# Physico-Chemical Processes for Wastewater Treatment

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**Lecture 14**

## Aeration - III

Good day everyone and welcome to this lectures on treatment of water and wastewater by Physico-chemical methods and in the previous lectures we studied regarding the various treatment units. Then we went on and understood the flow equalization basin, and then we started with the Aeration.

So, in the aeration first we studied regarding how to find out the solubility of any gas in the water and what is the maximum solubility limit using the Henry's law and Henry's constant and also then we studied the how the temperature with respect to temperature we can find out the solubility by determining the values of Henry's constant at different temperatures. Thereafter, in the previous class we studied regarding the oxygen transfer rate.

So, how the oxygen actually transfer from the gas into the liquid and what are the various mass transfer resistances which are there during the transfer of oxygen from the gas phase into the liquid phase. So, we are we found out that during this transfer process, there are resistances in the liquid fields which are surrounding the interface. So, there will be a gas fluid mass transfer resistance gas fluid mass transfer resistance and similarly liquid fluid mass transfer resistance.

Out of this we studied that there is a term which is called as overall mass transfer coefficient kLa which helps in determining the oxygen transfer rate and that kLa is very, very important in determining the overall maximum oxygen transfer rate that may happen. So, today we are going to start with the problem trying to understand how to calculate the value of kLa in one of the conditions.

There are many methods available in the literature which helps to determine the value of kLa under various conditions. And also there are a lot of literature is available, how to calculate the kLa in various bio reactors with different types of fluids present inside the bio reactors and other types of systems as well.

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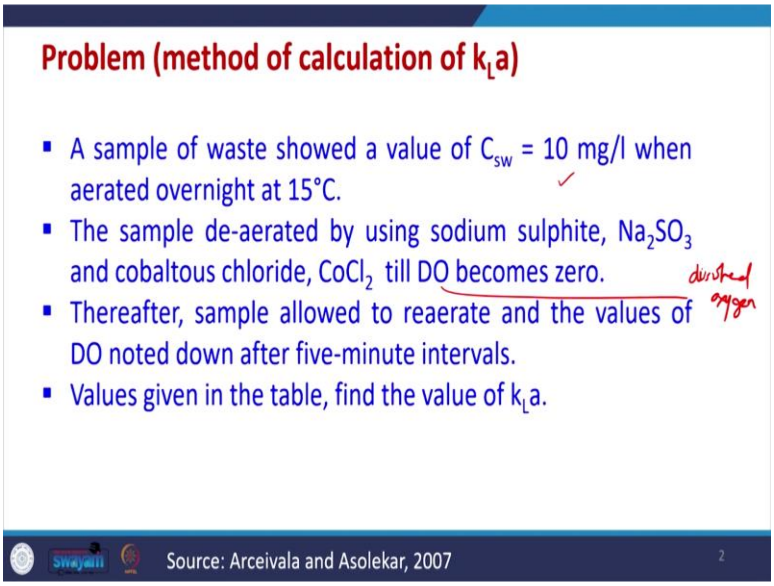


So, will try to understand these aspects today. So, will start with the problem itself today. So, suppose we have to find out that kLa in one of the water which contains some waste, so, how do we do that? For doing this what we do is that first we have to find out the saturated value. So, suppose this value is already known and we know, it is 10 milligram per liter. So, after that, what we do is that it will be aerated for long, so, that saturation condition is reached and we know the value of oxygen present in that water or wastewater.

Now, after that, what we do is that we add some chemicals actually we which use up all the oxygen which is present. So, that chemicals may be like sodium sulfide, then cobalt test chloride et cetera and we add them till that DO becomes 0, DO means here dissolved oxygen, so that dissolved oxygen that dissolved oxygen becomes 0 under that condition.

So, as soon as he becomes 0, we start and we do not add any of these further and we start to re-aerating whatever naturally, it happens, the regeneration of that water. And the values of DO are then noted down after 5 minutes or any time interval and values for this type of measurements are given in the following table. And what we have to do is that we have to find out the value of kLa.

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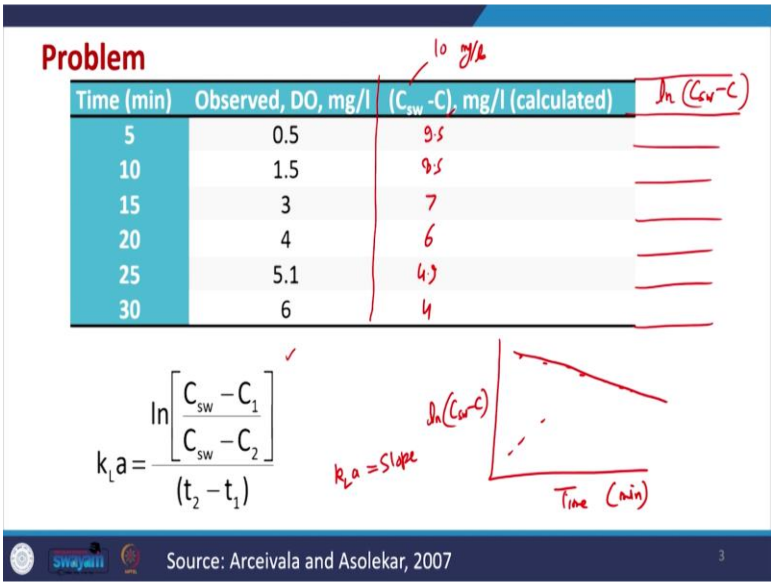


So, this is the values of 5, 10, 15, 20, 25, 30 the values are given and then observed DO’s are also given. Now this CSW was already given to be 10 milligram per liter in the previous slide. So, from that we can calculate the CSW minus C, so what does it mean? So, that means 10 minus 0.5 it will be 9.5 then it will be 8.5, 7, 6, 4.9, 4, so these value will be can we calculated. And after that what we do is that kLa we can be found out using this formula. Now, this saturation conditions are known.

So, for doing this in place of that what we can do is that we can further on a find out the ln value of CSW minus C at any condition. So, C is already there and CSW is, so, this already we have calculated, so, we can find out each of these ln values at this condition. So, all the 5 conditions, we can find out. And from there what we can do is that, we can plot a graph also. So, we can plot a graph of ln CSW minus C versus time and that time will be in minute, so, for and that graph will be it may be it is likely to be like this, it will decrease and from the slope we can find out the value of kLa.

So, this way we can the slope will give the value of kLa and that will be deported. So, that will give the average value of the kLa for whole of the things. So, that is possible, we have to fit only line on that. So, this way we can find out the value of kLa. This is only one of the methods there are a large number of methods which are available for finding out the kLa. I will discuss this further in the today’s lecture as well as further lectures also.

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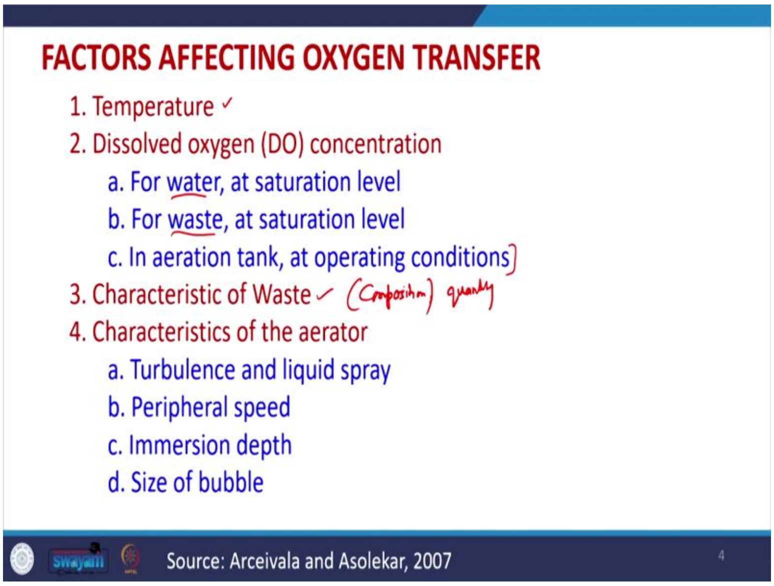


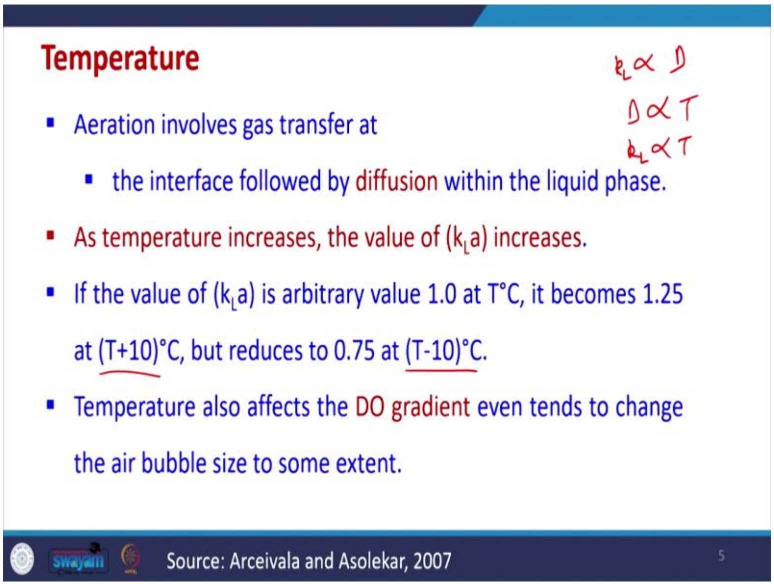


Now, what are the factors which affect the oxygen transfer? We already know that temperature, temperature is we have discussed a lot with temperature that dissolved oxygen decreases certainly the oxygen transfer rate is also a function of temperature that we are going to study. Similarly, dissolved oxygen concentration at any condition, what is the saturation value of oxygen inside the water if it is pure water. For waste it will be different than the water and also depending upon the operating condition the values may be different.

Similarly, the characteristics of waste and whatever the composition of that particular water and their quantity of each of the, so that is composition and quality both will be taken together. So, quantities of each of the things et cetera, their basic nature whether they are hydrophobic, hydrophilic whether they depending upon that whether they alter the surface tension or not, so all these properties are very important with respect to characteristics of waste that actually affects the amount of oxygen transfer that can take place.

Similarly, characteristic of the aerator itself. So, what type of aerator we have choosen, so that will depend upon that, what is the turbulence and liquid spray level that it has created? What is the peripheral speed, what is if it is a diffusion type, what is the immersion depth, what is the size of the bubbles which are getting created when the air gets diffused inside the liquid and it comes to the top or the liquid surface?

So, these are many other factors are possible. So, we will try to discuss some of them, the first 3 and then we will discuss the fourth point, when actually we will try to discuss the different types of editors. So, this is there, going further, the first effect is like effect of temperature in the aeration rate. So, aeration actually involves gas transfer at the interface and where that diffusion of oxygen takes place within the liquid phase.

So, that means it is affected by how quickly the diffusion occurs. And for your just information that diffusion itself is directly temperature controlled, and that diffusion increases with increase in temperature. So, that is why the value of kLa also increases with increase in temperature. And if you remember previous slides, the kLa kL value individually was directly proportional to diffusivity. So, that means answers diffusivity is directly proportional to temperature. So, KL is directly proportional to temperature. So, this is there.

So, if kLa has a some arbitrary value at some t degree centigrade, so it will become higher at higher temperature, and it will decrease at lower temperature if we go on increasing the temperature by 10 degree or decreasing the temperature by 10 degree. So, thus the temperature has lot of effect on kLa and thus it has effect on the aeration rate and oxygen transfer rate also. Temperature also affects the to DO gradient and even tends to change the air bubble size to some extent later on.

So, this is possible. So, temperature has lot of effect during the aeration and this is very important parameter. After then the dissolved oxygen concentration are DO value. So, in the aeration systems where we want denitrification also to happen along with the usual gas elimination or something like this, and where we are providing oxygen for nitrification also to happen in the biological systems and other places that DO value will be very high around it may range from 1.5 to 20 milligram per liter even much higher than that.

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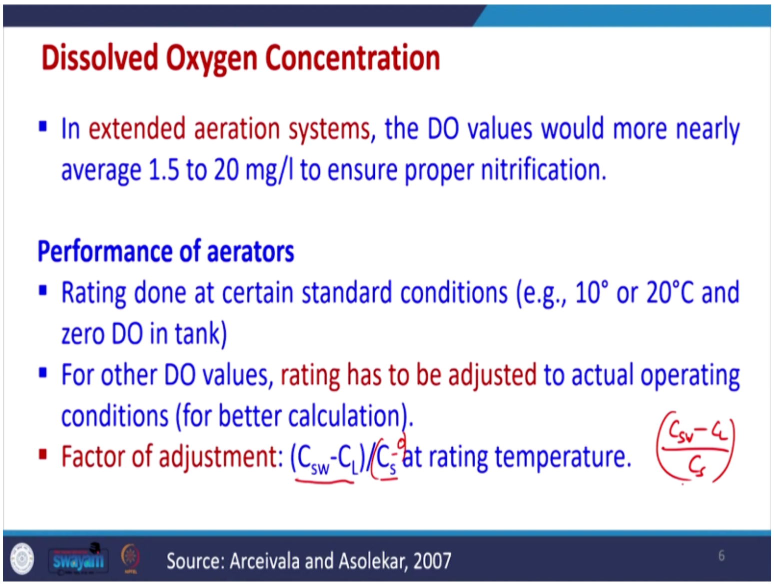


So, performance of aerators up that is actually aerators that type of aerator that we select, so, there is a rating done for the aerator and that rating is actually done at certain standard conditions. So, for better comparison of different aerators always rating has to be done at certain standard conditions and those standard conditions are like 10 degree or 20 degrees centigrade, 20 degree centigrade is more common with the 0 DO in the tank. So, whatever rating they are giving that presuming that that tank contains no DO which is actual in actual condition which is not possible.

So, this rating for our users for design of aerators for selection of aerators, that rating has to be adjusted to actual operating condition. So, this is very, very important consideration, we should always remember this point and there is a factor of adjustment and that factor of adjustment is CS minus CL divided by CS itself at the rating temperature and this CS is because actual water may have different concentration, this actual the saturation value.

Similarly, in the water they are assuming 0 DO, so, that is why this 0 is there and this is there. So, we have to always adjust multiply the rating by this to get the actual value for our aerator that we are going to select how to select. So, this is important for dissolved oxygen concentration.

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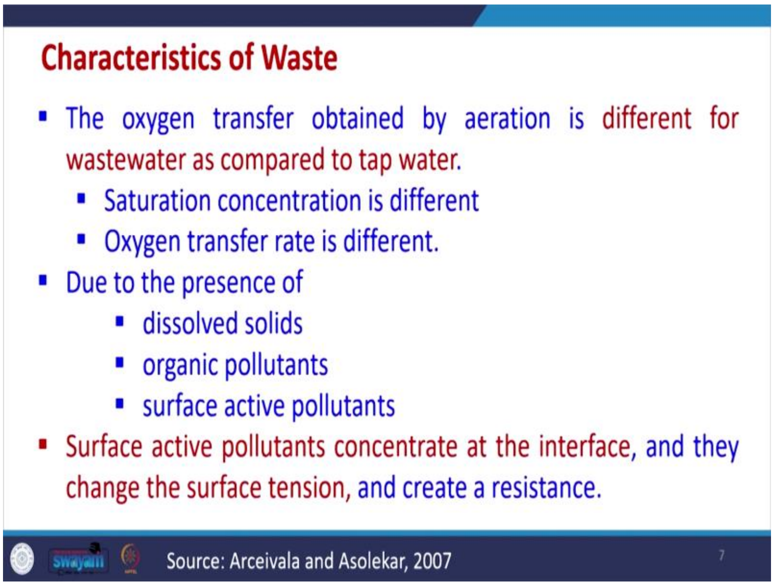


Then a characteristic of waste. So, type of waste in which the aeration is going to be carried out. So, this is very, very important and it actually affects the oxygen transfer rate a lot. There may be a number of components which may be present in the water and that may be hydrophobic, hydrophilic, there may be some type of surfactants which are present and so, all those things actually they add on additional resistances in the water. So, and that causes a lot of problem.

So, the oxygen transfer rate actually will depend upon the type of waste, the quantity of other pollutants present in that wastewater. So, the oxygen transfer rate in general for different water as compared to type water because of the presence of many things. And also under the actual wastewater condition the saturation concentration is different, oxygen transfer rate is also different. And this is because that dissolved because of the presence of many dissolved solids, organic pollutants which may be present. So, this is possible.

So, oxygen uses rate will be there because of organic pollutants. Then maybe a large number of surface active pollutants also, what are the surface active pollutants like surfactants, so and then there may be these type of surface active pollutants actually they go to the interface more. So, some foam forming suppose components are present sector, so, they will always get collected at the interface and this they change the surface tension and as soon as the surface tension changes, it actually creates additional resistance.

So, overall oxygen transfer rate may decrease depending upon the characteristic of waste which is present in the that wastewater, so this is there. Now, what we have to do is that that some adjustment has to be made for actual wastewater using a ratio which we have defined like alpha. So, that ratio is like kLa for wastewater and kLa for type water which has been actually done.

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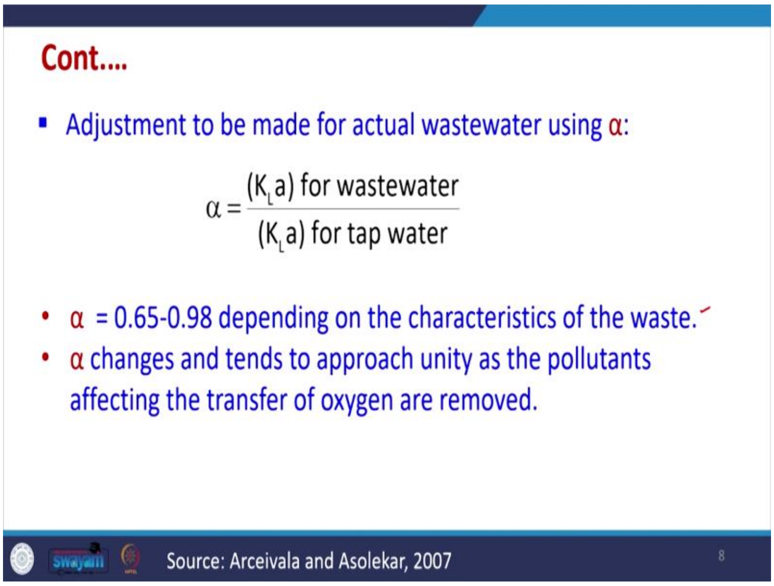


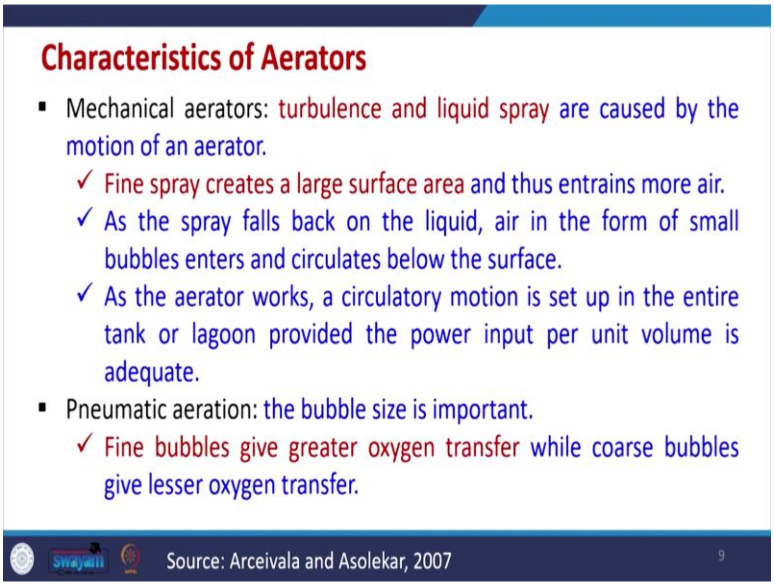


kLa which has been reported by the rating person or using 0 DO condition. So, this is there and this ratio actually depends upon the characteristic of the waste and it may vary from 0.65 to 0.98. Also during the treatment process remember or during the treatment process, when actually the wastewater is getting treated, so, all these pollutants are slowly and slowly getting removed. So, this alpha value also changes and it tends to approach the unity as the pollutants affecting the transfer of oxygen get removed.

Adjustment to be made for actual wastewater using α:

$$\alpha = \frac{(K_L a) \text{ for wastewater}}{(K_L a) \text{ for tap water}}$$

So, this is important parameter with respect to selection of any aerators. There are certain characteristics of aerators also which are very important. Aerators can be classified into different categories. So, we will discuss it later, but here we are trying to understand the what is the effect of the type of aerator on the oxygen transfer. So, there are one classification is like mechanical aerator and pneumatic aerator.

So, in the mechanical aerators, turbulence and liquid spray is actually created by the motion of some of the sections of the aerator itself. So, during that process turbulence will be created as well as a spray will also be created of the liquid itself. So, if the spray is fine spray, it creates a large surface area and thus it entrance more here. So, more amount of air will go inside that good mechanical aerator.

Also when the spray falls back on the liquid, air in the form of small bubbles also enter and circulate below the surface. So, it also helps in the aeration process. So, this is another good thing with respect to mechanical aerators. Then as the aerator works, a circulatory motion is also set up in the entire tank. So, some cells are the circulatory motion is created inside the tank and lagoon and they provide the power input per unit volume which is good enough for aeration to happen.

So, this is another thing. In the pneumatic aerator, aerators the bubble size is one of the most important criteria. Fine bubbles which may be there they give greater oxygen transfers while coerce bubbles. So, this may be their bigger size bubbles lesser oxygen transfer. So, if the number of bubbles are high, that is a that will be giving more oxygen transfer. Also the number of bubbles, size of bubbles, all these are dependent upon that how much depth at which the aeration is being done, how much depth at which the air is being released, diffused inside the liquid and how much time and what is the air or gas velocity.

So, that flow rate of air is also very important under those conditions. So, there are number of possibilities by which the oxygen transfer may vary. Now, an oxygen there are certain oxygenation and mixing requirements of any aerator. So, what are it has any aerator has to function. So, and all those depending what is the requirement, power requirement that will also be determined by these considerations. So, these functions are oxygen input requirement.

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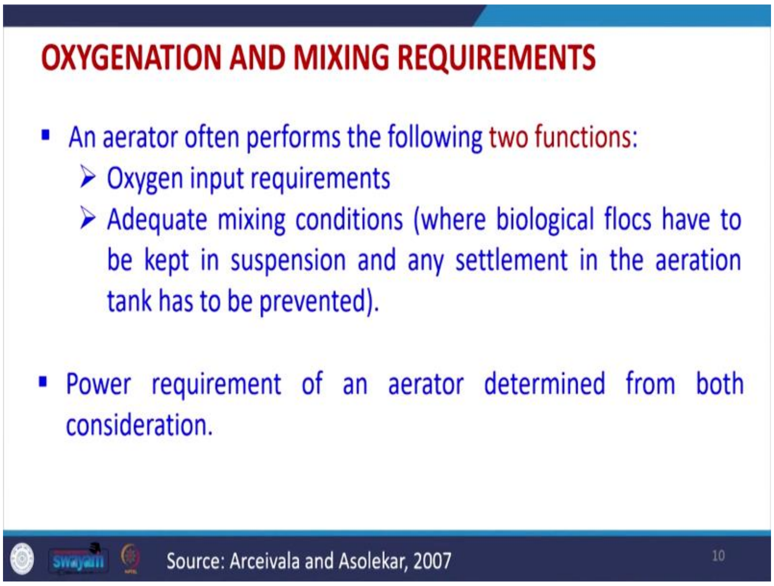


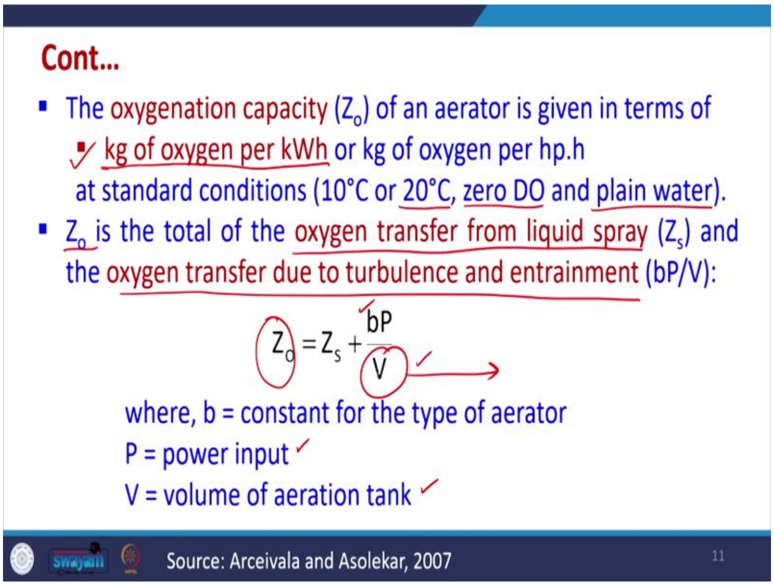


So, how much amount of oxygen we require? So, this is the most important consideration for aerator. So, this is there and we should calculate the power rating depending upon that. Second thing is that how much mixing has to be done. So, it will be more correct for aerators like process where some treatment by biological microorganisms is being done. So, how much mixing is essential because if mixing is not there, so, the pollutants are not coming in contact with the microorganisms.

$Z_o$ is the total of the oxygen transfer from liquid spray ($Z_s$) and the oxygen transfer due to turbulence and entrainment (bP/V):

$$Z_O = Z_S + \frac{bP}{V}$$

where, b = constant for the type of aerator

P = power input

V = volume of aeration tank

So, that means their degradation is not possible. So, mixing is very essential along with the oxygen. So, depending upon that whether mixing requirement is there or not or on depending upon that the power requirement may vary. So, it will incorporate both oxygen input requirements as well as the amount of mixing or adequate mixing whatever is that requirement. So, the oxygen, oxygenation capacity of an aerator is given in terms of, this is calculated in terms of kg of oxygen per kilowatt hour.

So, how much is the oxygen capacity? Now, if your requirement of oxygen is higher, so, you can always go for higher kilowatt hour capacity aerator and generally these are reported at standard conditions at 20 degrees centigrade 0 DO and for simple water which does not contain anything.

Now, for overall power requirement is then calculated using the oxygen transfer from the liquid spray. So, Z0, this Z0, the total capacity will be the sum of oxygen transfer from the liquid spray, the ZS as well as the oxygen transfer due to turbulence and entrainment. So, both will be together present. And this is calculated using this equation where b is the constant for the type of aerator, P is the power input which is there and V is the volume of the tank.

So, depending upon, so, we can calculate the Z0, whatever is the oxygen requirement of us. And from the aerator ratings, we can tentatively calculate the V value also. And we can play with the P and V, so that the essential requirement with respect to Z0 is met, which is the oxygen our requirement of oxygen for aeration to happen properly inside an aerator. So, this is there.

Today we will end with this. We will continue with the aeration section, there are different classification of aerators, different types of aerators which are actually used in the effluent treatment plant for other various uses in the industry, they can be classified differently also. So, there may be a packed bed aeration, there may be submerged aeration, also whether the aeration is air in water type, or water in air type.

So, we may classify aerators into different categories. So, we will learn this aspect in the next lecture. And thereafter, we will perform some design calculations with respect to removal of certain amount of gases or pollutants and try to come up with some design problems and solve them in the later classes. So, we will continue with the aeration section in the next class. So, today, we will end this lecture with this and we will continue later on. Thank you very much.