Aspects of Biochemical Engineering
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Lecture - 52
Air sterilization – II

Welcome back to my course Aspects of Biochemical Engineering. Now we are discussing the air sterilization process today; I am planning to discuss some problems the numerical problems on air sterilization process, designing of air filter. Now, in the last day lecture you can remember right I try to discuss that what are the different processes, through which we can kill the organisms, we can remove the microorganisms or kill the microorganism.

There are 3 different processes we have one is called stabilization, and another is the thermization, another is the pasteurization. What is sterilization? Sterilization either you kill them all microbes present in the particular media or air. And thermization you just reduce the load of total microbial population. And pasteurization is mainly we target for pathogenic microorganisms. Now in the fermentation industry as I told you sterilization plays very important role uh, because we want to grow our desired organism as you know that atmosphere we have lot of different type of microorganisms they are present there.

So, if you allow those organism to interfere in the process majorly our purpose will not be served. So we shall have to maintain the dual conditions and we observed that most of the biochemical industry they are operated aerobic fermentation, they use the aerobic fermentation process. Now in the aerobic fermentation process major drawback is the dissolve oxygen concentration because your microorganism can take the oxygen which is dissolved in the media. They cannot take the oxygen which present in the air.

So, we shall have to pass the air now we know the air comprehensible of lot bacteria, lot of different type of microorganism. So if you if you just (Refer Time: 02:30) the air through the media there every possibility a lot of (Refer Time: 02:35) may grow in the media. So we said have to sterilize the air and also the media that is required that is also to be sterilized. And also we shall have to sterilize the vessel in which the fermentation take place also the pipeline and other things where the sample is to be drawn everything is to be sterilized.

So, we observed 2 major concept one is a major source of contamination, one is the air, another is the media. Now in the last lecture I tried to discuss how the air sterilization process can be workedout. And I discussed the different way we can sterilization the air one heat, one is the by using electromagnetic waves or by using germicidal spray. So whenever we talk about air then we find 2 type of air one is moving air and another is stagnant air. For stagnant air we usually use UV rays, or we use the germicidal spray because suppose particularly I can give the example in the (Refer Time: 03:48) breaking industry. That we need a big room called the cultivation of cord.

So naturally cord is usually where formation takes place in open vessel and the room should be sterilized. And that we put some kind of chlorine chlorination of this room. So that you know it is free from the contaminants, but the question comes in if you have a moving air; how the moving air we can we can remove? So there are heat and that you know filtration 2 kind of devices can be used for removing the microorganisms present in the air.

Now when we use the heat literally that you know that when you increase the temperature the protein present the inside the organism they will be denatured, as soon as they will be denatured then the biochemical activity of the organism will be lost and your organism will be killed. So that is, but one problem with the heat in case of air where air is the non conductor of heat. So initially that is not good media for air sterilization. So it has been found that may be that type of filtration is a device through which we can remove the contaminants present in the air very easily.

Now a filtration also we have found you know different types of filter; we use the fiber type of filter we have membrane type of filter. Now in the in case of fiber type of filtered the organisms there entrapped in between the fiber. Now if the fiber as for example, glass wool fiber if you use then if you compress it then when you compress it we find and that pore size will decrease. So as per our requirement then we can design the air filter. Now I there are different principles involved for removing the particulate matter by the filtration that they discussed in the last class and we have come back cross one parameter that overall collection efficiency.

This can be theoretically estimated as well as heat this can be estimated on the basis of the correlation between the single fiber if you correlation we have on the flow characteristics of the fluid that you know we can find out the overall efficiency of the process. And that we can correlate with the single fiber efficiency from single fiber efficiency we can find out the thickness of the air filter.

Now the today we want to discuss some kind of problem that on this realization process first let us discuss.

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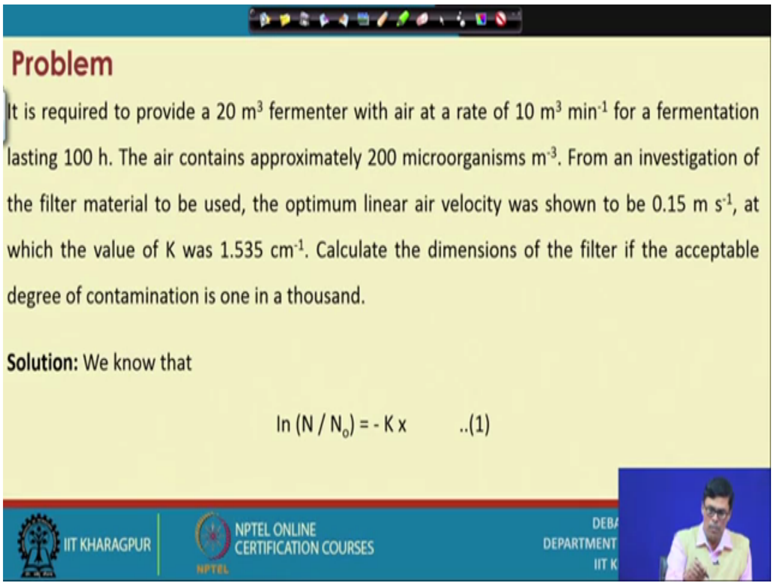

Now it is required to provide 20 cubic meter fermented with air at the rate of 10 cubic meter per minute for a fermentation, lasting for 100 hours the air contains approximately 200 microorganism part milliliter. Now from an investigation of the air material the filter material to be used the optimum linear velocity was shown 0.15 meter per second, at which the K value is 1.535 centimeter inverse.

Calculate the dimensions of the filter if acceptable degree of contamination one in thousand. Now here I forgot to mention one particular one important thing that when you design any kind of air sterilization or medium sterilization process. We considered that what is the label of sterility we are going to maintain?

Now label of sterility we can maintain in different way as for example, 1 we can have 1 in air 1 in 1000 am I right; that means out of 1000 organism that 1 by 10 that organism should be present 1 in 1000. So I can do the sterilization on the basis of 1 in 1 million 1 in 10 million; the more when you want a more critical sterilization conditions. Then we lost a sterility will be more high because 1 in 10 million 1 in the that kind of (Refer Time: 08:30) sterility is not that important that you can reduce that 1 in 1 million 1 in 1 lakh like this we can do that. So here the 1 in 1 1000 is mentioned here.

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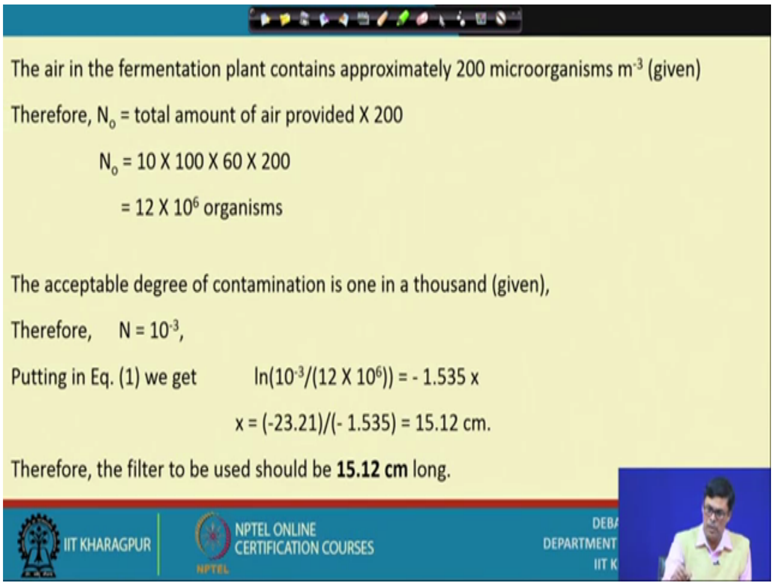

Now we have in the last lecture I have shown you that that thickness of the filter that can be correlated with the like this ln N by N 0 equal to K into x. Now the how you calculate the air how much organism present in the air? How we can calculate? And now let me show you that that if you look and look at the problem what is we have 200 micro organism per cubic meters. And it is flowing at a flow rate of 10 cubic meter per minute. So then you know this is lasting for 100 hours.

So if you want to find out per hour it will be 10 into 60 then the cubic meter per hour. Then if you multiply this then you will find the how much volume up air is there. Then if you know if you so this is like this if I calculate 10 cubic meter am I right 10 cubic meter per minute. So if you multiply by 60 because the 1 1 1 hour is equal to 60 then this. This we can write like this then it will be very easy though we have 1 by minute this is 10 cubic meter per minute am I right?

So, how you can convert it into per hour this is now 1 hour equal to 60 minutes. So this miniseries will cancel so 10 into 60 you can do that. And stay 100 100 hours how much volume will be there you multiplied by 100 then you will get the total volume. Now per cubic meter how much micro organism present 200 microorganism.

So you multiply by 200 you will get the total number of microorganism in the air. So this is exactly what we have calculated, you can see it then this is the inlet and what is the microorganism we are targeting 1 in 1000; that means, 10 to the power minus 3 1 in 1000. So how we can write 10 to the power minus 3 am I right.

So, what is the formula? l N N by N 0 equal to K into x right. Now N N value already we know that N to the power minus 3 then we put it here this is the total number this is the N 0 and this is this is K value. So we can easily find out the what it should be the filter how are the length of the filter we can use a 15.12 it is not very difficult you can easily do that. Now let us consider the second part that what is the cross section area of the filter is given by the flow rate of the linear velocity. Now cross section how you can find out pi r square.

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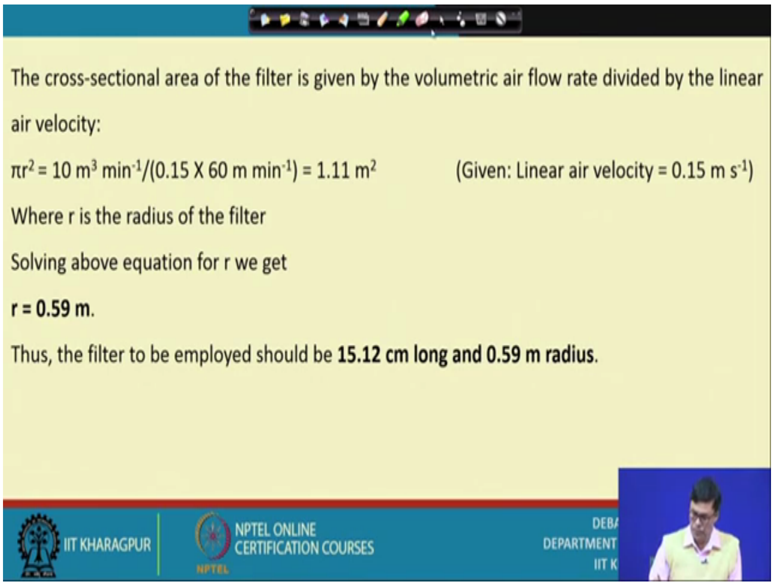

So r is 0.15 meter so we can easily find out that this is the per area now. Now where that where I the solving the above parameter then we can find out r equal to that then we can find out the r equal to that 0.59. So the cross section of the filter is coming about this radius is 0.59 meter and length is this the that we can easily calculate. That how we can we can we can do the calculation of this particular because I hope you understand that because how we have calculated because you know that we know the flow rate, flow rate we know flow rate is what? Flow rate is cubic meter per minute am I right.

Now if you divide by the velocity of air velocity air then; obviously, we will get the cross sectional air. What is the velocity is meter per minute am I right? So minute will cancel and meter 1 meter will cancel this square so it will be area. So we can easily do that. So this is how we can calculate the radius and the length of the air filter.

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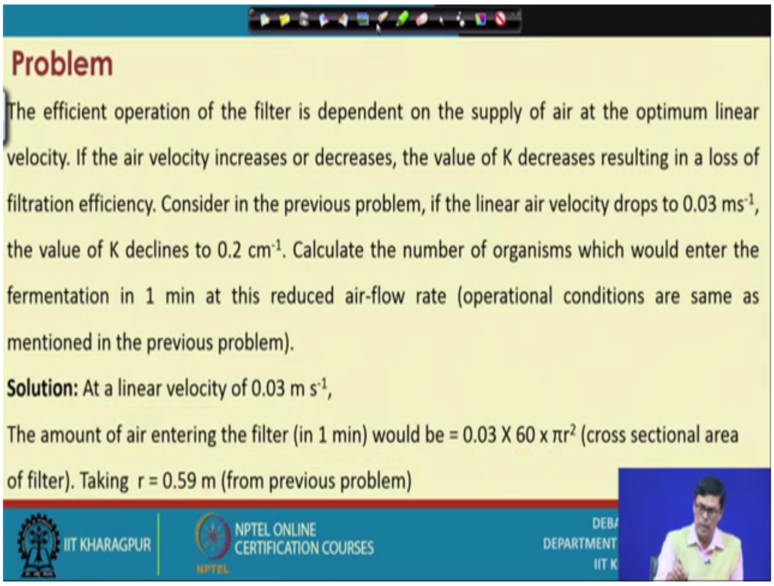

Now next problem is that for efficient operation of the filter is dependent on the supply of air at optimum linear velocity. If the air filter increases or decreases the value of K decreases resulting the loss of filtration efficiency considered the previous problem that show we considered whatever data we have been the previous problem, if the linear air velocity drop to 0.03 meter per second the value K declines to 0.2 centimeter inverse. That calculate the number of organism would they enter into the filter in 1 minute had the reduced flow rate and operation conditions are same as mentioned in the previous problem.

Now how we can solve that? Now and the linear velocity is what is 0.03 this is the point the meter per second the amount of air entered in 1 minute; however, we can easily calculate multiplied by 60 per minute then pi r square. So you know that you can find out the amount of that that radius is 0.59; so you can easily find out how much organism is entering into the in the system. Then the amount of air entering in the filter is 1.59 5 1 point.

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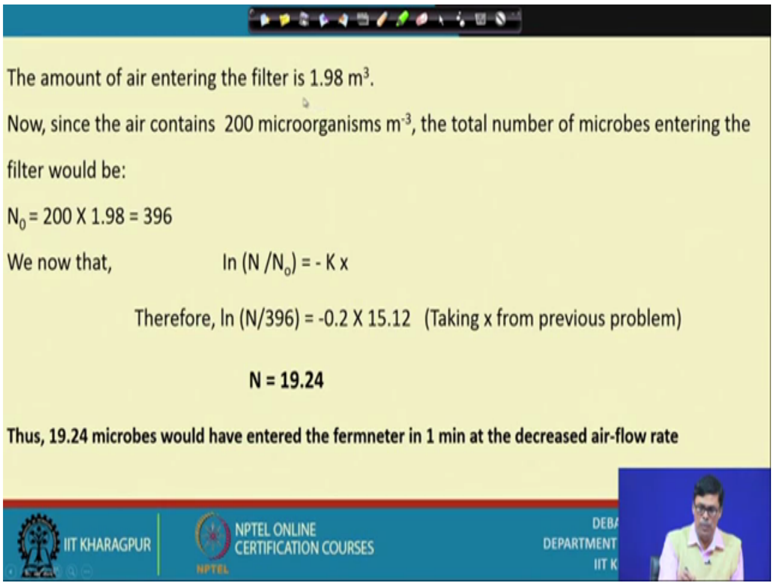

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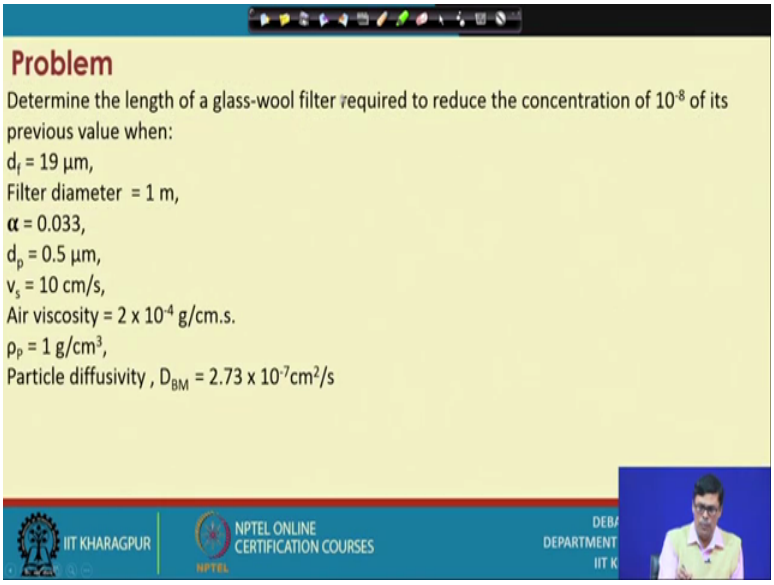

We find out that 1.98 cubic meter now the air contains 200 cubic meter micro 200 microorganism per cubic meter the total number of microbes entering would be how much. So, this we know that this volume so we can really find out the N 0 value. Now if you know the N 0 value we know N value and N value we can easily find out. That what is the how much delay there how much organs were leaving the filter. So 90 as microorganism entered the per meter 1 minutes at the decreased air flow rate. So this we can do it very easily now let us say let us try to solve some other problem that determine the this is the design of the air filter design the length of the glass wool file filters required to reduce the concentration 10 to the power 8 of its origin previous value. That means, what I want to tell that N by N 0 that is 10 to the power minus 8, where the original value that you know that is given there.

Now d f is the diameter of the fiber is 19 micron the filter diameter is 1 meter 1 meter the alpha is alpha is the solid fraction or you know filter fraction solid fraction means I told you that 1 minus alpha is equal to void fraction. Void fraction in free space alpha is the how much that filter occupied in the field that you know in the filter material how much volume is occupied then d p is the 0.5 microns and superficial velocity 10 centimeter per second air viscosity 2 into 10 to the power minus 4 gram per centimeter per second. And the particle density once a gram per centimeter cubed and diffusivity is 2.73 into 10 to the power minus 7 centimeter square per centi per second.

So, these are the different problem is given so it is it is. So we shall have to so we can consider this problem like this. Now this is suppose this is the air filter and this is the air filter that we have we know this is we have the air filter like this. So we pass air in and this is air out. So you here we know the flow characteristics of the air what is the diameter of the filter, what is the velocity of the air viscosity all this thing particle deposit everything know. So we shall have to find out what is the length of this air filter to get this value N by N 0 will be 10 to the power minus 8 am I right let us see how we can solve it.

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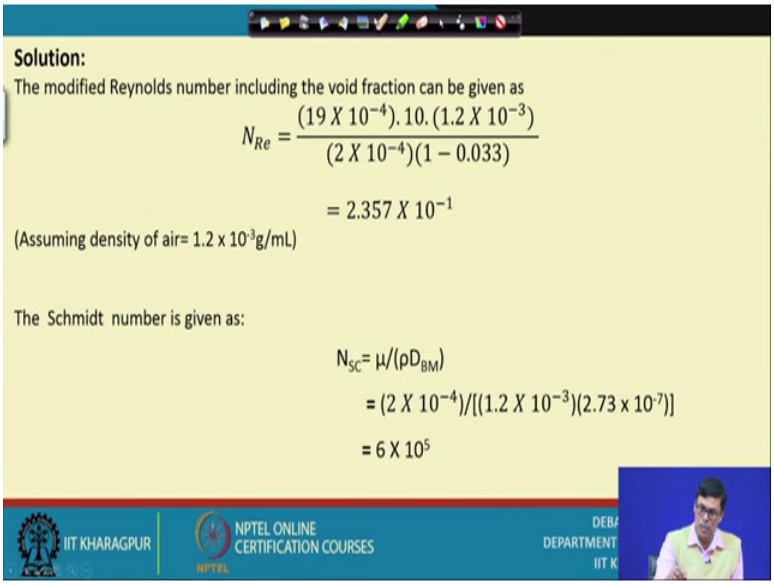

Now first we shall have to calculate the Reynolds number or how we calculate the Reynolds number? This is this is the diameter of the filter and this is the velocity that. So Reynolds number equal to D u rho by mu am I right, thought that u is the velocity that we can put it here and this is the rho value, that is the density and this is the viscosity and this is the this is the void fraction. So we will get the Reynolds number like this assuming the air densities 1.2 into 10 to the power 3 gram per milliliter. Now the Schmidt number is equal to mu by rho into D B M now D B M is the diffusivity of the air.

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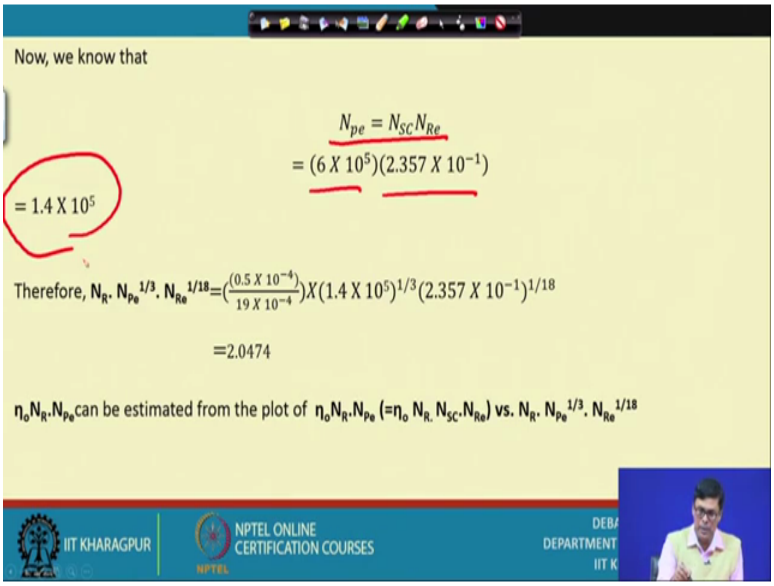

Now mu value is given here this is the mu is the viscosity of the air, and rho is the density of the air and the diffusivity of the air is given here. So we can easily calculate what is the Schmidt number Then we have the correlation that peclet number equal to Schmidt number into Reynolds number. So we have already found out what is the that that Schmidt number and Reynolds number. So our peclet number will come 1.5 into 10 to the power 5.

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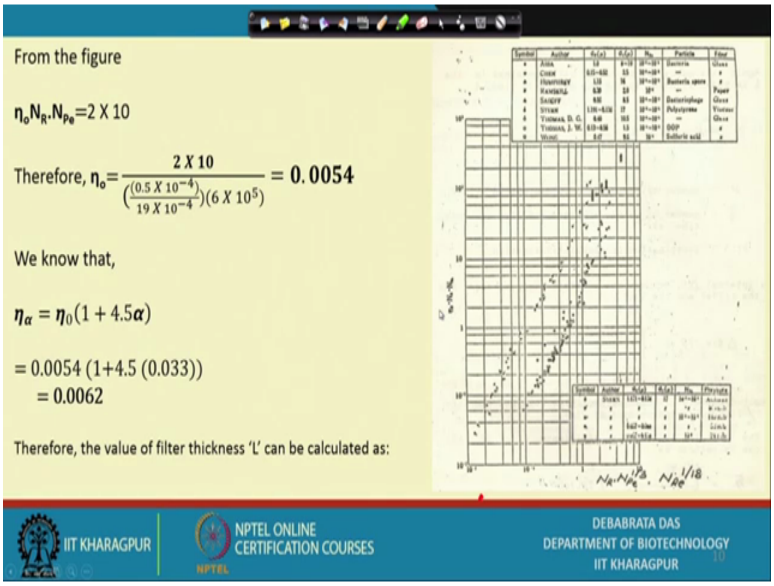

Now that you know that if you look at if you look at this figure that you know here we have the correlation inner in Pe peclet number to the power 1 by 3 into Reynolds number 1 by 18 this is correlated with the overall collection efficiency inner and peclet number. So you can we can we can we can find this and from this curve we can find out this particular value. Now if we if we find out this value then we can find out from this we can find out the eta 0 value.

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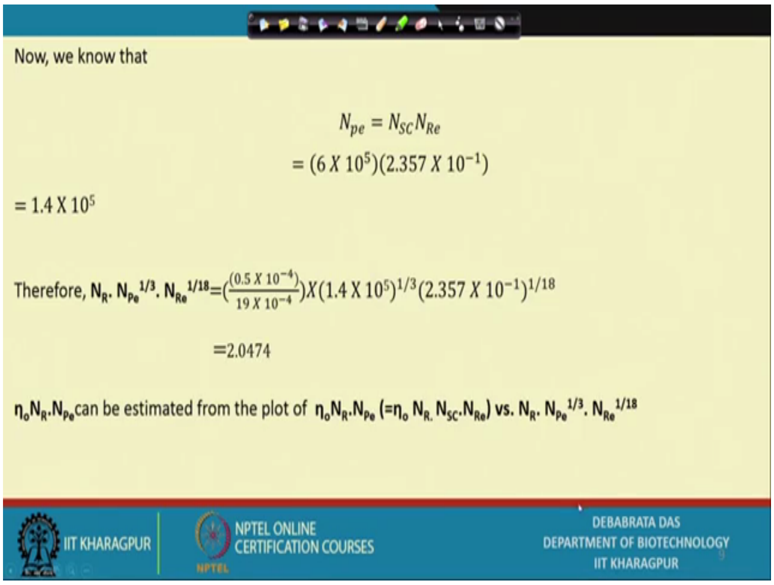

Let us see how we have solved this now here we have inner is what a geometrical ratio in the diameter of the particle by diameter of the fiber this is we have the peclet number already we have determined this is the peclet number and this is the Reynolds number we determined.

So this is coming about 2.3 and so you have from the figure you have this is N R into we can write N P to the power 1 by 3 N R e to the power 1 by 18. So if this is correlated with eta 0 in R and N P e. So if you have a you have curve like this, so if you know this value I can find out this corresponding value. So N 0 N R N P can be estimated from the plot in this versus this.

Now we have we have done this and we find that this value is equal to that 2 into 10, now from that we can find out what is the eta 0 value eta 0 you know collection efficiency and we know that single fiber efficiency eta alpha is it a 0 1 plus 4 if the alpha value lies in between 0 to 0.1.

So here alpha value is 0.033 so it is like the very much in between that. So we can find out the single fiber efficiency. Once we find out the single fiber efficiency now we have the correlation of with the single fiber efficiency and the length of the filter because I was talking about this filter length am I right? This is the length of the filter that we have this is this is we call it L.

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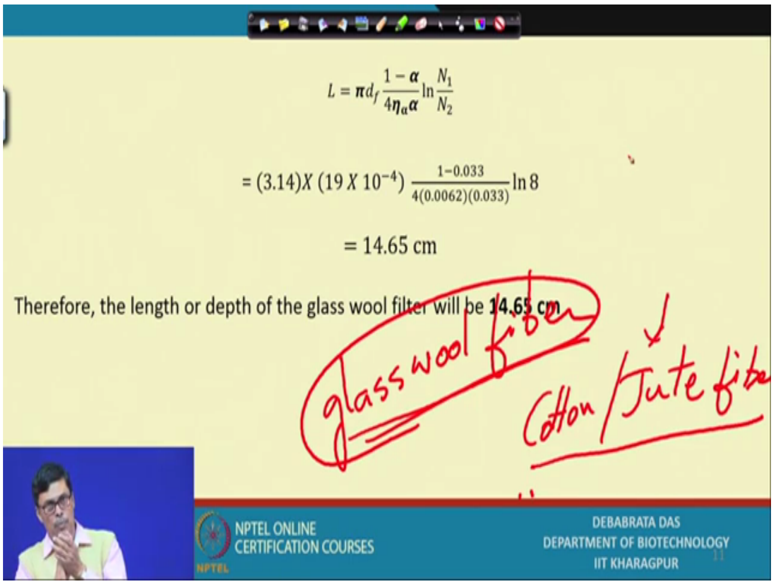

So, L can be related with this is like this. So here pi we know diameter of the fiber you know, alpha we know, that the solid fraction and eta eta alpha we know in 1 N 2 you know, the N 1 is the final cell mass concentration and N 2 is the incoming cell mass concentration from that we find out, the length of the air filter is coming about 14.65 centimeter. So this is we can we can easily find out that we can easily design the know what do you call that you know that the air filter for will be the thickness to get the desired amount of sterility of the air.

Now another thing I want to raise here that suppose in the biochemical industry we have 2 vessel one is Inoculum another is Production Fermenter am I right? Now usually the Inoculum vessel suppose this is one cubic meter and usually this size this usually the 5 to 10 percent; that means, 0.5 to this if suppose I I can tell you that if the capacity is capacity of production fermented 200 cubic meter the Inoculum volume will be how much? It is 10 to 20 cubic meter ok.

Now naturally the air requirement for the small fermented will be less as compared to the bigger fermenter. Now question comes how will design our air filter because we have I have already shown you that for Inoculum vessel we can have this we can horizontal these kind of things we can have we can pulse the air in and air out and we can find out the area like this. Now when you go for this is inoculum vessel I V. Now when you when you consider the production fermenter; now naturally it is 10 times higher 5 to 10 times and if you increase the 5 to 10 times then what is a surface area will increase very much and if you increase surface area there is the operational problem.

Now question comes the how you can reduce we can make the things very compact because this way we can maybe make the things very compact how we can make the things very compact? Suppose inside this inside this the air filter; if we have some cubical arrangement like this we can always have a cubical arrangement like this. So we can have we can increase the surface area am I write; we can increase the surface area. So here we can pass the air, we can take out the air like this, so this is a. So we can we can we can do in 2 ways the otherwise one is we can put it in and we can take it out like this or we can take it in and form in inside you can take it out.

So in that way we can increase the surface area and make the things very compact. So you know this is how you can make the things very compact in case of bigger fermentation process. So, so another one issue I want to take into consideration that in the industry we use the glass wool fiber, but you know that we know that glass wool fiber is very costly as compared to cotton or jute fiber, but question comes why we go for a glass wool fibers? The reason is that the glass wool fiber it can be reused again and again we sterilizes again and again and cotton and jute fiber we it is very particularly I can tell you in case of jute fiber that if you regenerate the jute fiber again and again it will be becoming precise.

So you cannot use that, so and another problem is that when you pass the air through a filter there will be some kind of resistance that you know that on the flow of the air filter, as there is a resistance there will be some kind of friction, as there is a friction there is the heat regeneration take place. Now in case of jute and cotton fiber it can catch the fire very easily, but in case of glass wool fiber it can the fire temperature is quite high. So in that way we find the drag coefficient for the particular Reynolds number in case of glass wool fiber is much less as compared to that jute and cotton fiber. And we find that that you know that the acquisition since it is more in cotton fiber, so every possibility that cotton and jute fiber can catch fire that is why we cannot use.

So in conclusion I want to tell you that I try to discuss the air sterilization process which is very important part of the any kind of fermentation industry. And what we are basically targeting that you know that that we it is very difficult to get the 100 percent sterility of the air. What we do what we what we can do 1 in 1000, 1 in 10000 1 in 1 (Refer Time: 28:49) 1 in 1 million 1 in 10 10 million; that means, out of 1 million organisms you are allowing 1 organism can particulate throughout the filter. Then because a 100 person that sterility were to find out that what should be the exact that thickness of the air filter for 100 percent stability is very difficult to achieve.

So in the air filtration we always the air filtration means medium filtration we always considered that that what how much organism is allowing out of how much initial input so on the basis of that we can do the design of the air filter. I discussed that how you can discuss the thickness of the air filter both on the basis of that that you know flow characteristics of the fluid also by using that kind of equation that we have that L N N by N 0 equal to K into x from that we can find out that is called lock penetration theory from that we can find out the thickness of the air filter.

Thank you very much.