Biological Process Design for Wastewater Treatment
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Lecture 30
Advanced Biological Wastewater Treatment: Moving Bed Biofilm Reactor (MBBR)

Welcome everyone in this NPTEL online certification course on Biological Process Design for Wastewater Treatment. So, in the previous few lectures, we started studying regarding the Advanced Biological Wastewater Treatment. And in the previous two we studied regarding the fluidized bed reactor followed by membrane bioreactor, now we will be further study the Moving Bed Biofilm Reactor which is called as MBBR. So, we will be studying regarding MBBR in this particular lecture.

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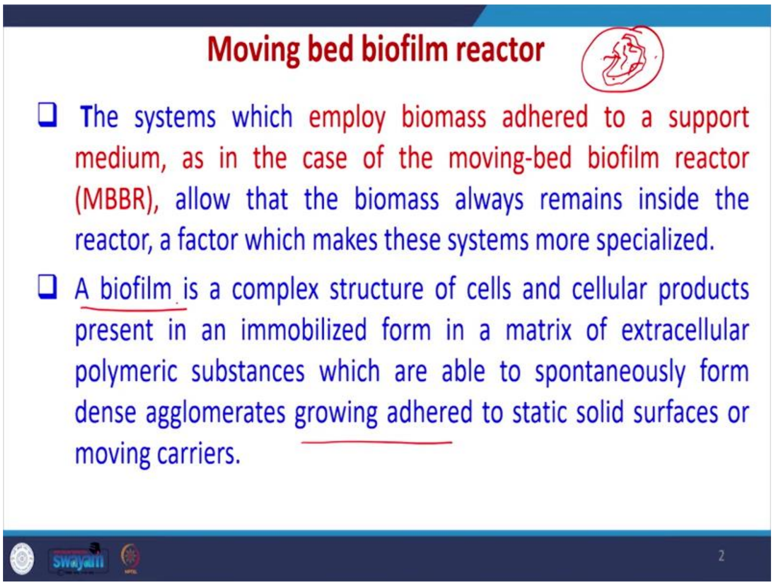

So, what is the moving bed biofilm reactor, the system actually this system employ biomass or microorganisms which are adhered to is support medium. That means, we have some support this is there some support medium. So, biomass or microorganisms are adhered to the support medium and this support medium give on moving inside the reactor. So, this is a bed on which microorganisms is grown and this bed actually moves inside the reactor that means moving bed biofilm reactor.

So, which essentially contains a biofilm which is attached to a bed which is actually a supporting medium and since the density of supporting medium is smaller along with the biofilm grown on it, this system can move inside the reactor. So, this is moving bed biofilm reactor and the biofilm which actually grows on this particular support is a complex structure of cells and cellular products which is present in an immobilized form in a matrix of extracellular polymeric substances which are able to form dense agglomerates growing and getting attached to their static solid surfaces or moving carriers. So, these biofilm is grown on these moving carriers and these moving carriers move inside the reactor.

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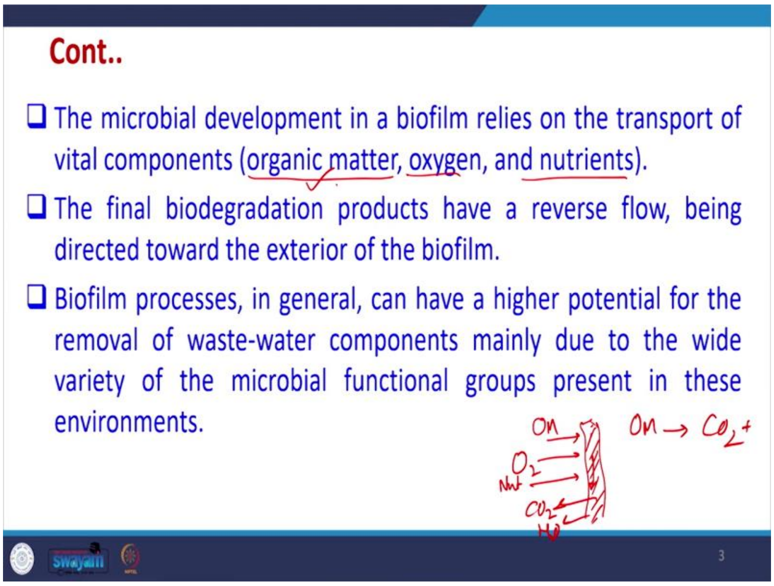

The microbial development in a biofilm relies on the transport of vital components. So, how the biofilm will grow depend upon the various factors and their movement inside the support as well as in the biofilm. So, the movement occurs of the organic matter which is required for growth as a field. Similarly, oxygen and nutrients. So, all these are essential for any microbial development to happen inside a biofilm.

The final biodegradation products have a reverse flow that means first the wastewater containing the organic matter will go inside this biofilm along with that oxygen also has to go and nutrients also have to go if they are not present in the organic matter itself then the degradation will happen inside the biofilm. Now suppose this is the biofilm, so, we have organic matter which should go then we should have oxygen which should go also nutrients also if they are not present they should go inside this biofilm.

Now, once they go inside certainly the organic matter will degrade into CO_2 and, etc. So, the final products which are generated these should come out of the system. So, this is the final biodegradation products have a reverse flow being directed towards the exterior of the biofilm. The biofilm processes in general can have a higher potential for the removal of wastewater components mainly due to a wide variety of microbial functional groups present in these environments. So, this biofilm may contain various types of microorganisms or microbial materials which can help in the degradation of the pollutants.

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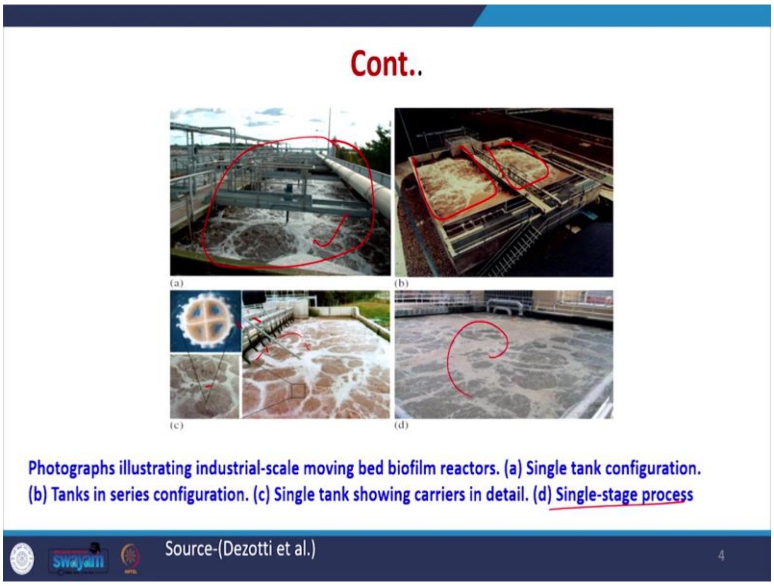

Now, this is schematic actually photograph illustrating the industrial scale moving bed biofilm reactors. So, this is a cell like as we can start with a single tank configuration we can see a big single tank then we have a double stage tank, which is there and then tank in series we can have multiple tank in series and then also a single stage process. So, there are different possibilities.

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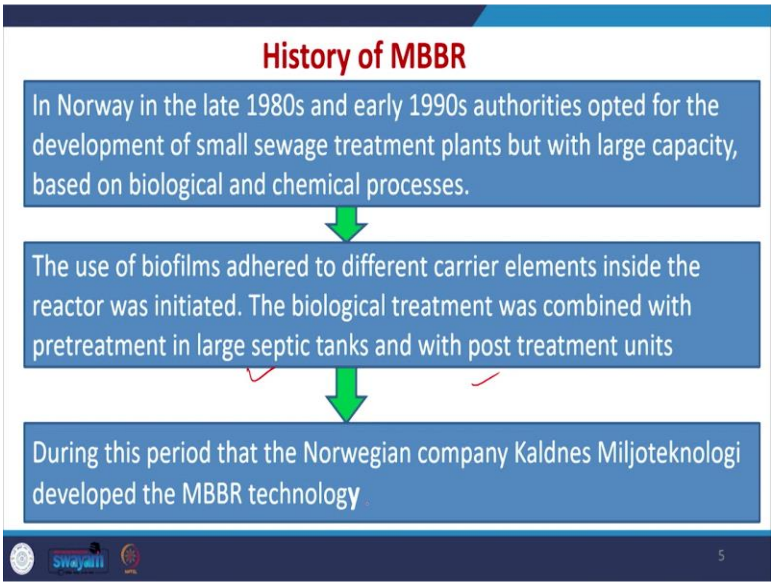

Essentially what happens in the MBBR that we will be discussing the MBBR got developed in Norway in 1980s and early 1990s When the authorities opted for development of small sewage treatment plants, but with large capacity that means, they require the treatment of water to be done in larger quantity, but this overall sewage treatment system should be smaller and this overall treatment should be based upon the biological and chemical processes.

So, the use of biofilm attached to the different carrier elements inside the reactor was initiated, because overall area has to be increased and treatment efficiency, if it is faster, then the size of the sewage treatment plant can be smaller. So, the biological treatment was combined with the pretreatment in the larger septic tanks and with post it went units during this period, the Norwegian company developed it is MBBR technology which was further developed by various researcher.

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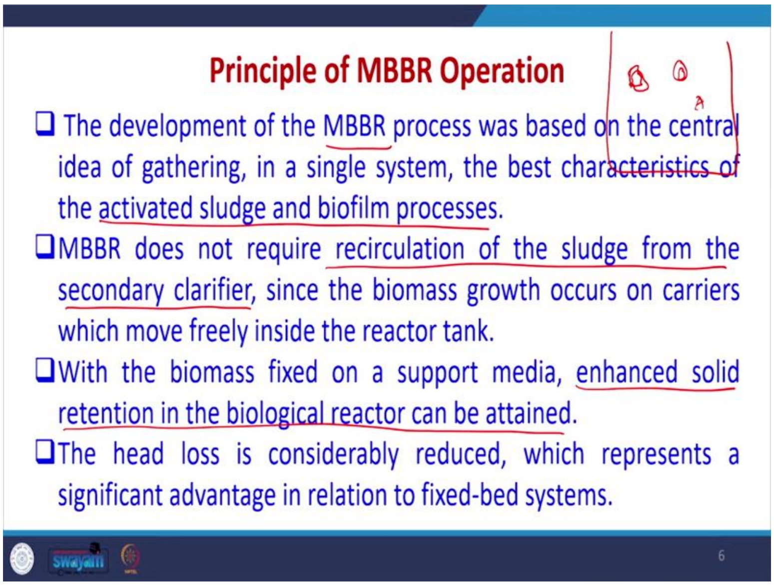

So, principle of MBBR operation, the development of MBBR was based upon the central idea of gathering in a single system the best characteristic of the activated sludge process as well as the biofilm process. So, activated sludge process was already well known and biofilm process like the trickling filter is also known. So, when both have to be combined together then we have MBBR process the moving bed biofilm reactor.

MBBR does not require recirculation of the sludge from the secondary clarifier since the biomass growth occurs on the carrier, which move freely inside the reactor tank. So, there is one good advantage is that we need not recirculate the sludge from the secondary clarifier because the biomass is already grown on some carrier and which itself is moving inside support this is the reactors we have some carrier on which a biofilm is grown.

And similarly, we have different types of dishes moving all around the reactor and with the biomass fixed under support media enhances solid retention in the biological reactor can be attained the head loss is considerably reduced and which represents a significant advantage in relaxation session to the fixed bed systems. So, there are different possible configurations of MBBR.

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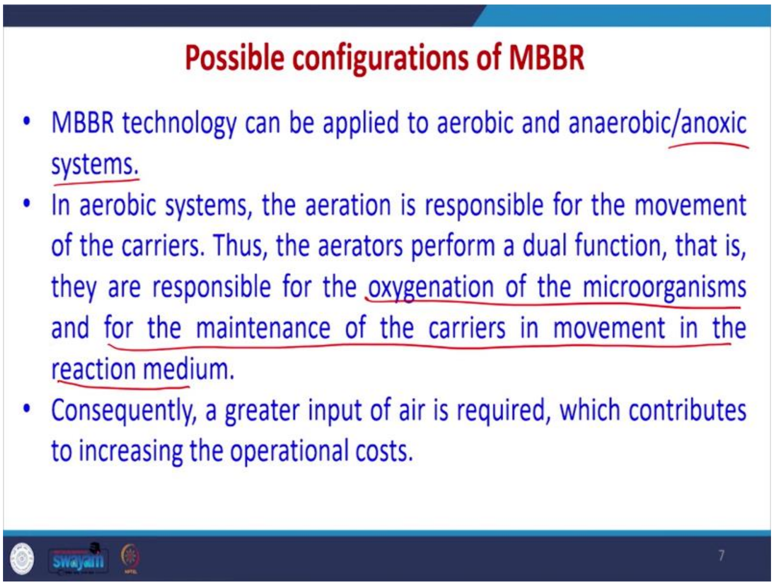

So, MBBR technology can be applied to aerobic treatment, anaerobic treatment or anoxic systems also, in aerobic system, the aeration is responsible for the movement of the carrier. So, since the carrier have to be moved all inside the system, then we have the aeration which is responsible as does the aerator performs a dual function that is they are responsible for the oxygenation of the microorganism and also for the maintenance of the carrier in the movement in the reaction medium inside the reactor for aeration system MBBR is very good.

Consequently, a greater input of air is required which contributes to increasing the operational cost in the MBBR as compared to traditional activated sludge system, since we have to move the bed biofilm moving bed biofilm all inside the reactor that means the air input has to be higher than only the movement will happen.

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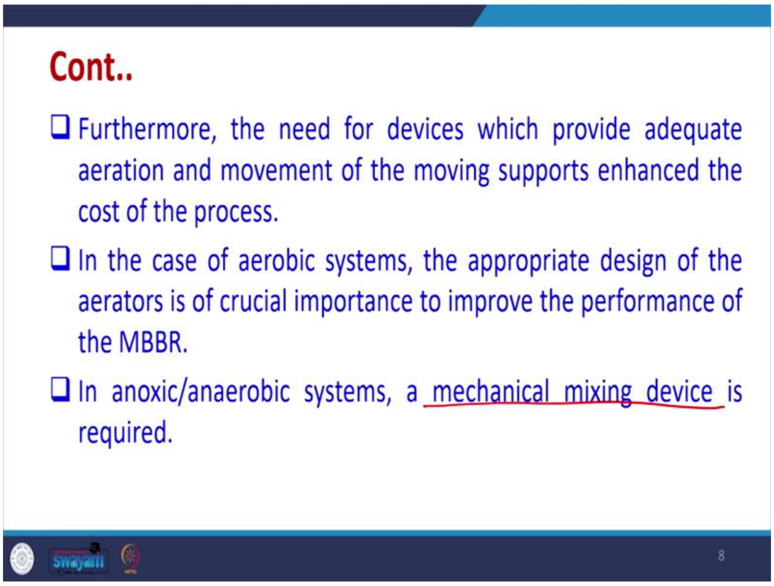

So, furthermore, the need for devices which provide adequate aeration and movement of the moving support enhances the cost of the process. In the case of aerobic system, the appropriate design of aerator is of crucial importance to improve the performance of the MBBR in anoxic and anaerobic system since we cannot use the air. So, in this case, we have to use a mechanical mixing device for doing the movement of the moving bed biofilm. So, that means the mechanical mixing has to be used then only we are able to move the biofilm along with the surface on which it is grown. So, this is there.

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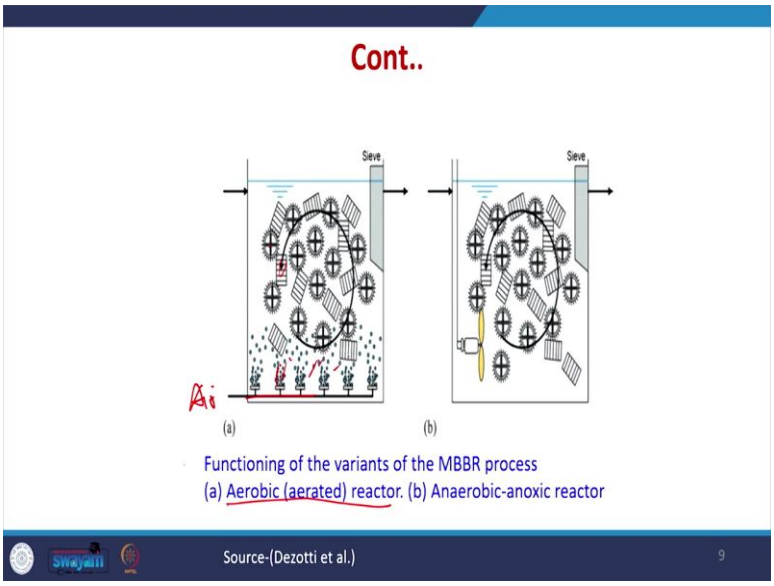

Now we can see here the functioning the other variants of the MBBR processor. So, in that aerobic reactor, we have an air which is going inside the reactor. So, we can see here different types of here the MBBR with this the film the bed is this is the packing on with the biofilms will be grown and because of the aeration which is happening all these moving all these beds, smaller beds with the biofilm they are able to move all inside the reactor.

Now, in the case of anaerobic or anoxic reactors is we cannot use air. So, in this case we have to use a mechanical device for mixing this is done and this is how the moving bed MBBR process can be used for an aerobic treatment.

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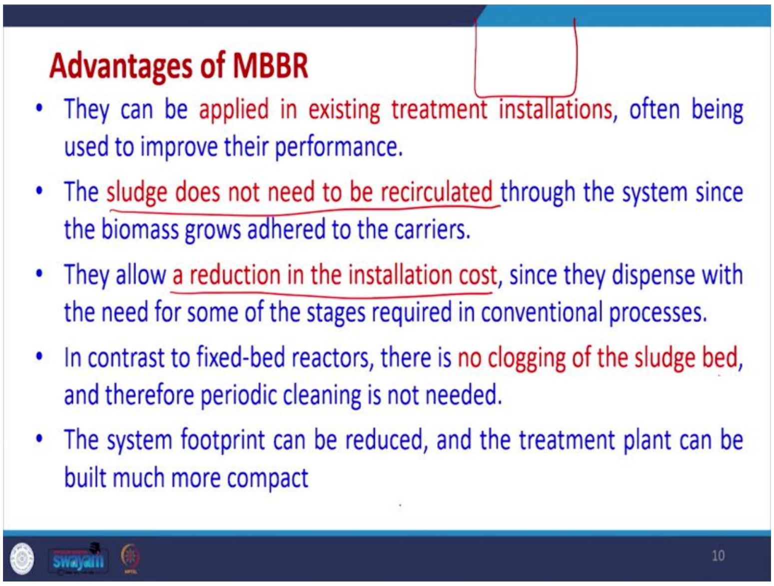

Now, there are certainly some advantages of MBBR they can be applied in the existing treatment distillation that what does it mean to suppose we have an activated sludge process. So, in place of the activated sludge process, we can use these carriers along with their biofilm, we can just put them inside the system and start using this MBBR system in the place of activated sludge the system only thing is that we have to use more amount of air so, that this system moves all inside the reactor and this is in a floating mode.

So, we can use the existing treatment installation for MBBR. Now, the sludge does not need to be recirculated to the system since the biomass growth are there to the carrier itself. Now, this allows a reduction in the installation costs since they dispense with the need for some additional stages which is required in the conventional processes. In contrast to the fixed bed reactors, suppose we start comparing with the fixed bed reactor, there is no clogging of the sludge bed and therefore, periodic cleaning is not required.

So, we have advantage also as compared to fixed bed or tickling bed reactor, the system footprint can be reduced and that treatment plant can be built much more compared because we are using more concentration of microorganism in the same reactor and also the performance is increasing.

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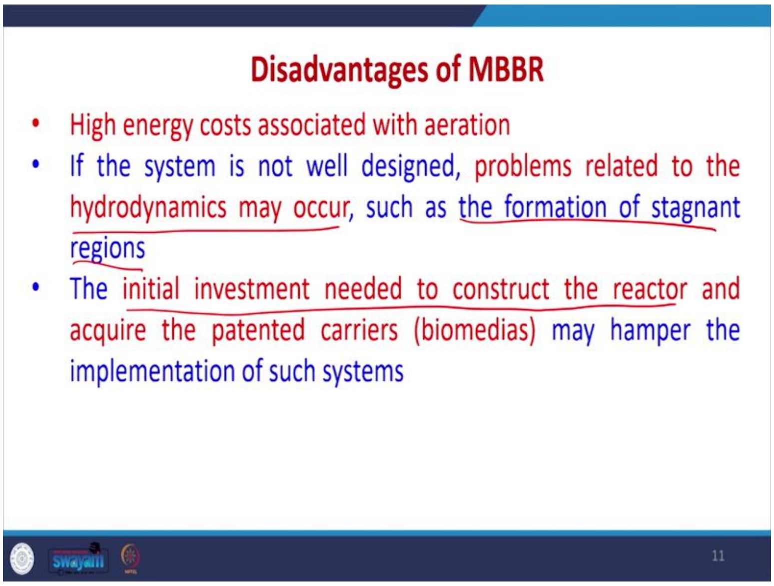

The disadvantage of MBBR is that higher energy cost associated with a higher amount of aeration since the bed has to be continuously floated. So, aeration has to be certainly be higher, also there are problems related to hydrodynamics. So, it is possible that some stagnant regions may form. So, these stagnant regions where the wastewater treatment will not happen.

So, we have to avoid the formation of stagnant regions. And this can be done only if the hydrodynamics of the overall reactor system is good, then also the initial investment needed to construct the reactor and acquired the carriers may also increase the cost and may hamper the performance of the search system. So, this is possible. So, we have to see that whether we have to use the MBBR or not, but certainly there are many advantages associated with the MBBR.

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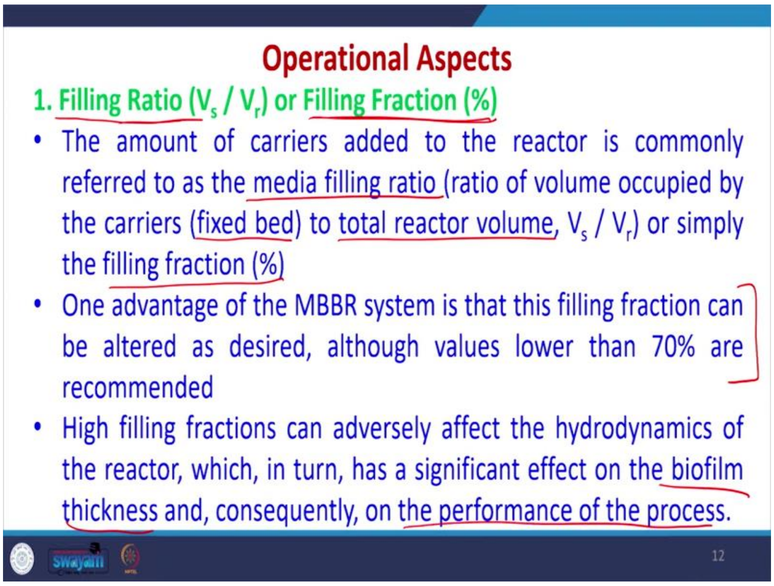

Now, there are certain operational aspects associated with MBBR. So, we are now going to study the operational aspects of MBBR one by one. So, one of the first operational aspects of MBBR there are many operational aspects which need to be understand for proper operation of MBBR the foremost operational aspect is called as filling ratio on the filling flexion this can be defined as the amount of carriers added to the reactor.

That means how much amount of carrier is there inside the reactor and it is also called as media filling ratio the ratio of volume occupied by the carriers which are essentially the fixed bed to the total reactor volume. This can simply be put as filling fraction, one advantage of MBBR system is that this this filling fraction can be altered as desired. So, although the value lower than 70 percent are recommended, but we can always change it to 50 percent 75 percent like this.

So, this filling ratio is under the control of operator. Higher filling fractions can adversely affect the hydrodynamics of the reactor and which will lead to a stagnant region and if the hydrodynamics of the reactor is not well, in turn, it will have a significant impact on the biofilm thickness and consequently on the treatment efficiency. So, this is very important. So, we have to avoid higher filling fractions. So, we can see filling fraction that we have to use will also depending upon the surface area requirement.

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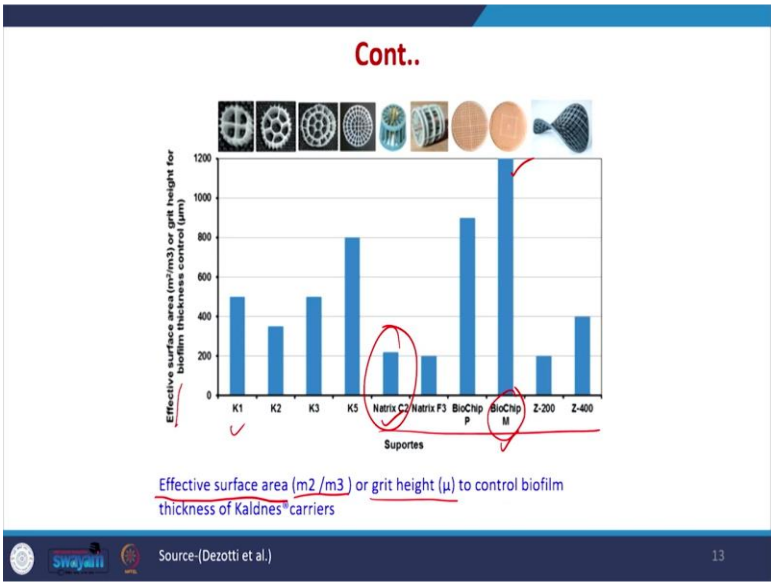

So, that means, and we want to also see that what is the volume of the packing materials or these materials on with the biofilm has gone. So, the effect is surface area that surface area which is exposed for biofilm grown per meter cube is important and this is also referred to as grit height for this carrier. So, for different types of carriers which are named as K1, K2, K3, K4 and these are the different carriers which have been developed by different companies.

Now, there the effective surface area requirement is grit. So, we can see the BioChip M has very high surface area around 1200-meter square per meter cube. So, if suppose we have certain requirement of surface area, so, and that surface area is fixed. So, the actually the total amount of BioChip M which will be required which will be lesser as compared to if we go matrix.

So, the filling fraction in case a BioChip M will be much lower as compared to this. So, this way depending upon the requirement certainly there may be certain the cost may be higher there may be some other advantages, disadvantages etc. So, those things also have to be taken care, but the effect to surface area, which is defined as meter square of surface area per meter cube of the that particular packing material is one of the important parameters which has to be taken care in the selection of materials for move MBBR.

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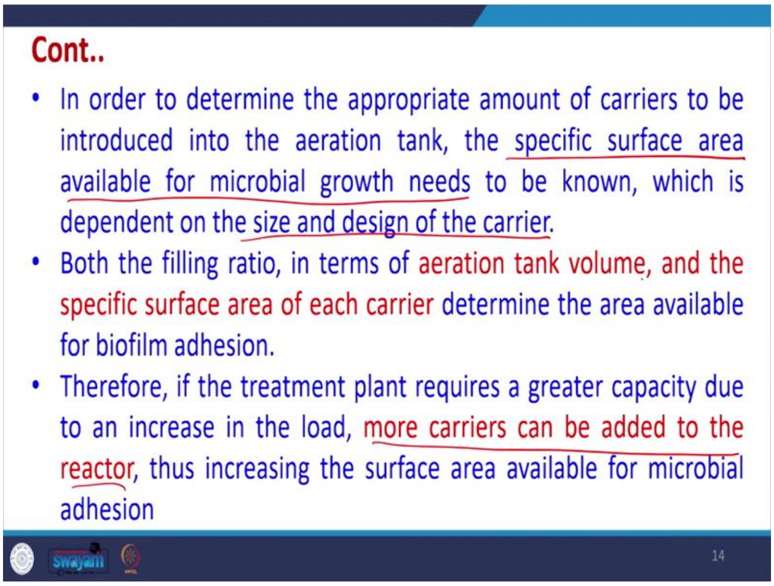

In order to determine the appropriate amount of carriers to be introduced in that aeration tank the specific surface area available for microbial growth needs to be known and which is dependent upon the size and the design of the carrier. So, this is important both the filling ratio in terms of aeration tank volume and the specific surface area of each carrier determines the area available for biofilm growth or adhesion.

Therefore, if the treatment plan requires a great capacity due to increase in the load, more carriers can be added to the reactor thus increasing the surface area available for microbial growth. In turn also we can use some carrier which has much higher surface area. So, in that case, the same amount of carriers will be there certainly additional costs will be required because we are using carriers with higher surface area.

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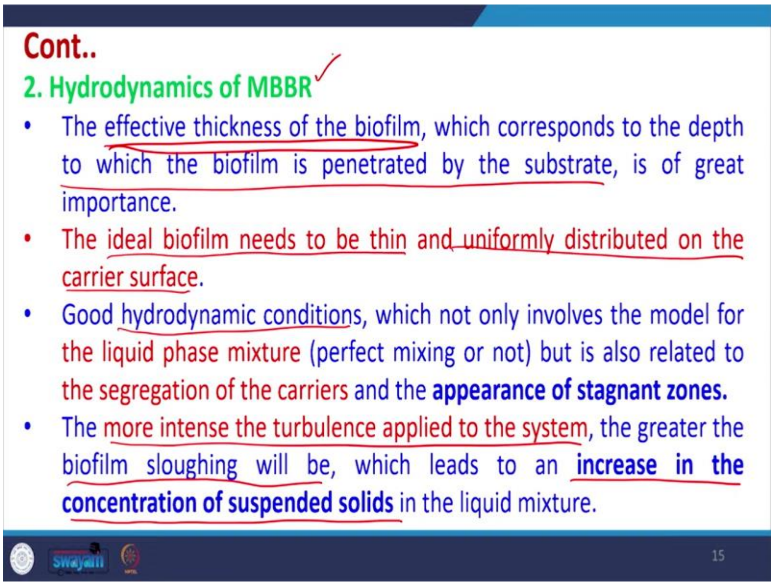

Then the second important parameter is hydrodynamics of MBBR the effective thickness of the biofilm which corresponds to the depth to which the biofilm is penetrated by the substrate is of great importance. So, this affected thickness of the biofilm is very important because the movement of organic matter oxygen happens only through this thickness also the products also come out through this thickness.

So, smaller the thickness better it is for the treatment the ideal biofilm needs to be thin and uniformly distributed on the carrier surface. So, this is the ideal condition good hydrodynamic conditions, which not only involves the model for liquid phase mixture like perfect mixing or not, but they are also related to segregation of the carrier also and appearance of stagnant zone.

So, we had to see that the hydrodynamic condition should be such that proper mixing of liquid phase happens also the separation of carrier that means that carriers are separated from each other with some distance third thing that there should not be any stagnant zone. So, we have to determine the hydrodynamic condition in such a manner that all these three conditions are met the more intense than turbulence applied to the system.

So, suppose any condition we have more mixing and we are using more aeration so, that mixing is happening or turbulence is more. So, under that condition greater if turbulence is more the biofilm sloughing will be happening. So, this will in turn may help that the biofilm is thin, however, it will also increase the concentration of suspended solids thus we have to see that we have to cross check that how much turbulence is good enough for our system also we have to maintain a proper hydrodynamic condition.

So, that the mixing in the liquid phase is proper the carriers are separated good enough distant from each other and also there should not be any stagnant zone appearing inside the reactor. So, the hydrodynamics is very important criteria for MBBR.

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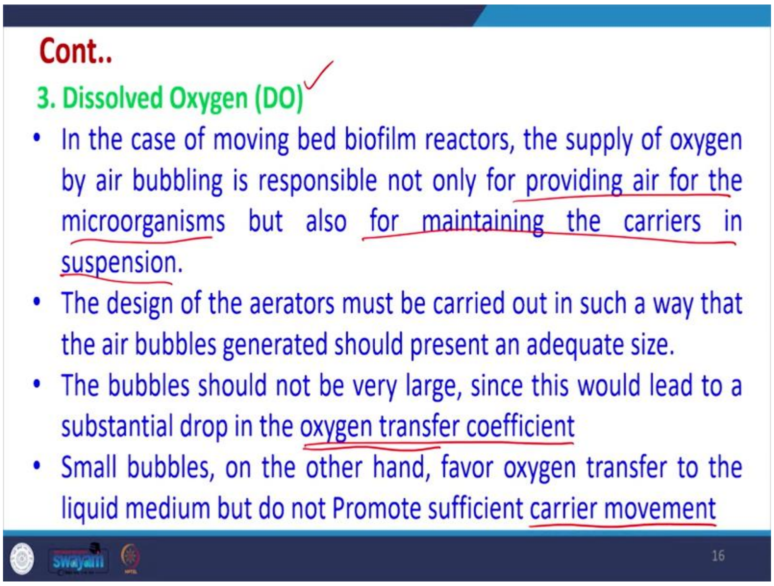

Then the dissolved oxygen in the case of MBBR the supply of oxygen by air bubbling is responsible not only for providing air for the microorganism, but also for maintaining the carriers in suspension. So, the dissolved oxygen level in the reactor is very important that design of aerators must be carried out in such a way that the air bubbles generated should be present on adequate size and all throughout the reactor, the bubble should not be very large, since this should lead to substantial drop in the oxygen transfer coefficient.

Also, smaller bubbles on the other hand favor oxygen transfer to the liquid medium but do not promote sufficient carrier movement. So, we have to optimize the bubble size so, that the carriers on which the biofilm is grown their movements should also happen and also the size should be good enough so, that we have proper oxygen transfer happening also. So, the bubble size is very important along with the dissolved oxygen concentration inside the reactor.

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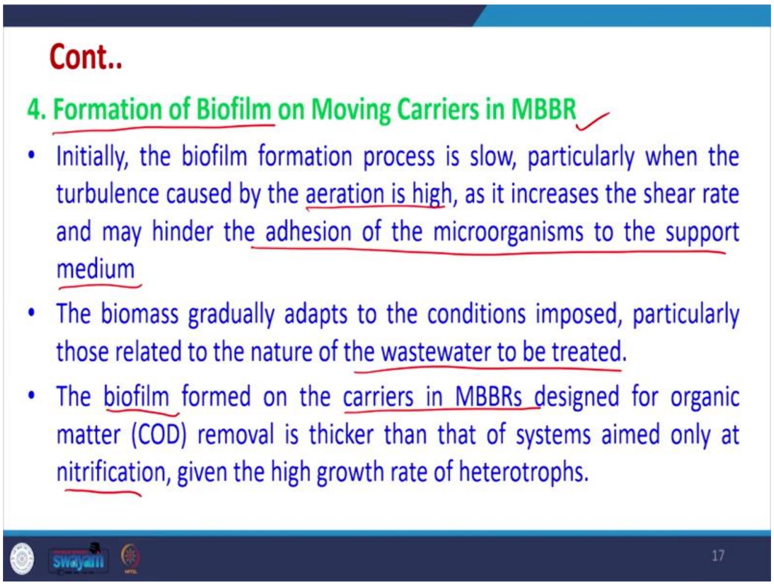

Further on the formation of biofilms on the moving carrier in the MBBR is very important that how the biofilm formation takes place on these carriers initially the biofilm formation process is slow So, generally and particularly when the turbulence caused by the aeration is high. So, we have to see that the aeration is lower in case earlier so, that the biofilm formation occur and in the case when the turbulence is high, it increases the shear rate and it hinders the adhesion of the microcosm to the support medium.

So, we have to properly check the turbulence, so, that the biofilm formation occurs properly the biofilm or the biomass gradually adapt to the condition imposed and particularly those related to the nature of this wastewater to be treated. So, the biofilm grows only with time when the acclimatization of the microorganism happens with respect to the water, wastewater to be treated.

The biofilm formed on the carrier in the MBBR designed for organic motor removal. If suppose COD is higher, then the biofilm is thicker than that of the systems which are aimed only at nitrification. So, the thickness of biofilm will also depend whether we want to go for COD removal or we want to go for nitrification. So, depending upon these things that thickness of biofilm will also affect.

So, overall the formation of biofilm is highly affected by the turbulence in the reactor also the biofilm thickness is their desirability depends upon the whether we are going to perform the COD removal or we are going for nitrification that depending upon these requirements of the biofilms thickness may be different.

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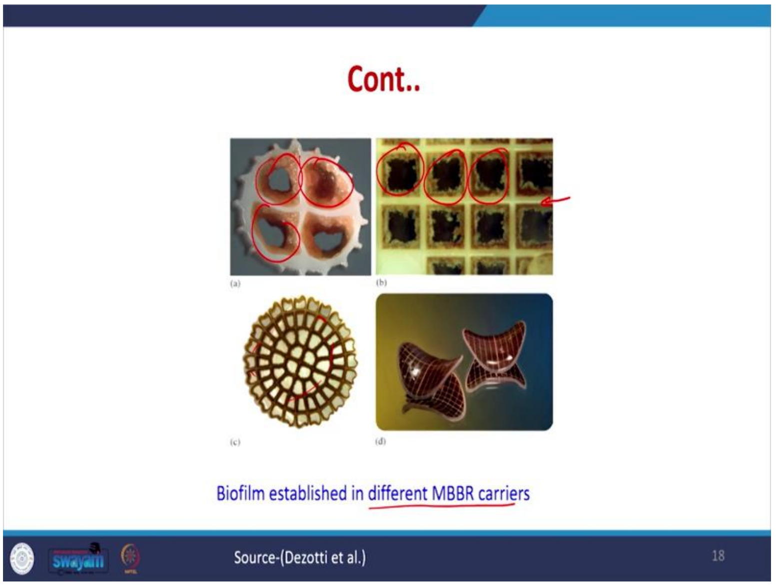

So, we can see the biofilm established in different MBBR carriers. So, we have this MBBR carrier we have the biofilm which is grown. Similarly, this is the MBBR carrier on which these biofilms are grown here. Similarly, the other type of carriers we can see that there are biofilms may grow depending upon the type of carrier, there, how the pores are exposed, this is also depend on what is the surface area of that particular carrier and also depending upon the type of material also.

Whether the biofilms can properly get attached to this carrier material or not. So, depending upon these factors, various factors, pH may also affect this performance significantly. So, how the biofilm grows on the MBBR carrier this essentially affect the overall performance of the MBBR also.

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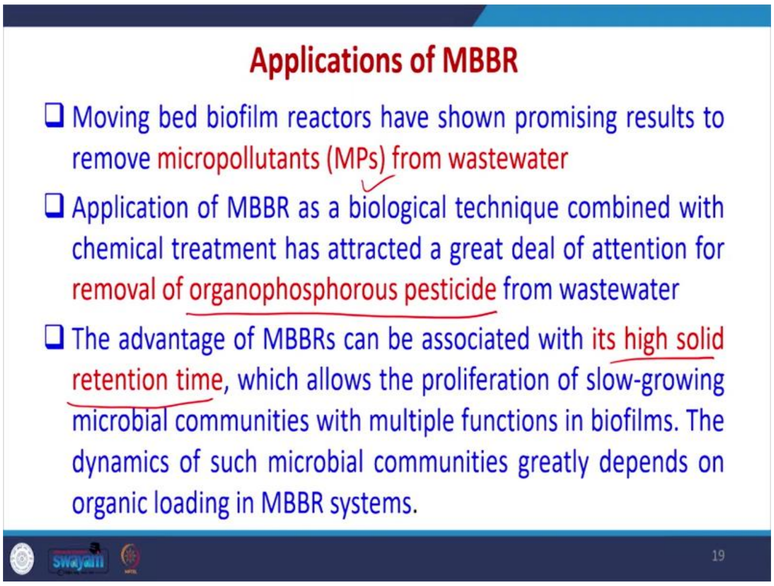

So, there are different applications of MBBR. So, moving bed biofilm reactors have shown very promising results to remove micro pollutants from wastewater. So, all those micro pollutants which are coming into the wastewater they have shown very good result as compared to activate sludge process for removal of these micro pollutants. Also application of MBBR as a biological technique combined with that chemical treatment has attracted a greater deal of attention for removal of organophosphorus pesticides. So, we can go for treatment of different types of pesticides, these things have been reported in the literature. So, they have shown very good results.

Similarly, the advantage of MBBR can be associated with its high solid retention time, which allows the proliferation of very slow growing microbial communities with multiple functions in the biofilm. So, these biofilms can perform very well under different conditions and the dynamics of such microbial communities greatly depends upon the organic loading in the MBBR system.

So, whether it is how much loading is there, what type of loading is there depending upon that the performance may be affected, but since we can maintain high solid retention time, the performance is generally better of MBBR. So, till now in the advanced biological treatment system.

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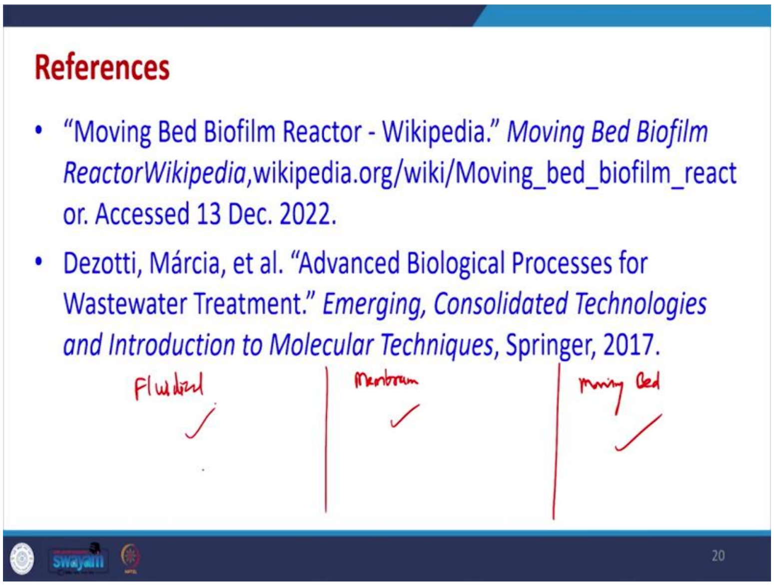

We have studied three types of system these are the reference related to a moving film biofilm reactor, but overall summarizing the three types of advanced biological treatment system that we have studied. So, first was fluidized bed reactor. So, then the second was the membrane bioreactor membrane bioreactor and third was moving bed bioreactor among all these reactors the moving bed by reactor is very common, and these are being used in many industries where the COD loading etc., is very high.

Also, the uses of membrane biofilm reactor or membrane reactor is increasing in the wastewater treatment as compared to the fluidized bed reactor. Fluidized bed reactor are still not very common in the wastewater treatment system, but moving did MBBR are very common nowadays, and they are used in various industries, they have different advantages and disadvantages that we have discussed in the previous lectures.

So, we you can go back and revert to back depending upon the requirements we can use any of these fluidized bed reactor or membrane bioreactor or moving bed bioreactor. So, these reactor systems can be used in all the biological treatment systems that we have studied till now, there is a lot of sludge which is getting generated. So, moving further on in the next slides, next lecture onwards, we will be studying how to manage the sludge because sludge is generated in the primary treatment in the secondary treatment in the aerobic process.

Similarly, in the various advanced biological treatment processes, also a lot of sludge is generated. Though management of sludge in biological treatment system is essential part of that overall treatment structure. So, we will be studying regarding the sludge management and how to take care of the sludge, how to further manage, dispose, or utilize these we will be studying in the next lecture onwards. So, thank you very much. We will continue further.