Advanced Aquaculture Technology
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Lecture 33
Aerator performance

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Hello, everyone. Welcome to the third lecture of Module 7, Water Quality Management of the subject Advanced Aquaculture Technology. My name is Professor Gaurav Dhar Bhowmick, I am from the Agricultural and Food Engineering Department of IIT Kharagpur.

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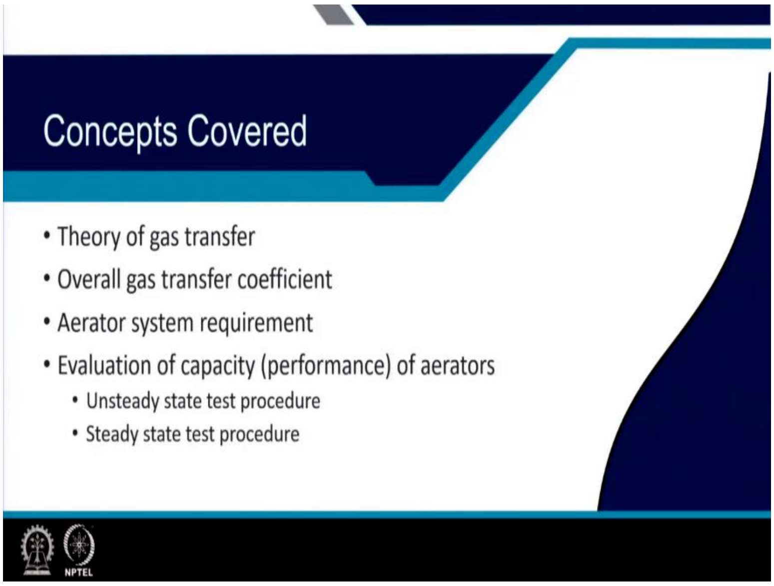

So, in this lecture, I will be continuing with the discussion that we already had about the aerators, different kinds of aerators the necessity and the performance details. So, here, we will more cover the theoretical part of it. So, we will discuss about the theory of gas transfer, how the overall gas transfer coefficient can be calculated and you can find it out for your design aerator. And all

And what are the different types of aerational system requirements and the evolution of the capacity of aerators in case of using the unsteady state procedure and steady state test procedure. So, all these tests procedures will be discussed in details and in the follow up lecture, I will be discussing with you a couple of real-life scenario where we will do all the calculations by ourselves to find out the different aeration efficiency, oxygen transfer rate, etcetera.

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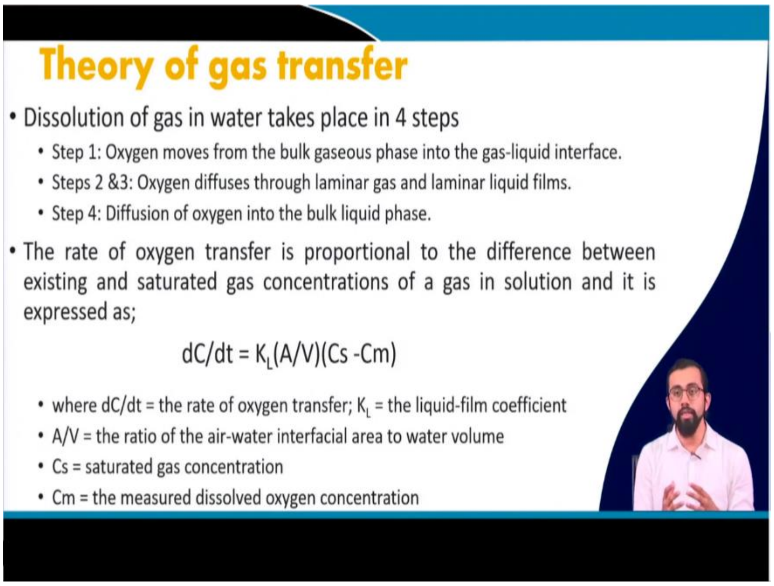

So, herewith we start with a theory of gas transfer first. So, in order to discuss about the gas transfer, because you know that is the basic of aerators. right Now, when we discuss what aerators is nothing but it will help us enhancing the transfer rate of the gas for a particular gas from atmosphere to liquid state or atmosphere to water state, from to the water. okay

So, this dissolved rate, this dissolved gas transfer from atmosphere to water, it actually involves four different steps. First, if I talk about say oxygen, so, okay oxygen molecule, first it moves from the bulk gaseous state. So, in this case, its atmosphere, from gas-liquid interface. okay So, it is like suppose I have a wall. okay So, one side there is gas in the other side I have liquid and this is the wall or this is the interface that I am talking about. okay

So, from in the beginning, from gas, the water will get attached to the gas-liquid interface first, then from this gas-liquid interface, the oxygen will diffuse through this laminar gas and then the laminar liquid film. After it reaches the liquid film then it goes to the diffuse bulk liquid phase. Again, there are four steps, first from the bulk gaseous state to the gas liquid separator or the gas liquid interface. There we have say two liquid films, two films. okay

First film is the laminar gas film. Second is the laminar liquid film. So, it will transfer, in the second step it will diffuse through the liquid film sorry laminar gas film. The third stage it will diffuse through the laminar liquid film. At the end it comes in contact with the liquid phase and it will directly diffuse to the bulk liquid phase. You understand, right?

These four different steps that involves in a way, it is a very basic steps of dissolution of gas into water. okay This is a very important because you need to know this funda otherwise in future when we will be discussing about details like how these different phenomenas different equations we will be discussing, you have to remember this very easy four steps. okay Then this oxygen transfer, this oxygen transfer it does depend on different parameters.

We already discussed, right? Remember, we discussed about the involvement of the dependency on the area to volume ratio. okay Second thing, the difference between the saturation gas concentration and the measured gas concentration. okay So, these two are the major parameter in which the rate of oxygen transfer actually depends on. okay

So, if I theoretically represents you this all these fundamentals that I have just discussed, how it can be described, how it can be presented, dC by dt like the change in the rate of oxygen transfer with time. This C is what, C is the gas concentration, the concentration is denoted by the denotes by the letter, this alphabet C. So, dC by dt is the rate of oxygen transfer or in general gas transfer, it is equal to K_L, this K_L is the liquid fill coefficient. okay

How this coefficient is coming into the picture? Just forget about KL first and forget about this equaled. First, this dC by dt is directly proportional to the ratio of air to water interfacial area to water volume that is A by V. And also, it directly proportional to the difference between the saturated gas concentration minus measured gas concentration or dissolved oxygen concentration. okay

So, dC by dt it directly proportional to these two factors. In order to make it in an equation form what we do we simply add one coefficient, we name it liquid film coefficient or KL in short okay. To make it more easier because see we when we discuss about a particular type of aerator, the basin that we will be using or the tank that I will be using is same, right? So once the tank that I will be using is same for say like any particular type of aerator at different conditions. So, this A by V ratio is also same. Considering this A by V ratio which is also constant for your particular experiment and KL which is a coefficient which is also a constant.

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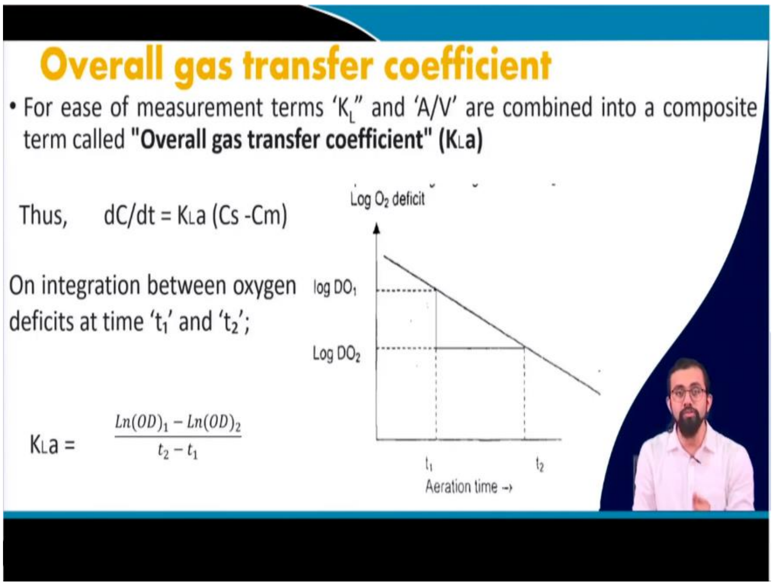

So, considering this both of this factor we came up with this idea of a term which is composite coefficient term which we call overall gas transfer coefficient KLa. okay This overall gas transfer coefficient is KL multiplied by this surface area to volume ratio. okay This is this number is, it is a constant for a particular experiment that we will be doing for any particular aerator okay. So, now, the equation reduces down to dC by dt equal to KLa into Cs minus Cm. okay

When we do this integration of oxygen deficits say like from t1 to t2 okay, from time t1 to t2. So, during this time, this is aeration time, during this time if we do the integration of this equation this dC by dt equal to KLa multiplied by Cs minus Cm will come up with KLa equal to $Ln(OD)_1$ minus $Ln(OD)_2$ over t2 minus t1. What is this OD 1? This OD is the oxygen deficit. okay How do we calculate this oxygen deficit?

We know the saturation concentration right? , Cs. At t1 what will be the DO? Say suppose when you start your aeration the DO at the beginning it was 3 milligram per liter or say like 3 PPM okay. And we know that saturation concentration is 9.07 milligram per liter at 20 degrees Celsius. So, what will be the DO deficit in this particular case? 9.07 minus 3 which is 6.07, so this is the DO deficit 1.

Secondly, DO deficit 2 say like after 1 hour of continuous aeration, your DO level increase to 6 PPM. So, now, what will be the DO deficit? 9.07 minus 6 which is 3.07 PPM, so, this is the DO deficit or oxygen deficit 2. If you do the logarithmic log of these two, this log of OD 1 minus log of OD 2 divided by t2 minus t1 you will get the value of KLa which is like overall gas transfer coefficient value. you, You understand the point?

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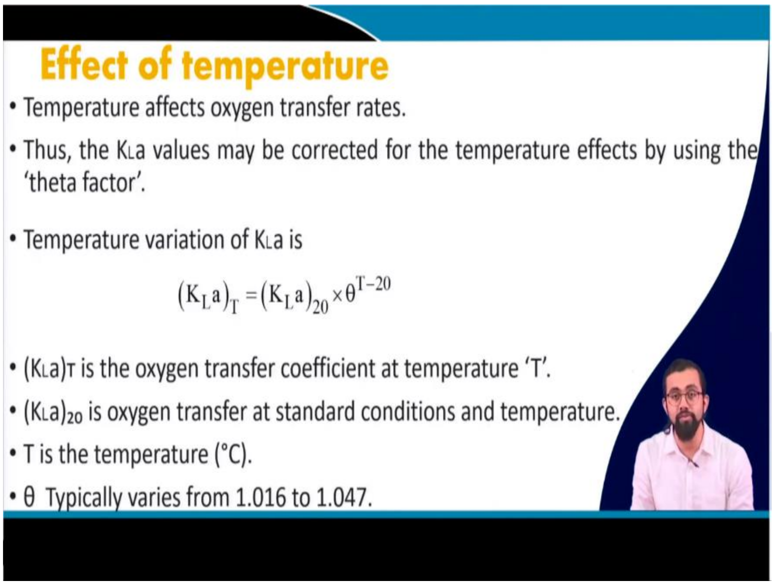

So, now, what are the parameters at which this overall gas transfer coefficient is actually depending on? One of the major parameters is temperature. You might have realized that every time I discussed I was telling about the saturation concentration and all the value whenever I am mentioning the value every time I am mentioning the temperature because temperature is a major factor we already discussed based on like temperature can change the diffusion rate like anything.

So, this overall gas transfer coefficient is also depending upon the temperature. How we can calculate this value, revised value at any temperature? It can be easily calculated, like when we have like say KLaT at a particular type of at a particular temperature say like instead of 20 degree we want to get the value at 30 degrees Celsius. At 30 degrees Celsius, so KLa30 is equal to KLa20 which is standard multiplied by theta to the power t minus 20.

Here, the capital T has to be replaced with 30. So, the equation will become KLa30 equal to KLa20 multiplied by theta to the power 30 minus 20 which is 10. This theta, this theta value is typically varies from 1.016 to 1.047, based on different types of aerators and all, in different conditions. In general, you will be provided with the value this theta value.

So, this theta factor is actually the factor which gives you the correction for temperature effect. You understand? So, that is how we finalize, we got to know the value of overall gas transfer coefficient at a particular temperature. okay Remember, this T is here the T is actually calculated in degrees Celsius. Do not use the Fahrenheit values.

Here, the T is in degrees Celsius is the equation, whenever we will be using this equation, if you have a data in Fahrenheit, convert it into the degrees Celsius and then use it. okay So, this KlaT is like overall, so now, if I am asking you, like at any temperature, and I am providing you the data for the theta value, the temperature factor, and also, I will give you the value for the KLa20, you can easily find out the overall gas transfer coefficient at that particular temperature whether it be 10, 30, 40, 50 anything okay. So, that is how we find out the overall gas transfer coefficient.

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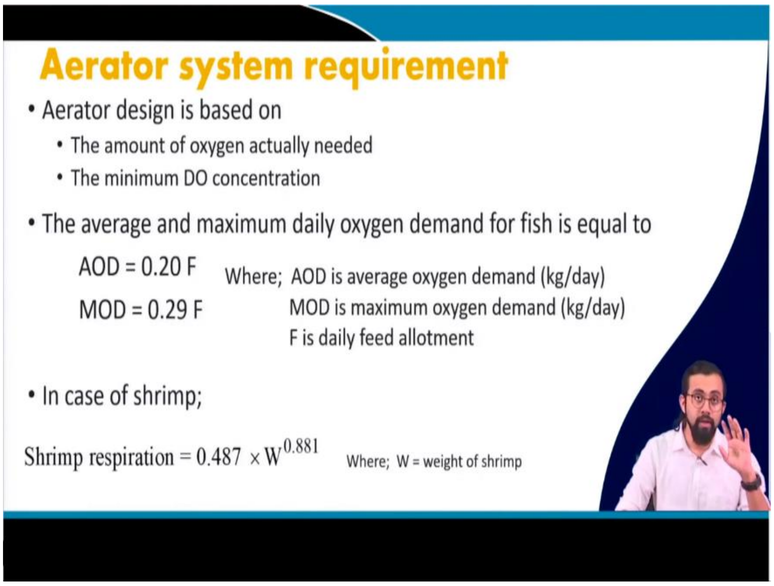

Now, so based on that, we have to go for this different requirements of aeration systems.right? When we will be designing the aerator, this design will definitely has to be on the basis of something. So, the first thing is the amount of oxygen that you need to supply. Okay. And the second thing minimum DO concentration that you are expecting to have in your system. These two are the basic criteria on the basis of what you will have to choose the aerator and you have to choose its efficiency.

You have to choose its power performance and everything. So, in general, the aerator when you choose, you have to choose on the basis of the amount of oxygen that it requires and the minimum DO consideration that you are expecting in your system. Okay IN A On a thumb rule, whenever, like you do not have much of a details about the system design and everything. okay So, you just remember this equation, average oxygen demand in kg per day, this is a thumb rule, I am again saying in case of fish or something normal fish if you are culturing fish in your tank.

So, at least you tried to provide 0.2 percent, like 20 percentage of your feed value. So, if suppose your feed value is like suppose 100 kg per day, at least your average oxygen demand has to be 20 kg per day. You got my point? So, this value this is actually this value is actually daily feed allotment, this is the standard kind of thumb rule, okay look at this is not true for everything.

Anyway, we will be discussing in details, like how we can find out the actual value, actual oxygen demand and all, but this is like a thumb rule if you do not have any other details you can go ahead with this. okay And in case of maximum oxygen demand, which should not be more than say like 30 percent around 0.29 times of the daily feed allotment.

So, just remember these values. okay So, this is just a thumb rule, this is not actual all the time it may, you can survive with this, with this value you can like I mean like you can go ahead with these calculations for the time being but it is better to go ahead with the proper calculation and proper designing. And all okay

In case of shrimp also we have this specific value for like in general for shrimp respiration we follow this equation, it is a standard equation which we normally follow when we calculate the requirement of oxygen for our shrimp, any shrimp produce. So, it is like 0.487 multiplied by W to the power 0.881 whereas this W stands for the weight of shrimp weight of the individual shrimp or total shrimp, this is based on your calculation requirement, based on your data it actually varies. So, this equation you are trying to remember shrimp respiration is equal to the 0.487 multiplied by W to the power 0.881. okay

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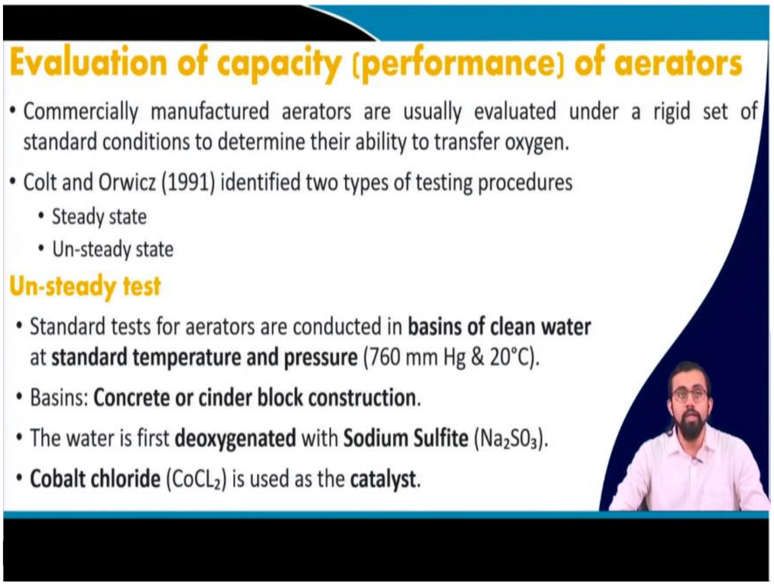

So, when we evaluate the capacity or the performance of any aerator, suppose you have designed some aerator or you have procured any aerator from a manufacturing company. So, you have to design you have to know the performance details. Most of the times it is given along with the aerator like it is in along with the leaflet but depending upon your farm requirement depending upon the species that your culturing and depending upon, like your intent, the stocking density, oxygen requirement based on different factors, you have to know the performance of the aerator on that particular scenario. okay

So, in general, how to define or how to evaluate the capacity of aerator, there are two different procedures given by Colt and Orwicz 1991 its in his paper, the first one is the steady state procedure and the unsteady state procedure okay. So, in the beginning we will discuss about the unsteady state procedure, which is more famous and more commonly used all over the world. And there is another one with a steady state procedure. I will be discussing with you about it in details later slides.

In case of unsteady state procedures, what we do, it is a standard test of aerator, we we have a like you know basin of a clean water at a standard temperature and pressure at like, standard temperature means here I am always discussing, whenever I will say standard temperature, it means 20 degrees Celsius. And whenever I will be saying standard pressure, or the atmospheric pressure, that means I am talking about 760 millimeters of mercury pressure. Okay.

So, remember this the 760 millimeter of Hg and 20 degrees Celsius, that is what the standard temperature pressure. Whenever I will be discussing about it in I will be saying about it in this aerator performance evolution. So, this STP is 760 millimeter of Hg and 20 degrees Celsius. The basin it can be of concrete or the cinderblock construction. The water has to be first deoxygenated with the sodium sulfite.

Why to deoxygenated it? Very easy, I told you, it's very easy for you to understand the value the aerator performance, you can better be understand when the actual condition when it will start aerating at that moment the water at which it is dwelling. Suppose like you are starting, you are doing the performance test, it is better to have the DO level as low as possible at the beginning. Say supposed almost near to none or, near to 0.

The moment it is almost near to 0 and you know notice saturation concentration is like 9.07. So, you have a wide gap, when you have a wide gap and with time it will keep on replenishing the DO level what will happen you will get a very nice curve and your test procedure will be more fine or more accurate. okay So, that's why, you know the oxygen scavenging, so now sodium sulfide is a very standard oxygen scavenger.

So, we use this sodium sulfide for deoxygenated purpose or otherwise there are other thumb rules also. What we do, as you know, is simply go for boiling the water. Suppose you have, definitely it is not possible for when you have a very huge amount of basin, very huge amount of pond size. And all But in small cases what we do, normally it is a standard practice sometimes, we boil the water, when we boil the water all the oxygen all the gas and all it gets transferred to the atmosphere.

Then you close the lid and put it in you know, try to cool it down. Like Let it cool down for a couple of hours or so. What will happen that water will be very low in air concentration, like very low in diffused air. Whether it be oxygen or any other. okay So, that is also a standard way of doing that, but in general when you will be discussing about this huge basin definitely is not possible.

So, there will use different kinds of chemical scavengers, sodium sulfide is one of them. Also, this process is can be further enhanced or if you add the cobalt chloride $CoCl_2$. Cobalt chloride is used as a catalyst for this reaction to take place much faster way. okay So, cobalt get chloride is used as a positive catalyst here and sodium sulfide is used as n oxygen scavenging chemical here. Now, the final product that we will be getting it is highly deoxygenated, okay that means the dissolved oxygen level is very low.

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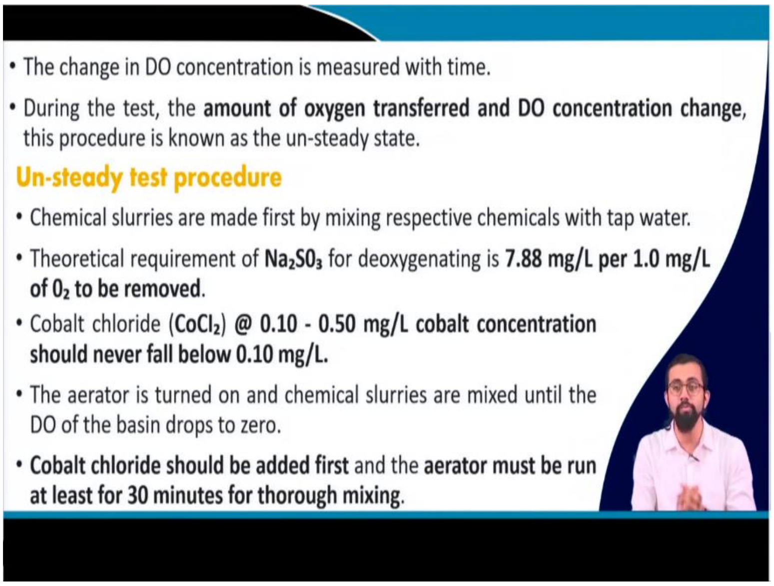

Now, the you will start your experiment. Once you start the experiment, what do I mean by start the experiment, you start running the aerator. So, once you start the start running the aerator and you have different DO meter or DO probes fit at different position of your tank, you can monitor in real-time scenario that how the development is getting increased, from 0 say like after 10 minutes is like 2, then after 10 minutes is like 2.5, after 10 minutes is 3.5, like this it will keep on increasing.

That value you have to write it down or somehow you have to jot it down neatly after a possible in per minute manner. Or in general case, at least 2 to 3 minutes after or 5 minutes after. You write it down and then you make a graph out of it. So, from that graph, why we need this graph, I will tell you, how to calculate the different aeration efficiency that since I will go and discuss about in detail.

So, in general during the test the amount of oxygen transferred and the DO concentration change is measure, so that is why this process is called unsteady state procedure. You understand the reason why it is called unsteady state because you are changing the concentration of DO with time and you are calculating the aeration efficiency and aeration transit, oxygen transfer rate.

So, based on that, because of that it is called unsteady state procedure. In general, to discuss more in detail, it is better to provide it with the theoretically at least 7.88 milligram per liter of sodium sulfate per 1 milligram per liter of oxygen to be removed, cobalt chloride concentration of around 0.1 to 0.5 is better, but it should not fall below 0.1 milligram per liter at any point of time.

The aerator when you start when you turn it on the chemical slurries has to be mixed until the DO of the basin drops to 0. And cobalt chloride should be added first and then the aerator must be run for at least 30 minutes for thorough mixing. Once the thorough mixing is done when the DO level drops to 0 then we start calculating the procedure, start the procedures actual procedures when we start write it down the values.

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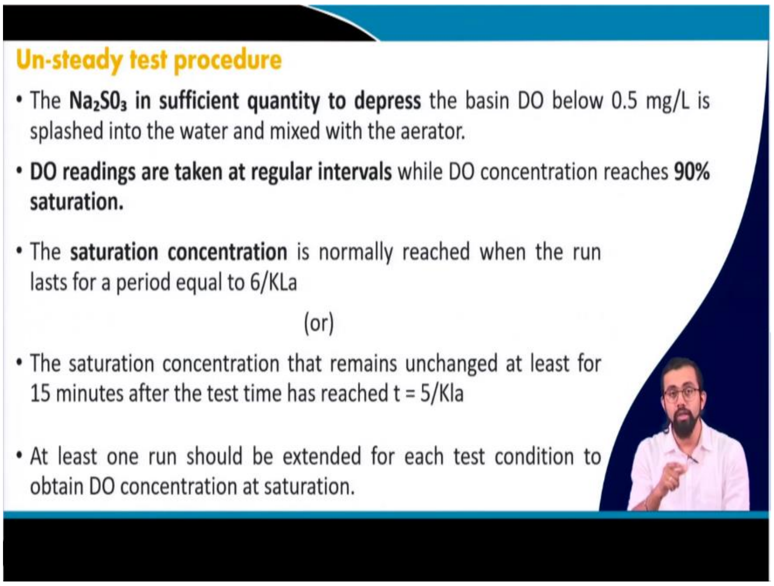

The zero reading is taken at a regular interval and once the DO concentration reaches 90 percent of the saturation. What does that mean? As I told you at 20 degree Celsius and then STP 9.07, 90 percent of it when it reaches like say around 8 or 8.1 milligram per liter once it will reach the DO concentration of your tank you should stop the experiment.

So, once you will start from say like 0 or something and once it will reach like 7, 8, 7.58 something like that, you stop the experiment. Stop the experiment and that will be you start calculating the measure the further details. There are two standard rules for it, saturation concentration either, there are three actually, first, we already discussed 90 percent of the total saturation concentration.

Second, the saturation concentration is normally released when the run lasts for at least the period equal to 6 by KLa. You know KLa, right? The overall oxygen transfer coefficient. And you also know what is the unit of it, it is time inverse like second inverse or minute inverse or hour inverse, right? This is the unit.

So, if you divided this 6 divided by KLa in time it will get the value in time. That time, that minute or that hour is the time for which it takes normally for reaching the saturation concentration. This is the standard way of dealing, it is a very standard procedure. Or I suppose the saturation concentration that remains unchanged at least for 15 minutes after the test time has reached 5 by KLa.

In all these three cases you should understand that you should stop the experiment now. Because you have reached the saturation, almost reached the saturation concentration, it does not make sense to go ahead further it will take a lot of time to reach the actual saturation concentration. So, that duration you have to, you calculate up to this duration and you go ahead with the further calculations.

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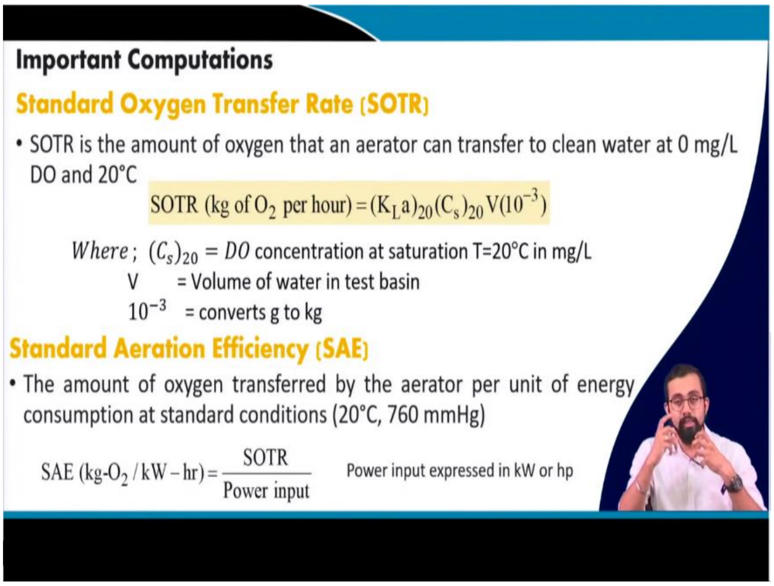

In general, how to calculate these things, you remember these values, try to understand the basics behind this equation. Standard oxygen transfer rate from the name itself you can easily understand it means the transfer rate of oxygen that means kg of oxygen per hour, this is the standard unit that by which we can easily denote it like say SOTR.

How to calculate this SOTR? It is simple enough, you just multiply with the overall gas transfer coefficient KLa at 20 multiplied by the saturation concentration at 20 multiplied by V that is the volume of your basin multiplied by 10 to the power minus 3. Why 10 to the minus 3? Let me give you, I am breaking it down so that you will get this proper dimensional analysis as well as you can understand the unit behind it.

SOTR, we quantify it by means of kg of oxygen per hour. KLa, what is the unit of it, per second or per time. Say like per hour per minute whatever. Cs, which is the DO concentration. In general, it is in milligram per liter, milligram per liter the same value can be converted to gram per meter cube, but because it is like simply 1000 multiplied by 1000 multiplied by 1000 both a numerator and denominator.

So, milligram per liter is equal to gram per meter cube. So, this gram per meter cube, so now if you say KLa20 which is 1 by T, 1 by time multiplied by gram per meter cube. So, say like 1 by hour multiplied by gram per meter cube multiplied by V, V is in meter cube, so meter cube meter cube will get cancelled out then gram in order to convert it to the kg you do this multiplied with 10 to the power minus 3.

So, if you multiply with 10 to power minus 3, now, it will become kg per hour that is the for SOTR. So, that is how we calculate the standard oxygen transfer rate. Second part is much easier, Standard Aeration Efficiency. Once you know the standard oxygen transfer rate just simply divide it with the energy consumption or in general the aerator that you will be using it is per unit of energy consumption at standard condition.

In general, the power input, if you see the power input for this kind of aerator are normally expressed in kilo watt or hp, hp means horsepower, you know horsepower, it is like around 746 746 watt is in 1 horsepower. So, from this value, you can simply calculate the standard aeration efficiency which is kg of oxygen per hour per kilowatt. These two are very important parameter you have to really remember this equation, it is very easy, but it is very important parameter for calculating discussing anything about the aerators.

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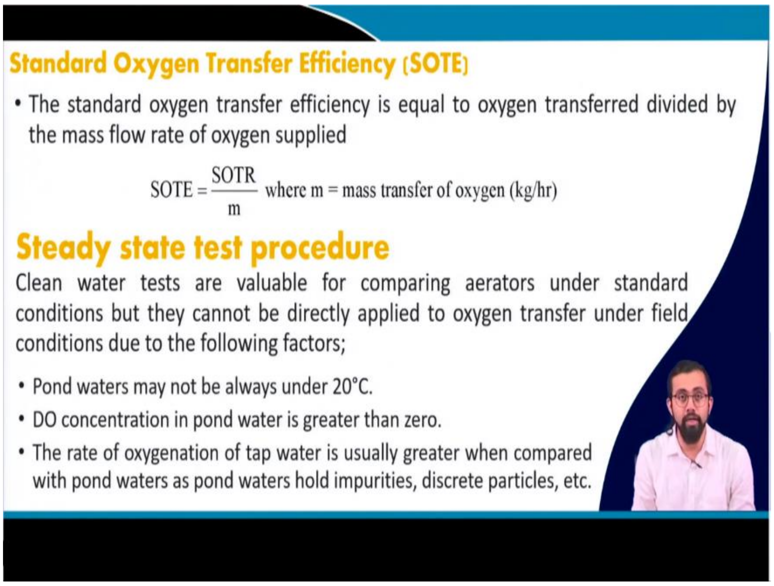

We discuss about standard oxygen transfer rate, we discuss about standard aeration efficiency, we now if we discuss about standard oxygen transfer efficiency, this is not the aeration efficiency, this is not that, this is we are discussing a more standard oxygen transfer efficiency. That can also be calculated very easily, you simply divided with a mass transfer of oxygen.

During that period of time or on an average what is the rate of oxygen that is getting transferred. Mass transfer means, here the unit will be kg per hour. So, it will be kg per hour when you divide, when you divide the SOTR with this mass transfer rate of oxygen you will get the value of standard oxygen transfer efficiency. This is what all we discuss, it is all about the unsteady state procedure.

What will be the case like when we discussed about the steady state procedure. In case of steady state, the problem is like you cannot directly test your aerator in the pond water condition. There are some problems. There are a lot of problems involved with that I will discuss with you in detail. Because in case of unsteady state, you can do it in clean water. So, you can easily rise from 0 to almost 90 percent of the saturation and all the things.

But in case of pond water directly if you want to measure it is difficult. There are some problems, first of all that pond water may not always be under 0 and exact 20 degrees Celsius. DO consternation of the pond water is obviously always more than 0, you cannot do it, you cannot make it 0 because if you start making it 0 all the aquatic animals are already there they will die.

So, steady state condition is more like in real-time situation under the field condition, but it cannot be done, it can be done, there are some factors it involves, I will discuss with you next say, next slide. And the problem is the rate of oxidation of the tap water is easily much greater than compared to the pond water because of it holds the impurities, discrete particles.

When we discuss about impurities, I mainly focus on different kinds of surfactant, when we discuss about the district particles, we discuss upon different suspended solids, dissolved solids, etcetera.

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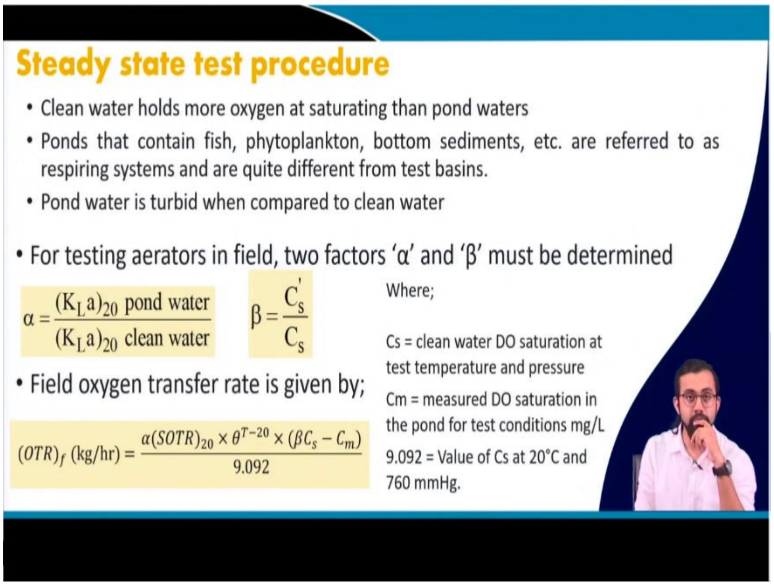

See this procedure. So, in case of steady state test procedure, clean water, we know that the clean water holds more oxygen at saturating point then the pond water. Second thing, pond that content fish, phytoplankton, bottom sediments are referred to as the respiring systems are quite different from the test basins.

So, there is a continuous deduction in DO is going on when you are experimenting in case of real-time scenario in the field conditions steady state condition. And also, the pond water is much turbid than the clean water that also makes a huge difference in the proper disseminating of oxygen molecules over the water body.

Therefore, the scientists came up with the idea that the testing procedure when it will be done in real-time condition like saying field condition we have to introduce couple of factors. First one we knew we call it alpha factor, alpha factor is the ratio between the overall gas transfer coefficient of pond water upon overall gas transfer coefficient of the clean water.

Why it is important? Just give you an one example, one simple example, just remember it, this alpha value is majorly depend on the surfactants, different kinds of impurities because in the presence of surfactant what will happen, it will reduce the surface tension of water and once it will reduce the surface tension of water it will affect on the overall gas transfer coefficient as well.

Because of that the alpha value is it is in case of KLa20 it is much higher than pond water in general. Same in case of beta, this beta factor is equal to the DO concentration at the particular temperature or particular field condition and the saturation concentration at real-time at like clean water at the same temperature. So, how does it matter? Because at the same temperature saturation concentration of DO can be low can be high anything.

But in general, it can be high, why high, because this value this water, in pond water it is turbid in nature, it has different other factors different other dissolved material, like dissolved solids, suspended solids, etcetera. They have their own heat capacities. So, because of all this reason, what happened the beta value the actual saturation concentration can be higher than in clean water scenario, that is why this beta value is introduced.

So, now, if I say what will be the field oxygen transfer rate, earlier we discussed about the standard oxygen transfer rate, it will almost same, but we have to introduce couple of factors. The equation will become OTR f which is like field oxygen transfer rate which can also be given in kg per hour equal to alpha into SOTR 20 like standard often transported at 20 degrees Celsius multiplied by theta temperature correction factor to the power t minus 20 multiplied by beta Cs minus beta Cm.

This beta Cs is the factor which will help you to eliminate the problems related to these impurities like solid impurities. So, this beta into Cs which is like the clean water DO saturation minus measured DO saturation at the pond for test condition. Divided by 9.092. What is this value coming from?

This is the value of Cs at 20 degrees Celsius and 760 millimeter of Hg. So, if you know this equation, it is very important this equation we need to utilize it more and more in other aerators discussion and all.

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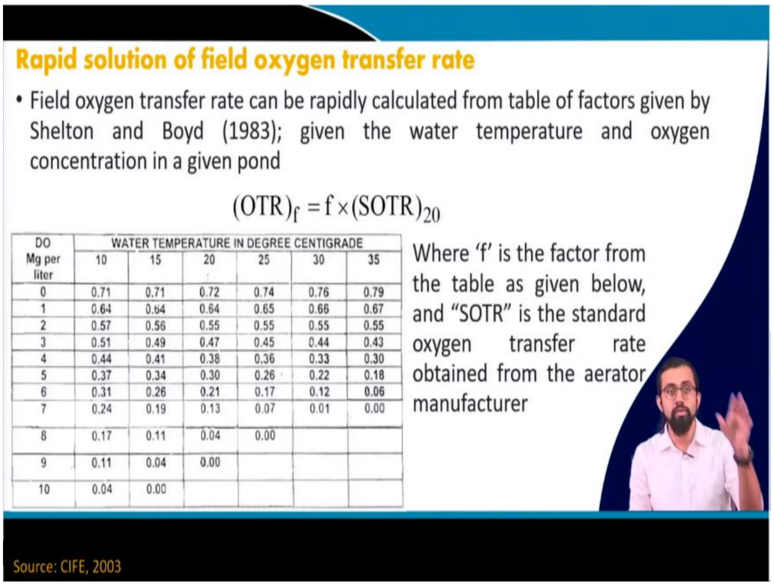

So, from there how we can calculate this field oxygen transfer rate. We already understand, this field oxygen transfer rate there is a simplified form of it as well. If you know, actually this table is given by Shelton and Boyd in 1983. So, what they have found out, in general this field condition, field oxygen transfer rate is always equal to almost proportional to, not proportional it based on some factor but this almost is proportional to this SOTR 20, like standard oxygen transfer rate at 20.

This f value which you know varies a lot, this f value is can be easily calculated using this table. They have done an extensive study and they come out with this DO concentration by at different temperature. If your temperature is lies between any of these points, so like 10, 15, 10 to 35, if any of this point you can interpolate easily and you can get the value even your DO value is somewhere in between you can easily interpolate it and you can easily get the desired f value. You just simply multiply that f value with SOTR 20 you will get your oxygen transfer rate at field condition.

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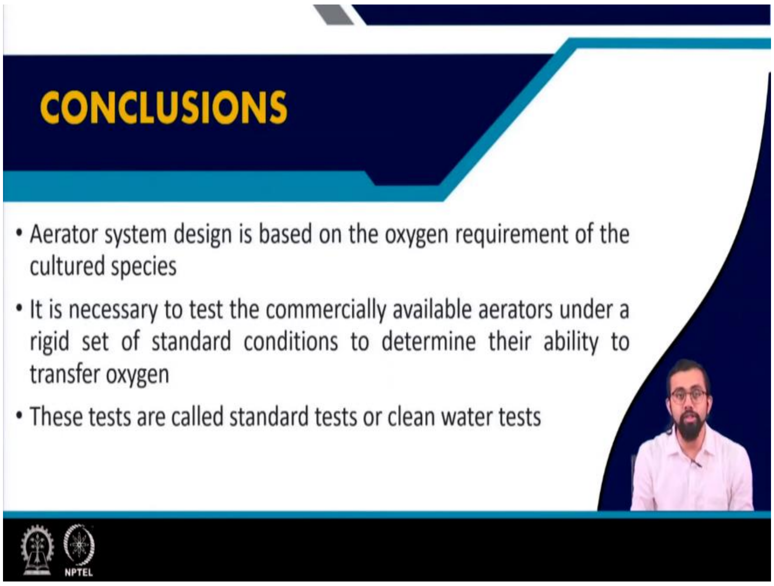

So, this is what all everything about the aeration, different kinds of aerators and the values and the calculation procedures and all the equations that involved with it. In the next lecture, I will discuss with a real-time problem. And we will discuss, we will try to find out that how the different aeration efficiency, standard oxygen transfer rate and even field conditions in steady state condition, how we can calculate the steady state oxygen transfer rate.

Aerator systems normally designed. So, in conclusion, we can say we discuss about the dependency of aeration systems for oxygen requirement in our farm or pond. It is necessary to test the commercially available aerators under a rigid set of standard conditions to determine their ability to transfer oxygen and these tests are called the standard test or the clean test.

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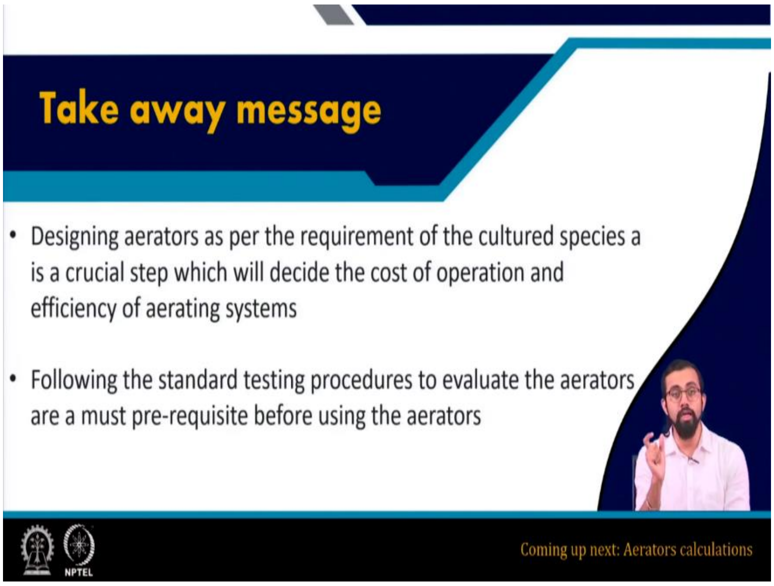

Designing aerator is very important for your culture species which is like which is crucial step which will decide the cost of operation and the efficiency of your aeration systems. Following a standard testing procedure, it can give you the proper evolution of the aerators and which is a must pre-requisite before you use it in your farm. So, that is it for now in this lecture material.

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These are the reference that you can go through. Thank you so much. In the coming lecture, I will be discussing about the different real-time example and we got to know more in detail and you to be better if you have a calculator with you. So, to do the calculations by yourself. Thank you so much. See you in the next lecture.