Wastewater Treatment and Recycling
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Lecture – 17
Natural Purification in River: Effects on DO and BOD

Hello friends. So, we have been discussing in the earlier lecture that various processes that act for the natural purification of the waste, particularly the organic waste and some sediment entered in the river with the waste water discharge. So, this lecture will be elaborating further on how this processes affects the DO and BOD in the river, how this time line of DO and BOD changes within the river.

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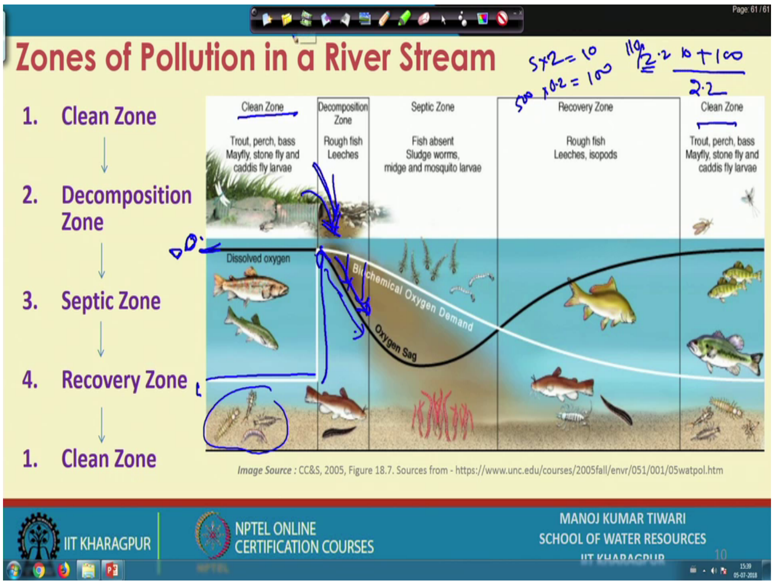

So, if we see the different zones of pollution in a river stream, particularly when it is receiving a waste stream ok, so what happens post that point. Now typically there are four different type of zones which can be considered in a river when it is receiving a sewage discharge or waste water discharge right. So, the these four zones are the clean zone, decomposition zone, septic zone and recovery zone right.

The clean zone that you are seeing here; that is you can say that either first zone or may be the last zone also. So, what happens that the river is initially let us presume that river is initially clean, so in its natural state ok. There is a good amount of dissolved oxygen so let say this is the, the black line you see is the dissolved oxygen level, so there is a good amount of dissolved oxygen and this dissolved oxygen is near its saturation value ok. So, near saturation value of the dissolved oxygen is there, there are fishes, there are aquatic organisms ok. There are some smaller creatures at the bed or bottom of this, so that kind of condition is there.

Now what happens that when a waste is introduced in the river, a waste stream comes introduced in the river then the first zone that we get, means immediately after in like introduction of this waste stream that we call it decomposition zone ok, when this decomposition of the waste starts. So, initially you see the BOD is very low ok, let say, for say this is your the background value ok, any background value you can take it ok, but often very low value around may be 10 5 4 whatsoever you take.

Then when waste is stream comes and it gets mixed with the river water, so the BOD value of the river water suits up, because your waste is going to have a very high BOD value and as we discussed that there is going to be dilution happen, so because of this dilution factor this BOD suits up ok. So, for say your initial BOD is, let say 5 milligram per liter and flow rate is 2 meter cube per second. So total mass introduced here is from 10, while your waste stream which is coming in having a flow rate of 0.2 meter cube per second and a BOD value of say 500 ok. So how much this becomes? This becomes 100 ok.

So, total as we discussed in the previous lecture if you try to figure out the total concentration here, so total mass is 10 plus 100 divided by total flow is 2.2 ok, so that is 110 by 2.2, which is close to 45 or 4 that way ok. So, from 5 it has shooted up here ok. Now what happens that at this particular point BOD is very high, the dissolved oxygen is adequate, so the microorganisms start degrading or decomposing the organic matter present in the water.

So, you will see that the decay of BOD starts the, because of. Primarily the biodegradation process, primarily it is the micro organisms. So, these microorganisms will actually start decomposing organic matter and for the purpose they will consume oxygen, its generally aerobic microorganism, so they need oxygen for converting organic matter or decomposing organic matter. So, in the process they will consume oxygen and what will happen, what eventually will happen that the level of oxygen if you see here. So, this was your BOD and BOD will start decreasing slowly, while there is going to be a rapid fall in the oxygen level, because this oxygen is getting consumed for the degradation or decomposition of organic matter.

Oxygen is not only getting consumed, oxygen is coming from the atmosphere also, so there is a oxygen transfer is still taking place at its standard rate, so there is oxygen transfer, but the rate of decomposition here or the net rate of decomposition here, net rate of oxygen depletion here is much higher than the rate of oxygen coming in the system or rate of re aeration and that is why the net oxygen level starts falling and so is the net BOD, because the amount of organic matter is getting decomposed and as a result bog BOD also start decreasing.

So, this, once this process starts there, the kind of like fishes and these thing it becomes difficult for them to survive, still some of them can survive, but it increasingly become difficult because oxygen level is falling and then we entered to the septic zone, where the dissolved oxygen or DO reaches its minimum. So, this is the minimum dissolved oxygen, let say it has come down, most of the oxygen has depleted in consumption of the organic matter and since the oxygen supply has fallen rapidly, their will not be any fishes in here, there will not will be only some slug warms and mosquito larvae present in the water ok.

Some midges and this kind of things also be there. While in this zone also your BOD or whatsoever organic matter present is keeps on decreasing. What happens that since the BOD level is falling. The requirement of oxygen for further degradation also starts decreasing ok. So, now, since the requirement of oxygen or the oxygen uptake for the BOD decomposition starts falling and your re aeration is re aeration still taking at that place, so you comes at point where this is almost equal and then once further BOD decreases the consumption rate of the BOD, consumption rate of the DO becomes smaller as a oppose to the re aeration rate. So the amount of dissolved oxygen which is coming in the water exceeds this rate and as a result this dissolved oxygen is again starts building up.

So, the dissolved oxygen concentration again starts increasing and then we enter to the recovery zone, where the river is trying to recover back, it is trying to reach to again its like, again trying to reach to the clean zone or natural conditions. So, in the recovery zone again we will see that the organic waste is further, will be further decomposed and the oxygen will start building up and it reaches to a significant level, the fishes started, the fish population is starts appearing ok.

So, those kind of thing start coming in and then water once like this a by the end of recovery zone and when it almost attends back the original dissolved oxygen or near saturation dissolved oxygen level, it enters, river enters again in the clean zone and the conditions here will prevail back here ok. So, these are the four major zones clean zone, decomposition zone, septic zone and recovery zone or if you are seen from the introduction point of view where the waste is getting introduced in the nature. So then there is decomposition zone where the decomposition start septic zone, the worst condition, the minimum dissolved oxygen, recovery zone; river again tries to get back to its like original state so tries to recover it. And then eventually it enters the clean zone, where it has received where it has attained its earlier pristine, near pristine stage.

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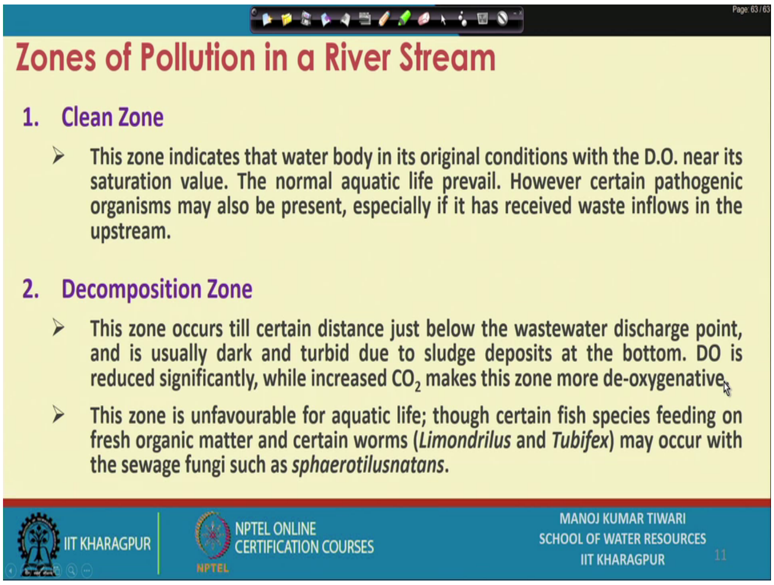

So, in clean zone which, it indicates that the, it is your original DO is near its saturation value, the normal aquatic life is there in the river. However, particularly if your clean zone is coming after the waste introduction, if beyond this point there is no waste introduction it is relatively better, but after this waste introduction if you are in this clean zone, you can still like have some of the contaminants or some of the microbial impurities which have not been decomposed or which has not been degraded, they can still persist over here.

So, it is not advised that way to directly consume this water if it is coming out of after, if your point is in the downstream of the point where the waste has already been introduced, so then one should avoid direct consumption of that water or the consumption of that water without proper treatment. Then in the decomposition zone it will occur to a certain distance, below the waste water discharge point where it is introduced.

It will be usually in the dark and turbid, because the lot of waste is getting introduced so that immediate point one can see a color change also, there could be sludge deposits at the bottom, because lot of solid materials and waste sludge also comes along with the water, so they can get deposited in the water DO is introduced significantly, while CO2 increases and which makes this zone as like more de oxygenative zone kind of thing. This zone is unfavorable for a aquatic life, but certain fish, species can a still survive as we discussed.

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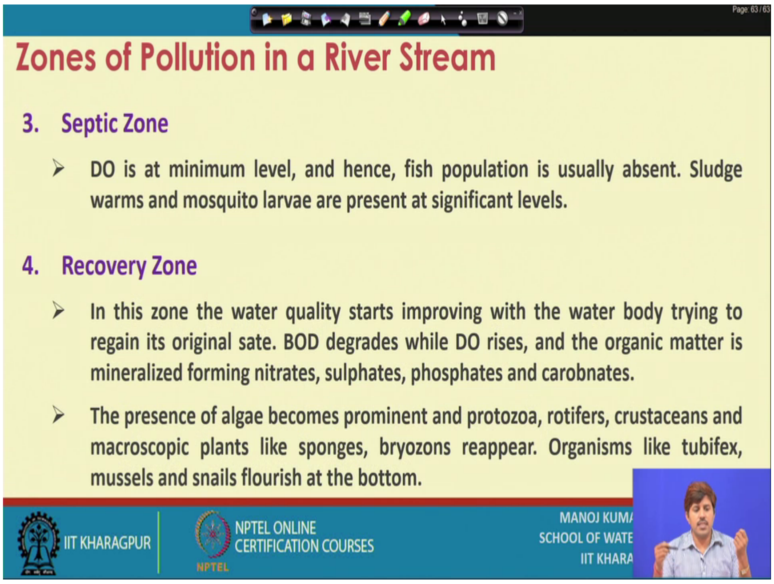

Then it enters septic zone when DO is minimum level and fish population are usually absent, there will be sludge warms mosquito those kind of thing and then eventually comes to the recovery zone, where the water quality starts further improving, this water body tries to regain its original the BOD degrades and DO rises ok.

The organic matter is more or less a, is typically gets mineralized in this zone into the nitrates, sulphate, phosphate and carbonates this kind of thing and rest escapes in the form of CO_2. The presence of algae become prominent, there could be protozoa, rotifers and other microscopic plants can come. There are like microorganisms also (Refer Time: 13:12) organisms, small organisms can also come. The bottom will see the muscles and snails all they can come at the bottom.

So, that way the river is basically gets cleaner and cleaner as it moves ahead in the recovery zone, and post that as we discussed it comes again back to the clean zone.

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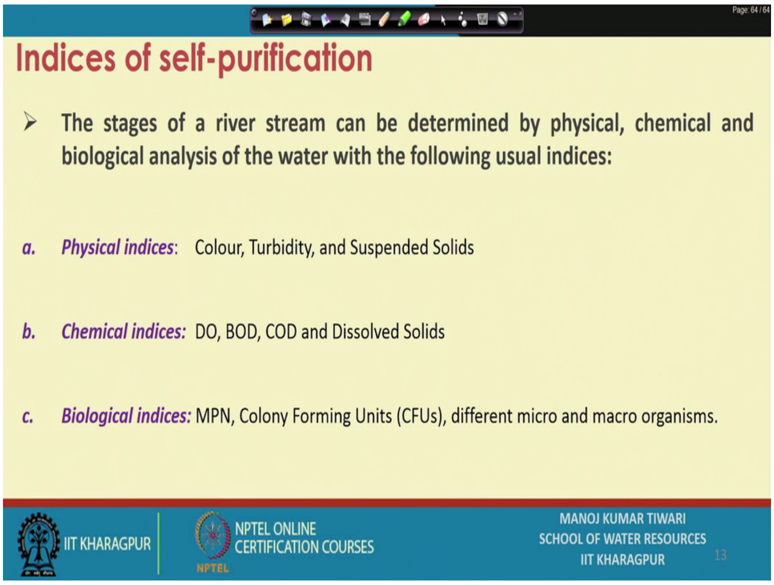

So, if we, there are certain daises based on which we can assess the status of self purification ok. So, as we say that river could be in the different zones or the different type of conditions, it could be in, so how do we know where, what conditions is prevailing and what kind of like what is the pollution level and which direction its moving. So that that is typically done by the measurement assessment or analysis of water with certain qualitative parameters which are the usual indices for the self purification ok, so, those quality parameters which are typically used.

There are certain physical indices which are based on the color, turbidity and suspended solids ok. So, what is the color, because if water is in a clean zone we will see relatively transparent water like not so dirty or polluted water. We will see the turbidity low, we will see this suspended solids very low, which eventually leads the turbidity, but if it is in the let say decomposition zone. So as waste is getting introduced we will see a much darker or dirtier color, increased turbidity increased suspended solids.

In septic zone relatively we will see lesser suspended solid, because they can get settle, but still there is there could be, because of this microbial activities and all that, it is not going to be that transparent and a turbidity will lower as suppose to that decomposition zone, but still it will be higher. Recovery zone it tries to improve and by the time it reaches clean zone, again it will attain a less turbidity a very less suspended solids and almost transparent color.

The there are chemical indices in the form of dissolved oxygen. What is the level of dissolved oxygen? And as we discussed the dissolved oxygen varies in clean zone, we will see the dissolved oxygen level near saturation value. In the septic zone we will see the dissolved oxygen level very low minimum less than around less than 2 or close to 2. In the decomposition zone, we will see that dissolved oxygen level falling and in recovery zone we will see that dissolved oxygen level increasing, BOD also, the very high BOD values, we are there in the sort of composition zone or septic zone.

The lower BOD values we are in the clean zone ok, very low value clean zone or if it is getting further lowered we are in the recovery zone that way. COD is similar indicator of BOD, there could be dissolved solids, so that could be one of the chemical indices what is happening to the metals, what is happening to the dissolved nutrients and those kind of stuff. Then there could be biological indices in the form of MPN, what is the, we discuss this, what is the bactological pollution in the water. There that could be assessed in the colony forming unit or CFU as well. There we can specifically analyze selective macro and micro organisms to see the biological state of the water.

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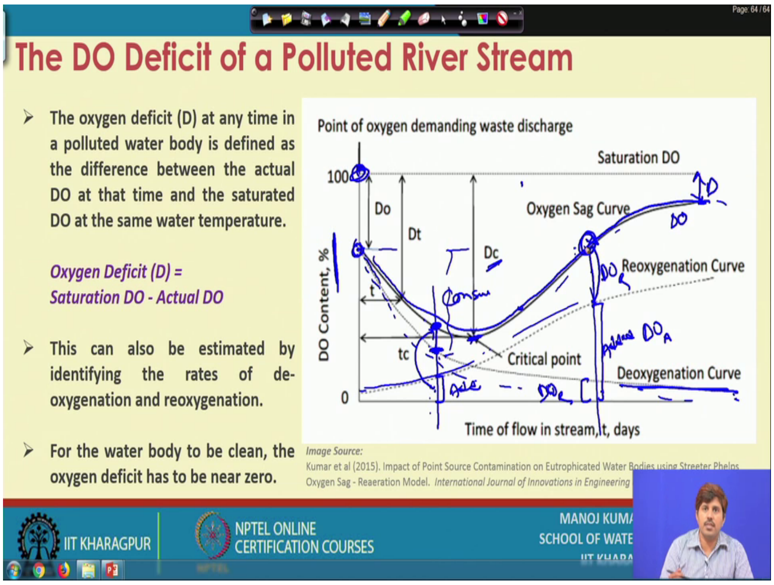

Now DO deficit, if we see if a polluted stream, so as we were discussing earlier, the DO level initially falls and then builds up ok. So, if you see let say at any given point of time, if this is my saturation D DO which is 100 percent ok, this scale is in terms of percentage. So, if this is my saturation DO, the dissolved oxygen level initially or when the waste is getting introduced for say is here ok.

Now, if this, if the dissolved oxygen level is here, so this is the difference, if this is my DO profile ok, this is my D existing dissolved oxygen concentration ok. So, if this line is my DO profile let say so at any given point of time the difference between the existing DO and the saturation value is called DO deficit or the oxygen deficit right. So, when the water is having a DO value near saturation, we know that your DO deficit or oxygen deficit is very low ok, when it is in the septic zone, when your dissolved oxygen level is minimum your DO deficit is maximum or we can call it critical, the DO deficit ok. So, that way we get the deficit of the dissolved oxygen in the river right.

Now if my initial DO of the river is let say here and this is my saturation value 100 percent, my existing DO is here and waste is getting introduced at this point of time. So; obviously, my DO level is going to fall as we discussed and then it will touch a minimum, and then start again sort of recovering.

Now, this fall and gain is because of two distinguish processes ok. So, we discussed that the decrease in the de dissolved oxygen is primarily because the organic matter is getting decomposed so BOD demands the oxygen and that oxygen is getting supplied from the quota of the oxygen, which is dissolved in the water and as a result DO level in the water falls. So, the fall in the dissolved oxygen level is essentially, because the BOD or the organic matter getting decomposed and that is what this process is consuming oxygen or consuming the dissolved oxygen.

So, this process is called de oxygenation process and this you can see a de oxygenation curve here ok, which says that you forget about the; like DO profile at the movement ok. You see if there is no dissolved oxygen coming in the system right, if there is no dissolved oxygen coming in the system, then the profile of the dissolved oxygen would have been like this, because it is basically getting consumed by the process.

The microorganisms are consuming oxygen for the purpose of oxidation of organic matter and as a result the oxygen is getting consumed and your dissolved oxygen level is falling like this. However, your actual dissolved oxygen profile is like this and not like this, because it is another process which is re oxygenation or re aeration process, which sort of makes up for the oxygen in deficit, and the from the atmosphere the oxygen gets transfer into the water.

So, these re oxygenation will there, there is a re, at whatever re oxidation rate of water is based on that it will keep on adding oxygen in the water. So, there is one process which is making oxygen decrease, there is one process which is making oxygen increase, at any point summation of these two values will give you the total oxygen. So, initially it is here, now let say at this point of time you are having this much of oxygen has been added, while this much of oxygen has been; like from oxygen it has, from initial point this much of oxygen has been consumed ok.

So, this much oxygen consumed and this much oxygen added. So, this mush consumed means still this must is remaining and then there after this amount has been added, so you shift this amount about over and above this and you will get the true value of the dissolved oxygen level ok. So, you can try this at any point, so let say for this point this much oxygen is added ok. So, let us you say that DO added and this much oxygen is still remaining in the system, so this is your DO remaining.

Now you, this much is added and this much is already remaining, so you add the remaining DO remaining over here and you will get to the value of the actual dissolved oxygen. So, this oxygen sag curve, sorry this oxygen profile or the oxygen curve or DO profile which is also called as oxygen sag curve, because there is a sag is coming, if you see this curve. So, you can clearly see that there is a sag in this profile and that is why this is called oxygen sag curve or DO sag curve ok.

So the DO curve or DO profile or DO sag curve is actually this sum of deoxidization and re oxygenation profiles ok. So what is the deoxidization and re oxygenation? You add these two and one is going to get the oxygen curve. So, this oxygen deficit at any time in a polluted river body will be defined as saturation DO minus actual DO, what is the saturation dissolved oxygen level and what is actual dissolved oxygen level and the gap between that is called oxygen deficit.

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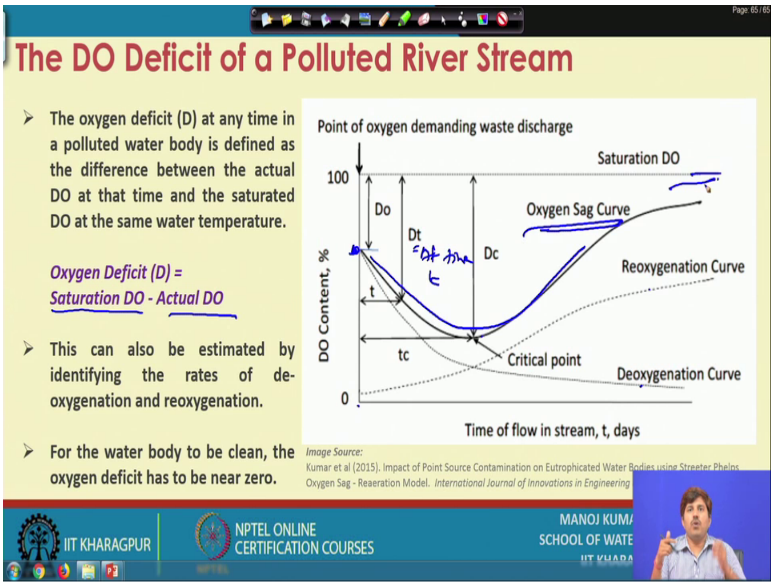

So, like this is oxygen deficit at time t, this is the critical oxygen deficit when the oxygen level has fall to the minimum so that deficit becomes maximum, and this is the initial oxygen deficit at time 0. So, when you started this is at time 0, this is the deficit in the oxygen. So, this can also estimated by identifying the different rates of oxygenation and re oxygenation curve and for water body to be clean, the oxygen deficit has to be near 0.

So, as good the oxygen dissolved oxygen level is there in the water that indicates that there is not much of dissolved organic impurities present in the water or dissolved organic carbon present in the water. And that makes that sort of kindly a gives an indication that the water or the river is in the good state ok, or is not very much polluted, because if there is too much of organic pollution, it will consume the dissolved oxygen and the DO level will falls.

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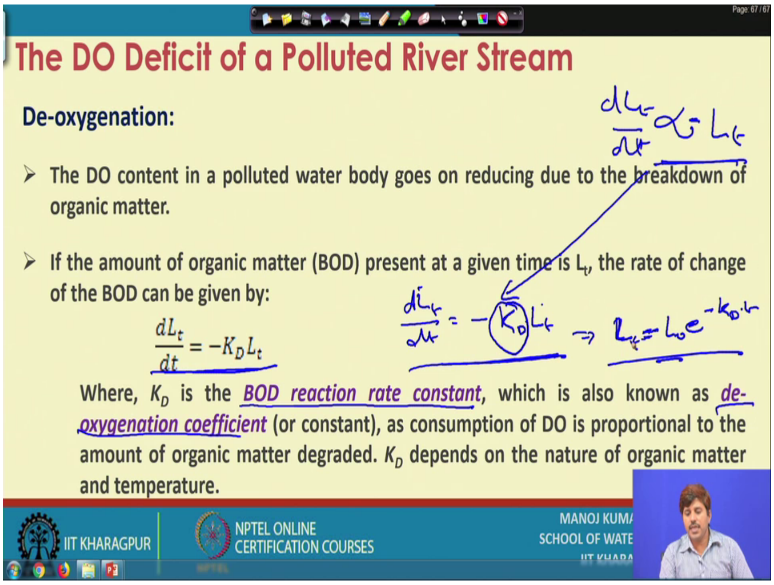

So, a good healthy DO level, a DO level near saturation indirectly indicated that river is nearly clean. Particular in terms of the organic contaminant, it could be still polluted by the metals or by the heavy metals other things which does not consume oxygen, but it is relatively clean from the oxygen consuming contaminants ok. As we said there is pos, there is de oxygenation and re oxygenation the two processes which in combination gives us the dissolved oxygen profile. So, the DO content of a polluted water body goes on reducing with the breakdown of organic matter which is the de oxygenation process and that can be seen by this expression typically.

So, if L is the organic matter present or BOD present Lt, so rate of change of the BOD is actually proportional to the K D times Lt existing BOD, so this is the simple first order expression ok, or we can say that rate of change of BOD is proportional to the existing BOD, which makes it the first order and here or, because it is decreasing so proportional to the minus of this thing and if we add a proportionality constant, so this expression becomes like this.

Now, here K D is the BOD reaction rate constant, how BOD is decreasing right, so that is what K D is, K D is called BOD reaction rate constant, but we know that sort of the rate of the; like organic matter decomposition, the bacteria utilizes dissolved oxygen for organic matter decomposition. So the consumption of dissolved oxygen, how much dissolved oxygen getting consumed in the process will be proportional to the amount of organic matter which is being degraded. So, more amount of organic matter being degraded more is the consumption of organic matter right.

So, that way, actually the rate at which the oxygen gets consume or rate at which the BOD gets degraded is the same rate at which oxygen gets consumed, and that is why we know that the rate of oxygen consumption we earlier discussed is the de oxygenation process and this rate is called de oxygenation coefficient or de oxygenation constant also.

So, K D is either will be referred as BOD reaction rate constant, which is same as the de oxygenation constant or de oxygenation coefficient and its, it depends on the nature of organic matter and the what is the existing temperature, based on that it depends ok. And it is a simple first order expression, so we can solve this, eventually you will get Lt is equal to L 0 which is initial BOD into L 0 to e to the power minus K D times t. This is standard solution of this expression ok.

So, that way we can get the BOD at any given point of time; that is how the BOD gets degraded.

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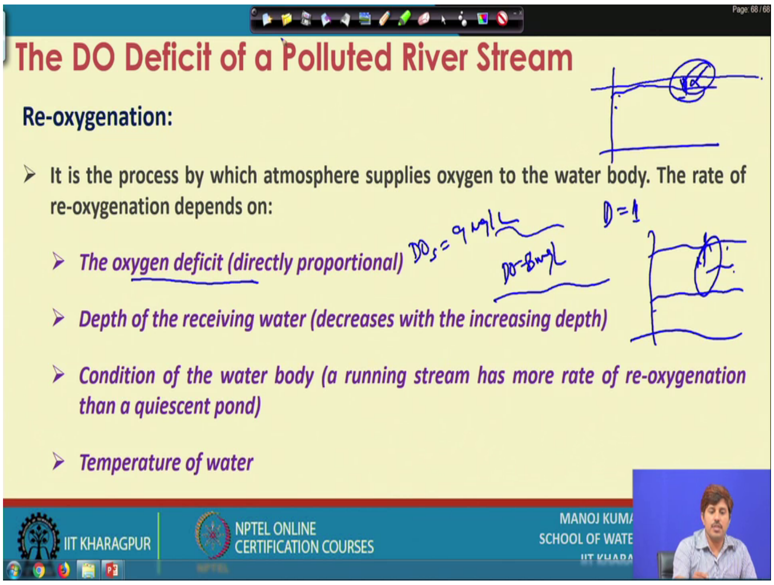

So that is the de oxygenation part and then we have the re oxygenation part which is, process which by which the atmosphere supply the oxygen to the water body and its rate will depend on the oxygen deficit, so it is typically deposit to the deficit of oxygen. Because if you are having river with a let us say your saturation dissolved oxygen is 9 ok, 9 is your saturation value and your existing DO is 8 milligram per liter, so your DO deficit is 1.

Now your oxygen level if you see could actually existing oxygen level is here, the maximum oxygen could actually be there, so there is very little deficit and your rate will be very slow, because rate is proportional to this deficit also, so rate is going to be very slow. However if you are having a river system, where these saturation level means it could (Refer Time: 29:37) like these and your existing level is very low, so you are having a good enough deficit and then the rate will be very high, the rate of oxygen transfer will be relatively very high.

So, it is actually directly proportional to the deficit. Then depth of the receiving water body, it decreases with increasing depth, if your depth of water body is high, so the rate of oxygen transfer particularly the lower status will be very low. The condition of water body; of course, a running stream will have more turbulence and more re oxygenation then a static pond or quiescent scheme stream, and what is the temperature of water, because our saturation DO depends on the existing temperature of the water bodies. So, that way it will be basically function of these things.

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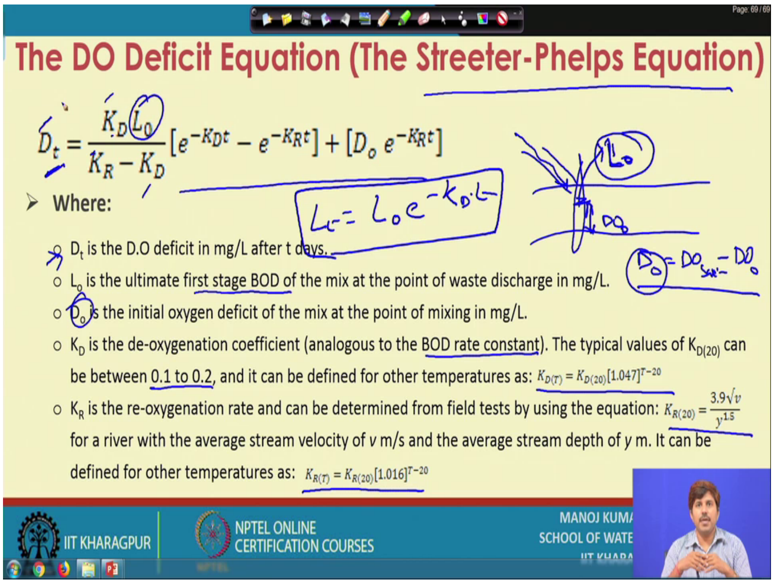

Now, the DO deficit is presented through a very popular equation which is typically known as the Streeter Phelps equation ok, and this is, the Streeter Phelps equation is the one which like gives us the profile of DO. So, the DO sag curve you saw earlier can actually, mathematically represented through this equation which is called the DO deficit equation or the Streeter Phelps equation ok. So, the equation is that DO deficit at any given point of time t, here D is the deficit. So, DO deficit at any given point t is equal to K D into L 0 minus K R by K R minus K D and e to the power minus K D t minus e to the power K R t and D 0 e to the power minus K R t.

So, here your D t is the DO deficit at any point t at any given point time t, L 0 is the ultimate first stage BOD of the mix after the point waste is mix. So, if this is my river, I am having, I am so sorry, I am having a waste stream coming in over here. So, after this point what is the my ultimate BOD is actually L 0 so ultimate BOD is estimate of the organic matter, so what is the total amount of organic matter present ok, because that is an estimate of the ultimate BOD.

So, total amount of organic matter present or the ultimate BOD at this point. DO is my initial oxygen deficit, so what is the dissolved oxygen level at this point of time. So if dissolved oxygen level is let say DO 0, so DO is actually the DO saturation minus DO 0, so that becomes my D 0 or the initial oxygen deficit. In K D and K R the de oxygenation and re oxygenation coefficient ok; so K D which is the de oxygenation or the BOD rate constant, the typical values are 0.1 to 0.2 at 20 degree Celsius and at other temperatures we can estimate following this expression. So, at K D, at any temperature is K D at 20 degree to the power 1.147 t minus 20 in degree Celsius ok, where t is in the, here t is temperature in degree Celsius.

similarly K R is the re oxygenation rate and this typically can be determined using this equation at 20 degree Celsius, where v is the velocity and y is the average stream depth ok, and a for other temperatures similar to this we can use this expression for determining the K R at other temperatures. So, once we know that, once we have an estimate of K D and K R and we know what is the ultimate BOD or the total amount of waste which is being added to that we can estimate how what will be the deficit at any given point of time ok.

So, knowing the amount of BOD and these three, these two different rates we can predict the profile of the dissolved oxygen, and the profile of the BOD prediction is also same and simple. So, as we discuss the profile of BOD is equal to L 0 e to the power minus K D into t. So, this expression this simple first order expression will give us the profile of the BOD or profile of the organic matter present in the system, while this Streeter Phelps equation will give is the profile of the dissolved oxygen or dissolved oxygen deficit, DO deficit which eventually can be taken of a profile of dissolved oxygen as well ok.

.So, that is how these two are determined and then we, let us conclude that is the, let us conclude these discussions here only. And in the next class we will again discuss the further integrities of how this works and how we can get the minimum and maximum, the minimum DO level in a river water and a how far it is going to arrive the estimate of those.

Thank you.