Membrane Technology
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Lecture-27
Dialysis, membranes and modules, mass transport in dialysis, diffusion analysis, applications

Good morning students, this is lecture 27 under module 9. In today's lecture, we will discuss about dialysis, its basic principles, advantages, various membranes that is being used for dialysis purposes. Then we will try to understand the mass transport in dialysis and we will discuss about diffusion analysis that is Donan dialysis and 2 applications of dialysis.

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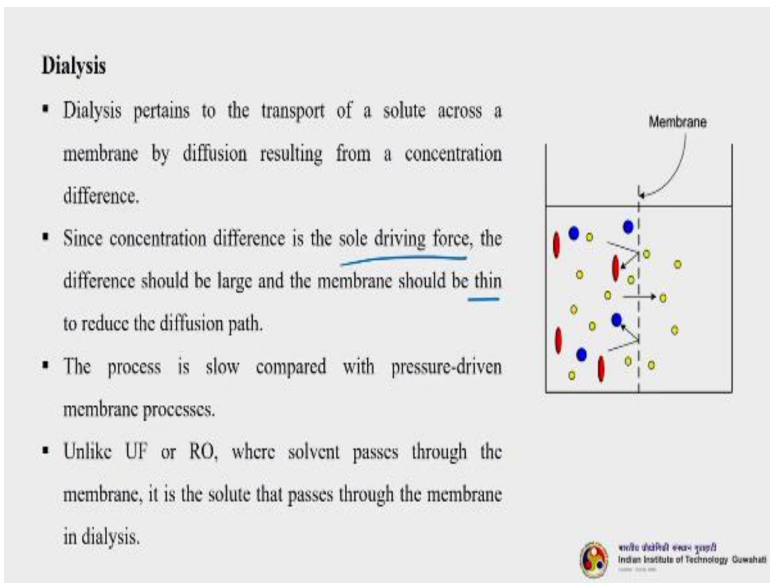

So, a dialysis pertains to the transport of a solute across a membrane by diffusion resulting from a concentration difference, there is no external pressure is applied here. Like in reverse osmosis or ultrafiltration or microfiltration. So, here concentration difference is the sole driving force and the difference should be large and the membranes should be thin, to reduce the diffusion path because if the membrane will be thick, it will provide an external resistance to the diffusion path.

So, that diffusion of the solute so will slow down or will be less. But the process is extremely slow compared to pressure-driven membrane because pressure-driven membrane processes are actually under certain external force, that is pressure so they are a little fast. Here, it is happening spontaneously by the virtue of the concentration difference that is the sole driving force.

And of course other things also placing important role like that efficiency and solubility across the membrane material which is being used the forces of the membrane, the type of membrane and all these things also place an important role.

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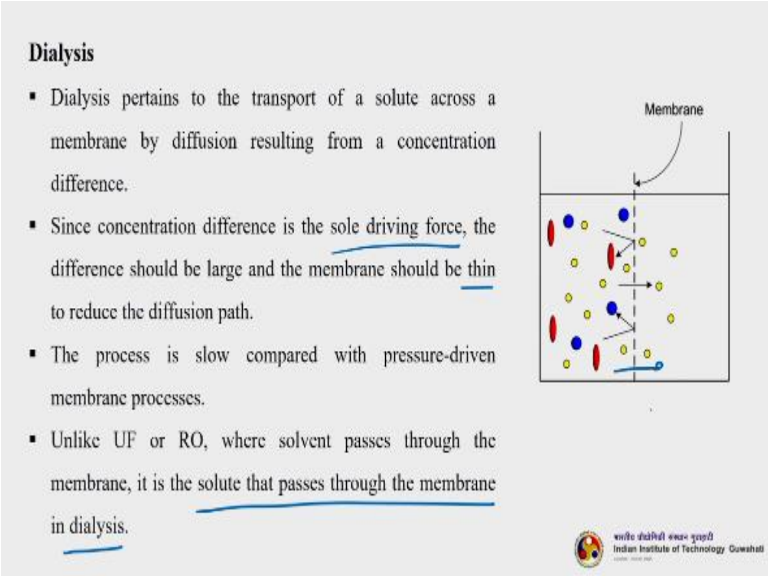

So, like ultrafiltration and reverse osmosis where solvent passes through the membrane, it is the solute this passes through the membrane. So, this is very important. So, in ultrafiltration reverse osmosis, we have seen that we are pushing the solvent through the membrane. So, the permeate is containing always the aqueous medium. Whatever the solvent, whatever you can call it and the solute are getting resulted on the surface of the membrane.

But in dialysis, it is the reverse, that means the solute are passing, whereas the solvent is being hold and the feed side or the retender side. You can see this here, 3 types of solutes are being I have shown you. So, the small solute which is this yellow color, so they are permitting through so they are passing through the membrane. .

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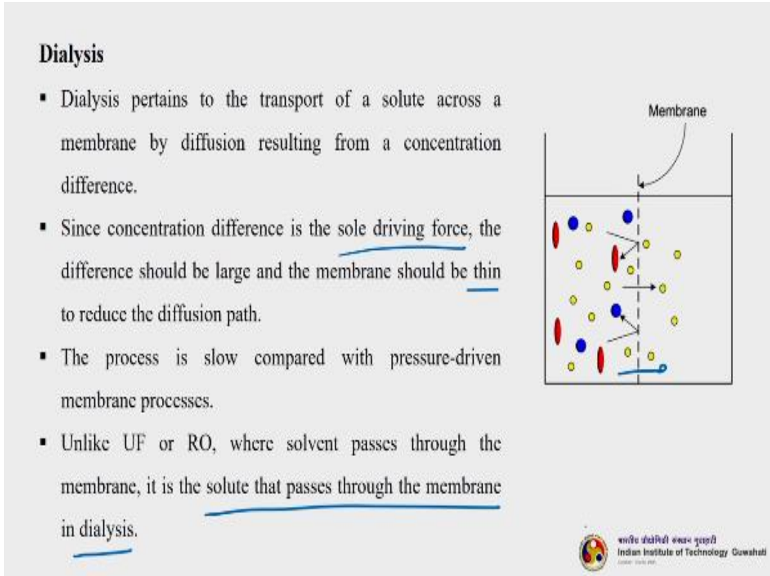

Whereas the large solutes this blue one and the red one by virtue of their signs, they are getting return on the surface of the dialysis membrane.

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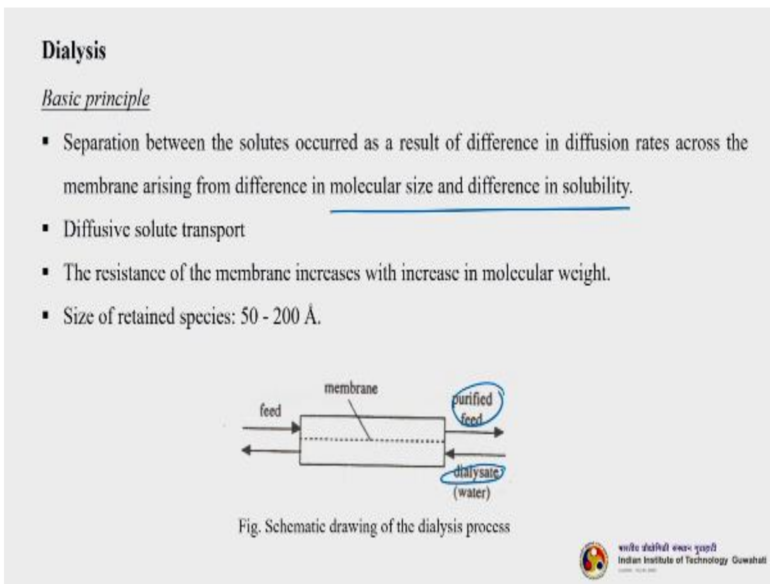

So, separation between the solutes occur as a result of difference in diffusion rates across the membrane that is arising due to the difference in the molecular size as well as solubility. So, mechanism is the diffusive solute transport. So you can see here, this is the schematic diagram of the dialysis process where the feed is flowing in one direction and you get a purified feed here.

And in the reverse direction, we are flowing the water which is known as dialysate. It may be water, it may be any bumper solution and any other solvent also. So this is a counterfeit arrangement, actually feed and dilates are flowing across each other in the reverse direction.

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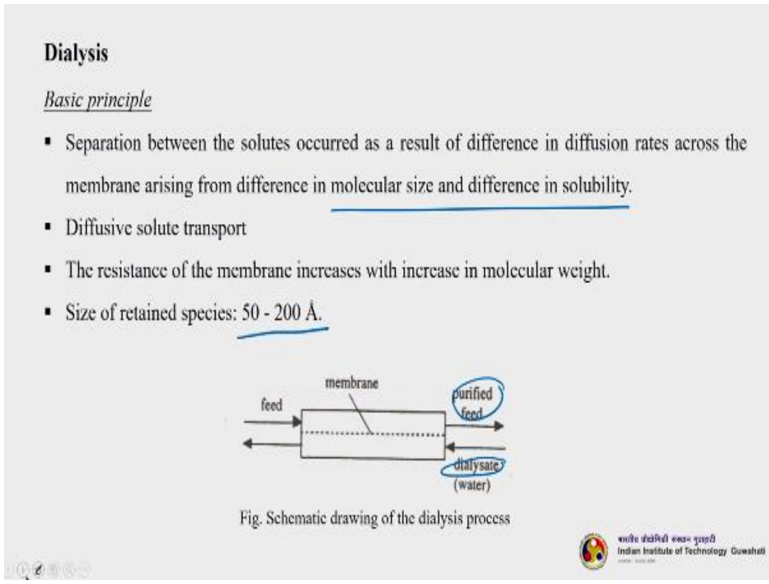

So usually the resistance of the membrane increases with increasing the molecular weight and the size of the return space is about 50 - 200 angstrom.

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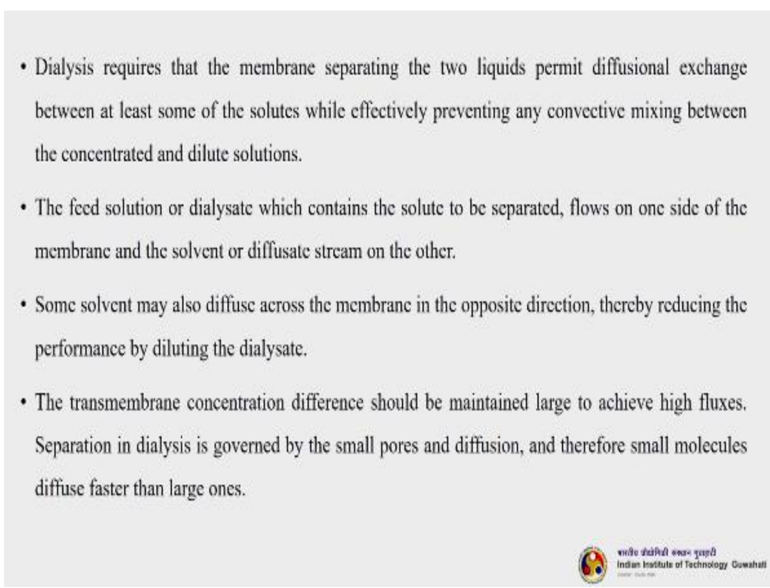

So dialysis requires that membrane separating 2 liquids a permit diffusional exchange between at least some of the solutes while effectively preventing any convection mixing between the concentrator and dilute some results. Now, please note that, the membrane is semipermeable membrane. And membranes are in such a way, that it will allow the passage of certain solutes whose sizes are very low compared to the pore size of the membranes.

And it will not allow the convection mixing of the solutes in both sides in the permeate sides or retended sides. So, here in dialysis, we called it upstream side and downstream side. So upstream side is air feed side and the downstream side is the permeate side.

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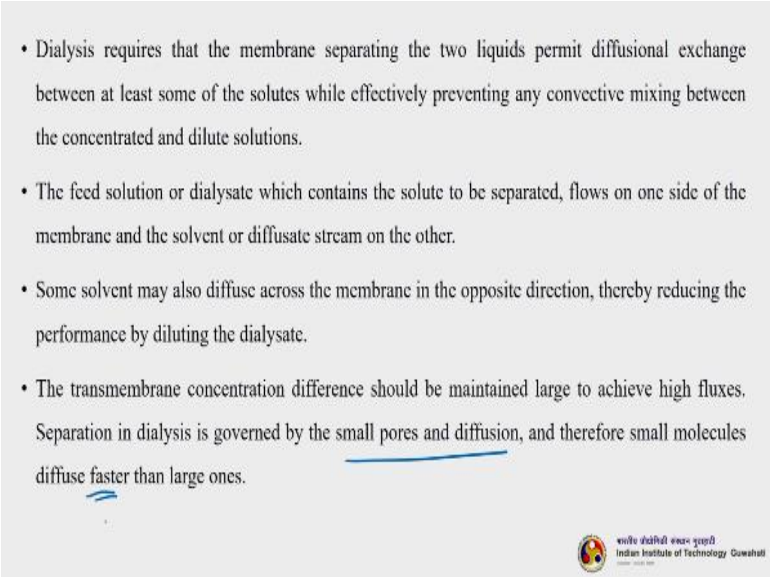

So the feed solution in the dialysate which contains the solute to be separated flows on 1 side of the membrane and the solvent or diffusion a stream on the other side. So, some solvent may also diffuse across the membrane in opposite direction. Thereby reducing the performance by diluting the dialysate. The transmembrane concentration difference should be maintained large to achieve high fluxes.

Separation in dialysis is governed by small pores and diffusion, and therefore small molecules diffuse faster than the large ones. So this is the principle actually.

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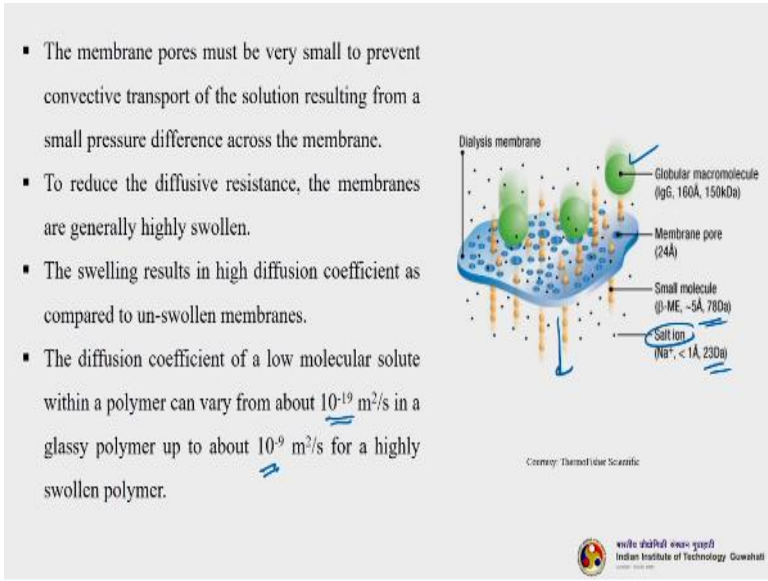

The membrane pores must be very small to prevent convective transport of the solution resulting from a small pressure difference across the membrane. To reduce the diffusive resistance, the membrane are generally highly swollen. So the swelling results in high diffusion coefficients such compared to un-swollen membranes. That diffusion coefficient of a low molecular weight solute within a polymer can vary from about 10 to the power of - 19 per meter square second in a glassy polymer up to 10 power of - 9 meter square per second for a highly swollen polymer, you can see this is another schematic representation of the dialysis process.

You can see that globular proteins, the big sizes. So, there are getting return on the surface of the membrane whereas the small molecules. about 5angstrom78 dalton, 23 dalton. Now the salt ion as well as small molecules. So there permeating through the downstream side or they are getting permeated or transported to the permeate side.

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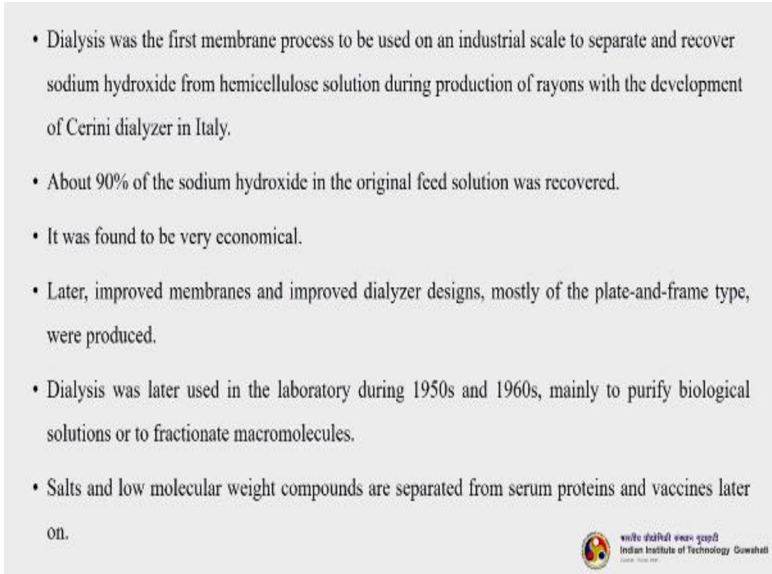

So dialysis was the first membrane process to be used on an industrial scale to separate and recover sodium hydroxide from hemicellulose solution, even in the production of rayons with the development of Cerini dialyzer in Italy. So Cerini dialyzer was one of the most adopted well adopted dialyzer in industries, mostly textile industries.

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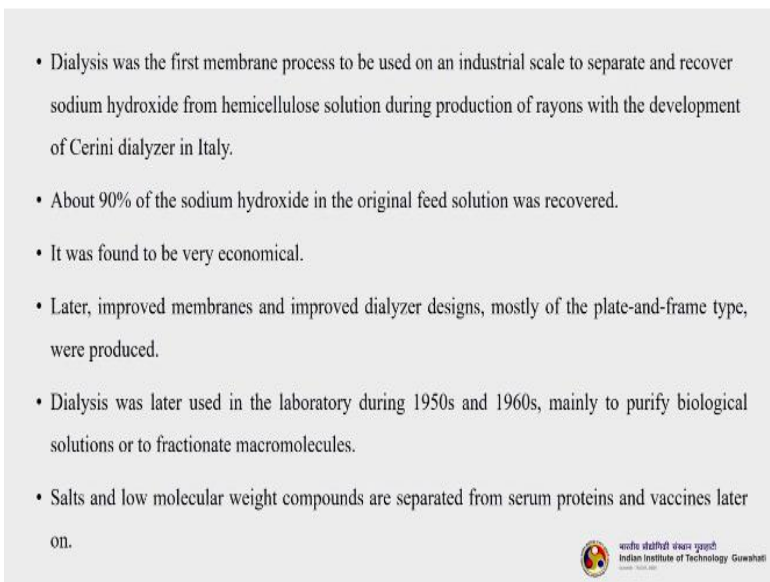

So what is happening actually during the production of rayons the hemicellulose are getting mixed with sodium hydroxide to a very high concentration. So in sodium hydroxide is very costly and in industrial parlance it is better, if you can recover sodium hydroxide from the hemicellulose solution. Using the Cerini dialyzer about 90 % of the sodium hydroxide in the original feed solution was recovered.

So it was found to be the process was found to be extremely economical. So later on the cerini dialyzer was modified and adopted in various industrial purposes. So, further improved membranes and improved diligent designs mostly of the plate and frame type where produced. Dialysis was later use the laboratory during 1950s and 60s mainly to purify biological solutions, or to fractionate macromolecules.

Later on salts and low molecular weight compounds are separated from serum proteins and vaccines in the year 1960s and beyond that.

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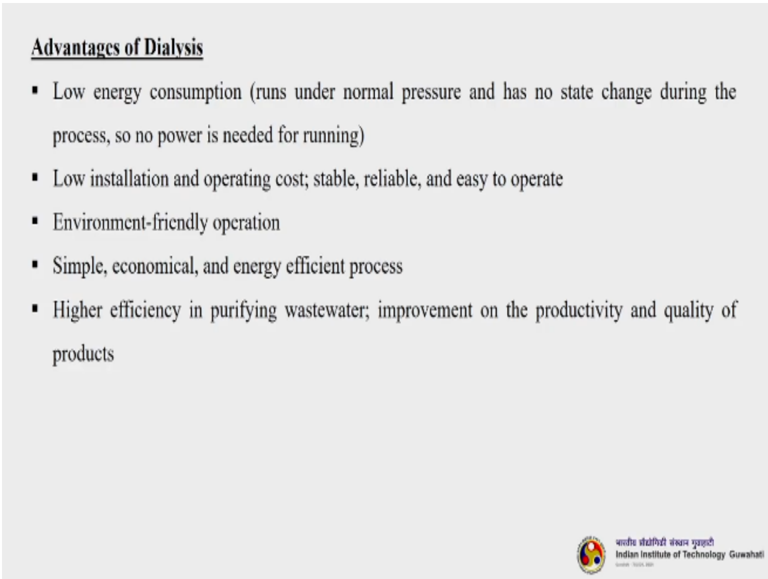

If you look at the advantages of dialysis, so low energy consumption is one of the most important advantages. Because you do not know an external force so you do not need energy.

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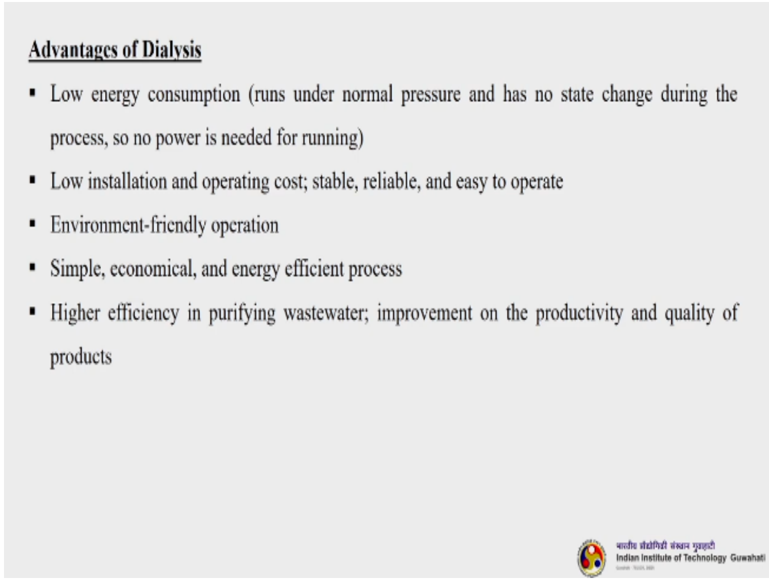

So it runs under normal pressure and has no states change during the process, so no power is needed for running. So it has a low installation and operating cost, it is stable, reliable and easy to operate, it is an environmental friendly operation, it is simple, economical and energy efficient process, higher efficiency in purifying waste water; improvement on the productivity and quality of the products. So these are some of the advantages of dialysis.

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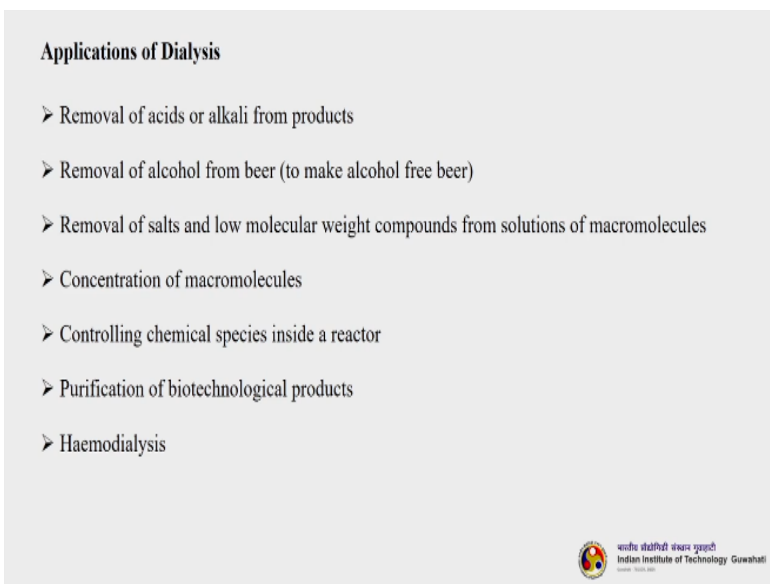

So the applications of dialysis are innumerous. Numerous applications are there. So removal of acids and alkali from products, removal of alcohol from beer to make alcohol free beer, removal of salts and low molecular weight compounds from solutions of macromolecules, then concentration of macromolecules, controlling chemical species inside a reactor, purification of biotechnological products, haemodialysis, these are actually some of the applications of dialysis.

We will see one or two such applications today in our subsequent discussion.

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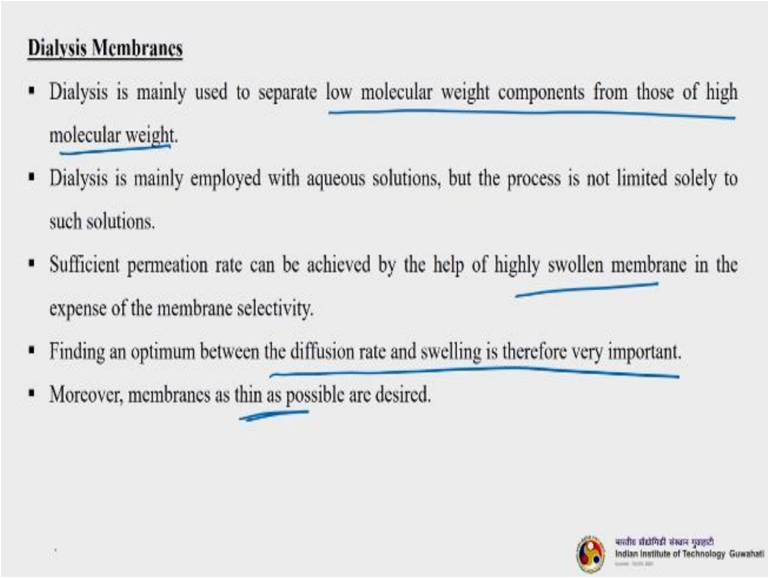

So, let us now discuss about the dialysis membranes. So dialysis membranes are very different from other usual membranes, which are employed in your ultrafiltration, microfiltration or reverse osmosis. So dialysis is mainly used to separate low molecular weight components from those of high molecular weight components. And dialysis is mainly employed with the aqueous solutions, but the process is not limited solely to such solutions.

Sufficient permeation rate can be achieved by the help of highly swollen membrane in the expense of the membrane selectivity, this is just what we have discussed, so if the membrane becomes swell the selectivity is comes down but the permeation rate or the diffusion rate of the solutes become high.

So finding an optimum between the diffusion rate and swelling is therefore very important. So, moreover membranes as thin as possible are desired.

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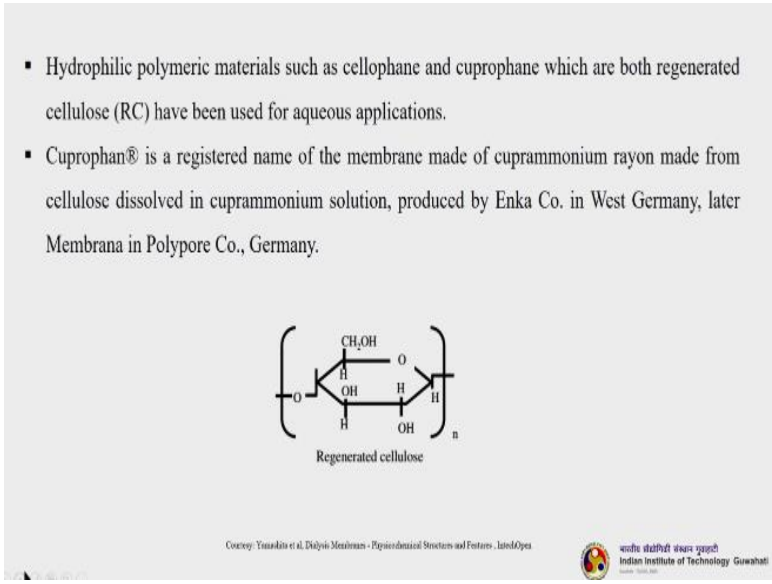

Hydrophilic polymeric materials such as cellophane and cuprophane which are both regenerator cellulose have been used for most aqueous applications. So you will see different literature different books and you will notice that most of the dialysis membranes are from RC that is Regenerated cellulose. So these regenerated cellulose is a variety of cellulose, we have discussed this in our 2nd or 3rd class when we discussed about membrane materials.

In details of the properties of cellulose membrance and properties of the regenerated cellulose.

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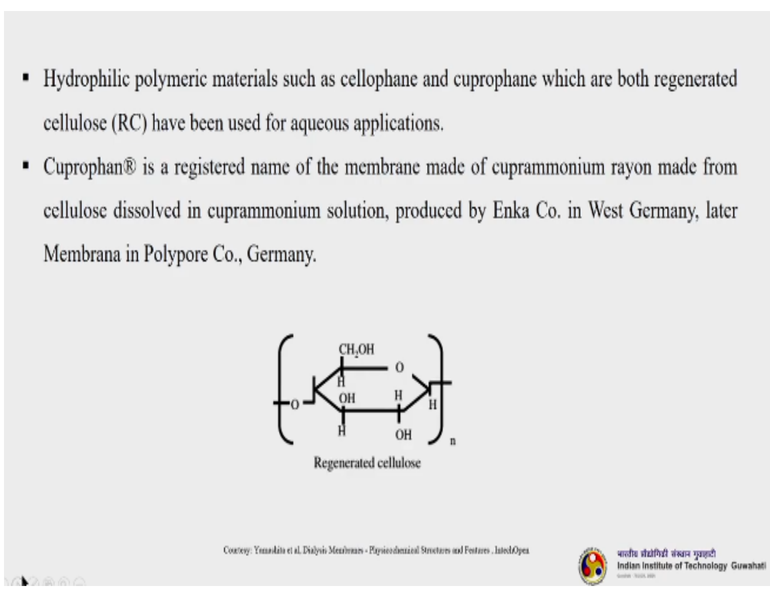

So, Cuprophan is a registerd name of the membrane made from cuprammonium rayon made from cellulose dissolved in cuprammonium solution. It is produced by Enka corporation in western

Germany, later it become the membrana in Polypore corporation Germany. So this is the structure of the regenerated cellulose.

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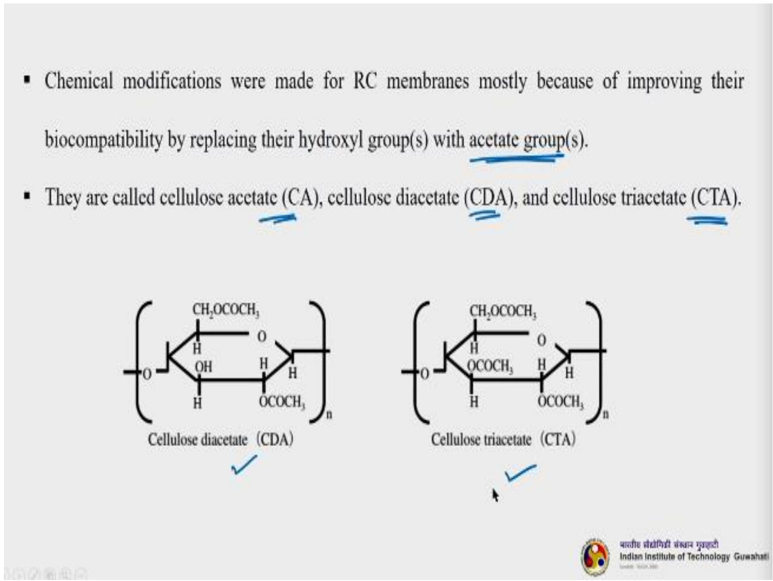

So, then chemical modifications were made for regenerative cellular membranes mostly because of improving their biocompatibility by replacing their hydroxyl groups with acetate groups, then they are called as cellular acetate. CA cellulose diacetate CDA, or cellulose triacetate CTA. So this is cellulose diacetate structure and this is cellulose triacetate structure.

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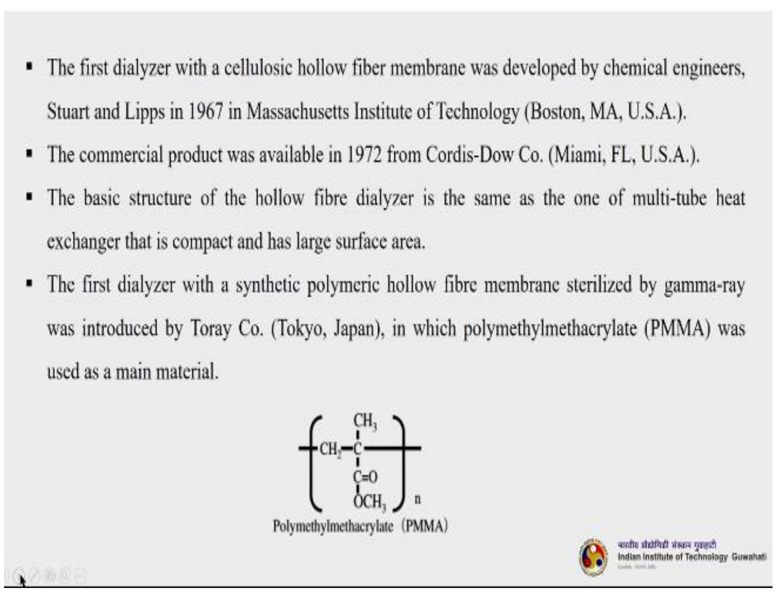

So the first dialyzer with a cellulosic hollow fiber membrane was developed by chemical engineers, Stuart and Lipps in 1967 in Massachusetts Institute of Technology that is MIT in Boston in United

States. The commercial product was available in 1972 from Cordis-Dow company, which is located in Miami in United States. The basic structure of the hollow fibre dialyzer is the same as the one of the multi-tube heat exchanger that is compact and has large surface area.

The idea is to have as in a small area, you can achieve a large surface area.

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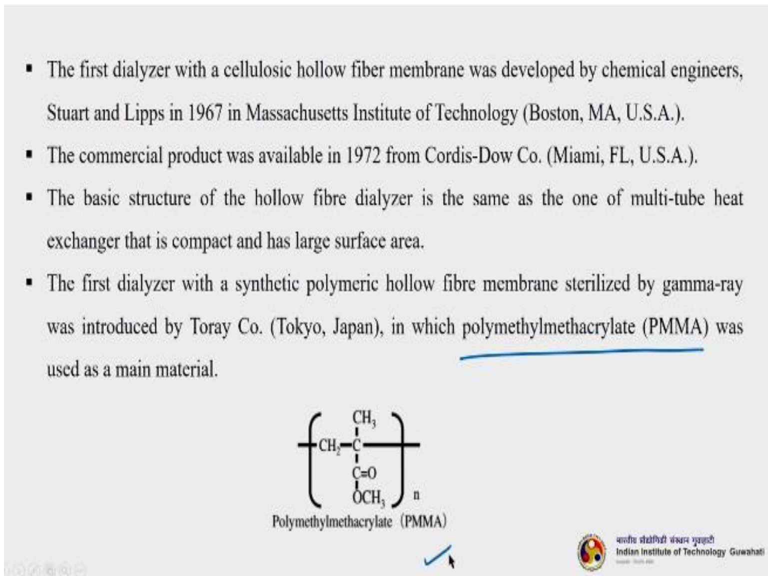

The first dialyzer with a synthetic polymeric hollow fibre membrane sterilized by gamma-ray was introduced by Toray corporation in Japan in which polymethylmethacrylate which is called as PMMA was used as the main material. So this is PMMA structure.

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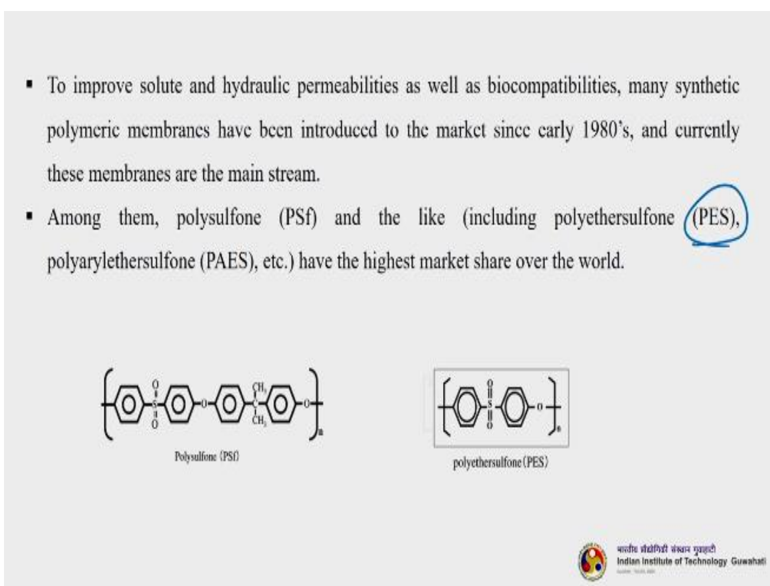

To improve solute and hydraulic permeabilities as well as biocompatibilities, many synthetic polymeric membranes have been introduced to the market since early 80s, and currently these membranes are the main stream. So among them are PSf polysulfone and the like including polyethersulfone, PES, polyarylethersulfone PAES have the highest market share although the values.The PES is very versatile and it is most widely used.

So, it is a derivative of polysulphur number polyethyl sulphur and it has the highest market cell and over the entire world.

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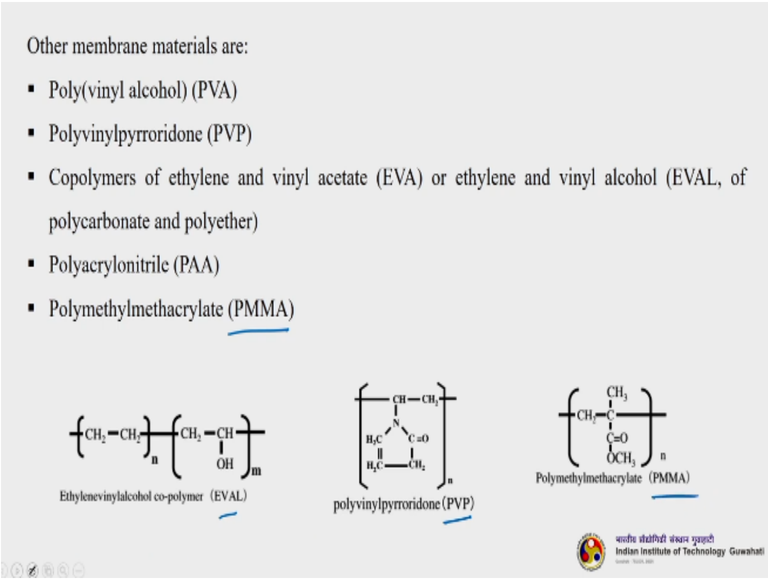

So, there are few other membrane materials also so these are called just listed here. This is PVA poly (vinyl alcohol), then PVP polyvinylpyrroridone. So copolymers of ethylene and vinyl acetate (EVA), or ethylene and vinyl alcohol (EVAL of polycarbonate and polyether), polyacrylonitrile (PAA), polymethylmethacrylate again (PMMA). So these are some of the structures of this is EVAL, this is PVP and this is again PMMA.

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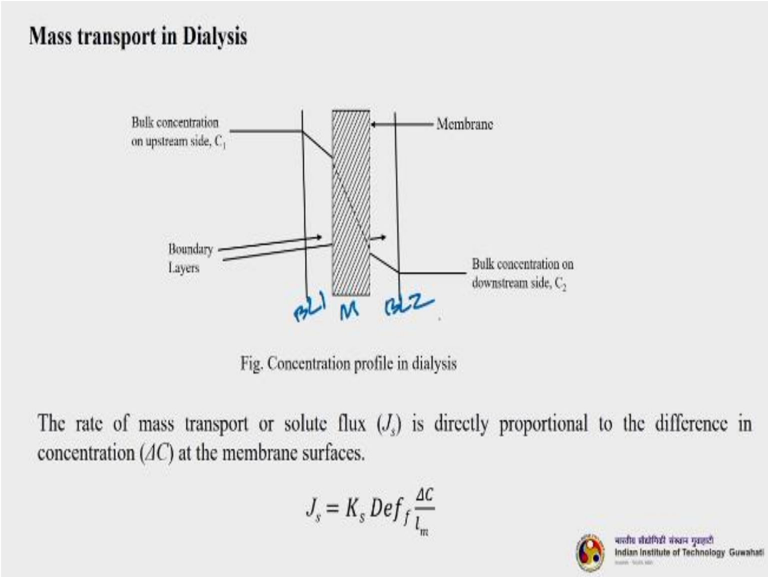

Now, let us understand the Mass transport in Dialysis. Please have a close look at this particular figure. So, this figure is telling you about the concentration profile and dialysis. So this is your membrane and this is boundary layer. So we can call this is boundary layer 1, this is boundary layer2. So we can describe the master square if when there is no boundary layer also.

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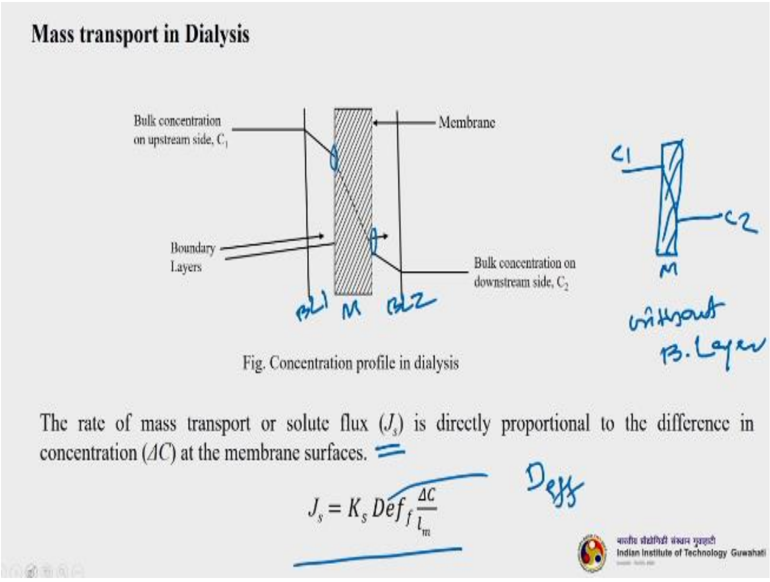

Then your membrane will become something like this. So the concentration profile will look like this it will go look this C1 and C2 so, this is membrane. So this is without boundary layer. So here it is the bulk concentration C1 then it is the bulk concentration C2 on the downstream side and then the interface concentrations are also here. So that which I have not shown here and the rate of mass transfer on the solute flux, just what is our interest?

Our interest is to calculate solute flux, because here the solute is getting transported not the solvent is getting transported. So we are will be calculating the solute flux. So the Js or the solute flux is directly proportional to the difference in concentration at the membrane surface. So you can write Js equals to Ks D effective. So this is actually Deff effective diffusivity then delta c / lm.

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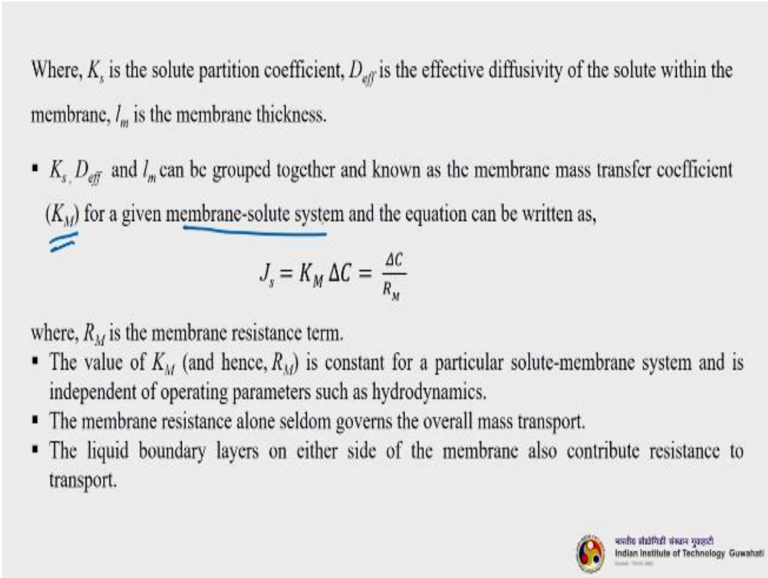

So, Ks is the solute partition, Deff is the effective diffusivity of solute within the membrane and lm is the membrane thickness. Ks, Deff, and lm, these are all constant and then can be grouped together and that can be known as the mass transfer coefficient (Km) for a given membrane solute system. Please remember that Km is fixed for a membrane and a solute system a particular system.

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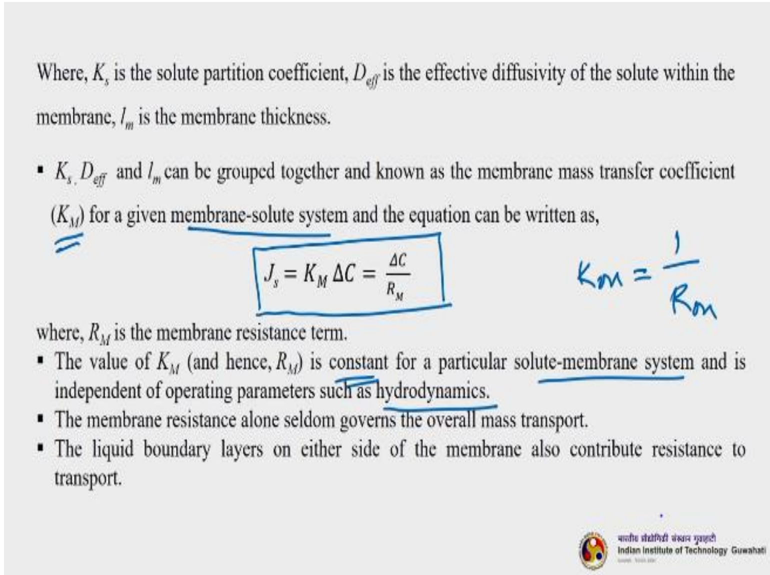

And the equation can be written as so Jsequals to Km deltaC or deltaC/Rm. So, you know that Km is reciprocal of 1/Rm. So Rm is the membrane resistance term. Now the value of Km and hence Rm is constant for a particular solute-membrane system and is independent of operating parameters such as the hydrodynamics of the modules. So the membrane resistance alone seldom governs, there are overall mass transport. The liquid boundary layers on either side of the membrane also contribute resistance to transport.

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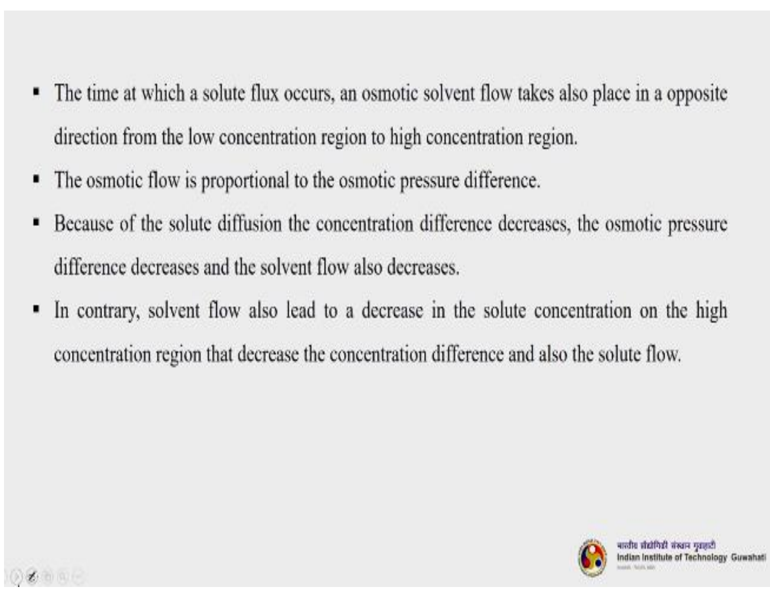

So, the time at which a solute flux occurs and osmotic solvent flow also takes place in opposite direction from low concentration region to high concentration region. The osmotic flow is proportional to the osmotic pressure difference. Because of the solute diffusion the concentration difference decreases the osmotic pressure difference decreases and the solvent flow also decreases. In contrary, solvent flow also lead to a decrease in the solute concentration on the high concentration region that decreases the concentration difference and also the solute flow.

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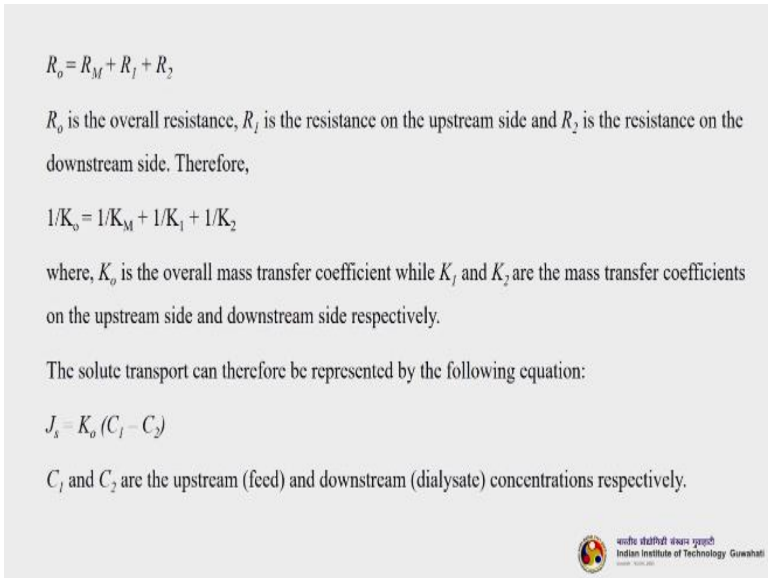

So, you can write the overall resistance as Ro equals to Rm+R1+R2. Where Ro is the overall resistance, R1 is the resistance on the upstream side and R2 is the resistance on the downstream side. We therefore can write that 1 over K0 equal to 1 over Km+1 over K1+1 over K2, you know, that resistance has can be added in series similarly the mass transfer coefficient also expressed in series. So, K0 is the overall mass transfer coefficients.

In K1 and K2 are the masses transfer coefficients on the upstream side and downstream side respectively. So the solute transport can therefore be represented by the following equation, so Js equals to K0(C1-C2) where C1 and C2 are upstream feed and downstream dialysate concentrations respectively.

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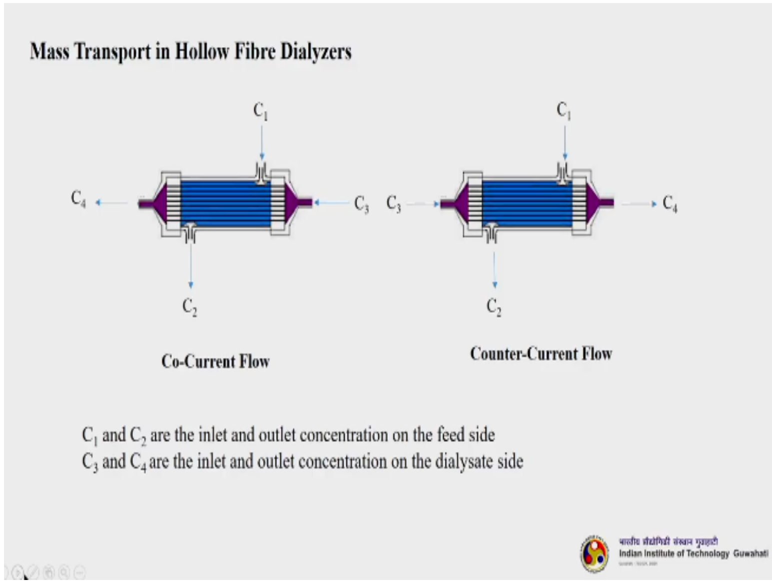

So, please have a look at this is mass transport in hollow fiber dialyzers. So you can see there are two different types of dializers I have shown here 1 is for the Co-Current Flow and another is their Counter-Current Flow. In the co-current flow the feed and the dializers are flowing in the same direction. So, it is coming like this and it is flowing in the same direction. And in the counter-current flow it is in the opposite direction.

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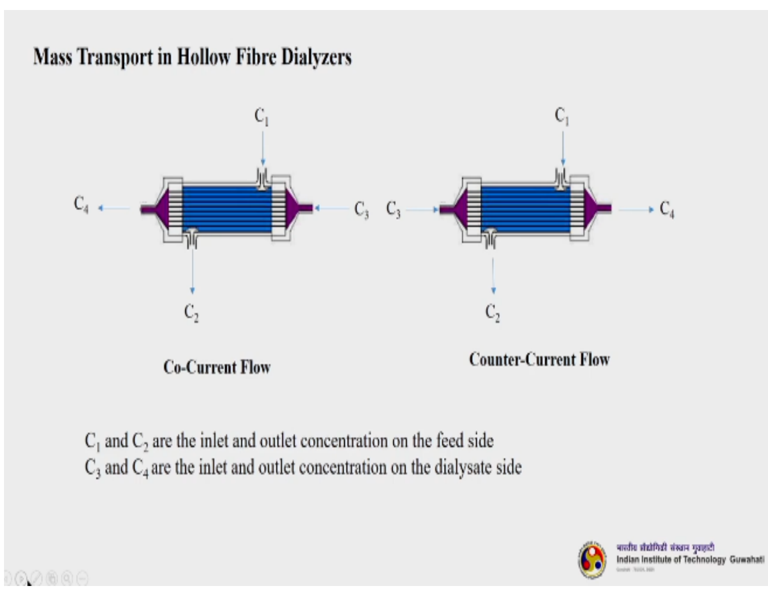

So, C1 and C2 are the inlet and outlet concentration on the feed side and C3 and C4 are the inlet and outlet concentration of the dialysate side.

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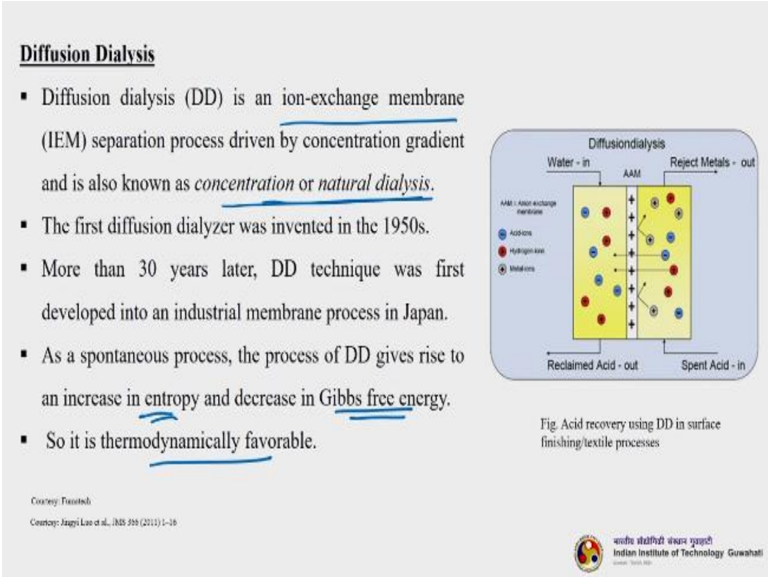

Let us discuss about diffusion dialysis. So let us understand what is diffusion dialysis. So, diffusion dialysis is an ion-exchange membrane separation process. Now here the membrane, is ion external membrane, driven by concentration gradient and is also known as the concentration or natural dialysis. Mostly it is also known as Donnan dialysis due to the donnan equilibrium constant. So the first diffusion dialyzer was invented in the early 1950s.

More than 30 years later, diffusion dialysis technique was first developed into an industrial membrane process in Japan. As a spontaneous process the process of DD or diffusion dialysis gives rise to an increase in entropy and decrease in Gibbs free energy. Hence, it is thermodynamically a favorable separation. You know, what is donor dialysis? So, when charged solutes are separated using a membrane, ion-exchange membrane either a cation exchange or anion external membrane.

Then, there is differences in the solute concentration on both sides of the membrane. So, that they do not form an equilibrium. That means, whatever solute is here in the upstream side, the same solute is not is in equilibrium in the opposite side .That means, there is difference in concentration, due to the diffusivity and the membrane properties and there are so many things .So, these are actually this is known as donnan equilibrium.

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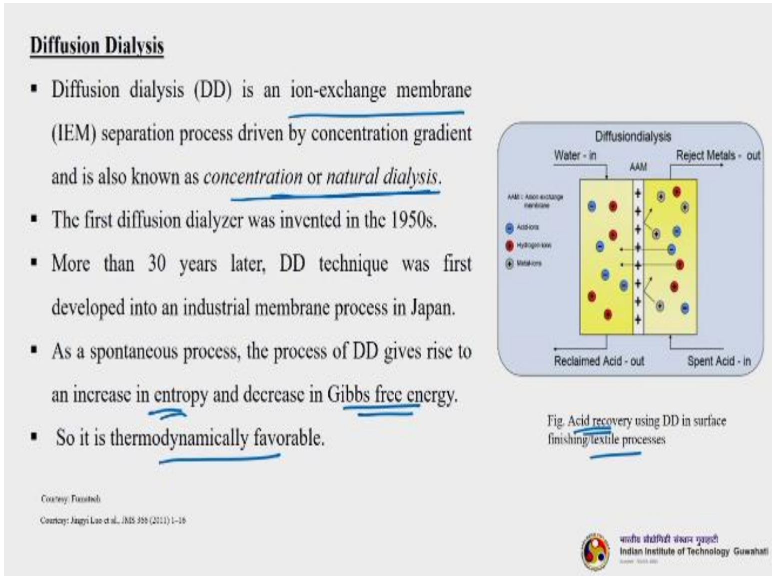

You can see, this is in classic example of acid recovery using donor dialysis process a diffusion dialysis or donor elect in surface finishing or textile processes. So in most of the surface finishing and metal manufacturing companies as well as textile industries, you will have spent acid back. Spent acid back content, so many different types of metals also. Now acid is a available product, it has to be recycled.

Otherwise then the cost of the process will increase unnecessarily. So now you need to treat it. So, treatments what you need to recover the acid. So the diffusion dialysis plays a big role in this acid recovery.

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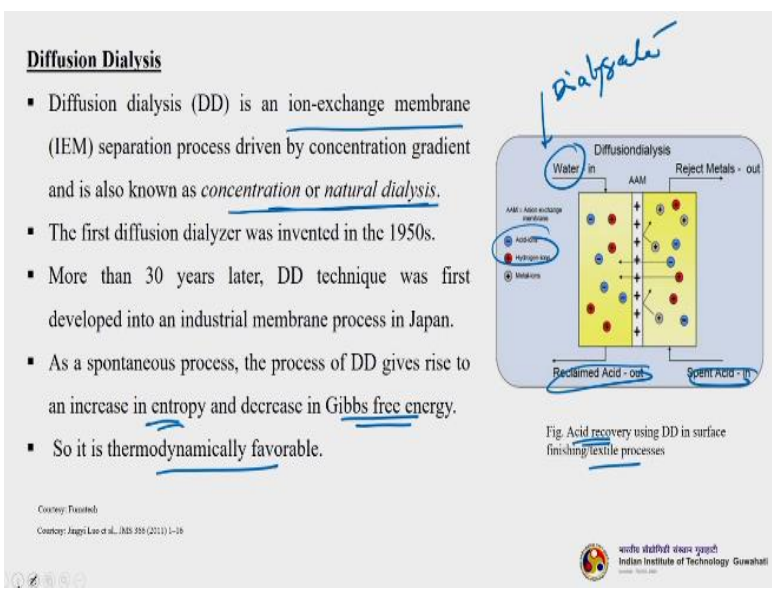

So, you can see how it is happening. The spent acid is being fed to the membrane, where it is aam, aam means a anion exchange member. That means this membrane is exchanging anions and it has fixed cationic charges. So, that is why cation sign is being imparted on them. The surface that cations are fixed to the membrane it interacted anions. So you can see here, then this blues are actually acid ions, red ones are hydrogen ions and this gray ones are metal ions.

And so, metal ions is very big that is why it is getting rejected and it is return on the surface of the membrane due in the upstream side. Whereas the hydrogen ions and acid ions, they are being low in size at permeating through the membrane. So that is why acid is getting the hydrogen ion and acid ions are getting into the downstream side. So that is what the acid is getting into the ground stream side and we can get that acid here. and as a dialysis you can flow water here. So this is a dialysate.

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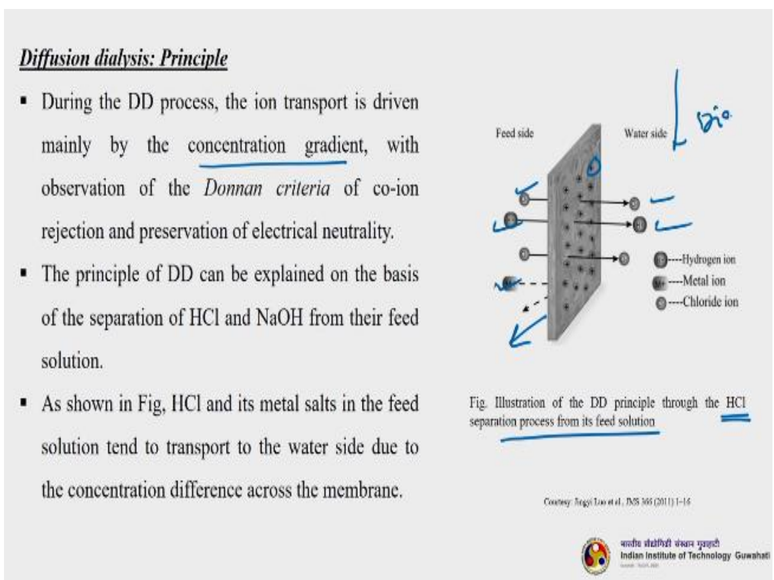

In another example, this is illustration of diffusion dialysis principle, for HCl separation from its feed solution. Now during, the diffusion dialysis process ion transport is driven mainly by the concentration gradient. So with the observation of the Donnan criteria co-ion rejection and preservation of electrical neutrality. So, the principle of DD can be explained on the basis of the separation of HCl and NaOH from their feed solution.

As shown in this figure, please see this as HCL and its metal salts in the feed solution tend to transport to the water side due to the concentration difference across the membrane. So, this is a anion exchange membrane. So it has fixed cationic groups. So, the feed side we have chloride and we have hydrogen ions and we have metal ions. So the metal ions are large in size. So it is getting rejected here whereas chloride ions as well as hydrogen ions are getting separated to the water side. So, this is the dialyzer side.

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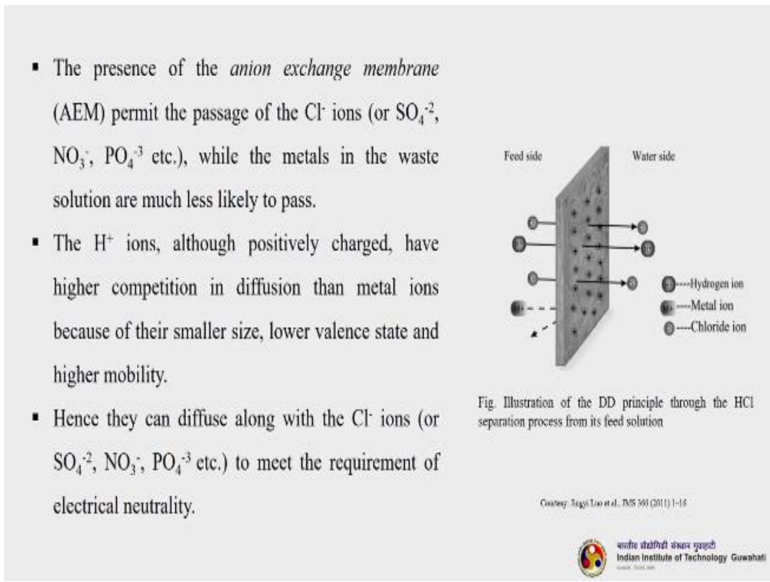

So, the presence of anion exchange membrane permeate the passage of a Chlorine ions which is negatively charged or sulphate or nitrate or phosphate ions all of them which are negatively charged while the metals in the waste solution are much less likely to pass because the size is big and there will be due to opposite charges it will be repelled also.

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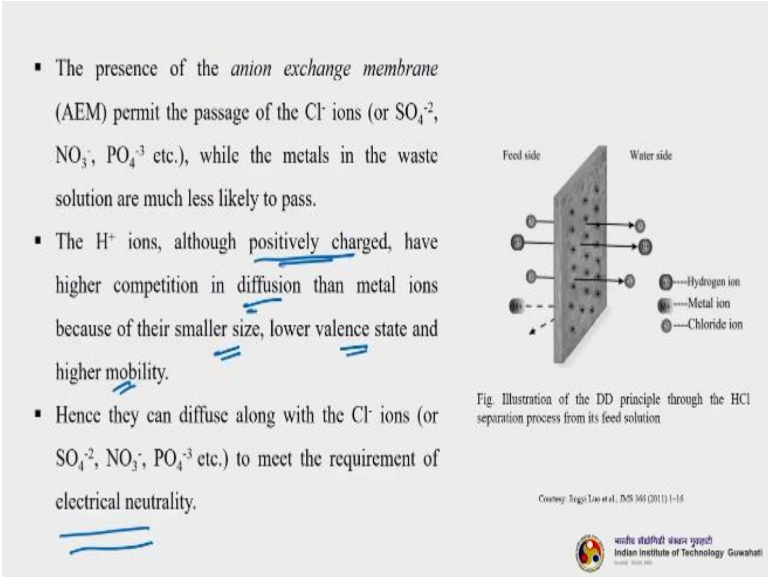

So the Hydrogen + ions although positively charge, have higher competition in diffusion then metal ions because of that smaller size lower valence state and higher mobility, so you can always ask that why the hydrogen being positively charged is not getting rippled. It will, it is not getting rippled that is the reason is that the size is very small. So, its rate of diffusion is so fast then the metal ions.

So in comparison the hydrogen ions are getting diffused, through the pores, and they can diffuse along with the chloride ions or sulphate, nitrate or phosphate ions to meet the requirement of the electrical neutron.

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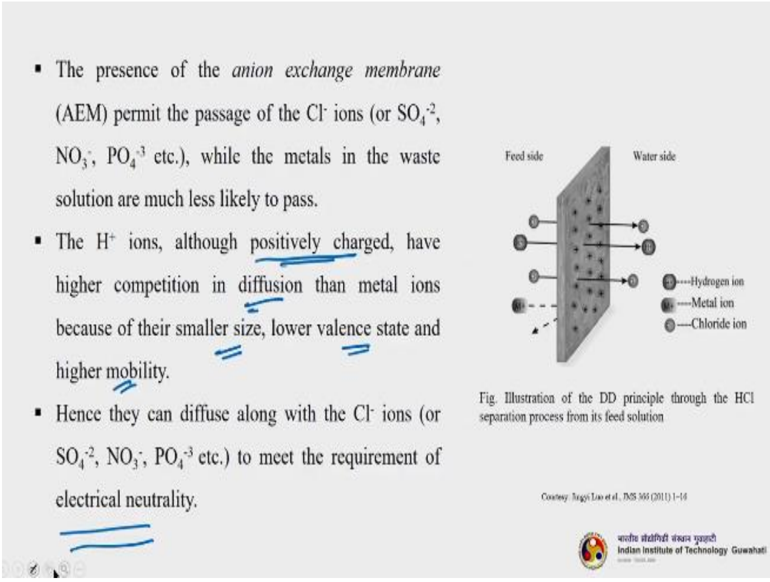

So to requirement of the electrical nutrient when neutrality when 1 charged membrane is separating positively and negatively charged ions, so the electrical neutrality has to be maintained .So due to this also the cations and anions transport opposite direction many times to maintain this neutrality.

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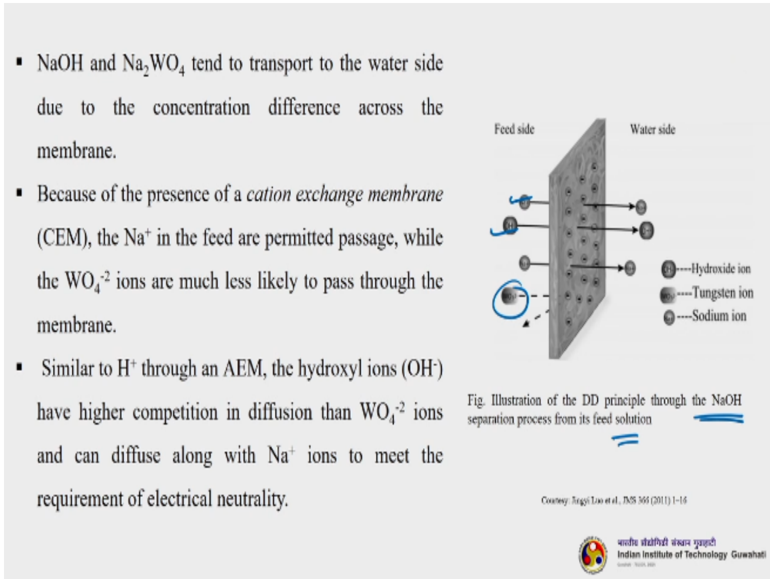

So this is another example in which sodium hydroxide separation is happening from its speed solution. The feed side content (NaOH) sodium hydroxide ions and then it has (Na2WO4) tungstate ions. these are tungstate ions are big ions. So sodium hydroxide and sodium tungstate tend to transport to the water side due to the concentration difference across the membrane. So here there is no ions. So obviously everything will try to pass.

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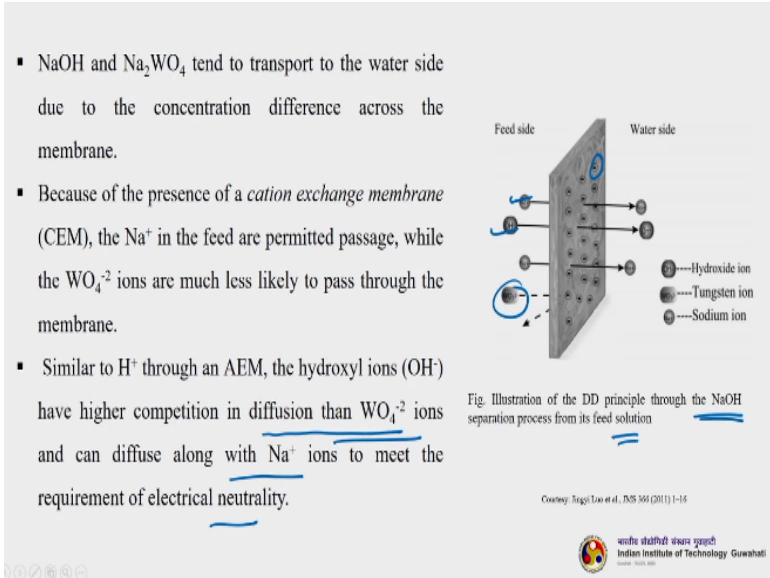

Because of the presence of a cation membrane with having fixed anions. The sodium + in the feed are permitted while as a tungstate - ions are much less likely to pass through the membrane. So it is getting repelled and due to size also it is not passing through the membrane. So, similar to Hydrogen + through an anion exchange membrane the hydroxyl ions have higher competition and diffusion than tungstate ions and can diffuse along with Sodium + ions to meet the requirement of the electrical neutrality.

Again the same concept here the inspired having the hydroxyl group is the same negatively charge. It is passing through because of the smaller size and to maintain again the electrical neutrality. Electrical neutral concept come into picture. When you will have a membrane that is either cation exchange membrane or anion exchange membrane.

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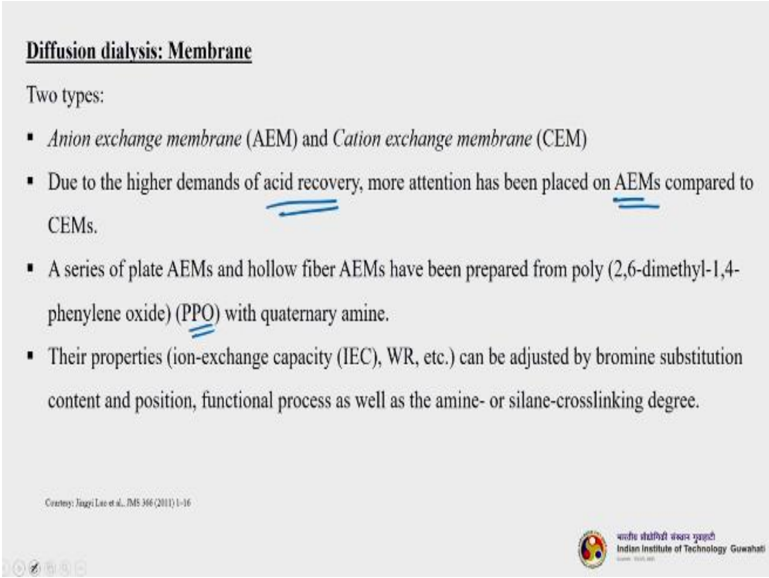

Let us discuss about the membranes. So 2 types of membrane basically either 1 have anion exchange membrane or cation exchange membrane. So due to the high demands of acid recovery in industrial parallel sector actually so more attention has been placed on anion exchange membranes compared to cation exchange membranes. So it is application is more that is why lot of work is done on anion exchange membranes.

So a series of plate anion exchange membranes and hollow fiber anion exchange membranes have been prepared from poly (2,6-dimethyl-1,4-phenylene oxide)which is known as PPO with quaternary amine. Their properties that is ion-exchange capacity, water retention capacity extractor can be adjusted by bromine substitution content and position, functional processes as well as amine or silane crosslinking degree.

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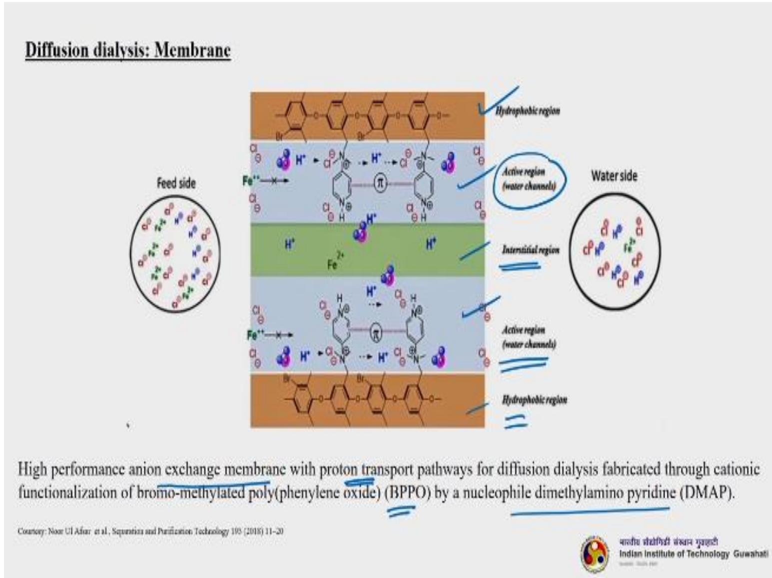

So, this is one classical example of a high performance anion exchange membrane with proton transport pathways. So, ions will transport but diffusion dialysis fabricated through cationic functionalization of bromo- methylated poly, or BPPO membrane by nucleophile dimethylamino pyridine DMAP. So you can see there are 1, 2, 3 ,4, 5 bridges .The 1st region is the hydrophobic region followed by a active region the water channel through which actually here protons will transport or chlorine items will also transport.

Then we have a interstitial region, .then we have a active region water channels. Then we have again a hydrophobic regions. So this region, this region, this region so these are actually the regions in through which here protons and chloride ions and all these ions transport will takes place. See this, why there are different types of membrane together to enhance ion selectivity of a particular ion transport.

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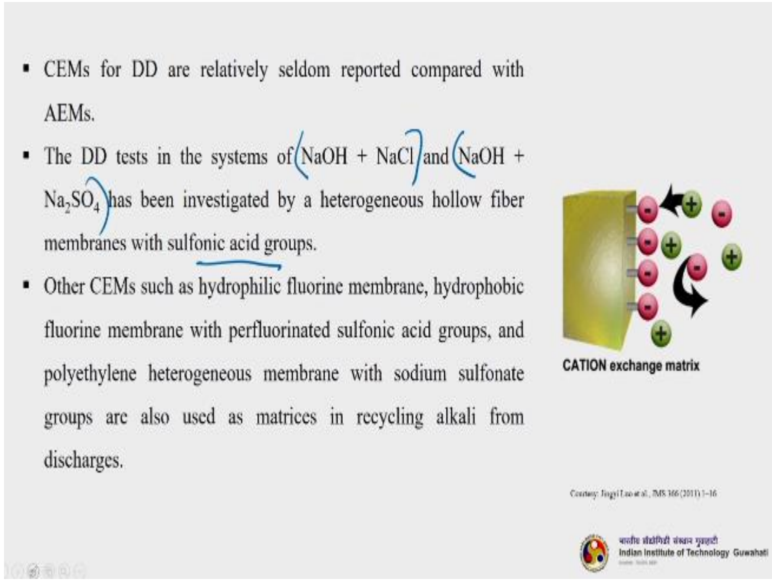

So, Cation Exchange Membranes for Diffusion Dialysis are relatively seldom reported compared with the AEMS. I already told that AEMs lot of applications in a district. So the deposition dialysis test in the system of Sodium hydroxide +NaCl, this is one composite system or Sodium hydroxide and it is so Na2SO4 sodium sulphate has been investigated by a heterogeneous hollow fiber membranes with sulfonic acid groups.

So, other CEMs such as hydrophilic fluorine membrane, hydrophobic fluorine membrane with perfluorinated sulfonic acid groups, and polyethylene heterogeneous membranous sodium sulfonate groups and also used as matrices in recycling alkali from discharges.

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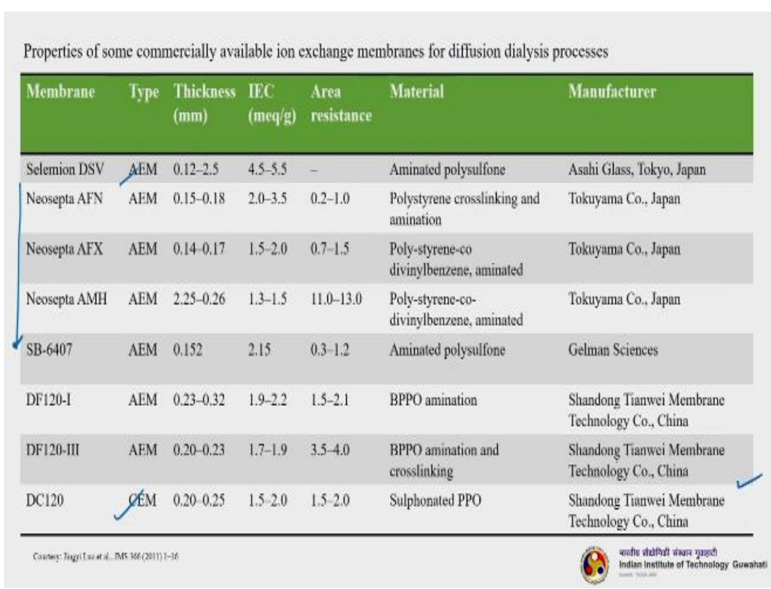

Properties of some commercially available ion exchange membranes for diffusion dialysis processes

Membrane	Type	Thickness (mm)	IEC (meq/g)	Area resistance	Material	Manufacturer
Selemion DSV	AEM	0.12–2.5	4.5–5.5	–	Aminated polysulfone	Asahi Glass, Tokyo, Japan
Neosepta AFN	AEM	0.15–0.18	2.0–3.5	0.2–1.0	Polystyrene crosslinking and amination	Tokuyama Co., Japan
Neosepta AFX	AEM	0.14–0.17	1.5–2.0	0.7–1.5	Poly-styrene-co divinylbenzene, aminated	Tokuyama Co., Japan
Neosepta AMH	AEM	2.25–0.26	1.3–1.5	11.0–13.0	Poly-styrene-co-divinylbenzene, aminated	Tokuyama Co., Japan
SB-6407	AEM	0.152	2.15	0.3–1.2	Aminated polysulfone	Gelman Sciences
DF120-I	AEM	0.23–0.32	1.9–2.2	1.5–2.1	BPPO amination	Shandong Tianwei Membrane Technology Co., China
DF120-III	AEM	0.20–0.23	1.7–1.9	3.5–4.0	BPPO amination and crosslinking	Shandong Tianwei Membrane Technology Co., China
DC120	CEM	0.20–0.25	1.5–2.0	1.5–2.0	Sulphonated PPO	Shandong Tianwei Membrane Technology Co., China

So, this table shows you the properties of some commercial available ion exchange membrane for diffusion dialysis process. So, you can see these are the membrane trade names actually are given here. The types are also given here and AEM all these things this is the only one CEM here, the thickness is given, the ion exchange capacity is given, area resistance is given, that the material is given. Other company name on the manufacturer name is also given.

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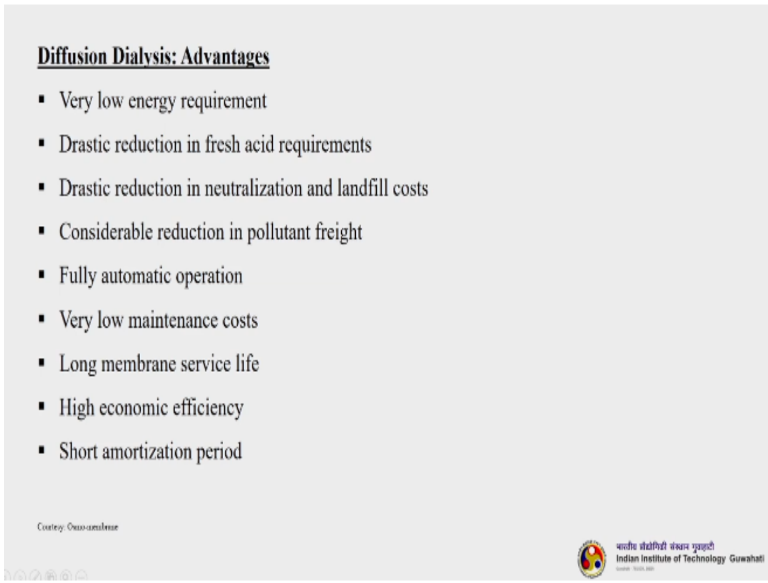

So, the advantages of diffusion dialysis is it is very low energy requirement on energy efficient process. Drastic reduction in places requirements. Drastic reduction in neutralization and landfill costs. Considerable reduction in pollutant freight. Fully automatic operation, very low maintenance costs. Long membrane service life. High economic efficiency and short amortization period. Amortization means when you have taken some loan and have some mortgage and all these things, .

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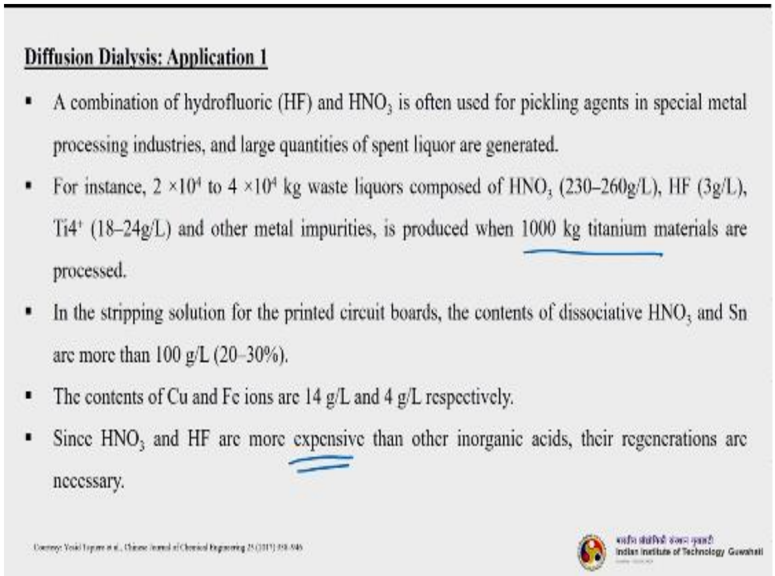

Let us see to applications. The first application is the present dialysis. So a combination of Hydrofluoric and HNO3 is open used as pickling agents in special metal processing industries. And large quantity of spent liquor are generated which contains both these acids for instance 2 into 10 power of 4 to 4 into 10 power of 4 kg of waste liquors composed of a Nitric acid about 230 - 260 g/L and Hydrofluoric acid about 3 g/L then Titanium 4 + about 18 - 24 g/L and other metal impurities is produced.

And 1000 kg of titanium materials are processed, so it is a huge amount of spent liquor actually containing so many available components. So in the stripping solution for the printed circuit both the contents of dissociative, Nitric acid and tin are more than 100 g/L. So almost 20- 30% and the contents of Copper and Irons are 14 g/L and 4 g/L respectively. Since Nitric acid and Hydrofluoric acid are more expensive than other inorganic acids, so there region themselves are necessary for industrial parallel actually.

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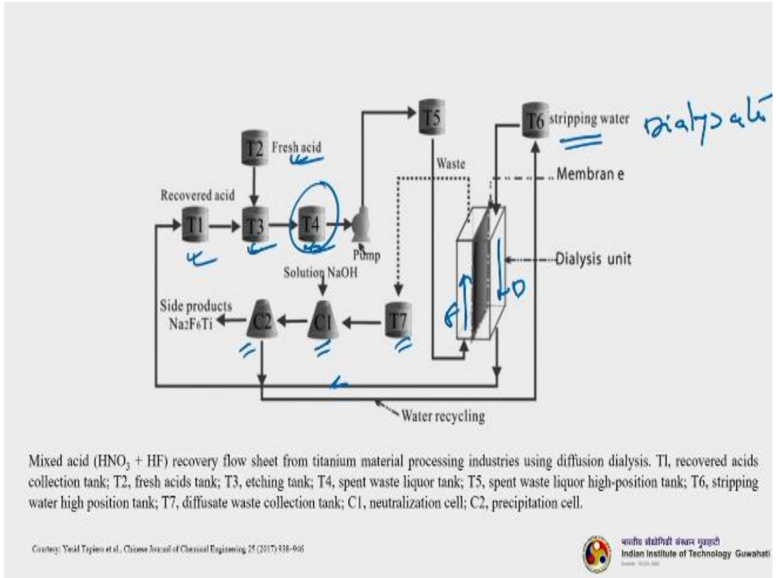

So this is how, actually this is a schematic diagram of regeneration of spent acids. Where I mixed of Nitric acid and Hydrofluoric acid is getting recovered. So you can see this T1 is the recovered acid collection tank here. T2 is the fresh acid tank, then T3 is the etching tank where it is being carried out then T4 is the spent waste liquor tank, from here actually our process of this recovery starts, so then it is pumped and its goes through a dialysis unit, you can see here.

And from here, we are supplying dialysis the stripping water or we can call it a dialyzer. OPR Water is being supplied here in the reverse direction, so you see this is the direction of visualization of heat. This is the direction of dialyzer in counter current operation and then the recover acid here it is getting recycle to the recovery acid tank and C1 is the neutralization cell here and C2 is the precipitation cell.

So this is actually taking, T7 is the one which is the waste collection tank or the dialysate waste collection tanks, so it is containing this metals. So, the needs to be percipitated and then needs to be recovered. So the C1 is neutralization and C2 is precipitation cell. So this is an schematic of we can understand from this actually, how the recovery of mixed acids are carried out in industries.

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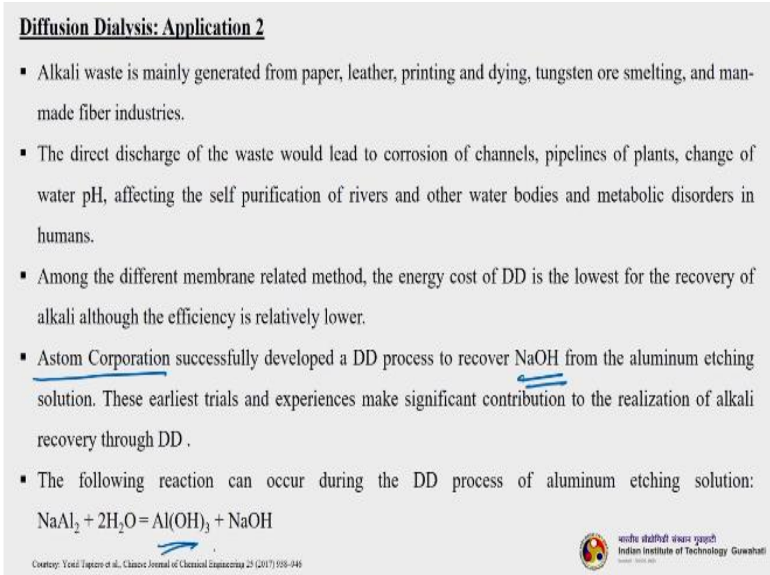

The next application is regarding alkali waste. So, alkali waste is mainly generated from paper, leather, printing, and dying, in the street tungsten or smelting otherwise fiber industries. So the direct discharge of the wastes would lead to corrosion of channels, pipelines of plants, change of water pH, affecting the self purification of river and other water bodies and metabolic disorders in humans. Among the different membrane related methods, the energy cost of Difussion Dialysis is the lowest for the recovery of alkali through the efficiency though, the efficiency is relatively lower.

Astom Corporatiion successfully devoleped a DD process to recover Sodium hydroxide from aluminium etching solution. These earlier trials and experiences make significant contribution to the realization of alkali recovery through Difussion Dialysis process. The following reaction can occur during the DD process for aluminum etching solution. So Sodium aluminate +2 water will give you aluminium hydroxide warm act + sodium hydroxide.

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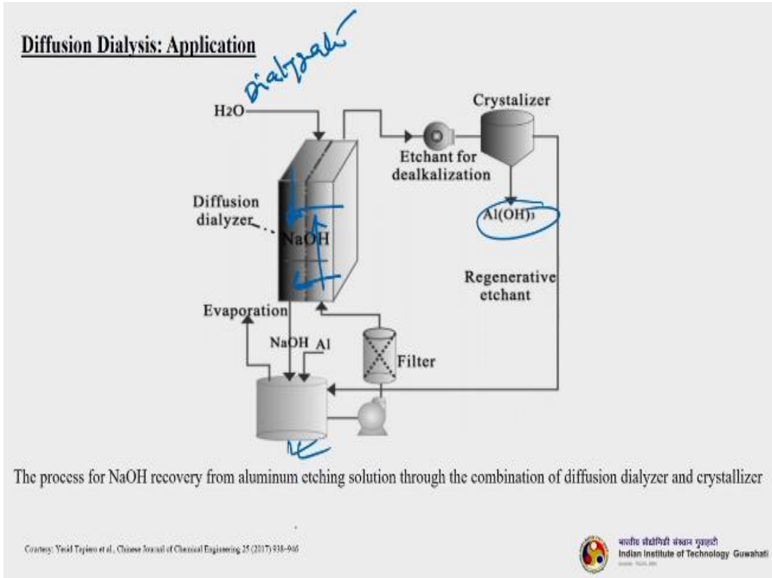

So this is the process of recovery of Sodium hydroxide. So you can see here this is actually the tank which is containing the Sodium hydroxide and Aluminium. So it is being pumped to here so this is the feed flow and from here this is the dialysis flow . So this is water, is being passed through in the reverse direction of the feed flow. So then the Sodium hydroxide transport occurs from here to here. So the Sodium hydroxide is getting collected in the dialysis side and again getting recycle with here.

And whatever the spent, what about the purifier echoes solution without Sodium hydroxide is coming? So that goes to crystallization. Where you can call alumina or this Alumina hydroxide and that the etchant is recycled back to the Sodium hydroxide recovery tech.

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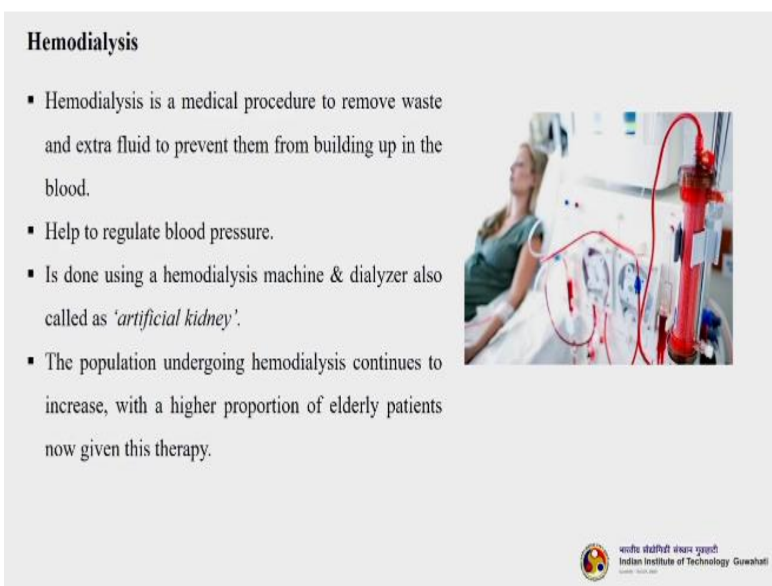

You know, hemodialysis is one of the most important application of the dialysis process. Now hemodialysis is the medical procedure to remove waste and extra fluid to prevent them from building up in the blood.

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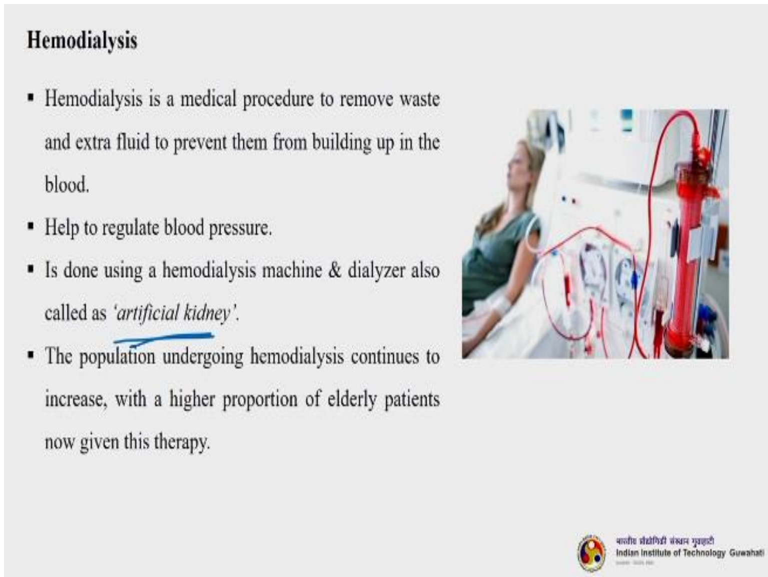

So, it helped to regulate blood pressure is done during a hemodialysis using a hemodialysis machine and the dialyzer. The dialyzer also known as a artificial kidney. So in 1960 artificial kidney to came into picture. The population undergoing hemodialysis continues to increase, with the higher proportion of elderly patients now given this therapy. You can see how this is being done actually.

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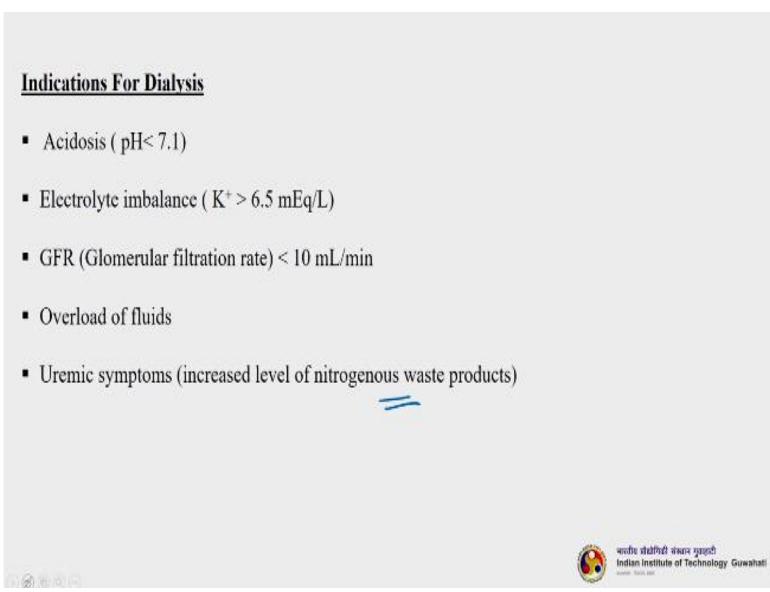

So, when you will decide the dialysis is required, so when the acidosis that is pH becomes less than 7, 7.1. But electrolyte imbalance will happen, that means, let us for example the potassium ion concentration becomes more than 6.5 will equivalent for latest and then otherwise when Glomerular filtration rate GFR is less than 10 ml/min. Then overload of fluids and Uremic symptoms, of course increase level of nitrogenous waste products.

So if all these things are happening in a human body, then you need to go for dialysis.

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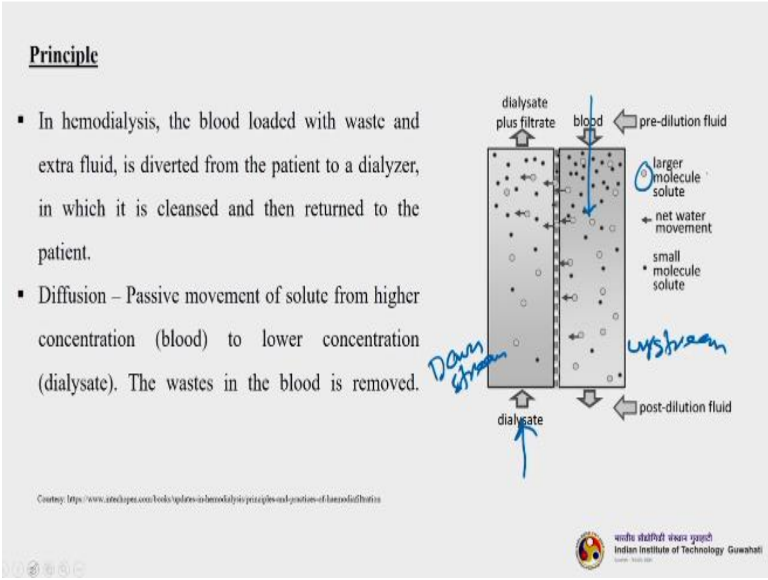

So, the principle is something like this. So in hemodialysis the blood loaded with waste and extra fluid, is diverted from the patient to a dialyzer, in which it is cleanest and then return to the patient. So, diffusion passive movement of solute from higher concentration blood to lower concentration dialysis these waste in the blood are removed. So, you can see the blood is pumping through the dialysis unit this is the feed side or upstream side.

And this is downstream and you are pumping a dialyzer may be water or a buffer solution in the opposite direction, in a direction that is opposite to the field direction, you can see the large molecular solutes, ok there will be return here and very few will only pass through, so net water movement and small molecular solids doing pass through.

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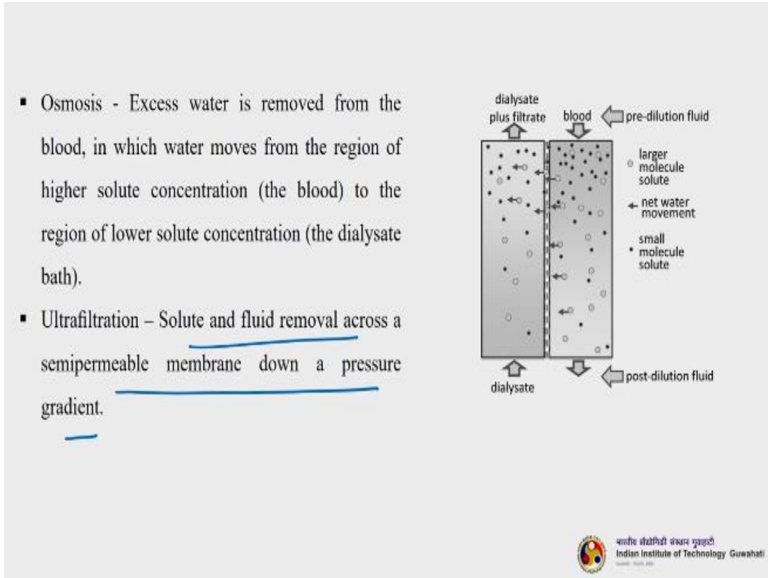

So, excess water is removed from the blood in which water moves from the region of higher solid concentration that remains the blood to the region of lower solid concentration the dialysate bath. Ultrafiltration is used in the next step so solute and fluid removal across the semipermeable membrane down the pressure gradient is being carried out after it passes through the dialyzer or dialysis membrane.

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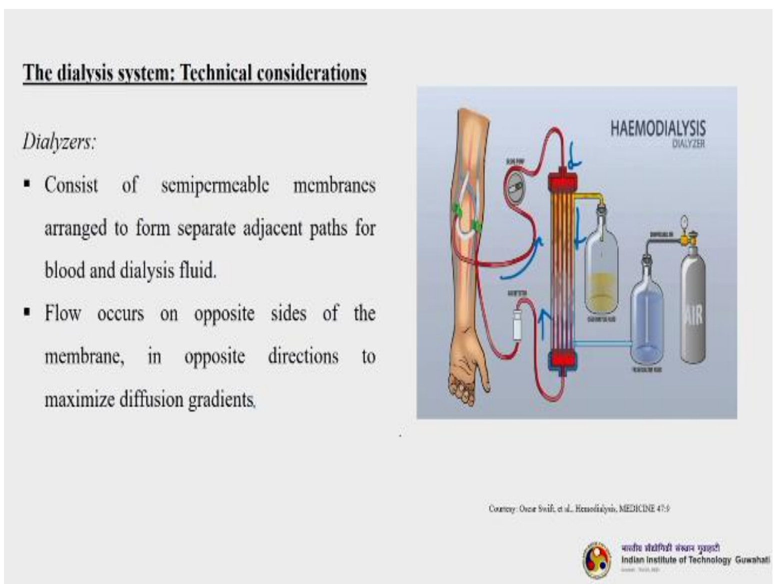

So, different types of dialyzers are actually available. So the dialyzers is consist of a semipermeable membrane arrange to per separate adjacent paths for blood and dialysis fluids. So of course on opposite sides of the membrane in opposite directions to maximize diffusional gradients, so you can see here this is a dialyzer actually, so here the blood is getting pumped and it is coming like this then the and the blood is flowing from this direction then you are passing here buffer solution, or you can call dialysate or it will be water also.

Through this side in the opposite direction to the blood flow, then the separation occurs. And whatever you are getting here is getting collected that is understood the logarithm of salts. And the ones the blood is purified, its volume is reduced as well as the toxic components are removed then the blood is feedback to the human body again.

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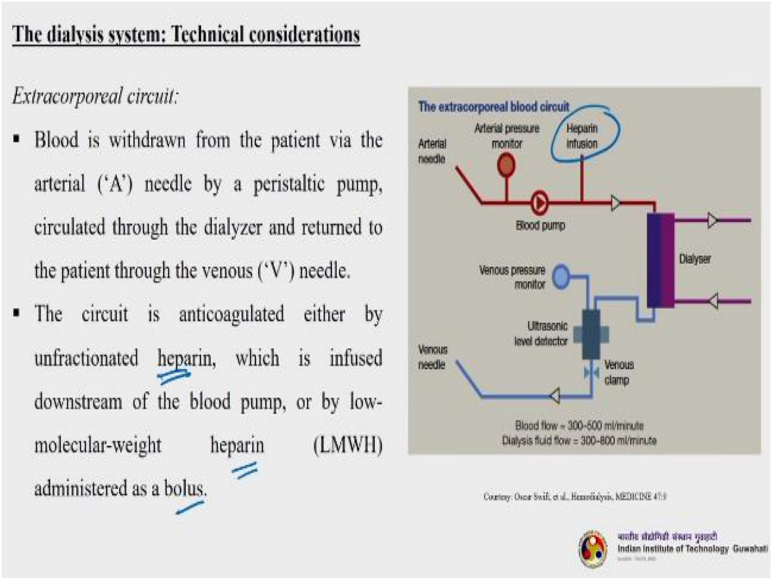

So, extract corporeal circuit so blood is withdrawn from the patient via arterial by a peristaltic pump, circulated through the dialyzer and return to the patient through the venous needle. So by arterial, pump or arterial needle the blood is being pumped out from the patient to that to the dialysis and in the after the dialysis is over the blood is again, the clean blood is being pumped back to the human or the patient using a venous needle.

So the circuit is anticoagulated either by unfractionated heparin, which is infused downstream of the blood pump, or by low molecular –weight heparin administrated as a bolus. So what is heparin infusion is taking place? Heparin is a anticoagulant. So it will, not allow the blood to coagulate or settle down.

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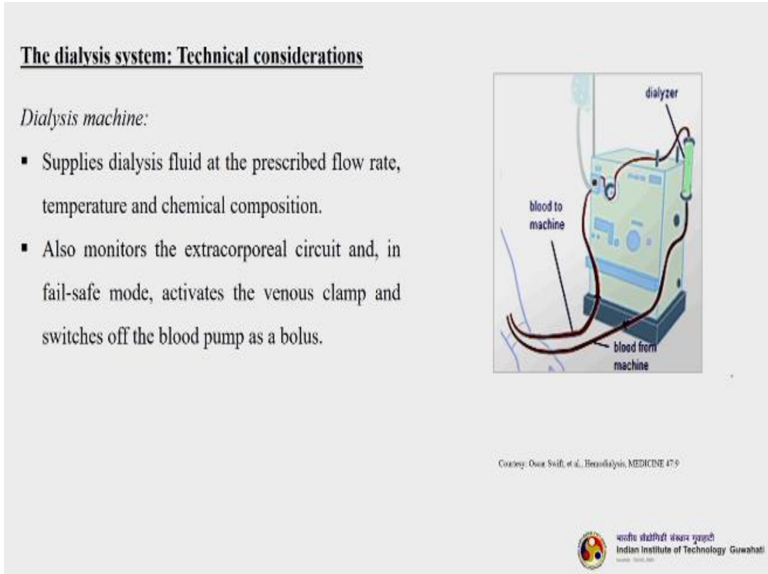

So, dialysis machine so supplies dialysis fluid at the prescribed flow rate, temperature and chemical composition. Also monitors the extracorporeal circuit and in fail-safe mode, activates the venous clamp and switches off the blood pump as a bolus. You can see this is how it looks actually that diagram.

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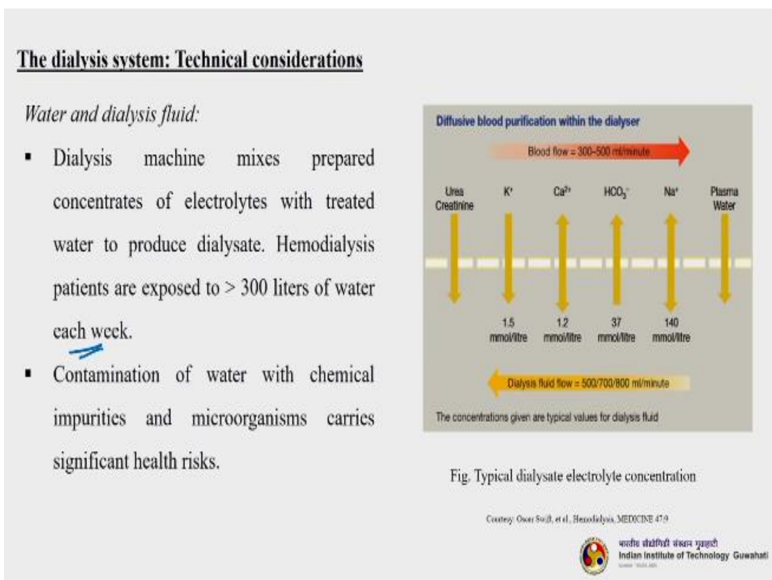

So, water and dialysis fluid. So dialysis machine mixes prepare concentration of electrolytes with treated water to produce dialysate. Hemodialysis patients are exposed to get greater than 300 liters of water each week. The contamination of water with chemical impurities and microorganisms cases significant health risks. You can see how you react within potassium ions, calcium ions then carbonate ions or bicarbonate ions and then sodium ions are getting transported or plasma water is also getting transported from across that dialysis membrane.

So, usually the dialysis fluid flow is about 700 or 800 ml/minute, whereas the blood is flowing at the flow rate of 300 to 500 ml/m.

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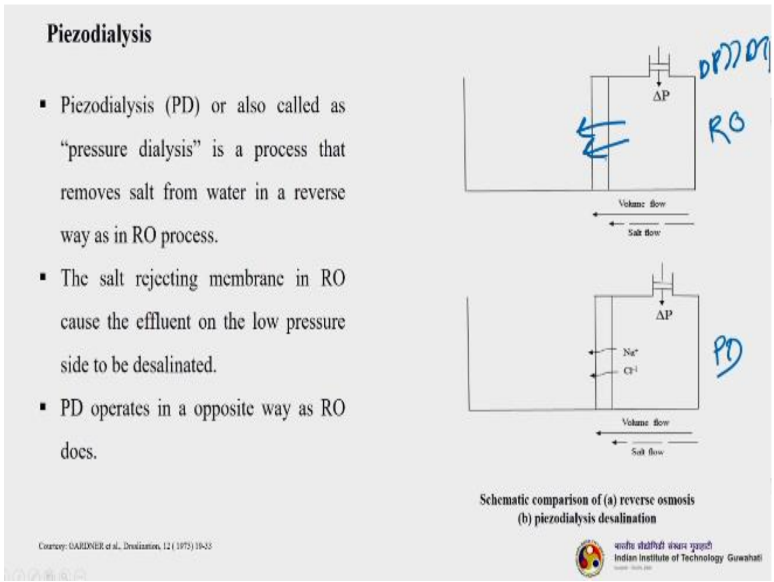

So, another classic example of a dialysis is dialysis processes is Piezodialysis or known as PD. So Piezodialysis is also known as pressure dialysis. So it is a process that removes salt from water in the reverse way as the two reverse osmosis. So it is just opposite to reverse osmosis. See how reverses this is RO, so this is PD. So in RO what is happening? I am pressurized in it.

So that this delta pi should be much greater than delta pi, delta p must be grater than delta pi then only here solvent will flow from higher concentration to lower concentration, this is RO.Solvent is flowing, not the ions, but here in PD what is happening I am pressurizing it, The same solvent is not flowing but ions are getting transported.

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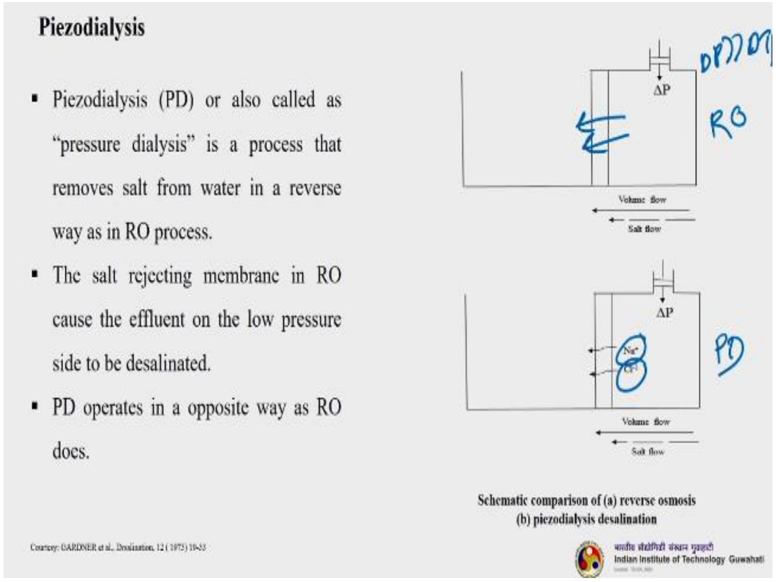

What are the ions the sodium ions and chloride ions. By virtue of their diffusivity and the virtue of their size, they are very small sizes and by virtue of the diffusivity, they will transport across the membrane. So, the salt rejecting membrane in RO cause the effluent on the low pressure side to be desalinated. Here it operates in the reverse way as the PD is separating the ions from the highly concentrated solvent side and getting a transported to the low concentrator solvent slide.

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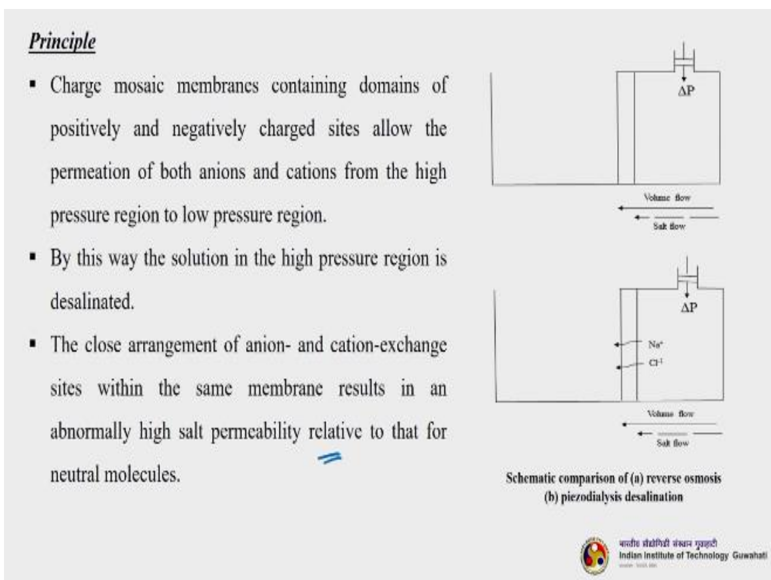

So, Charge mosaic membranes containing domains of positively and negatively charged sites allow the permission of both anions and cations from the high pressure region to low pressure region. So, by this way the solution in the high pressure region is desalinated. The close arrangement of the anion and cation-exchange sites within the same membrane results in an abnormal high salt permeability a relative to that of the neutral molecules.

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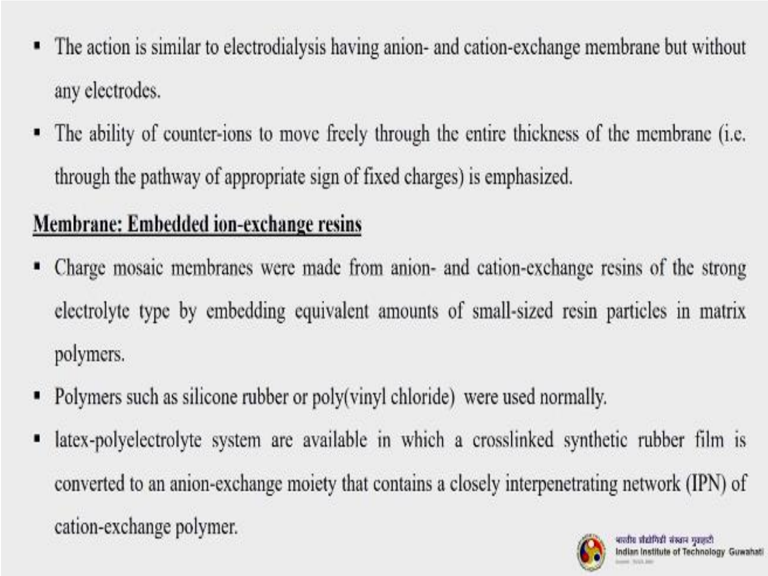

The action is similar to electrodialysis having an anion and cation exchange membrane but without any electrodes.

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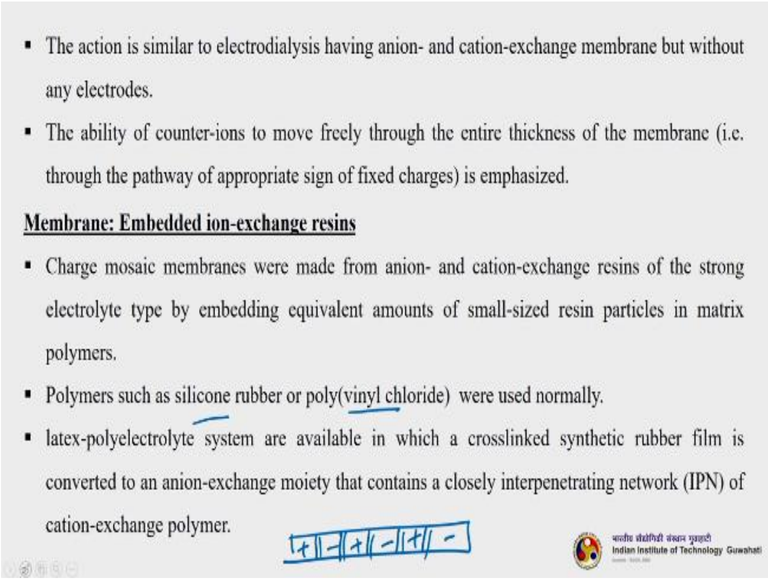

So, mosaic membrane can be something like this, so a cationic group followed by anionic group again cationic group followed by anionic group. Cation anion something like this, may be separated by a neutral region. So, these are mosaic membranes. So, here there is no electrodes, so separation is happening only due to the concentration difference that is what is the driving force as well as the diffusivity of the solutes.

So the ability of counter-ions to move freely through the entire thickness of the membrane that is, through the pathway of appropriate sign of fixed charges is emphasized. So membrane embedded ion-exchange resins. So, charge mosaic membranes were made from anion and cation exchange resins of the strong electrolyte type by embedding equivalent amounts of small sized resin particles in matrix polymers.

Polymers such as silicon rubber or poly vinyl chloride PVC are usually used. Latex-polyelectrolyte system are available in which a crosslinked synthetic rubber film is converted to anion exchange moiety that contains a closely interpenetrating network of cation-exchange polymer.

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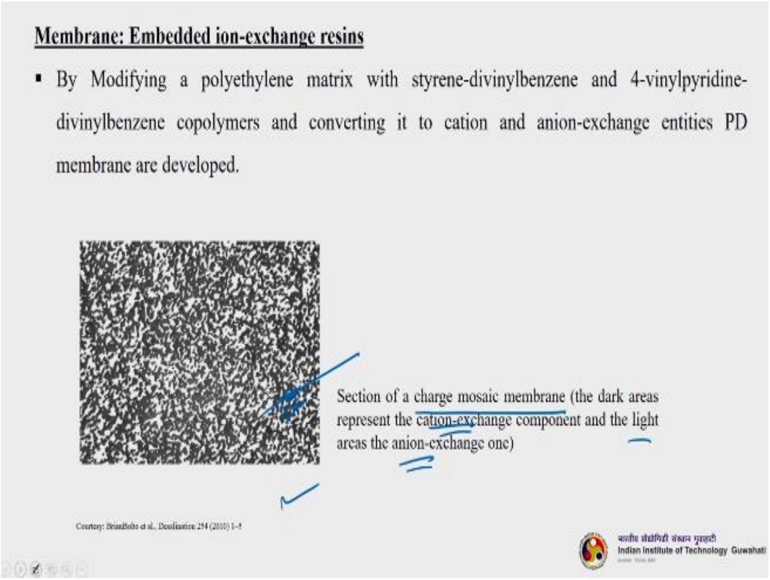

So, by modifying a polyethylene matrix with styrene-divinylbenzene and 4-vinylpyridine-divinylbenzene copolymers and converting it to cation and anion exchange entities PD membrane are developed. So this is ah the section of a charge mosaic membranes you see whatever the dark dark circle dark areas so that are represented the cation exchange membrane. Whatever is white so that the light areas, so there are actually anion exchange regions.

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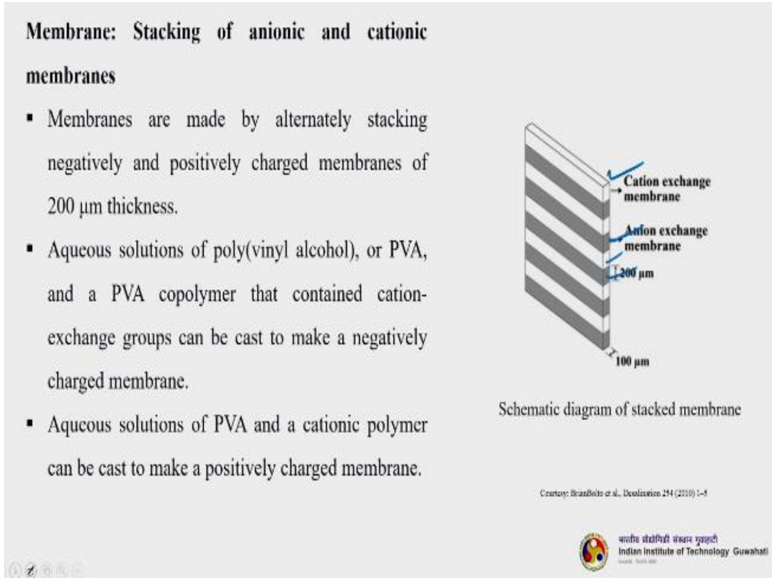

So, we can have stack membranes also as I was just showing you and drawing .So membranes are made by alternatively stacking negatively and positively charged membranes of 200 micron thickness. So we have a cation membrane then we have anion exchange membrane. We have a cation exchange membrane then we have anion exchange membrane something like this. So an aqueous solution of PVA or a PVA copolymer that content cation exchange groups can be cast to make a negatively charged membrane.

Aqueous solution of PVA and a cationic polymer can be cast to make a positively charged membrane.

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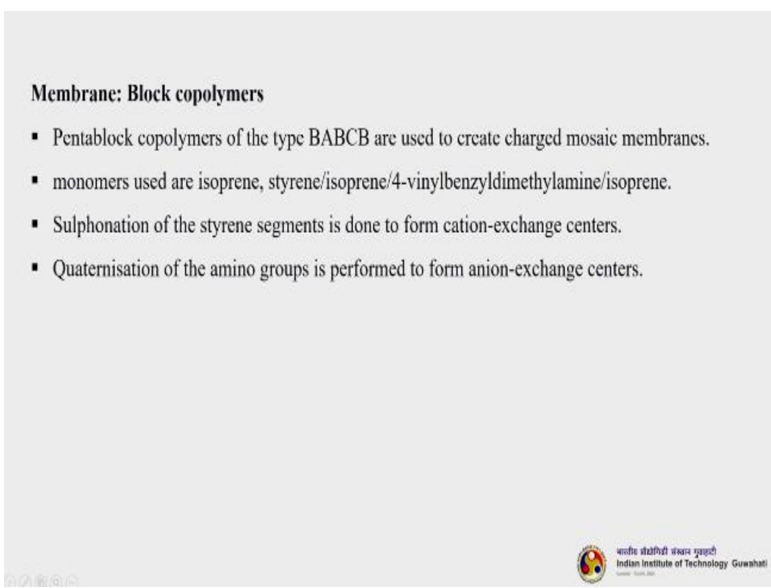

There are other copolymers also. Pentablock copolymers of the type BABCB are used to create charged mosaic membranes monomers used are isoprene, styrene/isoprene/4-vinylbenzyldimethylamine/isoprene. Sulphonation of the styrene segments is done to form cation exchange centers. And then Quaternisation of the amino groups is performed to form anion exchange centers.

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So the Piezodialysis that advantages are so minor component like salt, passes through the membrane and not the major component which is water. So small leak causes loss of only some of the product instead of contamination of the entire product steam. So, this is a very big this advantage actually.

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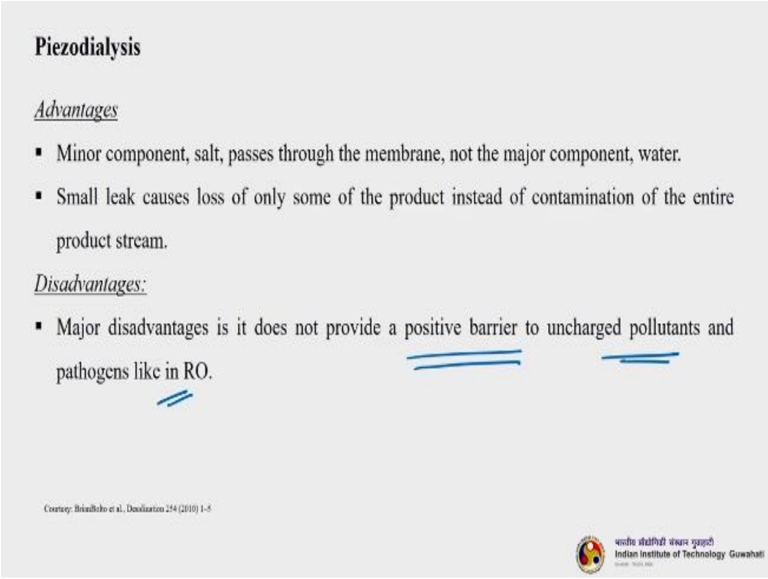

How the disadvantage is that, it does not provide a positive barrier to the uncharged pollutants and pathogens just like in reverse osmosis.

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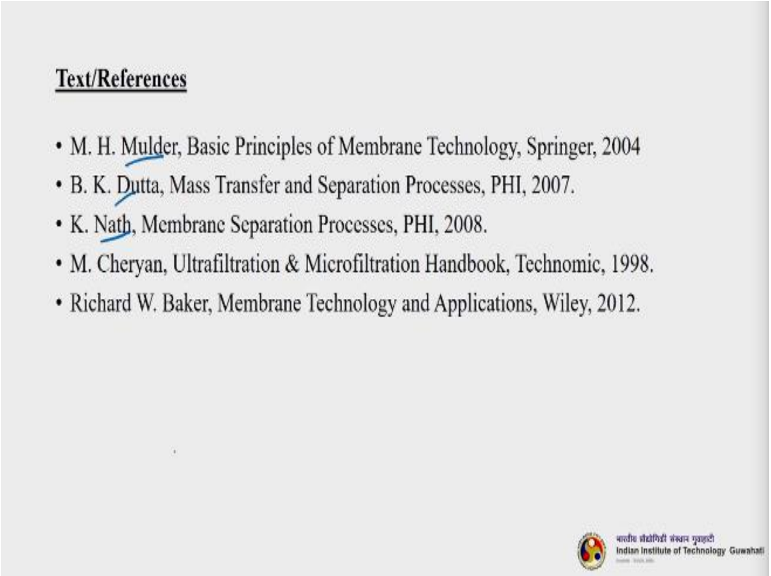
So this we conclude todays lecture.



So please refer Mulder, K. Nath book for dialysis, even you can read B.K Dutta book also.

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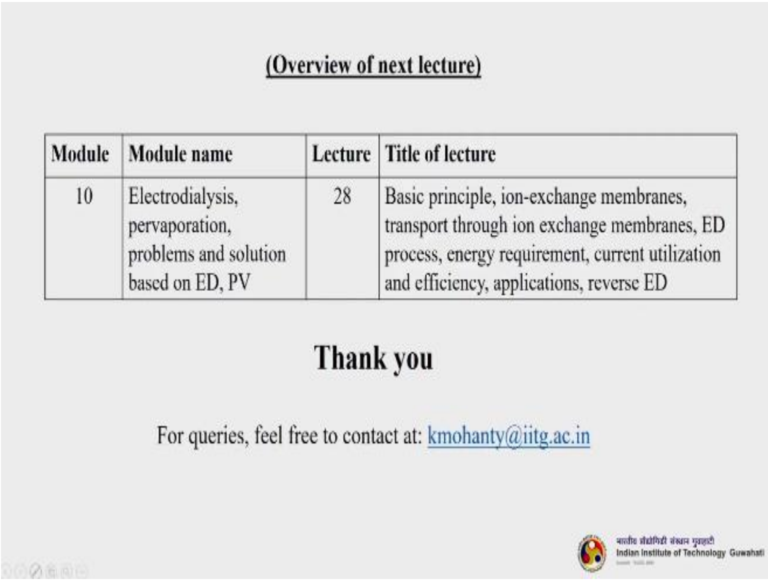

So, in case you have any queries please feel free to write to me came on kmohanty@iitg.ac.in. So thank you very much. In the next class we will discuss about electro dialysis in detail. Its basic principle and ion exchange membranes, transport through ion exchange membranes, electrodialysis process, energy requirement current utilizer, and efficiency applications and what is reversely. , thank you very much.