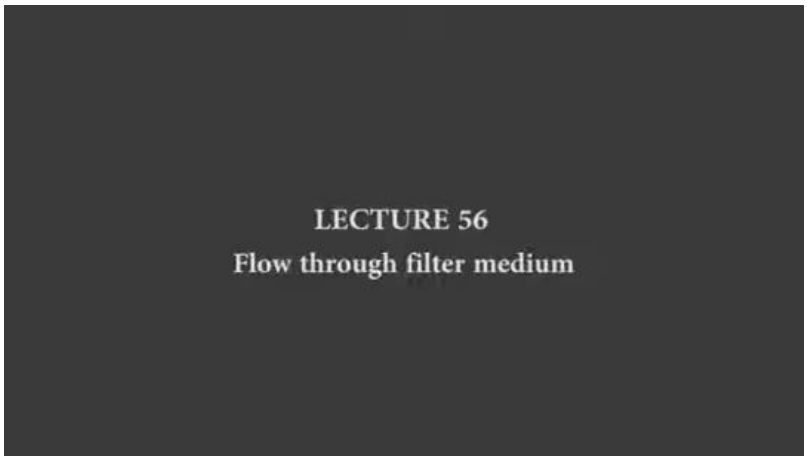
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

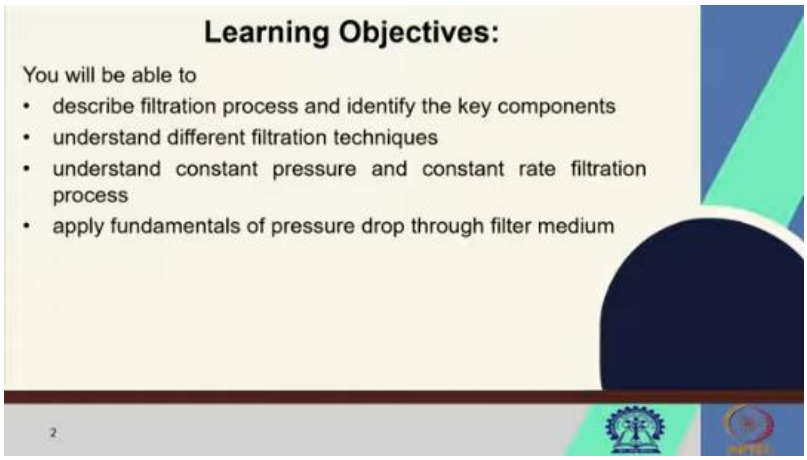
Lecture56

LECTURE 56 : Flow through filter medium

Hello friends, hope you are doing well. So, in the last week—the week of the 12th—under the topic of the impact of fluid flow in food processing and preservation, we will cover another topic: flow through a filter medium. So, okay. As the name indicates, we will look at the filtration process, mainly focusing on solid-liquid filtration. Since our focus is mainly on food processing and preservation, we will take examples from food processing and



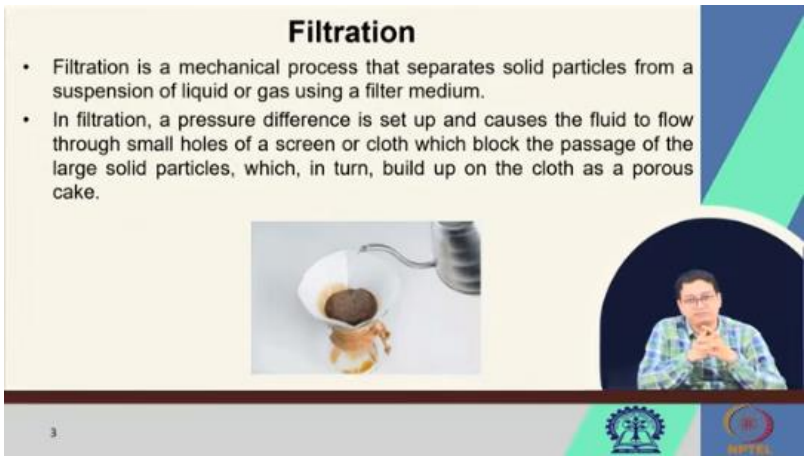
how filtration actually helps in food processing and preservation technologies. So, in this case, what would be our learning objective? After completing this topic, you will be able to describe the filtration process and identify its key components. We will try to look at the basics—the fundamentals of the filtration process—and examine what the major and key components are that are required to make any filtration happen.



There are many types of filtration processes available, but we will focus, within our short period of time, on those that are very important, and we can quickly go through an overview of this filtration process and its components. We will be able to understand the different filtration techniques that are very relevant in the food industry, specifically in the food and beverage industry. Then, you will be able to understand the fundamentals of the filtration process, mainly constant pressure.

Filtration and constant rate filtration. So, what is the constant pressure filtration? How do you know the mathematical expression looks like? How are they derived? And also, the constant rate filtration process, because these two are, you know, many times occur in the food and beverages industry. Finally, you will be able to apply these fundamentals. In order to calculate the pressure drop through the filter medium, as you know, the pressure drop is a very important thing, as I mentioned earlier, because that actually finally decides the pumping power requirement. All right, with this, we will slowly move

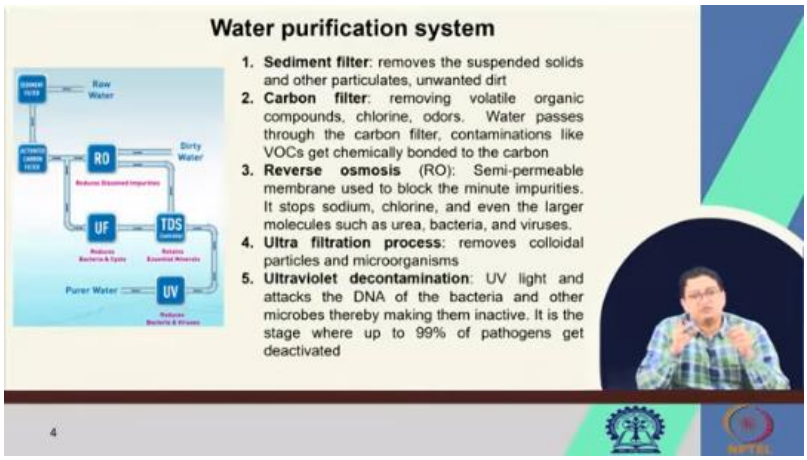
to the main part of our topic. OK. So, here, if you look at what is filtration? Filtration is nothing but a physical mechanical separation process to remove the solid particles from any suspended liquid or, many times, this suspended liquid is also called the slurry. In everyday life, when you wake up in the morning, perhaps you have come across the filtration process, like the picture is showing over here. OK, so let us say you are making tea. In hot water, the boiling water, maybe you put the tea. OK, so after



you know, two to three minutes, you want to strain it out. OK, so this is one kind of sieving process, and also you can say the filtration process. Now, if you look at the examples of making coffee, OK, so when you get the coffee, like coffee liquor, OK, what we do is we have a container at the bottom. We can put a filter paper, OK, make it conical in shape, put a filter paper on the top, and put hot water. So, if you wait for a sufficiently long time, the coffee liquor will eventually flow through the coffee and be collected at the bottom over here.

OK. So in filtration, in the food and beverage industry, the main key part is the pressure differential. So, we have to provide some pressure differential using some mechanism so that we can make the fluid flow through the small holes or screen or filter media so that we can have a filtrate out from one end, and that is actually desirable. All right, now what it says is that you know liquid can flow through the small holes or screen, okay, that is made of maybe any kind of semi-permeable membrane, wet cloth, you know,

whatever you can take, and so that you can block the larger solid particles and you are getting your liquid out. So, this liquid out we call the filtrate. Now, let us look at a very simple but everyday system we encounter: the water purification system. So, what is the idea of a water purification system? To purify the water, that means to remove different kinds of you know, any impurities.



So, if you look at this picture, we have raw water, sorry, raw water. So, in the first two steps, you know, we use a sediment filter and a carbon filter. So, the job of the sediment filter is to remove the large suspended solids and other particles or unwanted dirty material. So, the raw water passes through this sediment filter. So, this is also a filtration process, then it passes to the carbon filter, the activated carbon filter.

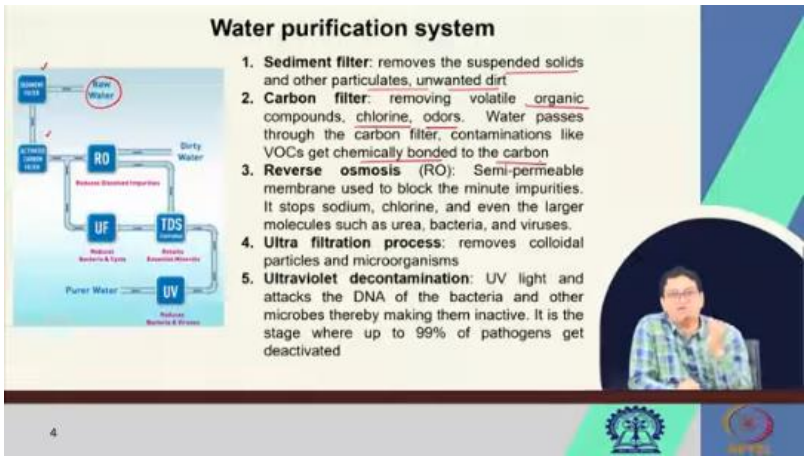
So, what is the job of the carbon filter? So, what it does? So, if any kind of, you know, bad orders are there, any volatile organic compounds are there, if you start consuming, then you will not feel actually good taking it. So, what it does? This carbon filter, this kind of contaminants, it can, you know, bonded to the, it can be

So, after bonding to the carbon it can be easily removed. So, water passes through this carbon filter while flowing through this carbon filter this kind of odors, chlorine and VOCs volatile organic compounds. they chemically bound with the carbon and that is how they are removed. Then it passes through the RO. RO is the reverse osmosis.

So, reverse osmosis is a membrane filtration technique. In the reverse osmosis, we also use a semi-permeable membrane. Then also UF. UF is called the ultra filtration process and finally, UV process. UV process is the ultraviolet decontamination process.

So, in the Reverse osmosis process. So, what is the osmosis process? If you really think about it, it is a very fundamental thing in the osmosis process. Let us say you take a resin, or here we call it a kismis.

If you put it into water, after a while it will swell up and become plump. What happens? Within the resin, you will have a high concentration of sugar. Now, water passes through the membrane and makes the resin plump. So, this is called the osmosis process.

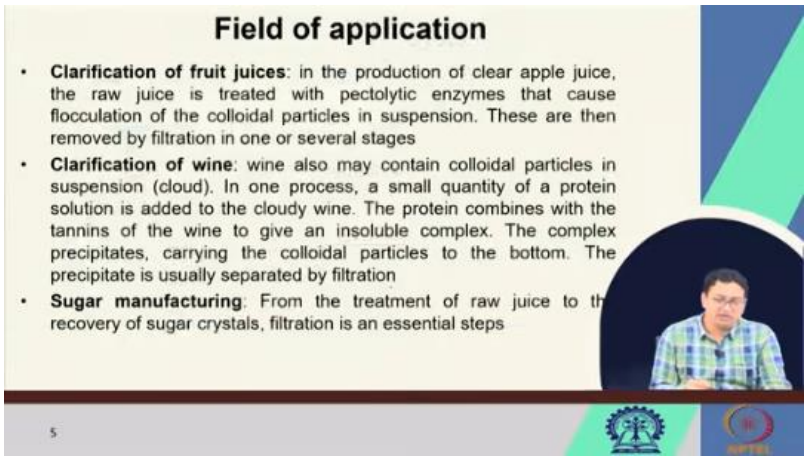


That means the liquid is moving from a lower concentration zone to a higher concentration zone. Reverse osmosis is the opposite of that. So, we apply a very high pressure to the high concentration solution so that we can allow the liquid to pass through the membrane where the solid particles are arrested. So, this is the reverse osmosis process, and the pressure has to be more than the osmotic pressure.

So, that is the basic idea of reverse osmosis. So, in this case, semipermeable membranes are used to block minute impurities. So, it also stops different kinds of elements like sodium, chlorine, and even larger molecules such as urea, bacteria, and viruses. Ultrafiltration is also a membrane separation process, a membrane filtration process that removes colloidal particles and microorganisms. The job of the UV is to simply decontaminate

the material if any kind of bacteria or other microbes are present. So, in the food processing industry, perhaps During the COVID period, we have all come across UV lights. They were actually used extensively to kill microbes on surfaces. Basically, the UV decontamination process is a surface contamination process that kills or inactivates different kinds of microorganisms by attacking their DNA. So, this is also done during the process.

So, the idea of explaining this is to give you that, you know, filtration, purification, clarification, or they are many times used at the same time, but they are not actually the same, okay? We encounter this system every day, okay. Now, what are the fields of application in the food and beverages industry? So, clarification of fruit juices.



So, when fruit juices are actually squeezed let us say here we are giving example of the apple juices ok. So, when it is squeezed from the raw material. So, the juice is become very hazy and cloudy. So, there is very high amount of turbidity that is because of presence of different kind of you know polysaccharides, gums,

waxes different kind of materials are there. So, initially they can be you know separated with some centrifugal filtration techniques, but how about the remaining part. So, remaining part we do with the enzymatic clarification process. So, once the enzymes are applied like pectolytic enzymes what they do they react with the pectins and other materials and what it will do it will you know give the flocculations of the solid particles within the juices.

Now, the flocculations of the colloidal particles in the suspension does not look good even in this one makes the high viscous products and it gives very cloudy appearance. So, after that we also go for the filtration process and that follows in a several stages. So, that is one applications clarification of wine. So, even in the wine the similar way During wine actually preparation, so some small quantity of proteins or protein solutions are also added to the cloudy wine.

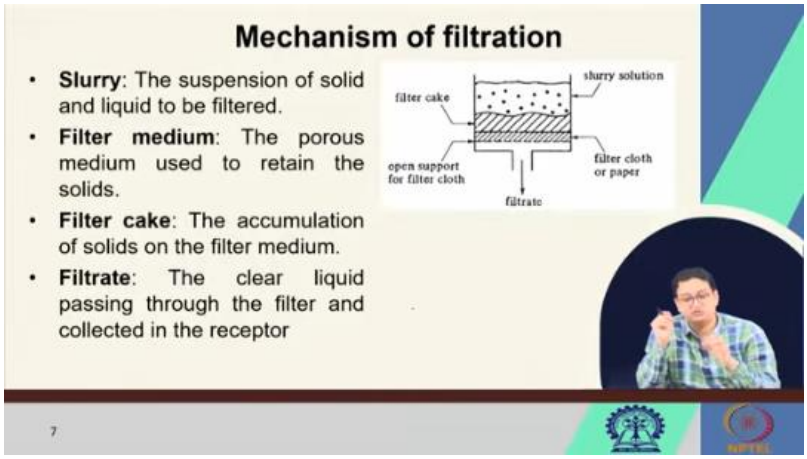
So what it does, this may be, you know, protein may be casings. It can, you know, protein combines with the tannin and makes it an insoluble complex. So this complex can be further filtered. Many times during the wine processing, different kinds of filter aids are also used, like clay and other things. These are also very helpful to trap the larger particles, and eventually, when they are trapped in the clay, they are actually

getting filtered out. So, I am trying to, you know, give you the idea or a brief overview of where it is being actually applied. In the sugar manufacturing process, even from the start

to getting the sugar crystals, filtration is a very core step and a very critical step. As I said, when the sugar juice is extracted from the sugarcane, it has a lot of impurities. During this process and that step also, filtration is required. Even towards the, so when one step is initially the filtration is done, so we have a clear juice, then they are, what have they, transferred to the evaporating and

concentrating tank. So, when the evaporation is occurring, what is happening is water is being removed. So, we are having a very highly concentrated material, okay. So, when the sugar crystals start forming, we will have some liquid also remaining with that, okay. So, we have to remove that liquid using the filtration process. So, I am not going into the real detail of the sugar manufacturing and all this process, but just to give you the idea where they are applied, and in fact, there are many other

Applications are there—you name it, ok. Now, coming to the basic mechanism of the filtration. So, if you look at it—if you, as I said, if you remember—you have a filter paper, and you pour coffee and put hot water. So, the filtrate comes out, which means your coffee liquor. So, here we can say that coffee liquor is the filtrate. Now, what happens during filtration?

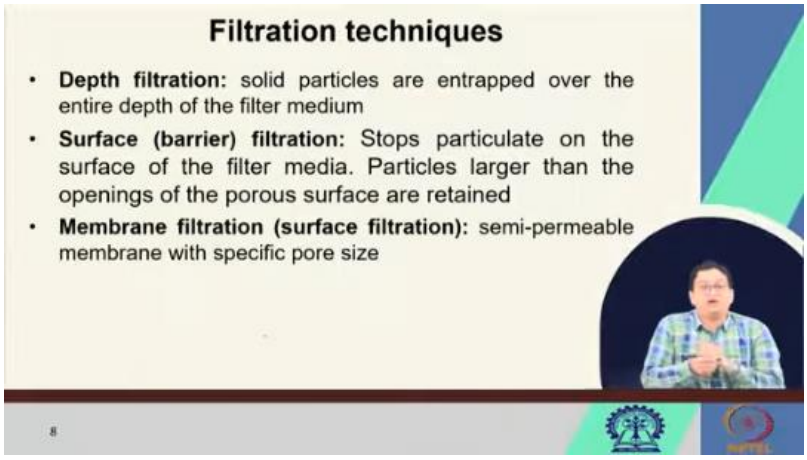


So, here we use a filter medium; many times, the filter medium is also called septum. So, the filter medium is the very essential and core part, ok. Here we have the suspended solution or the slurry. So, this one has got some solid particles.

So, while it flows through this filter medium, the particles get deposited on the surface. So, they start blocking the pores—the openings, ok. So, over the period, as the flow goes on, there will be a development of the cake. So, that is called the filter cake.

That means the deposition of the solid particles. So that is called the filter cake. So over the period, this thickness will increase. So now this filter cake also starts acting as one of the filtration mediums. So, key terminologies over here: the slurry that actually has to be filtered.

Filter medium: it could be anything—cellulose material, paper, or any kind of other semi-permeable membrane. Then coming to the filter cake. So, this is nothing but the accumulation of the solid on the filter medium, and over time, as the filtration goes on, the thickness of the filter cake will go on increasing, and finally, we get the filtered clear liquid passing through the filter and collected in the receptor. Now, coming to the filtration techniques, if we

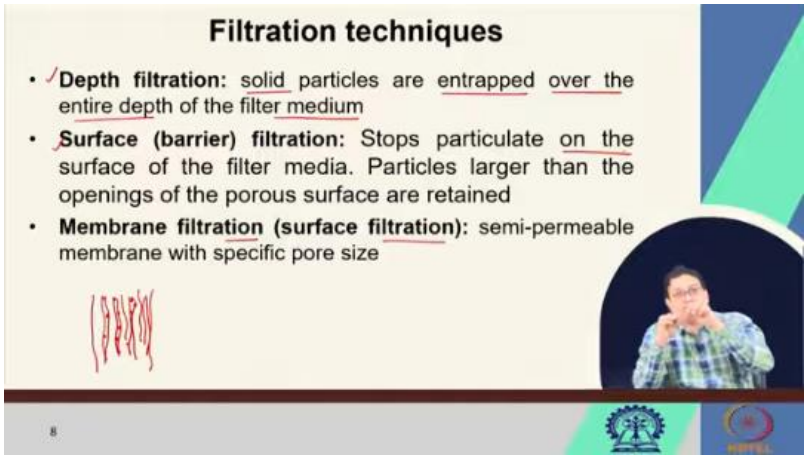


talk about the filtration techniques, broadly they are classified into two. First of all, depth filtration and surface filtration. Another one I have added: membrane filtration. This is also one type of surface filtration technique, but the broad or major categories are these two. The depth filtration and the surface—many times it is called the barrier filtration.

The name indicates depth in depth filtration. The entire filter medium is used for the filtration techniques. What does that mean? That the large amount of solid particles are entrapped over the entire depth of the filter medium. So if you have, let's say, a filter medium is like this and it has got a lot of pores, okay? So the The fluid passes through, and while it is passing through these pores or voids, the particles actually get entrapped over here. So that is the idea of depth filtration.

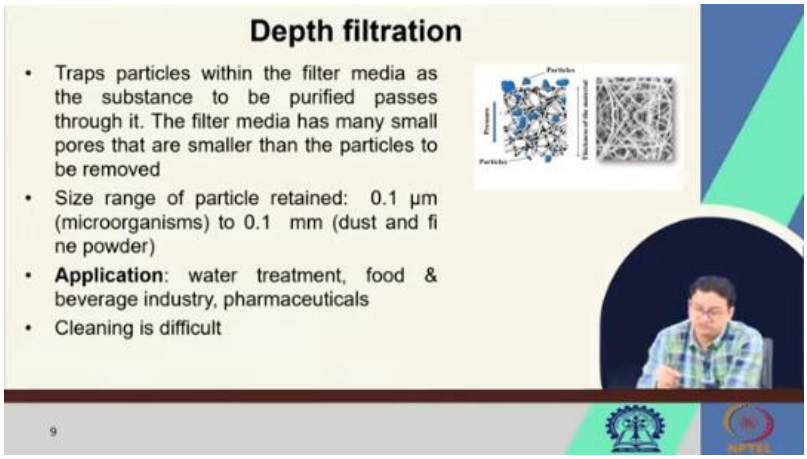
In surface filtration, it stops the particulate or the solid particles on the surface itself. That means you have a membrane—you can take a membrane or any filter media—and the fluid is flowing. Sorry, rather, I would say slurry is flowing. What happens? The solid particles

get deposited on the surface of the filter medium. So, particles larger than the openings of the porous surface are retained.



Membrane filtration uses a semi-permeable membrane with a specific pore size. So membrane filtration again can be classified into many types: microfiltration, nanofiltration, ultrafiltration, and RO also. So let us look at it a little bit more in detail—the depth filtration. If you look at this picture, so let us say this is the, you know, the internal structure of the filtration medium. So when, as I mentioned at the very beginning, the pressure has to be applied in order for the filtration process to occur.

So the pressure is applied. So while it is flowing through this medium or the pores, the particles get actually entrapped over here. So, there are many types of capturing mechanisms are there for the particle ok. One is called sedimentation although basically this is not you know filtration techniques, but in the sedimentation what happens? The you know heavier particles they actually settle down at the bottom.



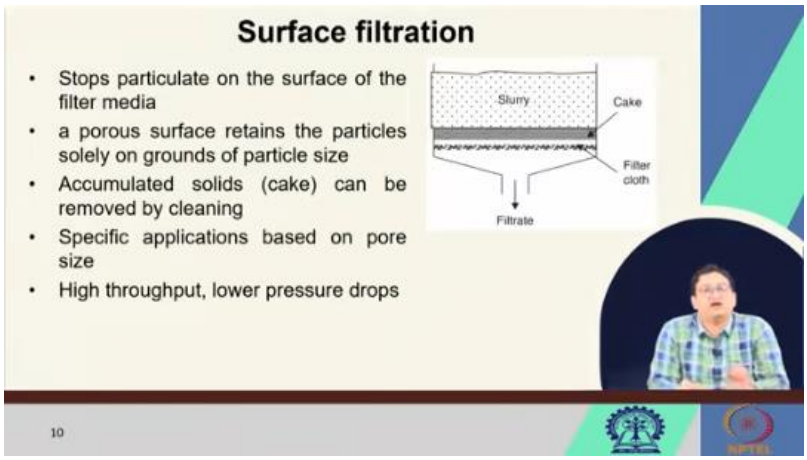
ok and it can be taken out or the pure liquid can be taken out. So, this is the you know sedimentation techniques. Sheaving mechanism, interception mechanism, electrostatic deposition ok. So, in the electrostatics deposition just quickly I will tell you in the electrostatics deposition. So, if you have a you know

The material with a different charge so, this that will actually attract you know each other. Let us say you have a you know filter membrane it has got the different charge the internal part and the particles that is actually passing through this membrane has got a opposite charge. So, basically the separation has to be the following the electrostatic deposition. So, as I was saying that the particles the slurry is flowing through this medium and the particles is getting arrested over on the

Surface of the filter medium internal part. So, that means it traps the particles within the filter media as the substance to be purified passes through it. The filter media has many small pores that are smaller than the particles to be removed. Now, what is the size range of the particles retained? Usually, 0.1 micron to 0.1 millimeter falls under the category of 0.1 millimeter size for dust and fine powders.

Applications depend on the requirement and, you know, how you can afford it, which is very important, and also the efficiency of the process. The water treatment plant, food and beverage industry, and pharmaceuticals. Cleaning is very difficult. So, in depth filtration, let us say you have a cartridge. So, if you have a cartridge, let us say all the particles are actually trapped within the internal part of the fiber of

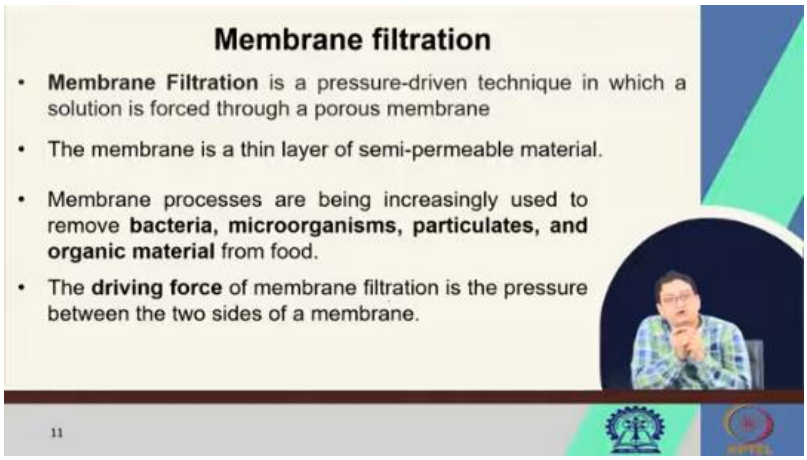
the cartridge. Cleaning the internal part would be very difficult. You have to pass the wash fluid, but even passing the washing fluid does not give very good results. Surface filtration, as the name indicates, is limited to the surface. The cake formation occurs over here. Now, we have a filter cloth or filter medium over here.



As I was mentioning that it actually arrests all the particles on the surface of the filter media. The porous part actually retains all the particles only on the grounds of particle size. So, if the particles are larger, they will be arrested. Otherwise, it will can pass through. So, that is why you have to wisely choose the kind of what kind of filter cloth or the filter medium we are getting.

Sometimes you have seen when we go for the sieving let us say we want to strain the coffee liquor out or tea out. So, that sieving or the strainer it can arrange the larger leaves, but still at the bottom you will see very small small particles will be there because the opening size is larger so that it can it will actually allow the smaller particles. It can be it can have a specific application based on the pore size. Now these cakes that is the depositions the cakes can be you know washed or can be removed in the time interval.

It has got high throughput and also the lower pressure drop. Now coming to the membrane filtration, ok. So, as the name indicate it uses the membrane that is actually semi-permeable in nature. Why it is semi-permeable?



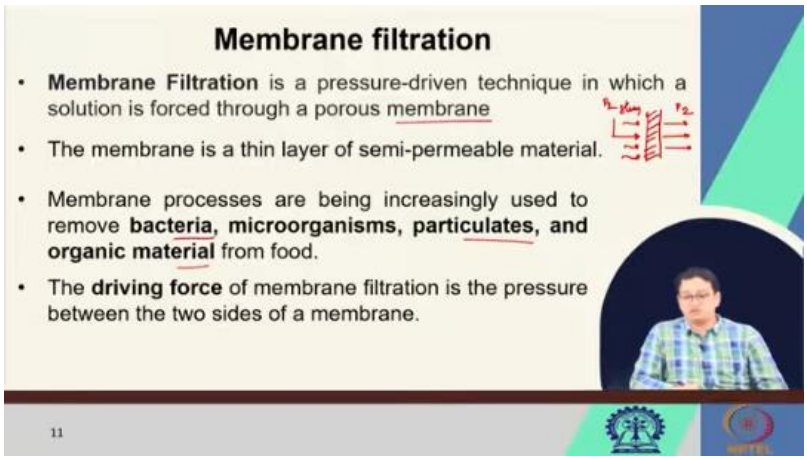
Because it will allow some material and it will not allow some other material, ok. It is based on the size of the pores. It is also a pressure-driven technique, which means you have to apply pressure to make the filtration occur, in which the solution, slurry, or suspension is forced through a porous membrane. The solution, slurry, or suspension is forced through a porous membrane. So, all the membrane filter mediums are actually porous in nature. So, if you take one of the examples, I forgot to mention the filtration technique in the previous

days, if you remember, we used to have these water purification systems from the brand, Eureka Forbes, or whatever it is. In the earlier days, we used to get the water and we used to have a filtration system. So, it has got two parts: the top part and the bottom part. And the top part actually had a filter candle. The filter candle is basically made of ceramic.

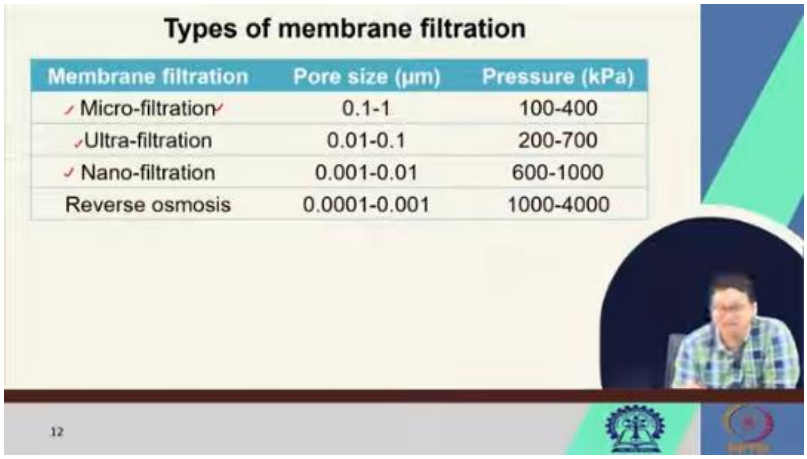
It has a very porous structure. We pour all the water into the top tank, and if you wait for a while, you will see the purified water collected in the bottom tank. So, the filter candle looks like an inverted candle. So, what happens? When the filtration occurs for a very long period, you will see the filtration is not very efficient because it will have the

Deposition of the cake on the surface. So, over time, you need to get it washed. So, we take out the filter candle, and you will see there will be cake formation on the surface. So, you clean it with normal water, and then it restores the operations again. So, that is one of the examples that just came to my mind. Then, the membranes in membrane filtration are used for the removal of bacteria, microorganisms, and different solid

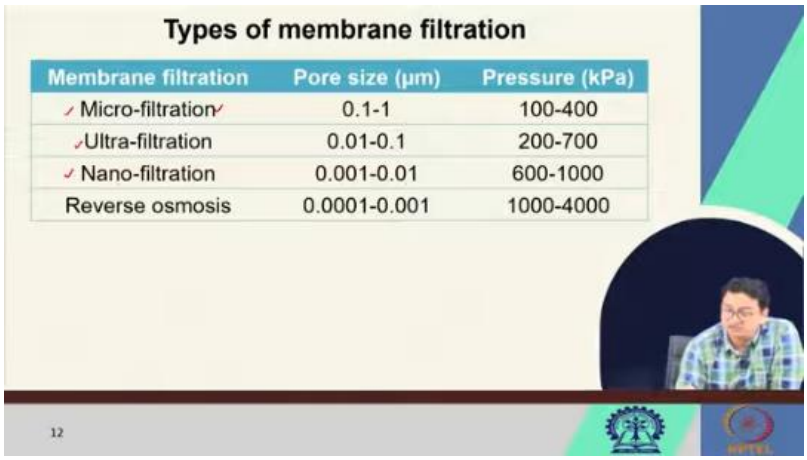
particulates and organic material from the food. The driving force of membrane filtration is the pressure between the two sides of the membrane. So, let us say you have a membrane over here. So, let us say this is the membrane, and here the slurry is flowing, and here we are having the filtered output. So, here you have P2, and here you have P1, okay. So, the pressure differential across the thickness of this membrane is very important, okay.



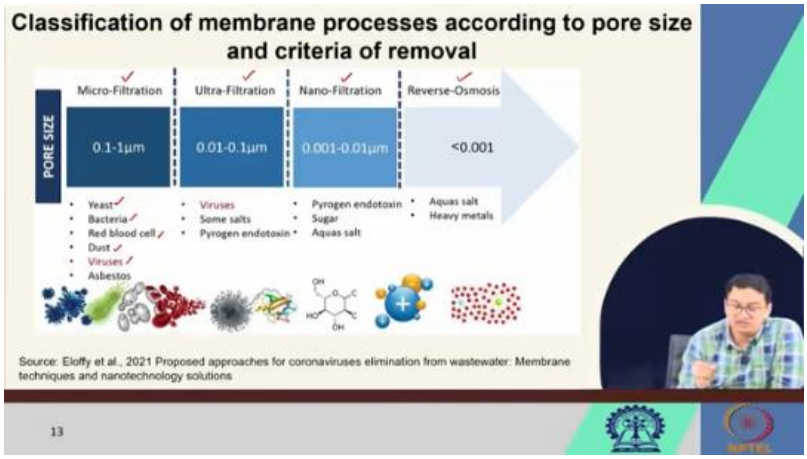
Now, coming to what kind of membranes are actually used for the membrane filtration process. So, there are actually four major membrane filtration techniques. Microfiltration, ultrafiltration (also called UF), nanofiltration (NF), and reverse osmosis (RO). So, in the membrane filtration technique, when we talk about microfiltration, the semi-permeable membrane has got a pore size of 0.1 to 1 micron. It may vary slightly.



The pressure is required in terms of kilopascals, 100 to 400 kilopascals. In the ultrafiltration technique, the pore size further decreases to between 0.01 and 0.1. The pressure required is even a little bit higher, ranging from 200 to 700 kilopascals. Nanofiltration, 0.001 as the name indicates, goes to the nano range of 0.01 micron. The pressure requirement is 600 to 1000. RO reverse osmosis ranges from 0.0001 to 0.001, and the pressure requirement is much higher.



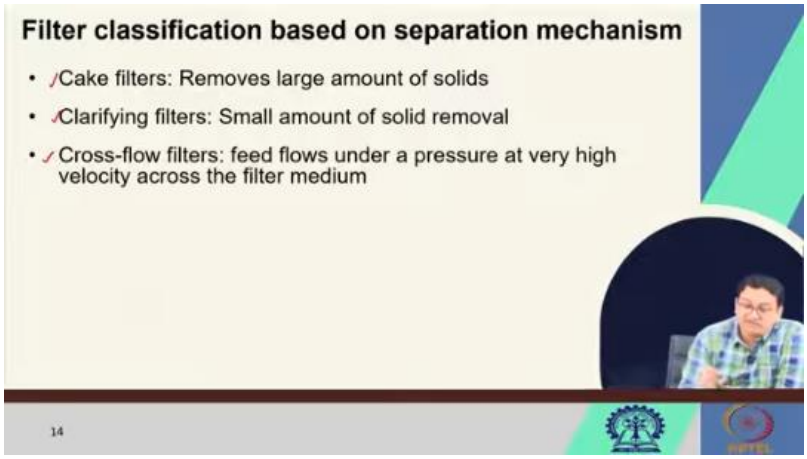
So here, this figure shows how to classify the membrane processes according to the pore size and criteria of removal. These are actually all the pore sizes we have just looked at in the previous slides. We discussed microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. As you move to the right, the pore size decreases. If you look at microfiltration, most yeast, bacteria, red blood cells, dust, and viruses can actually be removed. In UF, other viruses, which are smaller, some endotoxins, and some salts can also be removed.



In nanofiltration, sugars, aqueous salts, some multivalent ions, and monovalent ions can be removed. Aqueous salts mean if you take NaCl, table salt, you will have Na+ and Cl- ions. So, you will have the ions, and they can be removed with nanofiltration techniques. Even in reverse osmosis (RO), heavy metals and aqueous salts can also be removed.

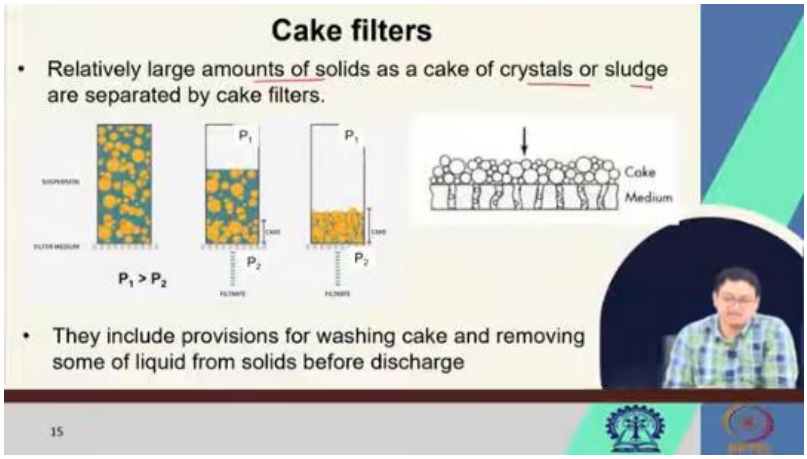
So, this one actually is giving you the application of different membrane filtration techniques: microfiltration, ultrafiltration, nanofiltration, RO, and where it can actually be used. So, these are the basic criteria of the removal. Now, we will look at the filter classification based on the separation mechanism. So, separation mechanism means they

are actually classified into three categories: cake filters, clarifying filters, cross-flow filters. Cake filters remove a large amount of solids.



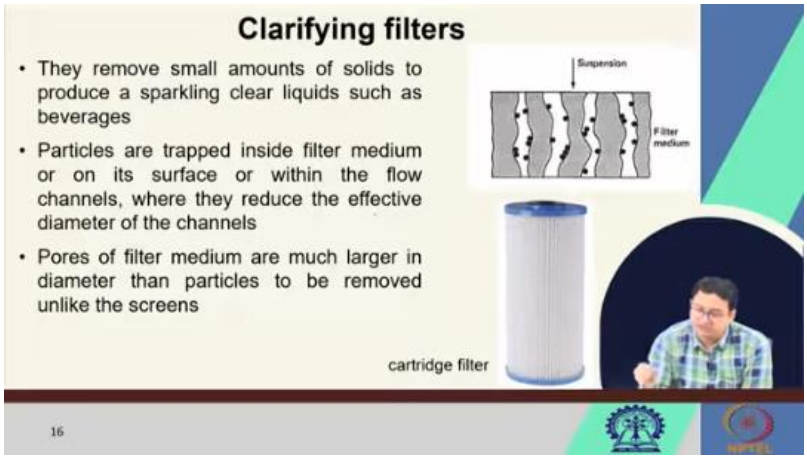
This process is also called the cake filtration technique. Clarifying filters actually remove a small amount of particles. In the cross-flow filters, feed flows under pressure at a very high velocity across the filter medium. Let us look at it. Let us look at some pictures; then we will have a better idea, okay?

In the cake filters, if you look at the basic filtration technology or mechanisms, we have a filtration medium and cake is actually being deposited on the top, okay? And over time, as I said, the thickness of the cake will be developed. So, in this case, this is called cake filters. A relatively large amount of solids, such as cake, crystals, sludge, are separated by the cake filter. So, you look at this picture: we have higher pressure upstream, and downstream we have lower pressure on the other end. This is the filter medium, and these are the slurry or suspension, okay? So, as time proceeds,



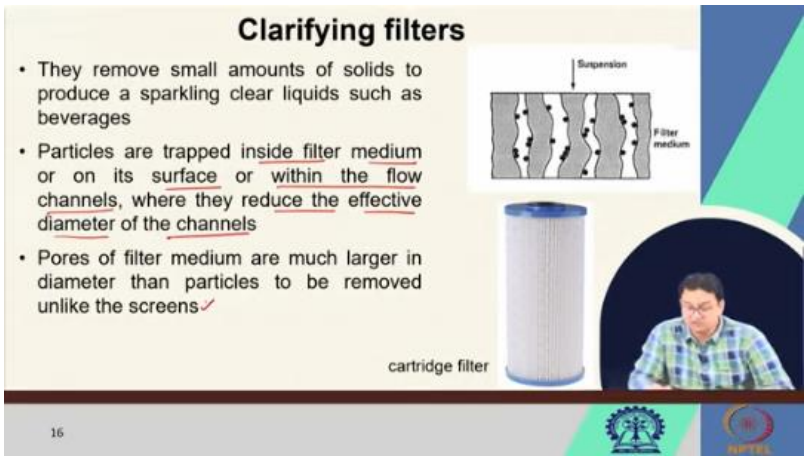
So, there will be a cake formation. So, it will simply block the pores over here on the surface of the filter medium. So, this acts like a, you know, bridge between the particles. So, once it blocks, the other, you know, suspended solids will simply be deposited over one another and eventually it will, you know, form a cake. So, this is called the cake filter or the technique is called cake filtration.

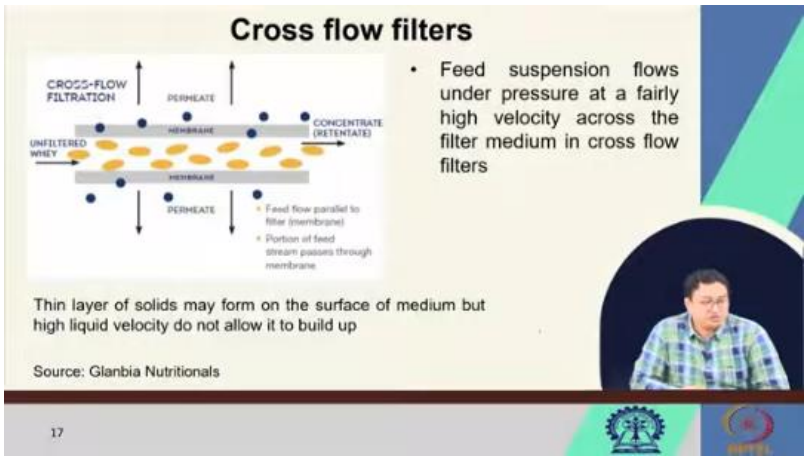
Now, coming to the clarifying filters. So, in the clarifying filters, it actually removes small amounts of solids. So, what happens? So, you have a filter medium. So, in the filter medium, there are pores through which the liquid can pass.



Now, these pores are usually larger than the size of the particle to be removed, the size of the particle to be removed. So, the fluid can easily pass through, and while flowing, the suspended particles will be entrapped within the material, within the filter medium. So, particles are trapped inside the filter medium on its surface or within the flow channels where they reduce the effective diameter of the channels. So, eventually, what does it do? It actually blocks the passages.

That is why the effective diameter is getting down. pores of the filter medium are much larger in diameter than the particles to be removed unlike the screens. So, this is one example that is actually cartridge filter we call that is act as a clarifying filters. Coming to the cross flow filters. So, so far what we have looked at we have a filter medium.





And there we are having higher pressure in one end. That means from that let us say upstream part the suspended solids or slurries are actually being filtered. So the direction is nothing but it is a perpendicular to the membrane surface. Now what is the cross flow? The cross flow is the flow is across.

That means you have the membrane over here. Now, the material, the slurry is flowing in this direction, not in this direction, not this one. Flowing in this direction and that means the flow is cross flow and the filtration occurs like in this direction. And we will get the filtrate out or permeate out. All right.

So, that is the idea of the cross-flow filters. The advantage of the cross-flow filters—what happens? So, because of the, you know, flow velocity, OK, the deposition of the cake on the surface of the membrane is very minimal, OK. So, that is the advantage of the cross-flow filters, all right. So, the feed suspension flows under pressure at a fairly high velocity across the filter medium, and that gives us the advantage.

A thin layer of cake will be deposited on the surface of the medium. So, we will stop here today.

Thank you so much.