Wastewater Treatment and Recycling
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Lecture – 51
Alternate Wastewater Treatment System MBR and MBBR

Hello friends, and welcome to this last class for the week 10: where we will be talking about alternate some of the Alternate Wastewater Treatment System. So, in the previous classes of this week, we did talk about the basic idea of the how the conventional treatment systems are laid out. And then we did talk about the alternate systems in the forms of wet land and we did talk about the SBR and SBBR. This class we are going to discuss the MBR which is Membrane Bio Reactors and MBBR which is Moving Bed Biofilm Reactors. So, that is what we are going to discuss in this particular class.

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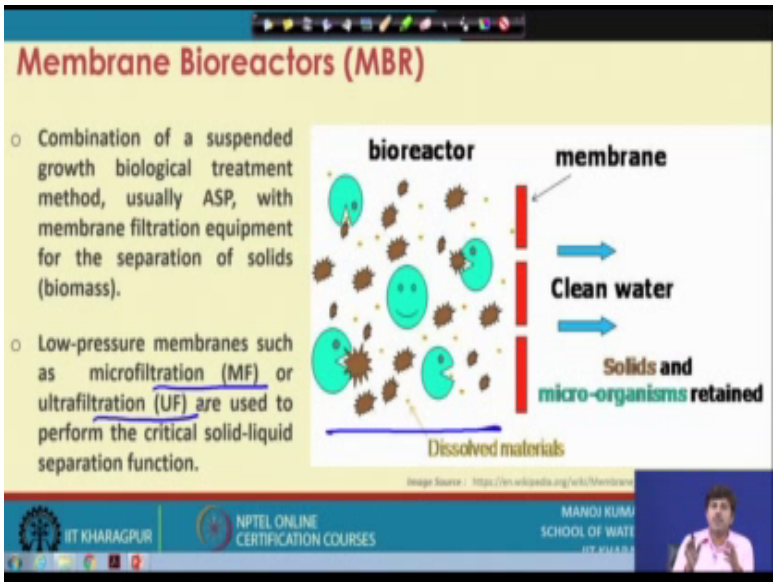

So, the membrane bioreactors are basically a combination of suspended growth biological systems usually the activated such process which is used with the membrane filtration equipment ok. So, this membrane filtration equipment it is means we will have the traditional conventional treatment system ok. And what we do for the separation purpose in the say typically activated sludge process. So, in activated sludge process for the separation we have a secondary clarifier at which separates the solid content or sludge mass with the water.

So, the sludge mass is separated from the water in a secondary sediment in the secondary clarifier or the secondary sedimentation tank in a conventional activated sludge process. But the efficiency of the secondary settling basin may not be very good ok. So, that is we may still get some solids washout in the effluent. Now what is done and then the other aspect is that we have to kind of recycle the sludge back to the activated sludge systems.

Now what alternatively is done in a MBR that instead of going for a settling basin secondary settling basin a membrane is put a semi permeable membrane is put which allows usually water to pass through, but retains the solid ok. So, that way it is a combination of your typical say activated sludge process with membrane filtration equipment for the separation of solid purpose.

And since we are dealing with wastewater so, usually high end membrane like RO or nano filters are not used. What is used is either micro filtration membranes or ultra filtration membrane. So, these are relatively low pressure membranes so that is why they are preferred. So, these low pressure membranes such as your micro filtration or ultra filtration are used to perform this solid liquid separation function ok.

So, that is what actually happens in a membrane bioreactor where there would be bacteria which will be kind of growing when they consume the dissolved organic matters and in the process lot of solid is generated and that solid is separated using a membrane. So, as we say that conventional or typical size of a micro organism or typical size of bacteria is of the order of 1 micron. So, if we go for micro filtration which can filter say up to 100 particles larger than your 100 nanometers or we go to ultra filtration which can filter particles of the order of say ten nanometers or those way.

So, we will that way be able to separate majority of the bacteria or majority of the biomass from the water and the water that we will get will actually the kind of clean water where solids and micro organisms will be retained on the other side of the membrane. So, that is what actually happens in this typical membrane bioreactors.

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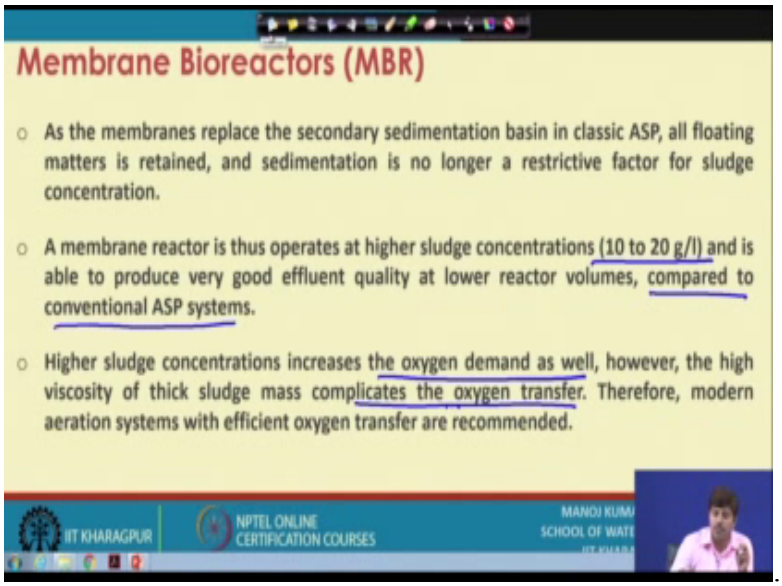

So, as the membrane kind of replace the secondary sedimentation basin or secondary clarifier in an activated sludge process all floating materials are retained ok. So, and this way the like we do not need your secondary sedimentation process. And we can actually have a higher sludge concentration as well within the reactor ok. So, we will have higher sludge concentration because of our very good solid returns and ability because your conventional secondary clarifier works on a principle of gravity. So, higher because of the higher specific weight of the biomass they settle, but for very fine particle this settling may not be that efficient.

So, if it is a granulated or good biomass it will settle quickly but alternatively if it is say a kind of a system which is kind of fluffy or there is a biogas entrapped in system so the settling is not that effective. But when you put a membrane system so, this kind of retention is very good; retention of solids are very good with this membrane. And since we can retain lot of the large portion or almost all of the sludge produced. So, we will we can operate the reactors at higher sludge concentration. And we can operate these reactors at sludge concentration as high as 10 to 20 grams per liter. At times even higher like up to 30 gram per liter can also be used for these systems.

So, when we operate this at a higher sludge concentration so they produce kind of very good effluent quality at lower reactor volume also. So, that way the performance would actually be better than the conventional activated sludge systems. So, higher sludge

concentration is the main reason because if you have lot of biomass so they will quickly degrade or decompose the organic matter present in the system they will the rate organic matter decomposition will also be higher and that way the extent which the BOD can be reduced or extent to which the organic carbon concentration could be reduced in the water would be greater as oppose to the conventional activated sludge system.

However if there is lot of biomass, if there is higher quantity of biomass present in the system so there are going to be the high oxygen demand as well. Because for the purpose of decomposing organic material they will the micro organisms will demand for oxygen. So, the oxygen demand of the waste increases that way they need higher dissolved oxygen. But since there is lot of micro organism the water is actually or the wastewater is actually the more viscous because of this thick sludge mass present. And since it is the viscosity or lot of solid this things materials are present in the system so the rate of oxygen transfer also complicated and in fact it decreased.

So, at one place we have higher oxygen demand and the rate of oxygen transfer has that way decreased. So, therefore, the requirement of aeration is very critical in the membrane bio reactor systems. So, we must ensure that a good aeration system a high end or modern aeration system which can efficiently transfer the oxygen to the water medium must be present in at membrane bioreactor for the ideal performance of the systems.

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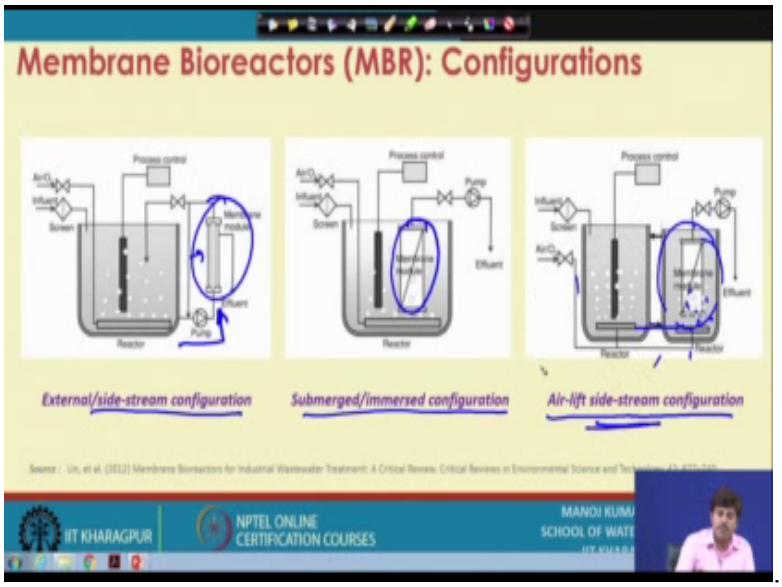

So, that is how the oxygen requirement needs to be kind of taken care of. Now if we see the various configuration of membrane bioreactors so there are two popular configurations of the membrane bioreactor. There is kind of external or side stream configuration which is the oldest configuration. So, when membrane bioreactors were planned initially it was planned this way only.

So, in this configuration what happens that there is the membrane process is not within the reactor, but is outside the reactor in and a side stream or a stream from the reactor from your treatment system from activated sludge process say or from your aeration basin is passed through this membrane ok.

So, that is what happens in a external or side stream configuration; when your membrane system is not in the reactor is outside the reactor. The other one we have is submerged or immerged configuration; where your membrane system is actually within the aeration system ok. So, this is called kind of immerged configuration or submerged configuration which has been developed at a later stage for kind of reducing the energy requirement of the external systems.

Mixing these two kind of new configuration is being used nowadays and is being developed not that popular though still is the air lift side stream configuration; where the membrane is in the side stream, but it is not dry that way it is still the water is pushed through this and in the separate module there in a separate membrane module, because where the aeration is also provided.

So, based on the air supply the we get a air reactor. So, based on this air supply and this is kept in the suspension and that way like the membrane works within the wet system here within in fact membrane here also will be immerged, but still it is in a side stream ok. It is not in the main aeration basin so that is; what is the kind of the different configuration.

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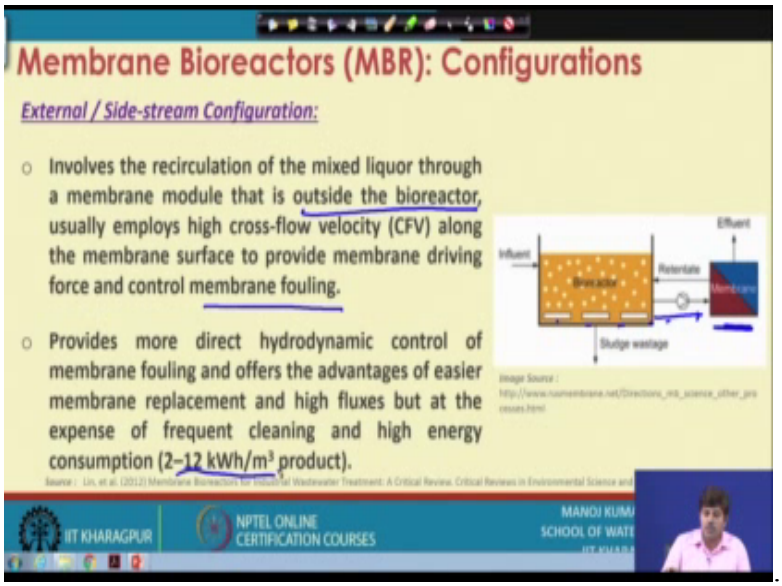

Now, these different configurations have different features so for say if you see the external or side stream system which is very simple you have a membrane bioreactor, where there is a aeration unit the water is taken to a membrane system outside. And we get the effluent and the retainent or the concentrate is again pushed back to the reactor.

So, this involves the recirculation of the mixed liquor through a membrane module that is outside the bioreactor ok. So, this usually implies kind of a high cross flow velocity along with this so there will be a basically as we discussed in the previous week; the membrane processes could be the kind of a there is dead end system and there is a cross flow system.

So, generally cross flow membranes are more preferred in order to prevent the fouling as well. So, this is kind of also puts a high cross flow velocity along with the membrane and that way kind of controls the membrane fouling also to some extent. So, this provide more direct hydro dynamic control of the membrane fouling and offers kind of advantages in terms of easy membrane replacement. Because it is just outside we can take the membrane we can change it fix it. So, that is there and plus we can actually pass the high flux through this ok. But the problem is that energy consumption is quite high of the order of 2 to 12 kilo watt hours per meter cube of the water treated ok. So, that is what is the problem; otherwise it is efficient.

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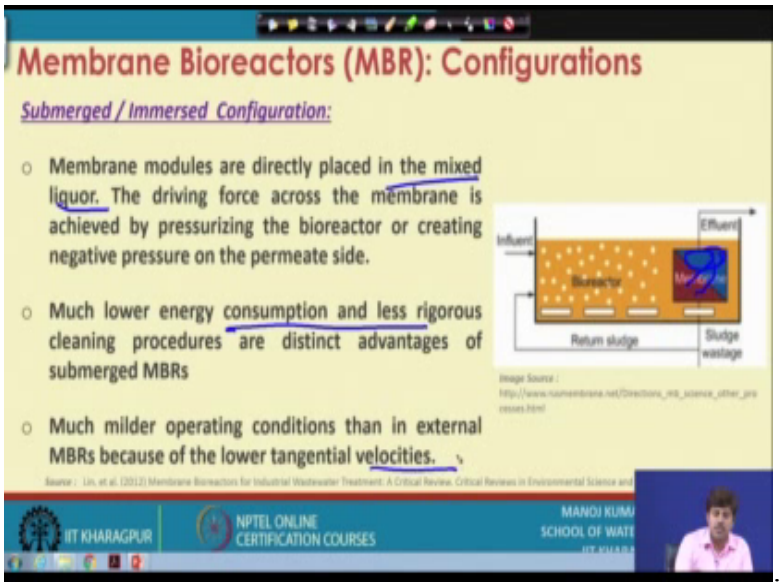

So, in order to reduce the kind of energy consumption which is used in the side stream membrane bioreactors. Submerged or immerged configuration was developed so in that one the membrane system was within this bioreactor itself ok. So, what happens here that membrane modules are directly placed in this mixed in this kind of mixed liquor ok.

So, what happens that the driving force across the membrane is achieved by pressuring the bioreactor or how we get the effluent is we can create the vacuum at one side. So, when you create the vacuum at one side it will suck the water through the membrane and that way we will get the kind of water towards the permeate side and reject comes with retains within the reactor ok.

So, we do not need those kind of separate system or separate channel for all those things. So, that way the energy consumption here is lower ok. The cleaning process is less rigorous it is within the system so it can be kind of cleaned that way so they are the basic advantages of the submerged MBR submerged systems ok. The kind of operating conditions are milder than external MBR's because of the lower tangential velocities; so that is the kind of basic features over here.

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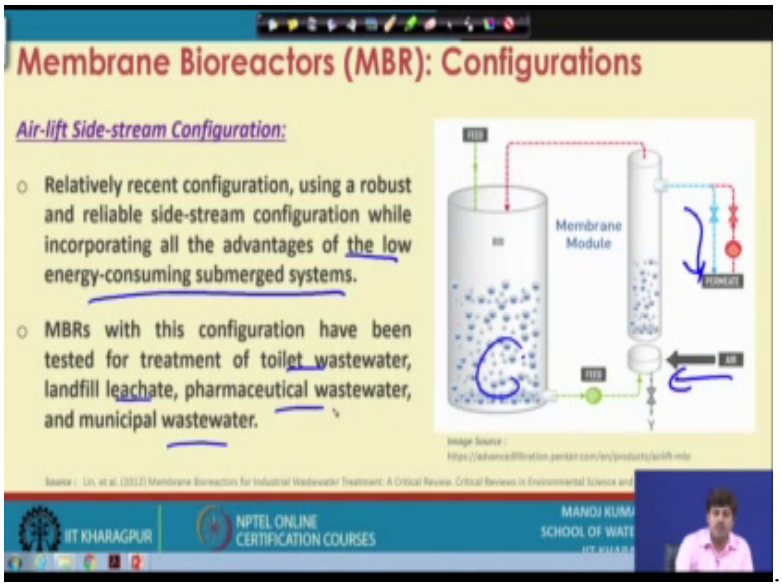

And if we see the third configuration which is air lift side stream configuration so, we will have kind of air feed incoming air coming in and the feed comes from a bio bioreactor bio system over here ok. So, from here the feed comes and here the air supplies comes and then it passes through a membrane module and the permeate is collect over here.

So, these are relatively recent configuration which uses a robust and reliable side stream configuration but incorporates the advantages of low energy consuming submerged system as well ok. So, these configuration is getting quite popular as been used for treating variety of wastewater including pharmaceutical and landfill, leachate, toilet, wastewater, municipal sewage so all those things it has been actually applied on.

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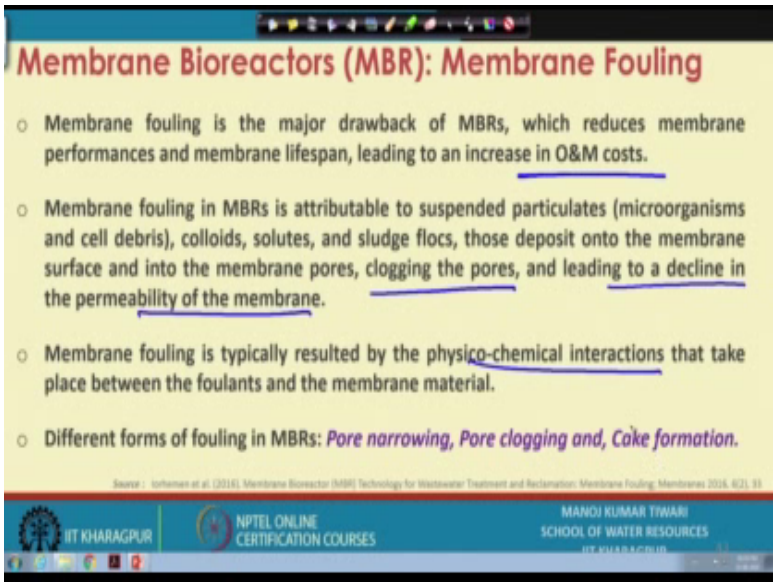

Now, one of the major problems of the membrane is the fouling of membrane because once we are using a membrane process and that too for filtering a large particle like biomass ok. So, there is possibility of fouling and that is one of the major drawbacks of these membrane systems. So, this kind of if membrane fouling takes place this will reduce the membrane performance and membrane lifespan as well. And that way we will have to basically use the fouling control measures or replace the membrane so it eventually increases O and M cost of the system as well.

So, membrane fouling is kind of attributed to the basically suspended particles which are micro organisms and cell debris; there could be colloidal, solutes, sludge flocs. These actually deposits on the membrane surface and then move on into the membrane pores so that way they can clog the membrane pores as well and that is how they lead to decline in the permeability of the membrane.

So, the flow prevents the head loss increases quite a bit so your system might actually be completely fail if you if one is not able to control the membrane falling properly. So, this fouling is typically resulted by these physico-chemical interactions that takes place between the foulant and the membrane material. So, how much they can attract these membrane materials or how it is getting defused in the system so those kind of things will be there. Now there are different forms of fouling in the membrane reactors there are it is not (Refer Time: 16:13) formed we can say the different stages as well. So, pore

narrowing, pore clogging or cake formation could take place in these membrane bioreactors ok.

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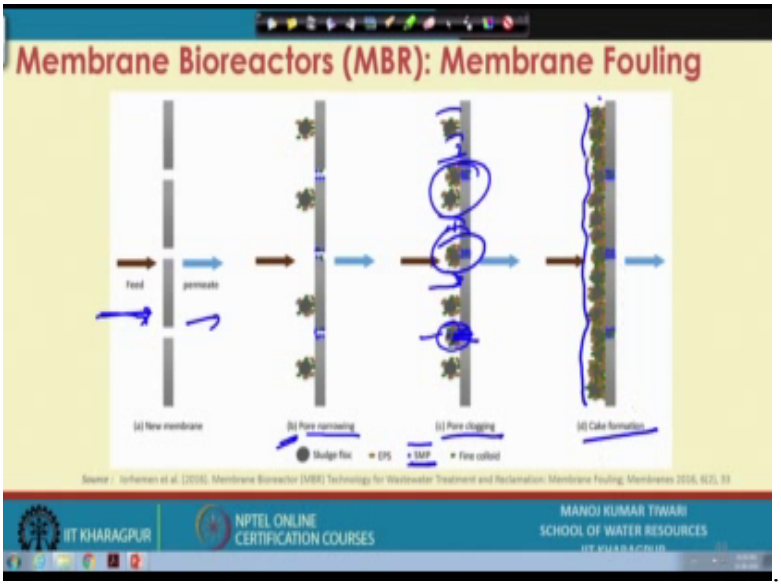

So, what happens that if you see if you have let us say a very new membrane so we will get the feed and we will get the permeate pretty easily that way. But when this clogging is starts so what will happen first that as a first step there will be first thing will be the pore narrowing. So, some of these suspended particles suspended micro organisms or suspended those kind of things will get entrapped here.

So, that way the pores of the membranes get narrow down ok. So, that is what is the first stage of the membrane fouling when there it is pores get narrow down. Then eventually when they get narrow down and these things try to basically pass on so they come over here and they can actually clog the pores ok.

So, that becomes the pore clogging so that way they will some material could actually diffuse inside these pores and that way they can clog these pores so that is what is known as pore clogging. And then eventually at the end what we will see that if it is not removed because pore has clogged. So, things will come and stick over here they do not have a passage to go anywhere.

So, slowly we will see that kind of formation of the cake takes place on the surface of membrane which is called the cake formation or the another stage of the membrane

fouling. And then the flow through your membrane will be completely kind of stopped and one will not be able to kind of get the desired flow or desired treatment from these membrane systems or desired retention from these membrane system.

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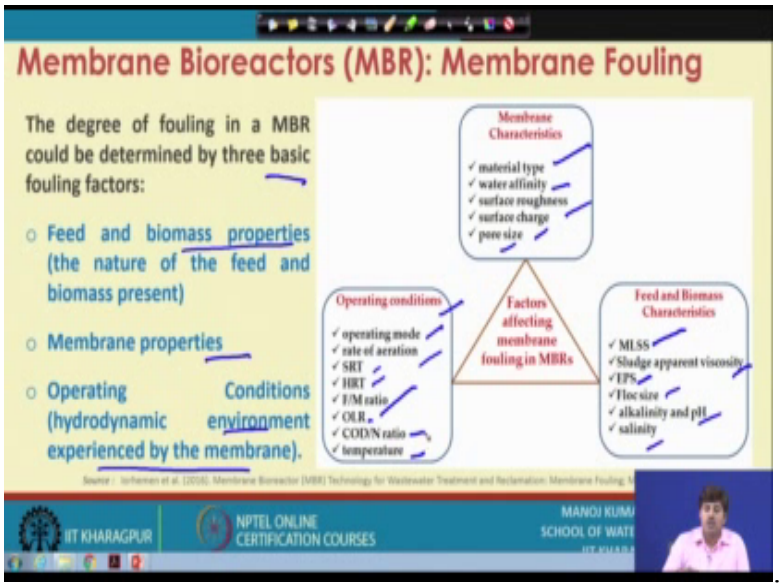

So, that is how basically the problem takes place. So, if we see there are various factors that effects this membrane foulings in membrane bioreactors ok. Now these are can be categorized into three different categories there are three basic fouling factors. So, one is the feed and the biomass properties; so how is the feed and what are its property. So, like what is the MLSS concentration, there is sludge apparent viscosity, extra polymeric substances. What is the floc size, alkalinity and pH, salinity those kind of thing.

Then there are membrane properties so characteristic of the membrane in terms of what is the material type, how much is the water affinity, the surface roughness, surface charge, what is the pore sizes, the type of material, characteristics; all those things will come over here. And then at the end we have operating conditions which kind of are the hydrodynamic environment experienced by the membrane. So, what kind of environment membrane is having in which it is being operated.

So, the mode of operation, rate of reaction, sludge retention time, hydraulic retention time, what is the foot to micro organism ratio, organic loading rates, COD to nitrogen ratio, temperature, pH so all those things will come into the picture here. So, that way all these things eventually govern the kind of govern the degree of membrane fouling ok.

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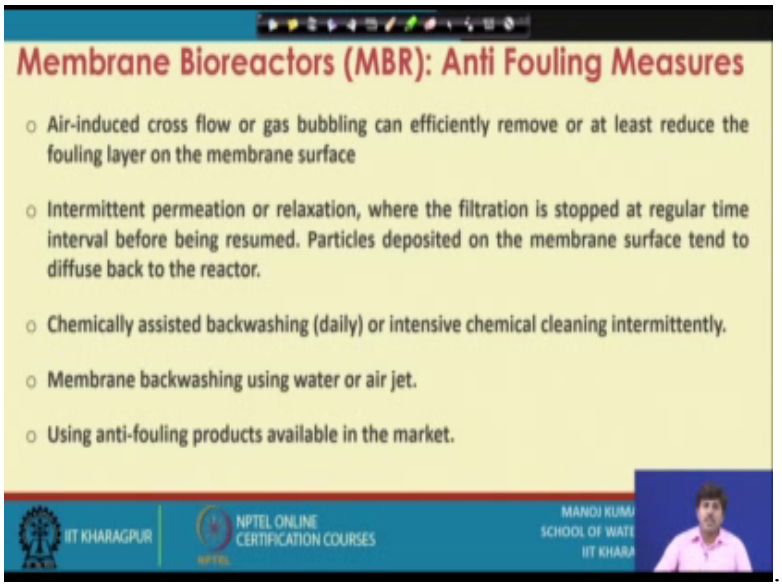

How to control this? So, this there are anti fouling measures which can be taken which can be adopted for controlling the membrane fouling. So, those are kind of we can have air induced cross flow or gas bubbling which can effectively remove the whatsoever foulant has basically been deposited on the surface of membrane or at least remove at least reduce their concentration, reduce the degree of fouling that membrane has gone under through.

There are intermittent permeation or relaxation. So, what we can do that the process when it is happening we can actually stop the process for sometime if it is allowed to ok. If our filtration process filtration system is allowed to be stopped at regular interval. So, we should stop that at regular interval.

So, what happens that particles which has been deposited on the membrane surface will tend to defuse back to the water. And that way some actually is to some degree these reduction of the membrane fouling could be taking place just by stopping the flow through the membrane or just by removing the pressure. There are other means like there are chemically assisted backwashing where we can have some kind of acidic or alkaline solutions depending on the nature of the fouling ok.

And or we can actually this can be done on a daily scale or we have intensive chemical cleaning procedures which can be taken once in a few months that way. Once or twice in a year or that kind of system can also be taken. Then there are membrane backwashing

which we just can backwash it using a simple water or air jet that way. There are various anti fouling products available in the market they also can be used for reducing this membrane fouling.

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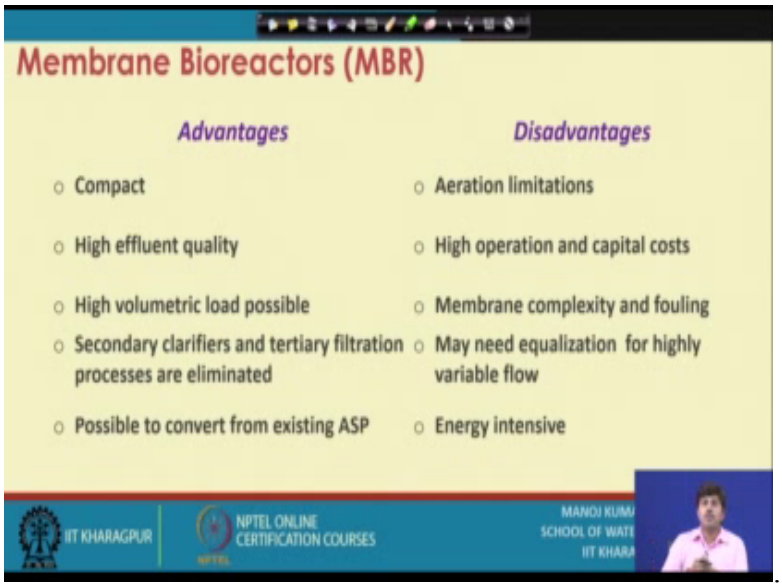

So, if we see the advantages and disadvantages of these membrane system. So, the membrane systems are quite compact. So, because we do not need to go for a secondary settling thing we do not need to have a sludge recycling mechanism. So, those kind of things can be taken off that way the system would be quite compact the area requirement is low. And it can actually since there is lot of sludge or lot of biomass in the system which can be operated the system if system can be operated with the high amount of sludge.

So, what will happen that when the organic loading rate or the kind of BOD that is applied to the system to the aeration system can also be increased. So, our system will be able to withstand high organic loading rate and that way we can actually make a compact system for same amount of the flow because we are permitted to load at a higher organic loading rates.

Their effluent quality is good because of lot of as we discussed if there are significant amount of biomass present in the system. So, they can decompose or degrade the organic matter at higher rate there is high volumetric loading possible. So, organic loading as

well as volumetric loading we can increase. There is secondary clarifier and tertiary filtration process are eliminated usually.

We are putting a water coming through a ultra coming through ultra filter or micro filter so the quality of water in terms of solids removal and these things is pretty good. And it is possible to convert an existing activated sludge process to membrane process by just putting through a membrane either in the reactor directly or through a side stream channel so that is also another advantage.

On the disadvantages front there are aeration limitation as we discussed that it needs high end aeration ok. The high operation and capital cost is there we are going to work with the membrane so the cost increases and particularly the water has to be passed through membrane under pressure conditions.

So, the energy cost will also be increases so it is a energy intensive process. The membrane complexity and fouling so managing the membranes operating the membranes and dealing with the membrane fouling is another disadvantages. And it may need equalization for highly variable flow if those kind of flow is expected. So, similar to activated sludge process this also may need a kind of equalization tank.

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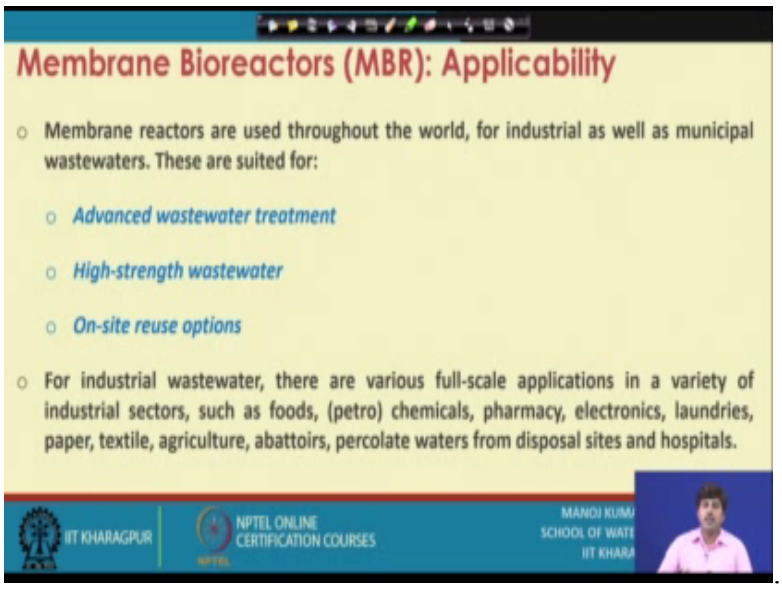

So, if we see the applicability front membrane reactors are used throughout the world for industrial as well as municipal wastewater systems. These are suited for advanced

wastewater treatment also because as we discussed that we are using the membrane processes so which comes under advanced wastewater treatment category. It can be used for high strength wastewater even if particularly the biodegradable wastewater of high strength. So, it will be doing the job at much higher degradation rate as conventional activated sludge process because of the higher retention of the biomass or higher retention of the sludge in the system.

And it that way it can be actually used for onsite reuse option the water we are getting is filtered from ultra filter or nano filter. So, ultra filter or micro filter so that way it can be reused that way. For industrial wastewater these also a very popular treatment system nowadays ok and there are various full scale applications in variety of industrial sectors such as food, petro chemicals, pharmacy, electronics, paper pulp and paper, textile, agriculture and kind of other industries as well including hospitals.

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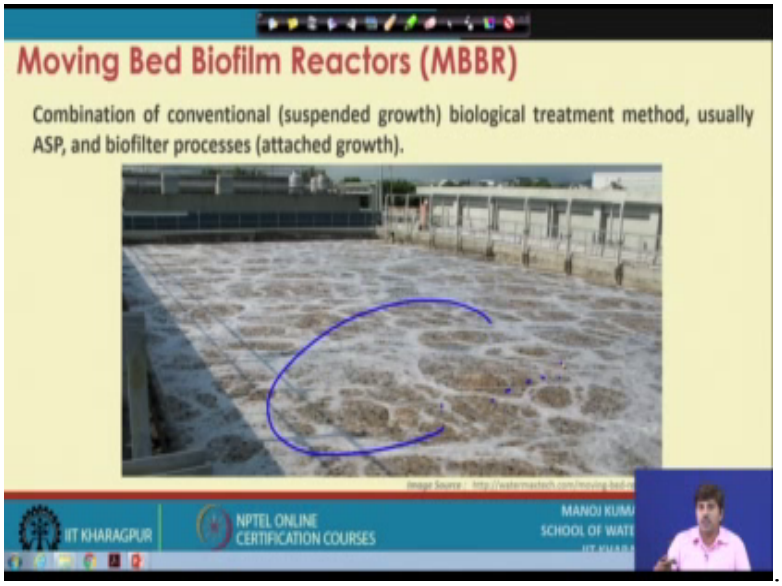

So, that is about the Membrane Bio Reactors or MBR systems. There is another system which is getting quite popular these days is MBBR which is Moving Bed Bioreactors or Moving Bed Biofilm Reactors. So, these Moving Bed Biofilm Reactors like MBR we saw that in a conventional activated sludge process if we add a membrane step a membrane filtration step we call that as a membrane bioreactors. So, that is just a modification of a conventional activated sludge process.

Similarly this MBBR is also a modification of conventional activated sludge process usually; however, it is not necessarily has to be aerobic system we can modify the aerobic system as well same with the MBR also it is not necessarily has to be kind of aerobic system we can put a membrane with an aerobic biological systems as well. So, in MBBR how we do this modification so like in MBR we modify by putting a membrane here we as the name itself suggest that biofilm reactor. So, we integrate the concept of a bio filter process with the conventional activated sludge process.

So, conventional activated sludge process by definition is a suspended growth system and the bio filter process is by definition in attached growth system. So, we basically combine these concept of suspended growth and attached growth system. So, that we can actually get the advantages of both while reducing the limitation of both.

So, limitation of the suspended growth system is that biomass retention is difficult and we have to have a kind of secondary clarifier and those kind of thing and then biomass recirculation is needed those are the limitation of conventional activated sludge processes. The limitation of bio filtration process is basically when the growth is attached and we are having a media which is kind of fixed bed media.

So, what happens that growth takes place only on those media and as a result where there is not media. So, large portion of the tank could actually be remained unutilized. So, both these limitations are taken care of both these limitations get away when we go for a Moving Bed Biofilm Reactor or MBBR system.

So, what happens that within this reactor we put a media which is kind of a floating media inert floating media. So, that media also remain in the suspension and the growth takes place on that media. So, growth is attached, but that attached growth is also in suspension. So, that is how it combines the concept of suspended and attached growth system together.

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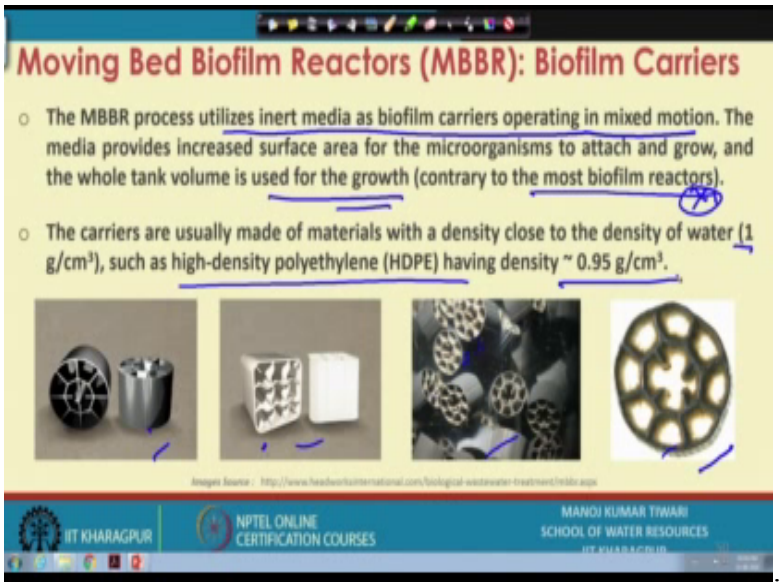

So, the major important aspect of the moving bed biofilm reactors is biofilm carriers ok. Otherwise it is essentially similar as an activated sludge process so apart from that if we are saying it a for aerobic system so apart from that apart from your conventional activated sludge process we do have a biofilm carrier which is kind of a media. So, this process utilize this inert media as biofilm carriers which operate in the mixed motion. This media provides increased surface area for the micro organisms to attach and grow and the whole tank volume is used for this growth which is not the case with most of the conventional biofilm reactor.

So, that is how we get the additional advantages of the system ok. So, this media will look like this these are some of the kind of examples of mediate could be like this it could be like this or in the system after growth it has taken place it will look like this and a closer loop you can see that the growth of the biofilm has taken place on this media.

Now, these carriers are made of materials with the density which is close to the density of water. Why because we do not want them to settle in the system right if you are having a very high specific gravity. So, what will happen that they will settle in the system they will try to settle in the system we will have a much larger mass of the media or much larger fraction of the media towards the lower part in the reactor.

If we go for a very low specific gravity so it will actually start floating. So, much larger portion of the media will actually be floating in the water near the top still your majority

of the reactor across the depth will be empty and there would not be much advantages of using this media.

So, that is why it is made with the particles which have density close to that of water. So, for purpose like HDPE's which has a density around 9.95 gram per cc is one of the preferred kind of material for making these biofilm carriers or media. So, it is has a density close pretty close to water and that is why when it is in the water it actually in remains in the suspension it floats it is covers the entire mass. And that is how it is actually quite helpful in the water.

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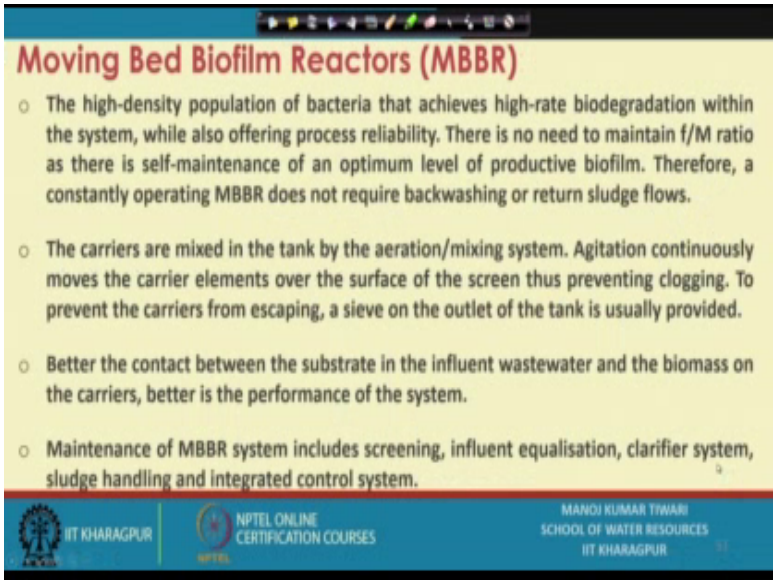

So these high density population of bacteria that is achieved ensures high rate bio degradation within the system ok. And that also offers the process reliability because that biomass is attached to the systems they do not leave the system. There is no need of maintaining food to micro organism ratio as the bio mass is retained in the system itself. Only thing is that we actually like to the exit point we have to put a filter kind of thing so that it does not go in the exit.

So, in order to prevent these carriers we have to put some sort of filter or just a mesh kind of thing which prevents these carriers to wash off from the system. So, these carriers are mixed in the tank by aeration or mixing system we can have a aeration or a mixing system ok; where it is agitated continuously and that way it is ensured. And we can have a sieve at the outlet to prevent these escaping of this carrier from the system ok.

And as better the contact between the substrate in the effluent and the biomass that will actually kind of improve the degradation rate or the extent of degradation. So, maintenance of this MBBR system including these screening, influent equalization clarifier system, sludge handling all means the essential part would still be there.

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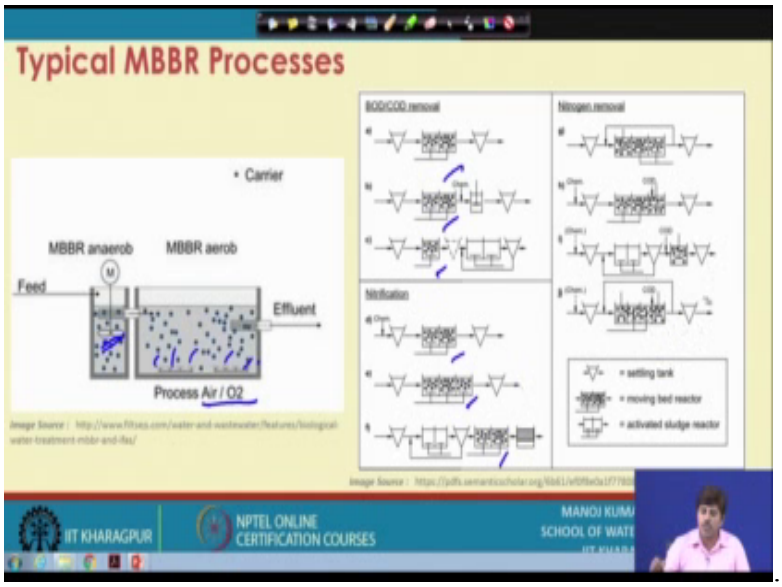

So, this typical MBBR process if we see we can have this thing by putting a mixture if it is a anaerobic system or it is a aerobic system just by the virtue of aeration. When we pass the air or oxygen they can remain in the mixing. And we can have all those configurations as we discussed with the conventional processes for the COD, BOD removal. If you want to have a nitrification system or if you want to have a added nitrogen removal with denitrification system as well. So, combination of aerobic anaerobic primary clarifier secondary clarifier those kind of thing all those process can remain there.

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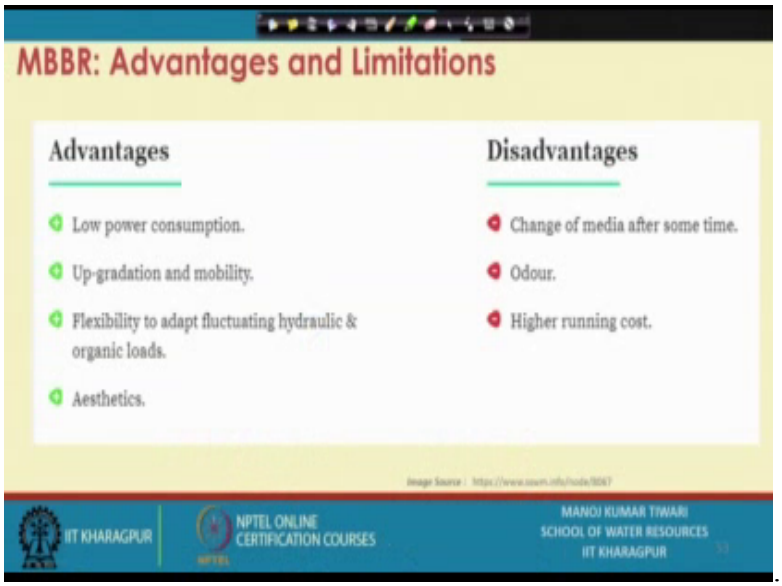

The only difference here is that it is based with the media. So, that is how it is advantageous the major advantages include low power consumption up gradation and mobility. So, we can upgrade the existing system by just putting carriers in that one. The flexibility of adopting fluctuating hydraulic and organic loading rate so, because the biomass grows on a attached media so the stability is better, aesthetically looks ok. The disadvantage is that we need to change the media after some time. Once this enough growth has taken place and then diffusion limitation comes across so those things needs to be kind of taken care of. It may generate some order and the cost of running is little higher than the conventional system.

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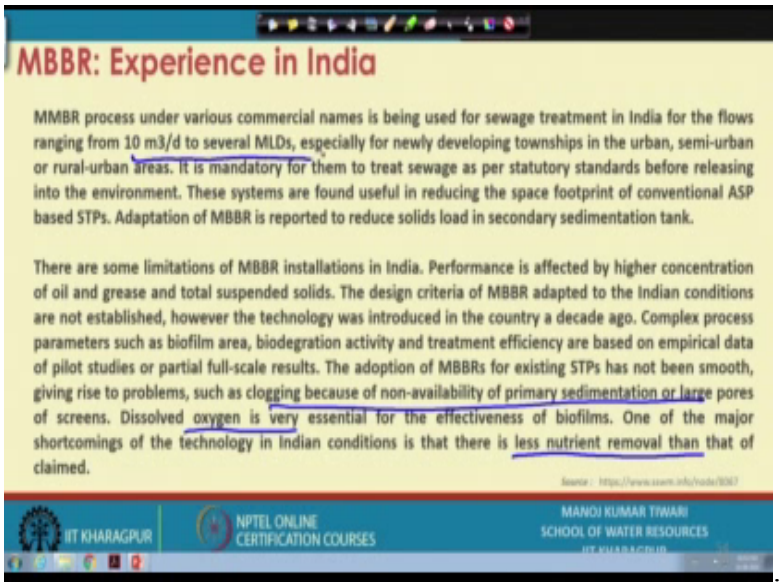

So, there have been basically quite a few MBBR installation in India around 2010 or 12 there has been some over 3, 400 installations. Nowadays it is much more so ever basically in the building complex various high end residential building complex or industrial building complex this is used. So, it have given a good performances; however, there has been certain issues as well.

So, issues such as kind of clogging because of non availability of primary sedimentation or screens because these complexes they do not go for the full process if they just end up having an MBBR. So, those kind of things can come in there is a limitation of the dissolved oxygen also for the effectiveness of biofilm so that could be there.

And what it has been observed in Indian condition that the nutrient removal has been observed lesser as oppose to which is traditionally claimed with the systems. These installations has been of the order of 10 meter cube per day to several MLD's ok. And kind of there has been growing interest on these there in the particularly there are statutory bodies also which are forcing the kind of multi story complexes coming in big cities to go for their own sewerage treatment system.

So, because of the complexity involved with operating in the membrane system or those kind of things it is very challenging for the units to install and maintain such system. This is rather simpler system which can produce a better quality effluent then the conventional system. So, many of these people are going for these systems and that way

dealing or hand that way kind of dealing their wastewater generated within the periphery and putting them for some reuse in the gardening or horticulture that way.

So, with this we conclude this week's discussion on to the different alternate configurations of the wastewater treatment systems. So, by far we have discussed most of the aspects related to the treatment relate to starting from the generation, quantification, qualitative analysis then treatments; so we kind of summarize this discussion here. And in the following two weeks starting next week onwards, we will be discussing the recycling of the wastewater or approach for the recycling and reuses for the wastewater. So, see you next week and.

Thanks for joining, have a good time.