Course Name: Industrial Wastewater Treatment

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Week – 04

Lecture-4: Membrane processes for wastewater treatment

Welcome back. So, we are in module 4, lecture 4 and we are discussing about the membrane processes for wastewater treatment. In this lecture, we will cover about the challenges in the membrane processes, about the membrane fouling process, what are the general forms of membrane fouling that happens when we are using or when we are treating the water or wastewater by using the membrane processes, the constituents in the wastewater which are responsible for the membrane fouling process, how we can control the membrane fouling process, what are the pretreatment which we require when we are using nanofiltration or reverse of process for the treatment of water or wastewater. Similarly, various indices which are used for finding out the treatability of the given wastewater by using nanofiltration or RO pollutants. We will calculate about the silt density index and modified fouling index and the various applications of the membrane processes in water and wastewater processes. So, when we are discussing the challenges in the membrane process, we mean that there can be a number of things that can reduce the efficiency as well as the cost effectiveness of the membrane process.

So, these are the challenges that we face when we use the membranes for the treatment of water or wastewater. So, membrane may have number of advantages, but they can also be impacted by certain problems which arises when we use the membrane for the treatment of water or wastewater treatment. So, membrane fouling occurs when the contaminants they accumulate on the membrane surface. So, they reduce the permeability of the membrane, and it requires frequent cleaning.

So, if we are having a lot of contaminants which are present in the water or wastewater, so they will start accumulating onto the membrane and they will not only reduce the permeability, but it will also reduce the amount of flux that passes through the membrane and hence it will require more frequent cleaning, or it may even require the changing of the membrane also. So, we need to strategize the things that is we need to include the pre-treatment before we take the water or wastewater directly to the membrane treatment process. So, we may treat the water beforehand and then we can take the water to the membrane process. So, that is called the pre-treatment process. Similarly, we can modify the surface of the membrane so that the fouling is reduced, so that comes under the surface modification process.

Similarly, we can also optimize the cleaning protocols. For example, we can use the cleaning of the membrane in place rather than taking it out and then cleaning it regularly. Similarly, the other challenge can be the energy consumption where the membrane process with high pressure requirements like RO process, so it can become very highly energy intensive process. So, that is why nowadays the research is going on so that we can develop energy efficient membranes, and we can optimize the process which can not only reduce

the environmental impact, but it can also reduce the energy consumption. So, cost consideration also becomes a very challenging topic here because the cost is high in case of the membrane, the capital cost as well as the operational expenses they can be significant.

So, that is why it is very important that when we are going for the membrane process, we should always take into account that what is the feasibility of the process, how much capital cost will be required, what will be the operational expenses that will be borne because the capital cost will again include the installation of the very costly membranes and the operational expenses will also include not only the cleaning of the membrane regularly, but the energy required for creating the pressure as well as the chemicals which will be required for the cleaning processes. So, this will increase the capital as well as the operational costs. So, that is why the advances in the membrane materials nowadays going on which focuses on the membrane technologies which can reduce the cost, and it can enhance the economic viability of these technologies. Sustainability is also a challenge in the sense that the environmental impact of membrane production, the disposal of the used membrane, the chemicals which are used for the cleaning and maintenance of the membrane. So, this also is a matter of concern that is where we are going to dispose the membranes.

The processes which are used for membrane production also creates a lot of environmental impacts and similarly the chemicals which are used for the cleaning and maintenance. So, they also become a concern for the disposal of such type of waste that is generated from the cleaning of the membrane process. So, that is why the sustainable membrane development and life cycle assessment are very important, so that we can minimize the environmental footprints. So, we are discussing about the membrane fouling process. So, it means that the potential deposition and accumulation of the solute which is there in the solvent which we are treating.

So, they deposit as well as accumulate on the surface of the membrane and this process is called the membrane fouling. So, such type of potential deposition can take place not only with the salts which are present in the water or the wastewater, but it will also take place because of the organics which are present or if we say that if there are certain bacteria which are there, or we can say the mixed liquid volatile suspended solids which are there. So, they also are the potential depositors which can foul the surface of the membrane, they can grow like a biofilm on the surface of the membrane, and they can foul the membrane, they can reduce its capacity to filter the water further. Important parameters which are used in the design and operation of the membrane system, so it includes the fouling things that is we have to have a kind of pre-treatment which is required depending upon the type of the water or the wastewater that we are trying to treat by using the membrane process. So, we should know that what type of contaminants it is having, and which contaminants will impact our membrane process.

So, before going to the membrane process, we can choose that we can have a pre-treatment process which can remove some of the contaminants which can contaminate or foul the surface of the membrane. Similarly, once we are using these membranes, so they will no matter foul. So, we should also see that what type of cleaning are going to adopt and what should be frequency of the cleaning so that the process of the membrane treatment goes on

unhindered. Similarly, we have to also fix the operating conditions that is what are the conditions which we require, what should be the pressure that will be required, what type of membrane that we are going to use and what type of chemicals we are going to use during our process of the membrane treatment. Similarly, cost is also another important parameter based on the cost only we can decide that whether it will be feasible or it will be infeasible using the membrane technology for the treatment of water or wastewater.

Similarly, the performance of the membrane also becomes a very very important issue. So, when we talk about the general forms of the membrane fouling, so these build up of the constituents which are there in the water or wastewater, so this also can lead to the fouling of the membrane. So, it is just like that the constituents which are present in the water or wastewater they get adsorbed, they get stuck onto the surface of the membrane and they basically foul the membrane systems right. So, they also block the pores of the membrane, and this will reduce the flux that is passing through the membranes. After the build up of the constituents there can be another form of fouling that can take place.

For example, we can have the chemical precipitates being formed due to the chemistry of the feed water or the water or the wastewater that is being treated by the membrane. So, there are certain chemical species may present that can precipitate at a certain condition and they also can lead to the fouling of the membrane. Similarly, there can be certain substances which can react with the surface of the membrane, so they can corrode the surface of the membrane, they can erode the surface of the membrane and they can lead to the degradation of the membrane and that is why the membrane basically gets fouled or its performance reduces because of certain reacting species which are present in the water or the waste water which it is treating. Similarly, there can be the presence of certain biological agents for example, when we are talking about the waste water treatment by using membrane process, so there are number of biological agents or the microbes which are there, so they also can start attaching to the membrane surface and they can start colonizing on the surface of the membrane because they are getting the nutrients there, they are also getting a surface to attach themselves and so they start forming a biofilm on the surface of the membrane. So, this will lead to the fouling of the surface as well as it will lead to the reduced efficiency of the membrane filtration.

So, the constituents which are present in the waste water which are responsible for the membrane fouling process, so it may include a number of things for example, when we are talking of the fouling that is when you are talking of the deposition of the constituents onto the surface for example, it can form a cake like formation on the surface of the membrane or it can form a biofilm on the surface of the membrane. So, this can be because of the metal oxides which are present, so these metal oxides may deposit onto the surface of the membrane. Similarly, we can have organic and inorganic colloids which can deposit onto the surface of the membranes, and they can foul the membrane. Similarly, we can have the bacteria which can get deposited onto the surface of the membrane because they are not getting filtered out along with the water. So, they remain at the surface of the membrane, and they foul the surface of the membrane.

Similarly, the microorganism concentration that is when we are having a number of microbes which are present, so they can colonize onto the surface of the membrane and similarly polarization also can lead to the reduced efficiency of the membrane process. So,

the damage can be reduced by controlling these substances by using a process which is called pretreatment process. Similarly, we can have the precipitation taking place onto the surface of the membrane, so that also can lead to the fouling of the membrane. For example, we can have the calcium sulfate precipitates, calcium carbonate, calcium fluoride, we can have barium sulfate, metal oxide formations, silica. So, they all can precipitate, they all can form a layer on the surface of the membrane, and they can foul the surface of the membrane.

For example, here it can be limited by reducing the formation of such type of precipitates either by adding acids or by limiting the concentration of these substances, so that they do not precipitate onto the surface of the membrane. Similarly, we can also play with the pH, so that such type of precipitates may not form onto the surface of the membrane. So, then there can be damages to the membrane also. For example, not only fouling will reduce the performance, but the damage to the membrane will also reduce the performance of the with water or wastewater treatment by using membrane processes. For example, we can have acids, we can have bases, we can have pH extremes, we can have flea chlorine, we can have bacteria, free oxygen, so they all can lead to the damage or erosion of the surface of the membrane.

So, this can be reduced by controlling these substances by using pretreatment process. Similarly, the extent of the damage will also depend upon the type of the membrane that we are using. So, if we are using a robust membrane, so then it may possible that it can bear these conditions, but if we are using the membranes which are very prone to these attacks, so then they can be damaged very fast, and we have to replace the membranes at a very early stage. So, the mechanism that leads to the reduced performance of the membrane, so it includes a number of processes. For example, we can have the pore narrowing.

So, pore here means the pores of the membrane, so they can start narrowing down because of the deposition of certain materials or in into the pores, so that will lead to the narrowing of the pores, and it will also lead to the lower flux passing through the membrane. Similarly, we can have the pore plugging where the membrane is plugged by a certain material. So, this will lead to the non-filtration or non-passing of the solvent through the pores, and this will lead to the reduction in the performance of the membrane. Similarly, we can have a gel or cake layer formation taking place on the entire surface of the membrane, so that also can lead to the reduced performance of the membrane for the treatment of water or the wastewater. So, here the gel or cake formation caused by the higher concentration of certain constituents which are present in the water or wastewater, so they lead to the formation of a layer on the surface of the membrane because of the accumulation of these materials onto the surface of the membrane.

So, this is known as the gel or cake layer formation. So, if we are having a membrane, so if these are the pores that are there on the entire surface, we are having the formation of a layer which is called gel or cake layer formation. And here majority of the solid matter which is in the feed other in size than the pore size of the membrane, so this forms the layer which is deposited onto the surface of the membrane. So, then another process is called the pore plugging or pore narrowing. So, this occurs because the solid matter, which is smaller than the pore size, so bigger than the pore size causes the gel or cake formation whereas

the materials which are in smaller sizes, smaller size than the pore size or it is smaller size than the molecular weight cut off, so they start plugging the pores which are there.

So, they get stuck in the pores and they clog the pores or clog the membranes and reduces the performance of the membrane. Similarly, pore narrowing means that is we are having the pore size, and we are having very very small materials which can get attached, which can pass through the pores, but they can also attach to the sides of the pores, they will reduce the size of the pores and that is called the pore narrowing process. So, you can see here that these three diagrams, so if we talk about this first diagram, so this is showing that the filtration is taking place and the materials they are not basically blocking or they are not forming a gel formation on the surface, they are just blocking the sides of the pores. So, what happens that slowly and slowly the pore size they get reduced, and this is known as the pore narrowing process. Similarly, we are having a material which is or the constituent, which is passing through the pores, but it can be of similar size as that of the pore size, so they can get stuck into the pore opening and that is called the pore plugging process.

And then we can have the sizes which can be larger in size, or they can be smaller in size also, but they can form a cake type of thing on the surface of the membrane, so that is called the cake or gel formation. So, it is possible that the bigger size particles they may form a layer and on which the smaller size of particles they also basically get accumulated and because of which it forms a very very thin layer of cake or a gel which formed, and it will not allow the filtration process to take place further. So, these types of mechanism are found when we are having the filtration through the membrane surface, and they reduce the performance of the membrane process. So, how we can control the membrane fouling? So, we can we have already talked about the pretreatment of the feed water. So, how we can pretreat the feed water? So, that is that is the matter of concern.

So, we can reduce the total suspended solids because very high suspended solids concentration in the feed or in the influent. So, this basically may lead to the blocking and clogging of the membrane surface very fast. So, if you reduce the total suspended solids by using other processes like we can use the multimedia filter or we can go for micro filtration first of all and then we go for the nano filtration or RO process. So, then it can enhance the efficiency of such type of processes. So, it is very important that we reduce the total suspended solids up to a certain desired level.

So, that we can enhance the efficiency of the membrane filtration process. Similarly, we should reduce the bacteria which can otherwise go and form a gel or cake of the bacterial colonies. So, that basically can be reduced by ozonation of the water or by disinfection of the water or by passing the water through the ultraviolet rays. So, this can reduce the bacterial concentration in the feed water, or the wastewater and it will also enhance the efficiency of the membrane filtration process. Similarly, we can reaerate our water before we pass it through the membrane filtration process because deaeration it limits the oxidation of iron and manganese which can be present in the water or wastewater.

For example, if we talk about the groundwater. So, some of the groundwater may contain very high content of iron and manganese. So, they if they go into the feed stream and being treated by the membrane process. So, because of the presence of the oxygen. So, it may

oxidize to the oxides of the iron and manganese precipitates will adsorb onto the surface of the membrane.

Similarly, we can also go for reduction of these species. For example, we can reduce the iron and manganese precipitate them out and then we can pass the water through the membrane process, and we have to also ensure that the chlorine or ozone that we have used for the disinfection of the water. So, they also should be removed otherwise they also can lead to the damaging of the membrane material. So, this needs to be removed from the water or the wastewater before we take it for the membrane process treatment. And similarly, we also must see that the things which can get chemically precipitated onto the surface of the membrane.

So, they also should be removed before we go for the membrane filtration process. These are the steps that are required before the membrane filtration process is assumed, but we can also go for the back washing or back flushing of the membrane when it is being used in the process. For example, we can pass pressurized water, or we can pass pressurized air in the reverse direction so that we can get rid of these materials, we can remove the pore which are blocked, or we can reduce the membrane narrowing which is taking place the pore narrowing that is taking place. So, this can be removed when we are back flushing or back washing the membrane regularly by using water or air. Similarly, we can also go for chemical processes for cleaning the membranes.

For example, we can use the chemicals like sodium hypochlorite, we can use the chemicals like sodium hydroxide so that we can remove these fouling that has taken place onto the surface of the membrane by using this chemical treatment. And for this, we have to take out the membrane from the system and then we have to clean it and then we can put it back and we can start our service again in that case. What happens that when we are having a membrane process and if we are having a feed which is non-fouling in nature, so you can see on the y-axis we are having flux, on the x-axis we are having time. So, slowly and slowly the performance or the flux will reduce if we are having a non-fouling feed also because we cannot remove everything by using any treatment process. So, this means that there may be certain salts or dissolved solids or there can be certain colloidal particles or there can be certain bacteria also that can present in the water.

So, they also start reducing the flux of the membrane. This happens when we are having a very very non-fouling feed type of influent which is subjected to the membrane process. But when we are having a system which is having adequate pre-treatment also and, but we are using a periodic cleaning also in this case. So, what happens that slowly and slowly the flux will decline in such a case, then it will reduce to a certain level where we have to again clean it or so that efficiency of the membrane can be regained, or the flux of the membrane can be regained. So, we are using a cleaning process here right.

So, then our flux again enhances to a certain value. It will not basically go ultimately to the initial flux that we have started with, it will surely go to a certain higher value after the cleaning process. Then we can again start the process and as soon as it goes again beyond a certain limit, then we can again go for the cleaning of this type of membrane. And so, this process continues, we can see that influent which is having adequate pre-treatment,

and we are applying periodic cleaning also. So, then this may be the cycles that you will see for the variation of the flux.

So, these all the notches that we are seeing, so they represent the cleaning of the membrane. But if we are having inadequate pre-treatment, though we are having a pre-treatment cleaning also, but you can see that the flux declines a lot because there is an inadequate pre-treatment that has been done to the influent water or wastewater. So, that is why you see that the flux declines very very fast and again these peaks that we are seeing, so they are showing you the cleaning frequency of the membrane. And we know that as the fouling increases your cleaning frequency also increases. So, you can see that in the later stages, you find that you have to clean the membrane at a very frequent interval.

So, the pre-treatment for the nano filtration and reverse osmosis, it requires a very high-quality feed, so that we can go for the very efficient operation process. And for example, here when we are having the secondary effluent, so we have to go for the chemical clarifications, multimedia filtration, and electro filtration is very very necessary, so that we can enhance the performance of the filter. And similarly, we can also use certain cartridge filters that are having a core size of 5 to 10 micrometers. So, they also can be used for the removal of the suspended solids. We can go for the disinfection, so that we can limit the bacterial activity.

We can go for the exclusion of the oxygen, so that we can limit the oxidation of iron, manganese, hydrogen sulfide which are present in the water or the wastewater. Similarly, it is very essential that we remove the chlorine and ozone which are present after the disinfection process of the pre-treated water or the wastewater. Similarly, we have to also see that the pH should not be very low, or pH should not go beyond a certain level, so that it may erode the surface or damage the surface of the membrane.

So, we have to keep the pH between 4 to 7.5. So, if we want to assess that the treatability of a given influent, for example, we can have the water or wastewater subjected to nanofiltration process or RO process. So, we should also see that what is the treatability of such type of water and whether such type of water which you are treating by a nanofiltration process or RO process, they are fit for such type of process. So, for that we have to assess by using certain indices that we have developed. So, which one is called the silt density index, other is and modified fouling index, other is also known as the mini flux factor index. So, here what we do before we take the water which you want to treat by nanofiltration or RO process, we check it, we pass it through a 0.45 micrometer filter with 47 millimeter internal diameter and we allow a pressure of around 201 kilo Pascal's and then we develop such type of indices based on this filtration experiment that we have done and it gives us a certain index values and based on the index values we can decide that whether we can treat it by using a nanofiltration or RO process, whether our operation with nanofiltration or RO process will be efficient or not. So, here the time which is required for the collection of data it varies from 15 minutes to 2 hours depending upon the nature of the water that is how much fouling it can create, right. So, depending upon that we can choose a suitable time. So, the silt density index is defined as the initial time to collect the first 500 ml of samples divided by the final 500 ml of sample collection time. So, 1 minus this ratio that is Ti by Tf into 100 divided by the total time to which the filtration has happened.

So, this is how the test is done. So, we collect the initial 500 samples, and we note the time that how much time is being taken for 500 ml initially to be filtered. Then at the end of the experiment also we collect 500 ml sample, right and then we calculate what is the silt density index and it get gives us a measure of whether the water can be treated efficiently by using the nanofiltration or RO process or not. So, this is a static measurement, and the samples are taking at the beginning and end so that we can see that what is the rate of change of resistance that happened during the test. So, it is pertinent that initial 500 will take place a very less time in comparison to the final 500 samples because of the fouling that we take place during the filtration test. Then we can also have a index and modified fouling index and here what happens that the filtration is done and the volume of is recorded every 30 seconds and we do a filtration of around 15 minutes.

So, we record the volume of the water or the waste water every 30 seconds, right and we take the test up to around 15 minutes of filtration period and then we are having the data of the average flow that is taking place through the filters A is a constant that is there and the MFI is the modified fouling index which is given by seconds per square liter and VL is the volume total volume of the water that is collected. So, we draw a curve here that is 1 by Q is on the y axis and the throughput volume is on the x axis and we can get such type of curve the slope of this curve will give us the MFI value. So, after calculation of these indices we can see that the SDI value or MFI values so they can be obtained, and we see that for the nano filtration if our SDI values are between 0 to 2 then it is ok to take the water through the nano filtration process. Similarly, if it is between 0 to 10 the MFI values then the nano filtration process can be feasible. Similarly, for the RO process or for the hollow fiber membranes also the SDI value should lie between 0 to 2 and for the MFI it should lie also lie between 0 to 2.

So, RO and spiral wound membrane so in that case the SDI may go up to 0 to 3 whereas the MFI remains between 0 to 2. So, these calculations are done before we take the water for the treatment by using the membrane process that is the nano filtration process or RO process and once these indices are established based on that index, we can decide that whether the water is fit for being treated by using the membrane process or not. So, we can see here that if we are having the biodegradable organics in the water so we can use ultra filtration process we can use nano filtration process we can use RO processes. Similarly, for removal of the hardness we have to go for we have to opt for nano filtration and RO processes. Similarly, for the removal of the heavy metals you have to go for nano filtration or RO process, for removal of nitrate also we have to go for nano filtration and RO process, we cannot use micro filtration or ultra filtration in such cases.

If we are talking of the priority organic pollutants, so we can also go for ultra filtration in addition to the nano filtration and RO processes. If we are having the synthetic organic compounds, so in that case we have to apply the nano filtration and RO process. For removal of TDS also we can we have to use the nano filtration and RO process ok. For suspended solids removal we can opt for micro filtration and ultra filtration, we will never go for the nano filtration or RO process because they will clog the filter the very very fine size of the pores of the membranes. And similarly for bacterial removal we can also go for micro filtration ultra filtration and nano filtration or RO process right. And for the protozoa cysts, oocytes, helminths, ova, so we also can go for all these four types of processes

whereas, when we talk about the viruses, we have to use nano filtration or RO process only. So, when we talk of the micro filtration and ultra filtration in the wastewater treatment process, so here we can use the aerobic biological treatment process, and we separate the treated wastewater from the active biomass in an active distress process. So, we can use separation of the active biomass or MLVSS which is present in the aeration chambers and by using the membrane process right and so it also reduces the need of the secondary settling tank in such a case. Similarly, in the anaerobic process also the active biomass can be separated by the wastewater. So, when we talk of the membrane aeration biological treatment system that is also called the MABR that is membrane aeration bioreactor.

So, in that case what happens that we supply a pure oxygen through the tubular or hollow fiber membranes. So, that the bacterias they can get attached on to the surface of the membrane and they can lead to the removal of a certain type of species like for example, we can use this such type of process where we can treat the nitrogen which is present in the water by using the aerobic process on the surface of the membranes whereas, in the on the outer side we can have the anoxic processes taking place. So, nitrification and denitrification that can take place simultaneously in a reactor and we can get rid of the nitrogen in such type of systems. Similarly, we can also have a process which is called the extractive membrane bioreactor where we extract the organics from the inorganic constituents such type of treatment is called the extractive membrane bioreactors. So, you can see here that we are having the conventional process where we are having the primary sedimentation, we are having the aeration tank, and this is representing the active sludge process.

So, we are having the secondary clarifier and after that we can have the micro filtration or ultra filtration. So, this will enhance the effluent quality in such a case. So, we always use micro filtration or ultra filtration when we are going for the wastewater treatment processes right because, nanofiltration and the RO process they basically will clog very fast, and it will be very inefficient to use nanofiltration and the reverse RO process for such type of systems. Similarly, this in the membrane bioreactor we can also put the membrane inside the tank also. So, you can see here that the influent is coming we are providing the air and the permeate is passing through the membrane.

So, the biomass is retained here in the reactor and the permeate which is having a very high quality which is having very low ml VSS content in it. So, they it can pass through the system. Similarly, we can also put the membrane outside the aeration tank, and we can enhance the performance of such type of system we can recycle the retentate back to the aeration tank. So, we can see that when we are having active research process. So, this is the conventional system where we are removing the solids we are going for the pre-treatment or the primary sedimentation then we are going for the aeration zone we are going for the settling right after settling we go for the sand filtration and disinfection and then finally disposal of the effluent.

So, this is the conventional process that we use in the active research process. But in the membrane bio filter we can replace our secondary settling and the sand filtration here by the membrane process ok. So, we can see here that the membrane has taken the place of our secondary settling and sand filtration process. And similarly, it such type of process

can also be used in the anaerobic bioreactors. So, they are called ANMBR where AN represents the anaerobic and MBR represents the membrane bioreactors.

So, ANMBR basically can be used where membrane can be put outside, or it can also be put inside the reactors. So, here what happens that we can pump the wastewater from the anaerobic membrane bioreactor, and we can pass it through the membrane and then we can recycle our concentrate back to the reactor whereas, the effluent basically can be taken for the disposal process. Similarly, we can put this membrane outside, but we can also utilize the biogas that is getting generated from the membrane bioreactor from the anaerobic membrane bioreactor and we can use it for purging the membrane so that the fouling can be reduced. And here we can take the water from the top side because it is much cleaner right and then we can pass it through the membrane and then the whatever the concentrate is there so that can be taken back to the anaerobic bioreactor and the effluent is taken for the disposal. Similarly, we can put the membrane inside and whenever we are putting the membrane inside, we can utilize our biogas so that we cannot use air in such cases because it is an anaerobic system.

So, in that case we can utilize the biogas only for sparging of the membrane so that they can be decluttered, they can be de-clocked, it can enhance the efficiency of the membrane process. And we can also use the filter screen in such cases where again we can pass the biogas for de-clogging or de-fouling of the membrane. So, when we are going for the pretreatment for effective disinfection so we can utilize the membrane process because when we are having the suspended solids. So, the suspended solids it reduces the efficiency of the disinfection because they protect the microbes, they provide a shield to the microbes so that they can protect themselves from the effect of the chlorination or UV radiation and that is why in high suspended solid contents our efficiency for disinfection may go down. So, when we are going for disinfection process, we should always remove the residual suspended solids so that the disinfection can be achieved to the desired efficiency.

Similarly, we have to also go for the pretreatment for nanofiltration because when we are going for nanofiltration then we have to remove the colloidal and suspended particles so that we can go for the nanofiltration after that. So, nanofiltration can also be used for the wastewater treatment as we have already discussed that it may not be highly feasible for our wastewater treatment by using nanofiltration or RO processes, but in some specific cases it may be used for example, when we are having the effluent which is coming out from the wastewater treatment plant. So, we have to take the pre-filtered effluent in such cases, and it can be used for the treatment by using the nanofiltration process, but it can be used the water for indirect water bill reuse application such as if we want to inject the treated wastewater into the groundwater. So, we have to go for the nanofiltration first of all so that we can inject it into the ground. Similarly, when we are going for wastewater softening also can be used for the treatment of wastewater by using nanofiltration process.

So, if we want to specific reuse of such type of wastewater that is we are getting so then we can go for the process of nanofiltration. Suppose we are going for application of such wastewater in the irrigation purposes also so then it can be used at that point, or we are using for certain industrial applications also so we can go for nanofiltration of such type of pre-filtered wastewater. Similarly, the RO process can also be used for the wastewater treatment for example, if we are using it for indirect water bill reuse application so then we

can go for RO process also, but we have to always go for a pre-filtered effluent which is coming out. And similarly, we can also target the wastewater, which is having a certain specific compound for example, let us say we are having NDMA, or it is called nitroso-dimethyl amine in the wastewater or certain compounds which you want to remove which otherwise can cause harm to the environment where we are disposing the water. If you want to remove certain priority pollutants which have not been removed earlier by the conventional process so in that case also, we can use RO process so that we can target a certain compound and we can remove it from our systems.

Similarly, the wastewater treatment can be suitable for high pressure boilers, but again here we have to go for two stages of RO process so that we can produce a water which can be suitable for the high-pressure boiler. So, these are certain specific applications of the nano filtration process and RO process that can be applied for the wastewater treatment for a specific purpose. So, we stop here, and these are the references that we have used in preparation of these lectures, and we stop here, and we will continue the membrane processes in our coming lecture.

Thank you.