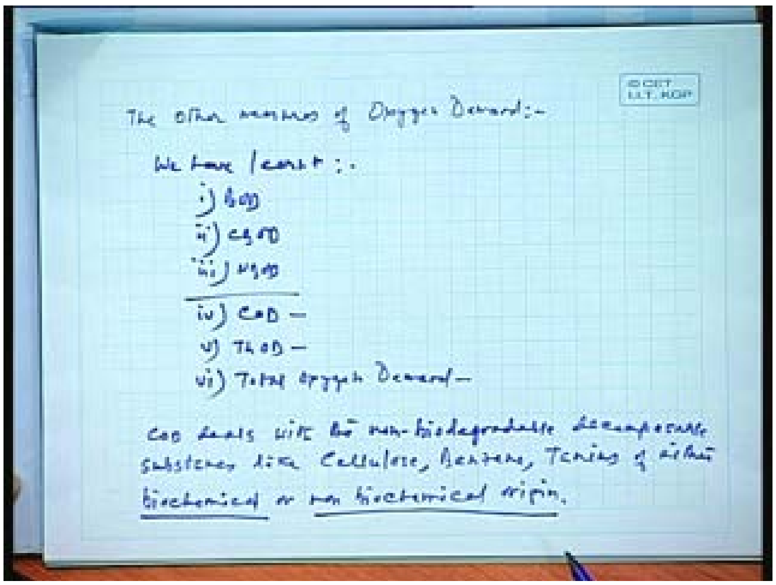
Fundamentals of Environmental Pollution and Control
Prof. Jayanta Bhattacharya
Department of Mining Engineering
Indian Institute of Technology, Kharagpur
Lecture No. # 10
Oxygen Demanding Waste in Streams Part – I

Once we start this topic this is you know about this oxygen demanding waste in streams, particularly in the streams. Let me discuss few things you know which should be you know continuation of the last class I mean you know there are few things that we need to discuss before we further proceed on in these streams first.

(Refer Slide Time: 00:01:11 min)

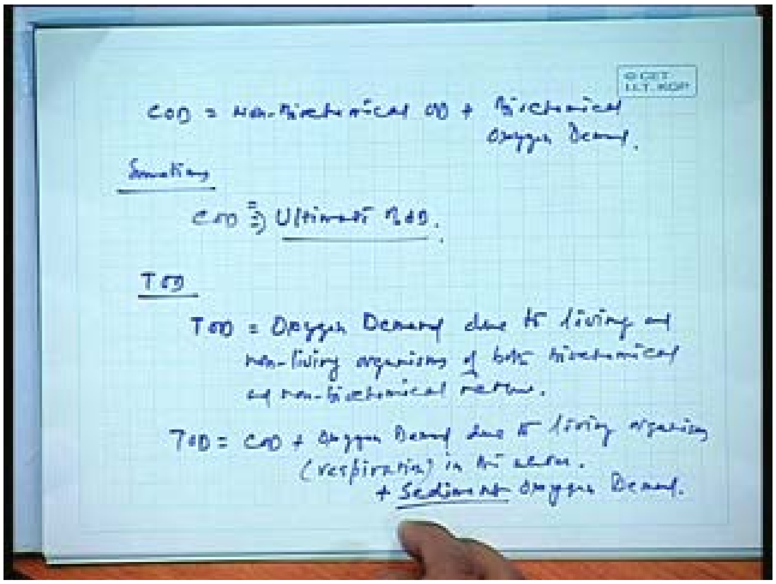


The other measures of, the other measures of, other measures of oxygen demand, other measures of oxygen demand, this other measures of oxygen demand you know this the way it is generally explained. There are few things you know we have learnt you know we have learnt, we have learnt about say BOD, we have learned about CBOD, we have also learned about NBOD. There are few more this three, apart from this three we also deal with some other oxygen demand, one very common is you know this is as you know COD. This is one is we have also talked about COD but I will explain you the difference here COD then you have theoretical oxygen demand ThOD and then we have total oxygen demand, total oxygen demand, total oxygen demand right, total oxygen demand right. Here in such cases you know you can see this BOD, CBOD, NBOD that we have explained. The COD what it means theoretical oxygen demand and total oxygen demand right.

COD particularly you just you know COD deals with, COD deals with, COD deals with the non-biodegradable, non-biodegradable decomposable substances like cellulose, benzene, tannins of either biochemical or non-biochemical origin right.

So the oxygen demand related out of this non-biodegradable decomposable substances like cellulose, benzene, tannins of either biochemical or non-biochemical origin say remember this thing, a cellulose may be of biochemical source right but a benzene is not necessary a biochemical source is not in fact. See in tannins also may be you know some of the tannins of biochemical origin, so there may be some artificial tannins also which are of non-biochemical origin. So this is what the COD, this is what the COD deals with, COD deals with then having said this there is another term you know, so COD is essentially as I have said COD is, COD is, COD is non-biochemical oxygen demand plus biochemical oxygen demand.

(Refer Slide Time: 00:04:48 min)

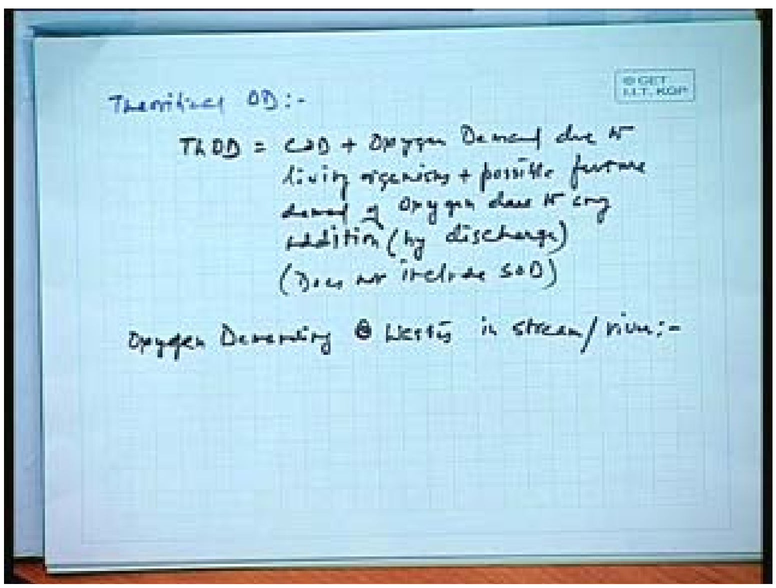


Sometimes, sometimes so, sometimes COD is also referred, sometimes COD, sometimes COD is also referred as, COD is also referred as ultimate BOD. Sometimes COD is also referred as or equal to considered as equal to, considered as equal to, equal to ultimate BOD. So this is what is the distinction that one makes you know COD and BOD and essentially as you have already said, as I have already said COD is essentially more than BOD, COD is essentially more than BOD. But it does not suggest that if you are finding out BOD will be able to find out COD right, it does not suggest at any point of time. So because of the nature of the waste may be different, the nature of the waste being important that will have more bearing than, than, than you know what is the BOD, what is, what is the NBOD or CBOD like this. So, in such cases so we can see that you know this is what the COD is.

Apart from this, this is we just as I have said theoretical oxygen demand you know later before going for theoretical oxygen demand, this is total oxygen demand say total oxygen demand TOD. TOD measures as the oxygen demand, oxygen demand, oxygen demand, oxygen demand due to living and living organisms of both biochemical and non-biochemical nature. So total oxygen demand apart from total oxygen demand is essentially COD plus oxygen demand, oxygen demand due to living organisms, living organisms should use them for respiration purpose. Due to living organisms oxygen demand due to living organisms in the, in the water, in the water, so this is you know total oxygen demand, this is what would be known as the total oxygen demand.

Let me repeat it again. TOD is equal to COD chemical oxygen demand plus oxygen demand due to living organisms in the water due to living organisms in the water. So this is what is the TOD, there would be a considerable demand of, considerable demand due to living organisms, living organisms in water mostly the features the plants that would be generally surviving in the water, they would also require oxygen for respiratory purposes. This oxygen demand then apart from that there is another kind of oxygen demand that generally one observes in this kind of thing is called sediment oxygen demand. The sediment oxygen demand arises due to, mainly due to sediment oxygen demand, sediment oxygen demand arises mainly due to the presence of organic substances in the soil substrate below the water. They would also undergo decomposition, they would also undergo oxidation and as a result of which you know they would also create a certain demand for oxygen that is what is known as sediment oxygen demand, this is known as sediment oxygen demand.

(Refer Slide Time: 00:09:57 min)

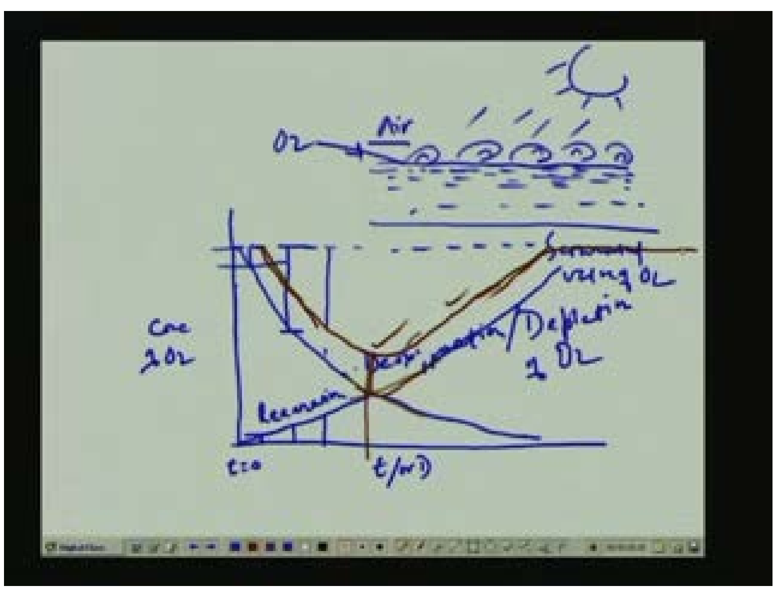


So this would be, this is the, this, this is mostly the total oxygen demand and theoretical oxygen demand theoretical, theoretical oxygen demand OD, theoretical oxygen demand essentially means, essentially means that that particularly when I mean you know in cases of mostly the TOD this is theoretical oxygen demand which is nothing but this is COD has to be included of COD and oxygen demand, oxygen demand due to living organisms plus the possible future demand of oxygen, due to possible future demand of oxygen due to any addition, due to any addition say by discharge, by discharge right.

So COD plus oxygen demand due to living organisms plus possible future demand of oxygen, due to any addition by discharge and does not include, does not include SOD sediment oxygen demand and does not include sediment oxygen demand and does not include sediment oxygen demand. So, this is what is you know precisely the kind of oxygen demand situations that you would like to see you know in most of this cases of water say any kind of wastes wherever there are, they are carrying municipal civic sewage waste or say any kind of wastes say dead bodies, a dead substances any part of a dead body all this would lead to the oxygen demand in the water required for their oxidation and different parameters that we can find out of all this would be known as say BOD, COD, NBOD, CBOD, TOD, ThOD and also you know the COD that we have already say discussed.

So I think this should be clear you know because you know in many cases people generally use all this terms but essentially whenever you are discussing about oxygen demand in if otherwise not mentioned, if otherwise is not mentioned COD and ThOD are not generally referred to, mostly referred to are COD and BOD. But this would be remember COD essentially would include, it would not include any living organisms only the dead organisms waste, wastes substances of biochemical origin right okay. So in case of you know you can ask me questions if you are not clear about it, I mean in any case you know in any situation you can always ask me questions about that. See this is about having seen this then we will go into the oxygen demanding waste, oxygen demanding wastes, wastes, oxygen demanding wastes in stream or river. When you are talking about a stream, we generally the difference is what is the difference between a stream and a river. A stream or stream is of narrower width and similarly the river is generally of larger width and higher depth, the stream is also essentially of small depth apart from that there is not much of a difference. There is two important things to understand here, I mean you know in the case of a oxygen demanding waste in stream and water, what we can think of you know if it is, if you are going to, if I want to show you in terms of a plot like this you know this is what it would be.

(Refer Slide Time: 00:14:57 min)



Okay, what we see now is suppose this is you know this is at t is equal to 0, this is where the you know if it is in a stream, if it is in a stream t is equal to 0 or you can write this as t or u or t or D distance, remember this t or distance you can distance is basically velocity into time. So you know considering the stream as a constant velocity we can correlate velocity and time there is absolutely no difference in this. What we try to see now is this here when, when I have said you know in the, in the case of a fixed body of water, in the state of fixed body of water we see there that the oxygen begins to deplete like this. The concentration of oxygen, concentration of oxygen, we generally observe this as a, you know we say that depletion of oxygen in the water is depletion of oxygen in the water can be exemplified like that. I have also said that depending on the nature of the waste, this particular shape would also change I mean we have already said that but considering that fact you know we have a particular behavior like this of the waste. What happens in case of a stream is somewhat quite interesting, somewhat interesting is depending on, depending on the deficit at any point of time, there would be you know on the surface you can see if it, if you just observe a stream, if you just observe a stream like this, if you just observe a stream like this you know here due to, due to different turbulence, due to different turbulence in the water, different kind of turbulence in water at the presence of sunlight, at the presence of sunlight, the presence of sunlight and in the presence of you know particularly you can see a air flowing.

So in the presence of air, in the presence of sunlight there would be an oxygen, there would be a surface addition of, this is there would be a surface addition of oxygen into the, into the stream. Oxygen would be added close to the surface, oxygen would be added to the close to the surface that doesn’t take place in a fixed body of water. It only takes place because of the turbulence in the water and that the water flows in the presence of sunlight, in the presence of oxygen, in the presence of air this particular situation takes place wherever the oxygen is essentially depleting below the surface, oxygen would be essentially depleting below the surface.

So what we can see now here is that you know you would observe that you know this is one at one side will find that the oxygen is this is deoxygenation is taking place, deoxygenation, deoxygenation or depletion of oxygen, of oxygen. On the other hand we would observe that there would be a simultaneously, there would be simultaneously almost about you know depending on this parameter how far the oxygen this is the saturated value, this is the saturated value of oxygen, saturated value of oxygen at that particular salinity. So we can see now there would be an increase in the oxygen depending on, depending on say this is, this depletion of oxygen would be like this.

Here this would primarily depend on the deficit at any point of time, this is the deficit, this is the deficit from the saturated value of, this is the saturated value the maximum value this is the oxygen where it is depleted depending on this particular deficit there would be the rate of oxygen that would be entered into the water would also begin to pick up. That is what is here you know you will find a reaeration taking place, a reaeration taking place. So you know we find that in a case like in an, in a body of water, if you in a body of water if you just observe this. So in a body of water when if it is in a stream, whenever it is in a stream there would be in the presence of waste, in the presence of a waste there would be initially this thing is deoxygenation. That is you know depletion of oxygen that we have seen also quite similar, almost similar to what we have seen in the case of fixed water, fixed water in a fixed vessel, water in a pond, water in a tank this is what we have try to model in the first case.

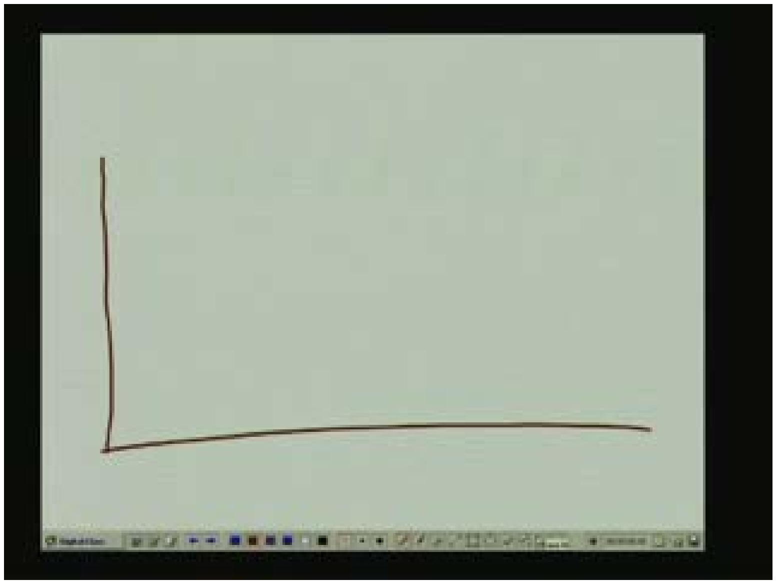
Here we are trying to model what we are trying to understand is when the water is in a free flowing condition. When the water is in a free flowing condition as I have said initially there would be a deoxygenation taking place, there would be a deoxygenation would take place is essentially due to the presence of waste like similar in the case of a fixed body of water deoxygenation would take place but simultaneously as because the water is essentially moving and it is producing different kind of turbulences in the, in the top surface of the water, in the presence of air there would be some reaeration taking place, there would be some addition of oxygen as well.

So if you see now what we observe now this the, how much of the reaeration would take place at any point of time would depend mostly on the, mostly on the deficit at that point. But this deficit would be counted together with this thing you know what is being added and what is being, what is the deficit. So here so all this thing you know would be basically depending on that so you can see here like this but whenever we have seen that you know whenever it has, whenever this deoxygenation has completely taken place, deoxygenation has taken place the saturated value this one would be following a particular pattern pertaining to a constant or a particular to any function or any parametric, any other parameter fixed or variable parameter this, this particular part of the curve would change.

So having said this, having said this what we can observe now is say if you are just trying to observe you find a cumulative, you find a cumulative condition of water sorry, sorry just one minute this is it would be essentially I mean I am sorry you know it would be like this, mostly like this or you know it would be anywhere like this so this one is also all right, so this one is also all right. We can take this one off okay so you can see this, so now you can find out that this is where this is, what is the, this is what is the cumulative of this. So you can see this, this is going like this, these two values the cumulative of this is what you are going to get here. So you can see in a stream particularly quite interesting to watch is that you know in a stream essentially what you would see is that in any case there would be ideally there should not be any situation where oxygen would be completely exhausted from the water, oxygen would be completely depleted from the water. There would be some oxygen always in the water in a running stream and that is because of the combined action of deoxygenation and reaeration, all right.

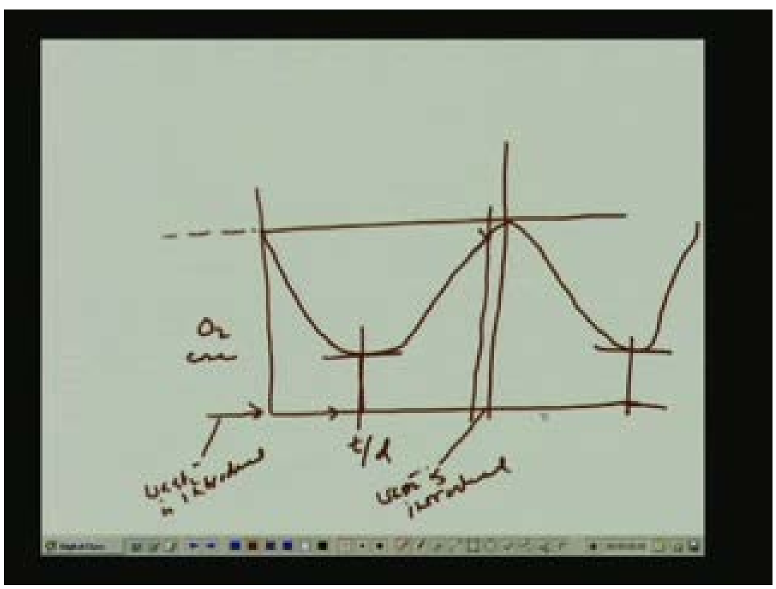
So this is, this is a typical phenomena that we generally observe in water. That is the typical phenomena that we generally observe in the water and this would, this would continue you know how far this would continue. Essentially as you can see here, as soon as it reaches the saturated value then the plot would be, the cumulative plot would be just following the saturated value of oxygen in the water that it cannot be, that it cannot exceed, that it cannot exceed. Again so again, again so you know if you just try to observe this now say okay.

(Refer Slide Time: 00:24:23 min)



Now let us try to observe this, this is you know there what would happen you know in a multiple stream, in a multiple sources of wastes. Suppose this is what, this is what who are is you know if you just try to observe this, okay just one minute.

(Refer Slide Time: 00:24:40 min)

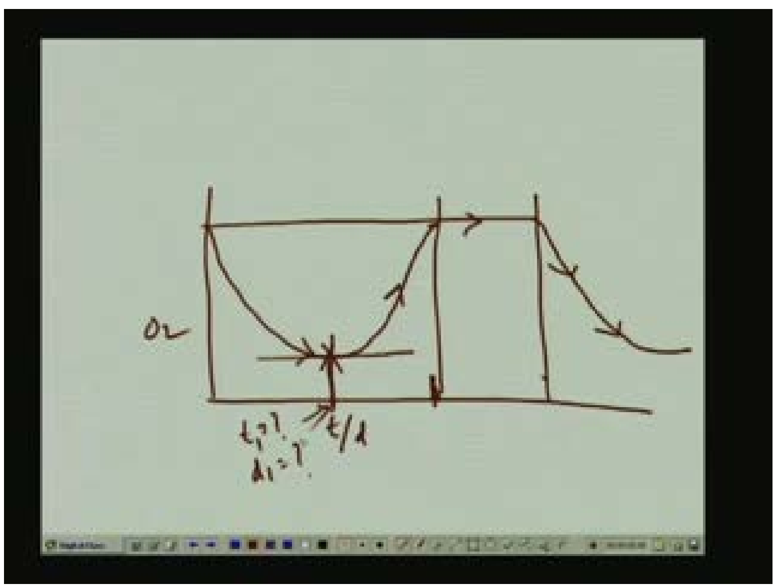


You just start from here so you can see know this, this is where this the, this is the place where waste is being introduced, waste is introduced, waste is introduced till that point of time as I have said this is the water was essentially if you see this the water was essentially at the saturated value, isn’t it.

Now as this point, at this point when there is waste is introduced here mostly the biochemical waste, mostly the biochemical waste remember this mostly chemical waste say you know having mostly of biochemical origin or decomposable, decomposable organic substances. As you can see here so here the typically as you can see this would be the plot like this okay, this is the stream as this is the, this is with distance t or d and this is the oxygen, oxygen concentration, oxygen concentration would begin to deplete like this and again, again begins to raise like this.

Similarly if there are multiple sources, if there are multiple sources again suppose waste is introduced, waste is introduced like you see in the case of, in the case of a river you know whenever is passing through different cities, the waste is being introduced at different locations. So we can see here that the waste would again the oxygen would begin to deplete and depending on the nature of the waste it would follow like this. So here you can see a particularly at different points, at a different distances you can see that of water would be generally relatively having say higher oxygen level you see you know this, there will be fixed oxygen level and at this point of time here before it is entering to the stream the oxygen would obtain it's the, obtain the value of its almost close to the saturated value of oxygen and then again follow then again you know as soon as the waste is introduced this would be like this or else you know just to make a somewhat you know more simple here just you know the plot it be just one minute.

(Refer Slide Time: 00:27:12 min)

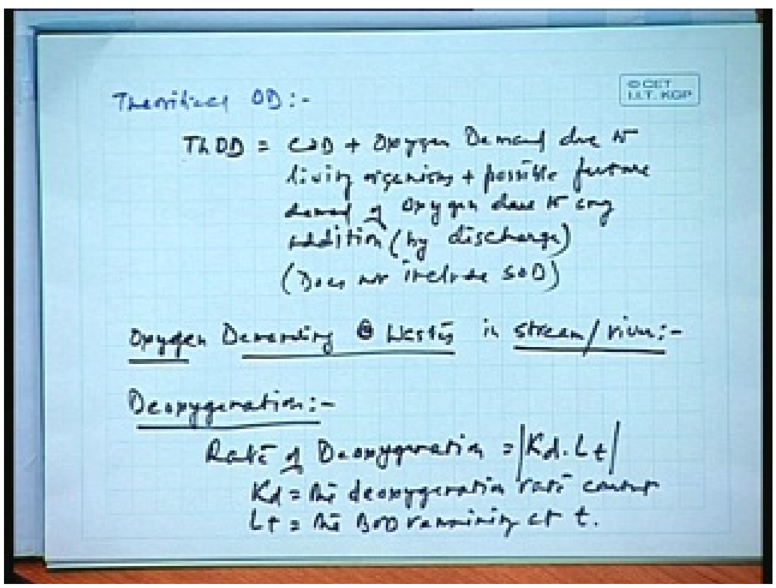


You know the same plot, the same plot can be you know further over simplified like this. This would be how it is like this, this is, this is how it would reach this value then it would remain constant. So, the concentration of oxygen would be like this again when the waste is introduced this would go down like this and here it is till this point when it is not, not having any source of, any source of waste, not having any source of waste this one can be, this is how it can be explained. So, this is you know in any case of t or d or d, t or d and oxygen concentration right this can also be simply be modeled, this can so simply be modeled you know how to what we observe. Here is this is a point you know where if you just see this, if you just see this one thing can be understood here this is where you know the, the, the, the at a critical distance the oxygen would be minimum, oxygen would be minimum. What is that function?

So, you know what we are trying to do here is when you are trying to see the minimum here the differentiation, differentiation of this function at this point should be 0 0 and say you know if double differentiation of that would be negative. So, in such cases you know you would we would find out that where this particularly, this would be having a value of minimum value, it would have. So the functions if you obtain this function and differentiating this function, we would obtain the concentration at which the oxygen would be minimum in the water and at what distance it would take place or at what time it would take place.

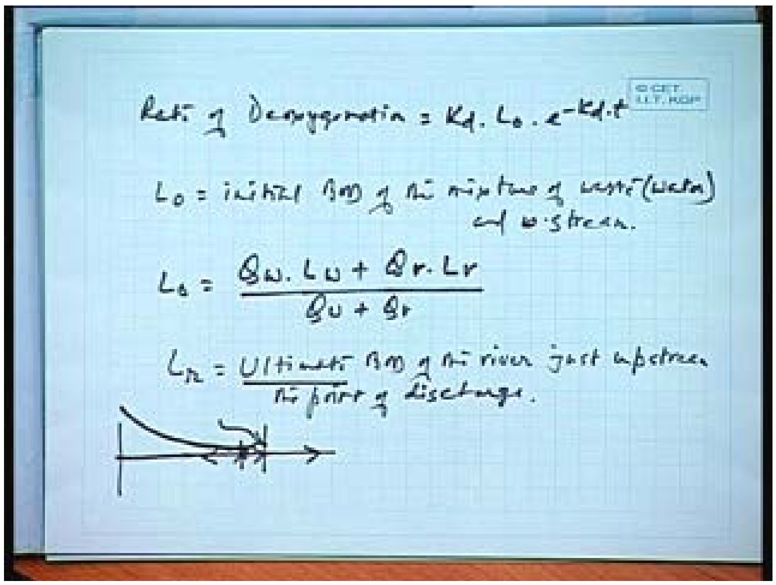
So, we can find out t_1 or say d_1 from this here, here you can see this point if you just observe this point whatever is t_1 or d_1 depending on the characteristics of the waste we can find out, we can very well understand what would be the value of oxygen at that point okay. Now having said this, this is, this is, this is particularly as I have said this is how it would be mostly be like. So we can see now you know we can see here we would try to observe.

(Refer Slide Time: 00:29:45 min)



Now this oxygen demanding waste in streams and all you know when we are trying to identify this, two aspects we would generally explain here one is deoxygenation, deoxygenation, deoxygenation when the oxygen would be depleted or would be removed out of the water. The same thing remains here say the rate of deoxygenation, if you remember the first order reaction rate modeling that we did, you remember in the last class where we have done this modeling we say that rate would be always proportional to, proportional to the remaining, BOD remaining at that point, remaining at that point and we say that explanation we have written as K reaction or Kr or K. Here it is K_d into L_t. The same thing remains K_d is, K_d is the deoxygenation, deoxygenation rate constant and L_t is equal to the BOD, the BOD remaining, BOD remaining at, BOD remaining at t, BOD remaining at t. What is important here is since there would be two cases taking place rate of deoxygenation and rate of reaeration would take place, we would not be always sure whether what would be the sign of this function. We would not be always sure about what would be the sign of this function, so in such cases what we would do here is we would just use the absolute value of K_d into L_t. okay is it clear and so this is what you know we would basically use the oxygen, this is now we would say that you know as you can see this can be, this can be further be you know the same the rate of deoxygenation, the rate of deoxygenation and that is the reason why in most cases it is written as K_d into L_t whether it is almost the similar case, similar case as that of you know in the fixed case as thereof of a fixed water body.

(Refer Slide Time: 00:32:08 min)



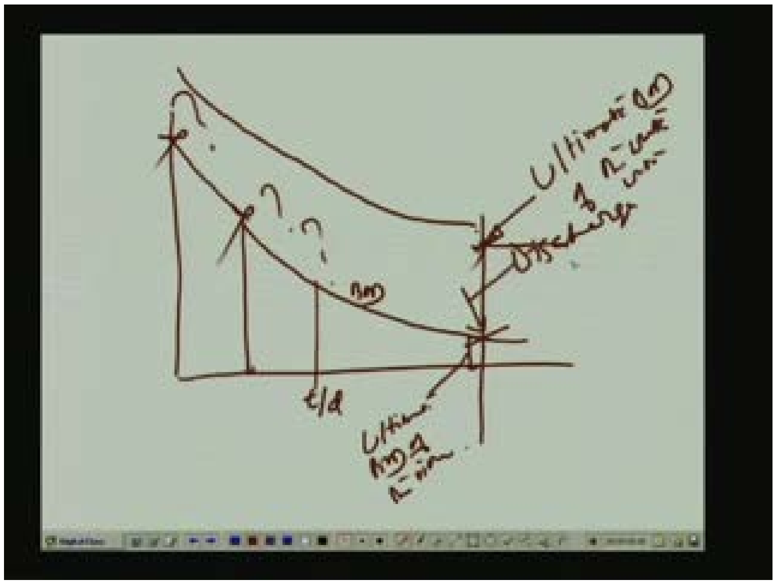
Here in most cases people write K_d into L_t it's essentially the absolute value of K_d into L_t. So here what we generally find is K_d into L_0 into e to the power minus K_d into t, K_d K_d into t. What is that L_0 here? The L_0 remains the same, L_0 remains same, L_0 is initial, initial, initial BOD of the mixture, mixture of waste and waste of stream initial BOD of the mixture of waste and stream.

We can say this mixture of waste and stream, waste or waste water we can write waste or waste water and this is, this is where you can very easily be written as this I'll let me explain is this is a quantity of waste at that point of time into L_w say that the ultimate BOD of that. Let me explain this again $Q_{r,}$ let me write it first then I'll explain this is and Q_w plus Q_r, this is Q_r okay. What is this L_0 is, L_0 as I have already written here this is then we have L_r, this L_r is this, this ultimate. What is this term ultimate means here?

Ultimate BOD remaining BOD of the river, ultimate BOD of the river just upstream, just upstream the point of discharge. What is the upstream? This is, this is say here this is, this is where the waste is being introduced, this is where the waste is being introduced. L_r would be, L_r is the oxygen BOD remaining, biochemical oxygen demand remaining at this point say at this instant here. Thus just the upstream is this side, this is the downstream, this is the downstream the upstream is this side, so just upstream the point of mixture.

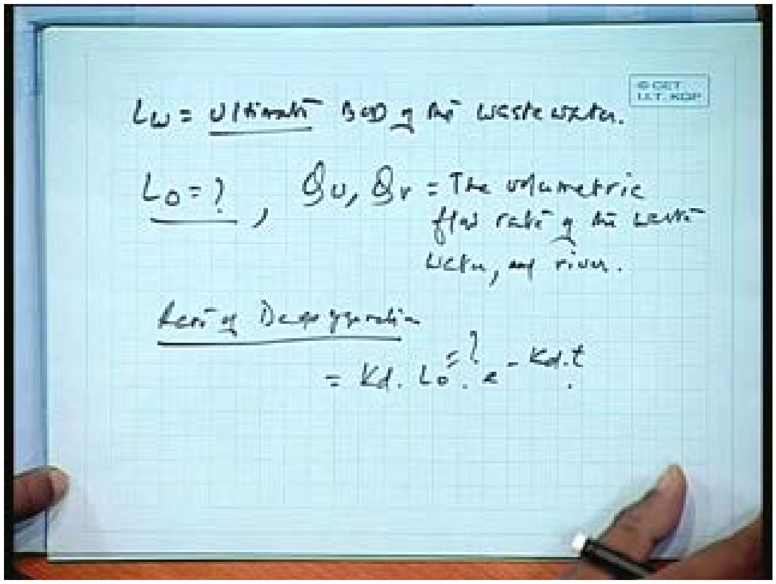
This is what it means this is number one. Another thing it says is the ultimate BOD. What is this ultimate BOD means? If this water, this river might have might have a continuous BOD is you know might have a BOD like say might have a BOD like this, might have a BOD like this, so here this is the BOD that we would be interested in. Say right at this point let me put this here, let me put this here like this here. If you can see this write this at this point of time say here this is the point this is where it is.

(Refer Slide Time: 00:36:15 min)



The river is, the discharge is taking place, this is where the discharge is taking place, this is where the discharge is taking place but this water is flowing, the river is flowing say a, say from, from a distance say from a source where if you can see like this, the water would be having a, the river itself would have a BOD. It will contain a BOD, this is BOD, this BOD is coming from say if you just remained it as time or distance here say this is just to show a frame, it can be also from here. So here or here, so here at this point whatever the BOD remaining at this point whatever BOD remaining here this point is ultimate BOD, ultimate BOD of the river is not this BOD is not this BOD, is not this BOD here or not any point BOD here where BOD is at this point, where the BOD is actually getting mixed with the stream, actually getting mixed with the say waste, waste source actually getting mixed with the waste source. That is why the term come is the ultimate, that is what it is said as the ultimate BOD of the river just upstream the point of discharge.

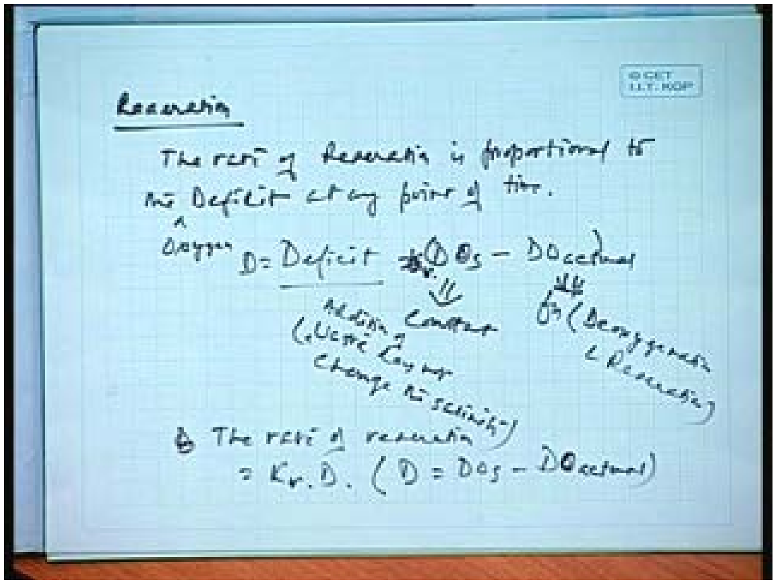
(Refer Slide Time: 00:38:03 min)



Similarly, L_w is the, L_w is the ultimate, ultimate BOD, ultimate BOD of the waste water, ultimate BOD of the waste water. The same, same thing may also be, same thing may also be said about the waste stream I mean if you just see you know, you know in a different way you know if you can think of the waste stream would also have say waste would also have say you know something like a very say it might have say at this point of time it might have a very small or is you know it should have higher generally it should have higher. So you know it's mostly say if we can consider this, the waste stream would be say like this. So at this point of time this is the ultimate, ultimate BOD of the waste water. Okay, okay I am sorry right sorry ultimate BOD of the waste water, as waste water this is where these two are getting mixed, this is where these two are getting mixed.

So this, the BOD, ultimate BOD of, ultimate BOD of the waste water plus the volume multiplied by the volume, multiplied by this the volume of waste water multiplied by the volume of with the river would give you the final value of the BOD at the point of the mixture, BOD at the point of the mixture. So here you can see this is what is the L_r L_w so you can see this and we can find out the value of L_0. If we know that you know this when it is Q_w and Q_r are essentially the volume, the volumetric, volumetric flow rate, volumetric flow rate of the waste, waste water volumetric flow rate of the waste water and that of the river and that of the river okay and that of the river, all right and that of the river. So this is what you know you will find out at this point, so given that you know in the, in the equation you know in case of a problem that we have to find out say if it is, if it is rate of deoxygenation, rate of deoxygenation has to be found out, rate of deoxygenation is say K_d into L_0. This is how the L_0 would be known, this is how the L_0 would be found out e to the power minus K_d into t. So either way rate of decomposition say if it is time is given or say you know the distance is given and the speed is given you can find out time Kdt, Kd L_0 you know you can find out the value of the rate of deoxygenation, okay. I think you know this much is clear, this there is absolutely there should not be any problem related to this okay. Having said this you know this the next part of this you know as you can further flow, move from here as we further move from here we can see the reaeration.

(Refer Slide Time: 00:42:27 min)



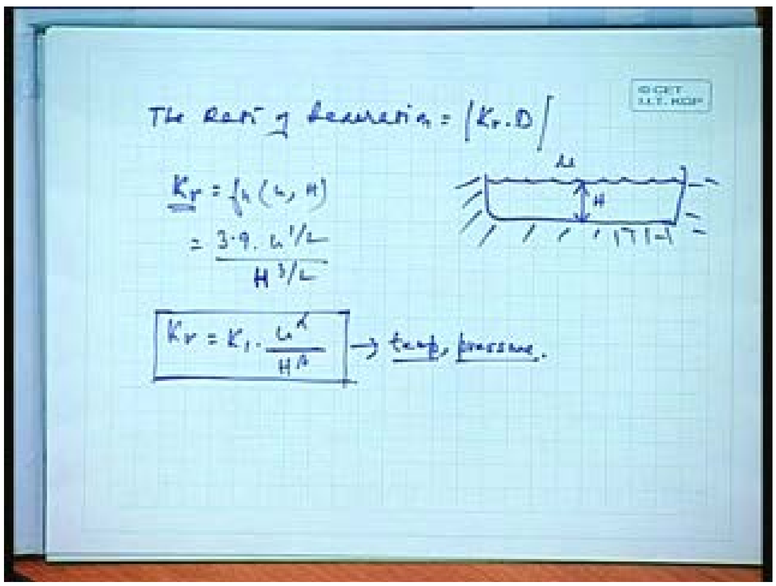
This the reaeration is the next reaeration, reaeration as I have said that the reaeration is the, in at the function that is here you know the rate, the rate of reaeration is proportional, proportional to the deficit, to the deficit at sorry proportional to the oxygen deficit you write oxygen deficit, deficit at any point of, at any point of time at a given location or at any point of time. This deficit is we find that this is important this deficit, this deficit is equal to DO saturated that is saturated value of oxygen that we have, I have already said that in a stream we would consider this to be constant. This is the saturated value is a constant, constant. The ideal is that you know the change there are the waste addition of waste, addition of waste, addition of waste does not change, does not change, addition of waste does not change the salinity, right.

This is what we assume this is dissolved oxygen DOS minus DO actual, at any point of time the DO actual is the DO actual, is DO actual dissolved oxygen that is present at that point of time DO actual. This DO actual is, DO actual is a function, is a function of function of say function of deoxygenation and reaeration. DO actual is a basically a function of deoxygenation and reaeration at that point of time, a deoxygenation and reaeration at any point of time it’s okay. And so this is sorry, this one is proportional as we said, this should be K K_r K_r sorry let me write it clearly again deficit rate of say sorry this is no, no, no not here, not here I am sorry. DOS, this one is this is what is a rate of reaeration, the rate of reaeration, please write it again, the rate of reaeration, the rate of reaeration. The rate of reaeration is essentially due to K_r into deficit, we generally say as this deficit here is equal to, D is equal to deficit K_r into D, K_r into D. So the rate of reaeration, the rate of reaeration is basically K_r into D where the D is, where D is, D is basically DOS minus DO actual minus DO actual, so it is DO, DO actual you can write actual or DO actual okay.

Now you would also say now the same thing you know wherever we are generally dealing with this whether this one would be the rate of reaeration would be increasing or decreasing. The rate of reaeration would be, the rate of reaeration would be increasing or decreasing. Again as we have said this is, this cannot be the identification of the function cannot be readily made here,

here also you would use the basically the absolute. We are, we would be using the value absolute but the difference is there would be the, these two functions are opposing function that is the function of deoxygenation and the function of reaeration should have two different signs isn't it. If one is decreasing the other one is increasing, the other one is increasing another one is decreasing like so in such a case in a function, in a function like this. So we can, we would come, we would come back to that later on but for the time being try to understand that this is what in since we cannot know in all situation whether it would be increasing or decreasing or this can, this particularly this reaction can be this can be written as the absolute value. This is generally the absolute value that we would be trying to know. So here you know as we have gone further on this, so here the rate of reaeration, the rate of reaeration as I have said let me write it again, the rate of reaeration just not to confuse you know this one is K_r into D.

(Refer Slide Time: 00:48:12 min)



Here this is you know we would try to find out the value of K_r. The value of K_r is generally there are two aspects of value of K_r. If it you are just considering a river, if you are just considering a river on a stream or anything like this, if you are considering like this, this would be, this would be you know this is, this would be stream depth, this one is it depends on the average stream depth H and the velocity, the velocity of the stream depends on K_r would essentially K_r is a function of, K_r is a function of u and H, u and H and it is generally written, generally used for this purpose of 3.9 u to the power half divided by H to the power 3 by 2, H to the power 3 by 2. So, here as you can see now this particular value, this particular value when we are trying to say this, this may be you know more characteristic function, more usual characteristic function here should be you know where in cases like this we can find out, we can very well write it like this K_1 into e to the power alpha H to the power beta.

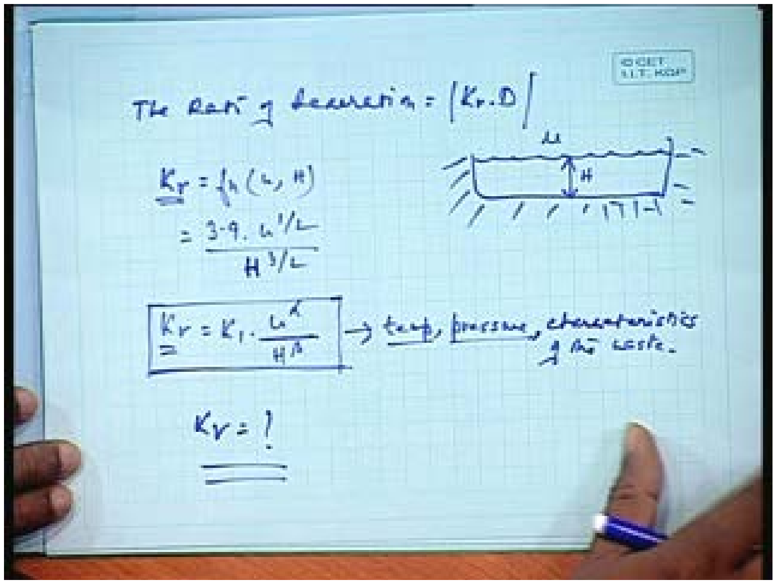
Depending on, depending on this you know this is though it's the standard function that we will use the characteristic of the function is essentially this okay, characteristic of the function is essentially this we should not, we should not try to always force on this values of K_r that would be you know sometime difficult because of there are various situations, there are may be extremely number of situations which should be actually changing this value say you know the first of all this the dependence of temperature, temperature say then temperature say in if it is a closed vessel or if in a closed stream like this pressure may be important, all these things are, all these things are of truly importance of this things, are of great importance here. So having said this so you know we can find out we can see you know if it is given in a particular situation, you know the velocity is given, the H is given you can find out in normal cases the value of K_r. The normal case is the value of K_r, there are certain values of K_r that would be given so that I will take off in the next class as such you need break for 5.

Preview of Next Lecture:

(Refer Slide Time: 00:51:25 min)

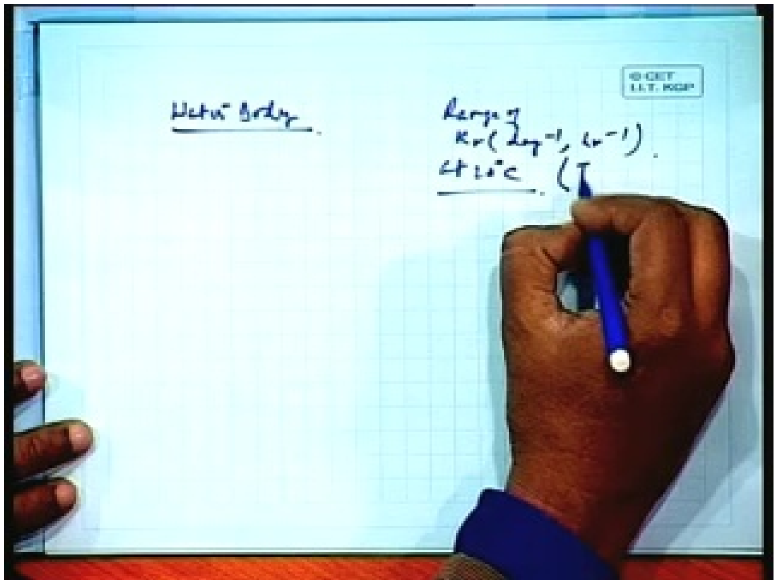
Okay, so will carry on with this, the study that we have been undergoing at presents.

(Refer Slide Time: 00:51:36 min)



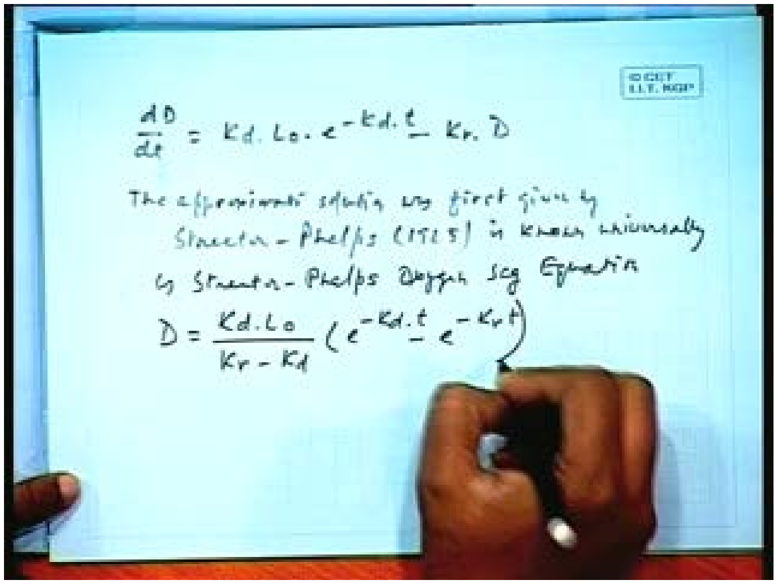
So if you see this, the earlier slide that I have shown you is that temperature, pressure, on the characteristic, characteristics of the waste. So this one is K_r essentially also depends on temperature, pressure, characteristics of the waste and various other things also in sometimes so it cannot be so simplify examined like that but none the less this one is this particular function that is this particular function given is generally suitable for all most all various kind of situations and for all kind of problems that we will see in our exams or anywhere would mostly use this equation if unless otherwise told, okay. In case if it is some other things are given in such cases we have to find out that way only okay. But before we go into this you know before we go into this, this there are few things that I would like you to see what is the value of, how this, what is, what are the likely values of K_r, what are the likely values of K_r how K_r essentially is the value of K_r one can experimentally what will be the value of K_r.

(Refer Slide Time: 00:52:58 min)



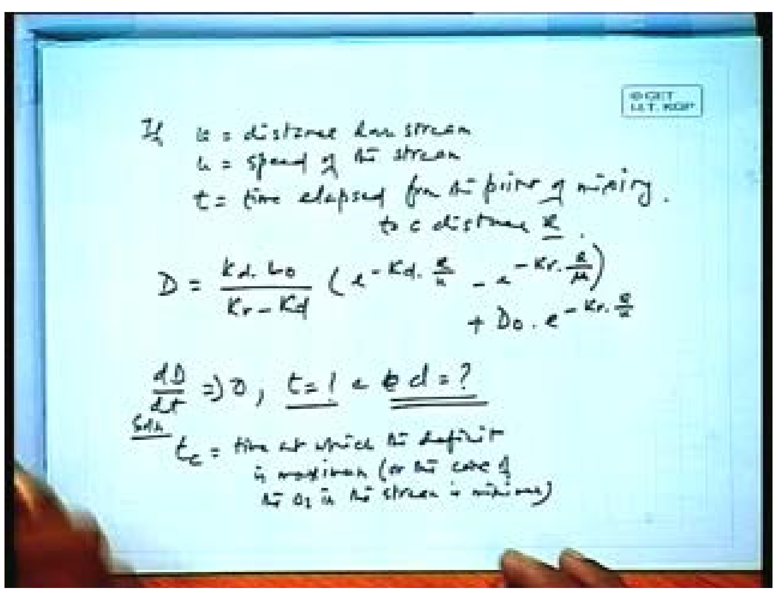
Say this type of water body, water body range of K_r remember the same way that we have seen in the case of K or in the case of you know in the K_d, this is essentially a time inverse function this is day inverse or hour inverse or you know some times say any other parameters like this hour inverse like this you know this is the range that we generally observe for that and at 20 degree centigrade. So the adjustment the typical adjustment that we have done in the case of fixed water body that also has to be done here if it is given for a different temperature right. You remember that function that I have given is that you know K, K, K theta is equal to K_0 into you know theta into another function t minus 20 that is you know temperature 35 minus 20, 15 so that value has to be given, theta is 1.047 that we explained so that function has to be implied. So at any temperature, difference is important for us than the absolute value of H in such cases, in such cases we can write a, the we can write a typical function where it is the rate of change of deficit this is dD by dt is equal to Kd into L_0 into e to the power minus Kd into t minus K_r into D okay, minus K_r into D.

(Refer Slide Time: 00:54:30 min)

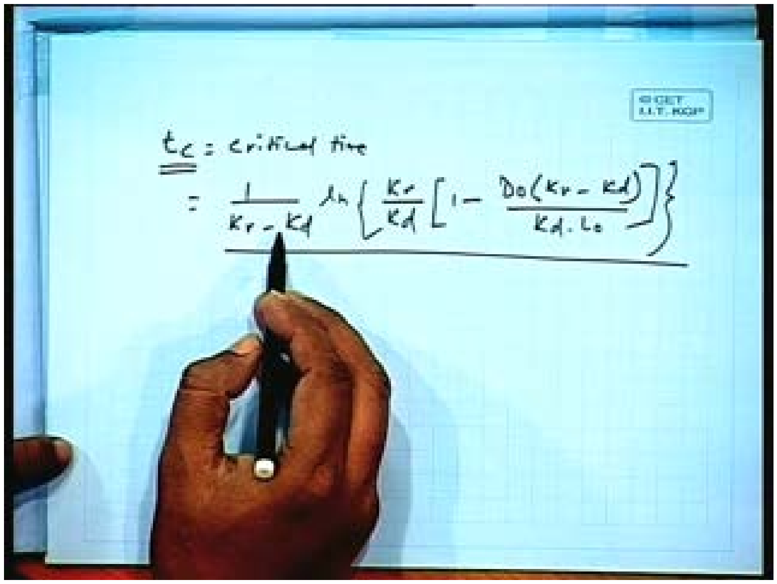


The approximate solution, the approximate, the approximate, the approximate solution was first given by Phelps, Streeter and Phelps, Streeter and Phelps in 1925, Streeter and Phelps in 1925 and is known as, it is was given by Streeter and Phelps and is known as, known universally as Streeter Phelps, Streeter Phelps, oxygen sag equation, Streeter Phelps oxygen sag equation right and this is the approximate solution was given and is known as this. This is what is the solution is what Streeter Phelps an approximate solution that it gave this Kd into L_0 divided by K_r into Kd, K_r into Kd e to the power minus Kd into t minus e to the power minus K_r into t known as is generally can be found out by can be generally can be found out like this.

(Refer Slide Time: 00:56:49 min)



(Refer Slide Time: 00:56:57 min)



This t_c would be this is equal as critical time, we generally also known as this as critical time also known as critical time. This t_c is nothing but 1 minus K_r into Kd log, log K_r into K_r into Kd, K_r into Kd 1 minus 1 minus, 1 minus D initial oxygen deficit minus K_r minus Kd divided by Kd into L_0. So this is how you know we can find out the value of, we can find out the value of this function you know I would say you know please carry it out in your, in your halls, try to see that you know this deficit, this differentiate equation you can derive.