at lower DO. Higher capital and maintenance cost for membranes is involved in this in this because of the fouling of the membrane that

is the one of the major issues with the membrane bioreactor. The higher capital and the maintenance cost of because of the membrane fouling because you just realize you have a membrane this tiny teeny fractions of flat sheet or the this fiber membranes, hollow fiber membranes they are keep on filtering the stuff and because of that there is a accumulation of there is a chance of clogging of its pore from the outer or from the inner side.

Because of the clogging after a while it becomes not usable at all or otherwise you have to do the back flushing or you have to do some physical or mechanical means of operation to get rid of those clogged pores or the clogged or the pore areas or pores of your membranes. That is one of the major problem that this phenomena is called the fouling of membrane ok. This fouling can be of different types I am not going to go into details of that, but this foulings are actually causing a major issues in the membrane bioreactor operations and all. The MBR can have a membrane module housed in the main aeration tank or you can have the side stream one also as you can see in this picture. The membrane module is placed inside the aeration tank itself and the effluent is collected from the there is a pump is there this from this pump we are providing some suction pressure, the water goes inside the membrane module we can collect it through the effluent.

We can also do it placing in the side stream conditions the water will be pushed through this membrane module it is like you know that is where I was saying inside out kind of a system. And because of the pressure positive pressure that we apply it will it will come out of this membranes with only the water will come out and only the rest of the portions can be easily collected as a sludge. In general vacuum of around 50 kilo Pascal say like 0.5 bar or 0.5 around 0.5 atm is applied in the membrane to draw the permeate from the mixed liquor while retaining the bio solid in the reactor itself. There are certain arrangements we do normally to minimize the bio fouling what we do just right next to the membrane media you provide the aeration. So, because of the aeration it will keep on this bubbles will keep on burst on the surface of this membrane and it will let it is like you know you keep on you know like you know heating the membrane slow like you know very with a very tannity force. What will happen because of that the clogging phenomena the solid will not be able to you know enter to the clogs enter to this pores and because of that there is a high chances of it will anyway happen with time. But you can just like you know literally increase the longevity of those membranes by having this kind of mitigation technique.

You normally provide by this diffuser adhesion systems which is quite famously used otherwise there are external there are different other chemical and the mechanical means are also nowadays people are working on. In IIT KGP I have also worked on this kind of systems where I provided this longitudinal vibrations and because of this vibration it will

it will because of this certain vibration if you keep on providing the biosolid will not get enough time to get attached to the surface of it. So, like this way we can have those changes and this process design will also vary with that. So, in case of MLSS in case of this MBR the MLSS concentration can be as high as 15 to 20 gram per liter which is much higher than the conventional ASP which where we cannot go for more than 3, 4 say like 6, 5, 6 gram per liter of MLSS. The hydrated range is 8000 to 1000 to make the processes most water effective cost effective and depending on the type of wastewater treated and SRT use the MLSS to MLSS of the sludge for this aerobic MBR in the it can range from 0.7 to 0.8. The typical value of SRT sludge retention time adapted in designing MBR is in the range of 5 to 20 days. The flux rate of permeate through membrane is generally in the range of 600 to 1200 liter per meter square per day. The OLR will organic loading rate will be 1, 2, 3 kg of BOD ultimate per meter cube per day in general we use and the sewage treatment for the sewage treatment 4 to 6 hours of HRT is enough with a F by M ratio of as low as 0.1 to 0.4 kg of BOD per kg of SRS per day is also can be used even much higher F by M ratio can also be used in practice ok.

The treatment of sewage with adapting the design values in this range the MBR is capable of producing of treated effluent with a less than 10 milligram per liter of BOD, COD of less than 30 milligram per liter and effluent turbidity can be as low as 5 NTU or naphthal naphthalimetric turbidity unit and all. So, in general how the membrane fouling occurs as I was discussing that the biomass present in the mixed liquor gets added to the exterior of the membrane when the effluent is withdrawn through the membrane surfaces. So, most of this some of this microorganisms may colonize on the membrane surfaces and start secreting, excreting this extracellular polymeric substances or EPS we call it. This extracellular polymeric substances it actually helps them it is like a it is like a adhesive. So, it like added to the surface of the membrane.

Also the final particles present in the wastewater also can enter to the pore of the membrane and you can block it. What are the consequence? Obviously, the fouling it will increase the pressure loss because you have now enough to provide much higher pressure to maintain the desired water flux. So, it will slowly it will completely damage the whole membrane module. What are the strategies as I was mentioning? Membrane agitation by mechanical scoring of the attached biomass can be done by using the rising air bubbles the diffuse aeration systems. The membrane can also be backwashed by reversing the direction of flow and with the chemical like you know 30 to 40 minutes a day with the dose of chlorine 5 milligram per liter.

Once or once in 3 or 6 months the membrane module can be cleaned with hypochlorite or the citric acid solution by submerging it in the separate external tank you just take it

out and submerging into there. Once in a week in situ cleaning can also be done with without taking the membrane module out of the aeration tank by flushing it with the hydro hypochlorite solution with the concentration of 100 milligram per liter for about 45 minutes followed by treated water back flushing for about 15 minutes to get rid of all the rest over of the hypochlorite doses. There are different case studies that I can showcase like where people have used the MBR for domestic wastewater treatment systems like in the first case the urban wastewater treatment systems MBR removed more than 95 percent of the COD with effluent COD concentration of effluent COD concentration of around 400 to 870 milligram per liter at 1.3 to 1.9 hour of HRT only in an integrated membrane microfiltration operated at high OLR of 6 to 13 gram of COD per meter cube per day.

Can you imagine within 1.3 to 1.9 hour only HRT only you can remove 95 percent of the COD of this load. Primarily treated sewage or the municipal wastewater of average effluent value of 425 milligram per liter using a flash sheet membrane submerged anaerobic MBR has a removal efficiency of around 90 percentage with an OLR of as high as not as high as like it is a standard of 1 kg of COD per meter cube per day at 10 hour of HRT. Removal efficiency of COD total nitrogen total phosphorus from hollow fiber hybrid MBR model were 98, 94.2 percent is 51 percent is an 80.5 percent is respectively from its initial concentration of 467, 40.4 and 7.3 milligram per liter of phosphate so, respectively. So, at a constant HRT of 10 hour with an under an OLR of 1.12 gram of kg of COD per meter cube per day as the research done by Liu et al 2010.

Landfill leachate dilution is with synthetic wastewater in anaerobic submerged MBR is also done with a capillary based ultrafiltration filtration unit which gives the improved COD removal of around 95 percentage of influence COD which is as high as 2800 to 5000 milligram per liter with leachate addition of 1, 10 to 20 percentage volume by volume basis at with an HRT of 2 days and OLR of 2.5 kg of COD per meter cube per day. And another study done by Liu et al 2004 they said like this COD to ammonia removal efficiency of 90 to 80 to 93 % respectively is done while treating the hospital wastewater with submerged aerobic hollow fiber membrane bioreactor with the average effluent concentration of less than 25 milligram per liter and 1.5 milligram per liter of 25 milligram per liter of COD and 1.5 milligram liter milligram per liter of ammonia nitrogen is possible while operated with an under an organic loading rate of 0.4 kg of or of COD per meter cube per day and HRT of 7.2 hour. You can see this success stories are why I am sharing with you that because this success stories tells us that you know what how efficient these are in terms of you know you know like you know in terms of uses in the municipal wastewater. Not only that it has been used in industrial wastewater as well for treating the industrial wastewater as well like aerobic hollow fiber hybrid MBR is used for treating the saline wastewater from a fish canning factory operated at OLR of 4 kg of COD per meter

cube per day and initial COD concentration of 18000 milligram per liter. It reveals the COD removal efficiency of 92 percent within an HRT of 5 days.

Same is happening in case of fuel oil and lubricating oil industry with the 99.9 percentage of removal can be happen can be done by aerobic this MBR. COD and TOC removal of 90 92 more than 90 percentage under oil loading rate of 3 to 5 kg of meter cube per day. It is done in different studies. In studies people have also shown that average removal efficiency of 80 percentage of copper, 98 percentage of lead, 50 percentage of nickel and 77 percentage of zinc under an HRT of 10 hour 10.3 hour is possible from by using this MBRs and all. So, there are different this success stories about this industrial wastewater application in a in their ETP. In discoloration of azo dye is also possible this MBRs because of the aeration tank which is present there it also consumes the converts the dye into some byproducts and also then, but in this particular case they have used the anaerobic flat sheet MBR. So, they have used some anaerobic flat sheet MBR and this anaerobic reactor is actually responsible for decolorization of this azo dye. The textile wastewater in the olive mill wastewater treatment system also there are there are existing literatures available where people have already tried this MBR and they got a quite good amount of success.

So, this is one of the very advance like you know type of I mean like in the wastewater treatment systems I would say and which has a quite a good amount of potential in near life. I would say not forget about near life it is actually being used all over world and different industries and municipality as the case studies as I have shown. And there are still researches going on to improve further the mitigation capacity of this membrane. So, that this membranes can be like you know that the cost effectiveness can be provided in this type of systems because the membrane can last for long if you have a very advance mitigation like you know techniques. It membrane this MBRs are also been used in pharmaceutical, brewery, food processing industries as well.

And this discussion gives us a very good overview about the membrane bioreactor and how this membrane bioreactors are you know what are the major issues that we are having as of now. The major issue is like the as I was mentioning the bio falling. So, if you can somehow deal if you can somehow if you are researcher if you actually think about doing a research on the in this kind of field. This is a very important field that we can actually work on. There are people who can work in this field and they can find out the solutions possible to get rid of the bio falling phenomena happening in the membrane bioreactor ok.

So, perfect so, we I would suggest you to go through this go through with this references

and get to know about more in details. And simply you search for this papers these papers will give you more in depth knowledge in depth idea about how the membrane bioreactor perform ok. And you can also search for it in online platform only in Google only you will see a lot of videos and all it will give you a much better idea when concept about like how it actually works. And it will be easier for you to actually you know replicate and it will definitely engrave in your brain much more easily after wise if you just go through. There are some more literatures you can go through it.

So, this is it for today for this module. I will see you in the next module. Thank you so much.