Thermal Processing of Foods
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Lecture 18
Advanced Separation Processes

Good morning everyone. Today we are going to see about advanced separation processes. So, the subsequent two classes also closely related to advance separation processes. So, today we are going to see about the fundamentals of separation processes and what are all the advanced separation processes? So, in which we are going to concentrate on membrane separation processes. In subsequent lectures we will be seeing, what are all the major membrane separation processes, and what they are used in food industry, and for food processing?

So, it is a alternative to thermal processing but, though the courses about thermal processing of foods. So, we have also seen other non-thermal technologies in few lectures before. And, also we discussed detailed about microwave ohmic heating as well as radio frequency heating. And, so this another three lectures we will be discussing about, the advance separation processes which are employed in the food industry.

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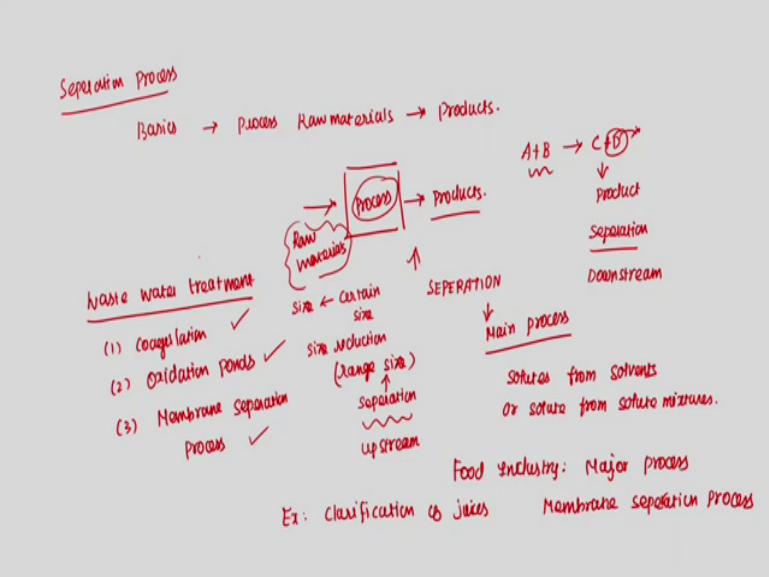

So, the first one we suppose to see is what is separation process and few basics about this. So, if any industry the main aim is to process raw materials and convert them into products. So, this is my process so I have a raw materials, so which are converted into products. But, so here my process requires my raw materials in some form. For example, so we take a size of

raw materials so we need certain size of raw materials. Or, for example, we can say that, if my size is too big so the contact surface area will be very much small.

So, that case we will process raw materials, the unit process is nothing but a size reduction. So, after size reduction I do not require certain size of the raw material. I need certain range of raw materials, range of size. So, in that case so I would go for a separation processes. From the separation process I will select the size range of the raw materials which will further fed into process. So, in that case my separation is employed in the upstream of the processes.

And, what happens in the downstream is for example if i take A plus B as a raw material and I will convert them in to C plus D so this is my product. So, in the C plus D my interest would be on the D only, I would want only D. So, in that case also I will go for separation processes to separate D from C. So, conventionally your separation can be from upstream side or from downstream side, so based on their requirements. And sometimes what happens this processes itself a separation processes. And most of the industries the separation process itself a main process.

So, this is a unit operation unit operation in the sense where, we do not involve any chemical reactions. The aim is just to separate, solutes from solvents or solute from a solute mixtures. So, for example, if we consider the waste water treatment, where the membrane separation is also very much famous. So, there may be three stages, the first stage would be coagulation or flocculation, the second stage would be of oxidation ponds, the third would be of membrane process. This way also the separation process can be done.

So, the main processes itself a separation processes. So, there may be a series of stages, the first stage I would be doing it in using the coagulation technique, the second stage would be of oxidation pond, the third stage would be of membrane separation process. But, in the food industry where we are going to concentrate, so the major processes itself a membrane separation process. So, the example would be the clarification of juices. It is nothing but the, to get the clear juice solution, clarification of juices. So, this is little introduction about the membrane processes.

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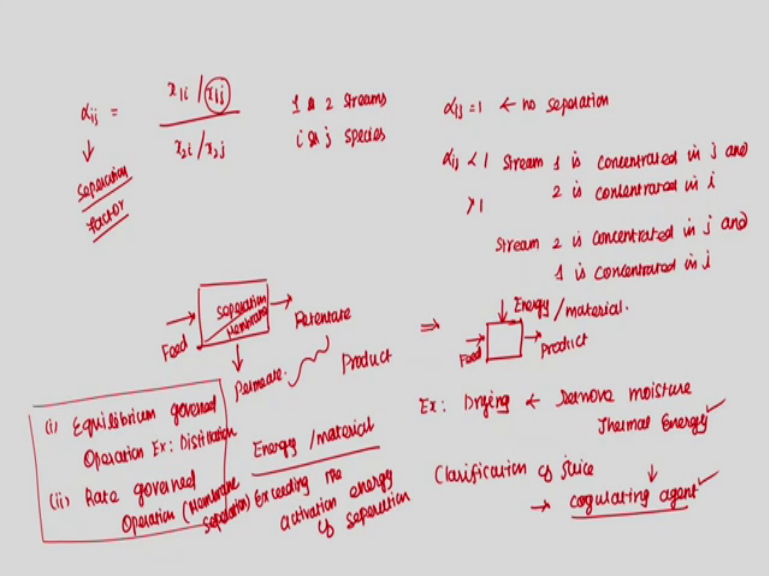

For example, how do I measure the separation? So, there is a parameter called alpha AJ, we call it as a separation factor. So, this is nothing but X1i upon X1j upon X2i X2j. So, this 1 and 2 are streams, and i and j are species. So, when alpha ij is equal to 1, so then there is no separation at all that is obvious. Because, the stream 1 have i upon j that and stream 2 have I upon j. If it is 1 then they both are equal, so then we will not any separation, so if alpha ij, so there may be a two situation 1 is less than 1, another 1 is greater than 1.

If it is less than 1 the stream 1 is concentrated in j and 2 is concentrated in i. So, that means so this is high and it is also high and so that your denominator would be dominating, so you will have alpha ij as less than 1. So, the greater than 1 is exactly opposite, stream 2 is concentrated in j and 1 is concentrated in i. So, this is the separation factor with which we can say whether the separation is possible or not or which species in which stream is concentrated. So, then for the separation so what is requirement.

So, for example, this is the separation process. So we send feed, so the feed is converted into the retentate and permeate. So, this both we call them as a product. So, this separation can be done using membrane as well. So, membrane separation as well, or if you take any common processes, so you have a membrane separation processes you have a feed you have a product. So, this separation to do then I need to use some other external agency. So, how do i separate something from the feed as I wanted? So, that can be used, that can be done using energy or any material.

So, for example, if you take the drying technology, so in the drying technology to remove the moisture or separate the moisture from the product, so what we are using is thermal energy.

So, and for example in food industry another just we told the example is clarification of juice. So, for that we use coagulating agent. So, what it does is it forms the coagulation with the undissolved solid and that gets settled in the bottom. Then your clear juice will be collected at the top. So, here the separation is done using a material, so in the drying of food products the removal of moisture is done using a thermal energy. So, to separate the desired product from the feed so we need to use either energy or a material.

And it is like the similar phenomena you might have studied in the chemistry. So you use the catalyst to reduce the activation energy of the reactants. So, here also so the energy or the material whatever you use, so that helps in exceeding the activation energy of the separation; so this is my external agent. And, also the separation works based on the two principles, so one is the equilibrium governed operation, the second one is rate governed operation.

In the equilibrium governed operations, so the product face as well as the feed face or in equilibrium, in the rate governed operation rate of the physical transport of species is responsible for the separation processes. So here in the equilibrium governed both, feed as well as product faces are very much important. The equilibrium governed we can say as a distillation so the rate governed or normal our membrane separation process what is of our interest.

So, this is the basic about what is separation, and what is a basic principle of separation and what are all the major categories, equilibrium governed as well as rate governed? So, this is the basic about the separation processes. So, we will see now the other things what are all the fundamentals of separations processes. And, what are all the advance separation processes in that we are going to concentrate.

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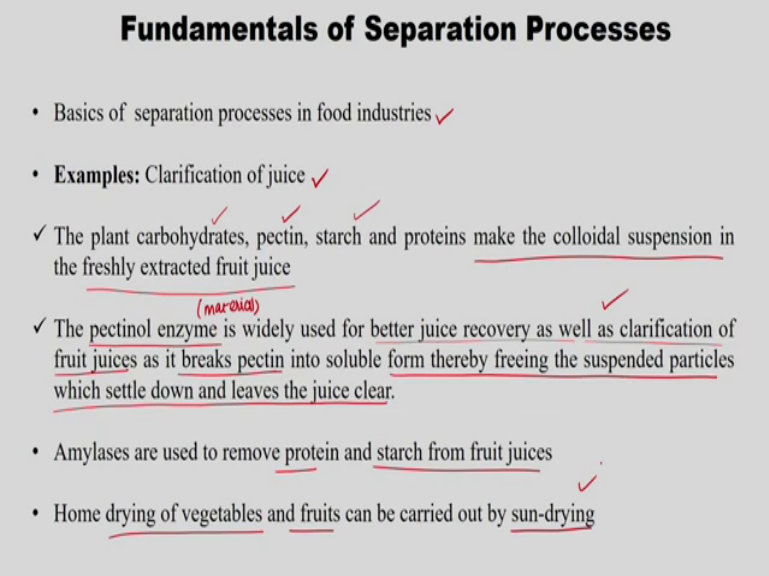

So, here is the fundamentals, the basics of separation processes used in the food industry. So, as I told earlier the food industry processes itself a separation processes. So, example is nothing but a clarification of juice. So, how it is been done, the plant carbohydrate, pectin, starch, and proteins so, these makes the colloidal suspension in the freshly extracted fruit juice. In the freshly extracted fruit juice, you will find all of them in the colloidal stage. So, we used the pectinol as a enzyme, so as I told it is a material we used for the separation.

The pectinol enzyme is widely used for better juice recovery as well as the clarification f fruit juices. What it does is, it breaks the pectin here and into soluble form. Thereby, freeing the suspended particles, which settle down and leaves the juice clear. So, if we add the freshly extracted fruit juice which contains pectin. If we pectinol enzymes that clarifies the fruit juice. So, amylases are also used to remove protein as well as starch from the fruit juices.

This one example and another example for the separation processes which uses energy is home drying of vegetables and fruit. So, if we keep it for sun drying using the solar energy the vegetables and fruit gets dried, so that is the using energy. So, here separation processes is done using a material, here the separation processes is done using a energy.

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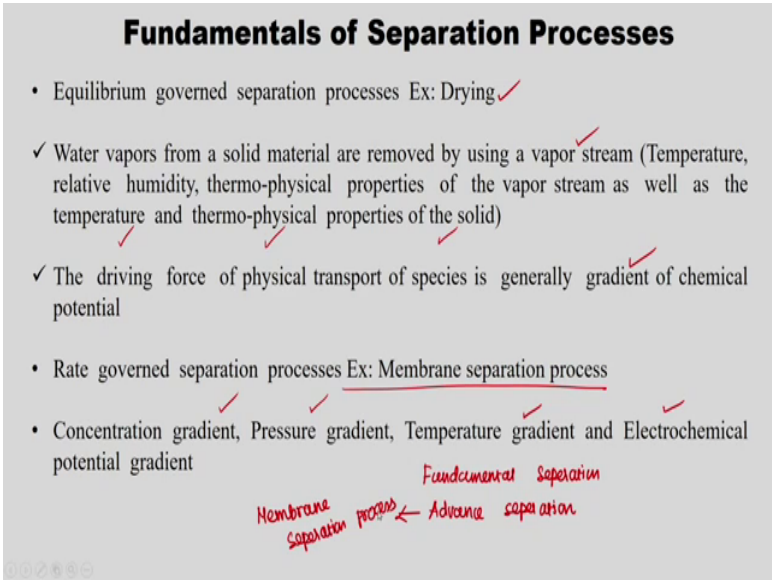

The equilibrium governed separation process are drying we just discussed. The water vapors from a solid material are removed by using a vapor stream. So, here the vapors stream the important parameters are temperature, relative humidity and thermos physical properties of the vapors stream as well as the temperature the physical properties of the solid is also important when we are doing the drying. Drying is nothing but a equilibrium governed separation process.

And, the driving force for physical transport of species is generally a gradient of chemical potential. So, based on chemical potential gradient only the separation occurs here. The rate governed separation processes example is membrane separation process. So, here the concentration gradient, pressure gradient, temperature gradient, and electrochemical potential gradient are used as a driving force.

So, the first separation processes is nothing but a osmosis. So, first we will see the fundamental separation process. So, then we discussed about the advance separation process. So, in the advance separation process we are going to concentrate only on the membrane separation process.

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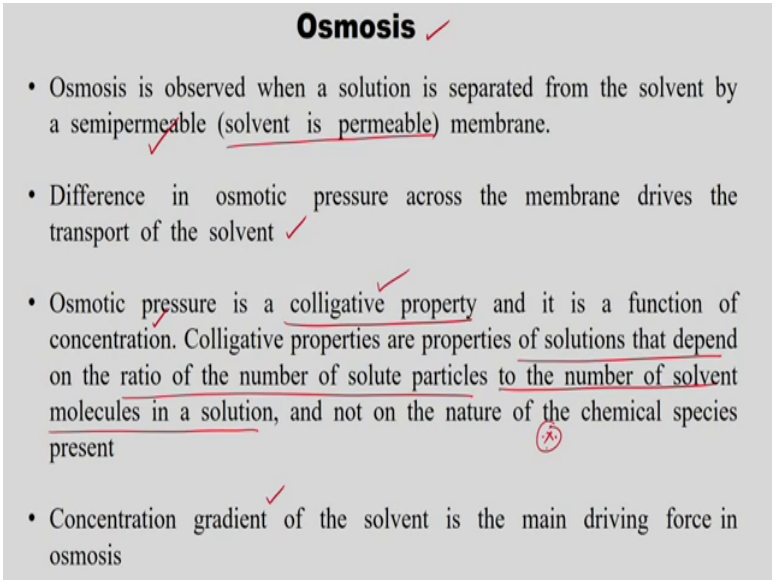

So, the osmosis is a basics separation processes so, this is observed when the solution is separated from the solvent by a semipermeable membrane. So, the semipermeable membrane here in the sense it permits only the solvent. The difference in osmotic pressure across the membrane drives the transport of the solvent. The osmatic pressure is a colligative property. The colligative property means the property of the solutions that depends on the ratio of the number of solute particles to the number of solvent molecules in the solution.

But, they are not depend on the nature chemical species. So, osmatic pressure here is a colligative property that means it depends upon the number of solutes, in the number of solvent molecules in the solution. And, also it is a function of concentration, so that is where we told in earlier lecture concentration gradient pressure gradient as well. So, then the concentration gradient of the solvent is the main driving force in the osmosis.

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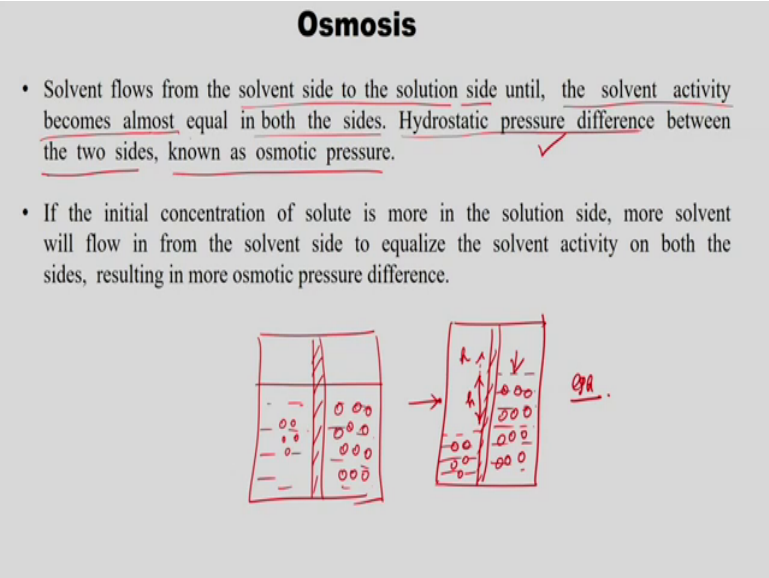

So, the solvent flows from the solvent side to the solution side until the solvent activity becomes a, almost equal in the both the sides, also the hydrostatic pressure difference between two sides known as the osmatic pressure. So, for example, so I have a system where I employ a semi permeable membrane. So, initially both the side, the one side the solvent is there. So, another side there is a solution with solute molecule as well as solvent.

So, after the separation happens because the semipermeable membrane we told that it permits the solvent molecule to flow from the higher concentration to lower concentration. So, after sometimes what happens is we will see a solvent increase in the other side. So, this side you will find less solvent. So, this height is contributing to the pressure so that is what we call it as a hydrostatic pressure difference between two sides so this is h so rho g H. So, this is nothing but a hydrostatic pressure between two sides which is known as a osmatic pressure.

If the initial concentration of the solute is more in the solution side, so that means solvent concentration is very low. Then more solvent will flow in from the solvent side to equalize the solvent activity, on the both the sides resulting in more osmatic pressure different. So that means, if the initial concentration of solute is more in this side than more solvent will be diffusing through the membrane so in that case this h will be higher than the case what we discuss. So, in that case so you will have a higher osmatic pressure difference.

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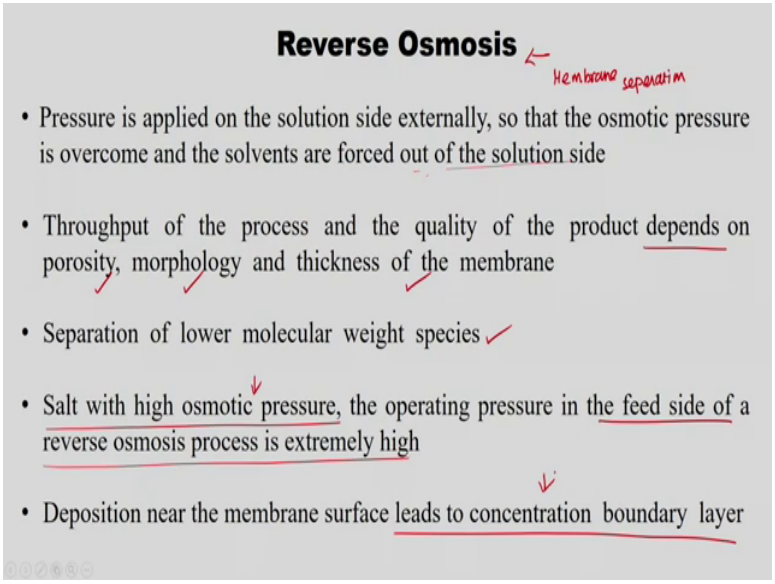

So, then another basic operation so, this also we are going to see in detail about them advanced membrane separation processes as well. So, here we will just see the basic definition and what happens in that reverse osmosis. So, the pressure is applied on the solution side externally so that the osmatic pressure is over comes and the solvents are forced out of the solution side. So, what we have done in the osmosis is, so from the solvent side the solvent moves to the solution side.

So, here we are developing a osmatic pressure. So, now the externally the pressure is applied so which has to overcome this osmatic pressure, if that is the case then solvent back diffuses to the from the solution side to solvent side so that is what reverse osmosis is. Pressure is applied on the solution side externally so that osmatic pressure is overcome the solvents are forced out of the solution side.

The throughput of the process and the quality of the product depends on the porosity, morphology and the thickness of the membrane what we are using in the reverse osmosis. The separation of lower molecular weights species is possible in the reverse osmosis. Mostly it is used in the desalination of water. Actually the salt with high osmotic pressure, the operating pressure in the feed side of a reverse osmosis pressure is extremely high, because, they have a high osmatic pressure to overcome that we need to apply higher external pressure, in that case the feed side operating pressure is extremely high in reverse osmosis.

The deposition near the membrane surfaces leads to concentration boundary layer. Once the membrane separation starts the concentration of solutes gets builds in the membrane surface that further leads to concentration boundary layer.

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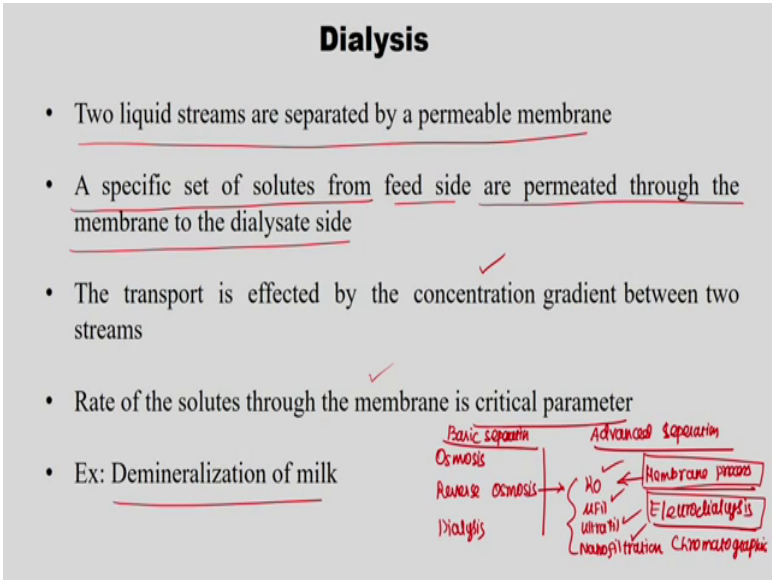

The next basic separation processes is dialysis, so here the two liquids streams are separated by a permeable membrane. The specific set of solutes from feed side are permeated through the membrane to the dialysate side. So, here the permeation of solute is possible from the feed side to dialysate side. The transport here is affected by the concentration gradient between the two streams what we are using. And, the rate of solutes through the membrane is a critical parameter in the dialysis.

So, the example in the food industry is demineralization of milk, so for that we use a dialysis operation. So, these are all basics, so osmosis, reverse osmosis and another is dialysis, so these are all basic separation operations. So, in that still this reverse osmosis will come under the category of advanced. So, this is basics separation processes, so the advance separation processes are, so all membrane processes, so which includes Ro micro filtration and ultrafiltration and Nano filtration.

So, all comes under the category of membrane separation processes, this is the advance separation processes dialysis. If it is done using the electrical input then we call it as a electro dialysis. So, that also advanced electro dialysis, so this also comes under the category of advanced separation processes. Apart from that there is an another advanced separation processes is called chromatographic separation processes. So these are all comes under the category of advance separation processes.

Anyway in the third lecture which talks about the electro dialysis and also we are going to intensely concentrate about the all membrane separation processes Ro microfiltration,

ultrafiltration, as well as nano-filtration in terms of food industry, what is there used in the food industry. So, chromatographic separation I will just give the very brief introduction.

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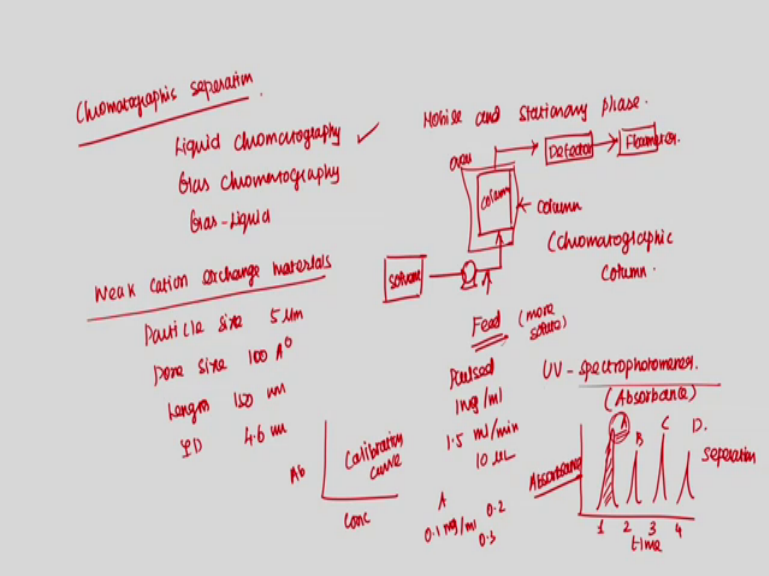

So, the chromatographic separation so this is also called advanced separation processes. So, this can be done in many ways for example liquid chromatography and gas chromatography and gas liquid and many variations are there. I will just introduce you about the liquid chromatography what exactly happens. So, here how we separate the components is based on the mobile and stationary phase. For example, my solvent is pumped and sent to the chromatographic column. We call it as a column, this is chromatographic column.

So, here the feed is injected in this line, so feed is injected in between the chromatographic column and solvent tank. So, then further it goes to detector, so this detector normally we use UV disable spectro photometer. So, this will give me absorbance versus time, to measure the absorbance then I will discuss about the calibration curve. So, this is detector and it further goes to the flow meter to measure the solvent flow rate. So, what happens here is feed is injected in between so the feed normally a pulsed feed.

So, which is about 1 milligram per ml with flow rate of around 1.5 ml per minute. So, the total volume handle would be around 10 micro liter. So, then sometime what happens, this chromatographic column, itself kept in a oven to maintain the temperature. So, that also happens, the most common material used in the column is nothing but weak cation exchange materials. So, the particles size is about 5 micron and the pore size is about 100 Armstrong and length is about 150 mm so, then ID is around 4.6 mm.

So, this is typical material which is used in the column and also how it detects the component. The separation how it happens is, so first we take a material. For example, in the feed contains more than 1 solute. So, each solute will come at different timings, for example, in X axis we have a time so 1 minute, 2 minute, 3 minute, 4 minute, so for example, solute A shows up. So, this is absorbance so the detector what you use is UV spectro photometer so it measure the absorbance.

So, I will take out here the solution then go for at 1 minute various time intervals, for example, 1 minute, 2 minute, 3 minute, 4 minute, I will just take the sample here at this outside of this column. Then i will go for the UV absorbance and i will get the peak at 1 and 2 and sometimes 3 and 4. So, this is nothing but different material A B C D material. So, that means at different intervals different materials comes out of the column. So, that is the way so based on the mobility then it gets the separation.

So, how do we get the concentration of the solute from the absorbance is we supposed to do the calibration curve. Calibration curve in the sense, for example, if i identify after 1 minute my A is showing up. So, A I will prepare various concentration, for example, 0.1 milligrams per Marlboro Lights, then 0.2, 0.3 like that I will prepare. Then, I will get the concentration verses absorbance. So, I will get the calibration curve.

So from that calibration curve I would be able to tell at 1 minute if my absorbance is this peak so how much is the concentrate A at 1 minute? So, after 2 minute your A will not be sowing up, your B will be showing up. So, at the time same calibrations curve I will do it for B concentration verses absorbance and C also same thing. So, from this I will be able to know which time which material is coming out of the column and what is its concentration. So, from the calibration curve I will be able detect my various components in the feed material.

So, this is the basics about the chromatographic separation anyway we are not going in too detail about the chromatography separation. We are only going to concentrate about the membrane separation processes. Which are reverse osmosis, micro filtration ultra filtration as well as Nano filtration and also we will discuss about the electro dialysis.

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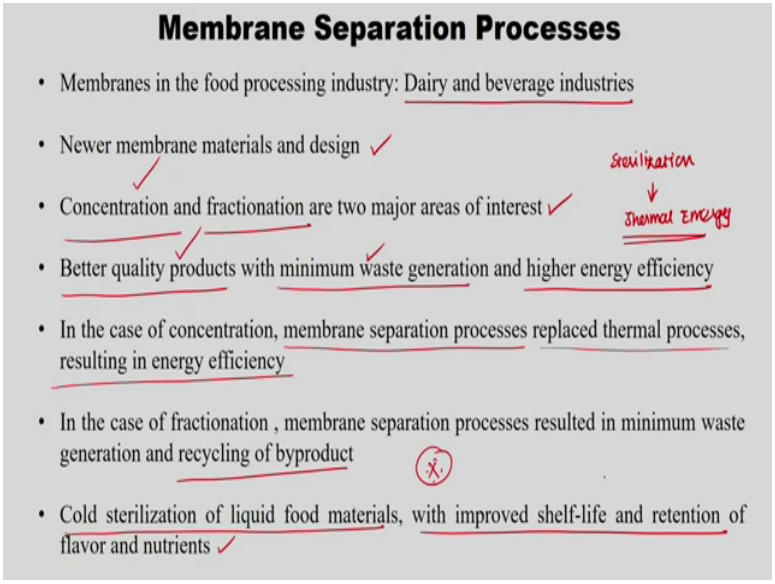

So, in the membrane separation process the major usage is in dairy as well as beverage industry. And, due to newer membrane materials and design so this field is very much useful in the food industries. And also the concentration and fractionation are two major areas of the interest in the membrane separation process. So, better quality products with minimum waste generation and higher energy efficiency would be the goal of the membrane separation process in food industry.

For example, I used sterilization, I used thermal energy. So, I have done it whatever seen in last 10, 15 lectures. So, the sterilization is done using a thermal energy. But here we use a filtration, the thermal energy. So, we are, here we are going to use the ultrafiltration technology which also filters the viruses. So, in that case I am not using a thermal energy, which will also cook my product. The product gets thermally damaged, if I do it using thermal energy. But, in case of microfiltration so can remove the viruses without heating the product.

So, that means so minimum waste generation as well as the quality of the product is enhanced. In the case of concentration the membrane separation processes replace the thermal process result in energy efficiency. So, if you concentrate on their area of interest to concentration. So, that is what I told the thermal process is replaced by the membrane separation processes. In case of fractionation membrane separation processes resulted in a minimum waste generation.

As well as the recycling of the by product is possible in the fractionation. But, that is not possible if I use a thermal energy. For example, I am removing the moisture using the thermal

energy. The moisture gets evaporated and it goes out of the system. But, in case of the membrane separation processes whatever permeate or retantiate you get. So, based on desired 1, sometimes your retantiate may be of desirable or sometimes your permeate will be of the desired product.

So, based on the desired product the undesired product can be recycled as a byproduct. But, that I cannot do in the normal thermal processing. The cold sterilization of liquid food materials, with improves shelf life and retention of flavor and nutrient is the major advantage of the membrane separation process as I told. So, I will be retaining the flavor and nutrients in case of ultra filtration. So, where my microorganisms get removed at the same time my flavor and nutrients of the food is retained.

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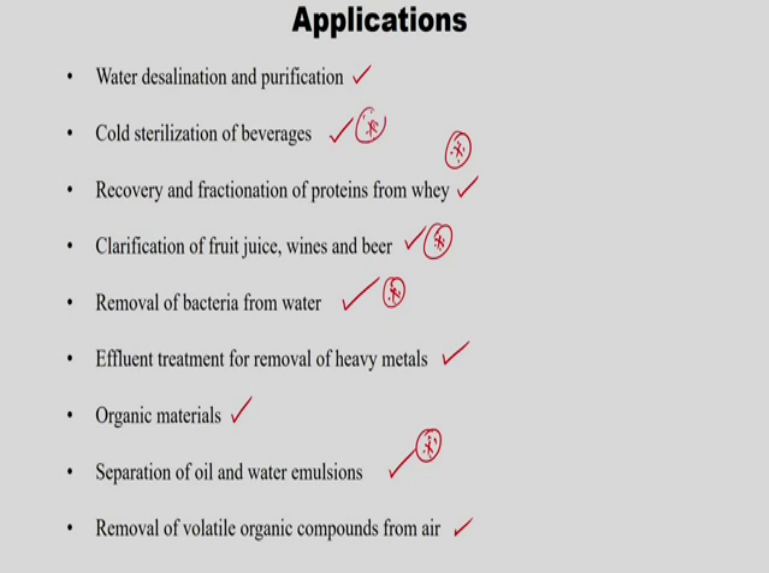

The application wise the membrane separation processes in food industry water desalination as well as purification, cold sterilization of beverages and recovery and fractionation of proteins from whey. So, this is very important application of membrane separation process in the food industry. And, also the clarification of food juices wines and beer and removal of bacteria from water.

And, effluent treatment for removal of heavy metals, organic materials. Separation of oil and water emulsions, this also used in food industry enormously. Removal of volatile organic components from air. These are common applications but, these few applications are very much used in the food industry.

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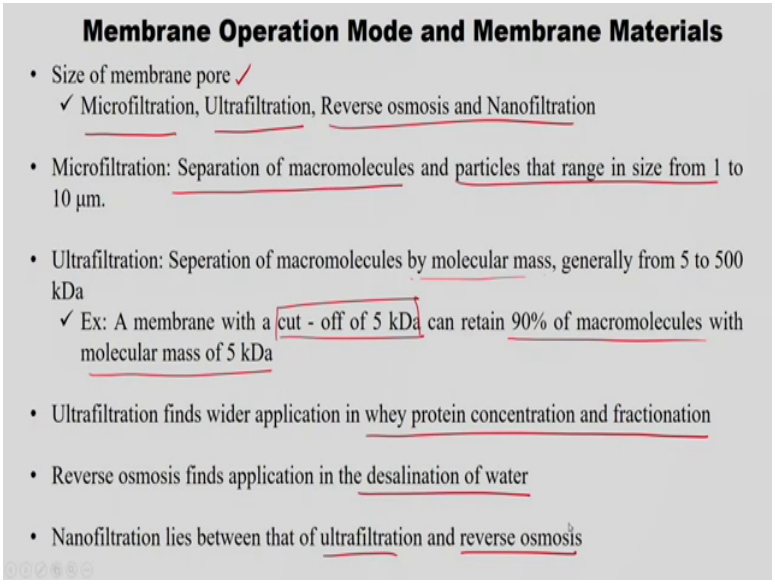

So, then membrane operation mode and membrane materials. The size of the membrane pores very much important. Based on that we will have variety of membrane separation processes as I told earlier microfiltration, ultrafiltration, reverse osmosis and nano-filtration. The microfiltration the separation of micro molecules and particles that range in size from 1 to 10 micro meter that is nothing but a microfiltration.

The separation of macromolecules by molecular mass so that is generally from 5 to 500 KDa kilo Dalton. So, that is nothing but a ultrafiltration. So, a membrane with the cut of 5 KDa so that retains 90 percentage of macromolecules with molecular mass of 5 KDa. The ultrafiltration finds wider application in the whey protein concentration and fractionation. And reverse osmosis finds application in the desalination of water and nano-filtration lies between that of ultrafiltration and reverse osmosis so based on the application.

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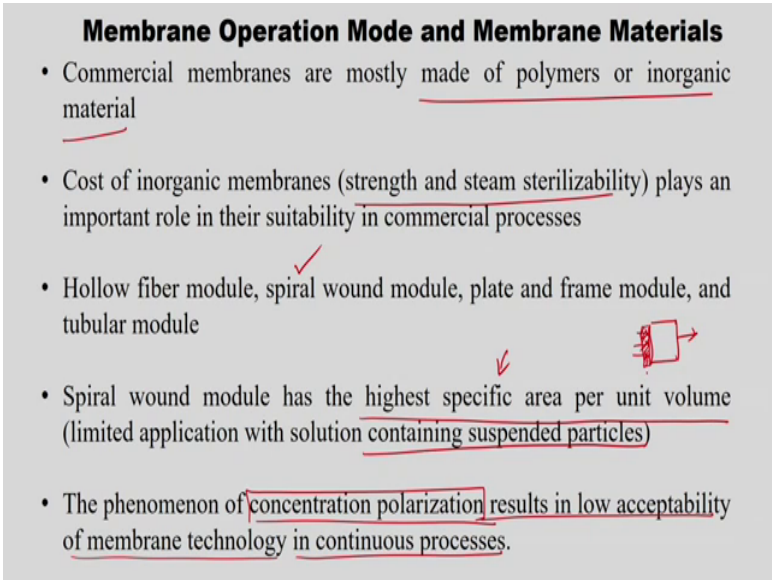

So, the most common membranes used are polymers or inorganic materials. So, the cost of inorganic materials are very much high compare to polymeric materials. Due to the instinct as well as the steam sterilizability and there are different modules with which the membranes separation process can be operated. One is hallow fibre modules, spiral wound plate and frame as well as the tubular module. The spiral wound module has the highest specific area area per unit volume that is what we supposed want to get the return it.

And, which has the limited application with the solution containing suspended particles because it cannot be used for the solution which has suspended particles. The phenomenon of concentration polarization results in low acceptability of membrane technology in continuous process. This concentration polarization word is nothing but, so I have a membrane, so here the solute gets retantate and permeate moves out of the membrane. So, after certain time retantate gets concentrated.

So, its forms a another resistance for further flow of the feed through the membrane. So, that is nothing but a concentration polarisation. So, the phenomenon of concentration polarisation results in low acceptability of membrane technology in the continuous processes. Because in the batch processes we know exactly the volume, so based on that the membrane can be designed. But, in the continuous flow it is the flow the operation is continuous. So, since it is continuous the concentrate of reatantate gets builded up in the membrane surface. So that is very much unwanted.

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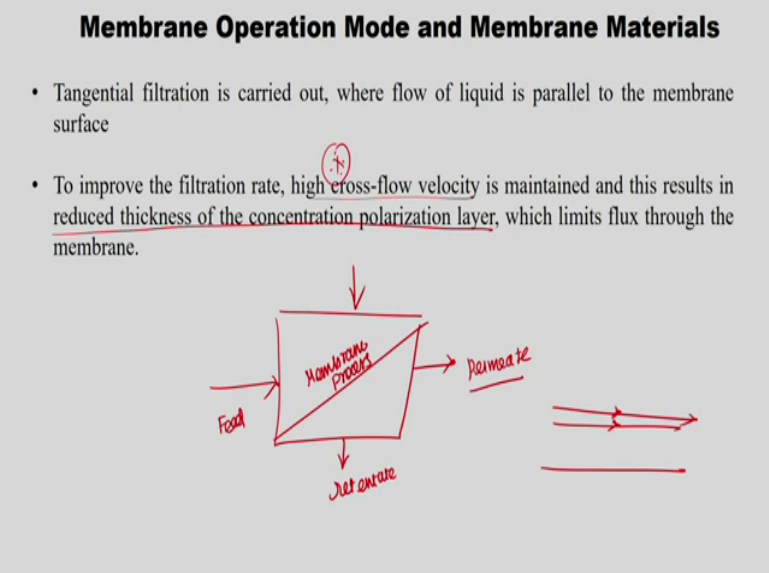

And the tangential filtration is carried out, where flow of liquid is parallel to the membrane. So as we said earlier so, this is my membrane process. So, where your feed is in here, so you will have the permeate, so then you will also have retentiate. Permeates is which passes through the membrane, retentiate is what gets retained in the membrane. The filtration is carried out were the flow feed is parallel to membrane.

For example, so if you have a membrane module like your flow of feed is also the same direction, the parallel to the membrane. This is the parallel line, the cross flow of permeate is perpendicular to the membrane surface. To improve the filtration rate high cross flow velocity is maintained and this results in reduced thickness of the concentration polarization layer. The cross flow is perpendicular to the membrane surface, so there is a possibility for the concentration polarization, but if we maintained the high cross flow velocity that can be avoided.

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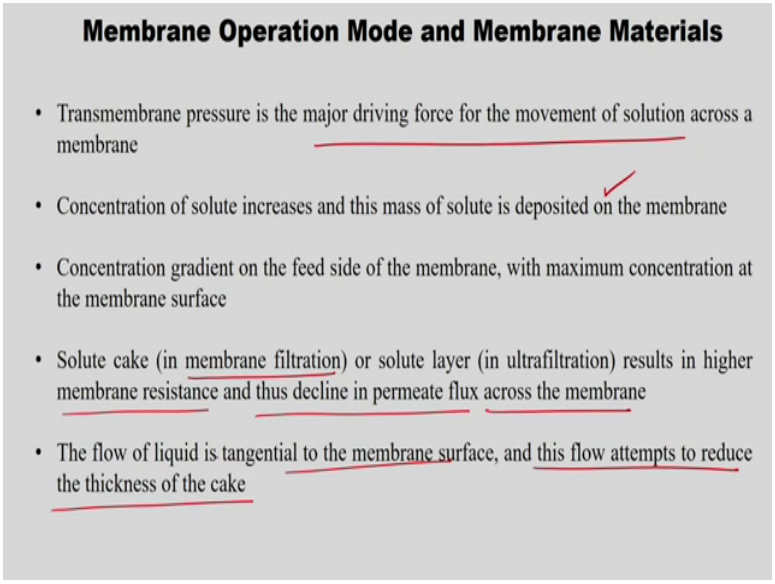

The transmembrane pressure is the major driving force for the movement of solution across the membrane. And, the concentration of solute increases at this mass of solute is deposited on the membrane surface we just discussed. The concentration gradient on the feed side of the membrane with maximum concentration at the membrane surface. So, maximum concentration happens at the membrane surface. And the solute cake or solute layer, solute cake in the sense in the case of membrane filtration.

Or solute layer in case of ultrafiltration results in higher membrane resistance and thus decline in the permeate flux across the membrane. So, that means the concentration polarization further acts as a resistance and this decline in the permeate flux across the membrane. The flow of liquid is tangential to the membrane surface, and this flow attempts to reduce the thickness of the cake. This we discussed in the previous slide itself.

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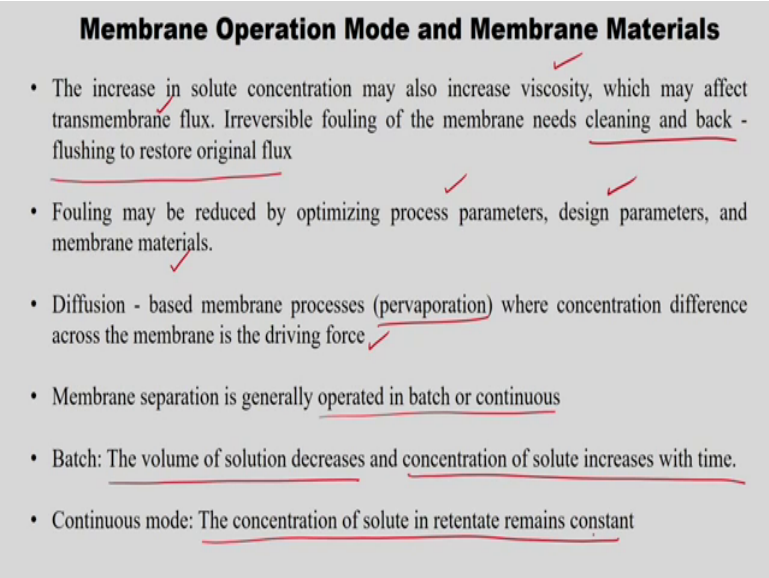

The increase in solute concentration may also increase the viscosity, which may affect the transmembrane flux. And irreversible fouling of the membrane needs cleaning as well as the back flushing to restore the original flux. The fouling may be reduced by optimising process parameters, design parameters as well as membrane materials. The fouling is nothing but a concentration of the retentate in the membrane surface. So which acts as a extra resistance for the permeate.

The diffusion based membrane processes which is nothing but a pervaporation where concentration difference cross the membrane is the driving force. Here it is a transmembrane pressure for other membrane separation operation. The membrane separation operation is generally operated batch or continuous mode, both are possible. The batch, the volume of the solution decreases and the concentration of solute increase with the time. So, the solution gets processes and concentration of solute increases with the time. But in the continuous mode the concentration of solute retentate remains constant.

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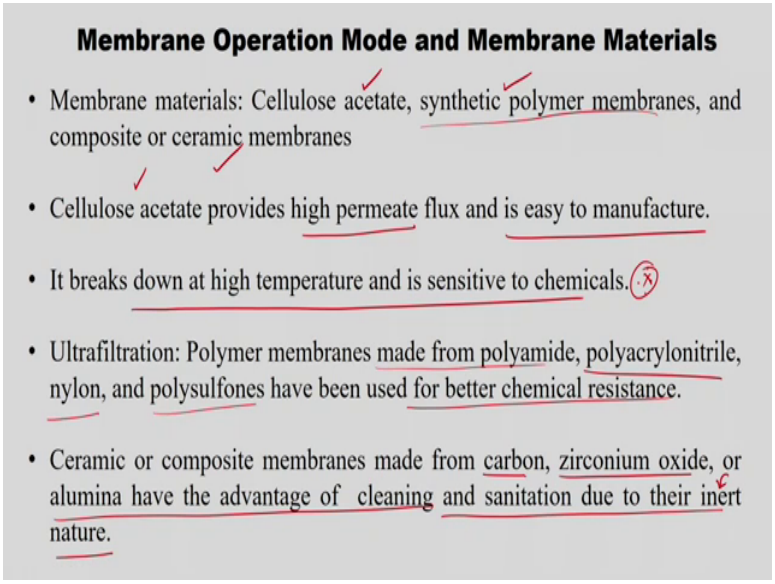

Then based on membrane materials wise the cellulose acetate and synthetic polymer membrane as well as composite and ceramic membranes are available. And cellulose acetate membrane provides high permeate flux as well as it is easy to manufacture. It breaks down at higher temperature and sensitive to chemical. So, that is the disadvantage of the cellulose acetate membrane. So this is the older one.

When the membrane separation processes started the cellulose acetate membrane where membrane were used, after the polymer area got picked up and we moved slowly on to the synthetic polymer membranes. So, ultra filtration polymer membranes made for polyamide, polyacrylonitrile, nylon as well as the polysulfones have been used for better chemical resistance.

And ceramic and composite membranes made from carbon, zirconium oxide, or alumina have the advantage of cleaning and sanitation due to their inert nature. So, this will not take place in the any reactions so their inert nature so they are very much wanted were your membrane should not react with the feed processed.

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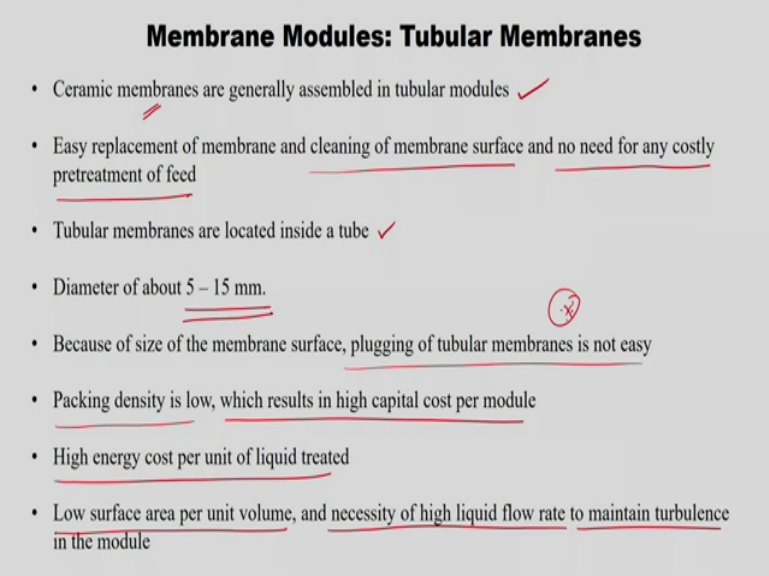

Now, we are going to see about the different modules, tubular hollow fibre membrane platen frame as well as the spiral wound module. The ceramic membranes are generally assembled in a tubular modules. If the material is membrane materials ceramic easy replacement of the membrane and cleaning of the membrane surface and no need for any costly pretreatment of the feed is the advantage of tubular membranes. Tubular membrane are located inside the tube and the diameter is about 5 to 15 millimetre.

And, because of the size of the membrane surface, plugging of tubular membrane is not easy. This is a disadvantage and packing density is low, packing density is how much membranes you can pack in a single tube. So which results in the high capital cost per module. And, high energy cost per unit of liquid treated. And low surface area per unit volume so, packing density is also low and surface area per unit volume is also low. Necessity of high liquid flow rate to maintain turbulence in the module that is also disadvantage of tubular membrane.

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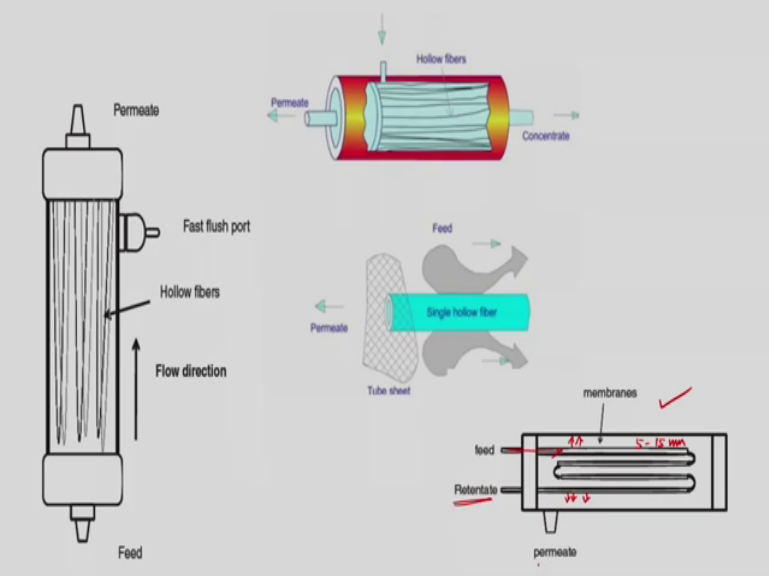

So, the next one is hollow fibre any we are having here so this is the tubular membrane. This is your tubes of 5 to 15 mm so here your feed is in. So, your permeate gets across the membrane and retentate will be retained and taken out, and the permeate comes out of the membrane and it gets collected in the tube module.

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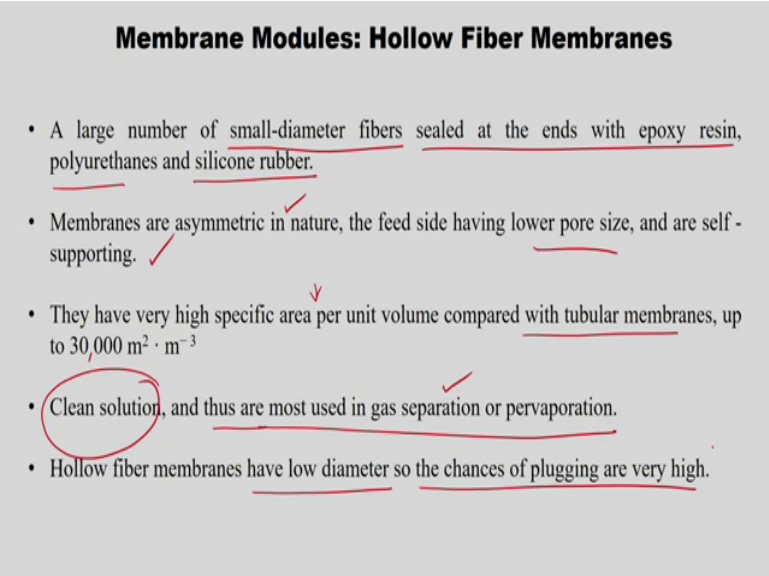

So, the next one is hallow fibre membranes a large number of small diameters fibres sealed at the ends with epoxy resin, polyurethanes as well as the silicon rubber. The membranes are asymmetric in nature, and feed side having lower pore size, and are self supporting. So, they have a very high specific area per unit volume. So, what are all the disadvantage of tubular

membranes so that are taken care in the hallow fibre membrane and per unit volume compared with the tubular membrane.

So, it is about 30,000 meter square per cube. And, cleaned solution, and thus are most used in gas separation or pervaporation. So you can use this hollow fibre membrane when your solution is cleaned so in that case so most of the time it is used in the gas separation or pervaporation process. And hollow fibre membranes have low fibre diameter so that chances plugging are very high as compare to tubular membrane.

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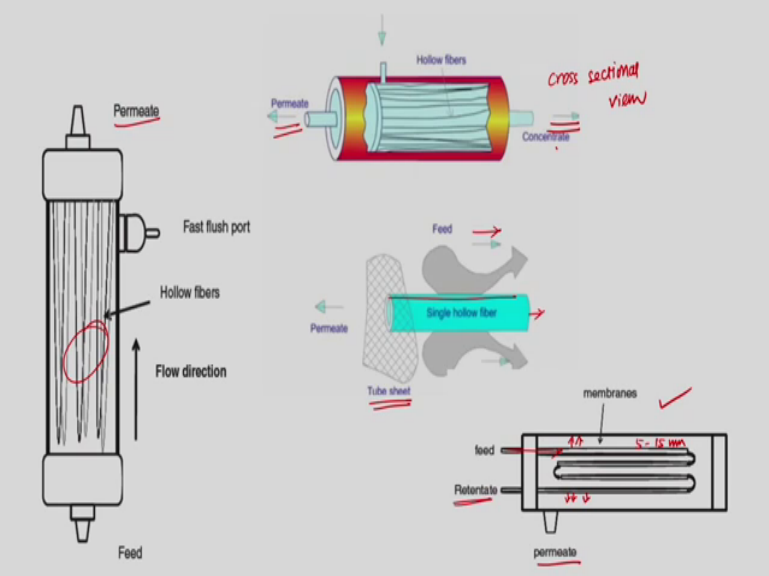

So, this is your hollow fibre membrane so this is hollow fibres start together in the tube and this is the flow direction, this is the tangential flow direction. So, permeate is getting collected here and the retentate will be inside the membrane. So, this is the cross sectional view of hollow fibre membrane. So, this is the permeate gets collected. So, this is the concentrate gets collected in here. So, this is the single hollow fibre so feed is in the tangential flow. So, your permeate gets in to the fibre that is getting collected and this is nothing but a tube sheet and concentrated will be taken out.

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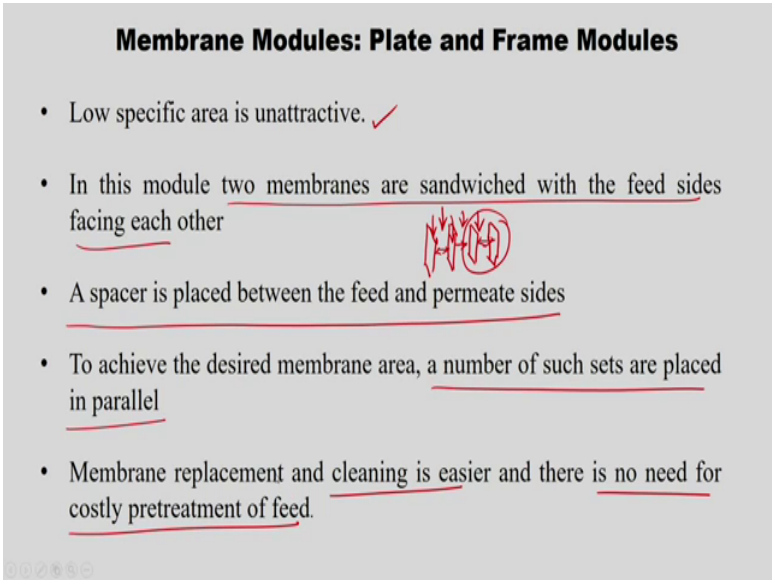

So, then next one is plate and frame module so here also low specific area which is also unattractive. In this module two membranes are sandwiched with the feed sides facing each other. So, that means so I have a membrane, so this is the feed side of this membrane, this is the feed side of this membrane. So, feed side facing each other it is tact, so that means the feed is going in between two. So, the permeate goes out of the membrane and retentate gets collected.

So, then you will have here the feed side then this is another membrane. So, this is the feed side facing each other so that means your feed retanted feed retantate this is an alternative module. The spacer is placed between the feed and permeates side and to achieve that desired membrane area, a number of such sets are placed in parallel. So, this is equivalent to your plate and frame plus which is used for filtration.

So this is based on the desired membrane area this kind of modules can be connected together to acheview particular decide membrane area. The membrane replacement and cleaning is easier because it comes with the separate modules so you can assembled disassembled them based on your requirement also cleaning is easy. It can be disassembled very easily and no need for costly pretreatment of the feed that is also advantage.

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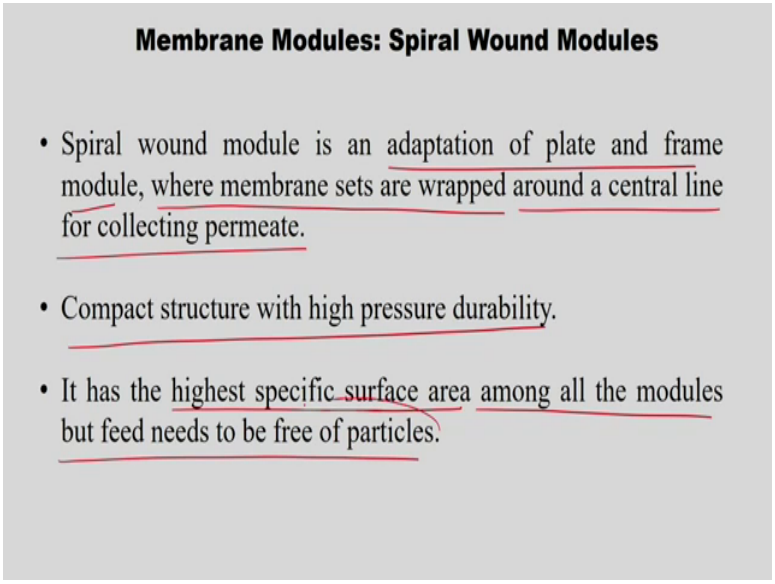

And spiral wound module is adaption of plate and frame module, so where membrane sets are wrapped around the central line. So, instead of keeping to membranes feed side facing each other, here we wrapped the membrane in the central line. So, compact structure with high pressure durability. And, also it has the highest specific area among all the modules but, feed needs to be free of particles that is disadvantage.

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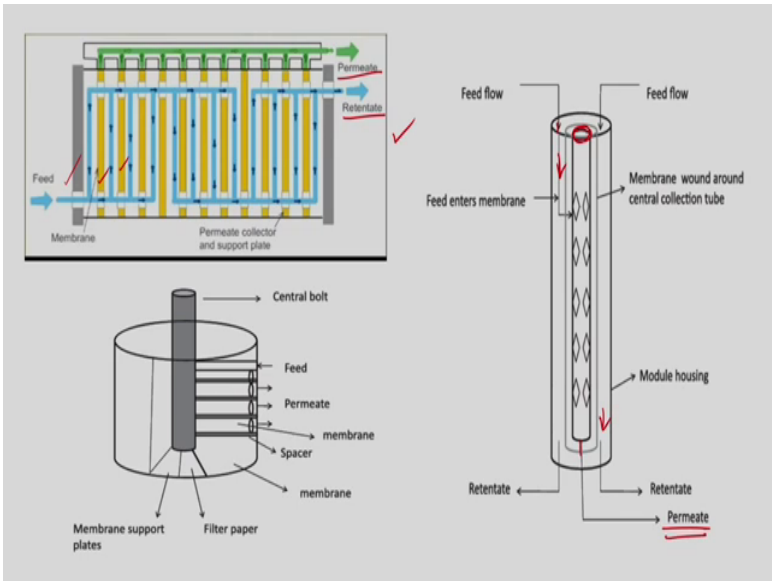

So, we are going to see here so this is your plate and frame modules, so if you see these are all membranes. So the feed is entered here so you will collect the retantate here and the permeate is getting collected from the membrane module here. So the feed as well as the

retantate goes in the alternative compartment. So this is nothing but a spiral wound, so spiral wound your membrane is wrapped in the central line.

So, what happens is the feed is employed here. So, this permeates through the membrane so your permeate is getting collected inside the tube. And your retantate will be in this side. This is nothing but a spiral wound membrane module.

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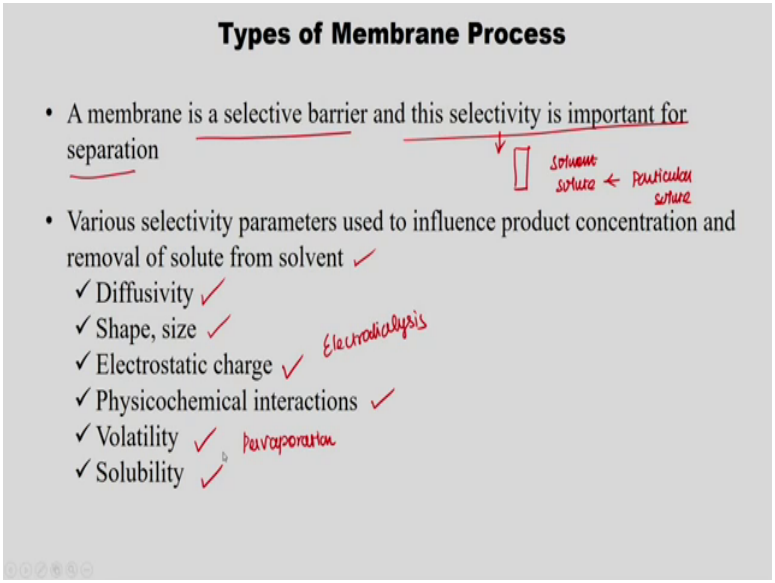

And, types of membrane processes so as we discuss few slides before. The membrane is selective barrier and this selectivity is important for separation. So, that means whether my membrane allows the solvent or solute or among the particular solute. Alright so based on this selectivity so we divide the processes and the various selectivity parameters used to influence the product concentration and removal of solute from the solvent. So, one is diffusivity size and shape of the particle.

Because, when we are discussing about the different modules, we also told certain modules are not suitable for solution containing particles. Certain modules needs only the clear solution. So, size and shape of particles is also important and electrostatic charge for example if u you are using electro dialysis. So, this is important parameter to be considered and physicochemical interactions between the membrane as well as the feed one of the module.

We also told the membranes are inert membranes carbon or zirconia carbon. So, and the violability will be taken care, when we use the pervaporation process and the solubility. So these are all the selectivity parameters.

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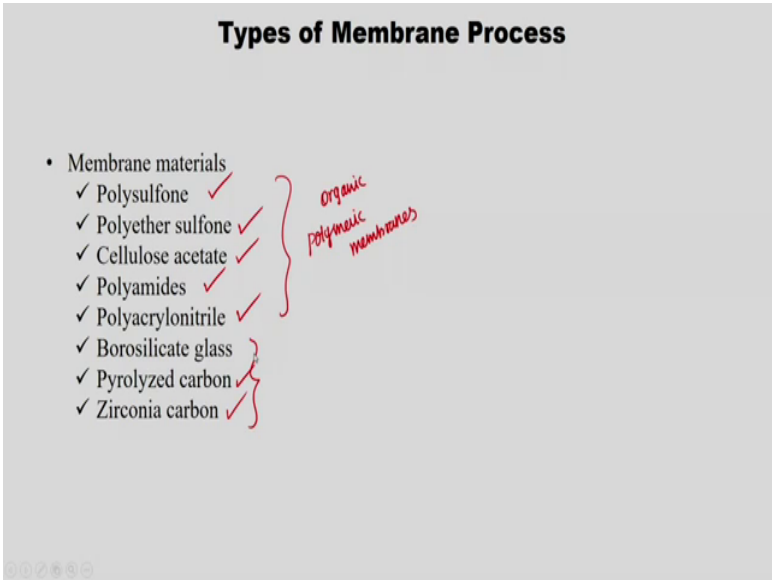

And membrane materials polysulfone, polyether sulfone and cellulose acetate polyamides and polyacrylonitrile. So, these are all polymeric membranes organic polymeric membranes. So, we also have the organic membranes which are nothing but a borosilicate glass, pyrolyzed carbon, zirconia carbon. So these are also widely used.

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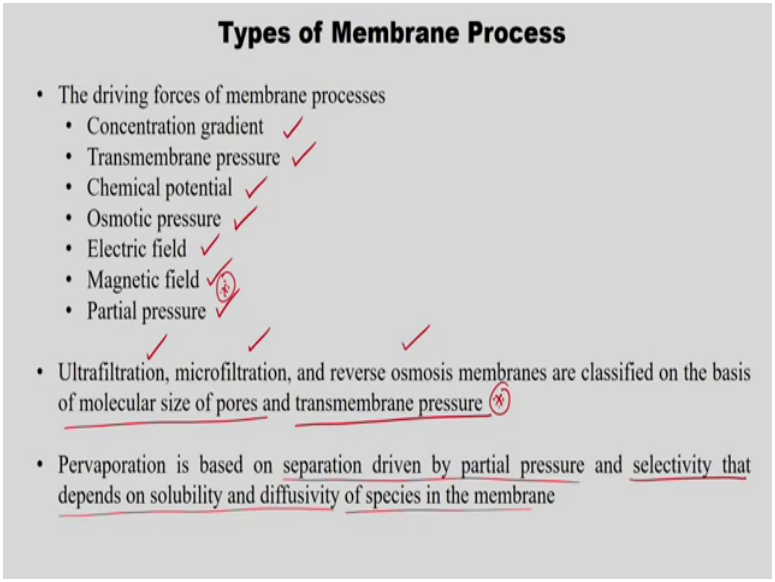

And the driving forces for membrane processes concentration gradient, transmembrane pressure, chemical potential, osmatic pressure, electric field, osmatic pressure in reverse osmosis, then transmembrane pressure and concentration gradient, magnetic field, partial pressure, so all of them are driving force based on the particular membrane separation process. So the major categories are ultrafiltration, microfiltration, and reverse osmosis. So,

these are all classified as on the basis of molecular size of the pore as well as the transmembrane pressure.

So, here major parameter or critical parameter based on which the classification is done is the molecular size of the pores as well as the transmembrane pressure. But, if we see the pervaporation technic which is based on this separation driven by the partial pressure. So, we have told here the partial pressure and the selectivity that depends upon the solubility and diffusivity of species in the membrane, solubility as well as diffusivity of the species in the membrane.

So, here I will stop this lecture. So tomorrow we will see about the various membrane separation process. So, in the todays lecture we discussed about what is called separation process, where it exactly used in the food industry. And, what are all the basic separation process and what are all the advance separation process. Advance separation process the major ones are chromatographic and electric field assisted separation process as well as membrane separation.

Chromatographic separation we just discussed very briefly because we are not going to concentrate much on that. And membrane separation process as well as the electric field assisted separation process. We are going to discuss in next two lectures. So, membranes separation process ultra, micro and Nano filtration as well as reverse osmosis. And electric field assisted membrane separation process, we will discuss about the electro dialysis. And, if possible we will try to do few basic problems.

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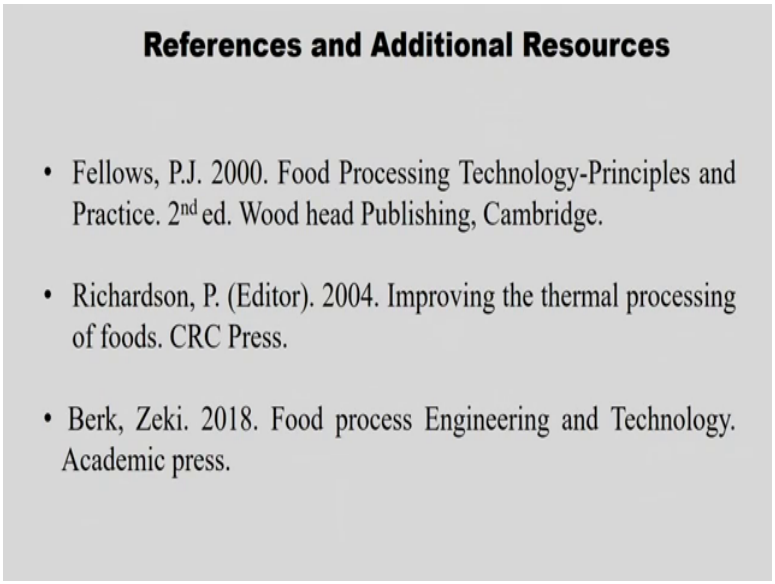

And these are all the resources and additional references, what i have used in this lecture thank you.