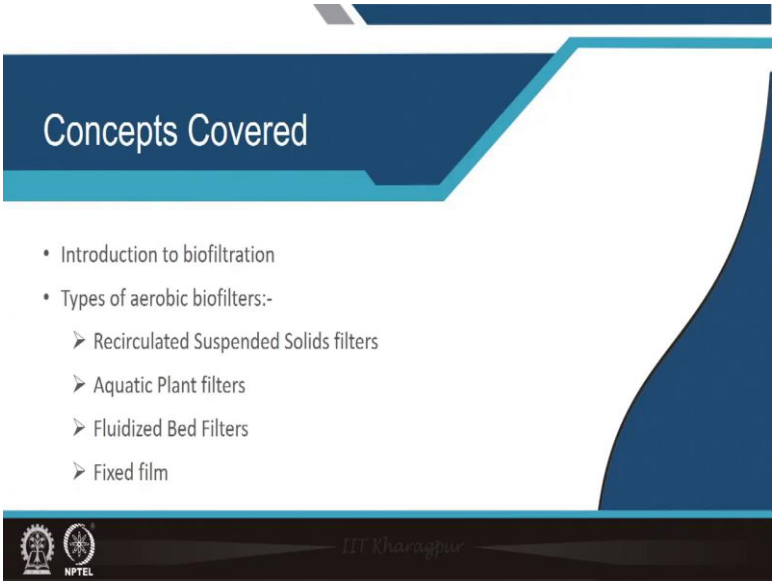
Advanced Aquaculture Technology
Professor Gourav Dhar Bhowmick
Department of Agriculture and Food Engineering
Indian Institute of Technology Kharagpur
Lecture 49
Biofiltration

Hello everyone, welcome to the fourth lecture of 10th module Technology of Cleaner Production. My name is Professor Gourav Dhar Bhowmick, I am from the Agriculture and Food Engineering Department of IIT, Kharagpur. In this lecture material, I will be discussing more about the biofiltration, the basic of which we already discussed a little bit in our earlier module and earlier lecture material as well. So, here I will be discussing more details about what are the different biofiltration procedure that we normally use in aquaculture sector.

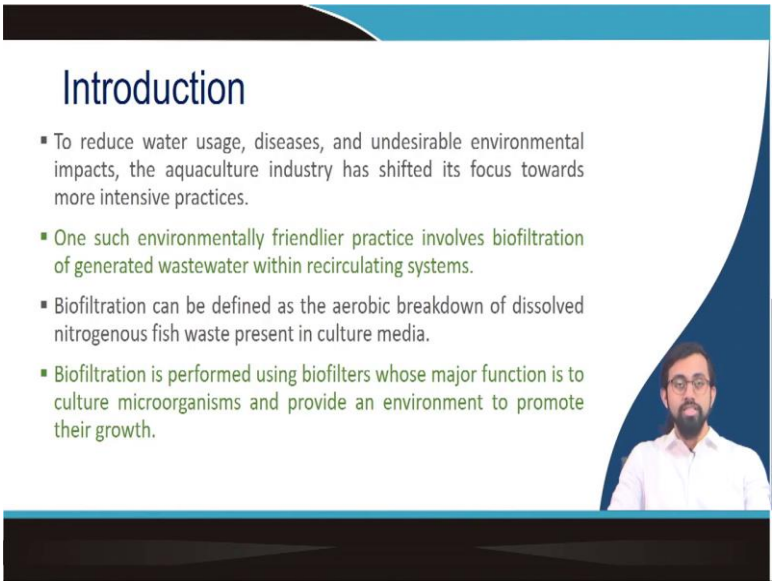
(Refer Slide Time: 00:56)



So, the concepts that I will be covering in this particular lecture material, the introduction to the biofiltration, what are the different types of aerobic biofilter that we normally use, like recirculated suspended solid filter, aquatic plant filters, fluidized bed filters and fixed film filters.

Couple of them you may heard of it, you may already remember the name that we discussed in like fluidized bed reactor like trickling filter, moving bed biofilm reactor, all these things you have already learned a little bit, in our earlier model. Here also, I will be discussing more in details about all these technologies even along with some other variants as well.

(Refer Slide Time: 01:35)



In general, when we talk about the biofiltration what is the basic need of biofiltration we all know. The first, the water the wastewater that is being generated from our aquaculture industry or aquaculture pond or tank needs to be treated, that is the first thing. So, how are you going to treat it? Then there comes different kinds of biological process.

We use different type of biological process to treat the wastewater because the wastewater it does have different types of carbonaceous and nitrogenous compounds, which can be reutilized by the microorganisms. So, when we use the microorganism or even some type of macroorganisms as well based on their type of treatment.

So, when they are used to treat the wastewater in a particular type of aquaculture pond and all, then we call them biofiltration technique. After the biofiltration technique, that water can either be thrown away in the surface water body, or what you can do, you can again put it back to your system.

So, to throwing away any surface water does not make any sense, because in that case, you have to take the water out again from the surface water body tends to supply the fresh water to your system. But it is a very specific case, there are some specific cases where you need to actually throw away to the surface body because suppose the water demand will be very stringent, and so in that case, you have to throw it to the surface water bodies.

But most of the cases what we do once the biofiltration is done, so we are 100 percent sure that the pollutant load is much lesser than its actual condition. In that case you can again put

it back to your aquaculture tank, you understand right? So, this is why biofiltration procedure comes into the picture. To reduce the water use, to reduce the disease contamination and also undesirable environmental impact, the aquaculture industry has shifted its focus to more intensive practices with the systems like biofiltration to treat their wastewater.

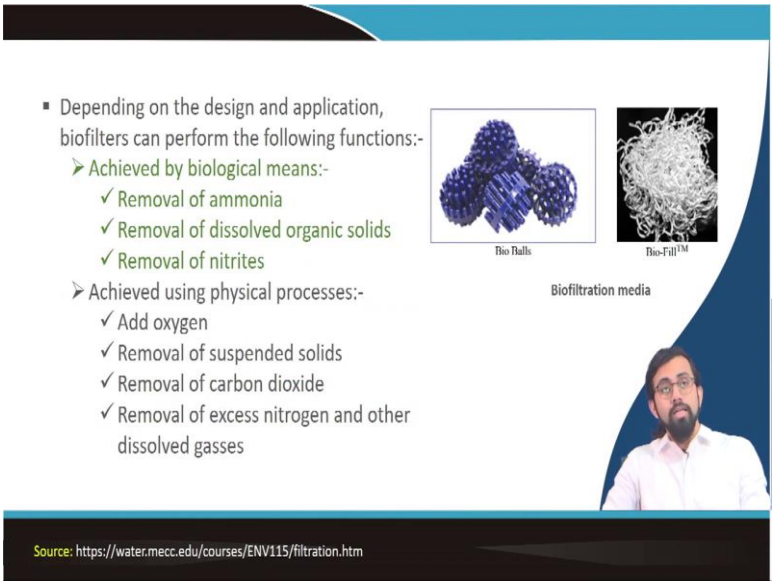
One such environmental friendly practice involves the biofiltration to generate the wastewater within the recirculating systems. It can be defined as the aerobic breakdown of dissolved nitrogenous fish waste present in the culture media. If you remember correctly, we discussed that what are the different types of compound pollutant that can be generated from the aquaculture wastewater, there if you remember, we discuss about different types of nitrogenous compounds, majorly ammoniacal nitrogen or ammonia, that is a major problem.

Either it is an ammonium ion form or free ammoniacal form, both the cases ammonium gas form, both the cases it is detrimental it is not acceptable in our because it is much, much lethal for your aquatic species and all. In order to get rid of these issues, so, what we do we again use a different module of biofiltration where the biological matter like say nitrifying bacteria and all will consume this ammonia and they will convert it into, in the aerobic condition it will convert it into nitrite or nitrate.

So, this nitrate or nitrite can further be utilized for some different purpose or you can have another anoxic reactor with or say like you know proper condition for your denitrification to take place where denitrifying microorganism they will consume this nitrate and they will convert it to dinitrogen gas and it can directly go to the atmosphere, dissolved back to the atmosphere.

In general, the biofiltration can be performed using the biofilter whose major action is to culture this microorganisms. How we can culture this microorganism? We can culture it, we can grow it in a suspended growth condition, we can grow it in attached growth condition as well. So, just the main motto of biofilter is to provide a specific environment for promoting the growth of these kinds of beneficial microorganisms.

(Refer Slide Time: 05:57)



And how they can provide it like different kinds of media that they can use. What type of media that they can use? If you see these bio balls or the bio fills these are only just a few example. If you see this peculiar structure of it, why the structure of it this peculiar structure with a lot of protrusion or say like lot of uneven surfaces. The main reason for it to provide maximum specific surface area for your bio fill to grow on its surface very precisely.

If you can grow this bio fill very precisely on its surface, what will happen the more amount of bio fill can be grown. The more the bio fill the more your treatment efficiency, the more the treatment efficiency of your system, that is it, so that is why we want to have the media to have maximum specific surface area as much as possible.

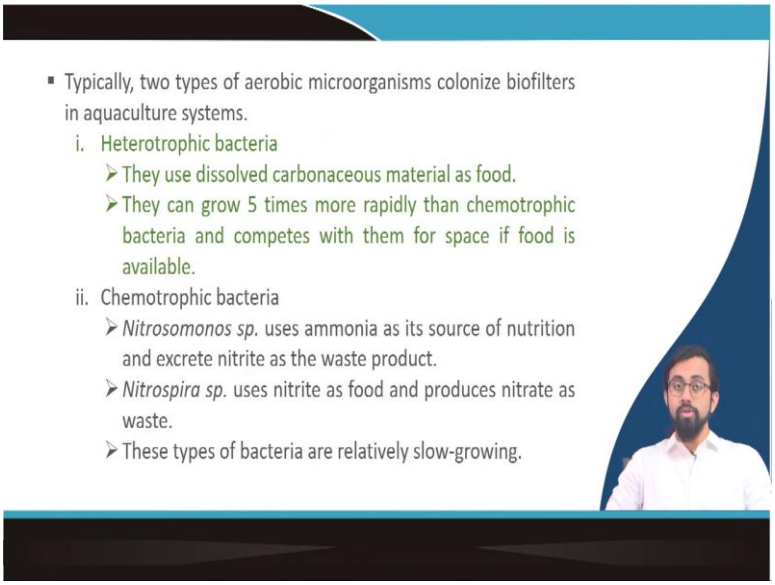
Depending upon the design and application biofilters perform the following actions majorly by biological means, they remove the ammonia, they remove the dissolved organic solids, they can remove the nitrites. Physical process, involving physical process we can add the oxygen. What do I mean by the physical process?

It can be either some rotating condition which is an air and water time to time. I will give you example in couple of size. So, in there the oxygen can be easily attached to the surface of this rotating drums. You can go ahead with the artificial aeration procedure, diffused aeration. You can supply with aeration.

Depending upon the type on expectation of your system. Other than that, you can use this physical process to remove the suspended solids, remove the carbon dioxide concentration

using different kinds of carbon dioxide scavenger and scavenging reactions, scavenging processes. You can use it to remove the excess nitrogen and other dissolved gases as well.

(Refer Slide Time: 07:58)



Typically, two types of bacteria or I would say like two types of microorganism, active microorganisms which are mostly aerobic in nature can colonize this kind of biofilters. What are those? First is heterotrophic bacteria and the second is chemotrophic bacteria. What do I mean by the heterotrophic bacteria?

They use the dissolved carbonaceous material as food and they can grow almost five times as rapidly, more rapidly than the normal chemotrophic bacteria and that is why they can compete with them for space if food is available. So, just realize, suppose you are having providing aeration and perfect environment for both chemotrophic as well as heterotrophic microorganisms to grow, you are providing with ample amount of food also, what do I mean by the food, means carbonaceous waste or nitrogenous waste.

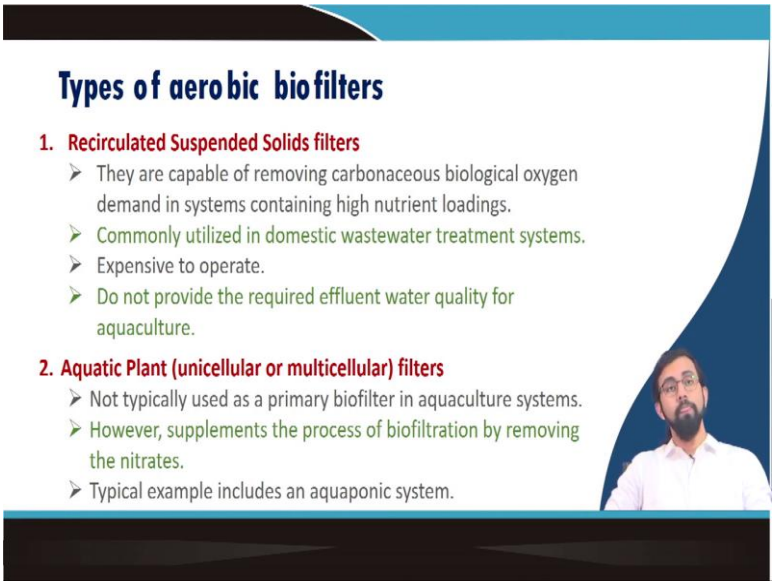
There is a chance the heterotrophic microorganisms they will outrun the chemotrophic microorganisms because they will generate in much faster way than the chemotrophic microorganisms. So, that is why you have to provide it with the proper culture if you are specifically willing to have Nitrosomonas, Nitrospira, this kind of chemotrophic microorganisms.

Either you can culture it or either you can provide this very specific route condition for this kind of microorganism to grow in your system. You already know what is Nitrosomonas

species works, how it works, it uses the ammonia as a source and of nutrition and it exhibits nitrite as a waste product. Same way Nitrospira or Nitro bacillus, it uses the nitrite as a food and produces nitrate as a waste product.

However, both of these chemotrophic mechanism mechanisms are relatively slow growing, and specifically compared to the heterotrophic microorganism. So, that can cause some time some nuisance and but it depends upon how you make sure that the expected microorganisms that you want to grow in your system will only grow and the rest it is not.

(Refer Slide Time: 09:52)



What are the type of aerobic biofilter? Recirculated suspended solid filter, they are capable of removing the carbonaceous biological oxygen demand in system containing very high nutrient loading, it can be utilized in the domestic wastewater treatment plant, it is however expensive to operate, but do not provide any required effluent water quality for aquaculture. So, that is why we do not normally go for this kind of recirculated suspended solid filter.

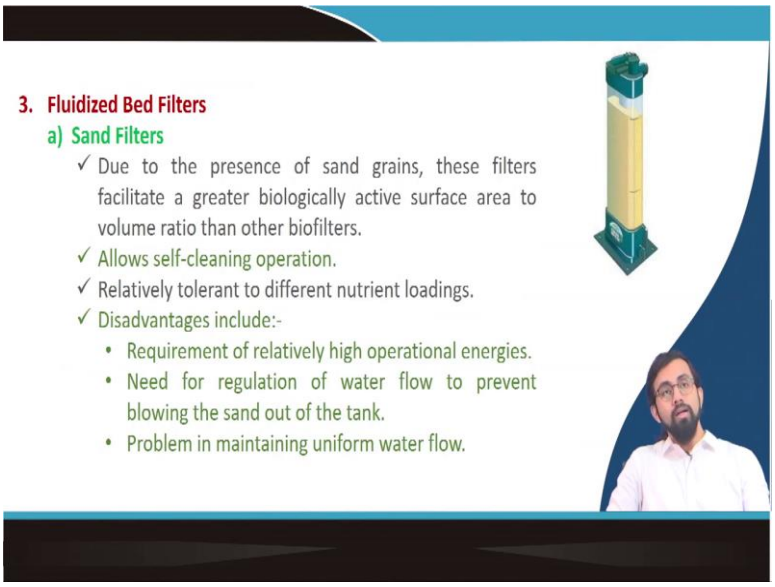
We can go ahead with the aquatic plant filters, it can be unicellular like the different kinds of specific species the algae species that is possible maybe, you can go ahead with a multicellular process that like especially the microalgae and the macroalgaes and all. I think in unicellular means like we can use sometimes some specific type of species also we can use like I think diatoms and all that is also possible, they can also be categorized here.

I am not sure about it, maybe they can also be categorized, I really prefer you to google it and you will get more detailed idea about it if I am wrong in this particular case. So, in general

the aquatic plant, the famous example is aquaponics if you remember that we treat the aquaculture wastewater by it is provided to the aquatic in these agricultural crops which are hydroponically structured or like vertical structured or like horizontal structure.

So, it may be a nutrient film technique, it maybe deep-water culture. So anyway, you are providing the wastewater generating from your aquaculture pond or the tank to the agricultural crops, these different types of hydroponic crop. This hydroponic crop what they are doing, they are filtering out. How they are filtering out? They are removing the nitrates, they can easily remove the nitrates from the systems and by this way they can reduce the pollutant load of the whole system.

(Refer Slide Time: 12:23)



You can find out the fluidized bed filters, if you remember, I think you definitely have seen the sand filters, that due to the presence of the sand grains, these filters facilitate much greater biologically active surface area to volume ratio for the bio film to grow much higher than any other biofilters.

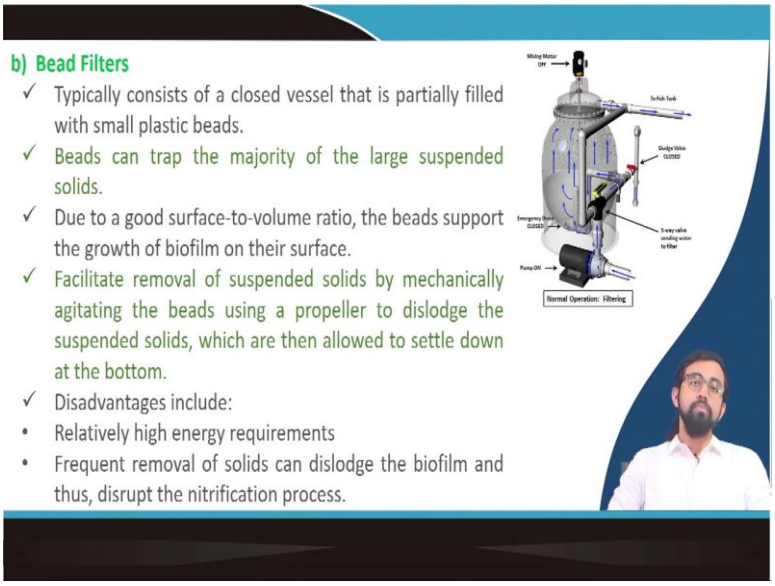
It also allows the self-cleaning operation, you just simply do the back flushing, sometimes we call them back washing, if you do this back flushing or backwashing you can easily clean this kind of sand filters and all. It has a very high tolerance level at different nutrient loading. What are the disadvantages of it?

Major disadvantages are the requirement of relatively high operational energy and also the need for regulation of water flow to promote or to prevent the blowing of sand out of the tank

is possible and the problem in maintaining the uniform water flow through the system, because what will happen, with time the clogging will occur and because of this clogging the water flow rate will become much less than its actual or set limit.

So, these kinds of problems are there. So, other than that the sand filters are very famous, it used to be very famous but now there are much better alternatives coming out, it is already in the market.

(Refer Slide Time: 13:47)



What are the other type of filter? Like bead filters, especially like in general it consists of this closed vessel as you can see, partially filled with a small plastic beads. It can trap the majority of the large suspended solids. Due to its very good surface to volume ratio, the beads can support a very high amount of biofilm on its surface.

And also, it facilitates the removal of suspended solids by mechanically agitating the beads using a propeller to dislodge the suspended solids. So, what is happening, suppose the beads are keep on collecting the suspended solids then after a while because of this agitation that you are providing, after a while when suspended solids make enough, they make a clock like structure, they bundle with each other, at the end they settle down because of the gravitational force. And which is settled down in the bottom and then that you can easily collect.

What are the disadvantages of it? The majorly it has a relatively high energy requirement. And because the energy, why it is required because the water levels the change in water level

and because of the water head that it keep on increase, you know water head right, it is the kind of resistance that you are providing when they are in the conduit channel.

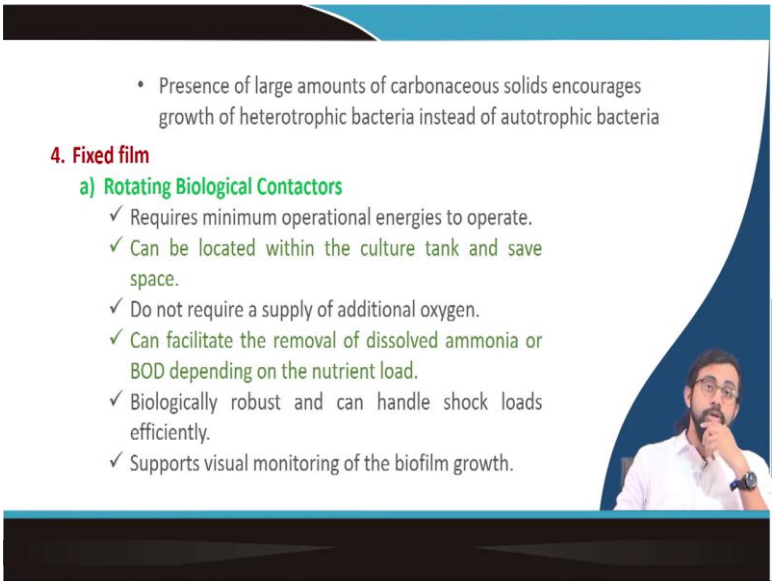
So, in this kind of, it is just kind of channel only, you are providing the wastewater you want it to be cleaned because of the waters or because of the sand surfaces and because they will keep on accumulating the biofilm and because of that it will keep on increasing the clog level. The more it will increase the clog it will, what will happen?

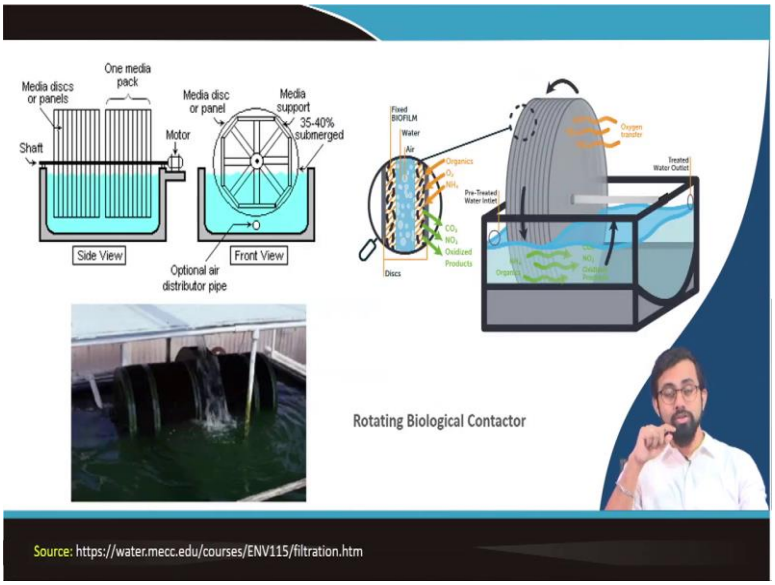
The water which is the flow rate will dissipate, flow rate will be very reduced like anything and because of that, not only that it will to maintain that flow rate you have to apply more and more pressure and which will put the pressure on your pump and at the end your energy requirement will be much higher.

Frequent removal of solids can dislodge the biofilm thus disruption in the nitrification process. So, not only you know, the problem is you know the nitrification microorganisms it needs a little bit higher amount of time for their growth, for their maturity to attain. However, because of the continuous agitation that we are providing in this kind of system, maybe the biofilm will not get enough chance to grow on its surface on this bio medias.

And even before that only it gets slugged off. That is possible and that along with the suspended solids it will slogged off and it will be collected in the bottom of the sediment this kind of chamber. At the end it is a loss for us, is not it, because your performance will be drastically reduced in this kind of cases. So, that is how this bead filter was and these are the disadvantages related to it.

(Refer Slide Time: 16:42)





Another disadvantages of it like is the presence of large amount of carbonaceous solid, it encourages the growth of heterotrophic bacteria rather than the autotropic bacteria or the chemotrophic microorganisms that we normally expect. Heterotrophic bacteria what they do, they sometimes actually reduce the carbonaceous compound in a high amount in a very huge amount. However, they are not as useful as the other autotropic microorganisms.

Anyway, so, that is one of the major drawback of this kind of systems, we can make it in our favor also using different other types of treatment of wastewater rather than aquaculture where there is a huge amount of carbonaceous what matters like say BOD COD level is very high, you can use this kind of systems which will promote the growth of the heterotrophic

microorganisms and which will consume the COD and BOD and give you a very less polluted water.

So, that is how we can play, once we know the system we can play it with like anything. Fourth one is a fixed film, it can also be like rotating biological contactor like, have you seen the rotating biological contactor, it looks like this, if you see this structure is this rotating biological contactor it keeps on rotating there is like a continuous this rotating drum, this is actually kind of drum like structure.

So, whole drum is actually kind of moving and it has this different disc like rotating like circular disc attached to it. And in between these discs, if you see the figure in the middle, where there is air and the fixed biofilm which is keep on growing on its surface of this disc. And because of that what will happen this biofilm it will consume the organics, it will take the oxygen and it will consume the ammonia and it will convert it to nitrate oxidized product and carbon dioxide.

Because of the continuous flow of air, because oxygen transfer is very easy, because 40 to 60, 30 to 35 percent of it is in submerged condition and almost 60 to 65 percent of it is outside in the air and when it is moving it comes in contact with a much more amount of atmospheric oxygen. And which will help it to treat much more better.

So, once the treatment is done, you see it is like it will take some moment of time, it is inside the water, it will consume all the nutrients present in the wastewater or like pollutant present in the wastewater, they consume it at the end they, at the end if you see one side the pre heated water inlet and the other side the water treated water inlet. So, by this way, you can treat the wastewater like anything. So, this is called rotating biological contactor.

It looks like a drum, it will keep you can keep on moving it using a particular type of like system and also you can provide the media support. So, through the shaft the motor system you can keep on rotating it and it will help you, it looks like, just to give you one idea about how it looks like so that it will be better for us to discuss. It requires a very minimal operational energy to operate because you just need to have a one motor which will keep on rotating.

It can be located within the culture tank and it can save the space and it does not require much of a supply of the additional oxygen because it will anyway come in contact with

atmospheric oxygen and there is a dissolved oxygen, the oxygen transfer can easily happen. It can facilitate the removal of dissolved ammonia or BOD depending upon the nutrient load. It is biologically very robust and it can handle the shock loads as well.

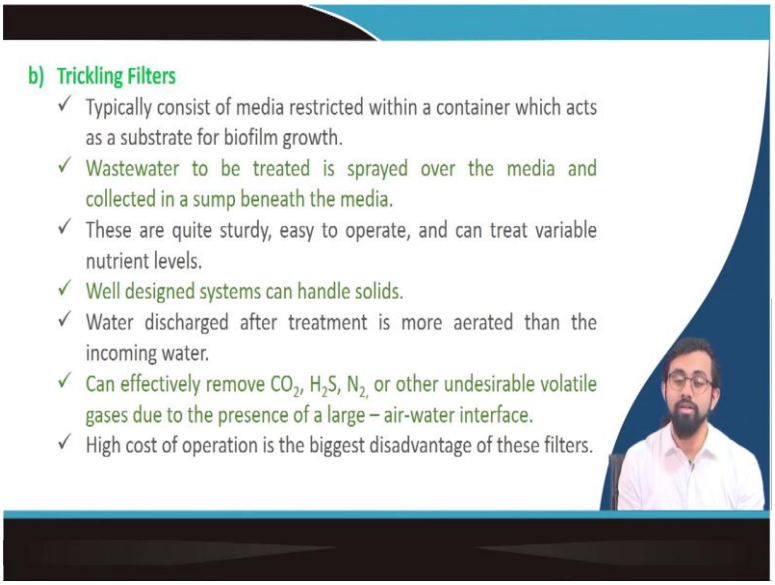
I think you know what is shock load, shock load means when suppose at a very particular time of, suppose you are designing your system for 100 milligram per liter of COD and say like 60 milligram per liter of BOD, but all of a sudden at a particular day suppose your system will receive like say 400 milligram per liter of COD and 300 milligram per liter of BOD because of certain less amount of water the more condensed I mean say more dense wastewater come to the picture.

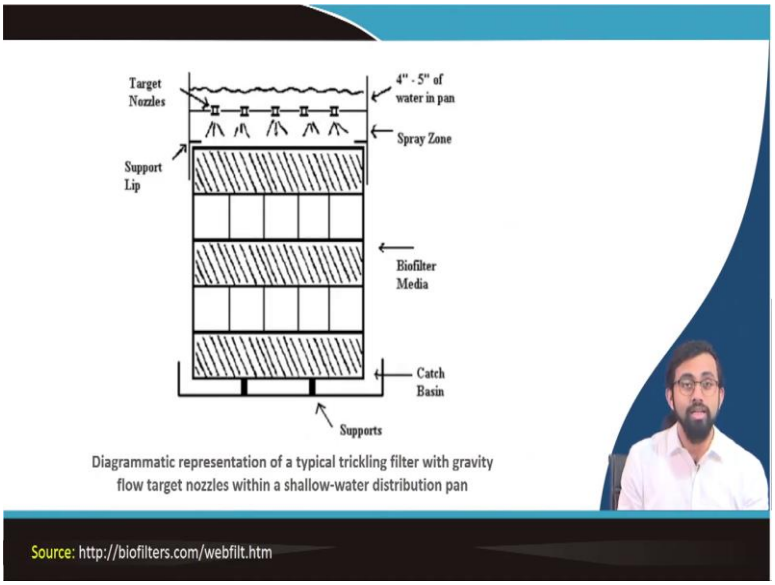
This kind of systems are robust enough to tackle these kind of situations, but sometimes what happened we sometimes some type of bioreactors are very sensitive, if it experience this kind of shock load it may completely disrupt its functionality. So, that is how this biological rotating contactor are the better version of all the other biological reactors that we normally have. It also supports the visual monitoring of the biofilm growth.

You can literally you can see it in your naked eye that how much of our biological growth I mean like the biofilm are actually growing on its surface because you can just simply go there and you can see by your naked eye. Whereas in case of other types of systems suppose you are having trickling filter, you are having any other type of sand filter, there unless until you make it completely transparent glass structure which is very difficult because it is a huge media and it has very high.

It has its own volume and weight and because of that you cannot just have it in a plexiglass structure or any other glass which is transparent in nature. You have to provide it with a continuous like either FRP fiber reinforced plastic structure or proper metallic body. But in this case, you can literally see them.

(Refer Slide Time: 22:15)





Another technology is like the trickling filter I am not going to details much because I hope you remember what we discussed about trickling filter in during our discussion on the wastewater treatment in earlier module, where we discussed like trickling filter is a type of attach growth, remember it is an attach growth process.

What is happening in case of trickling filter, there is this spray zone, the nozzles are there which are keep on spraying its wastewater over the bio media. In the bio media, this I mean like this media what is happening in the media there this biofilm they keep on growing because of perfect ambience, perfect atmosphere and all.

And at the bottom and through this media there are different amount of biofilm it is growing on its surface and its biofilm will keep on consuming the nutrient present in the wastewater and at the end the water will come and settle down and that water can be taken out in the collecting basin through the collecting basins. That is how this type of trickling filter works if you remember. We discussed about its design also if you remember.

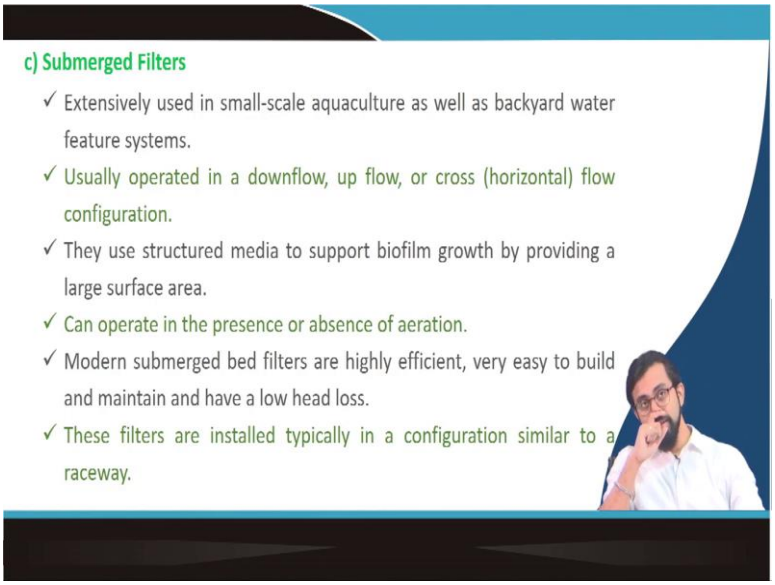
And so that is why I am not going into much of a detail. So, in general trickling filter is a system where we use typically it consists of the media restricted within a container which acts as a substrate for biofilm growth and wastewater is sprayed over the media and it is quite sturdy and easy to operate and can treat very high range of nutrient load, that is actually very good and also it can handle the solid if you provide make a proper design.

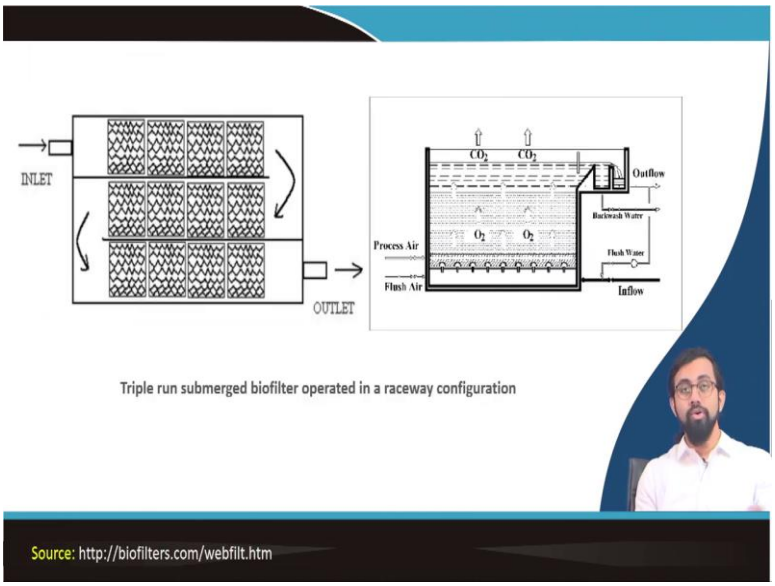
And not only that, the discharge effluent is much more aerated than the incoming water because it is like sprayed. So, when it is sprayed, what will happen it gets much higher amount of surface area to exchange the oxygen through the air when it is sprayed from the nozzle. And the nozzle is like, it is like there is a pivot and from the pivot it is like keep on moving like this, it is like in a circular or I mean like the clockwise or anti clockwise manner and there will be nozzles, in nozzles the wastewater is sprayed over the surface.

That is how it is done. And it can effectively remove the carbon dioxide, hydrogen sulfide, nitrogen and other undesirable volatile gases due to the presence of a large air-water interface that is also something very good. One of the biggest disadvantages like high cost of operation and the very large footprint that it requires.

So, but there are technologies which actually kind of surpass this one and we have a much better trickling filter. And we have some other technologies also which can also be used as an alternate to the traditional tricking filter process.

(Refer Slide Time: 24:47)



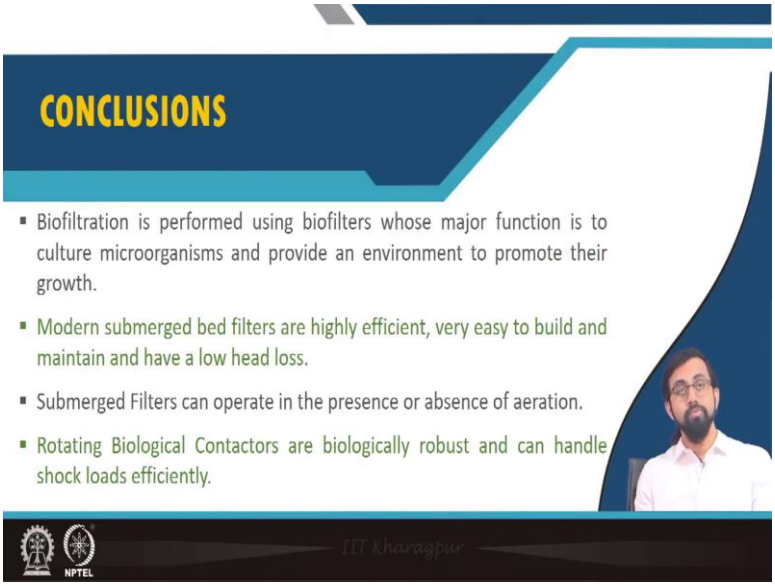


Submerged filter like extensively used in the small-scale aquaculture as well as the backyard water feature systems. It is actually usually operated in downflow, up flow, or crossflow situation. They are structured media to support the biofilm growth by providing a large surface area. It can operate in the presence or absence of aeration.

And modern submerged bed filters are very efficient and they can be easily to build and maintain and very low head loss. Low head loss means it needs less resistance for water to flow through it. And the filter it can be easily installed typically in the configuration similar to that of raceway. How it looks like, it looks like this. If you see this triple run submerged biofilter in the left, inlet this submerged biofilter this like submerged protruded structure is there, those structures are actually used to grow the biofilm.

And then when the water is moving through it and what will happen the wastewater, I mean like the pollutant present in the wastewater it will get consumed by those microorganisms and at the end it will go and once it go out of the outlet it will be very much fresh I mean like very much less of a polluted can be called.

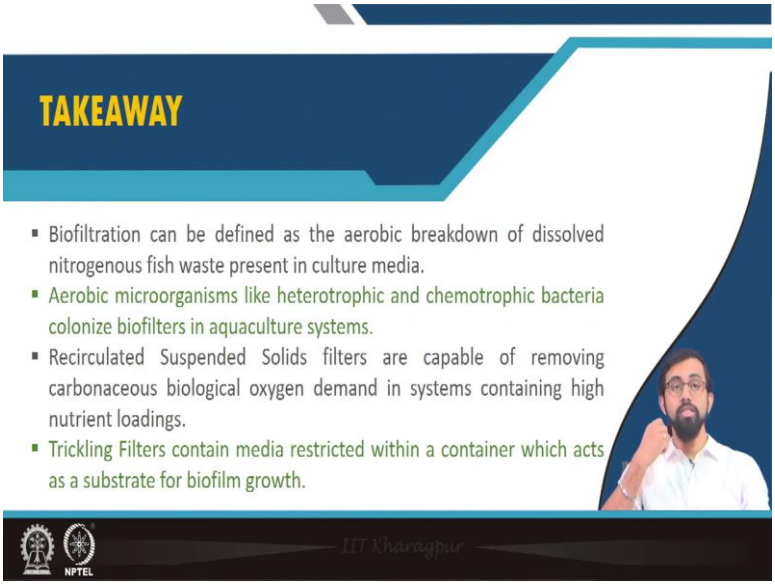
(Refer Slide Time: 26:21)



In conclusion what you understand like what are the biofiltration techniques that we can use in our aquaculture farm. The major biofiltration unit that we discussed is mostly either the submerged one or like the rotating biological contactor ones. So, whatever it is like, their major function is to culture the microorganisms and to provide an environment to promote their sustainable growth.

And this rotating all the other systems that we discuss they are very much robust in nature and they can handle a wide range of nutrients. However, it would be better to have, if you expected we have a shock load it would be better to have a rotating biological contactor and all.

(Refer Slide Time: 26:58)



What are the major takeaways from this lecture is like we know that aerobic microorganisms like heterotrophic or chemotrophic microorganisms, they can colonize biofilter. However, which one is kinda outrun the other when there is a perfect amount of nutrients available, it is heterotrophic one, they can easily outrun the chemotrophic microorganisms if there is much more amount of carbonaceous nutrient or say like, it is like it will get enough amount of atmosphere like a favorable atmosphere for them to grow.

In that case, we need to do some troubleshooting if you really want specific type of chemotrophic microorganisms to be there like say a Nitrobacter or Nitrosomonas, we need it. So, in that case, what we do we need to provide them with the exact situation or in some cases we may even inoculate it. What do I mean by the inoculate? We can supply this microorganism, some of it from the existing source.

These trickling filters it contains the media which is restricted within the container which also acts as a better substrate for the biofilm growth. We also had discussed in earlier module about the moving bed biofilm reactor, about membrane bioreactor, these are also some of the biofiltration techniques which are very famous.

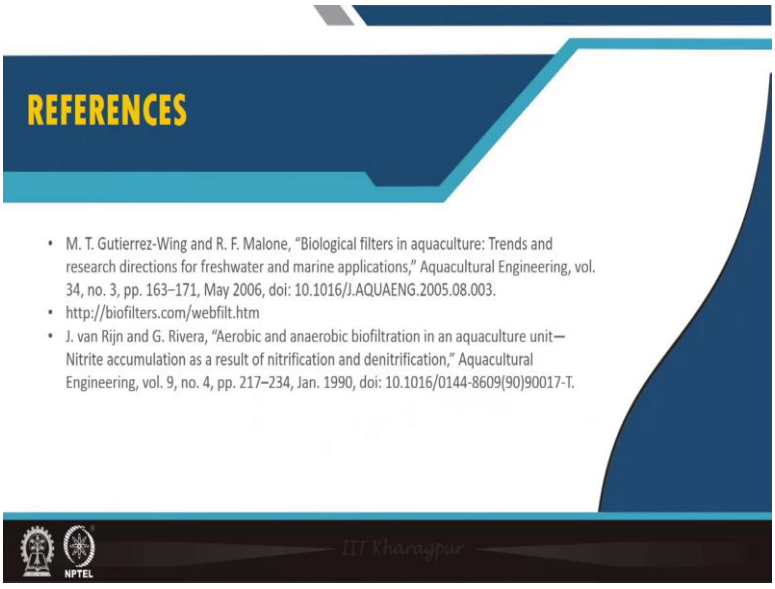
But membrane bioreactor is not actually a biofiltration technique, it is more like it is biofiltration plus mechanical filtration technique because we will be introduced some physical filtration techniques sorry because we will be introduced one membrane artificial membrane of say like microporous, Nano porous, Nano or ultra-porous like ultra-filtration

technique, ultra-filtration membrane, nanofiltration membrane or the microfiltration membrane.

If the filtration technique is much more fine like we go for in angstrom level then we call them reverse osmosis. In that case we have the pressure requirement is much higher and the energy requirement is also very much higher. But in that case the water that we will be getting is completely pure water even it is like completely void of any kind of microorganism possible.

And even sometimes when it will get rid of all the maximum portion of the ions if it is like a very high quality RO membrane. It can even help you to get rid of all kinds of ions presence in your system, in your water, in your final filtrate. So, I hope you got to know some idea about the biofiltration technique, how it works and all. I hope it is very much helpful for you to have some idea about how these different filtration techniques we use it in aquaculture industry.

(Refer Slide Time: 29:48)



These are the references that you can follow. You can take a picture or you can just simply go and google it, it will be much gave you a much better idea and more information about how to go ahead. So that is it for today. I hope this lecture actually helped you out with understanding much better about the biofiltration techniques. Nice to see you. I hope to see you again. Thank you.