Transport Phenomena in Biological Systems
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Lecture-63
Simultaneous Concentration Gradient and Velocity Gradient-Bioreactor Kla

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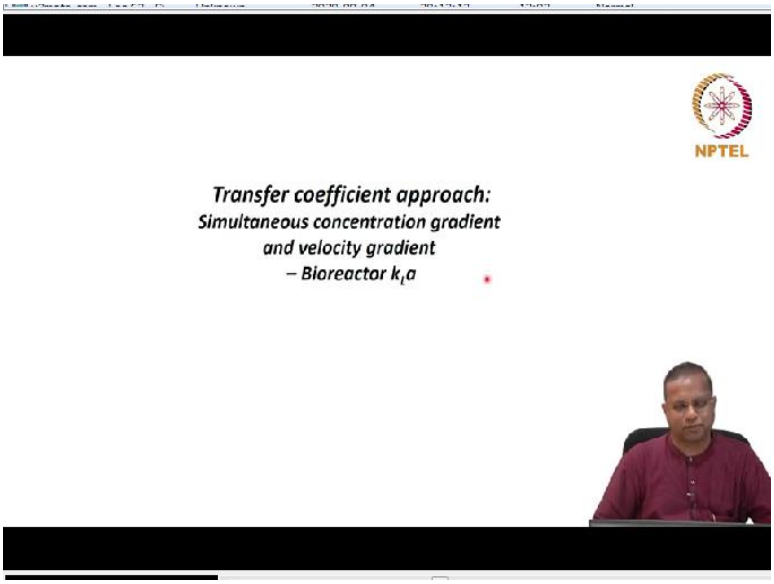

Welcome back, let us continue with discussion on simultaneous multiple driving forces. In this chapter we are going to look at the situation when there is simultaneous concentration gradient and velocity gradient, the same is a previous one okay, same the blood oxygenator one also had a concentration gradient and a velocity gradient. Our approach for the blood oxygenator was a little different to make few points right.

We had used the equations approach and then made god had shown you some aspects of that approach. Today I am going to talk about the transfer coefficient approach, this transfer coefficient approaches a little you call it elegant yes in its foundation and it is not based on molecular aspects in that aspect it is a little crude. So, you cannot use you cannot work things out from the fundamentals.

And because of that its applicability is not wide, it is applicable to the situation where you have actually a surety that it is indeed going to work based on experiments. That is the big drawback of

this the confidence that is associated with applying the numbers that you get out of this or numbers that you get for transfer coefficients are limited or the confidence is limited okay. However, this is very useful approach, much less complex mathematically complex and so on.

It is highly useful and design gives you wonderful designs and you know this approach gives you wonderful designs and good for operation gives you good insights also okay. So, both approaches are used and I am going to take the example of bioreactor k_La to illustrate this, we are all familiar with bioreactors and hopefully you know what k_La is, if not it does not matter I am going to tell you as a part of this class, this lecture as to what k_La is.

And we are going to use the transfer coefficient approach to get a handle on the k_La, we are going to probably do this lecture, this aspect or a few this aspect yeah this particular aspect or of your lectures that does not matter, will we will take breaks as and when it becomes necessary. Let us break it up into short segments for easy assimilation.

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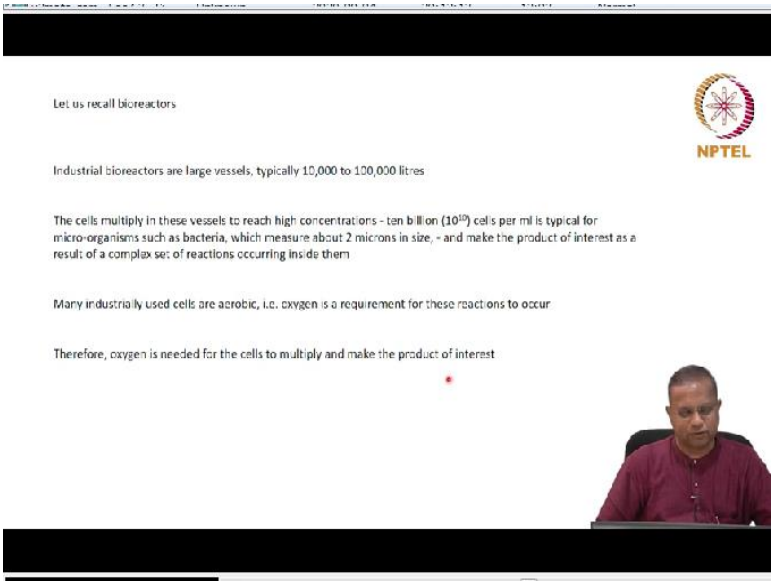

Let us first recall bioreactors, industrial bioreactors are large vessels you know, bioreactor is a controlled instrumented vessel right, that is used to produce bioproducts and industrial bioreactors are very large vessels typically 10000 litres to 1000,000 litres or 1 lakh litres, 1 lakh litres are reasonably common in the industry, 10000 to 1 lakh is very common in the industry, the cells

multiply in these vessels to reach high concentrations 10 billion that is 10 power 10 cells per ml okay.

It is that is a concentration it is typical for microorganisms such as bacteria which measure about 2 microns in size we all know this, we are all biological people, even if your background is different you can pick it up from here. These multiplied here and in the process make the product of interest as a result of the complex set of reactions that occur inside okay, many industrially used cells are aerobic they need oxygen.

Oxygen is a requirement for these reactions to occur and that is where the relevance of today's lecture comes. Therefore oxygen is needed for the cells to multiply and make the product of interest.

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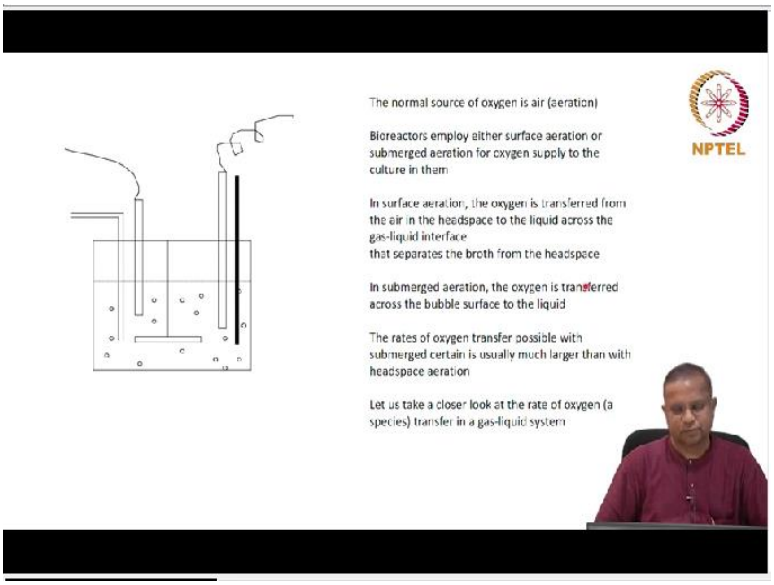

And this is the schematic of a stirred bioreactor, bioreactor comes in various sizes shapes and so on so forth types for that matter, they can be operated in many different ways we all probably know this, this is a stirred vessel where you have a cylindrical vessel here with a stirrer, that stirs keeps things in suspension, the steering is also needed for other things essentially for ensuring that oxygen becomes available to a larger part of this bioreactor.

That is also achieved by stirring appropriately and as we said earlier the any bioreactor has a highly instrumented in control vessel, this could be probably a pH probe, this could probably be a Br probe and so on so forth and this is the inlet of oxygen to possibly a microorganism based bioreactor. If it is mammalian cell bubbling through this is going to cause a lot of shear there would be a lot of difficulties.

So, surface aeration air is provided here the oxygen diffuses from here to here or transports itself from here to here because of the various driving forces present okay. So, you see the relevance of transport and this nice thing called the bioreactor, so many transport aspects that are present. The normal source of oxygen is air okay, simpler to use air has 21% oxygen and so that is available free.

And as long as you can purify it you can directly use it for free. Bioreactors employee either surface aeration that I mentioned okay which means you provide air oxygen here from the surface it goes inside that would obviate a lot of stirring or submerged aeration for supply of oxygen to the culture in them okay. There are always both sides to the thing, if you are unable to if the cells are shear sensitive to this mammalian cells you cannot stir at high speeds.

You cannot stare at high speeds, you cannot provide oxygen at high enough rates. However, the mammalian cells do not have a high oxygen uptake rate or they do not demand oxygen at high rates and therefore that is fine, the bacterial systems, microbial systems have oxygen uptake rates that are 10 fold that of mammalian cell uptake rates. So, you know there are various different things that we look at from a point of when we do bioreactors upstream by processing course and so on very interesting aspects.

In surface aeration the oxygen is transferred from the air in the headspace, the headspace is the region above the liquid surface here, from the headspace through the liquid across the gas liquid interface, this separates the broth from the headspace. In submerged aeration the oxygen is transferred across the bubble surface, that a lot of bubbles it has sent out the oxygen is transferred from across the bubble surface to the liquid, we look at this in greater detail.

And the rates of oxygen transfer possible with submerged aeration is usually much larger compared with headspace aeration okay. So, submerged generation oxygen rates are much larger compared to the head preservation because certain ignore preset, please ignore the certain thing. Let us take a closer look at the rate of oxygen transfer in a gas liquid system or oxygen as the species that is transferring itself from the gas bubble to the liquid broth to be consumed there okay. So, this is our system will continue for a few more minutes.

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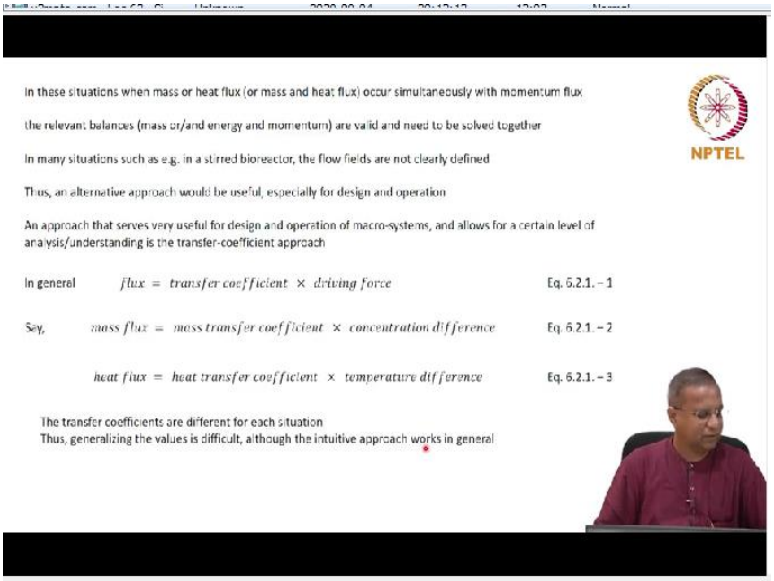

In these situations where mass or heat flux or when mass or heat flux occur simultaneously with momentum flux, the relevant balance is mass or and and or energy balances and or momentum balances can be written, they are valid and they need to be solved together, you could always do that. However, you know the downside of it now. In many situations that is a such as in a stirred bioreactor.

The flow fields themselves are not clearly defined, it is all in turbulent flow, it is rotating stirring it reasonably high rates and you no longer have laminar flow there. So, the flow fields are not clearly defined. Thus an alternative approach would be useful especially for design and operation. An approach that serves very useful for design and operation of macro systems and allows for a certain level of analysis understanding is the transfer co-efficient approach as I mentioned the beginning of this lecture.

In general this is the transfer co-efficient approach, in general flux is expressed as the product of a transfer coefficient and a driving force okay. So, this way it is similar but there are differences and come to the difference in a bit. For example okay this is equation 6.2.1- 1 in the textbook. For example mass flux is expressed as a product of a certain mass transfer coefficient, this is not diffusivity, this is a mass transfer coefficient times the concentration difference okay.

The concentration difference becomes a driving force here rather than the concentration gradient right. The gradient is kind of understood but this kind of a formulation turns out to be very helpful, if there is a concentration difference it has to happen over a certain distance and therefore this is fine. But explicitly speaking in this case the mass flux is written as the product of a mass transfer coefficient times a concentration difference not the concentration gradient. We will call this equation 6.2.1 - 2 and heat flux, for example is written as the product of a heat transfer coefficient times the difference in temperature equation 6.2.1 - 3. Note this is not temperature gradient but temperature difference. The transfer coefficients are different for each situation. Therein lies the limitation of this approach okay for a particular given set of situations this parts Reynolds number, this much other numbers and so on so forth.

$$\text{Flux} = \text{Transfer coefficient} \times \text{Driving force} \qquad (6.2.1\text{-}1)$$

i.e.

$$\text{Mass flux} = \text{Mass transfer coefficient} \times \text{Concentration difference} \qquad (6.2.1\text{-}2)$$

$$\text{Heat flux} = \text{Heat transfer coefficient} \times \text{Temperature difference} \qquad (6.2.1\text{-}3)$$

This coefficient is valid, that is the best that you can do this approach, but that is useful. Thus generalizing the values is difficult although the in intuitive approach works in general. So, I think let us take a break here before we get into the formulation you have been introduced to a new formulation, you have been introduced to some transport aspects in the bioreactor and so on and so forth.

And we are starting out this transfer co-efficient approach, so internalize those think about those and so on so forth and this is a short class that does not matter, when we come back we would continue with this approach, see you then.