Membrane Technology
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Lecture – 21
Factors Affecting UF Performance, Fouling and Permeate Flux Enhancement, UF Application1.

Good morning students, today is lecture 21 under module 7. So, in today's lecture, we will discuss the factors affecting the ultrafiltration performance fouling and how to reduce fouling and then various ultrafiltration applications. Since there are many ultrafiltration applications and it is extremely wide. So discussing everything is not possible in a lecture like this. So, I have given very few applications in which ultrafiltration plays a very significant role. And we will discuss one by one during our subsequent lecture today.

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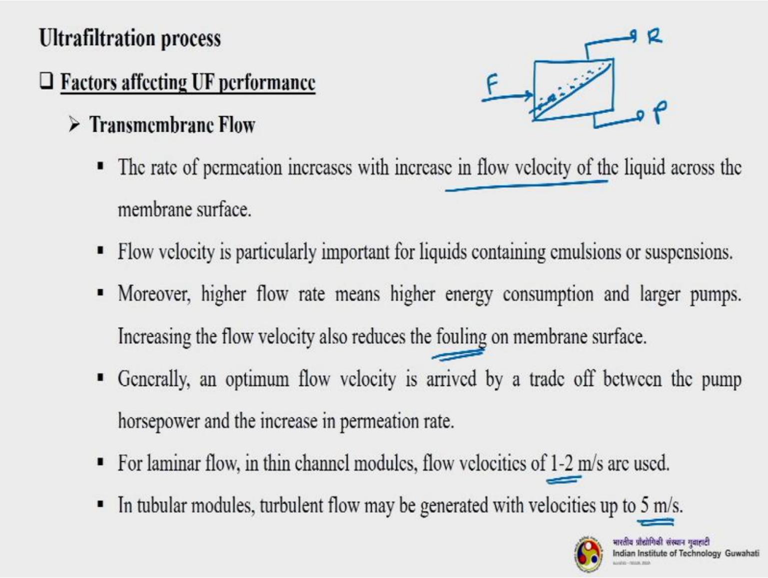

You know there are different types of factors that affect ultrafiltration performance. The first and foremost important thing is, of course, your membrane, what its pore size. Then, what is the membrane material and its properties. The next thing that comes into picture is the solute that I am going to separate. So solute means solute shape its size, its diameter. And its properties like whether it is charged or what type of charge it is carrying.

All these things plays a very important role. Now apart from the solute and membrane, the other factors that actually play a significant role in ultrafiltration performance that we are going to discuss. So, the first one is the transmembrane flow. So, you know the rate of permeation increases with increase in flow velocity of the liquid across the membrane surface. So, this we have discussed earlier.

Also I will just try to again make you understand. So, let us say this is our feed coming and we are getting a retentate and we get our permeate the usual across flow system. Now, what is happening as the progress in separation is happening. So, with respect to time, so, solute started getting deposited on the surface of the membrane. Now, we have discussed in one of our classes that one of the most important method to reduce the concentration polarization.

There are many of course, and subsequent fouling is to increase the cross flow velocity. Now, this is what this first line is telling that the permeation or the transport will increase when you increase the cross flow velocity. Because when you increase the cross flow velocity, the higher velocity will try to wash ever the solute that is getting deposited on the surface of the membrane.

Now, flow velocity is particularly important for liquids containing emulsions or suspensions. Moreover, higher flow rate means higher energy consumption and larger pumps. This is also not always a win win situation that you increase the flow rate, but at the cost of what of course at the cost of energy and pumping costs. So, increasing the flow velocity also reduces the fouling on the membrane surface.

Now, please understand that fouling is a consequence of the concentration polarization. So, generally an optimum flow velocity is arrived by a trade off between the pump horsepower and the increase in the permeation rate. You simply cannot go on increasing the cross flow velocity as per our V is it is not so. So, there should be a trade off. What is the pump horsepower that is actually pumping the feed flow feed and what is the permeation rate that we are getting and what type of membrane also we are using.

Suppose laminar flow in thin channel module flow velocities of almost 1 to 2 meter per second are used and in tubular modules turbulent where the turbulent flow regions comes into picture. So, almost we can go up to 5 meter per second.

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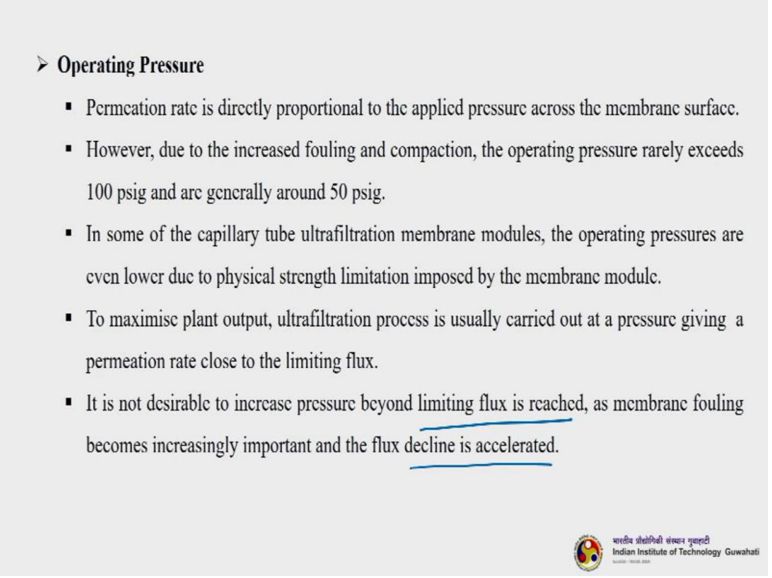

The next parameter is operating pressure. Now permeation rate is directly proportional to the applied pressure across the membrane surface. Now, this is of course, since ultrafiltration a pressure driven membranes process, the more you increase the pressure the more will be the permeation. However due to the increased fouling and compaction the operating pressure rarely exceed 100 psi and are generally around 50 psi.

So, in some of the capillary tube filtration modules, the operating pressure has been lowered due to the physical strength limitation imposed by the membrane module, because in the capillary system they cannot withstand higher pressure otherwise they will be destroyed actually. To maximize plant output ultrafiltration process is usually carried out at a pressure giving a permeation rate close to the limiting flux.

Now, it is not desirable to increase pressure beyond limiting flux is reached. As the membrane fouling becomes increasingly important and the flux decline is accelerated. We have discussed what is limiting flux in our in one of our earlier classes.

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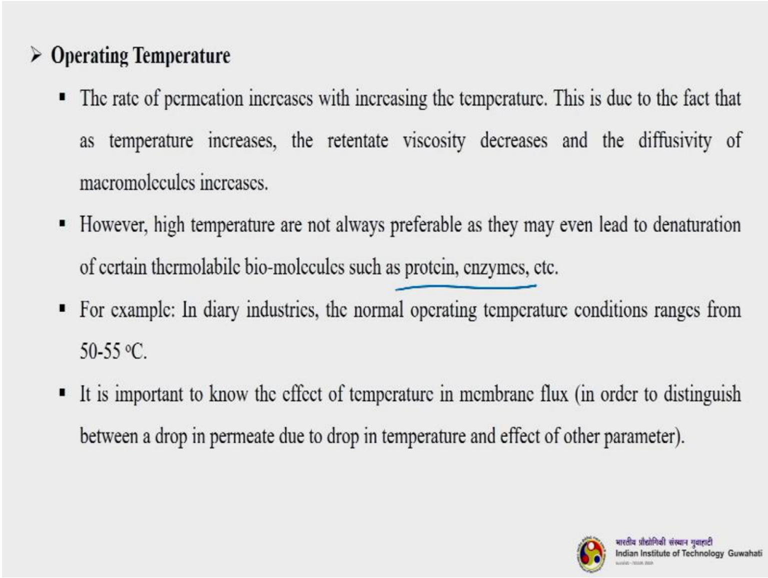

Now, the next parameter is operating temperature. Now, you know that temperature always necessarily do not play an important role in all sorts of ultrafiltration applications. However, wherever there is a temperature driven separation process of course, it will play a big role. So, that usually it has been seen that the rate of permeation increases with increasing temperature.

This is due to the fact that as temperature increases, the retentate velocity decreases, viscosity decreases and the diffusivity of macromolecular increases. Are you understanding that means, when I am increasing the temperature inside the membrane module, the retentate which is getting retained on the surface of the membrane, of course, in a liquid medium, its viscosity is decreases, because viscosity is a consequence of temperature.

So, when the viscosity is decreases, so, the diffusivity of the macromolecules inside the membrane, it is increasing. So, increasing temperature up to certain extent of course, perhaps the favour say, high permeation rate. Now, high temperature are not always preferable as they may be lead to denaturation of certain thermo mobile biomolecules such as proteins and enzymes.

Whenever I am doing some bioseparation, so, I cannot of course, increase temperature. For example, in dairy industries, the normal operating temperature condition ranges from 50 to 55 degrees centigrade. And another important thing is that the membrane which you are using should also be thermally stable. It is important to know that the effect of temperature in the membrane flux in order to distinguish between a drop in permeate due to the drop in temperature and effect of other parameter.

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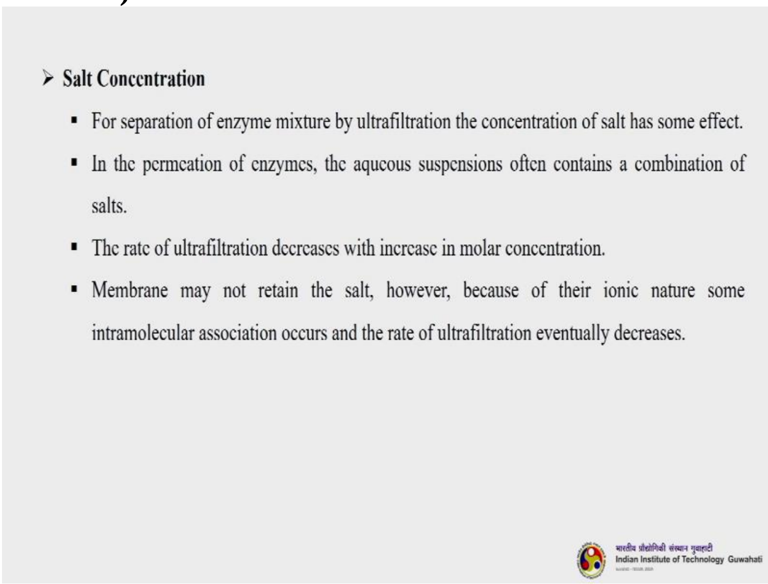

The next is salt concentration now, salt is not always used, but certain applications salt is used in a vapour media to enhance the performance. So for especially for separation of proteins and enzyme mixture by ultrafiltration the concentration of salt has some effect. In the permeation of enzymes the aqueous suspensions often contains a combination of salts. So, there may be more than one salt also possible.

So, the rate of ultrafiltration decreases with increasing molar concentration. Membrane may not retain the salt. However, because of their ionic nature, some intramolecular association occurs and the rate of untrafiltration eventually decreases.

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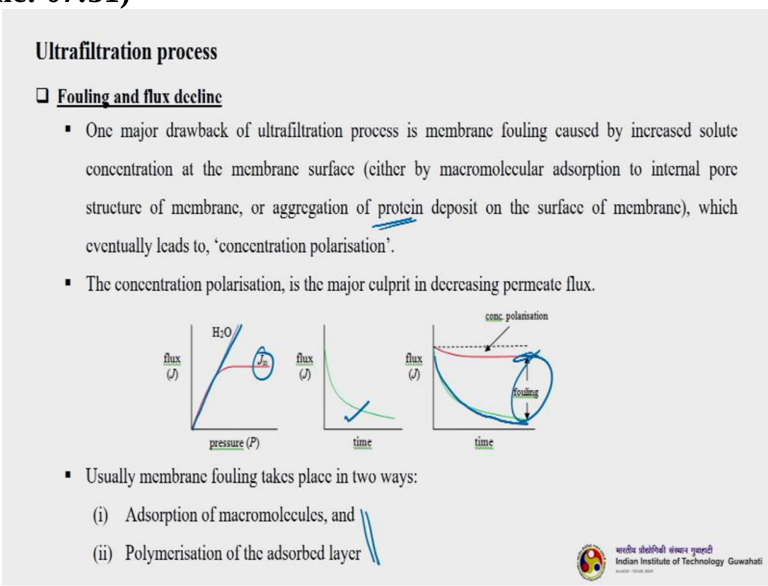

Now, let us understand and discuss the fouling and flux decline profile in ultrafiltration you know, it is same as in other processes also, but we will quickly go through once again so that it will also revise your understanding of the flux decline performance as well as fouling. So, one major drawback of ultrafiltration process is membrane fouling caused by increased solute concentration at the membrane surface.

So, either it is happening by the macromolecular adsorption to the internal pore structure of the membrane, or aggregation of protein deposit on the surface of the membrane. Like not always protein it just for example, I have written it is protein it is any solute that is I want to retain. so which eventually leads to concentration polarization. Now, the concentration polarization is the major culprit in decreasing the flow rate permeate flux.

Usually 2 types of fouling takes place, one is adoption of macromolecules and polymerization of the adsorbed layer. Due to this two thing fouling actually takes place. You can see the first figure flux versus pressure. So, you can see this is the straight line, this is the clean water flux our water flux and this is your limiting flux which we were just discussing. So, you can see this is the standard approx decline mechanism of profile in ultrafiltration system.

When here you can see that when the concentration polarization layer actually is built up, then the flux is declined like this the red one and when the membrane starts fouled, then you will get a flux decline profile like something like this. So, this magnitude is been told as described as the fouling. But it is not measured like that, it is just a schematic understanding.

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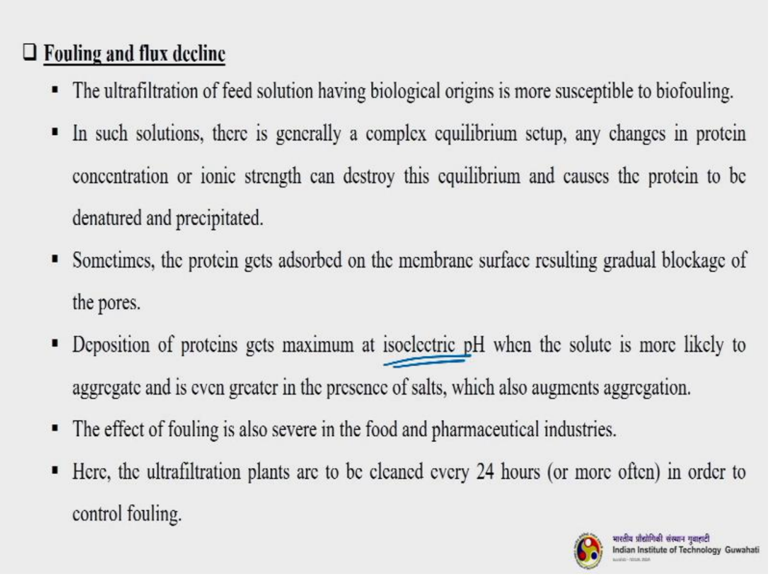

So, the ultrafiltrations of feed solution having biological origins are more susceptible to biofouling. Now, in such solutions there is generally a complex equilibrium setup any changes in protein concentration or ionic strength can destroy this equilibrium and causes the protein to be denature and precipitator. Now, sometimes the protein gets adsorbed on the membrane surface, resulting gradual blockage of the pores, deposition of proteins gets maximum at isoelectric point.

We have to understand what is isoelectric point in one of our classes and when the solute is more likely to aggregate and even greater in the presence of salts which also augments the aggregation. Now, we are discussing about proteins because proteins are more susceptible to biofouling proteins or enzymes when ultrafiltrations has huge application in pharmaceutical or bio pharmaceutical or bio technological industry dealing with various types of proteins and enzymes as well as antibodies.

So, the effect of fouling is also severe in the food and pharmaceutical industries.Here the ultrafiltration plants are to be cleaned every 24 hours in order to control fouling. So frequent cleaning up ultrafiltration systems is required because proteins are more susceptible to fouling.

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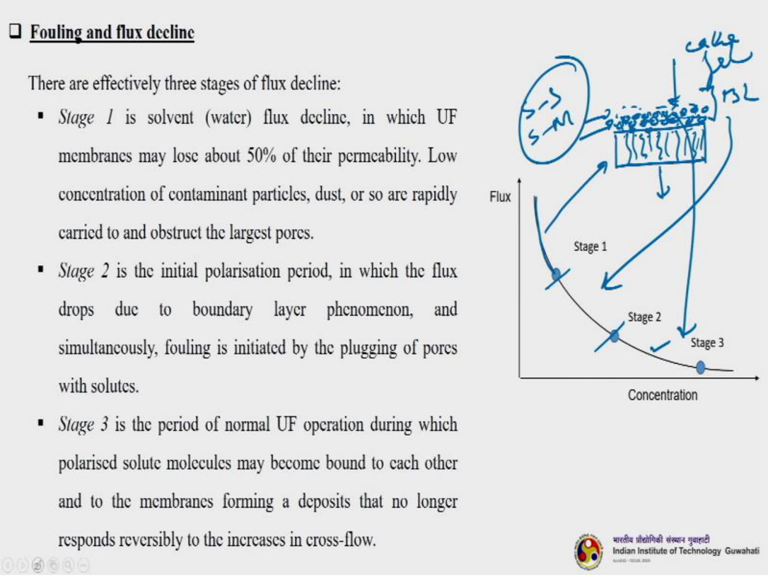

So, let us understand the different stages of fouling. So, usually stages in ultrafiltration fouling has been described by 3 stages stage 1, stage 2 and stage 3. So, in stage 1 the solvent or water flux decline is happening actually. So, I here from here to here. So, the membrane may lose 50% of its permeability. So, low concentration of contaminant particles dust or so, are rapidly carried out and obstruct the largest force.

Now in stage 2 from here to here, so, it is the initial polarization period, that means in which the flux drops due to the boundary layer phenomena. So, if you see, again I am trying to draw a membrane. So initially, the very small particles are this one they will get inside the pores and they we will get deposited also. So, low concentrations of contaminants of the particles will this one and most of the times your solvent will pass through.

So, this is stage 1, then slowly the concentration polarization or boundary layer build up will start. So, this is the boundary layer build up. So, this is happening due to this stage is happening in stage 2. So, fouling is initiated by plugging of pores with solutes. So, the pores will be plugged with solutes which have either mostly similar insights to it or smaller than it. So, it stage 3 this stage is the period of normal UF operation.

So, in which actually the polarized solute molecules may become bound to each other and to the membranes forming at deposits that no longer responds reversibly to the increases in cross-flow. That means what is happening this is strong interaction between solute as well as solute-solute. So, basically solute-solute interaction as well as solute membrane interaction now this interaction is becoming so, received that if you increase your cross-flow velocity very high then also they are not getting vast.

So that whatever now you can understand that also some sort of cake cake or whatever you can call a gel layer permeation is happening and the end subsequent fouling is getting rejected and due to that, you have this one profile looks like this in stage 3.

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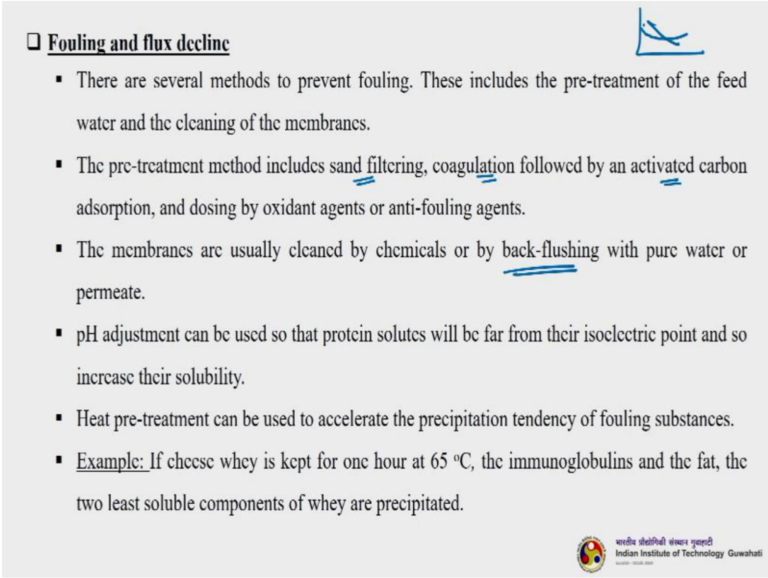

So, there are several methods to prevent fouling, this includes the pre-treatment of the feed water and cleaning of the membrane. So, it is very important if you are treating with wastewater, then the waste water from various waste whether it is waste domestic or industrial as well as processor wastewater from various industries. So, the contents various types of components.

Suspended solutes, dissolved solutes, heavy metals, oils, greases and what not the. So, maximum of them these things which are actually TSS suspended solutes and all needs to be removed before by using a usual filter mess or screen before it goes to the ultrafiltration system. If we do not remove that, then what will happen is that the plugging of the pores of the ultrafiltration membrane will become very fast.

And there will be a huge fouling and concentration build up and your plastic line will be very fast almost it will decline something like this. Which we do not want, we always want a plugs decline profile something like this. So, the pre-treatment methods include sand filtering, coagulation followed by an activated adsorption and dosing by oxidant agents or anti-fouling agent different types of pre-treatment methods are there you can depending upon what is the wastewater source actually.

So, you can either use sand filter or coagulation to precipitate something or do you can have an activated adsorption system activated carbon adsorption system in which most of the pollutants will be adsorbed to the surface of the, this one adsorbents or you can have some oxidant or anti fouling agents also. So, the membranes are usually cleaned by chemicals or by back flushing with pure water or permeate.

Once the process is over. So, you need to clean the membrane, as we have discussed that if you are treating proteins and all. So, every 24 hours there should be back flushing cycle or cleaning cycle. PH adjustment can be used so that protein solutes will be far from their isoelectric point and so increase their solubility. Our heat pre-treatment can be used to accelerate precipitation, a tendency of fouling substances. In certain case, example, if cheese whey is kept for 1 hour at 65 degrees centigrade, the immunoglobulins and the fat, the 2 least soluble components of whey are precipitated

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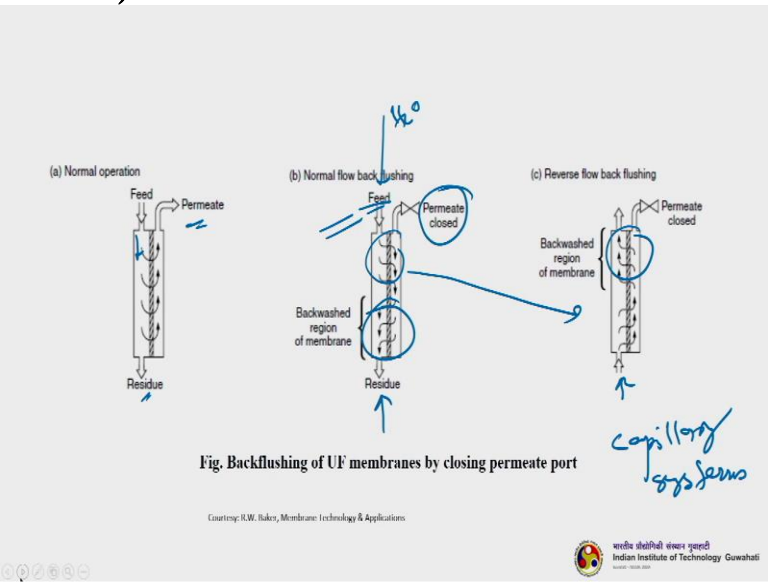

And let us see the back flushing we have never discussed black flushing in detail, we will just try to understand how back flushing actually happens. So, actually the cleaning process mechanism is that first once the process is over, so, you take out the membrane system. And try to use the fresh water from permeate side of the membrane and depending upon what type of membrane actually you are having and then try to clean it.

So, once that is over, so, at a very high flow rate of course, which is recommended for that particular membrane module. So, once that is over, then you can depending upon the nature of the solute that particular membrane is dealt in. So, you can either use for some detergents, or some either dilute little very dilute acid or dilute alkaline. So, and then again go for the repetition of the cycles.

After successive cycles when you see the permeate flux performance is good, or you are getting a good permeate flux. Then again, you stop this process and again do with fresh water. Some few times till you get your desired flux. Now, let us understand you see the a figure in which is the normal operation basically. So feed is coming feed is coming here. So this is the membrane and you are getting a permeate here and the residue intended here.

Now, how do I do back flushing. So what I am doing is then from the this this is a capillary tubes, this capillary systems. So, this particular figures, so what I am doing is that I am sending the feed here, I will send clean water, maybe deionised is water sometimes, but usually tap water also, it is fine. So you send it, then pressurize it, then what you do is that you close the permeate trap or the permeate valve through the permeate is getting collected.

Now, by doing that, what is happening is that we develop certain pressure. The pressure what is double lock it is in between the feed pressure and the permeate pressure. So, you can see that the when the; permeate is not getting actually collected it is closed. So, the permeate as well as the feed there exerting some pressure and most of the back washing is happening in this particular side in the lower side of the membrane.

This is one way then what will happen then you reverse then how what should I do about this area, now, this is the insert then I reverse the flow of the water. So, instead of flowing it from the feed side, I am now flowing it through the credit retentate side. Then the same process procedure will happen and the other half of the membrane will be cleaned by back flushing. So, this is how by flushing is done this is for example, in capillary tube membranes and usually for any other systems so, the procedure is same.

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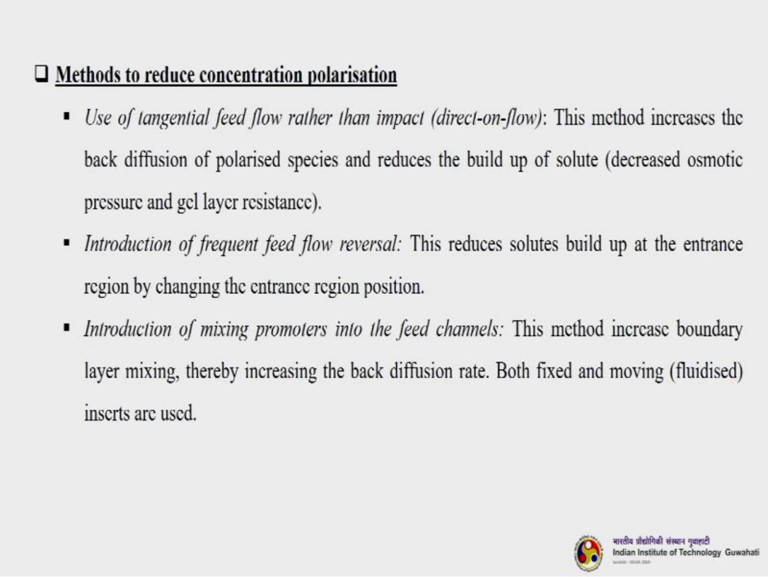

So; though have discussed how to reduce concentration polarization. So, I will just quickly go through these are some of the other techniques. So, you can use tangential feed flow rather than impact. So, that is direct on flow. So, this method increases the back diffusion of polarized species and reduces the build up of solute basically decreased osmotic pressure and gel layer resistance. Another method is introduction of frequent feed flow reversal. Now, this reduces solutes build up at the entrance region by changing the entrance region position.

So, just like I was telling here if you closely look at this. So, from here so, this is your feed right from feed is entering here. So, after successive operations now you entered your feed from here with the same membrane, so, there is a feed there is a feed flow port there is a retentate port. So you just reverse it after successive realism. The idea is that the entire membrane surface should be utilized for the separation processes and the concentration polarization build up will also be reversed.

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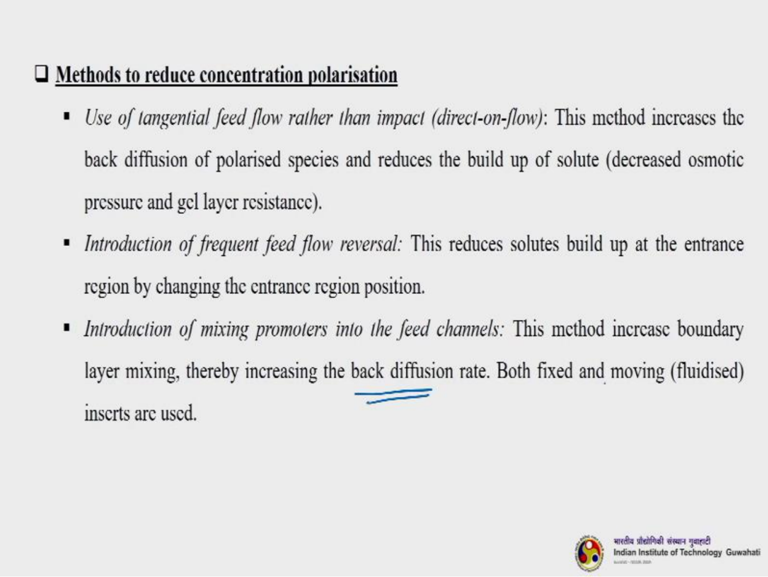

So, the introduction of frequent feed flow reversal that is called actually. So, then next one is introduction of mixing promoters into the feed channels. Now, this method increase boundary layer mixing, thereby increasing the back diffusion rate. Both fixed and moving inserts are used.

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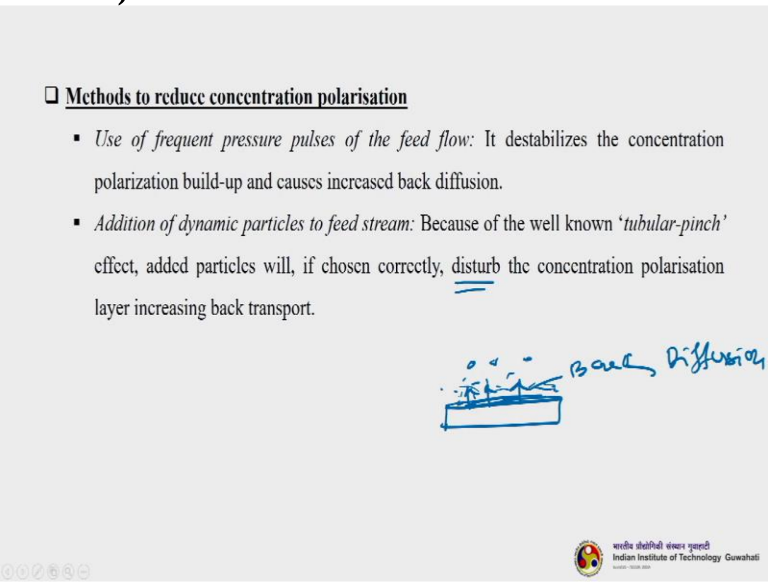

Then use of frequent pressure pulses of the feed flow. So, this is destabilizes the concentration polarization build up and causes increased back diffusion, when doing the pressure pulsing. So, addition of dynamic particles to feed stream because of the well known tubular pinch effect added particles will, if chosen correctly disturb the concentration polarization layer by increasing the back diffusion.

So, that means, suppose this is the membrane this concentration polarization is happening here you add some particles. So what will happen so, it will try to come here and it will increase the back diffusion. So, when it increases the back diffusion, so, the chances of this solutes that is getting deposited on the surface of the membrane here reduces. There by reducing the concentration polarization and of course, subsequent fouling also.

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Now, let us understand and discuss different types of ultrafiltration processes applications basically. So, water treatment, treatment of oily waste water, processing of whey, recovery of electro coat paint, concentration of latex emulsion, pulp and paper industries application, textile, clarification of fruit juice, PVA recovery in the this one cloth manufacturing industries and cold sterilisation.

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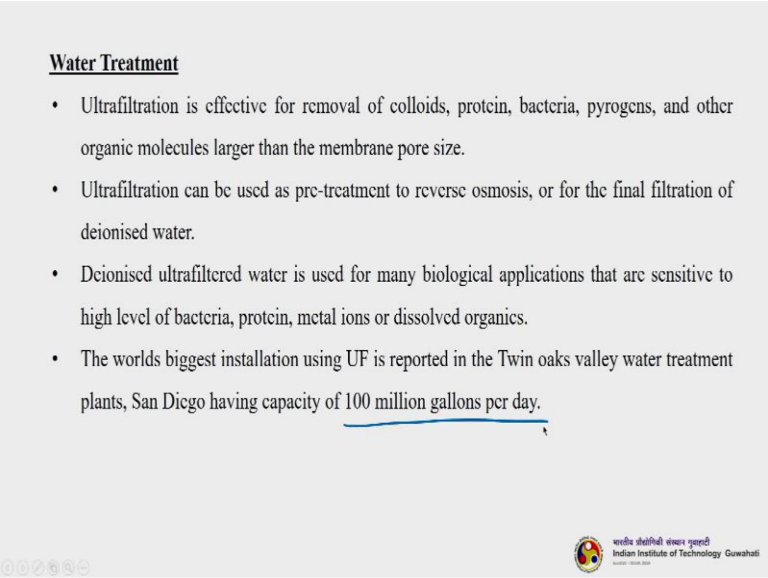

Now, water treatment is of course, an most important application of the membrane processes, membrane technology, whether it is ultrafiltration, reverse osmosis, Nano filtration or ultrafiltration. Now ultrafiltration is very, very effective for removing colloids, proteins, bacteria, pyrogens and other organic molecules, which are larger than the membrane pore size. It can be used as a pre-treatment to reverse osmosis or for the final filtration of the deionised water.

Now, deionised ultrafiltered water is used for many biological applications that are sensitive to high level bacteria, protein, metal ions or dissolved organics. The world's biggest installation using ultrafiltration is reported in the Twin oaks Valley water treatment plant that is in San Diego having a capacity of hundred million gallons per day million gallons per day.

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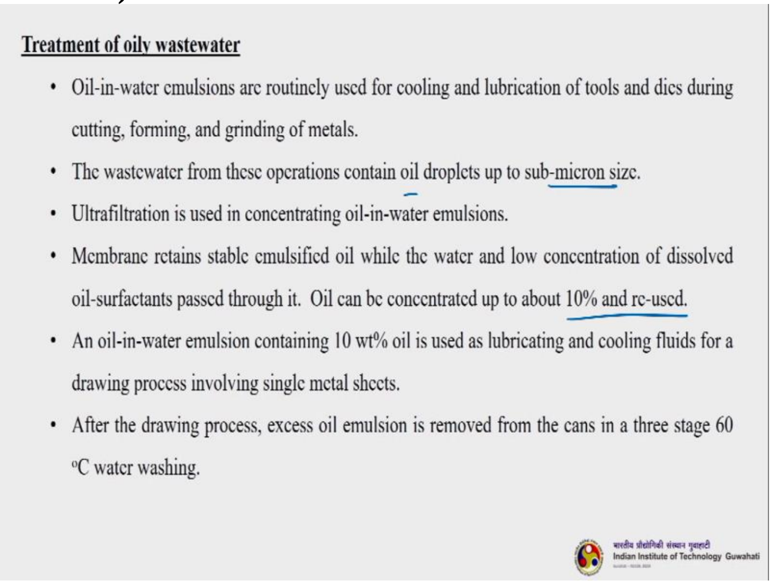

Now, the next application is oily wastewater. So this is one of the most significant application of the ultrafiltration. So oil in water emulsions are routinely used for cooling and lubrication of tools and dyes during cutting forming and grinding of metals mostly in refineries. Then near metallurgical industries and other process industries of course. The wastewater from these operations contains oil droplets to sub-micron size. Now, ultrafiltration is used to concentrate the oil water emulsions.

Membrane and retains stable emulsified oil while the water and low concentration of dissolved oil-surfactants pass through it. Oil can be concentrated up to about 10% and re used now in oil in water emulsion containing 10, weight percentage oil is used as lubricating and cooling fluids for a drawing process involving large metal sheets. So, after drawing process excess oil emulsion is removed from the cans in a 3 stage 60 degree centigrade water washing.

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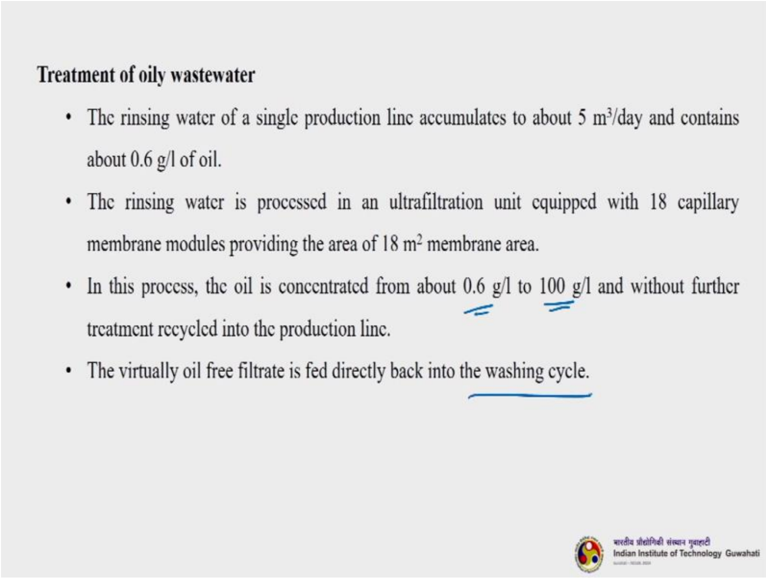

The rinsing of water of a single production line accumulates to about 5 meter cube per day and contains about 0.6 grams per litre of oil. The rinsing water is processed in an ultrafiltration unit equipped with 18 capillary membrane modules providing the area of 18 meter square membrane area. In this process the oil is concentrated from about 0.6 to 100 grams per litre and without further treatment recycled into the production line. The virtually oil pre filtered is fed directly back to the washing cycle. So, this water is getting reused basically.

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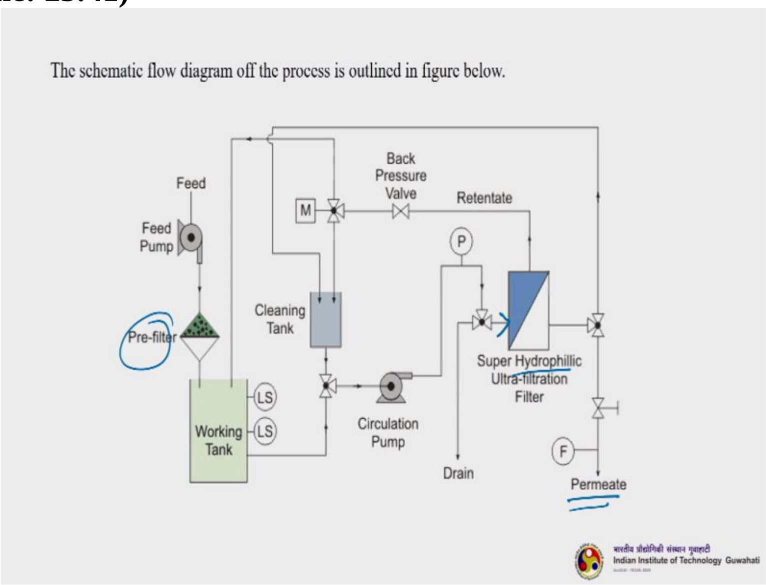

So, just closely have a look at this particular figure, a schematic diagram which is used to treat the wastewater. So, your feed is coming here. So, there is some sort of pre-filters on here as we have discussed just why pre-filter is required, we put it is being fed to the ultrafiltration system, then it is recirculated here and being fed to the ultrafiltration filter here super hydrophilic ultrafiltration membranes are being used.

Then your permit is getting collected here on ear retentive is being recycled to the cleaning tank. So, in this particular system, the choice of membrane also plays a very important role. So here you know that hydrophilic membranes are good. So, that they will not allow the development of here this one concentration polarization.

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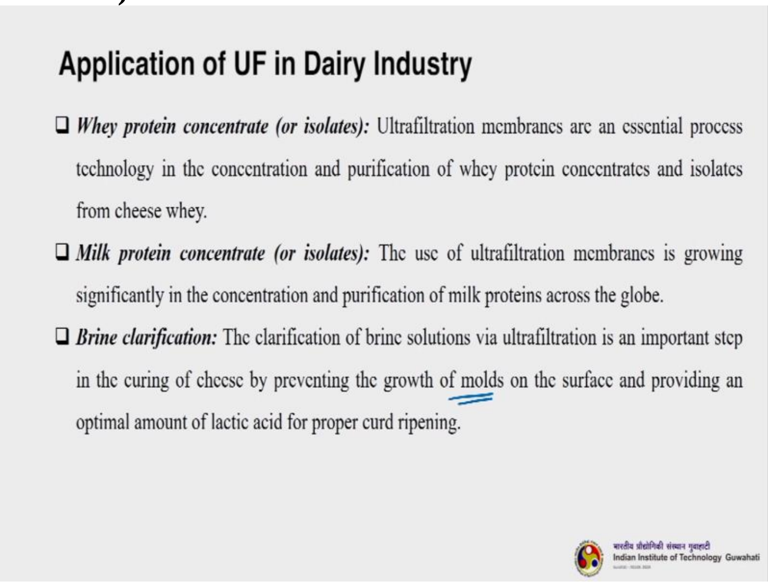

Now, let us understand and discuss the application of ultrafiltration in dairy industries, so many things that happens in the dairy industry different processes. So, we will discuss few. So, the first one is the whey protein concentrate or isolates. Now, ultrafiltration membranes are an essential process technology in the concentration and purification of whey protein concentrated isolates from cheese whey.

Second is milk protein concentrate isolates so they use of ultrafiltration membrane is growing significantly in the concentration and purification of milk protein across the globe. So, the next one is Brine clarification. This is also a part of the cheese manufacturing process. So the clarification of brine solutions by ultrafiltration is an important step in the curing of cheese by preventing the growth of molds on the surface and providing an optimal amount of lactic acid for proper curd ripening.

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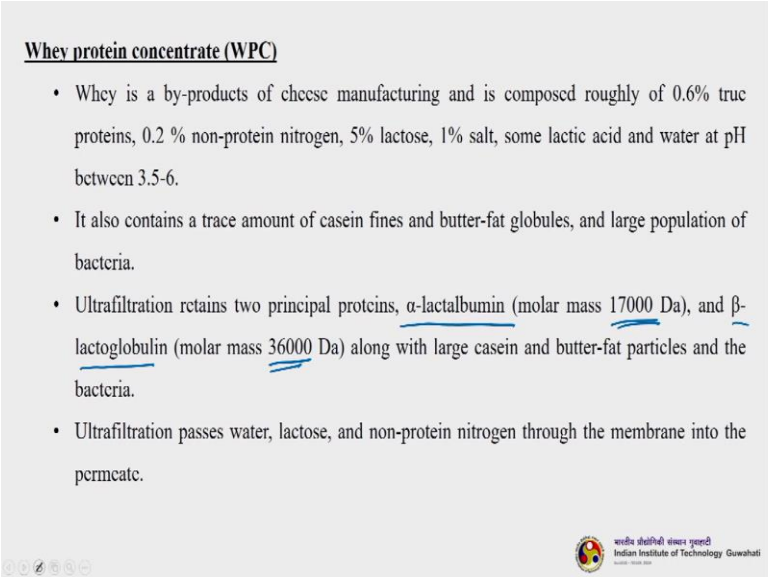

Now, let us understand how it happens actually the whey protein concentrate. So what is whey the whey is a by-product of cheese manufacturing, and it is composed roughly of 0.6% of proteins, 0.2% of non-protein, nitrogen, 5%, lactose, 1% salt and some lactic acid and water at pH between almost 3.5 to 6. Now, it also contains a trace amount of casein fines and butterfat, globules and large population of bacteria.

Now, ultrafiltration retains two principal proteins one is alpha lacto globulin, so it is molar mass is 17,000 Dalton, and another is beta lacto globulin it is molar mass is 36,000 Dalton. So these are the two most important or principal proteins along with large casein and butterfat particles and the bacteria. Now ultrafiltration passes water lactose and non-protein nitrogen through the membrane into the permeate.

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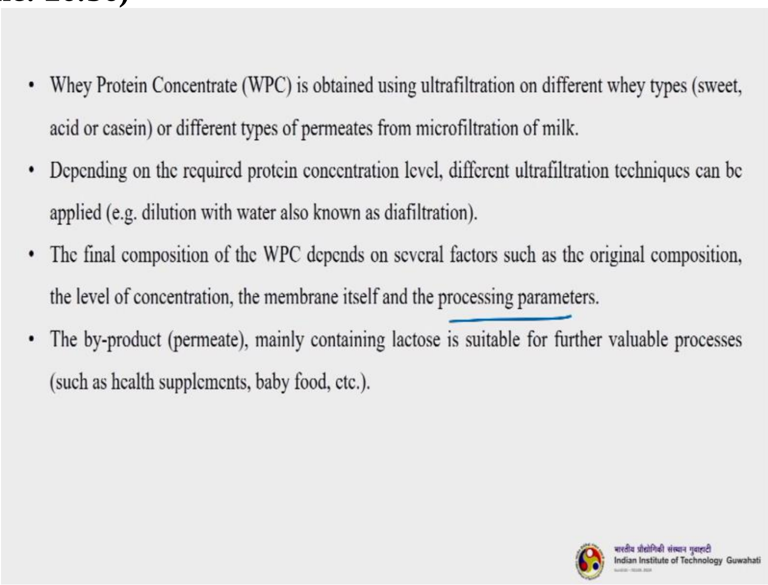

So, whey protein concentrate is obtained using ultrafiltration on different whey types as sweet acid or casein there are different types of whey that is coming out of the cheese manufacturing industry process or different types of permeates from microfiltration of milk. Depending on the required protein concentration level different ultrafiltration techniques can be applied, as for example dilution with water also known as diafiltration.

So, the final composition of the WPC depends on several factors, such as the original composition, the level of concentration the membrane itself and the processing parameters. That we have discussed what are the processing parameters today in our beginning of the class, so the by-product permeate, mainly containing lactose is suitable for further valuable processes, such as health supplements, baby food. So we again go for lactose enrichment.

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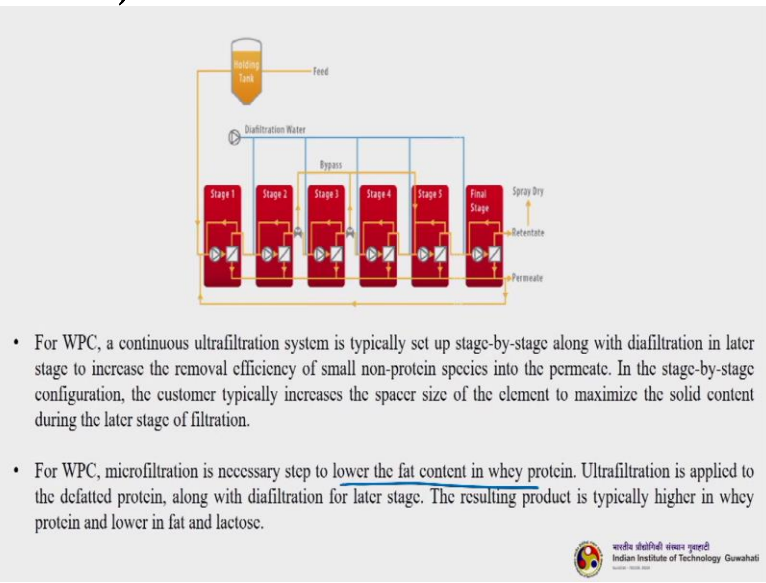

So this is a WPC system so, a continuous ultrafiltration system is typically set up stage by stage so it is not a single ultrafiltration membrane will do the job. So they are stage by stage or in series, along with the diafiltration in later stage to increase the removal efficiency of so in between a few ultrafiltration test, which is removed during the WPC, there are some repetition membranes also installed.

So in the stage by stage test configuration, the customer typically increases the spacer size of the element to maximize the solid content during the later stage of filtration. For WPC micro filtration also a necessary step to lower the fat contents. So initially, you use the micro filtration membrane to remove the fat content or ultrafiltration is then applied to the defatted protein along with diafiltration for later stage. So the resulting product is typically higher in whey protein and lower in fat and lactose.

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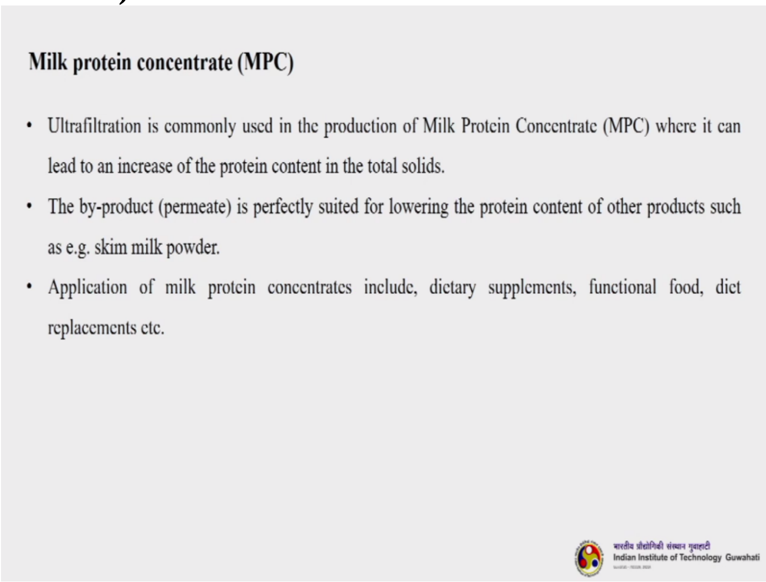

So, the next application is milk protein concentrate. So, ultrafiltration is commonly used in the production of milk protein concentrate, where it can lead to an increase of the protein content in the total solids. The by product that is permeate is perfectly suited for lowering the protein content of the other products such as skim milk powder or many times it is called skimmed milk powder. So, application of milk protein concentrates include dietary supplements, functional fruit that replacements etc.

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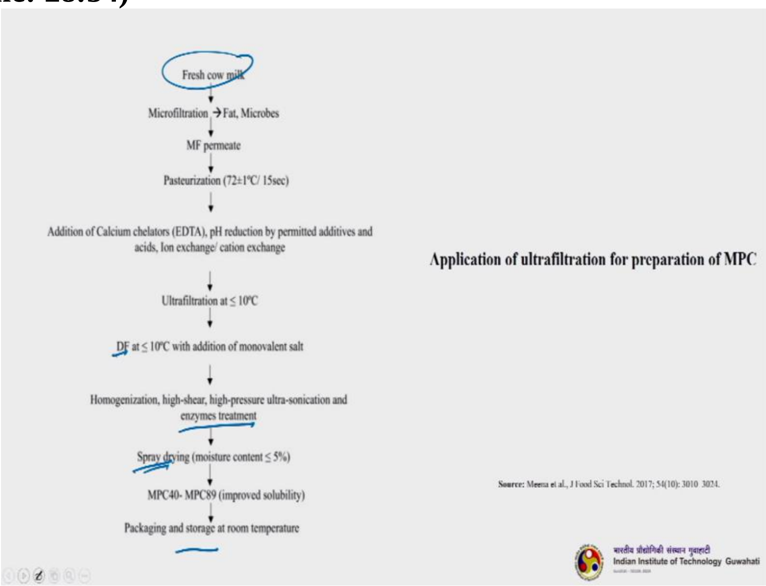

So, this is flowchart actually, this tells us about how ultrafiltration is being used for preparation of the milk protein concentrate. So, you take your fresh cow milk, so, it goes to the microfiltration test and as you have discussed, it will remove the fat and as well as other microbes, then we get a micro filtration permeate. Then you send it to the pasteurization plant so almost 70 to 100 + degrees centigrade per 15, 16 seconds.

Then you add calcium chelators which EDTA pH reduction is also done by permitted additives and it is ion exchange then you pass through ion exchange and cation exchange regions. Then once that is done, you send it to the ultrafiltration which is less than 10 degrees centigrade it is operating. So, then once whatever it is coming from the ultrafiltration system, you pass it to that diafiltration.

This is diafiltration at less than 10 degrees centigrade with addition monovalent salt, but then the next processes homogenization pass through the high shear and high pressure ultra-sonication and enzymes treatment. Finally, it goes to the spray drying where the moisture content is reduced to less than 5%. So, basically you make powder and whatever you may add some MPC40 or MPC89. These are stabilizers to improve the solubility and then you go per packaging storage. So, this is the flow chart how to prepare the milk protein concentrated.

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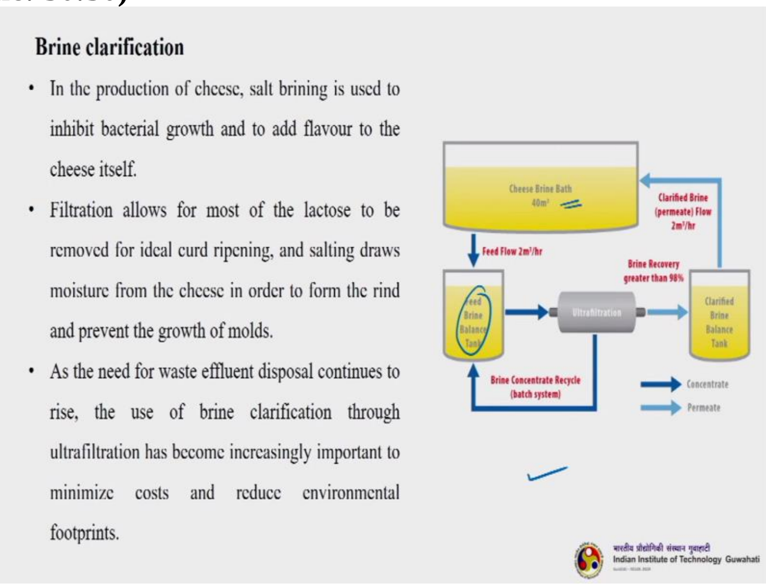

Next one is Brine clarification. So in the production of cheese salt brining is used to inhibit bacterial growth and to add flavour to the cheese itself. Filtration allows for most of the lactose to be removed for ideal curd ripening and salting draws moisture from the cheese in order to form the rind and prevent the growth of molds growth of molds the growth of fungi basically. As the need for waste effluent disposal continues to rise, the use of brine clarification through ultrafiltration has become increasingly important to minimize costs and reduce environmental footprints.

You can see the schematic diagram of the brine clarification process, the ultrafiltration and the brine the feed brine passing through the ultrafiltration and the concentrate brine is getting recycled to the feed tank and the permeate either you can collect it or you can send it to the cheese brain bath here for that recycle purposes.

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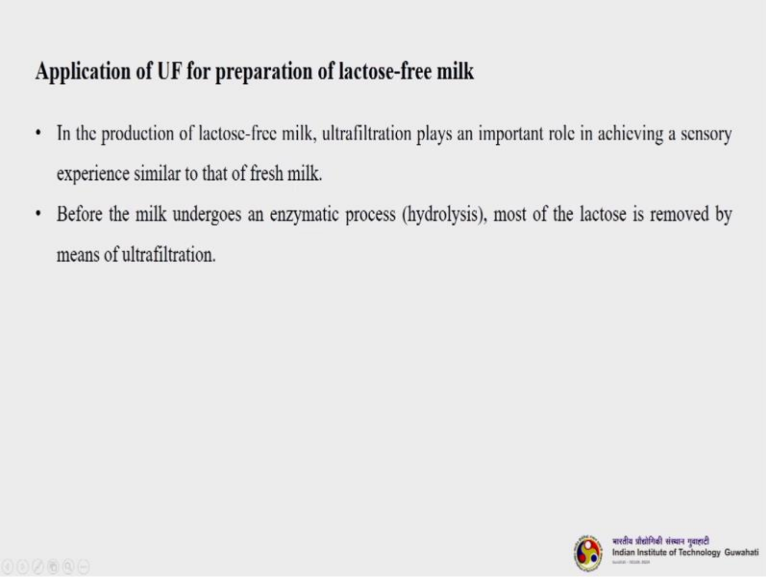

So application of ultrafiltration preparation of lactose free milk. So, in the production of lactose free milk ultrafiltration plays an important role in achieving a sensory experience similar to the fresh milk. Before the milk undergoes an enzymatic process most of the lactose is removed by means of using ultrafiltration. Now, again remember, in industries a single sense of single step ultrafiltration membrane will never give you the desired result. So, everything is done in or you can call it in series.

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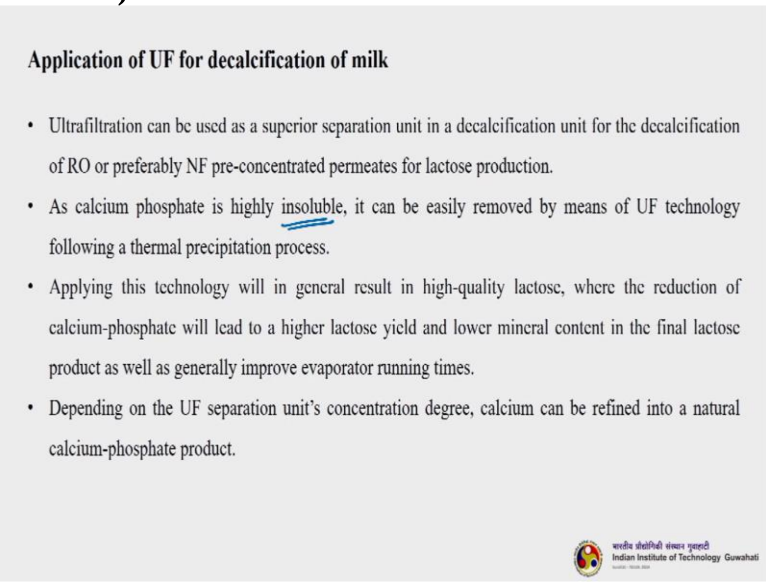

So, then application ultrafiltration; for decalcification of milk. Ultrafiltration can be used as a superior separation unit in a decalcification unit for the decalcification of RO or preferably NF pre concentrated permeates for lactose production, say this is, calcium actually. As calcium phosphate is highly insoluble; so, it can be easily removed by means of UF technology following a thermal precipitation process.

So, applying this technology will in general result in high quality lactose, where the reduction of calcium phosphate will lead to a higher lactose yield and lower mineral content in the final lactose products as well as generally improve upon running times. So, as you know in the milk or the dairy industries, so, there are so many evaporators which is jelly is being used to concentrate the milk products.

So, if you use if you do remove the calcium from the milk, then it will increase the evaporator reduce times because there will be no scale formation. So, depending on the ultrafiltration separation units concentration degree, calcium can be refined into a natural calcium phosphate product.

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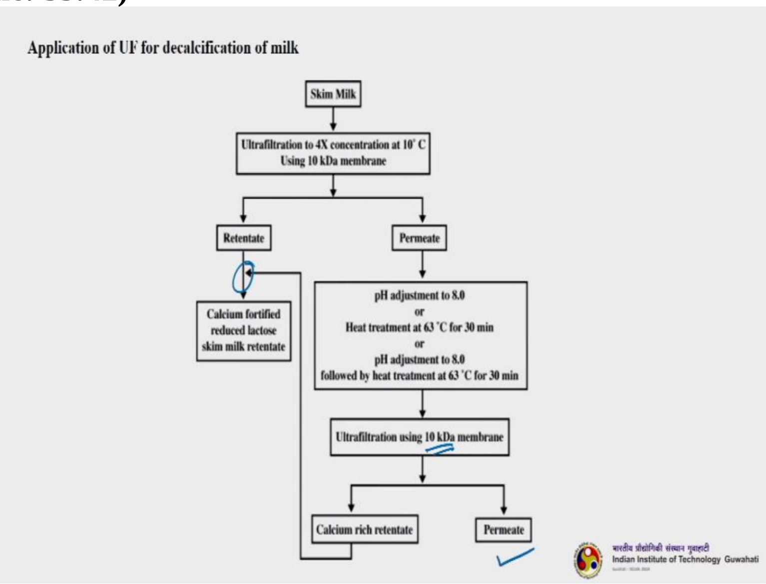

So, this is a schematic diagram of how that how decalcification of milk is achieved. So, skim milk is passed through ultrafiltration to increase the concentration almost to up to 4X at 10 degrees centigrade using a 10 kilo delta membrane. Then whatever the retentate is coming the retentate is actually calcium fortified, it will reduced with reduced lactose and skim milk retentate.

Then the permeate is goes through several treatments. So, you can adjust the pH to 8 or you can go for the heat treatment at 63 degrees centigrade for 30 minute or a combination of both then it goes to another ultrafiltration membrane having 10 kilo Dalton membrane and whatever do you get the calcium rich retentate it can be feedback and recycled to that retentate here. So you get calcium fortified reduce lactose there and you get permeate here.

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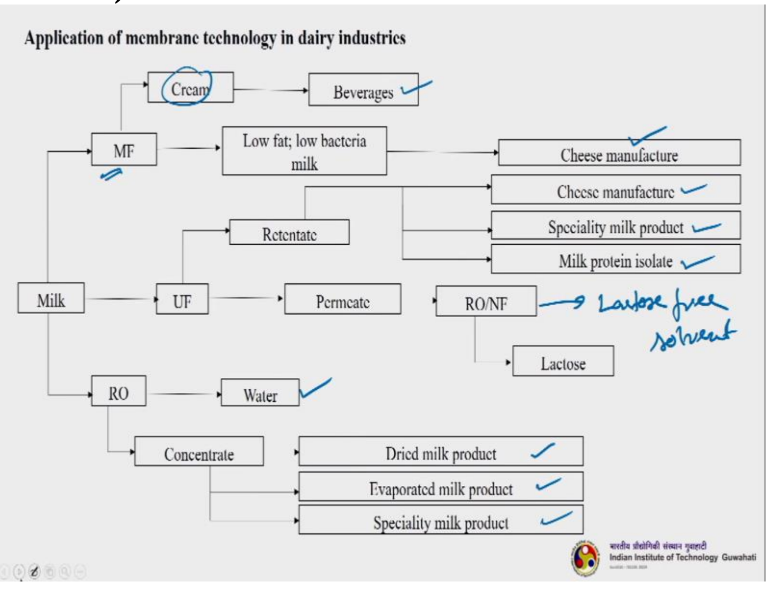

So students this is a general schematic of the application of membrane technology in dairy industries so, it is not dairy industries, you just learn today we discussed about MF and UF how they are being used in dairy industries. So, RO is also being used. So, you can see how it is happening. So, the milk which is coming to the micro filtration system initially so, it is giving me low fat low to the milk that means pattern bacteria removed.

So, that can straightaway go to the cheese manufacturing and whatever is coming here is a retentate so, that means the fat so, that is nothing but your cream, so that can be store go to the beverages section. The milk that is coming to the ultrafiltration and it is retentate it can go for cheese manufacture specialty milk product and milk protein isolate. Whatever is permeate so, that goes to again a RO NF system to remove lactose.

And whatever will come there that is basically we will have actually lactose free what do you can solvent it can be recycled mostly aqueous medium. So, milk that is fed to the RO system so, in the permeate side we get retentate coming out as a concentrated can go for a dried milk product evaporated milk product of speciality milk product. So, this is how the membrane technology plays a significant role in dairy industries.

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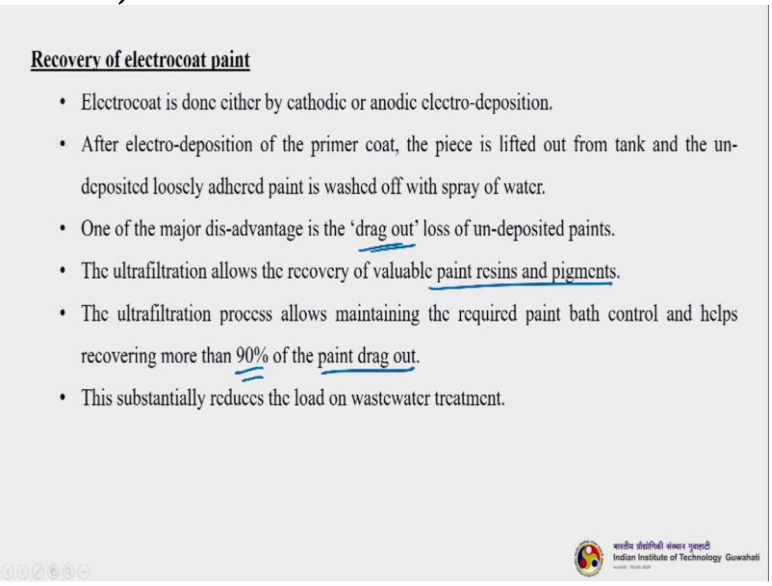

Next application is of course the recovery of electro coat paint. So, electrocoat is done either by cathodic or anodic electro deposition. After the electrode the position of the primer coat the piece is lifted get out from the tank and the undeposited loosely adhered paint washed off with a spray of water. Now, one of the major disadvantages drag out of the undeposited paints.

Now that is not actually good for the system. So, the ultrafiltration allows the recovery of valuable paint resins and pigments. So, UF allows you entering the required paint bath control and helps recovering more than 90% of that paint drag out. So, this substantially reduces the load on the wastewater treatment. So; if because we have almost removed the paints.

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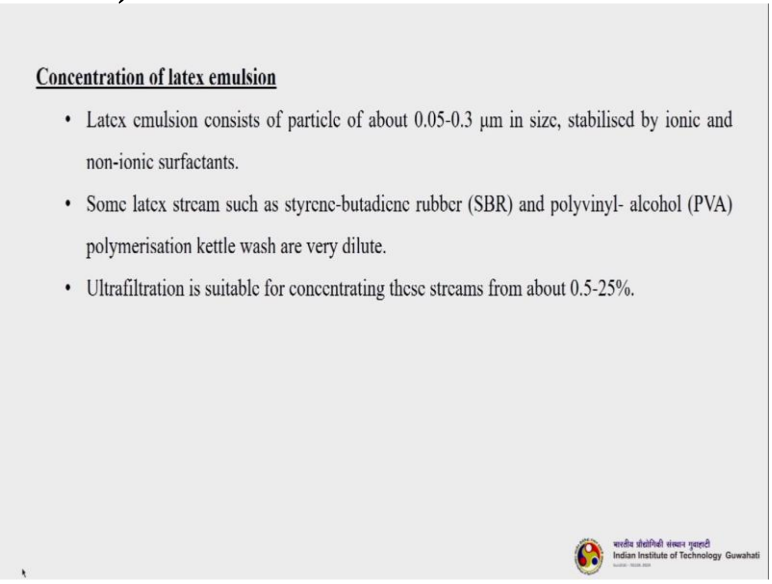

So, latex emulsion also can be concentrated using the ultrafiltration system. So, latex emulsions usually consist of 0.05 to 0.3 micron in size of the latex particles stabilised by ionic and non-ionic surfactants. So, some latex streams such as styrene butadiene rubber SBR or PVA polymerisation kettle wash are very dilute. Ultrafiltration is suitable for concentrating these streams from about 0.5 to 25%.

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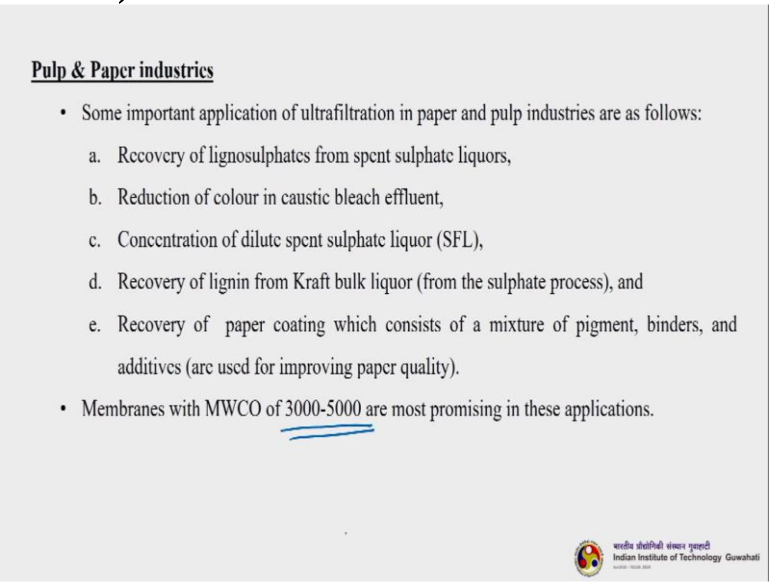

Then the application in pulp and paper industries; so, some of the applications of ultrafiltration in pulp and paper industry are recovery of lignosulphates from spent sulphate liquors. Reduction of colour in caustic bleach effluent, concentration of dilute spent sulphate liquor. Recovery of lignin from the Kraft bulk liquor from the sulphate process and recovery of paper coating which consists of a mixture of pigment binders and additives, so, these are used for improving the paper quality. So, membranes of 3000 to 5000 Dalton are most promising in these applications.

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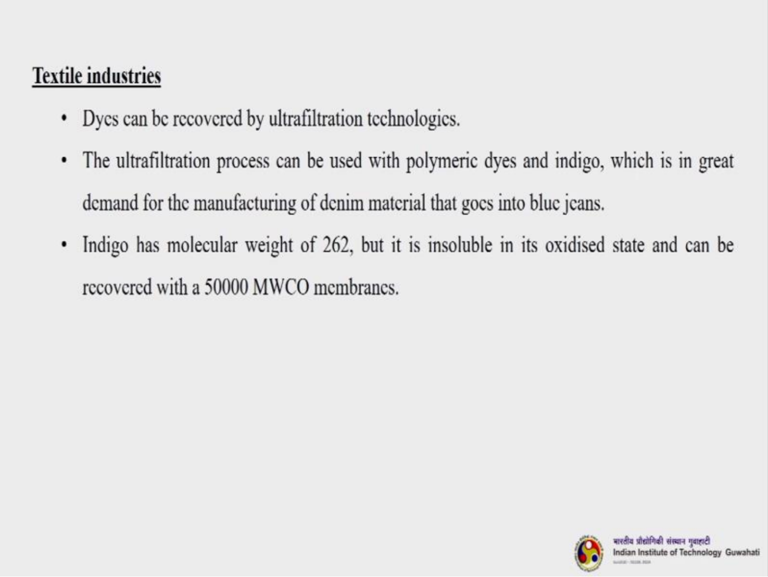

So and then textile industries: So dyes can be recovered by ultrafiltration technologies. The ultrafiltration process can be used with polymeric dyes in indigo, which is in great demand for the manufacturing of denim materials that goes into the blue jeans. So Indigo has a molecular weight of 262 Dalton but it insoluble in its oxidized state and can be recovered with a 50,000 molecular rate cut off membranes.

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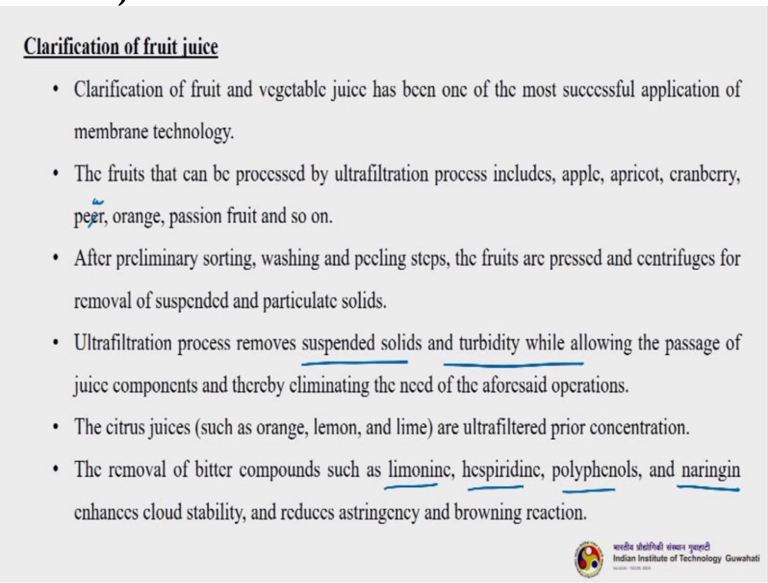

One of the most important applications of membrane technology in industrial scale is clarification of fruit juice. The meaning of clarification of juices basically, to remove the components which are not required for the fruit juice, as well as these components are actually destabilizes that produce that needs to be recovered. So the fruits that can be processed by ultrafiltration includes apple, apricot, cranberry, peer, orange, passion fruit and so on.

So after preliminary sorting, washing and peeling steps, the fruits are pressed and centrifuges for the removal of suspended and particular solids. Now ultrafiltration process, remove suspended solids and turbidity while allowing the passage of juice components and thereby eliminating the need of the aforesaid operations. So the citrus juices such as orange, lemon and lime or ultrafiltration prior concentration. The removal of bitter components such as limonine, hespiridine, polyphenols and naringin enhances cloud stability and reduces astringency and browning reaction needs to be removed.

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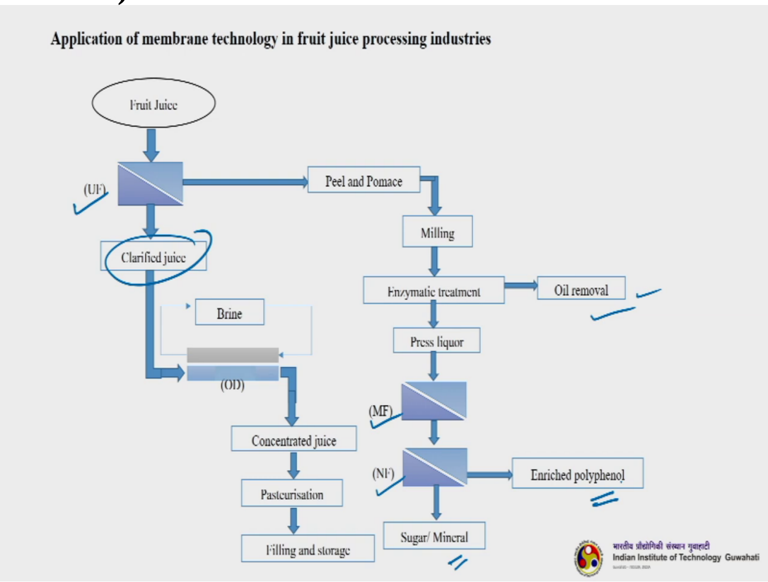

This is the schematic diagram of the application of membrane technology in fruit juice processing industries. You can see that fruit juice that is passing through the ultrafiltration membrane. So you get that clarified juice here. So that clarified juice is not that immediately collected and packed so it passes through separate systems. Here you remove the brine, brine is being added to remove certain other components, then concentrated juices we are getting here, then it goes to pasteurization and storage.

So whatever the peel and pomace is being retained on the surface of the ultrafiltration membrane, so that it goes through the milling and geometric treatment to remove oil then it is pressed, passes through a micro filtration membrane subsequent to a Nano filtration membrane. So, whatever you get is the enriched polyphenol and here you get sugar and mineral.

You can understand that the entire fruits whatever is being utilized varies apart from the juice; there are various other value added components that are being also recovered using membrane technology. So, it will remove certain oils especially oils are prominent in citrus fruits, then you remove some of the polyphenols which are very costly materials along with some antioxidants then some sugar and mineral is also being recovered.

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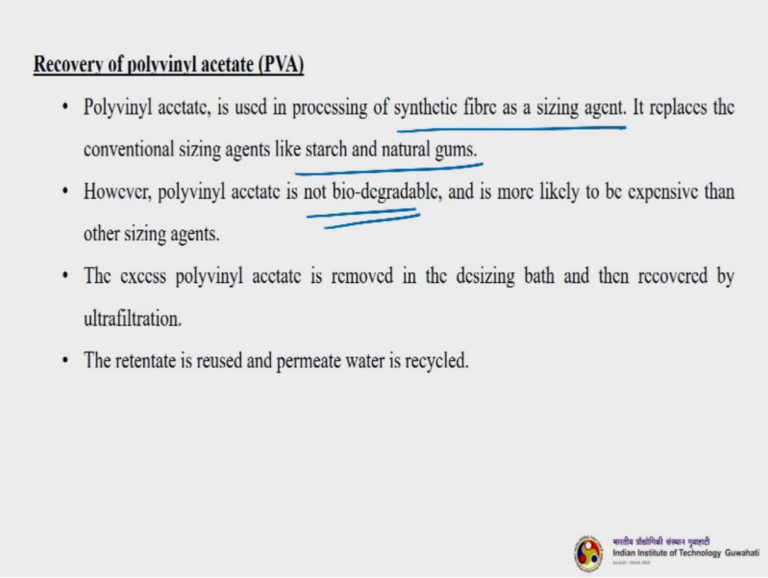

Another application is the recovery of polyvinyl acetate PVA. Now, you know PVA is used in processing of synthetic fibre as a sizing agent in textile manufacturing industries so it replaces the conventional sizing agents such as starch and natural gums. So, however PVA is not biodegradable, hence is more likely to be expensive than other sizing agents, the excess PVA is removed in the desizing bath, and then recovered by ultrafiltration. The retentate is reused and permeate water is recycled.

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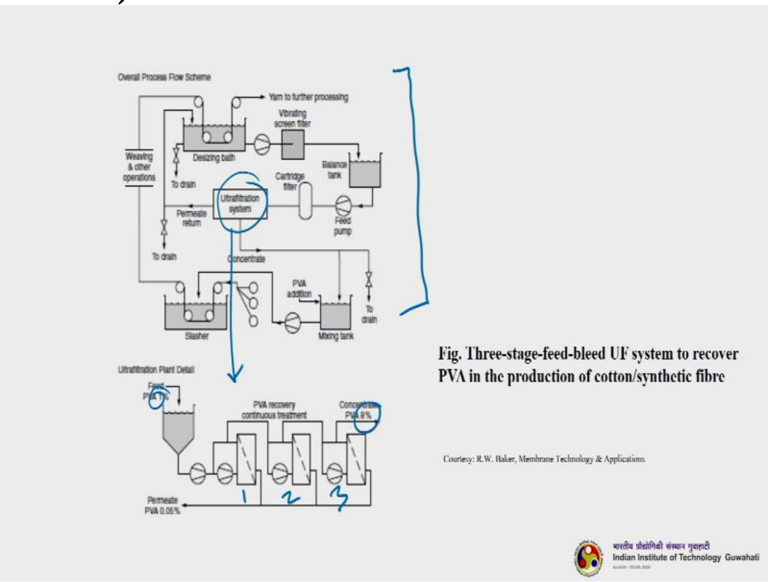

So, this scheme you can see. So this is the complete process. So, in which 3 stage feed-and-bleed ultrafiltration systems was used to recover PVA in the production of cotton and synthetic fibre. So here the ultrafiltration system is being shown here. It is a 3 stage feed-and-bleed system. So that you can see that in the feed the PVA percentage is only 1 percent. So now using a 3 stage, stage 1, stage 2, stage 3, we are enriching up to 8 %. So this is how PVA is being enriched and then recover.

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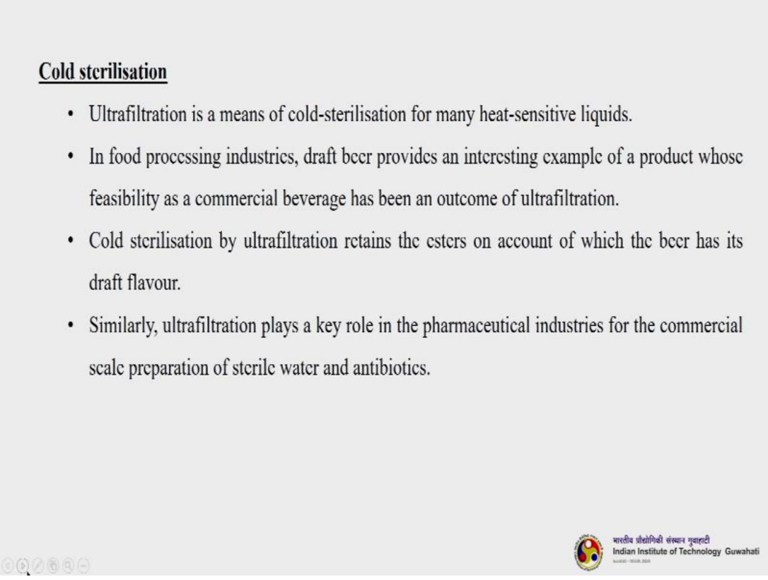

So the next is cold sterilization. So, ultrafiltration is a means of cold sterilisation for many heat sensitive liquids. So, in food processing industries draft beer provides an interesting example of a product whose visibility as a commercial beverage has been an outcome of the ultrafiltration technology. So, cold sterilization by ultrafiltration retains the esters on account of which the beer has its draft flavour. Similarly ultrafiltration plays a key role in pharmaceutical industries for the commercial scale preparation of sterile water and antibiotics.

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Now, today, we have understood the fouling and different parameters that affects the membrane processes, I mean, especially the ultrafiltration and in brief, we have discussed few ultrafiltration application as I told in the beginning of the class, there are numerous applications and it is difficult to cover all these things here. So, just try to give a glimpse of the different types of applications. So, most of the materials are taken from this Baker and K. Nath for today's lecture. You can please refer to these 2 books. So thank you very much.

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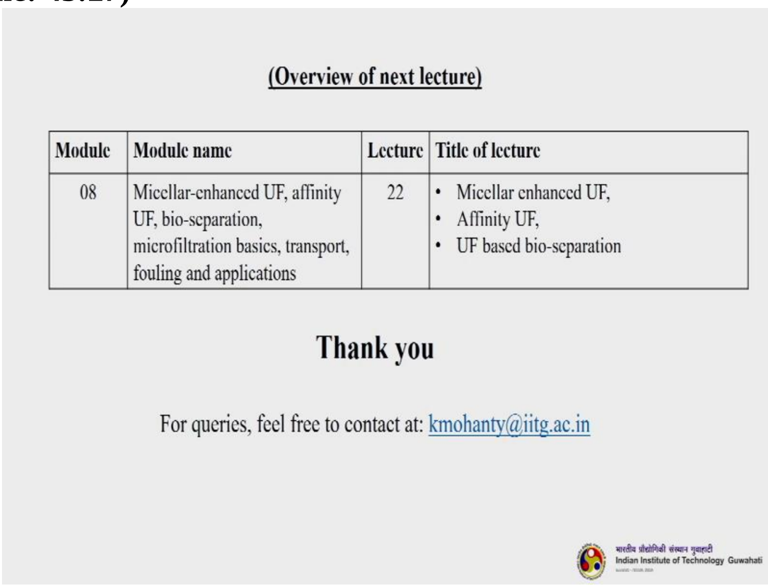

In the next class, we will start module 8, in which we will discuss 2 very important applications of ultrafiltration, which is called Miccellar enhance ultrafiltration. It has been studied thoroughly and affinity ultrafiltration. Then you will see ultrafiltration based bio separation. Thank you very much. If you have any query, please feel free to write to me at k mohanty at iitg.ac.in. Thank you.