Course on Industrial Biotechnology
By Prof. Debabrata Das
Department of Biotechnology
Indian Institute of Technology Kharagpur
Lecture 21
Upstream Processing: Air Sterlizer

Welcome back to my course the industrial biotechnology. Now I am going to discuss the that upstream processing and then it will be followed by the downstream processing.

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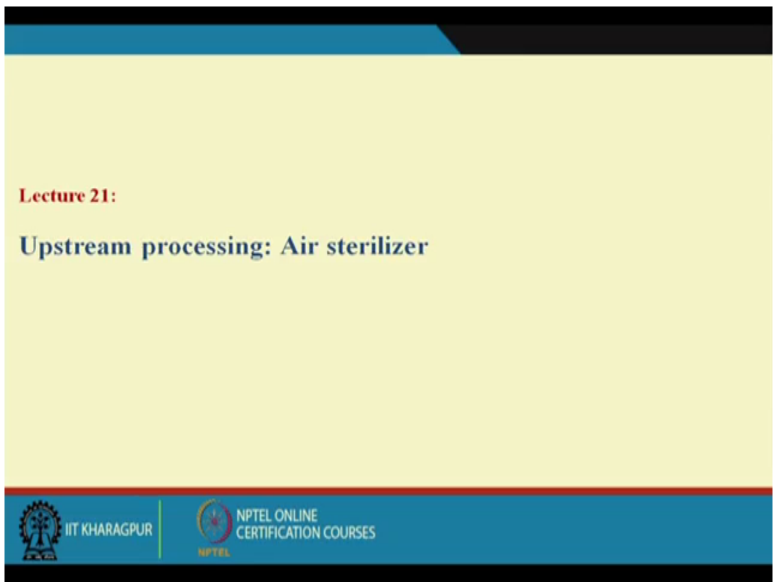

Now the upstream processing first time I am going to discuss the air sterilization. I as you know that in the formulations industry that one important aspect is the sterility. And sterility when we when we concern about the sterility then we try to find out what is the possible avenue through which we can have the contamination problem and one main ()((1:00)) is the air and second is the media and third is the may be your fermentation bases.

So and so everything should be sterilize because whatever do you do that everything should be sterilize so air sterilization is the very important aspect because most of the biotechnology industries they operated under ()((1:23)) in which condition and I I told you that micro organization can take the oxygen which is dissolves in the media.

We can take the oxygen which is present in the air. So the mass transfer of the oxygen to the fermentation is very important and so since oxygen is pairingly soluble in in in water so you have to you have to ()((1:49)) the air mode and mode so that mode oxygen transfer take place. So the that limitation problem of the dissolved oxygen limitation problem can be overcome.

So since we ()((2:06)) mode and mode. Then the possibility of contamination problem in the in the in the fermentation process. So so question comes how will we sterilize the air?

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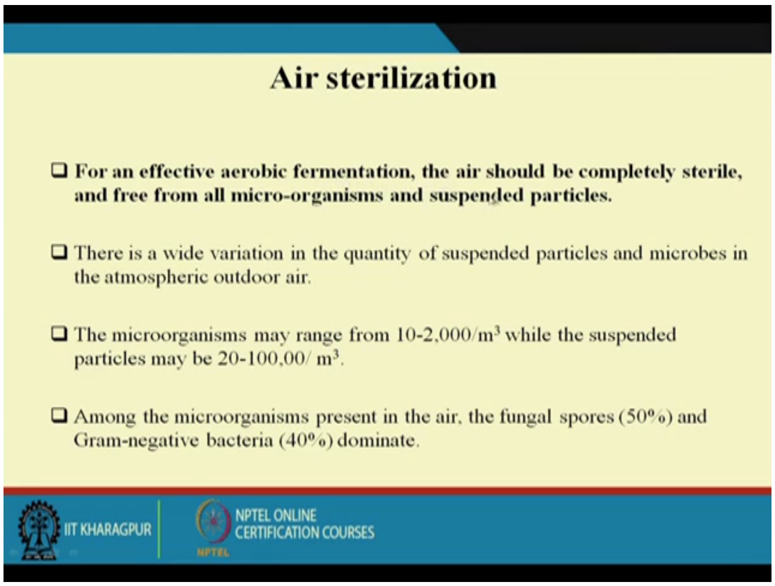

Now for an effective aerobic fermentation process air should be completely sterile and sterile and free from all micro-organisms and suspended particles. There is a wide variation in the quantity of suspended particles and microbes in the atmospheric outdoor air.

Now here I want to tell you a couple of things that particular one thing I want to mention that bio-chemical industry is usually should be located in little bit high altitude. And why it is high altitude because if you go to the high altitude the, the particular matters present in the in the in the air will be less.

And also you should not be in the metropolitan cities where you have particular matter concentration in the air is very high because why? The reason is that this particular matters, they are the killer of micro-organisms. So more micro-organisms present in the air, the air sterility of the problem will be more.

So it is usually prescribed that it should be in a place where you have less particular matter present in the air.

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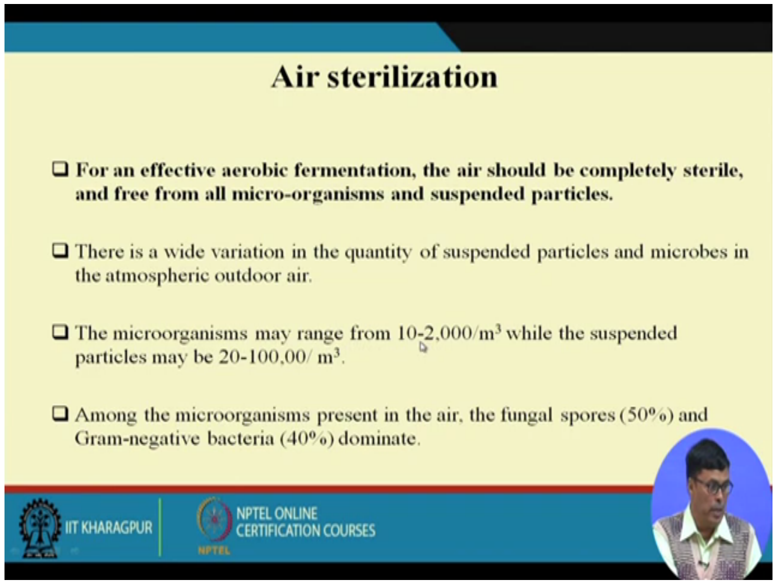

Now the micro-organism may may be in the range of 10 to 2 or 2000 per cubic meter while the suspended particles may be 20 to one hundred the about the 10000 per cubic meter. Among the micro-organisms present in the air, fungal spores 50% , gram negative bacteria 40% the the dominats.

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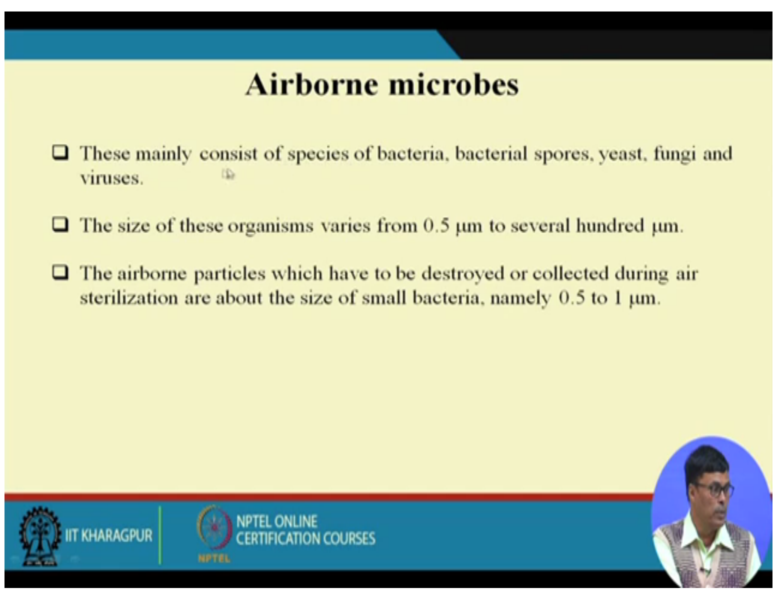

Now airborne microbes now now question comes that that what kind of microbes ()((4:10)) requiring in your system that is very important. I work with citric acid industry and we found that renewed fermentation process our main conflict is a essence.

And when we when we when we use any kind of sterility process then we should always target that what kind of organism you are going to remove and this can be removed in different ways. You can remove as we discussed the different process what happen then?

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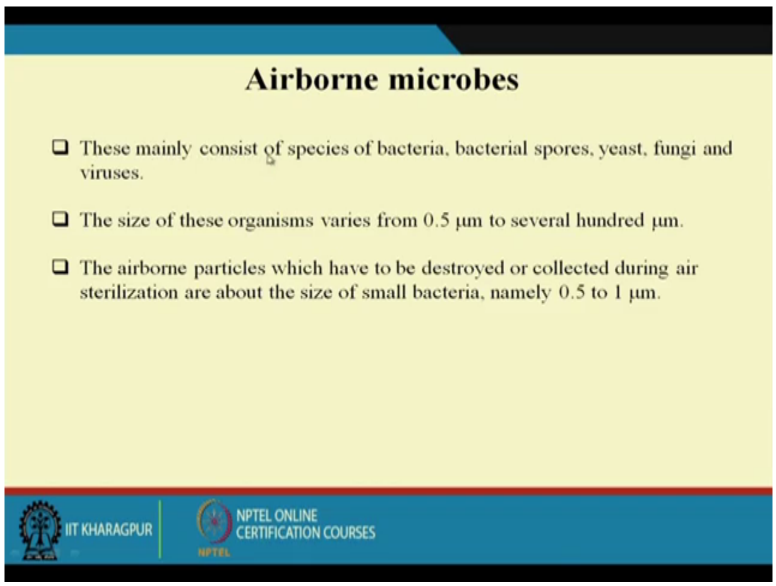

this this mainly consist species of bacteria, bacterial spores, yeast, fungi and viruses. The size of these organisms varies from 0.5 to several hundred microns. The airborne particles which have to be destroyed or collected during the air sterilization are about the size of small bacteria, namely 0.5 to 1 microns.

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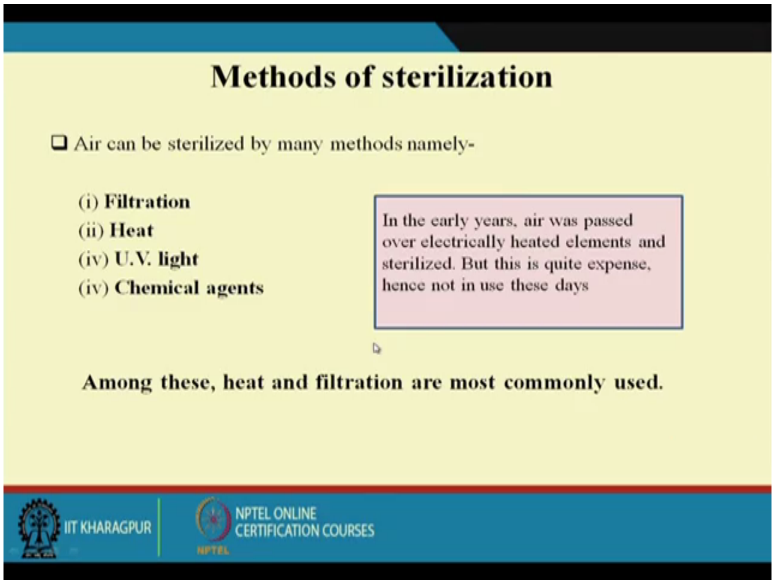

Now what is the sterilization technique that we have? We have sterilization technique that we have. We have physical separation technique what we call? filtration and filtration can be done in so many ways. We can use the fibers, we can use kind of membrane through which physically you can separate and then the heat.

Heat but heat is not suitable for sterilizing the air because air is a non conductor of heat so you required higher amount of heat for removing the the contaminants. And then UV rays the two type of two type of air we we used to sterilize one is stable air and the moving air. Now when we talk about for that any kind of formantants means passing air this is a moving air.

The air is passing, you have to spot through the the spotgur. So for that usually we we used the kind of physical separation technique what you call filtration but in case of stagnant air we use some either UV rays or ()((6:27)) space. As for example we know that in the operation theatre in the different hospitals.

And there this is usually there should be ()((6:38)) and then that they usually do with the help of UV rays. But in the fermentation industry like I can give the example of cheese making industry that where the cultivation is usually done in the open bags because the the curd formation usually take place in the open bag and the room should be sterilized.

And the sterilization of the stagnant air is done with the help of germicidal spray. germicidal I can give the one example of chlorine. Chlorine is a very has very good germicidal effect. It gives the coid kill the contaminance to a great extent.

So so this is the thing that we have so here in this in this lecture mostly I concentrate on the this air that contaminance present in the moving air that because heat is the not no good for the sterilization of the air.

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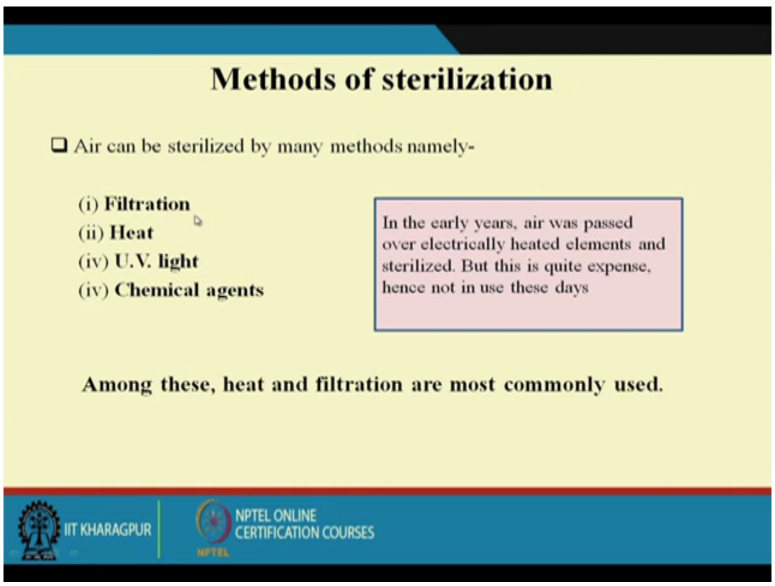

So filtration is the filtration is the kind of physical separation process through which we can separate the particular matters or cell present in the air.

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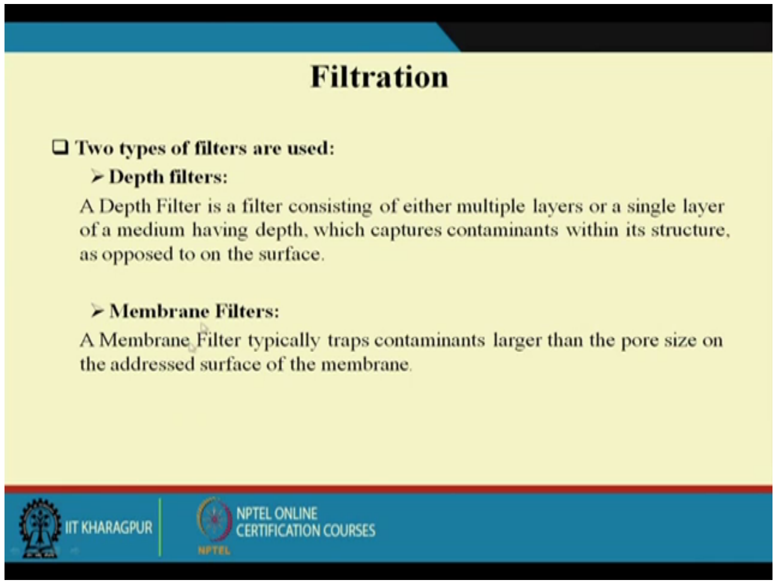

Now that filtration we have two types of filters we used. One is called depth filter and this is the membrane filter. A depth filter is a filter consisting of either either multiple layer or a single layer of a medium having depth, which captures the contaminants within the it's structure as opposed to on the on the surface. Let me give the very simple example, suppose suppose I told you glass wool fiber.

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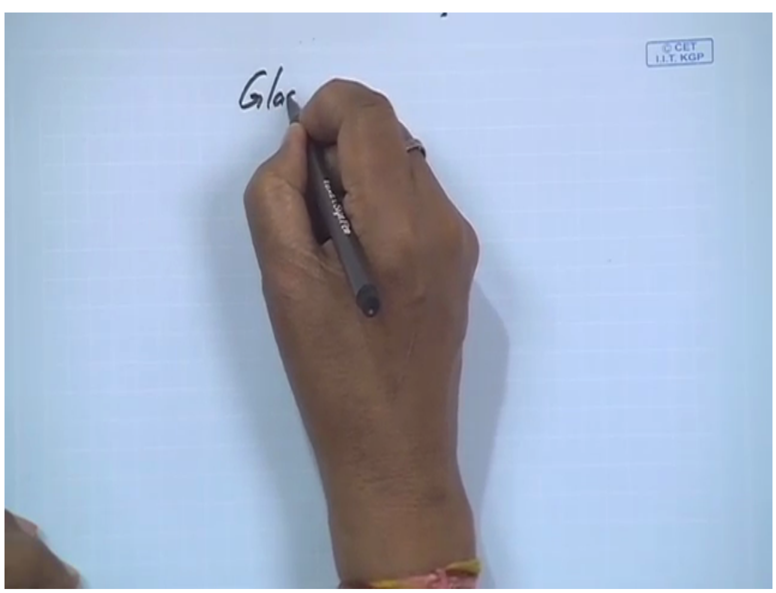

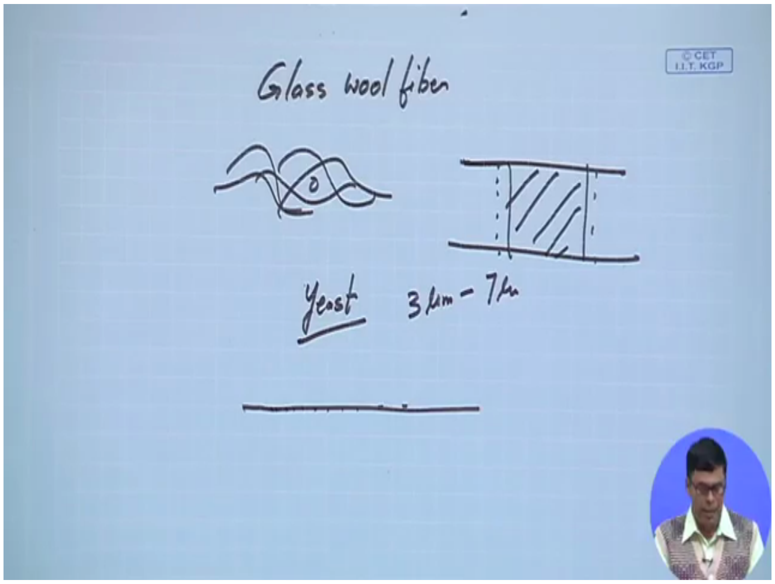

Glass wool fiber. Now glass wool fiber is looking like this. So the so you have this is a here, we put some kind of mess here and this is the glass wool fiber. So you can compress. We can we can we can we can make it compress, we can uncompress also. If you make it compress, your port size will be minimum and in the uncompress will be port size will be more.

So as per your requirement as for example I told you I I work with citric acid industry and our our main conflict is the essence. One main conflict is the bacterial yeast. So yeast it has the size about 3 microns to 7 microns 7 microns. So if the port we compress in a manner so yeast should be removed.

Most of the yeast in even some bacteria ()((9:21) through the filter doesn't affect our process to a great extent. So this is the depth filter that we have and membrane filter is very simple that we have a membrane here and membrane has some ports and inside the port as per and the the so basic difference between the membrane filter.

And the depth filter is that membrane filter we have some lot of operational program because if we if we reduce the size of the port then then life of the membrane because pressure across the membrane will be very high. If pressure across the membrane is very very high then the life of the membrane will be reduced to a great extent because .

And not only that howling of the membranes are present in other thing regeneration of the membrane that will be very difficult. Those are the problem very we have very problem. Because in case of membrane filter that is why industry particularly in the fermentation industry we go for depth filter by as for example glass wool filter we used.

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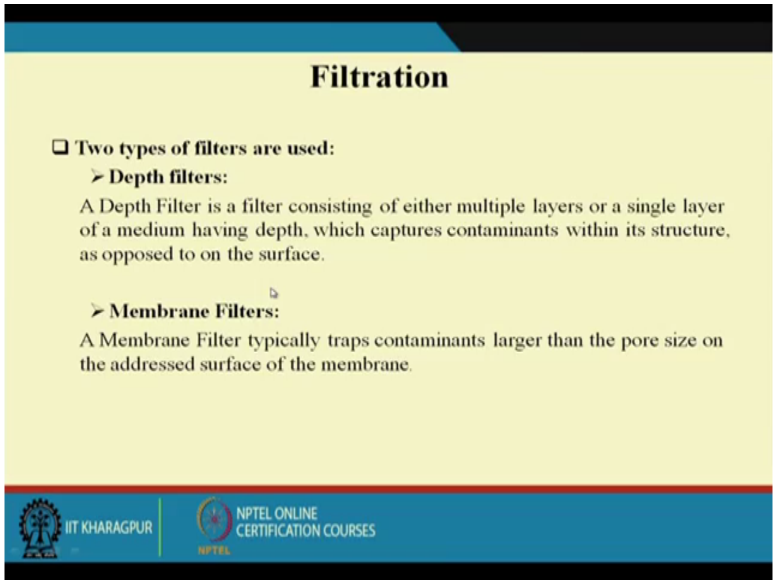

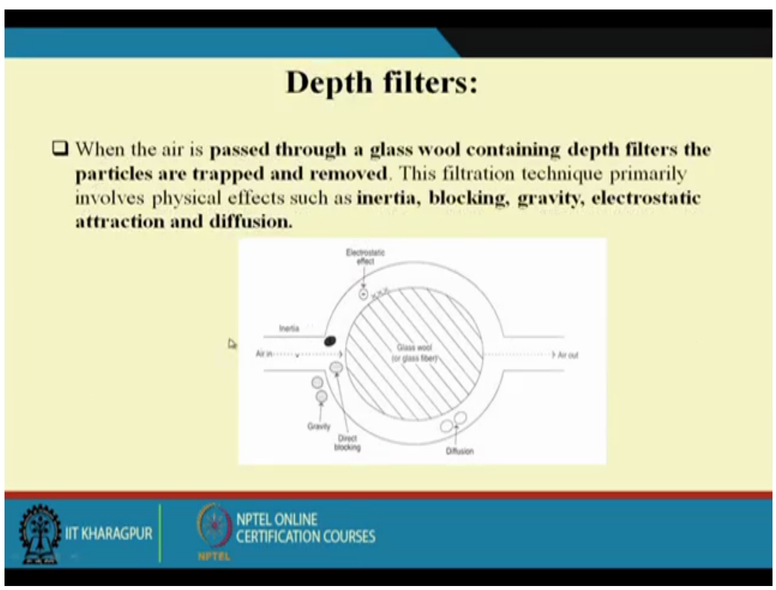

The in the depth filter air passed through a glass wool containing the depth filter and particles are trapped and removed. The filtration techniques primarily involve physical effects such as inertia, blocking, that gravity, static attraction electrostatic attraction and the diffusion. That as I will explain one after another how it is done?

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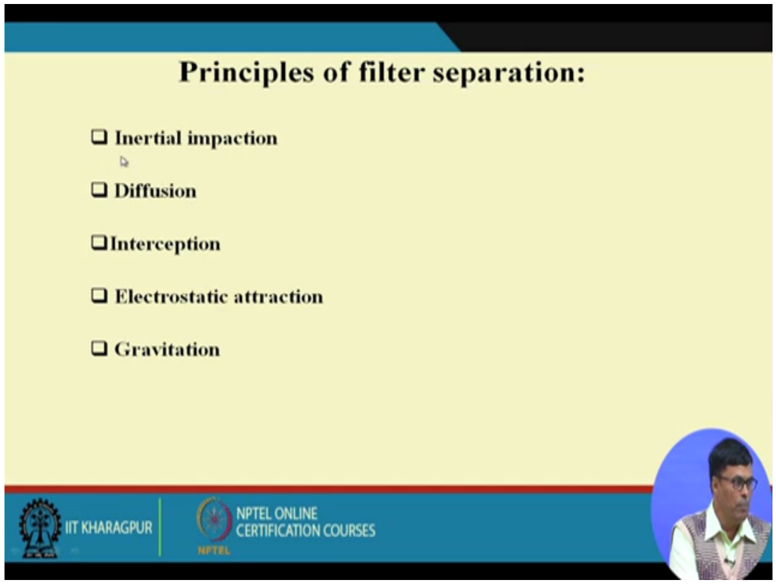

That first let us take so we have the inertial impaction, we have diffusion, we have interception, we have electrostatic attraction and the gravitation.

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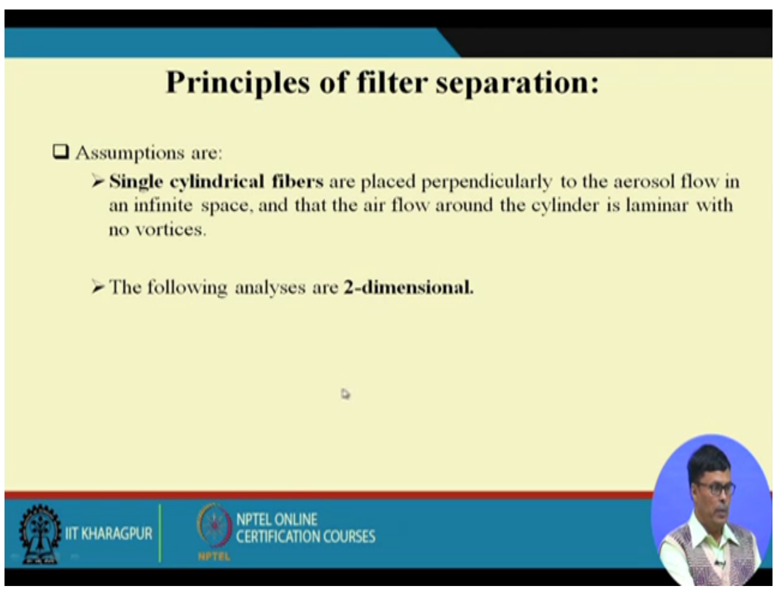

How it is the particle separation take place? So single fibers we can we can assume that the single fibers and it is if I take the cross section, this is the fiber.

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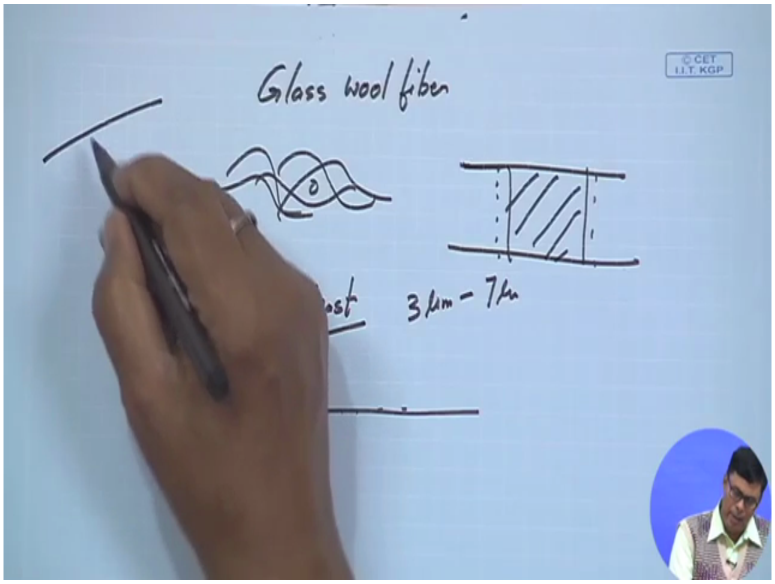

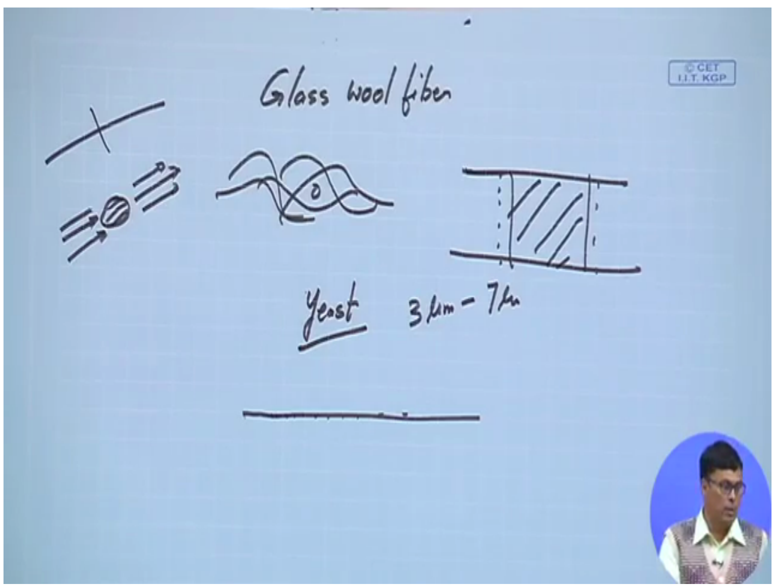

And if you take the cross section, it will be it looks like this. It is the circular and cross. Now as the perpendi perpendicular to the if the air is flow like this we can do the analysis of the system like this.

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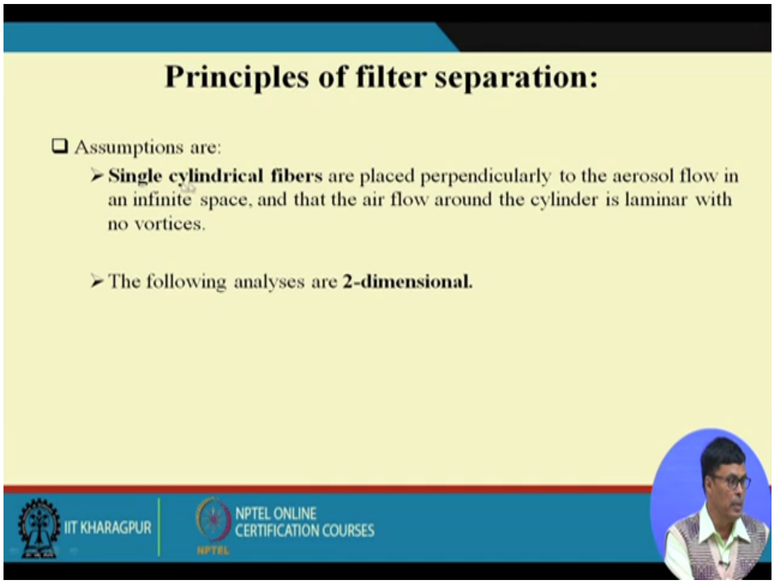

So we we we we make just like this single cylinder fiber is placed perpendicular to the aerosol flow in in an infinite space and that the air flow around the cylinder is laminar with no vertex. The following analysis is the two dimensional.

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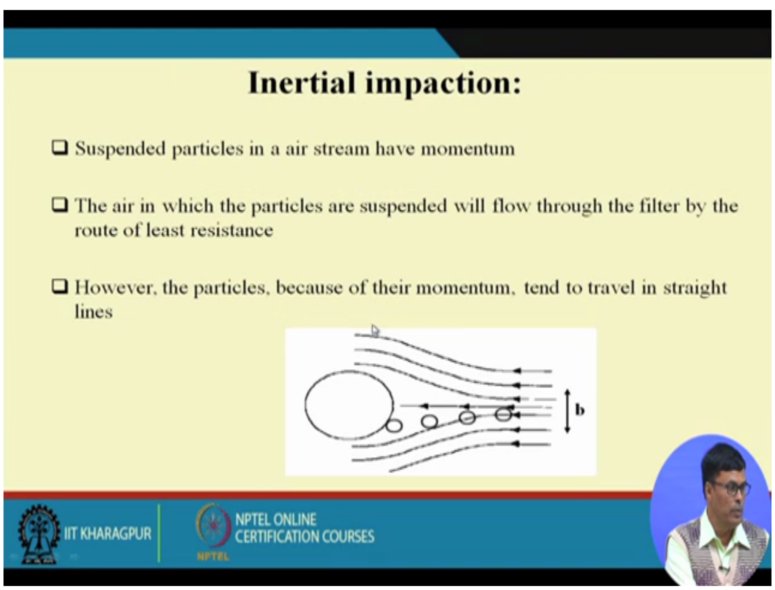

The inertial impaction let me tell you what do you call inertial impaction the suspended or the particles in a air stream has a momentum. Now air in which the particles are suspended will flow through the filter by the route or least resistance. However the particles because of their mom momentum tends to travel to in straight line.

So now we know Newton's first law of motion and first law of motion says that particle every particle try to move in the same direction because the inertia of forces. Now if if inertia force is very high because there there is a minimum velocity of the air stream is required for having this inertial impaction.

The if we have modes in that hen what will happen here you can see the particle is moving normally it is moving like this and touching the surface like this.

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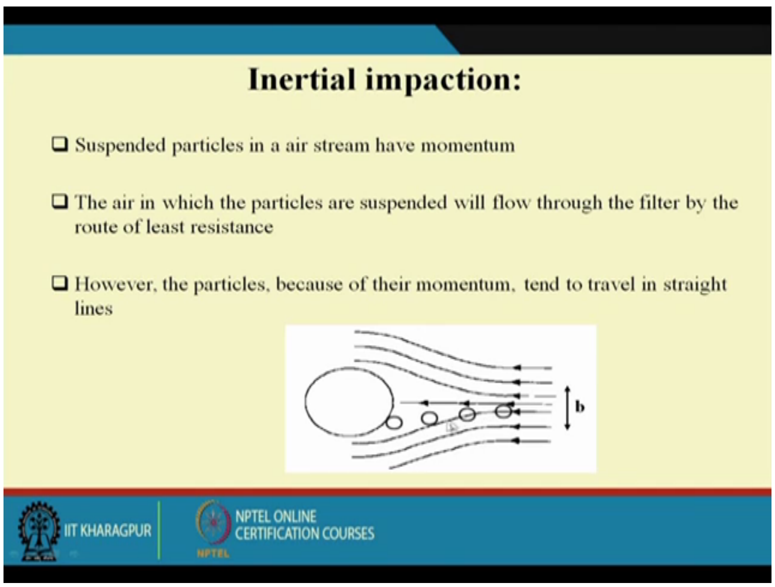

When you say the inertial impaction instead of moving this path it will follow the straight path because this is the air is flowing straight so the inertia instead of going this way it will go it will follow the straight path and deposited on the surface of the solid matrix. And this is called if the particle collected through this we call it particle collected due to the inertial impaction.

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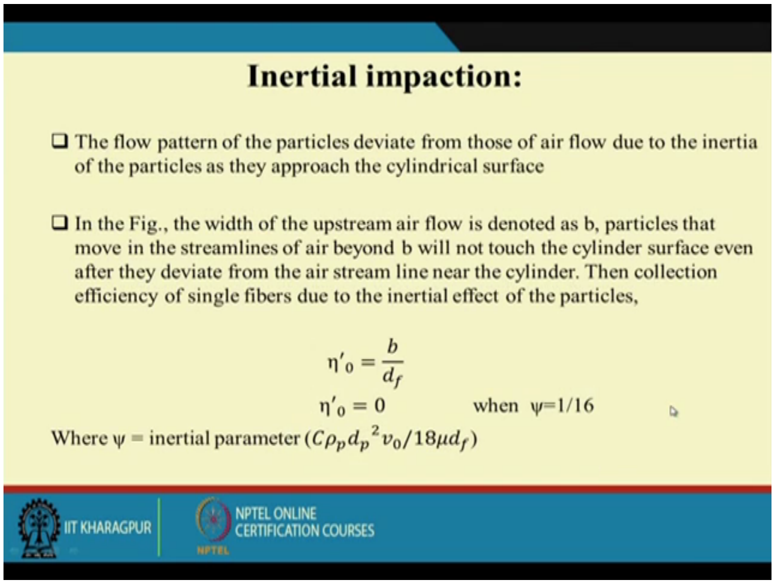

So the if you if you look look at here the flow pattern of the particles deviate from those of the air flow due to the inertia of the particles as they approach the cylinder. Because because this is this happens due to the high velocity of the fluid.

In the fig the width of the upstream air flow is denoted as B and particles that are move in the stream line of air beyond B will not touch the cylinder cylinder surface even after they deviate from the air stream line near the cylinder. Then the collection efficiency of single fiber due to the inertial impaction is usually expressed by B by df. What is B? B is the the effective width.

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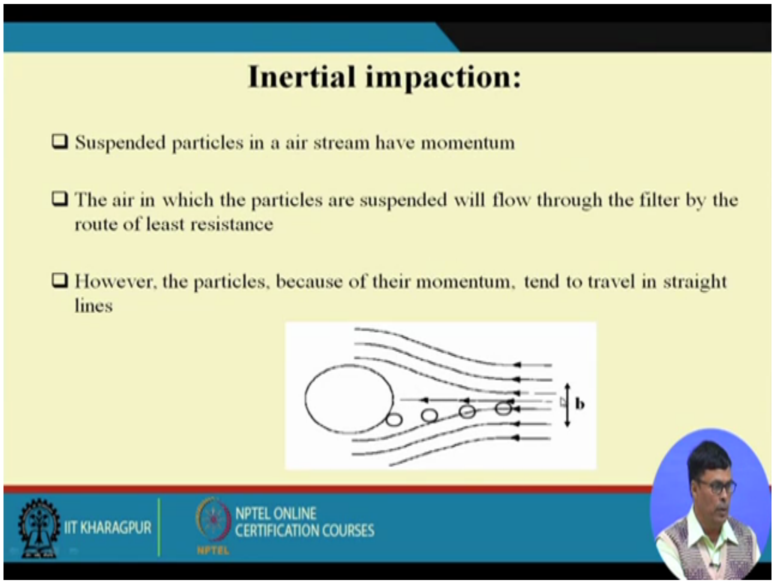

So what I want to know that this is which width of the air stream is effective. May be this is effective for here as we know that if there is a particle present there then straight way it can deposited on the surface of the this fiber. This is like this. That is why we consider this is a effective width of the air stream and diameter of the fiber is this is the diameter of fiber.

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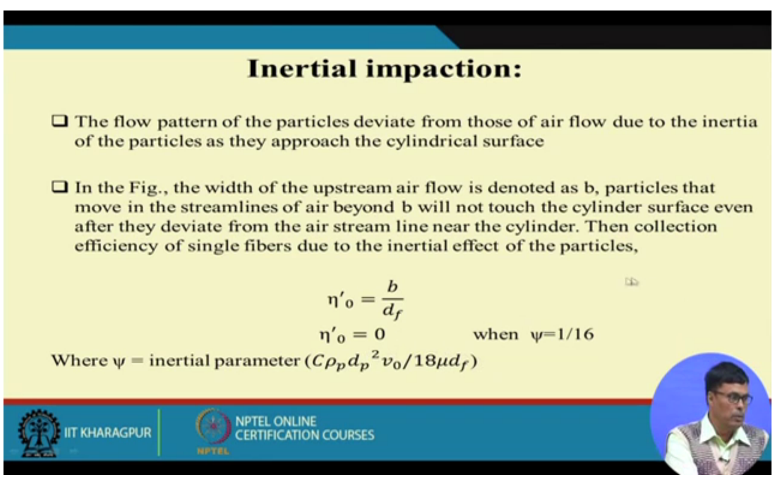

So collection efficiency of single fiber due to inertial effect of the particle is eeta equal to b by df. Now here the eeta will be equal to 0 when sie is equal to 1 by 16. What is sie? Is called inertial parameter. This is equal to c into rho P DP square V0 into 18 meu into DF.

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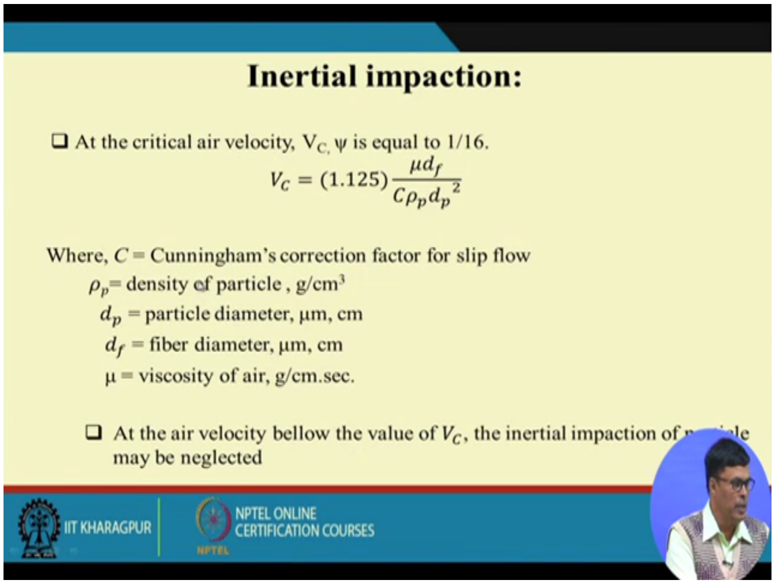

The C is the C is the Cunningham correction factor. PP is the density of particle. DP is the particle diameter. DF is the fiber diameter and meu is the viscosity of the air. The critical velocity is equal to that this one. That means the if the velocity is more than critical velocity then and only then the particle will collected through the inertial impaction that is the main thing all here.

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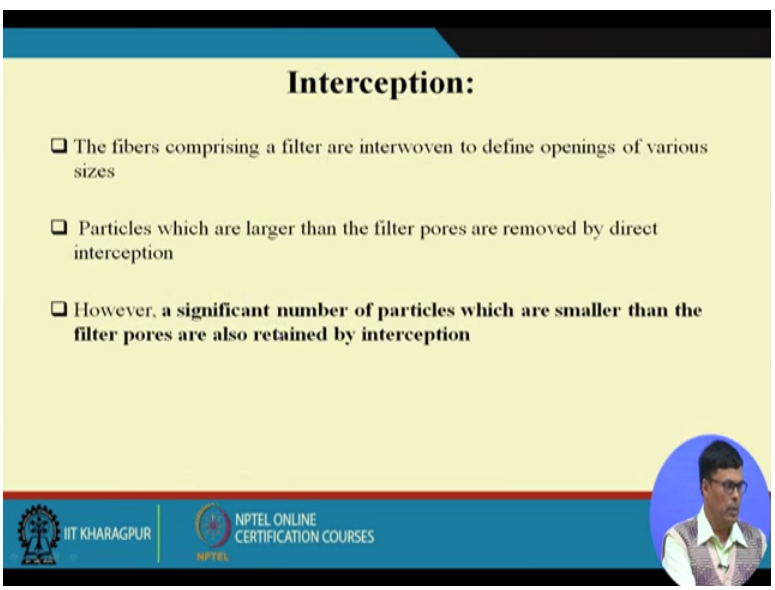

Then let me explain what you call interception. Interception means the that when particle moves here in the in this in this in this line the particle intercept with the fiber just deposited on the line it is there. Now when it is possible? It is possible suppose suppose a particle is going like this.

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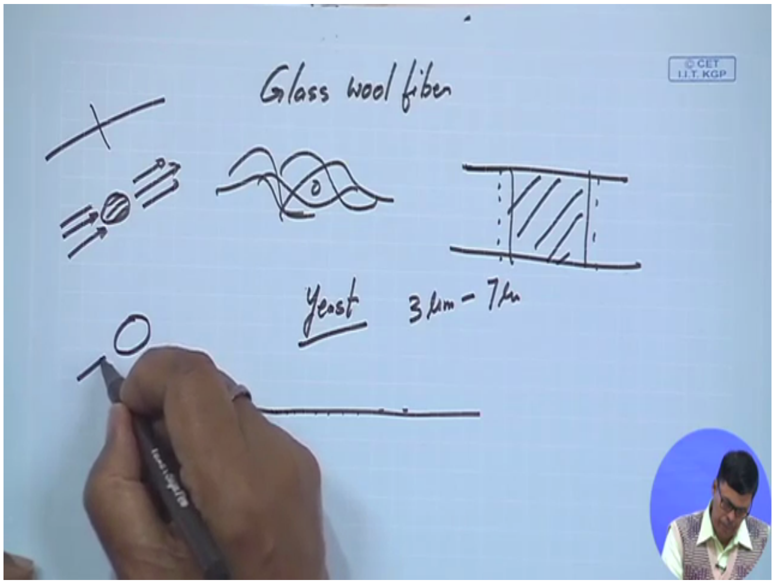

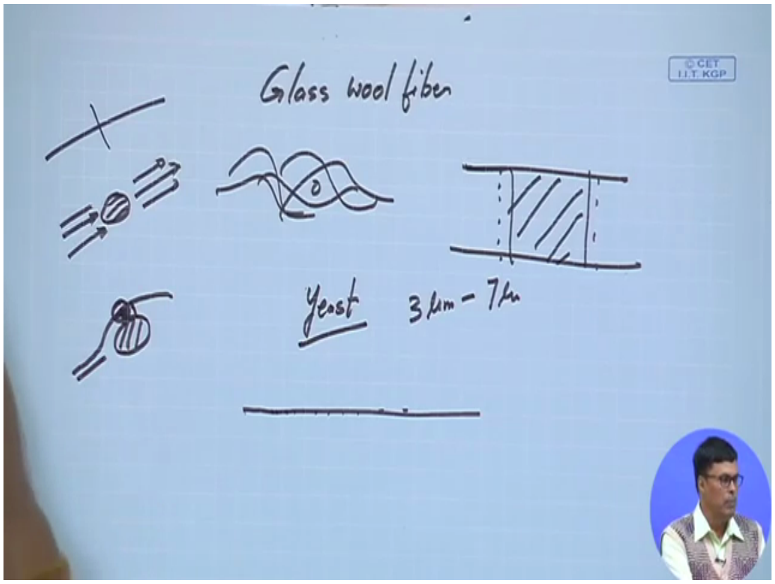

Now if this particle radiates is equal to the this width then and only then it will touch the surface of the fiber. Otherwise it will not stuck to the surface of the fiber. So this is if the particle collected like this we can call it the particles collected due to the interception.

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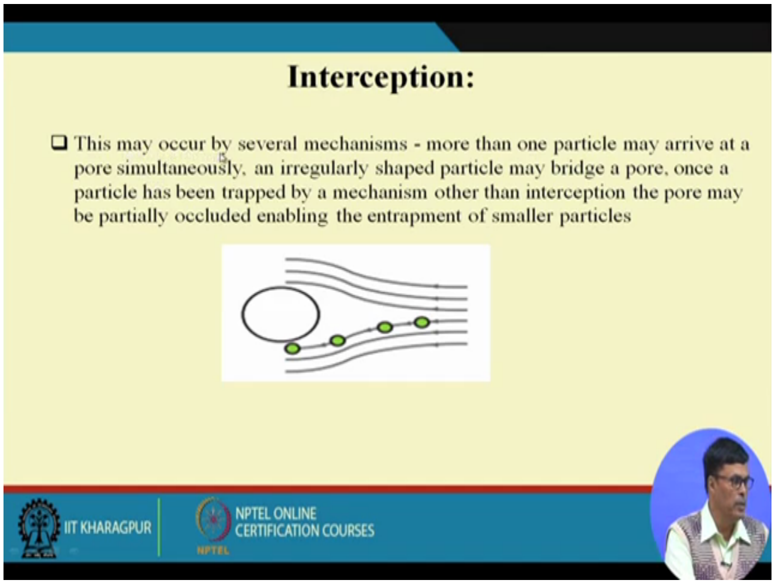

So this occurs by several mechanism by one more than one particle may arrive at a at a pore simultaneously, an irregularly shaped particle may bridge a pore and once a particle has been trapped by a mechanism other than the interception the pore may be partially occluded enabling the entrapment of smaller particles.

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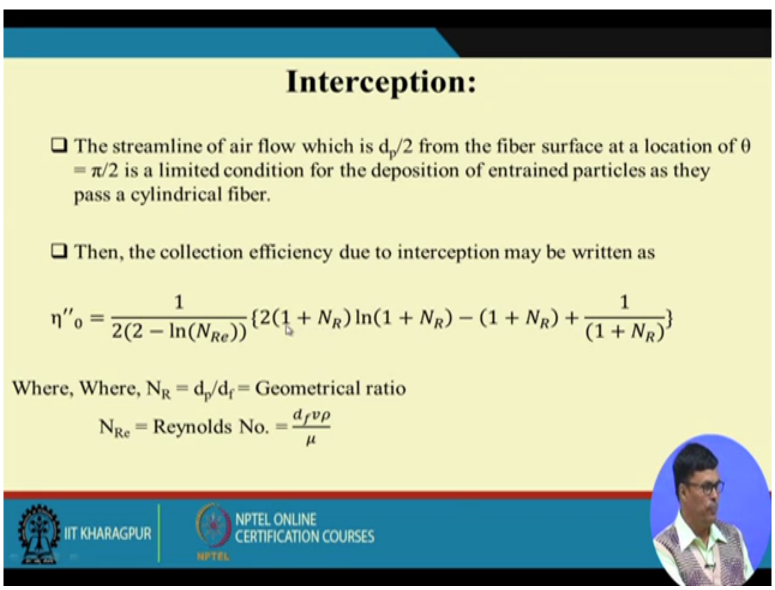

So this is the (())(17:11) that we have. Now the collection efficiency due to interception is expressed like this. Now here we come across one geometrical new term called geometrical ratio.

What is the geometrical ratio? Geometrical ratio is nothing but the diameter of the particle divided by the diameter of the fiber.

This is called geometrical ratio and NRe is the Reynold's number. Reynold's number is the flow characteristics of the fluid. DF VP by meu. Df is the diameter of the fiber, v is the velocity of the liquid and rho is the density of the air and meu is the viscosity of the air.

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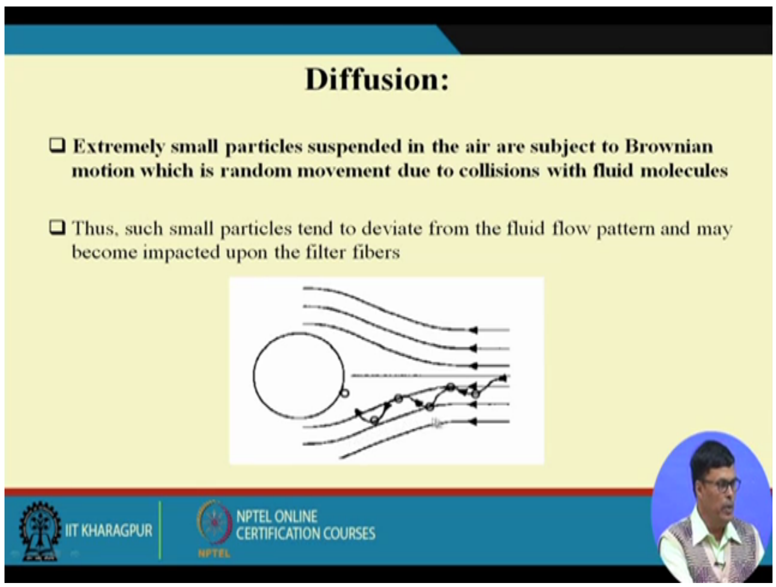

Now diffusion we define this this is usually takes place at a very low velocity of a air because the particles moves in the Brownian movement. Why? What is the Brownian movement? This particle strike this particle again strike this particle again strike this particle, ultimately deposited on the surface of the solid matric.

And if the if the particle deposited in the solid matric like this we call it particle particle collected through the diffusion. The extreme small particles suspended in the air are subjected to Brownian motion which is randomly which is which is random movement due to collision with the fluid molecules.

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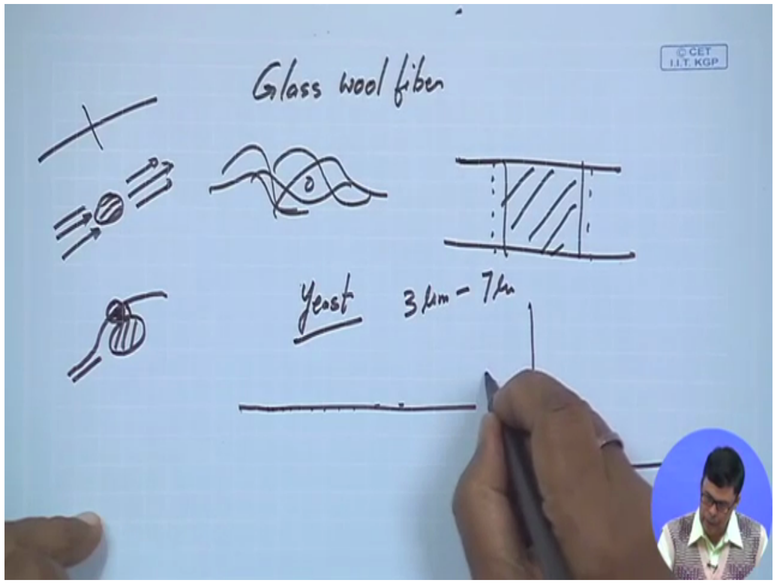

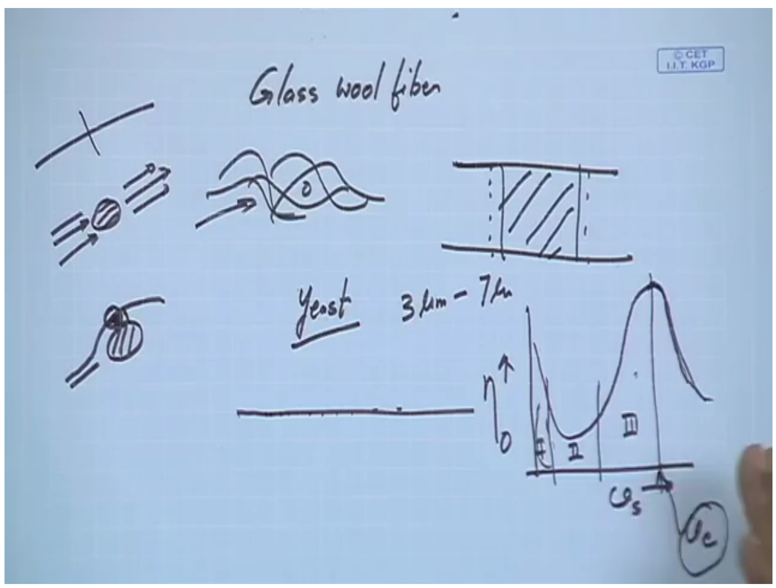

So if I if I if I want to draw like this that a plot this collection overall collection efficiency versus the velocity of the fluid velocity of the fluid the supervision velocity of the fluid. We can have a plot like this. So this is very important because here we have three different sections that this is air this is one this two this is three. So here the particles mostly collected due to the diffusion.

This is interception and this is mostly due to the inertial impaction with high velocity. But here there is a called critical velocity because in case of inertial impaction we have come across the we want critical velocity. What is that critical velocity? Above which the particle collected due to the inertial impaction. Because but this critical velocity is what?

Because above this velocity if you keep on increasing the velocity of the air the time will come that your dragging force of air is so high that will take the fiber out from the fiber. So what will happen the performance of the fiber will take down? So for designing of air filter we shall always have to consider this critical velocity.

The velocity when you design the on the circumstances the air velocity should be lower than this. Air velocity should be always less than that. This is the particle is very much essential.

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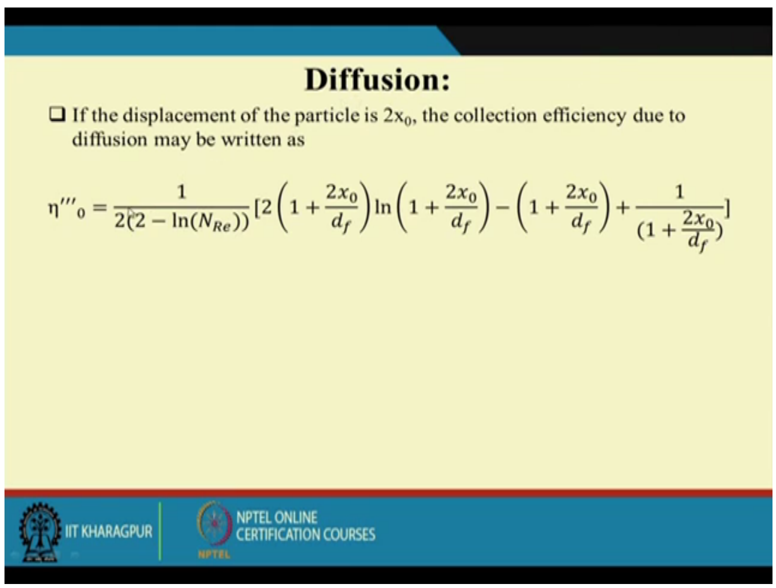

Now particle that overall collection efficiency due to due to diffusion is expressed like this. Now here in case of interseption we use air and air is the geometrical ratio this is this is usually replaced by 2x0 by df. Now 2x0 represented the displacement of the particle.

That is called how how much path is the that is 2x0 and then the collection efficiency is calculated as like that. It is exactly similar to (())(21:07) interception and the difference is that vp is decreased by 2x0.

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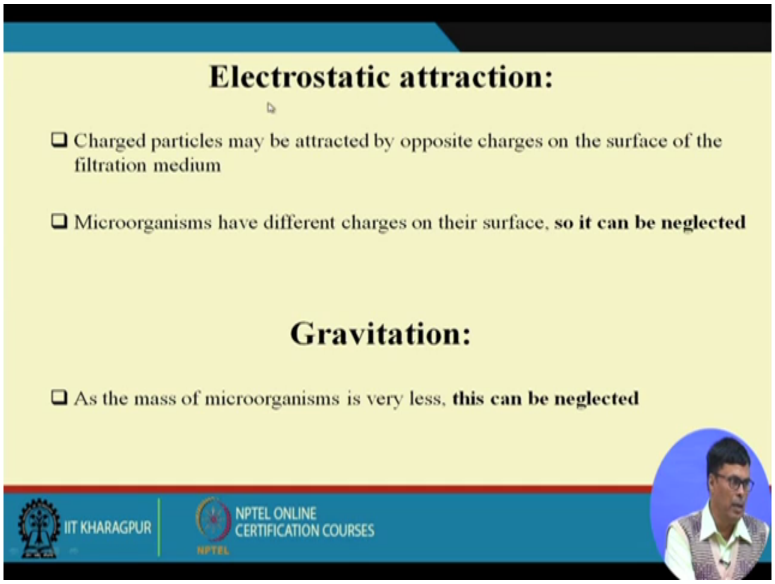

Now particle also can be collected with the help of electrostatic attraction but it is insignificant. Why it is insignificant? It has been found that that organisms I can give you typical example of (())(21:30). That you can look at the charge distribution of gaseous surface is defined. That may be 70% is may be neutral may be positive 20% may be other charge and the 5 to 10% are might be the other charge.

That that if the distribution of the charge of this organisms is different then naturally the your fiber has the only one charge. May be positive charge so if it is positive charge it will attract only the negative charge. Now if your particles has both positive negative and neutral charges then it will electrostatic particles separation through due to the electrostatic attraction can be neglected.

Now since in the in the air filter we target the smaller particle, the smaller particle is very low density. So particle separated through a gravitation also can be neglected. So usually the overall collection efficiency can be expressed as eeta 0 1dash eeta 0 2 dash eeta 0 three dash.

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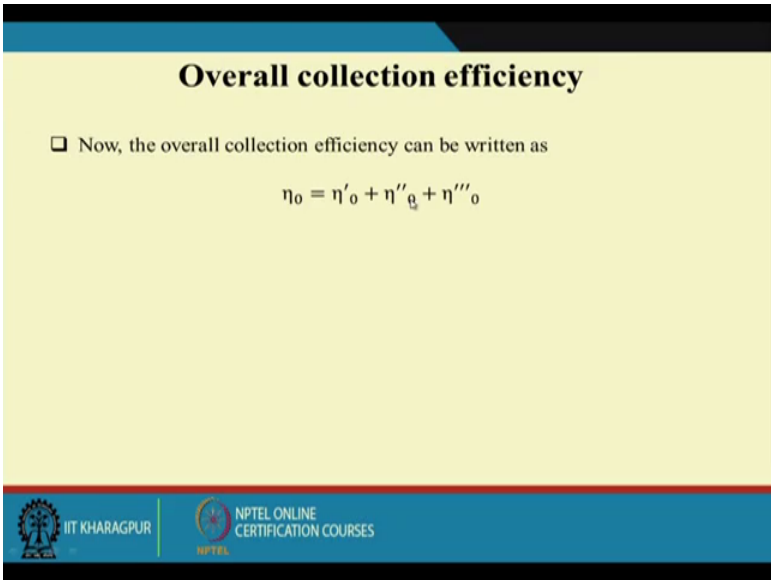

So this is collection efficiency due to inertial impaction due to interseption and due to diffusion.

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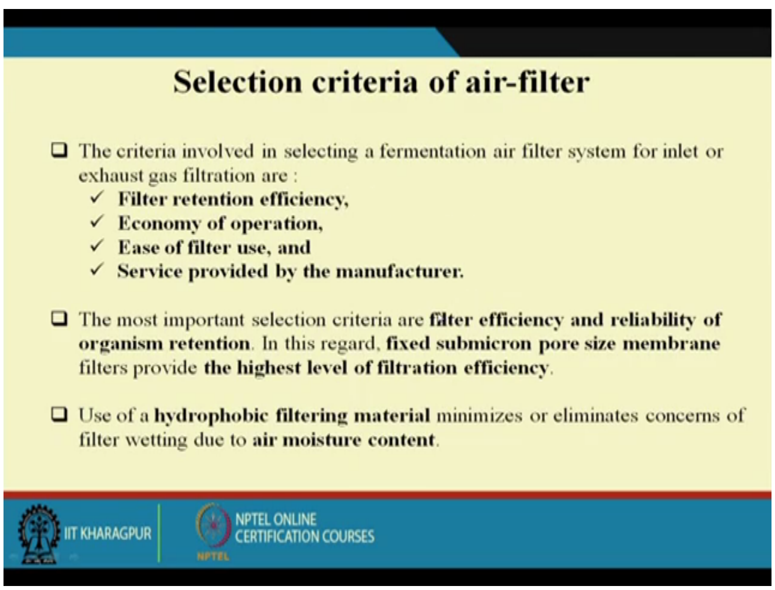

Now question comes that what are the selection criteria for for choosing this air filter? Then possible selection criteria we can select the air filter. What is the alteration efficiency, what is the efficiency of the filter? This is very important rule. Then economy of the operation because how much money we are going to spend for that.

Ease of filter use, how easily we can use the filter and service provided by the manufacturer. This is very important because this factor that the selection criteria of the air filter. The most important selection criteria filter efficiency and reliability of organism retention. In this regard the fixed submicron pore size membrane will provide the highest level of filtration efficiency. Now I I also saying that there is a term called absolute filter.

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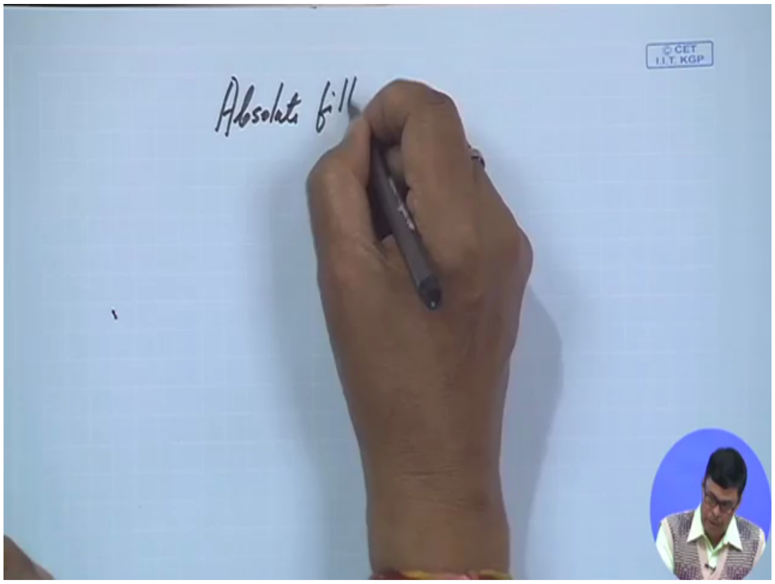

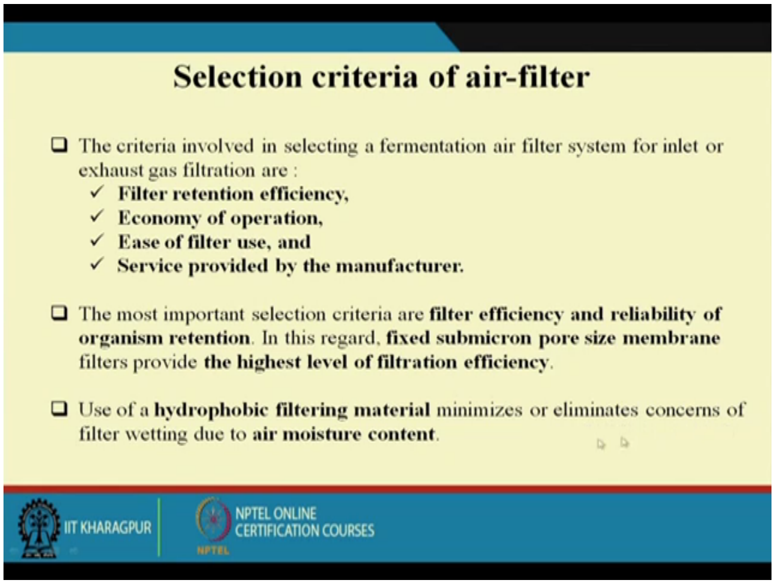

Absolute filter means absolute means what? That you know suppose when you use the membrane membrane is the diffused pore size is the point 55 microns. So if a point 5 micron particle more that point 5 that return in the fiber. So all the particle removed in this. That that is the absolute filter that we have.

Now use of a hydrophobic filtering material minimize or eliminate concerns of filter wetting due to the air moisture content. This is the important characteristics that we have. Now here we need to talk about glass wool filter talking about the glass wool fiber. Now question comes why we are selecting glass wool fiber? Why not jute fiber? Why not nicotine fiber?

The reason is that that a that if if we I told you that the term called drag coefficient. The drag coefficient in case of what you (())(25:06) Reynold's number we use that in case of glass wool fiber and in case of this jute fiber or nicotine fiber. The drag coefficient in case of cotton fiber jute fiber is much high as compare to that of glass wool fiber.

And this drag coefficient you can this is related to the pressure drop across the filter. If the pressure drop across the filter. If the pressure drop across the filter then there will be friction. Because no friction then more will be the pressure drop. Less friction less will be the pressure drop. The more friction means that more heat will be generated.

If no heat will be generated in case of jute fiber cotton fiber it will catch fire catch fire more easily. But in case of glass wool fiber it can distract high temperature so it will not catch fiber so easily. So that is the advantage that we have. So that is the main reason of use of glass wool fiber in the industry. .

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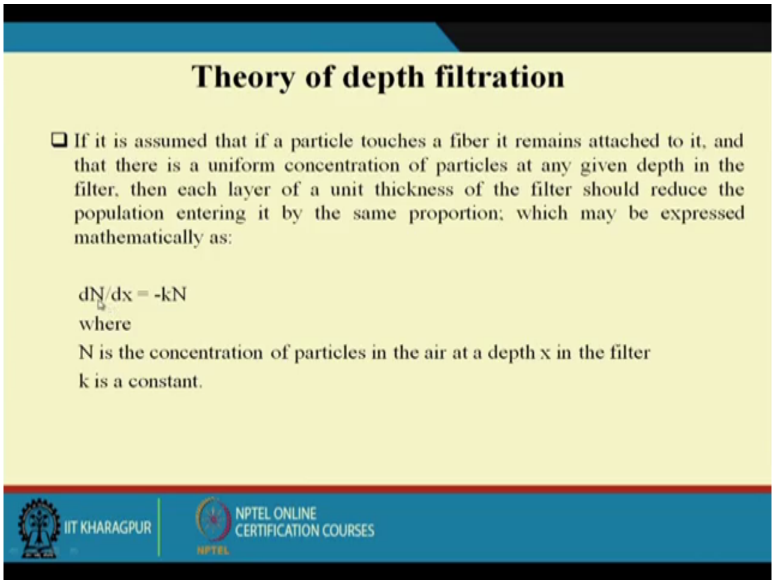

There is a depth filter that related to the particle can be expressed like this dn by dx. x is the filter depth and n is the concentration of the particles.this is the constant of kinetics.

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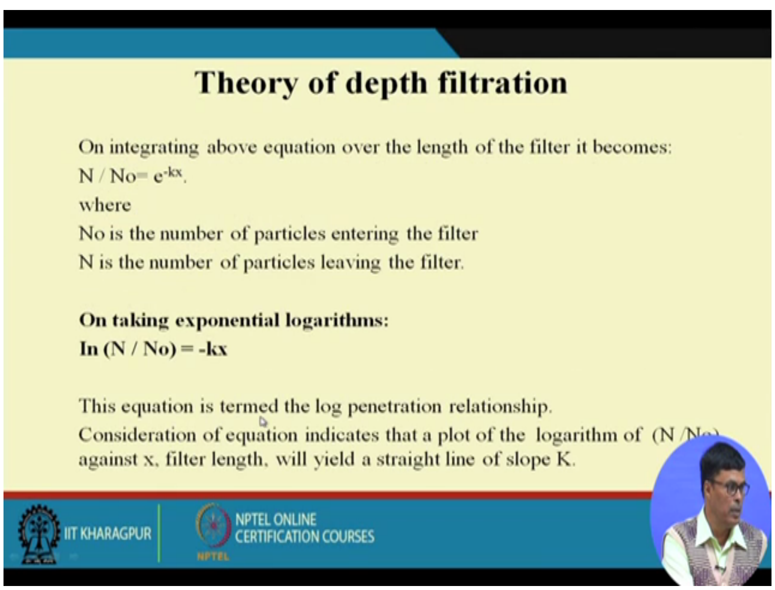

And we can express like this n by n0 we can express like this.

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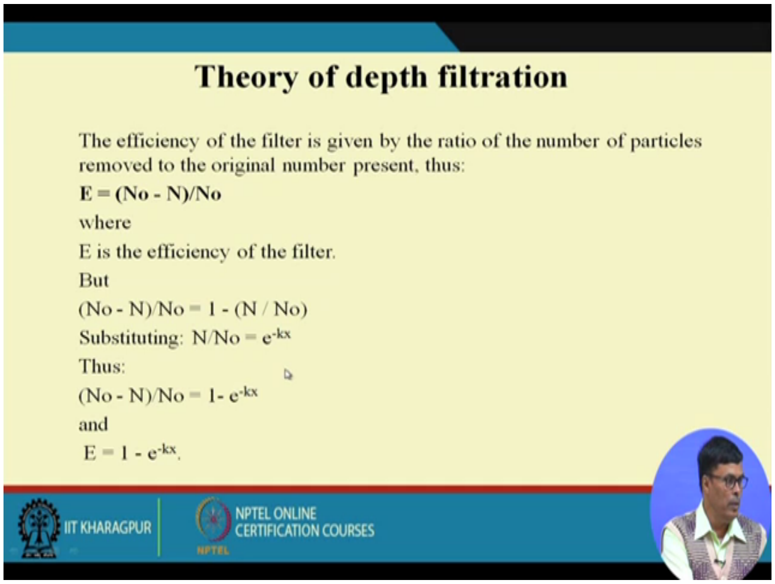

Then we can have this we can easily find out 90% (())(26:44) what is the expression we get 2.303 divide by k that.

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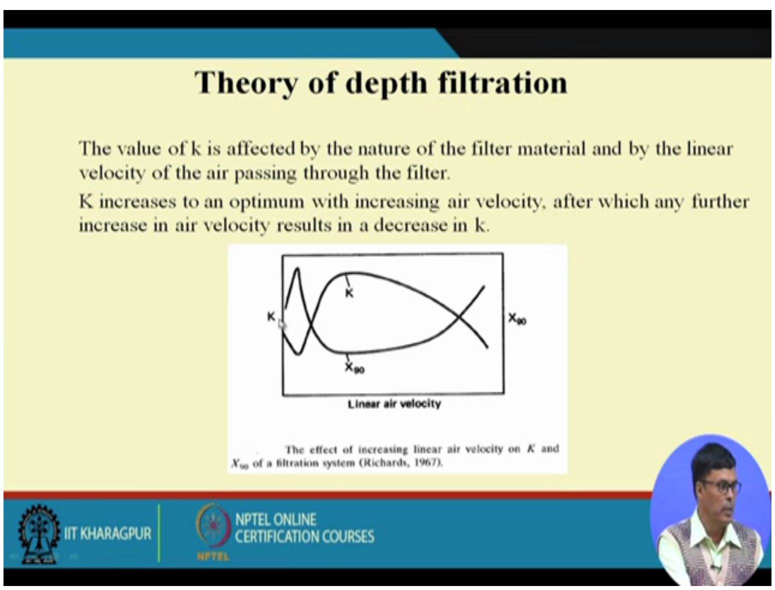

Now now if you plot this k value that is the (())(26:56) efficiency that if we keep on increasing it is it is decreasing. That your efficiency increases but again it (())(27:09) because at high velocity what is happening? The high velocity I told you the drag force is too high it will detach the particle from the glass wool fiber and it will take it out.

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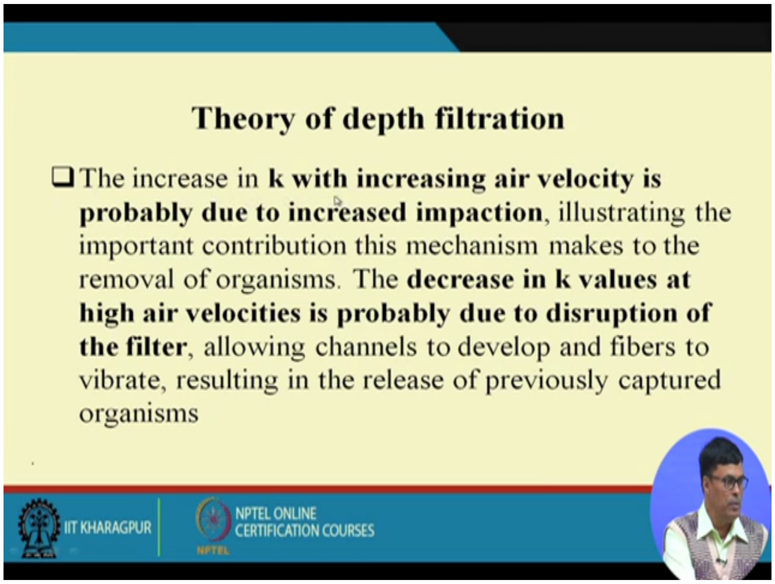

Now in case of k increasing air velocity is probably due to increased impaction, illustrating the important contribution this mechanism makes to the removal of organisms. The decrease of k values at high air velocities probably it is the disruption of the filter allowing channel to develop and fibers to vibrate resulting in the release of previously captured organisms.

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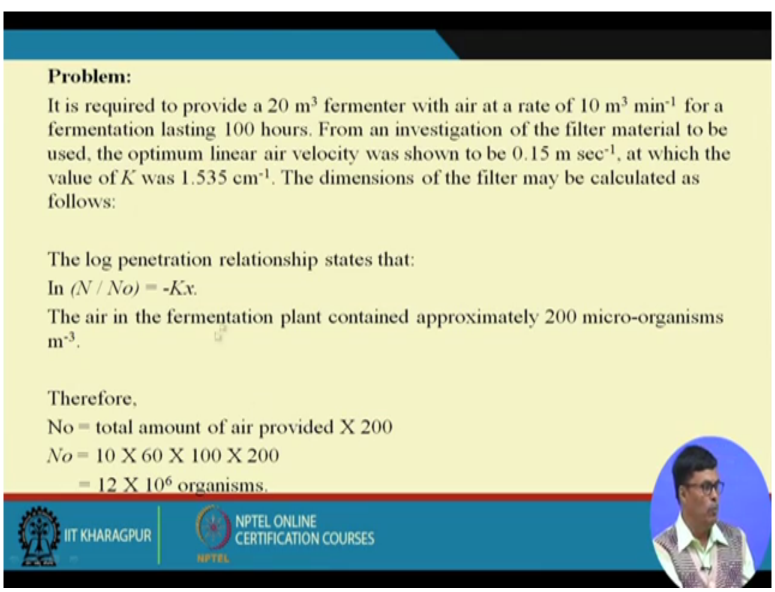


Membrane filters:

- These are **fixed pore filters** (which have an absolute rating) are very widely used in the fermentation industry and several manufacturers produce filtration systems for air sterilization.

- The pre-filter traps large particles such as dust, oil and carbon (from the compressor) and pipe scale and rust (from the pipework). The use of a coalescing (combined, united) pre-filter also ensures the removal of water from the air; entrained water is coalesced in the filter (air flow being from the inside of the filter to the outside) and is discharged via an automatic drain

Problem:

It is required to provide a 20 m^3 fermenter with air at a rate of 10 m^3 min^{-1} for a fermentation lasting 100 hours. From an investigation of the filter material to be used, the optimum linear air velocity was shown to be 0.15 m sec^{-1}, at which the value of K was 1.535 cm^{-1}. The dimensions of the filter may be calculated as follows:

The log penetration relationship states that:

$\ln (N / No) = -Kx$.

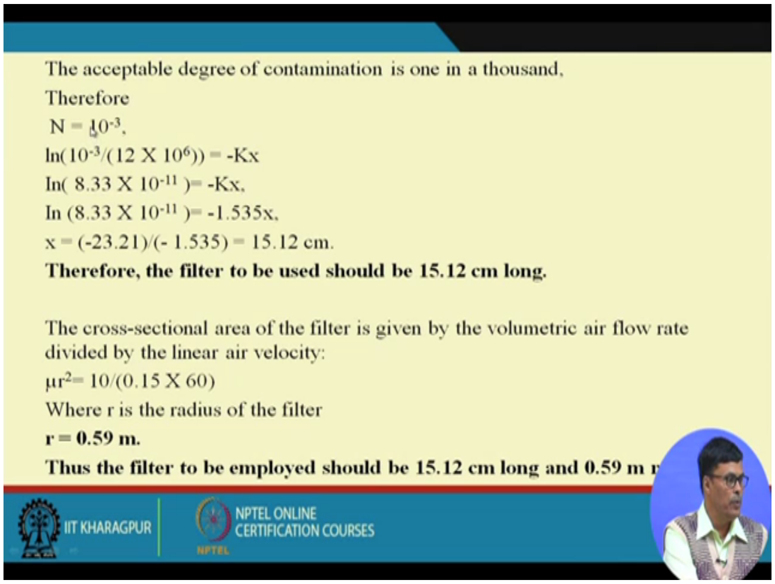
The air in the fermentation plant contained approximately 200 micro-organisms m^{-3}.

Therefore,

No = total amount of air provided X 200

$No = 10 \times 60 \times 100 \times 200$

$= 12 \times 10^6$ organisms.



So there is a problem here and it is required to provide 20 cubic meter fermenter with air at a rate of 10 cubic meter per minute for a fermentation lasting 100 hours from an investigation of the filter material to be used the optimum linear air velocity was shown to be point 15 meter per second at which the value k value suppose 1.535. This K should be the small k here is one k that is 1.535 centimetre inverse.

The dimension of the filter may be calculated as follows. It is very simple. So we can we can calculate that. We can n by n0 equal to k into x. Then we can we can find out what is the N0 value? How we can calculate so we have this reaction the air fermentation plant contained 200 microorganisms per cubic meter.how much air fermented is 10 cubic meter per minute.

Multiplied by 60 minutes in hour. Then 100 hours we need to find out how much micro organisms are there? Then what is the n value we wanted because acceptable degree of contamination is one in thousands just I want to point out point out design criteria of air filter we should assume that the what we are going to do .

what are the 10000 value of the how many thousand so as per your process is concerned you can decide on the basis of that you can design air filter and if you put this value you can find out x. X is nothing but the depth of the air filter. This is coming about 15.12 centimetre. Then we can if you if you calculate this this diameter of the (())(30:04) you can find out this is coming out 0.59 meter.

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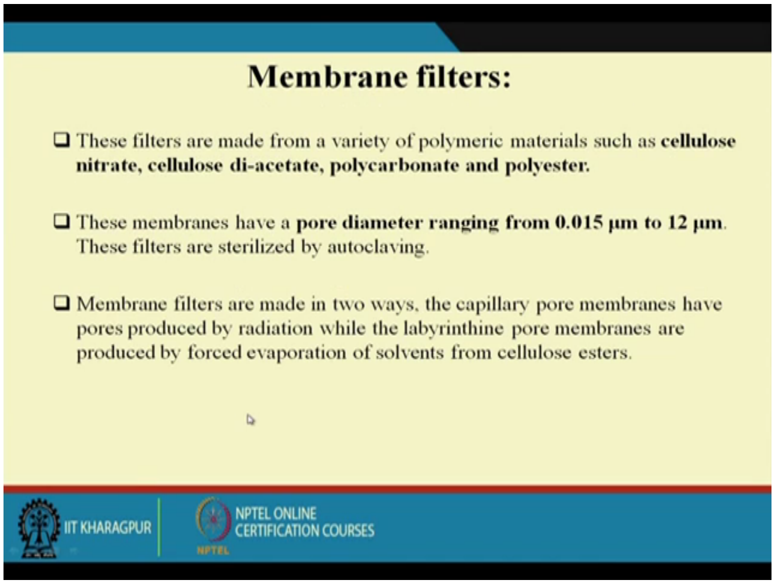

the membrane filter always we talk about and the examples are cellulose nitrate and cellulose di acetate, polycarbonate and polyester. The pore size ranging from 0.015 micrometre to 12 micrometre. Only the problem is that I told you that in case of membrane filter life is a life is very small.

Because heat is to be very high and as you know that in operation can depends on the pressure drop across in the process pressure drop in case of membrane filter is very high. So the operation cost is very high in case that is not easily adopted in the industry. Thank you very much.