Water and Wastewater Engineering

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Advanced Wastewater Treatment
Lecture # 33

Last class we were discussing about various methods of effluent disposal. we have seen that whatever effluent that is coming from the wastewater treatment plant will not be completely pure or some portion of the organic matter or pollutants whatever was present in the wastewater will be still remaining in the treated effluent because none of the treatment plants can achieve hundred percentage treatment efficiency. So if you dispose that one into existing water bodies then the nature will take care of the remaining pollutant and the water will become completely clean or clear. That is the principle of the effluent discharge into large water bodies.

We have also discussed about the land treatment, how we can treat the wastewater by applying in the land and what are all the various methods we are adopting for this purpose. We have also seen that nowadays it is always recommended to go for the reuse of wastewater rather than disposing it off in the existing water bodies or on land. The reason is the scarcity of water resources because not enough water is available in any place we are not supposed to waste any water, this is one reason. And another reason is, since the water or the wastewater effluent coming from the treatment plant will be containing so much of pollutant it will be deteriorating the water quality in the streams or lakes or estuaries or oceans so it is always advisable to go for the water reuse.

If you want to go for the water reuse we have also seen the different ways by which we can reuse the water. But the effluent, whatever is coming from that treatment plant is not meeting the standard prescribed for the specified use. So if you want to meet the standard for the beneficiary use we have to give some more additional treatment, these types of treatments are known as advanced wastewater treatment or tertiary treatment. So today we will be discussing in detail about the various advanced wastewater treatment processes available and what type of pollutant each type of treatment can be adopted.

Advanced wastewater treatment is required when we are going for wastewater reuse. The quality of the treated water should meet the standards for the specified use. For example if the effluent is coming from a wastewater treatment plant the bacteriological quality will not be meeting the drinking water standards and there will be so many organic materials both biodegradable and non biodegradable.

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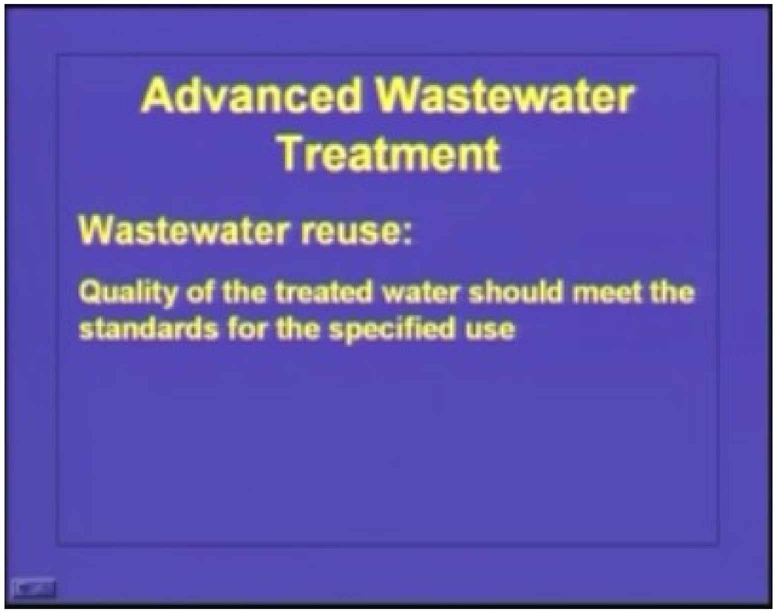

We were also discussing about non conventional pollutants as well as emerging pollutants. So most of these non conventional pollutants either they are non biodegradable or very less biodegradable so what will happen in the conventional treatment plants is whatever time or the process we are adopting it will not be able to completely remove this non conventional pollutants like pesticides, surfactants, heavy metals etc and emerging pollutants will also be present in large quantities, we don't even know what is the long term effect of this emerging pollutants so if these pollutants are present in the water or the wastewater effluent coming from the treatment plant and if you want to reuse them especially for domestic purposes it is not advisable unless these pollutants are completely removed from the system.

In the first class of the course we were discussing what is the water quality standard required for each and every beneficiary use and water quality standard is not a constant it will be varying with respect to the beneficiary use so similarly the degree of advanced treatment what all we have to provide also varies based upon the beneficiary use. If you want to use the effluent or the wastewater effluent whatever is coming from the treatment plant for drinking purpose it has to be treated to such an extent that it will be meeting the water quality parameters.

We will what this advanced wastewater treatment is. It is the additional treatment needed to remove suspended, colloidal and dissolved constituents remaining after the conventional secondary treatment.

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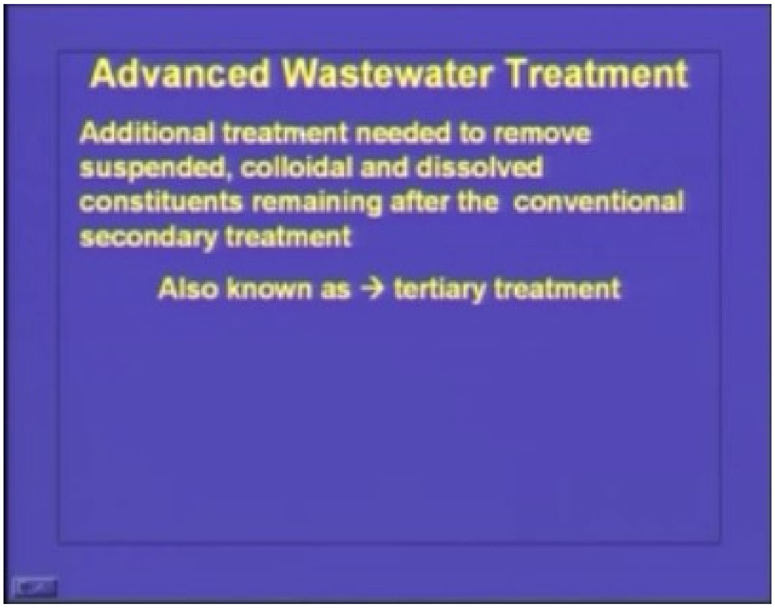

Hence, after the conventional secondary treatment there will be left over suspended solids, colloidal and dissolved solids and other organic matter. So if you want to remove this one we have to go for advanced wastewater treatment. As I have already mentioned this is also known as tertiary treatment and the pollutants we have to remove from this advanced wastewater treatment includes simple inorganic ions like calcium, potassium, sulphate, phosphorate etc. It is because if these ions are present in excess quantity the water will be having some problem depending upon the beneficiary use.

Yesterday we were discussing that if the dissolved solids concentration is very very high then we cannot use that water for agriculture purpose. We have also seen the characteristics or the water quality requirement for coolant water. We all know that the drinking water should meet all the specified standards. The other one is large number of highly complex organic compounds because we don’t know what different types of organic pollutants are present in the wastewater which is even too complex so in order to remove that one we have to go for advanced wastewater treatment.

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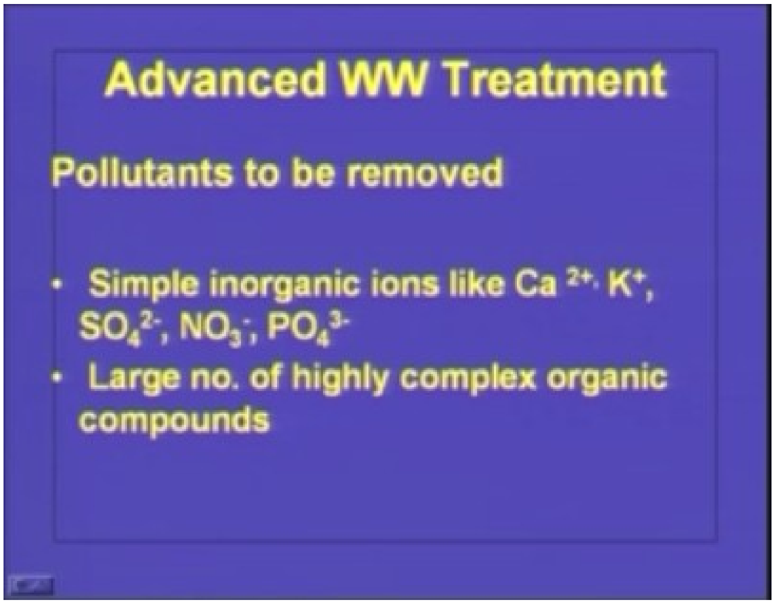

Need for advanced wastewater treatment: To remove organic matter and total suspended solids beyond what can be achieved by conventional and secondary treatment. Hence by using primary and secondary treatment we will not be able to remove all the organic pollutants. So if something is left over then we have to go for advanced wastewater treatment. Next is to remove residual total suspended solids, to remove nutrients, to remove specific inorganic and organic constituents. The inorganic constituents consists of heavy metals and we know that these metals are non destructive in nature so if they are present in the water or wastewater and while you are reusing it it comes in contact by water then it will be bio accumulating in the system and finally it will be getting concentrated in our body and it will have harmful effects.

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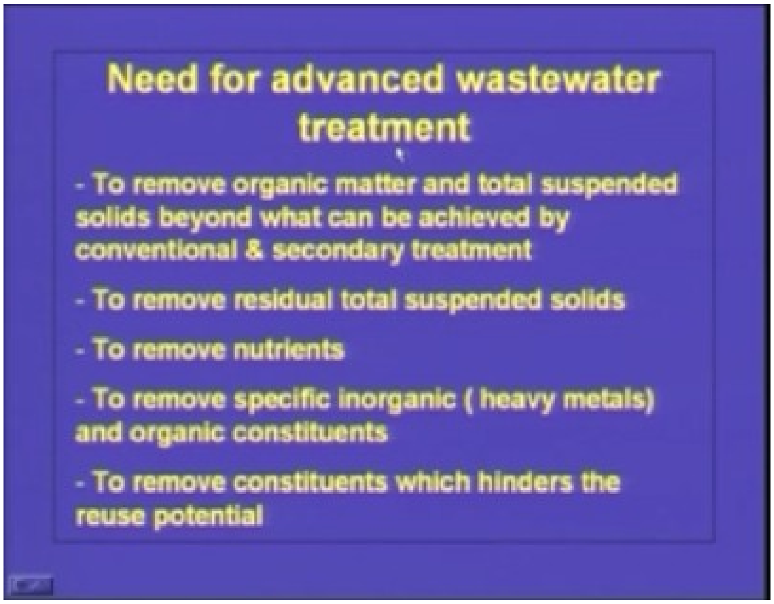

The other one is to remove constituents which hinder the reuse potential because if such constituents are present definitely the reuse potential of the treated effluent will be reduced. Now we will see what all are the classification of technologies. We will see the treatment technologies which can be used for each and every pollutant separately. Some suspended solids will always be coming out of the secondary treatment plant so if you want to remove the left over organic and inorganic colloidal and suspended solids we can go for either depth filtration or surface filtration or membrane filtration.

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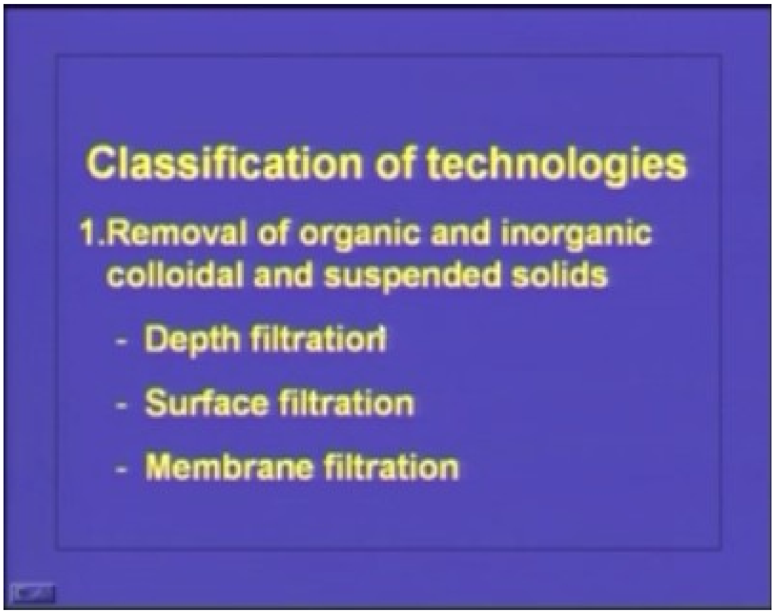

Now coming to the removal of dissolved organic constituents which is left over after the secondary treatment we can go for:

- carbon adsorption
- reverse osmosis
- chemical precipitation
- chemical oxidation
- advanced chemical oxidation
- electro dialysis and
- distillation

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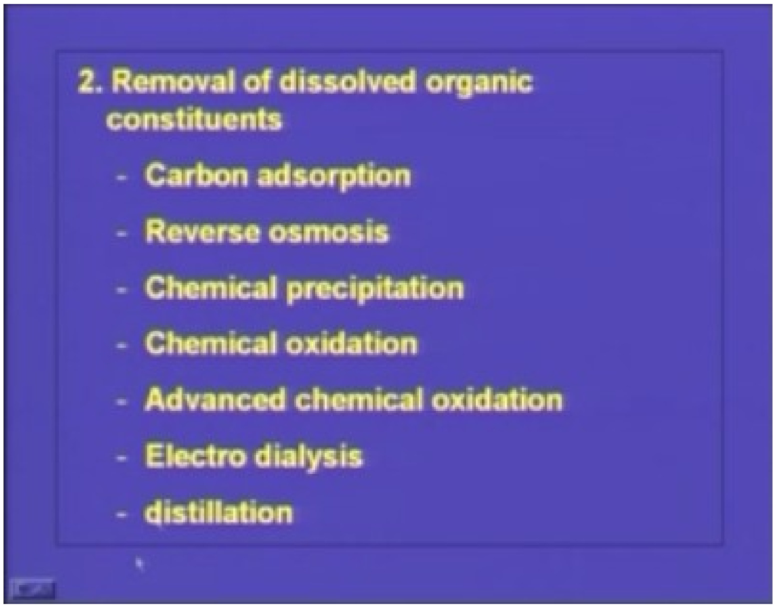

So, depending upon the pollutant and the cause and the feasibility of the technology we can choose any one of this method for the removal of organic constituents. Now we will see how we remove the dissolved inorganic constituents. We can either go for chemical precipitation, this we have discussed in detail when we were discussing about the hardness removal, then ion exchange, this also we have discussed in detail and another method is reverse osmosis, electro dialysis or distillation.

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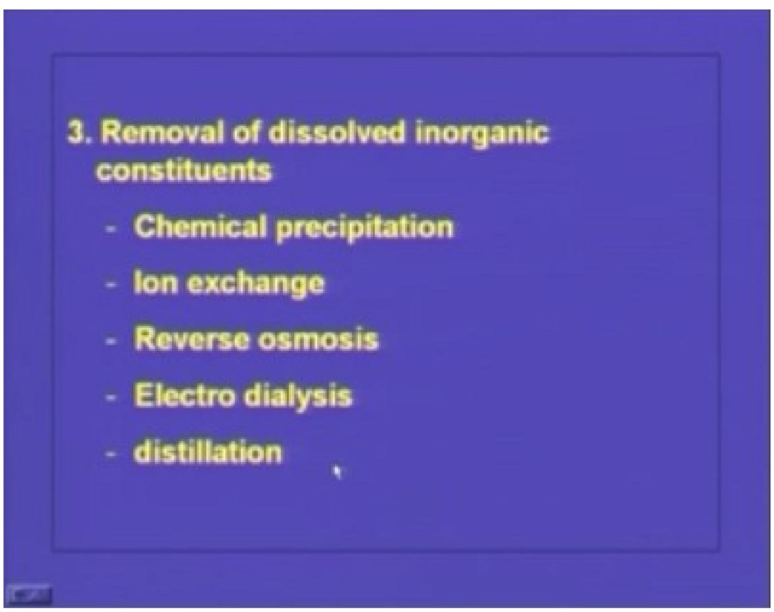

And if you want to go for the removal of biological constituents we can select any one of these methods;

- depth filtration
- micro and ultra filtration
- reverse osmosis
- adsorption
- ion exchange
- distillation and
- disinfection

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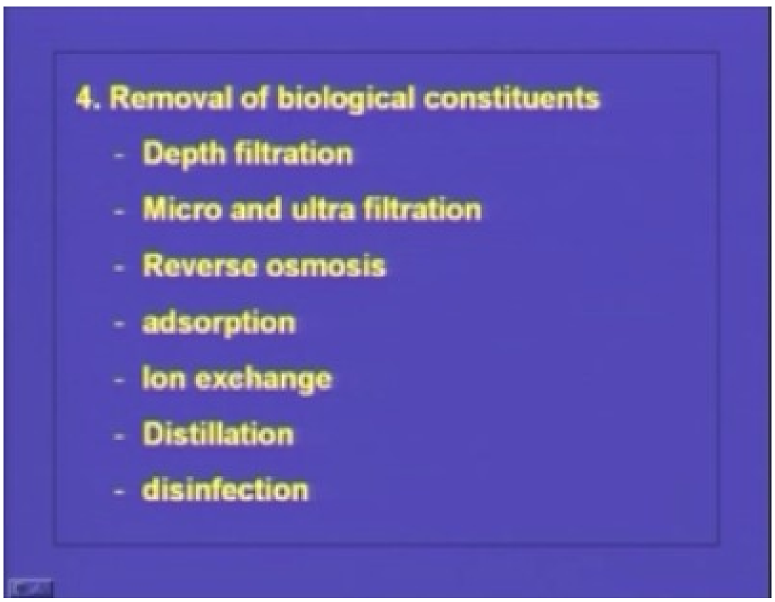

So now we will see the parameters which decide the selection of the technologies. One is the use to be made of the treated effluent. If you want to use the treated effluent for high priority purpose for example for drinking purpose or cooking purpose then definitely the extent of treatment required is very high at that time we have to go for either adsorption then any of the membrane processes and disinfections so that whatever constituents present in the system will be removed from the system that is why the use of the treated water decides the extent of treatment required and treatment method that we have to choose.

Next one is the nature of the waste water. This also depends on the selection of the technology depending upon the pollutant, depending upon the other characteristics of the wastewater. The third one is compatibility of treatment process. Though many treatment processes are available all the treatment processes may not be compatible for a particular circumstance or particular type of wastewater and for a particular type of use so we have to check the compatibility of the treatment process. Then we have the available means of ultimate disposal of contaminants because in any of these advanced treatment technology apart from the advanced oxidation or chemical oxidation most of the other methods generate some secondary pollutants which need further attention so we have to see which is the ultimate disposal method available for the contaminant so based upon that one we have to select the technology.

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The last one is the environmental and economic feasibility. Though the technology is compatible and we will be able to achieve the desired degree of treatment but if the cost involved is very very high then after treating the water the cost of the treated water will be much more than getting fresh water so in such cases the technology will not be advisable so we have to check both the environmental and economic feasibility of any of the technology before selecting the one.

Now we will see each and every technology in detail. First one is depth filter.
We have seen that depth filter can be used for the removal of suspended as well as colloidal materials what is left over after the secondary treatment and this depth filter can also remove a portion of the micro organism whatever is present in the treated effluent.

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We have seen in detail the design of a depth filter when we were discussing about water treatment. We have discussed various processes in detail in that one. We have discussed the rapid sand filter and we know that rapid sand filter is under the category of depth filter and we have seen that to operate the rapid sand filter what are all the parameters that affect the efficiency of the rapid sand filter, how to clean the rapid sand filter and what all are the mechanisms by which the pollutants are removed from the rapid sand filter system. so the same rapid sand filter can be used for the removal of colloidal as well as suspended solids from treated wastewater.

The second one is surface filter. We have seen that for surface filters the main removal mechanism is by straining so any fabric filters, slow sand filters or micro filters are coming under surface filters. We have seen the mechanism and operation of slow sand filter in water treatment so the same principle is applied for the waste water treatment also. There we know that most of the treatment is taking place in top portion of the slow sand filter so there a dirty layer of active bio mass will be forming and whatever the turbidity or the suspended solids coming along with the water or the wastewater will be getting strained by this layer so the pollutant will be getting accumulated mainly on the top portion of the filter that's why it is known as a surface filter.

So if you want to clean such filter we have to remove the top portion where the pollutants are getting accumulated. But the depth of the filter is also important especially when there is some organic matter present in the wastewater. The reason is when the wastewater passes through the depth of the filter the micro organisms will be acting and they will be taking care of the organic matter and converting it into carbon dioxide and water or other environmentally friendly product. So it will be taking care of both suspended solids, colloidal solids as well as a portion of the dissolved organic solids.

Now we will see the next treatment technology that is the membrane filtration process. This process can remove particle of 0.0001 to 1 micron meter so we can see a wide range of particles can be removed by this membrane filtration. And if the particle size is above 1 our coagulation percolation or the filtration will be able to remove the particles.

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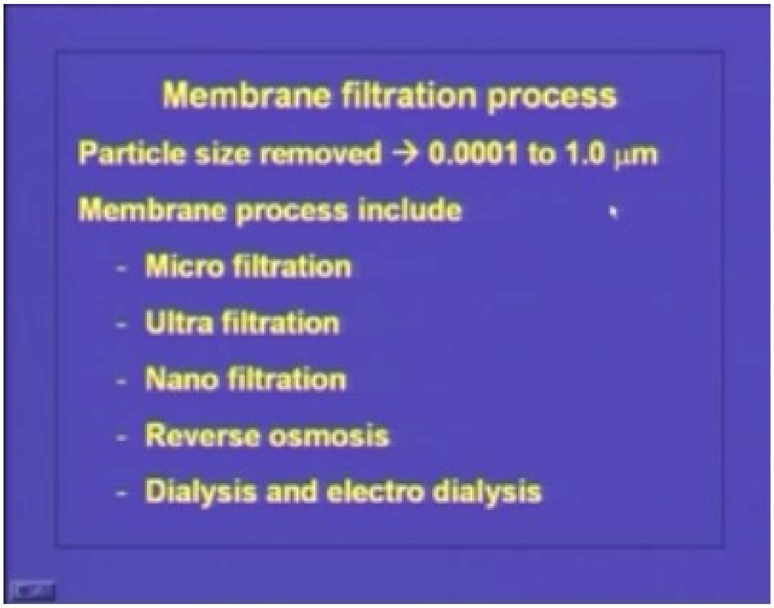

So the membrane process includes:

- micro filtration
- ultra filtration
- nano filtration
- reverse osmosis
- dialysis and
- electro dialysis

All process is coming under membrane processes. And by using membrane process we can remove even the dissolved solids present in the water because it is able to remove particles of size 0.0001 micro meter so this is coming in the range of molecular size. Now we will see what is the basis of this classification because we have seen that there are various membrane processes starting from micro filtration to dialysis or electro dialysis.

How we are classifying the membrane processes?
The classification is basically based on the type of material which the membrane is made of because this will decide the pore size and if the pore size is small it can remove small particle size and if the pore size is bigger it can remove only bigger particles so one basis is the type of membrane used.

The second one is the nature of the driving force. So either it is concentration gradient or pressure force or mere straining or some electrostatic forces. Hence, depending upon the driving force we can classify the membrane process. The other one is based upon the separation mechanism and the last one is based upon the nominal size of separation like what type of particles it can separate so it is based upon that one.

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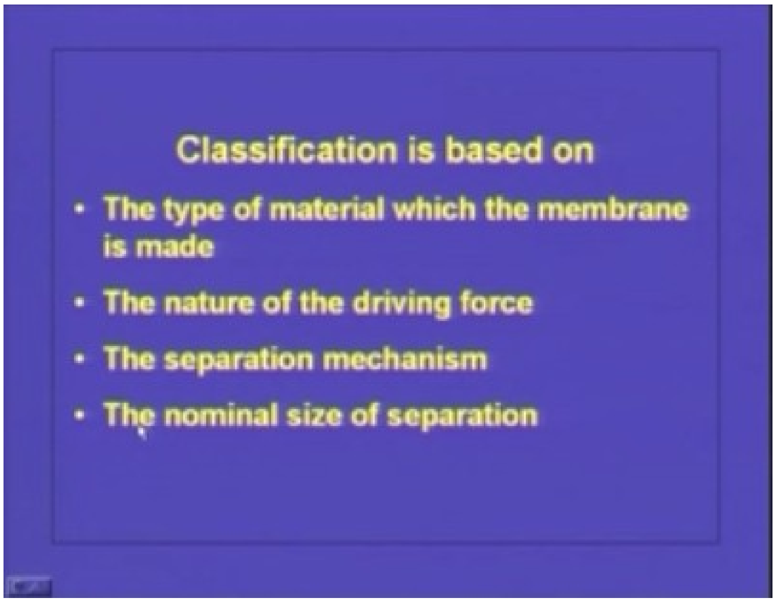

These are the four basis of classification of this membrane technology. So if you want to see how a membrane works either it is a micro filter or an ultra filtration or nano filtration or reverse osmosis whatever be the thing this is the basic system. This is the feed water (Refer Slide Time: 17:48) with a flow rate of Qf which is the feed water flow rate and Cf is the feed water concentration and Pf is the feed water pressure. So feed water is coming here and this is the membrane which is a semi permeable membrane, it allows only certain types of molecules to pass through that one and retain the other type of molecule. This chamber consists of the feed as well as the concentrate and here all the permeate is getting stored.

The permeate is represented by the letter p, Qp is the permeate flowrate, Cp is the permeate concentration because some smaller molecules will be getting permeated through this membrane depending upon the membrane nature and Pp is the permeate pressure. This Kw is the water mass transfer coefficient and Ki is the solute mass transfer coefficient. this chamber (Refer Slide Time: 19:04) is known as the container for membrane module because the membrane is placed in this one the feed water is coming like this and the permeate is going like this and whatever is getting concentrated because of the membrane process is collected through this way and this is the concentrate usually represented by the letter c and Qc is the concentrate flow rate, Cc concentrate concentration and Pc concentrate pressure and we can make a mass balance because whatever the feed concentration and feed flow rate is Qf Pf will be equal to Qp Cp plus

Qc Cc. So based upon that one we can find out what is the flow rate coming as permeate and what is the concentration of solutes coming out.

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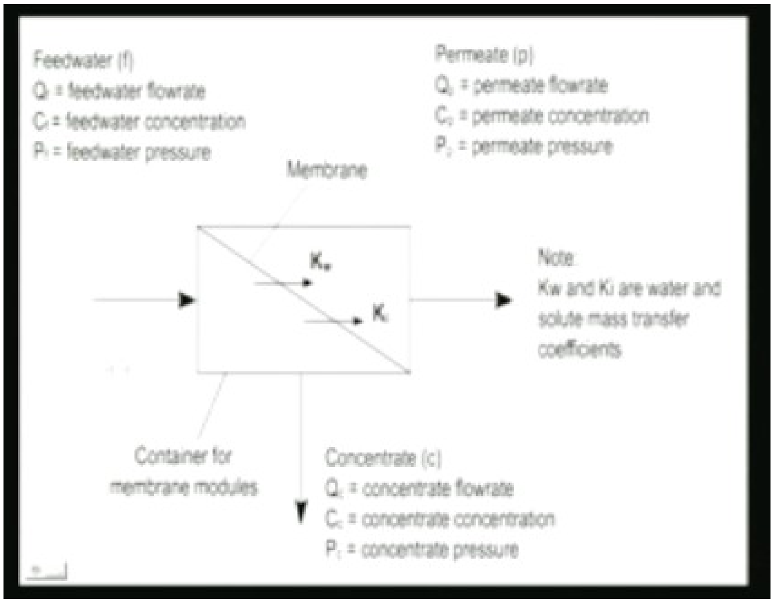

Now we will see the terminology used in the membrane process.

Feed stream: The influent to the membrane module.

Whatever is going to the membrane module is known as feed stream and permeate is the one coming out of the membrane after the treatment or the liquid that passes through the semi permeable membrane.

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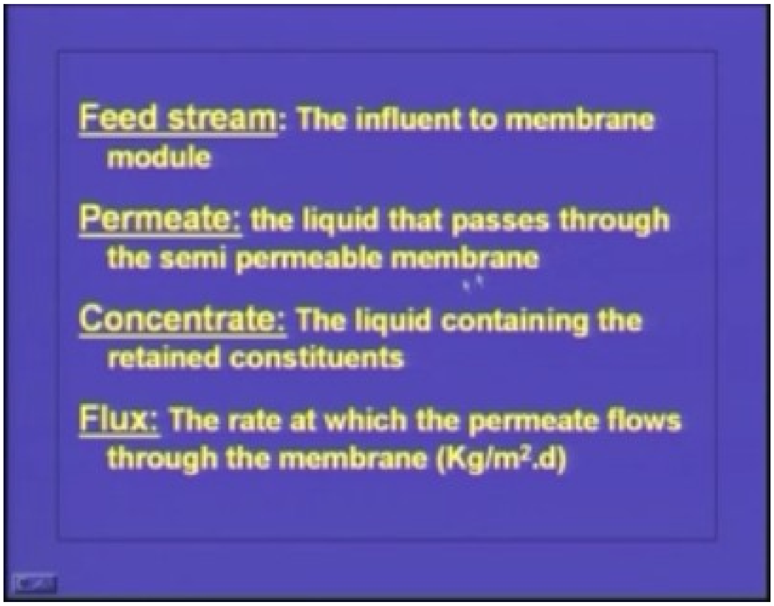

The next one is the concentrate: The liquid containing the retained constituents. we know that feed stream will be having a particular concentration and the semi permeable membrane will be allowing only the solvent to pass through that one and in between some solute also will be passing through that one so what will happen is all other solute will be retained in the other side of the membrane so naturally concentration of the solute will be increasing in this side so that is coming as the concentrate.

Now we will see what is this flux?
The rate at which the permeate flows through the membrane is known as the flux. It is usually expressed in the unit kilogram per meter square day.

Now we will see what are the different materials used for the membrane making.
For wastewater treatment most of the time organic materials are used, it can be either organic polypropylene or cellulose acetate, aromatic polyamides or thin film composites.

We have discussed about various membrane processes starting from micro filters ultra filtration, nano filtration, reverse osmosis and dialysis and electro dialysis. Now we will see what all are the driving forces in each of this membrane process.

The driving force in micro filtration, ultra filtration, nano filtration and reverse osmosis are pressure force. So because of the pressure force the solute is retained and the solvent is passing through the semi permeable membrane so the driving force is pressure force.

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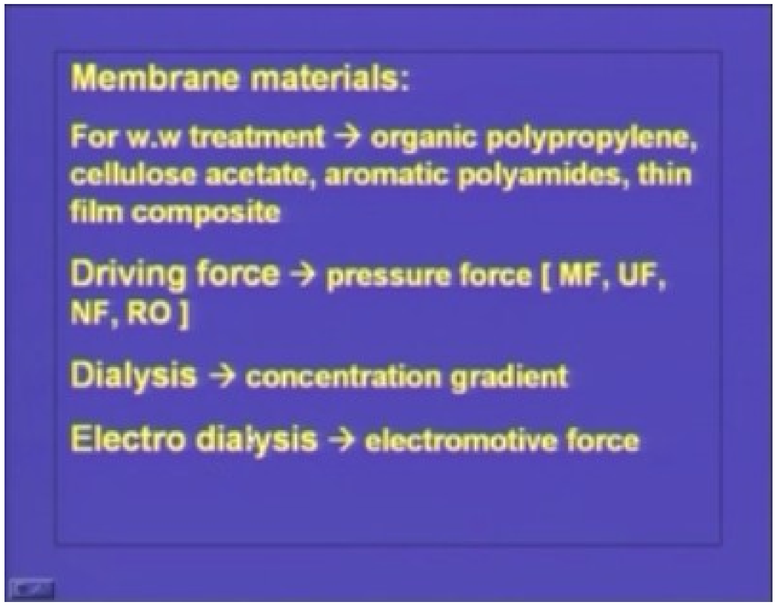

But when we talk about the dialysis the driving force is concentration gradient, we all are familiar about the dialysis and when we talk about the electro dialysis the driving force is electromotive force. We are applying some electric charge and based upon that one the particles or the ions will be moving towards the cathode or the anode based upon their charge and there will be some membranes which will be specific for the cations or anions. Like that we can separate the solutes from the system and get a concentrate of all the cations or anions and a solution without any ions. That is the principle of electro dialysis.

Now we will see how these membranes are configurated in the treatment systems.

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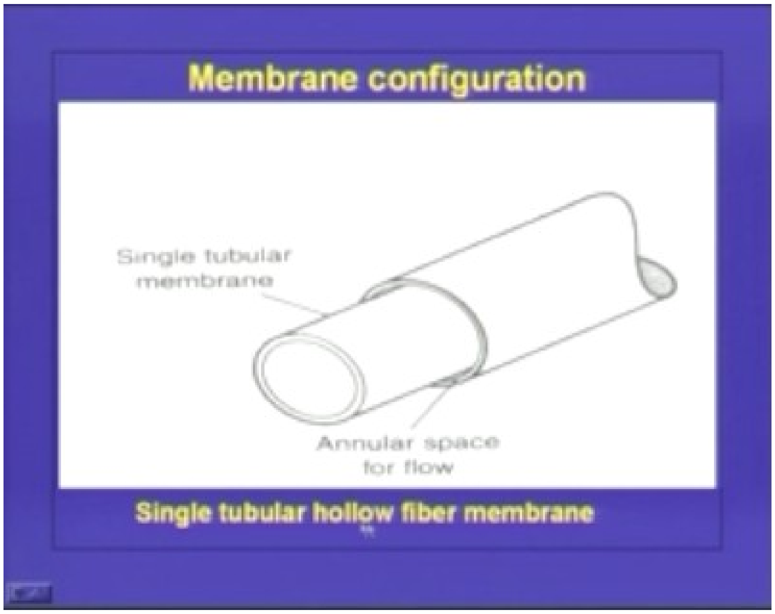

This is an example of a single tubular hollow fiber membrane. This is the single tubular membrane. The feed water will be going like this and it will be getting permeated through this one and we can collect the treated water from here. This is an example of single tubular membrane.

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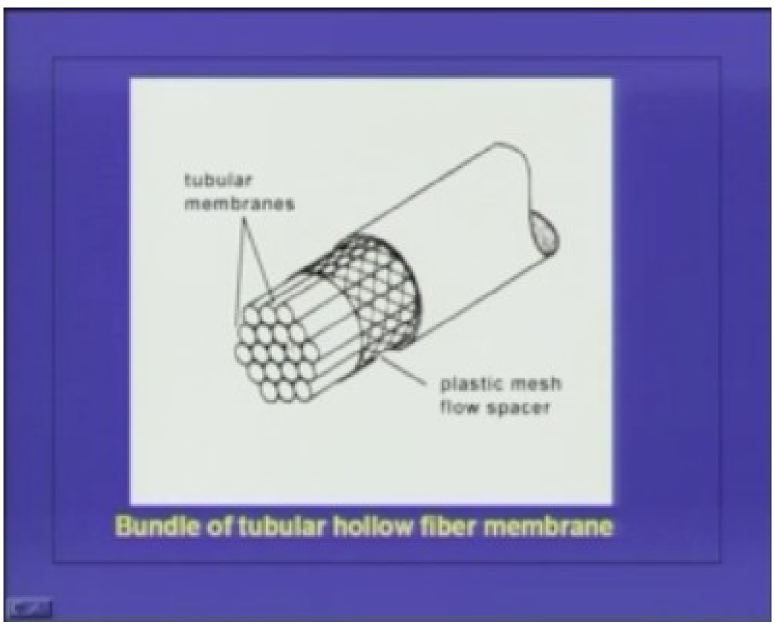

This is a bundle tubular hollow fiber membrane. Here what is happening is a bundle of tubular membranes are placed inside a container and this is the plastic mesh flow spacer.

This will be there so that the flow will not be disturbed and all these are individual tubular membranes so if you keep many membranes together then definitely the flow rate will be high or the flux will be high.

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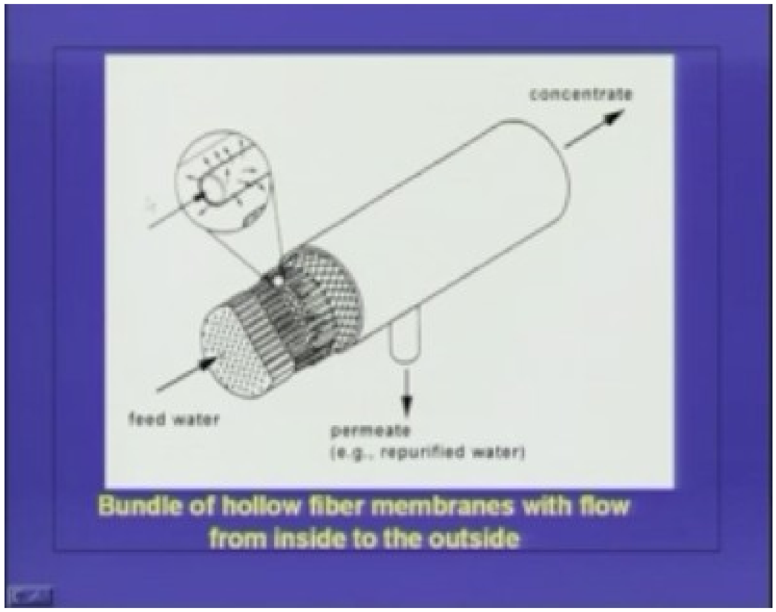

And here this is a bundle of hollow fiber membrane with flow from inside to the outside. In the earlier cases what was happening was the feed water was coming from the outside and it was entering and we were collecting the treated water from inside. Here what is happening is the feeding is from inside at high pressure so the water will be permeating and we will be getting the permeate or the treated water from the outside.

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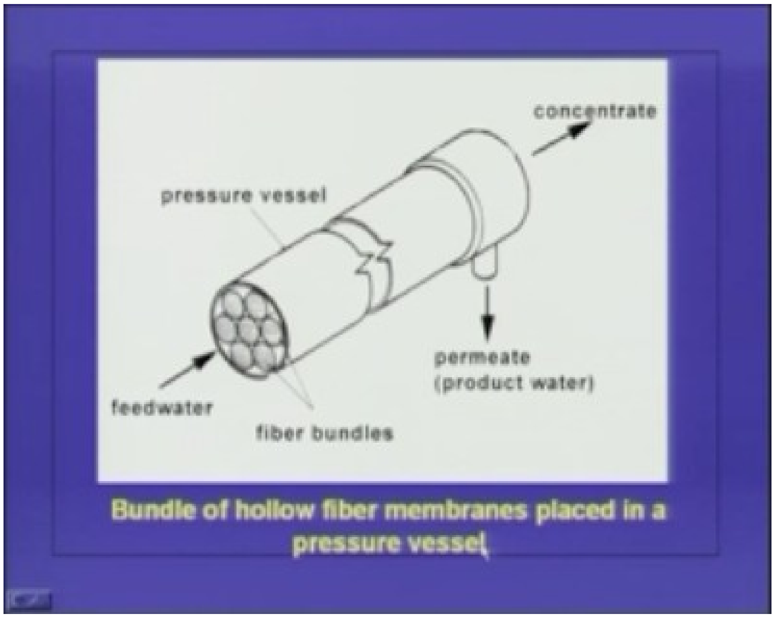

This is a bundle of hollow fiber membranes placed in a pressure vessel. this is the pressure vessel and feed water will be going and this is fiber bundle and these are acting as the semi permeable membranes and the feed water goes like this (Refer Slide Time: 24:42) and we can collect all the permeate from here and the concentrate will be coming out from here.

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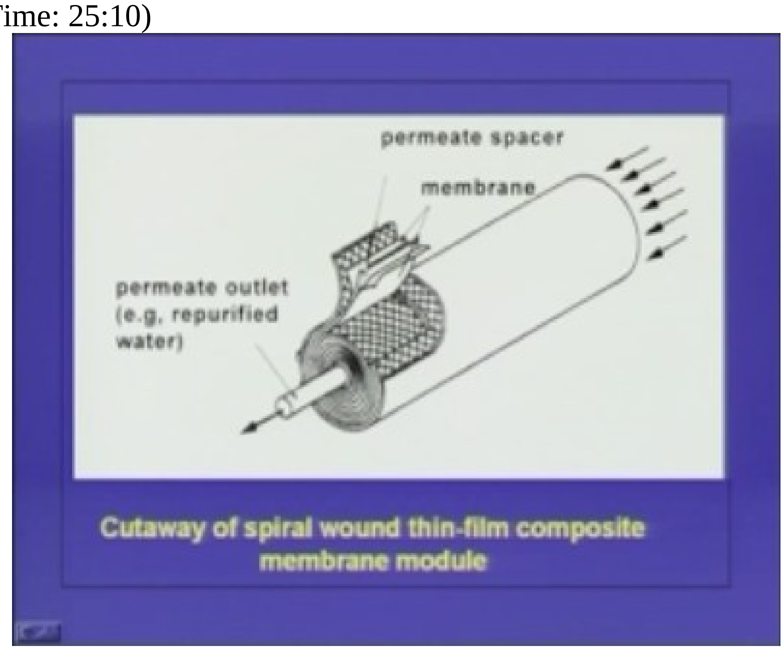

This is a cutaway of spiral wound thin film composite membrane module. This is the composite membrane module. So if you cut a portion of that one it will look like this. So these things are the membranes the white color things and in between we can see a mesh type of a thing this is the permeate spacer. If you put the membranes close by each other what will happen is the permeate whatever is coming out of the membrane will not be able to flow freely. If you place a permeate spacer then the flow will be smooth and we will be getting much better flux and everything will be collected like this and this is the permeate outlet or repurified water coming out through this one.

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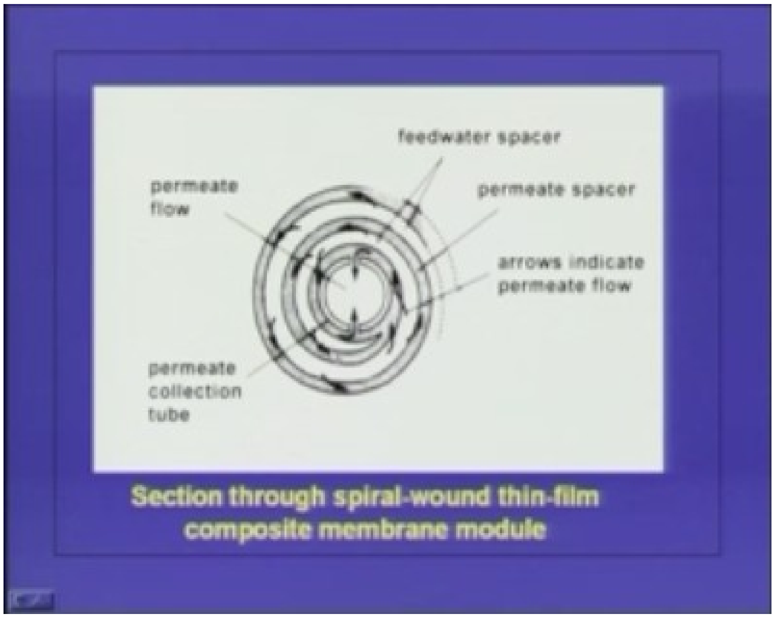

This is a section through a spiral wound thin film composite membrane module. This is the feed water spacer. We can see that the feed water will be entering through this pipe portion like this in a spiral way and these are your membranes. So what will happen is, this is the permeate spacer and these arrows indicate the permeate flow. The entire permeate will be flowing like this and finally you will be getting everything collected here. This is the permeate collector tube (Refer Slide Time: 26:23) so feed water is coming and this is the permeate spacer and this is the direction in which the flow is taking place and everything is getting collected here.

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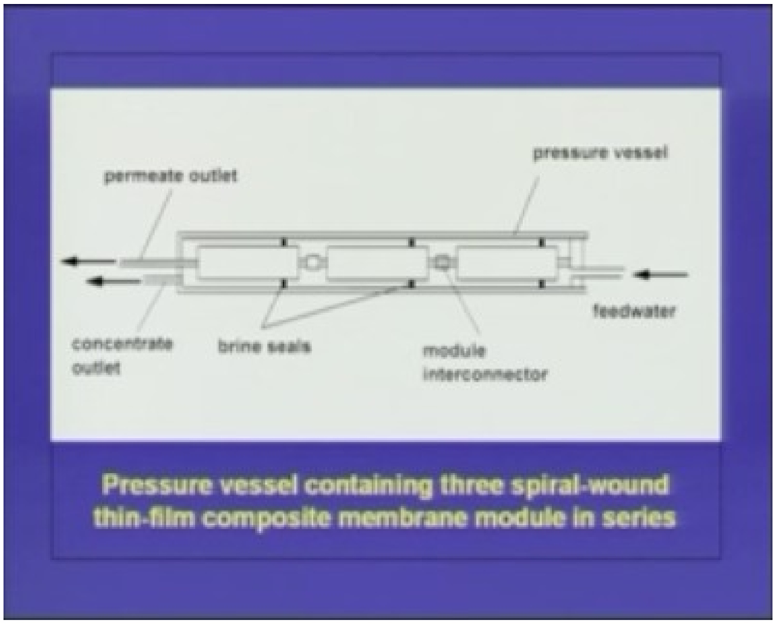

This is a pressure vessel containing three spiral bound thin-film composite membrane module in series. It is not necessary that you have to only go for a single membrane unit. If you want to get high efficiency or high removal then we can even go for a series of membrane modules. so this is an example of a series of membrane modules put in a pressure vessel, the feed water is coming here and this is the module inter connector and this is a brine sealer that means it is not getting mixed up and this is the pressure vessel. So the feed water is coming and it is getting treated here and it is going like this. Here we are getting the concentrate and here we are getting the permeate outlet (Refer Slide Time: 27:23). So, compared to a single module this module or this arrangement will be giving you a better flux as well as a better removal efficiency.

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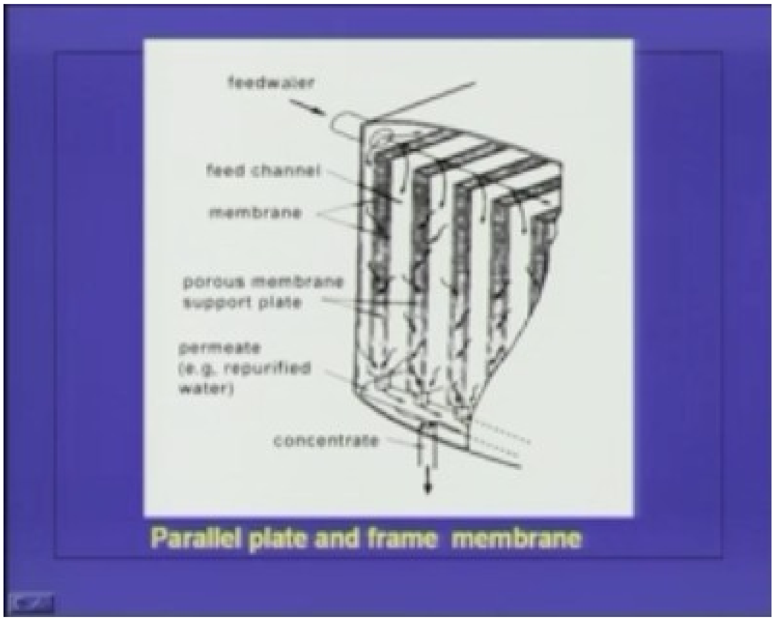

This is another arrangement a parallel plate frame membrane. Here we can see that this is the feed water inlet and these are the feed water channels. The feed water will be coming and you can see the arrow it is equally getting distributed into each feed water channel and these are your porous, these are the membranes and these are the membrane support plates. this is the membrane support plate and this is the membrane (Refer Slide Time: 28:10) and this is porous so what is happening is the feed water is going like this and it is getting filtered through the membrane and whatever is the filtered one is getting collected here which is used as the support plate and it is porous. So we can collect the permeate through this one and whatever permeate that is collected is coming here and it is collected from each and every channel or each and every membrane and everything is collected through this pipe and the concentrate will be coming through this one. So this is the arrangement in a parallel plate and frame membrane.

So depending upon the degree of treatment required and the space available we can select whatever module or whatever configuration we need. Now we will see filtration process for each membrane and for what purpose we can use this one and what all are the advantages and limitations of each process. First we will see microfiltration. It is used for the treatment of wastewater and usually it can reduce turbidity, remove residual suspended solids and this microfiltration can also be used as a pretreatment for reverse osmosis process. We have seen that this micro filtration is coming under surface filtration or surface filter.

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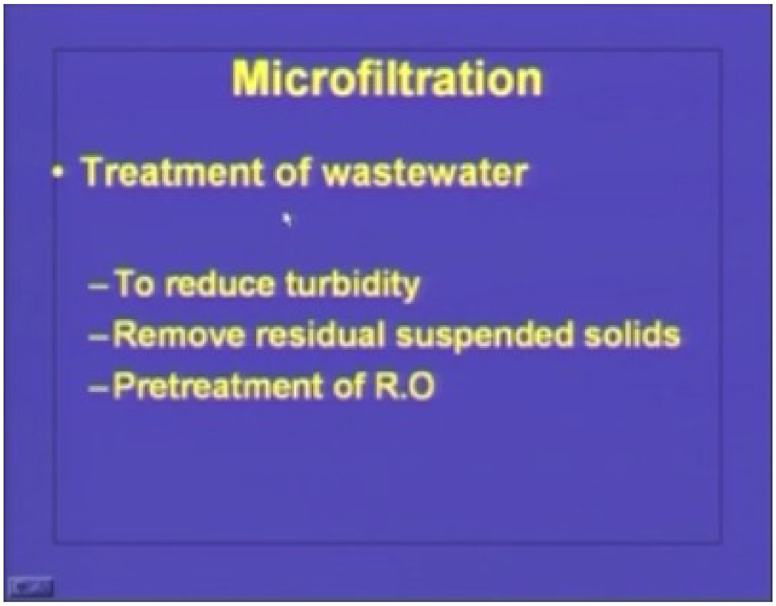

Now we will see a reverse osmosis process. If you want to discuss about ultra filtration the micro filtration and ultra filtration are coming under the same category but the only thing is that the particle size that is getting removed is different. In micro filtration the cut-off size is higher compared to the ultra filtration that is the only difference between micro filtration and ultra filtration otherwise the principles are same and the driving force are the pressure force involved in this filtration processes as we have already discussed.

Now we will see the reverse osmosis which is very commonly used especially for desalination purpose. If you take any solution which is having high concentration of the solute it is separated by a semi permeable membrane and the other side is having fresh water so what will happen is there will be a chemical, a pressure difference between these two sides and this pressure difference we usually call it the osmotic pressure because of this osmotic pressure it will have always a tendency. In this fresh water the concentration of the solute is much less compared to the saline water and it is separated by a semi permeable membrane so the fresh water will always have a tendency to go to this side so that the pressure will be or the concentration of the solute will be the same in both the places so that is what is happening here.

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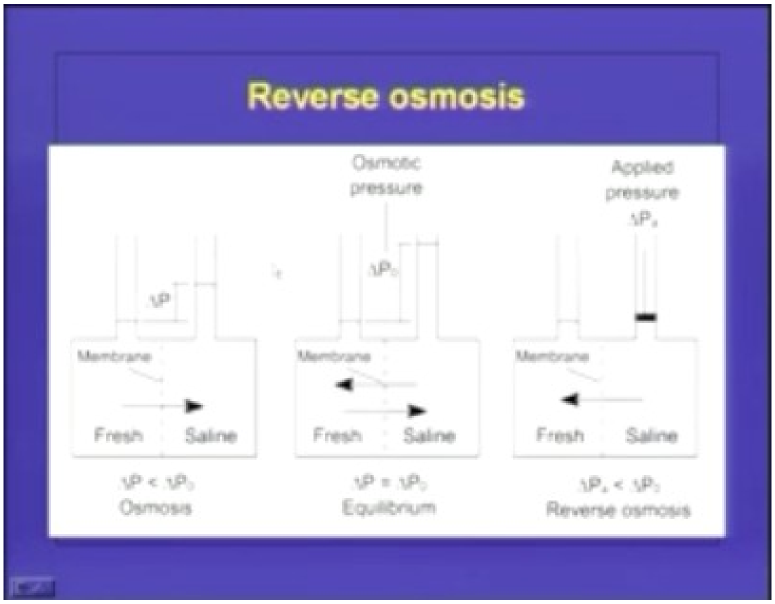

Afterwards at equilibrium delta p will be equal to delta p naught so the water level will be rising like this and when delta p or this pressure difference is equal to the osmotic pressure this flow will stop or this will be flowing this side and this side (Refer Slide Time: 31:46) and an equilibrium will be maintained in the system. But this is the process taking place in nature so whenever a concentrated solution and a dilute solution is there it is separated by a membrane, the process is in such a way that the fresh water will be going to the concentrated water side so that the osmotic pressure will be same in both the places or the pressure difference will be delta p equal to delta p naught or the osmotic pressure. Hence here the concentration will be getting diluted and diluted and diluted and finally it will be becoming the same. But if you use this process it is not going to help us in any way to treat the waste water whatever is coming as the effluent from the treatment plant.

So if you reverse the process for example, here (Refer Slide Time: 32:45) some pressure is available so if you apply some pressure which is in excess of this osmotic pressure then the flow direction will be getting reversed so we can see that here the applied pressure is much higher than osmotic pressure. So what will happen because of this semi permeable membrane here the fresh solvent will be or the water will be passing through the membrane and the solute will be getting concentrated here? This is the principle of reverse osmosis. That means in osmotic pressure or in osmosis the fresh water will be going to the concentrated water side to make the osmotic pressure uniform in both the sides but in reverse osmosis we are applying another pressure to counter the osmotic pressure and the applied pressure will be much higher than the osmotic pressure so the flow direction can be reversed. That is what is happening in reverse osmosis.

Thus, when the applied pressure is very very high the solvent will be passing through the semi permeable membrane and coming here and all the solute will be getting concentrated here so that can be used as a treatment option.

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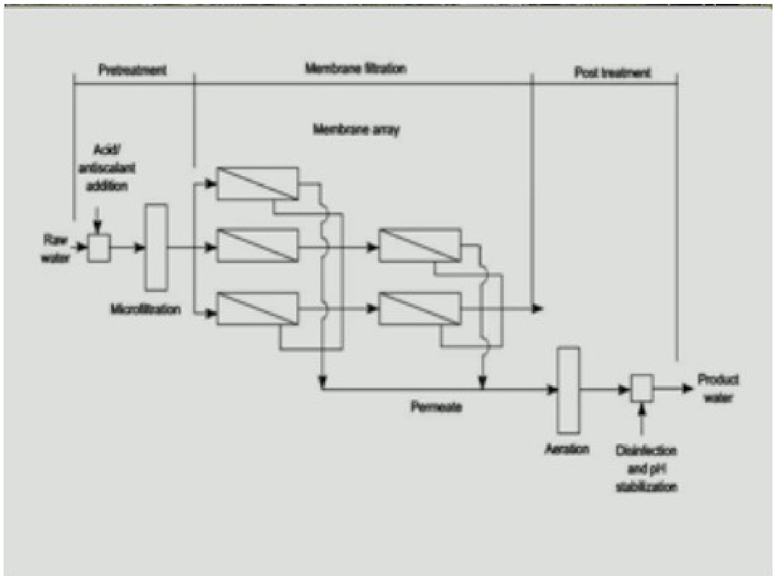

If you want to see how this reverse osmosis plant works this is the schematic of a reverse osmosis plant. First we have to give some pre treatments. We have to adjust the pH so that there will not be any precipitation and we have to remove all the suspended and colloidal particles that's why we are providing a microfiltration here. As we have already explained these are the different membrane arrays (Refer Slide Time: 34:46) a series of membranes are there, this is the first stage and this is the second stage so two stages are there and here three membranes are arranged in parallel and here it is two. The reason is though here the feed water flow rate is very very high hundred percentage of the feed water will not be coming as the permeate but only a portion of the feed water will be coming as the permeate so definitely when it comes here the flow rate will be less so here we are providing only two or in this arrangement itself we can keep one as the stand by unit also depending upon our requirement.

Thus, after this two stage membrane process we are getting the permeate completely treated. So either we can go for parallel processing or series processing depending upon the extent of treatment required. Once the permeate has come out then we have to go for aeration, disinfection and pH stabilization because what is happening is in membrane filtration almost all the solids either it is in colloidal form or suspended form it will be getting removed in microfiltration and whatever is there in the dissolved form almost all the ions will be getting removed in the reverse osmosis process so whatever water that is coming out will be having very less salt content. So we have to make the water stabilized before putting it to the distribution system otherwise this water will be having corrosive nature and the distribution system will be getting affected. After the reverse osmosis process a post treatment is very very essential.
Now we will see what all are the principles of this reverse osmosis.

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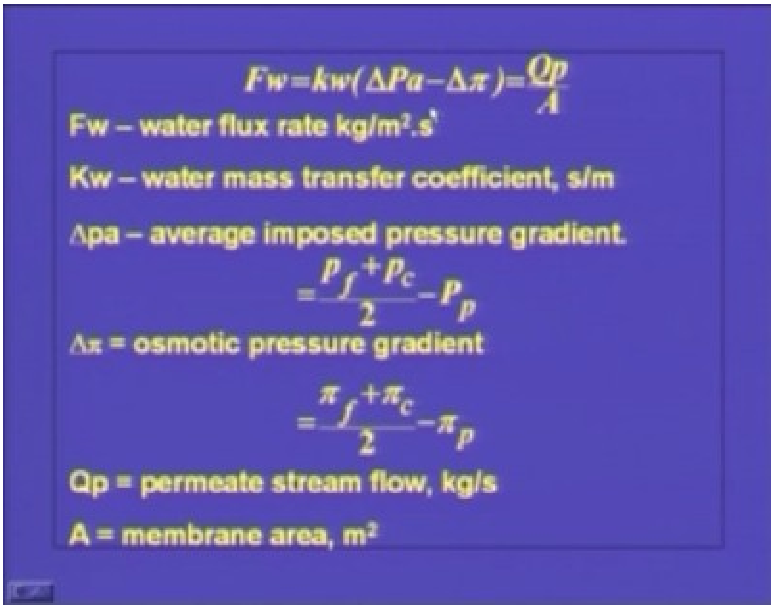

If you want to see what the water flux rate is in kilogram meter square per second it is equal to kw. This is the mass transfer coefficient for water in second per meter and delta pa minus delta pi which is equal to Qp by A where delta pa is the average imposed pressure gradient that means what is the external pressure we are applying delta pi is the osmotic pressure gradient so the difference between the applied pressure and the osmotic pressure will be the net pressure acting on the system with which the water is permeating through the semi permeable membrane. Therefore, if we can find out this mass transfer coefficient multiplied by the net pressure that will be equal to the flux or that is equal to Qp by A.

Qp is the permeate stream flow in kilograms per second and you will be knowing this A where A is nothing but membrane area in meter square. So if you know the membrane area and we know the osmotic pressure we can find out based upon the concentration of the solute present in the water and kw is a non parameter and we know what is the pressure we are applying so if you know all these parameters we can find out what is the flux coming out of the membrane or what is the flow rate of water coming out of the membrane.

Whenever we go for membrane process membrane fouling is a very serious problem. Therefore we will see what is this membrane fouling. As we know the feed water will be having some concentration of the solutes and we are putting a semi permeable membrane and applying high pressure. So because of the high pressure the solvent will be passing through the semi permeable membrane and the solute will be getting concentrated here and we know that the solute concentration will be varying in the liquid. More concentration will be there near the membrane and less concentration will be there in the bulk liquid. So because of the high concentration of the solutes near the membrane the osmotic pressure will be very very high there as the solute concentration is very high.

Thus, even if you apply a high pressure here the next pressure available there will be very very less. Therefore if the concentration gradient near the membrane is very very high the flux of the treatment system or the flux through the membrane will be reducing drastically. That is what is known as membrane fouling or membrane fouling can take place by various methods or for various reasons.

Membrane fouling can be defined as the potential deposition and accumulation of constituents in the feed stream on the membrane. That is known as membrane fouling. Once again, it is the potential deposition and accumulation of constituents in the feed stream on the membrane and it can be built up of the constituents in the feed water on the membrane surface or the formation of chemical precipitates due to chemistry of feed water or damage due to chemical agents.

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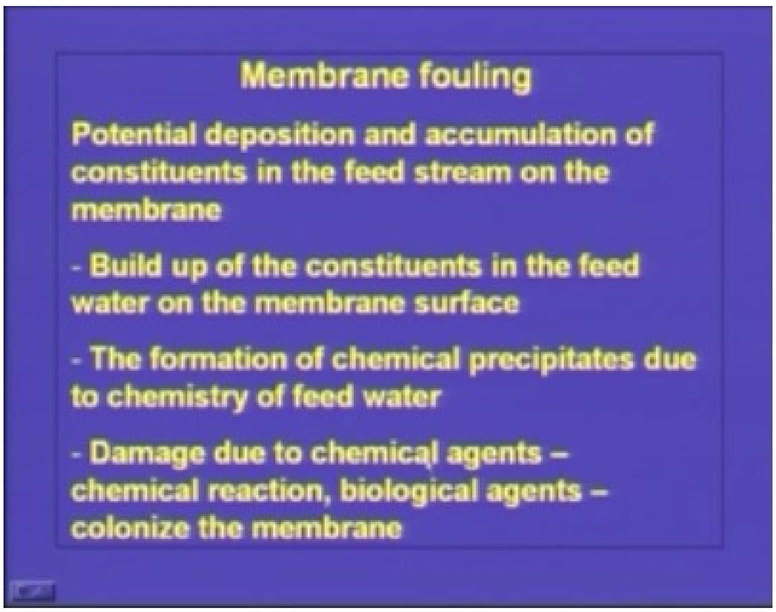

For example, if chemical compounds are present chemical reactions can happen and if biological agents are present colonization can take place in the membrane and naturally the pores of the membrane will be getting reduced and the flux through the membrane will be reducing. Or if you want to keep the flux a constant the pressure required to be applied will be very very high. These are the reasons for membrane fouling. So, if you want to avoid the membrane fouling we can avoid the membrane fouling to a certain extent by giving proper pretreatment.

What all are the pre treatment we have to provide when we go for reverse osmosis?
There should be some treatment to remove suspended and colloidal particles. We have already seen that most of the time micro filters are used to remove the suspended and colloidal particles whatever is coming through the feed water and another one is to remove the micro organisms. If micro organisms are present what will happen is it will go and get attached to the membrane and they will be start forming colonies on the

membrane so naturally the effective surface area available for the membrane process will be getting reduced drastically. So we have to remove the microbes before allowing the feed water to enter or go through the semi permeable membrane.

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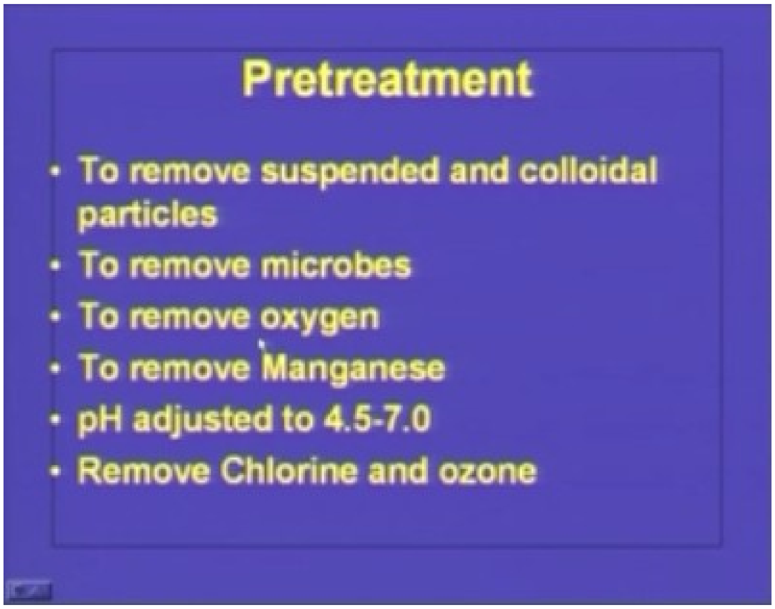

Another one is to remove oxygen. Why we have to remove oxygen? We have to remove oxygen because the feed water may contain iron manganese etc in the reduced form. So, if oxygen is present in the system these substances will get oxidized and their precipitate may be forming. if the precipitate forms on the membrane definitely the membrane capacity will be reducing. Therefore in order to avoid the oxidation of such material and subsequent precipitation it is always advisable to remove the oxygen from the feed water. There will not be any oxygen in the permeate coming out of the reverse osmosis plant so that is a reason why we have to leave an aeration unit as a post treatment option for reverse osmosis process. Otherwise the dissolved oxygen concentration in the permeate will be almost zero and we are not supposed to put it into the distribution system under that condition.

Though we remove oxygen there is a need to remove manganese also. Although you are removing the oxygen the manganese oxidation may not take place but it is always advisable to remove the excess manganese from the system and the pH should be adjusted to four five to seven to avoid scaling on membrane and another one is to remove chlorine and ozone from the system. The reason is chlorine and ozone are very very powerful oxidizing agents and we have seen that the membrane whatever is used for water treatment or waste water treatment are made up of organic matter so if these highly oxidisable material like chlorine and ozone are present in the treated water or in the feed water then it will be reacting with the membrane and the membrane will be getting destroyed at a faster rate. In order to avoid that one it is always advisable to remove chlorine and ozone.

Now we will see the different size ranges that we can remove using various filtration process. Coming to microfiltration we have seen that it can be used for the removal of colloidal and suspended particles. So usually the minimum size is 0.08 to 2 micro meter. So if you want to remove the micro organisms this microfiltration will be able to take care of that because we know that especially viruses may not be able to remove by microfiltration because the sizes of viruses are much smaller than this but bacterial size is in the range of 1 to 2 micron meter so we will be able to remove that one so again the size range is 0.08 to 2 micron meter and the materials commonly used for the membrane manufacture which is used for the microfiltration are poly propylene, acrylonitrile, nylon and poly tetrafluroethylene. These are the materials commonly used for the microfiltration membrane manufacture.

Now, coming to ultra filtration here the size range is 0.08 to 2 micro meter and ultra filtration can remove substances of much lower size. Here the size of filtration is 0.005 to 0.2 micro meter. So this lower limit and this lower limit is some what okay and the material used for the manufacturing or making of ultra filtration membranes are cellulose acetate, aromatic polyamides.

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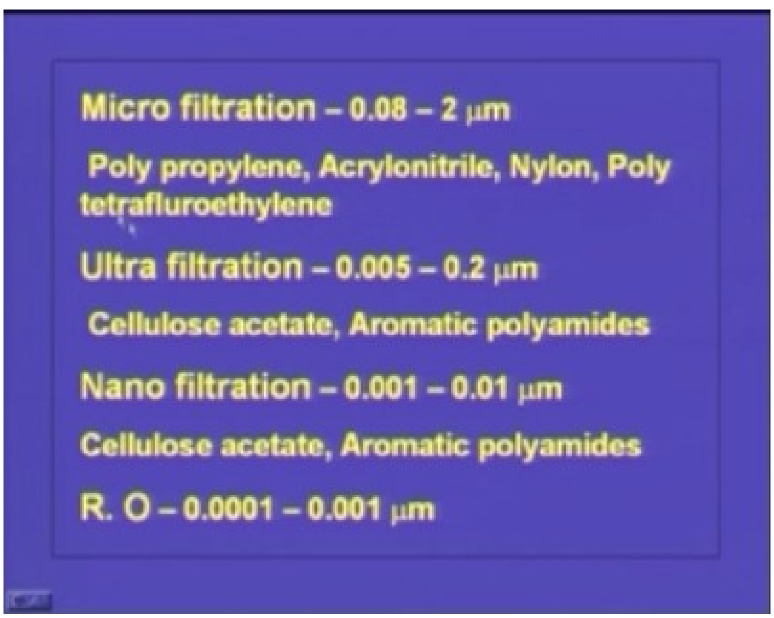

Now coming to nano filtration it can remove much smaller particles. Nano filtration is also known as dense filtration. So what is happening is above the membrane a water layer formation takes place so this water will be retaining most of the particles so that will be acting as a strainer and that will be retaining most of the smaller particles that is why it is known as dense filtration and it can remove particles of 0.001 to 0.01 micro meter. Here the most commonly used materials are cellulose acetate, aromatic polyamides and reverse osmosis. The size of particles that can be removed is 0.0001 to 0.001 micro meter. So R.O can remove almost all the dissolved solids.

For example, even if you want to remove sodium chloride or if you want to use the ocean water or sea water for the drinking purpose, for desalination of plants most of the time they use R.O plants, the reason is R.O process can remove particles of 0.0001 micro meter to 0.001 micro meter size. Now we will see the other process which is known as electro dialysis. In electro dialysis the ionic components of a solution are separated through the use of a semi permeable ion selective membrane.

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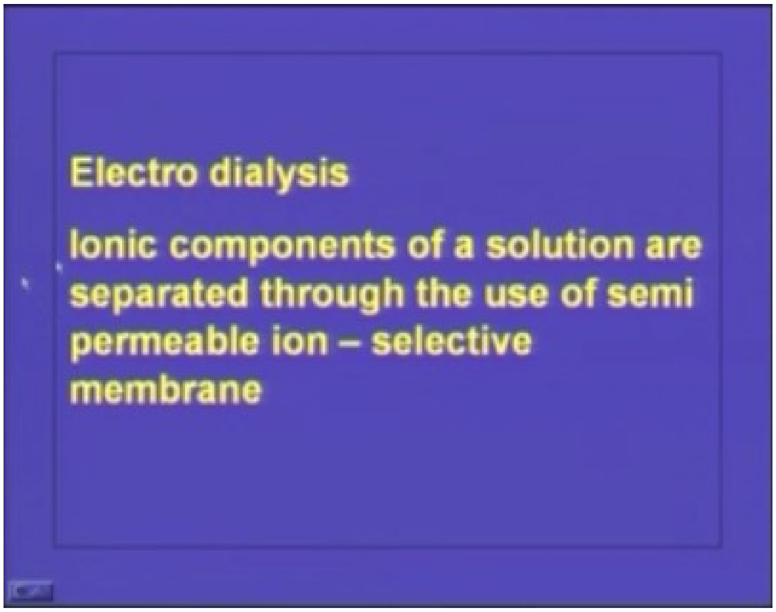

Once again, in electro dialysis the ionic components of a solution are separated through the use of semi permeable ion selective membrane. Now we will see how an electro dialysis system works.

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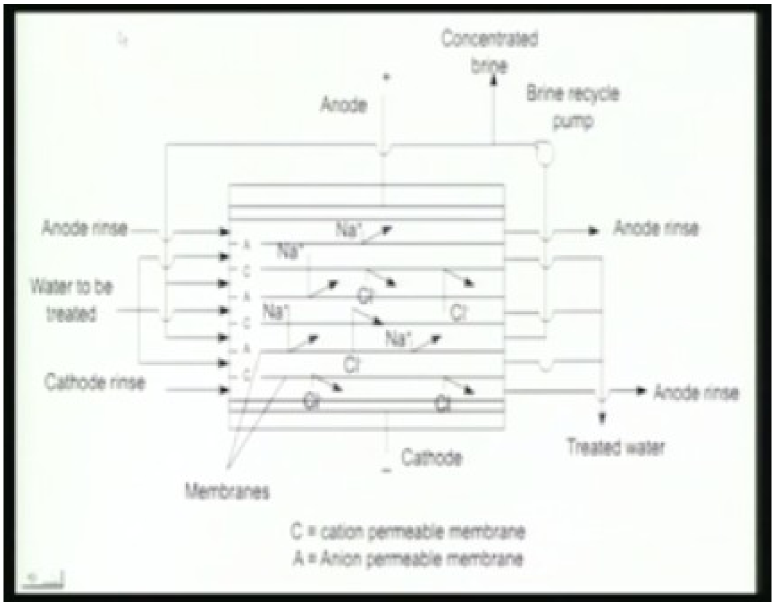

This is the schematic of an electro dialysis system. We can see that there is an anode and there is a cathode. Cathode is having negative charge whereas anode is having positive charge. Since this anode is having a positive charge the anions or the ions which is having a negative charge will have a tendency to move towards the anode and the positive charge cations will have a tendency to move to the cathode. That is the basic principle that we know already.

Here in the electro dialysis system apart from this cathode and anode we have a number of cation permeable membranes and anion permeable membranes. This A represents anion permeable membranes. It means that this will be having only the passage of anions and the cation permeable membrane is the one which allows only the passage of cations. So anions cannot permeate through cation permeable membrane and cation cannot permeate through an anion permeable membrane. So what will happen is these membranes will be helping the movement of ions because all the anions will be having a tendency to move to the anode and all the cations will be having a tendency to move to the cathode. But because of this semi permeable or ion specific membranes the movement will be restricted.

Now we will see how it is getting treated. This is the water to be treated entering into the system so we can see that this is coming here (Refer Slide Time: 49:06) or this is coming here and this is coming here so you will be having a high concentration of sodium and high concentration of chlorine. Thus, if there was no anion permeable membrane and cation permeable membrane then all these sodium ions will be moving towards this cathode and all the chloride ions will be moving to the anode. But here what is happening is the sodium and chloride solution or sodium ions and chloride ions are entering here and here we can see that there is a cation permeable membrane, C is there so this cation permeable membrane will be allowing the movement of sodium towards this side because cathode is here so definitely the sodium ions will be coming through this permeable membrane and coming here. Here there is another anion permeable membrane (Refer

Slide Time: 50:10) so we can see that it will not be having the free passage of this sodium ions so all the sodium because of this electro static attraction will be permeating through this cation permeable membrane but the anion permeable membrane will be retaining everything so all the sodium ions will be getting concentrated here.

Now we will see what will happen to the chloride ions. this is a anion permeable membrane and here is the anode so all the chloride ions will be having a tendency to move towards this one so what will happen is this chloride will easy pass through this anion permeable membrane and it will be coming here. But here we can see that again another cation permeable membrane is there so this cation permeable membrane cannot allow the passage of chloride ion through this one so all the chloride ion will be getting concentrated here. Similarly all the sodium ions are getting concentrated here so all the sodium will be coming to this side and all the chloride will be coming to this side so the middle layer will be free of sodium as well as chloride.

Similarly if you see this portion is another entrance of water to be treated so sodium and chloride will be there and here you have a cation permeable membrane (Refer Slide Time: 51:33) so this sodium will be coming here. And since there is an anion permeable membrane adjacent to that one it cannot move further it will be getting concentrated here and the chloride will be going like this. So if you see the system you will be getting alternate compartments having very high concentration of the ions and alternate compartments with very low concentration of the ions.

Here we can see that this compartment we will be getting very low concentration because all the sodium concentration will be coming to this side and all the chloride will be going to this side so definitely this one will not be having any sodium chloride or sodium ions or chloride ions whereas this will be having a high concentration and similarly here (Refer Slide Time: 52:30) there will not be any sodium or chloride because sodium will be coming like this and chloride will be going like this so this will be a treated water again this will be a concentrated solution and this will be a treated solution. Therefore in alternate compartments we will be getting treated water and in another compartments we will be getting highly concentrated solution so we can collect the treated water from these alternate compartments as shown here. Thus, we will be getting concentrated solutions from here and definitely whatever chloride ions are coming here will be concentrated.

Here (Refer Slide Time: 53:12) as we can see this is the cathode rinse and this is the anode rinse. So once again, as these are ion specific membranes because of the electrostatic forces as well as the performance of the specific membranes we can retain the ions in specified compartments and we can remove all ions in alternative compartments. So, in an electro dialysis system we will be getting both, treated water as well as concentrated water or concentrated solute. Therefore this system can be utilized for concentrating a solute also. This is the basic principle of electro dialysis system.

Now we will see what all are the parameters or what all are the factors that affect the removal efficiency of electro dialysis.

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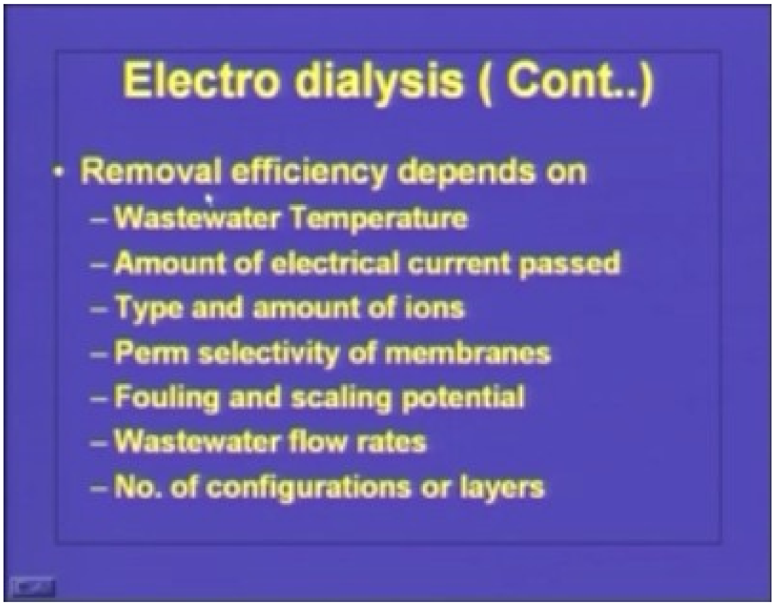

The removal efficiency depends upon the wastewater temperature and the amount of electrical current passed. If you apply a high strength field then definitely the movement of the ions will be very very fast so definitely efficiency will be high. But if the power or the electrical supply or the electrical current passing through the system is less then the treatment efficiency will be decreasing. The third one is type and amount of ions. Certain ions will be having high affinity if the charge is more. For example, monovalent, divalent etc. If the divalent ions are present it will be moving at a faster rate to the cathode.

Then we have the perm selectivity of the membranes, how selective the cathode membranes and the anode membranes are or how selective the cation membranes and the anion membranes are. Because sometimes what will happen is even though it is a cation selective membrane it will allow some of the anions to pass through that one so that will also affect the efficiency of the system.

The other one is fouling and scaling potential and next one is the wastewater flow rate. If you provide a small flow rate definitely the efficiency of the treatment will be very very high and the number of configurations or layers if you go for a single system definitely the efficiency will be less compared to a series of dialysis unit so these are the factors which affect the efficiency of the electro dialysis.

We have discussed the membrane process in detail. we have seen that in each and every process we will be getting the permeate and we have the feed water but a concentrate a solution is there that means it is having very high concentration of the solute so what can we do with the concentrated solution, is it whether we are allowed to dispose them into the existing water bodies, no, the reason is, the concentration of the solutes are very very high so it will be affecting the quantity of the treatment system. So the methods of disposal of concentrated waste streams are; one is oceanic discharge, deep ocean discharge or dilute with power plant cooling water because power plant cooling water quantity will be very very high so we can dilute this one with the power plant cooling water and discharge to the existing streams.

Then we have the surface water discharge provided the concentrated volume is very very less compared to the stream flow. The next one is land application but it is not advisable in fertile lands because if you dispose high concentration of dissolved solids in the fertile land the soil permeability will be decreasing and that will be affecting the soil properties. We discussed this in the previous class. The last one is discharge to wastewater collection systems.

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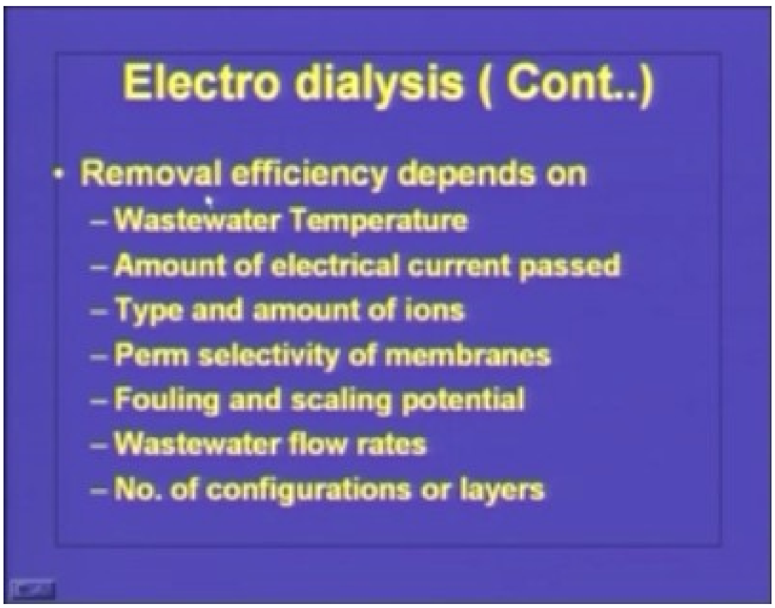

We can discharge the permeate to the wastewater collection systems provided the total dissolved solids concentration is less than 20 mg per litre. The other one is deep well injection and the next one is evaporation ponds, evaporate everything and the solids out of this one. Another one is controlled thermal evaporation.

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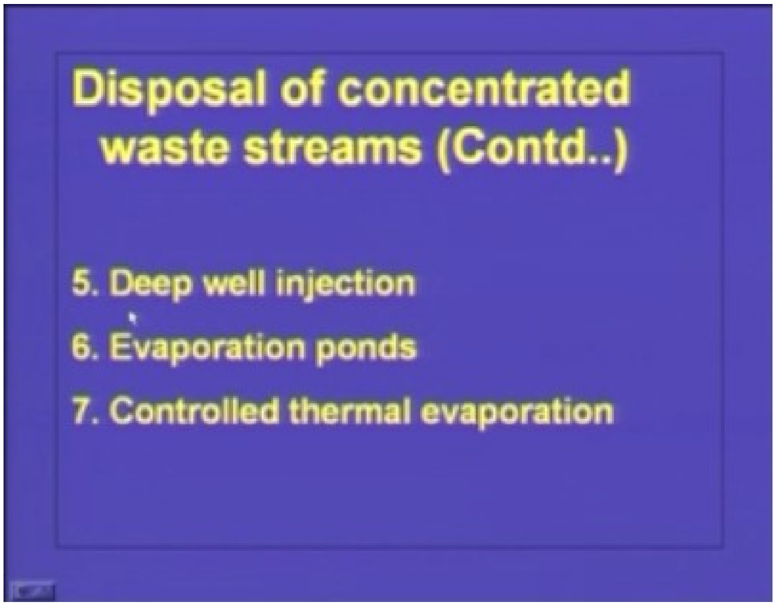

For this we are using the solar energy and here we are providing external energy for the evaporation and getting the concentrated salt. That salt can be used for some other purpose or it can be concentrated and disposed into chemically secured land fills. So the disposal of concentrated waste streams is a major problem in any of these membrane processes.

We will see the entire things we have discussed today. we have seen in detail the need of this advanced wastewater treatment because if you dispose the treated effluent from the secondary treatment plants we are just wasting the water that is one thing and another one is it will be increasing the pollution level of the streams or lakes or estuaries where we are discharging. So if you want to reuse the water depending upon the beneficiary use we have to improve the water quality to a certain limit but the secondary treatment is not able to achieve that limit so if you want to remove the left over organic matter or inorganic constituents or organic complex constituents or the left over suspended and colloidal particles we have to go for various advanced treatments. These advanced treatments are selected based upon the pollutant nature and the beneficiary use and the economical feasibility and environmental compactness.

We were discussing various treatment options in detail and we have seen the membrane process in particular today. In the next class we will explain about adsorption process.