Wastewater Treatment And Recycling
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Lecture - 18
BOD and DO Variations in Streams Receiving Wastewater

Hello friends. So, we will continue our discussion from the previous lecture. When we are talking about the variation of different parameters, when the waste is introduced in the environment, particularly in the river systems, we ended that discussion with Streeter Phelps equation which describes how the dissolved oxygen varies in a stream, in a running stream or river when a waste stream is introduced in it. So, we will further elaborate on to the variation of the biological oxygen demand or BOD and dissolved oxygen in the stream which is receiving the waste water or waste input.

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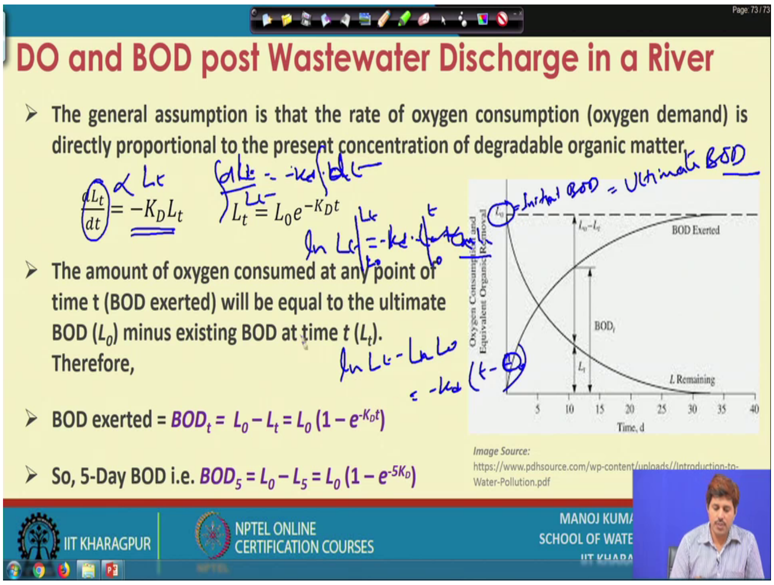

DO and BOD post Wastewater Discharge in a River

- The general assumption is that the rate of oxygen consumption (oxygen demand) is directly proportional to the present concentration of degradable organic matter.

$\frac{dL_t}{dt} \propto L_t$

$\frac{dL_t}{dt} = -K_D L_t$

$\int \frac{dL_t}{L_t} = -k_d \int dt$

$L_t = L_0 e^{-K_D t}$

$\ln L_t \Big|_{L_0}^{L_t} = -k_d \cdot \int_0^t dt$

$\ln L_t - \ln L_0 = -k_d (t-0)$

Initial BOD = Ultimate BOD

- The amount of oxygen consumed at any point of time t (BOD exerted) will be equal to the ultimate BOD (L_0) minus existing BOD at time t (L_t). Therefore,
- BOD exerted = $BOD_t = L_0 - L_t = L_0 (1 - e^{-K_D t})$
- So, 5-Day BOD i.e. $BOD_5 = L_0 - L_5 = L_0 (1 - e^{-5K_D})$

Image Source: https://www.pdhsource.com/wp-content/uploads//Introduction-to-Water-Pollution.pdf

So, for BOD, which is the biological oxygen demand, what happens that, there is a usual assumption which is taken that the rate of oxygen consumption or the oxygen demand is directly proportional to the present concentration of degradable organic matter ok. So, the amount of oxygen which is getting consumed is actually proportional to the amount of organic matter which is being degraded and the general conventional is that we take the amount of organic matter degradation typically in such stream as first order.

Now, there are again a quite a few assumption involved in it. It could be first order only when there is no dearth or no limitations of dissolved oxygen. So, assuming there is significant amount of dissolved oxygen is always present in the system ok, then the decomposition or decay of the organic matter decay of the BOD will actually be as a first order equation which we talked earlier also. So, how it happens? That let us say, let say this L t is your the oxi organic matter representation or BOD at that particular given time t or the BOD remaining at time t in the system.

So, initially the existing BOD or the initial BOD is L o which is there is system ok. That is, my initial BOD; that means, at time t 0, which is normally we call as ultimate BOD also. So, our ultimate BOD is L 0 and with time it reduces and reduction follows first order reduction follows first order. So, first order; obviously, first order means, the rate of change is going to be the proportional to the existing BOD L t and we can take that proportionality constant which is your de oxygenation coefficient as we discussed in the previous week.

So, K D times t and this equation is fairly simple to integrate. So, we can have d L t is equal to minus K D times sorry d L t by L t is equal to K D times d t right and then, if we integrate it both sides, K D being a constant will come. So, we will get ln L t is equal to ln L t is equal to minus K D and this side, it will be t plus of course, integration constant ok.

So, by like you have a integration constant, now what we can do? We can have this, let say from a time 0. So, your time t varies from here 0 to t. Then, we do not need integration constant and this we can have from at 0 our concentration is the L 0 or ultimate BOD to L t. So, this becomes ln L t this becomes ln L t minus ln L 0 and right side, it becomes minus K D t minus t 0 or t 0 is actually 0 over here right.

So, this equation eventually translate to this value and what we get is the solution of this equation as L t is equal to L 0 e to the power minus K D is into t. Now, this L t here is the amount of BOD remaining in the system or amount of organic matter remaining in the system since the amount of organic matter, there is the constant. So, initially if you see the, amount of BOD remaining at any given point of time, amount of BOD remaining in the system and amount of BOD exerted ok. BOD exerted is basically the oxygen consumed at any point of time.

So, the amount of BOD exerted plus amount of BOD remaining the sum of those 2 has to be equal to the initial BOD ok. Because, the amount which has been consumed and how much oxygen is still being demanded. So, that way, we can get this. So, BOD exerted if you want to determine that way. So, BOD exerted which typically we say BOD 5, means how much oxygen has been consumed in 5 days, that what we determined right.

So, BOD exerted or at any given time t will be equal to the initial BOD or initial estimate of the organic matter and remaining BOD in the system. So, L 0 and L t we know that my can be written as L 0 e to the power minus K D t. So, we can take L 0 as common factor and what we get is L 0 e to the power minus K D t.

So, this is the typical your value of BOD exerted this way ok. Say, 5-day BOD if you want to determine, so, BOD 5 will be L 0 minus L 5 which is L 0 1 minus e to the power minus 5 into K D if the K D unit is per day and on a base of log e right. So, that is how we can determine the BOD exerted and BOD existing or BOD remaining present in the system and this is how we can see the trend.

So, since this is the first order kinetics, this is the first order equation. So, you will see a exponential decay in the BOD remaining ok. And similarly, an exponential increase in the BOD exerted or amount of oxygen consumed. So, that is how the BOD profile looks like in river.

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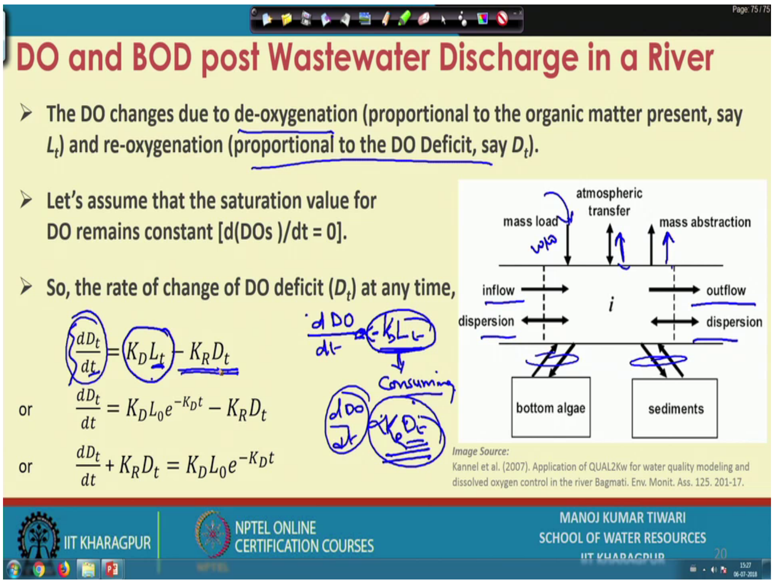

DO and BOD post Wastewater Discharge in a River

- The DO changes due to de-oxygenation (proportional to the organic matter present, say L_t) and re-oxygenation (proportional to the DO Deficit, say D_t).
- Let's assume that the saturation value for DO remains constant [d(DOs)/dt = 0].
- So, the rate of change of DO deficit (D_t) at any time,

$$\frac{dD_t}{dt} = K_D L_t - K_R D_t$$

or $$\frac{dD_t}{dt} = K_D L_0 e^{-K_D t} - K_R D_t$$

or $$\frac{dD_t}{dt} + K_R D_t = K_D L_0 e^{-K_D t}$$

$$\frac{dDO}{dt} = -K_D L_t$$

Consuming

$$\frac{dDO}{dt} = +K_R D_t$$

Image Source:
Kannel et al. (2007). Application of QUAL2Kw for water quality modeling and dissolved oxygen control in the river Bagmati. Env. Monit. Ass. 125. 201-17.

Because, there is if we ignore all other this thing, for dissolved oxygen, we have discussed this in previous lecture as well that dissolved oxygen changes primarily due to that de oxygenation and re oxygenation. So, de oxygenation which is proportional to the organic matter present in the system, as we were seeing that it is proportional to the amount of BOD present in the system or organic matter present in the system and re oxygenation which is proportional to the deficit of DO.

So, if my saturation DO is let say 10 and my existing do is 6, so, this re oxygenation will be proportional to the difference where it is existing. So, 6 and minus 6 will be proportional to 4. Now, if we see the different processes or different routes through which oxygen comes, and so, there will be some dissolved oxygen coming in the in stream, there will be some dispersion of oxygen, there will be some oxygen leaving this stream of you see, this is your control volume for say, there could be dispersion across this boundary as well.

Then, there is some mass load which may be coming from let say waste water stream. There could be atmospheric exchange or atmospheric transfers ok. There could be mass abstraction. So, something is being taken away there is bottom algae which can actually release or take up take oxygen depending on that and similarly, the sediment can exert oxygen demand as well as can consume oxygen for certain processes.

So, there are variety of roots, but for simplification purpose, we say let us ignore all other thing and see that the oxygen is being consumed for the decomposition or degradation of organic matter present. That means, through the route of de oxygenation which is one of the primary routes for the oxygen consumption in the river anyway and the oxygen inflow is in form of the atmospheric transfer which depends on the DO deficit which is proportional to the DO deficit.

So, further, if we assume that the saturation value for DO remains constant because, if saturation value also depends on the temperature, but let us for practical purpose at a time saturation value remains more or less constant. So, then we can see how this do varies. So, rate of change of the dissolved oxygen or rate of change of the DO deficit ok. Now, we see that DO deficit the route of DO coming in the system is actually in the form of is in the. If you see the DO deficit, it will be proportional to the de oxygenation time which is actually the consuming the DO right, you see the importance. There are 2 processes.

So, one processes which is the degradation of organic matter is consuming the DO and that is proportional to the rate of that is proportional to the existing organic matter. So, if we do in terms of dissolved oxygen, we see it is proportional to the organic matter present in the system the inflow of the dissolved oxygen, rate of the dissolved oxygen.

Or we can say it is actually K D times L t negative because, what this process is consuming oxygen right. So, since this process is consuming oxygen, this terms is going to be negative right. However, we are not talking about the rate of change of the dissolved oxygen. Here, we are talking about the rate of change of the DO deficit means, from how far we are from saturation value. So, more and more oxygen getting consumed the deficit increases, right. So, if there is more organic matter present in the system, more oxygen is likely to consume and the deficit is likely to increase. So, that is why, this term is positive here.

Now, the 2nd term that you see is actually for re aeration. So, we know that, the rate of change of the dissolved oxygen will actually increase with the re aeration. So, what is ever the existing deficit is there ok, accordingly, the oxygen will get transferred from atmosphere and it is going to increase. So, the K R is the re aeration constant. But, again since we are talking about the deficit, so, increase in the oxygen content means, decrease in the deficit. So, our deficit is going to decrease. So, rate of change for the deficit due to the re aeration is negative, ok.

Because it is decreasing, the deficit re aeration is decreasing the deficit ok. The deficit is reducing and the decomposition of the organic matter is increasing the DO deficit. So, that first term is positive and second term is negative ok. Now, we earlier saw that L t can be written as L 0 e to the power K D t and then, we can rearrange this equation as this ok. So, we take this term right side. So, we have this kind of equation which in fact, is a standard differential equation which can be solved by the application of integrating factor, ok.

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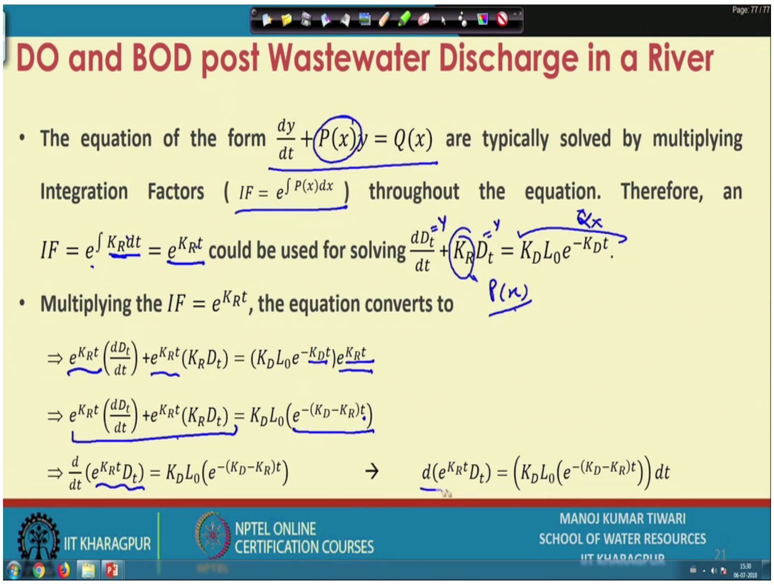

Page: 77 / 77

DO and BOD post Wastewater Discharge in a River

- The equation of the form $\underline{\frac{dy}{dt} + \boxed{P(x)}y = Q(x)}$ are typically solved by multiplying Integration Factors ($\underline{IF = e^{\int P(x)dx}}$) throughout the equation. Therefore, an $IF = e^{\int K_R dt} = e^{K_R t}$ could be used for solving $\overset{=y}{\frac{dD_t}{dt}} + \underset{P(x)}{\boxed{K_R}}\overset{=y}{D_t} = \overset{Q_x}{K_D L_0 e^{-K_D t}}$.
- Multiplying the $IF = e^{K_R t}$, the equation converts to

$$\Rightarrow e^{K_R t}\left(\frac{dD_t}{dt}\right) + e^{K_R t}(K_R D_t) = (K_D L_0 e^{-K_D t})e^{K_R t}$$

$$\Rightarrow e^{K_R t}\left(\frac{dD_t}{dt}\right) + e^{K_R t}(K_R D_t) = K_D L_0\left(e^{-(K_D - K_R)t}\right)$$

$$\Rightarrow \frac{d}{dt}(e^{K_R t}D_t) = K_D L_0\left(e^{-(K_D - K_R)t}\right) \quad \rightarrow \quad d(e^{K_R t}D_t) = \left(K_D L_0\left(e^{-(K_D - K_R)t}\right)\right)dt$$

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21

So, the typical equation is of this form and this type of equation are typically solved by multiplying a integrating factor on both the sides of the equation of the form of e to the power this function what we have, right. So, our existing equation is something like this. If you say that, y is equal to d t here, so, this becomes y and our P x becomes K R. This is our the P x and of course, this is our Q x.

So, if equation is of this form, so, we can use the integrating factor and our integrating factor has to be e to the power integration of P x dx. So, e to the power integration of instead of P x, we have K R. So, e to the power integration of K R into d t because this is our y here, ok. So, into this thing which eventually turns e to the power K R to the power t ok. Because, integration of K R D t will be K R into t so, this becomes e to the power K R t.

Now, if we multiply this integrating factor, this e to the power K R t on all the terms. So, what we get is this which eventually we can simplify it like this way ok. This is the simple multiplication. So, we have e to the power minus K D t and e to the power plus K R t. So, it becomes minus K D minus K R into t right and this side, this thing that we have actually, if we in the concept of integrating factor, this will eventually change to this form and then we get our equation like this and this is integratable equation. So, we can integrate this equation further.

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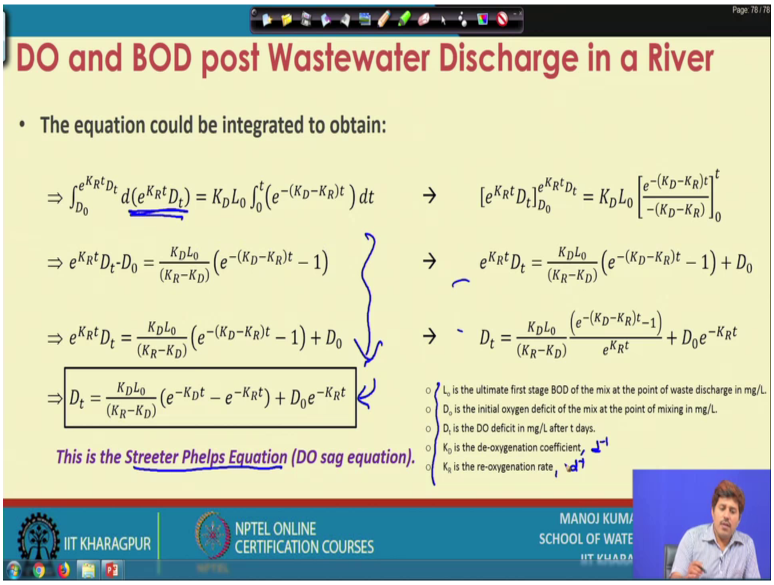

Page: 78 / 78

DO and BOD post Wastewater Discharge in a River

- The equation could be integrated to obtain:

$$\Rightarrow \int_{D_0}^{e^{K_R t}D_t} \underline{d(e^{K_R t}D_t)} = K_D L_0 \int_0^t \left(e^{-(K_D-K_R)t}\right) dt \rightarrow \left[e^{K_R t}D_t\right]_{D_0}^{e^{K_R t}D_t} = K_D L_0 \left[\frac{e^{-(K_D-K_R)t}}{-(K_D-K_R)}\right]_0^t$$

$$\Rightarrow e^{K_R t}D_t\text{-}D_0 = \frac{K_D L_0}{(K_R-K_D)}\left(e^{-(K_D-K_R)t} - 1\right) \rightarrow e^{K_R t}D_t = \frac{K_D L_0}{(K_R-K_D)}\left(e^{-(K_D-K_R)t} - 1\right) + D_0$$

$$\Rightarrow e^{K_R t}D_t = \frac{K_D L_0}{(K_R-K_D)}\left(e^{-(K_D-K_R)t} - 1\right) + D_0 \rightarrow D_t = \frac{K_D L_0}{(K_R-K_D)}\frac{\left(e^{-(K_D-K_R)t} - 1\right)}{e^{K_R t}} + D_0 e^{-K_R t}$$

$$\Rightarrow \boxed{D_t = \frac{K_D L_0}{(K_R-K_D)}\left(e^{-K_D t} - e^{-K_R t}\right) + D_0 e^{-K_R t}}$$

This is the Streeter Phelps Equation (DO sag equation).

- L_0 is the ultimate first stage BOD of the mix at the point of waste discharge in mg/L.
- D_0 is the initial oxygen deficit of the mix at the point of mixing in mg/L.
- D_t is the DO deficit in mg/L after t days.
- K_D is the de-oxygenation coefficient, d^{-1}
- K_R is the re-oxygenation rate, d^{-1}

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And what we will get by integrating this? So, do a integration with respect to this term in the form of integration factor and the eventually, this equation converts to this and which is the known equation. We have seen this earlier also. This is your Streeter Phelps equation or the classic Streeter Phelps equation which is the which gives the DO sag in a river or in a running stream which is also known as DO sag equation.

So, here this equation can be converted to 10 base also this is on log of exponential base and if accordingly, if you do at 10 base, so, this parameters or coefficients are going to be changed will have to divide it by the e value that way. So, this we get Streeter Phelps equation by solving all this equation like this. This solution, standard solution will not discuss each and every step in the detail and the notations remain the same L 0 is your ultimate BOD, D 0 is your initial oxygen deficit d t is the oxygen deficit at any given point of time and K D and K R are respectively de oxygenation and re oxygenation coefficients per unit time.

So, these are expressed per unit time. If your time is in day, so, these will be in day inverse, the unit of these coefficients.

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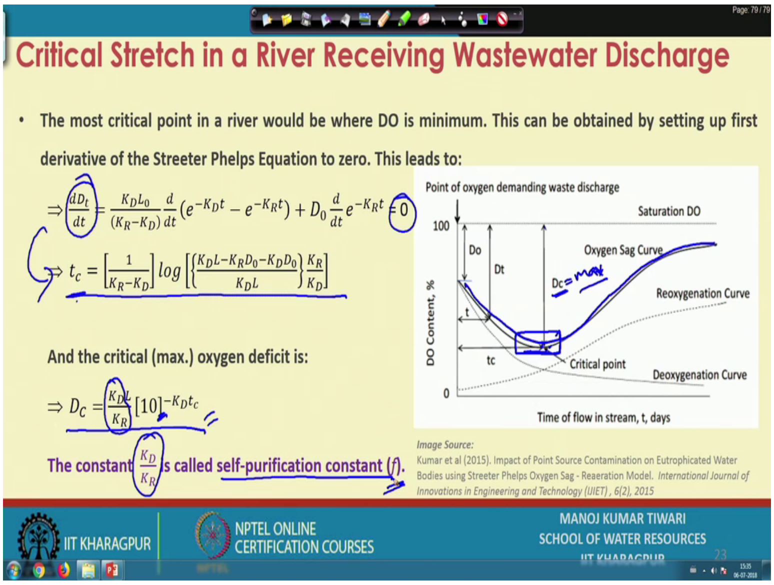

Page: 79 / 79

Critical Stretch in a River Receiving Wastewater Discharge

- The most critical point in a river would be where DO is minimum. This can be obtained by setting up first derivative of the Streeter Phelps Equation to zero. This leads to:

$$\Rightarrow \frac{dD_t}{dt} = \frac{K_D L_0}{(K_R - K_D)} \frac{d}{dt}\left(e^{-K_D t} - e^{-K_R t}\right) + D_0 \frac{d}{dt} e^{-K_R t} = 0$$

$$\Rightarrow t_c = \left[\frac{1}{K_R - K_D}\right] log\left[\left\{\frac{K_D L - K_R D_0 - K_D D_0}{K_D L}\right\}\frac{K_R}{K_D}\right]$$

And the critical (max.) oxygen deficit is:

$$\Rightarrow D_C = \frac{K_D L}{K_R}[10]^{-K_D t_c}$$

The constant $\frac{K_D}{K_R}$ is called self-purification constant (f).

Image Source:
Kumar et al (2015). Impact of Point Source Contamination on Eutrophicated Water Bodies using Streeter Phelps Oxygen Sag - Reaeration Model. *International Journal of Innovations in Engineering and Technology (IJIET)*, 6(2), 2015

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23

So, this way we can actually get the DO profile also and we have seen earlier how this DO profile looks like in the Streeter Phelps equation. So, this we will get a net dissolved oxygen profile like this line, like you are having here ok. Now, a few more information you can extract. So, when the waste is introduced in a river and as we discussed the different zones of the river receiving waste water. So, we had first zone of decomposition and their after a zone of septic zone and followed by a recovery zone. So, the septic zone was the one which is the worst condition and when we have the dissolved oxygen level touching minimum ok.

What we call typically critical point. So, we will have a zone where the dissolved oxygen levels are very low, are probably not able to sustain good enough of the fishes and those kind of thing in a typical sense. So, this particularly this critical level of dissolved oxygen or this point of dissolved oxygen ok, which is called critical point can also be estimated. Now, how we can estimate that critical point or at what point or at what distance? Because, time and distance are convertible in a river if you have a fixed velocity.

So, at what particular time this is likely to occur and this critical point is likely to occur can be obtained with the help of Streeter Phelps equation. So, this point is where the dissolved oxygen level is minimum, and dissolved oxygen level is minimum means, the DO deficit is maximum. So, that D C or critical DO deficit is actually the maximum and how we get minima or maxima from a equation, we take it is first derivations and we set that first derivative as 0.

So, that is what we can do here ok. The most critical point in the river can be obtained by taking the first derivative of this Streeter Phelps equation and that Streeter Phelps equation. If you see that, you take the first derivative of this Streeter Phelps equation and put that as equal to 0 and solve this. So, what we get? The critical time at which the DO will be minimum can be obtained by this expression ok. So, this expression will give us time and putting the this critical time in the original expression, we can actually get the critical distances, critical oxygen deficit as well.

So, the critical oxygen deficit or D C then can be obtained in as this depending on this equation ok. This probably 10 base otherwise, it will be e to the power minus K D in to t c. Now, the rate constant here that we have K D by K R is called the self-purification constant which is typically denoted as f and is an indicator of how what is self-purification ability or self-purification capacity of the river ok. So, that are few additional information that one can obtain from this Streeter Phelps equation.

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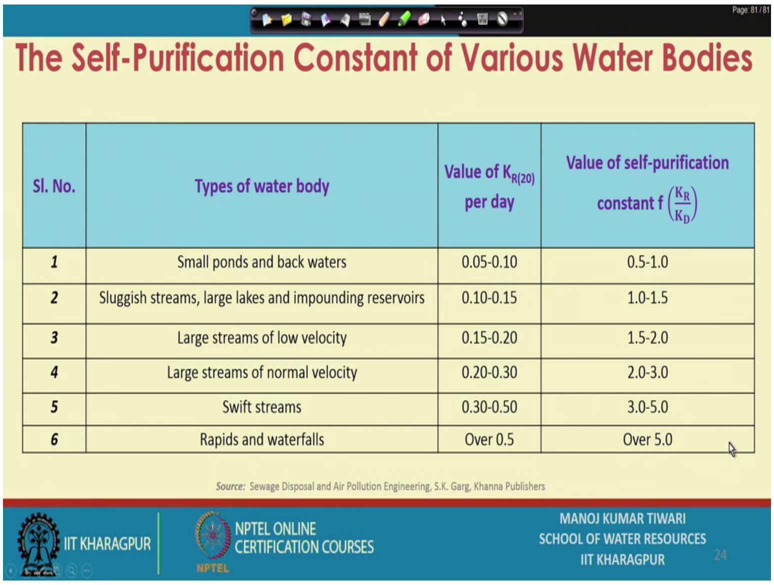

The Self-Purification Constant of Various Water Bodies

Sl. No.	Types of water body	Value of $K_{R(20)}$ per day	Value of self-purification constant f $\left(\frac{K_R}{K_D}\right)$
1	Small ponds and back waters	0.05-0.10	0.5-1.0
2	Sluggish streams, large lakes and impounding reservoirs	0.10-0.15	1.0-1.5
3	Large streams of low velocity	0.15-0.20	1.5-2.0
4	Large streams of normal velocity	0.20-0.30	2.0-3.0
5	Swift streams	0.30-0.50	3.0-5.0
6	Rapids and waterfalls	Over 0.5	Over 5.0

Source: Sewage Disposal and Air Pollution Engineering, S.K. Garg, Khanna Publishers

Now, if you see the self-purification constant of various water bodies, so, the small ponds or sort of water has very low value of K R ok. So, there the re aeration coefficient or they rate at which they get oxygen is very low and their self-purification coefficients also remains low.

We have sluggish stream or large lakes or impounding reservoirs having higher value of the self pur higher value of the your K R and relatively and respectively had value of yourself purification coefficient. So, as we move with large stream with low velocity, then with normal velocity, the swift stream or rapid and waterfalls which are having very high chances of re aeration. The re aeration coefficient is substantially high of the order of say 0.5. So, they have a self-purification coefficient of over 5. So, that means, there is they can actually do the purification of such discharge or organic matter decomposition at wide rapid rate ok. And they can tackle lot of organic matter as well.

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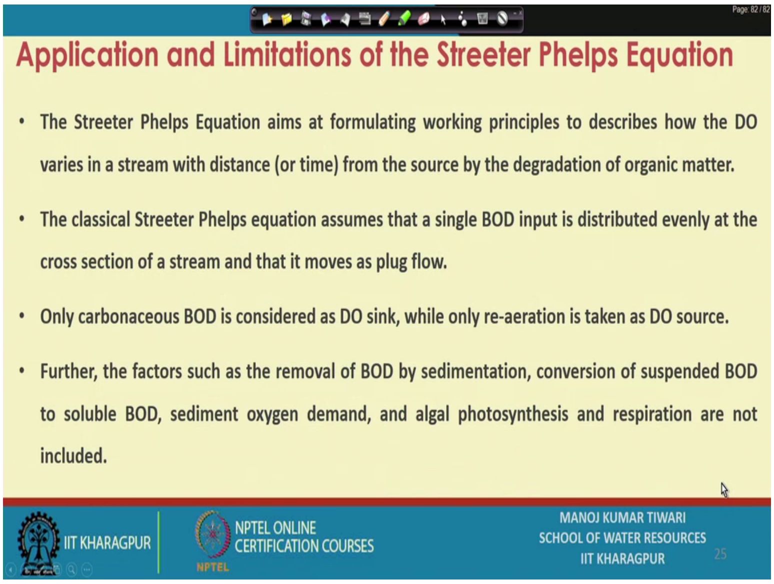

Application and Limitations of the Streeter Phelps Equation

- The Streeter Phelps Equation aims at formulating working principles to describes how the DO varies in a stream with distance (or time) from the source by the degradation of organic matter.
- The classical Streeter Phelps equation assumes that a single BOD input is distributed evenly at the cross section of a stream and that it moves as plug flow.
- Only carbonaceous BOD is considered as DO sink, while only re-aeration is taken as DO source.
- Further, the factors such as the removal of BOD by sedimentation, conversion of suspended BOD to soluble BOD, sediment oxygen demand, and algal photosynthesis and respiration are not included.

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25

So, there are quite a few applications of this is Streeter Phelps equations and as well as there are quite a few limitations as well. So, applications are like it is one of the widely used equation for modeling contamination, modeling in the river, particularly the dissolved oxygen and BOD level profiling in a river body.

So, it used largely for that time. It is used fir prediction of what would be the; what would be the dissolved oxygen level of at certain distance in the downstream or after certain time at a fixed location, what would be the level of organic matter if it is discharge at any given point in a river. So, how it is going to be very or for how long it will sustain. So, all those kind of critical information can be modeled we can a estimate the critical zone of the river. Also, what is likely to be the zone for the least dissolved oxygen concentrations or the highest do deficit as we are discussing.

And, we can also determine or we can also find out how is going to be the alike what is going to be the level of dissolved oxygen at the lowest level of the dissolved oxygen critical level of the dissolved oxygen. So, that way, the these are the like basics applications of this Streeter Phelps equation. However, there are quite a few limitations as we were saying and these limitations are very obvious ok. One can easily like if you if you see from the basics, how it has been derived and what kind of assumptions has been made.

So, one can easily know what are the basics limitations of this a classical Streeter Phelps equation. The first thing that it has assumed that there is a single BOD input. So, at the point where BOD is mixing in the river post that, there is no further BOD inputs because, we are straight away taking the like the L 0 which we have taken and we are considering it is decomposition day by day. We are not considering any additional input or any further input at any intermediate point of time or space in the river.

So, that is one of the consideration, one of the criteria has been adopted which may or may not hold true for a river body largely, if you are getting a large sewer, large let say, sewage discharge connecting to a river system and then a then typically the sewage discharges are done in the downstream of the city. So, of you are already putting all this waste in the downstream of city and after that, river is going to a low population zone out of the city area and this thing and there is no major contribution in terms of pollution or in terms of flow any way. There might be some limited contributions here and there might be some tributaries also coming in and joining in.

So, that will do further dilution and all those and until and unless those kind of major stuffs happens, the river more or less, does not get any large load of pollution or flow and that way, this Streeter Phelps equation can be held applicable to such stretches.

It also considers that, the flow in the river is in kind of ideal plug flow because, that is why, we are consider the first order decomposition ok. So, it actually it is not getting mixed in the, it is only getting mixed in axial direction and not in the literal direction which is one of the basic assumption of the plug flow. We will discuss the this what exactly plug flow means in one of the later classes, probably this week only. So, then it, it will get more clear, but the idea is that it plug flow thing is gets only mix in the axial direction and not in the literal direction.

There are another assumptions that it considers only one source and only one sink for the dissolved oxygen. So, the dissolved oxygen source is only the re aeration or only the re oxygenation where the atmospheric oxygen is coming in the water and dissolved oxygen sink is only the decomposition of organic matter. So, the decomposition of the organic matter or biodegradable organic matter is the one which is consuming dissolved oxygen from the system. So, that existing BOD and particularly that carbonaceous BOD we have not considered the NBOD also. So, the CBOD is the only considered source and the re aeration is the only considered sink, sorry re aeration is only considered source and the carbonaceous BOD or CBOD is now only considered sink for the dissolved oxygen in the Streeter Phelps equation.

It does not considered the other routes through which oxygen can actually either take a inflow or out flow from the system or from the river stretch. There is possibility of the removal of some of the some of the BOD or some of the organic matter by sedimentation. Then, the suspended BOD could convert to the soluble BOD there is a oxygen demand from the sediments oxygen can go to that also. There is photosynthesis which leads to the addition of the oxygen or production of the oxygen ignores that as well. So, there could be respiration for which oxygen is needed.

So, all these requirements are largely ignored in Streeter Phelps equation which works on a basic assumption that the rate the reason for change in the dissolved oxygen in a water is either de oxygenation or re oxygenation. So, the discussion we had so far was focused when waste is introduced in a river system and which is the prominent way of receiving waste. The waste is typically discharge into the water ways, only the particularly the liquid waste.

However, at times, it goes to the land applications or even at rare times, it will inject it in the sub surface or ground waters as well. So, the pollutants present in the waste will again get attenuated even if it is applied on a land or if it goes into the surface. However, the most of our majority of these processes are applicable in the other systems as well.

However, the dominants of some of the processes can change for say the contaminant discharge sort of in the soil or the contaminant which is applied to the land the adsorption become much more prominent because, there is the when you are putting it on a land your water is interacting or this thing is the interacting with lot of sediments lot of solid materials. It is, there is a lot of surface available as a post in a river, in a river the availability of surfaces are very low. Only you get bottom sediment and all that and bulk of the water flow as it is, so, the suspended solids. If it is, if there is not enough suspended solids, you hardly get too much of surface for adsorption purpose.

However, in land applications, since there is a lot of surface is available the adsorption process becomes much more prominent for the contaminant which are applied to the land. At the same time, the transport processes, particularly the advection diffusion and to some extension even dispersion becomes relatively less effects ok.

However, the leaching and the subsurface transport can also become more pertain what happens that the when you applied on the land and it does not have way or say capacity to flow horizontally. The water or the contaminant along dissolved contaminant along with the water will percolate to the sub surface and those contaminants can leach out then to the ground water.

But, if there is let say heavy rain or flood is occurring, it can take those contaminants through surface runoff also and can lead back to the water bodies. So, all these processes are there, the decomposition of organic matter in the soil will again depend on the type of microbial consortia present in the soil.

Many cases or majority of the cases, it will slower as compared to the decomposition on the liquid because, the microbial consortia or the ma microbes prefers the solubilized substrate or the when the organic matter in the soluble state. Since organic matter is soluble state, there are like more chances of solubilization and this thing in the water as a post to when it is applied to the land where organic matter can actually get adsorbed want to the soil minerals or soil mic this things.

So, there is the possibility that the bacteria or the microorganisms have to deal with the solid phase substrate or the substrate which is adsorbs on to the solid phase, organic matter which is adsorb on to the solid phase and that is relatively less preferred by the bacteria. So, that is why, the decomposition could becomes lower. However, that is not the case always there are it depends on the type of species present type of organic matter. Also, in some cases, one can see a faster rate of decomposition or faster rate of degradation on land rather than that in the water depending on the condition to condition bases.

However, in most cases, it may be it is expected to be slower in solid phases. Suppose, to that in the aqueous phase the decomposition of organic matter. The another important point particularly associated with the land application is that, there is or agricultural application, there is some soil organic matter also like soil also contains some of the soil organic matter and this soil organic matter is also a form of organic carbon or organic compound which can fulfill the need of the microbes for their for their substrate requirements.

So, in water generally a clean water will not have any organic in it or the BOD of the water is very low that way and when waste is introduced the organic matter present in the waste or BOD or the COD present in the waste is the source of the organic carbon which is available for the bacteria to decompose. But, in soil there is possibility of having alternate organic source. So, if you are having some difficult to degrade or relatively tough to degrade compounds in the waste water, your microbial consortia may not even attack that because, there is easy substrate available in the form, may be in the form of soil organic matter in those kind of stuff.

So, that way, the degradation or decomposition will also depend on how much is the ex-existing organic matter present in the soil.

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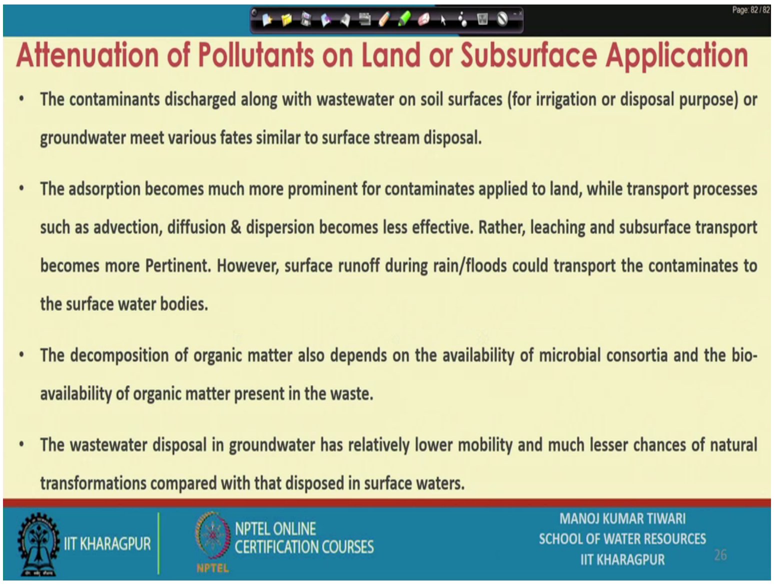

Attenuation of Pollutants on Land or Subsurface Application

- The contaminants discharged along with wastewater on soil surfaces (for irrigation or disposal purpose) or groundwater meet various fates similar to surface stream disposal.
- The adsorption becomes much more prominent for contaminates applied to land, while transport processes such as advection, diffusion & dispersion becomes less effective. Rather, leaching and subsurface transport becomes more Pertinent. However, surface runoff during rain/floods could transport the contaminates to the surface water bodies.
- The decomposition of organic matter also depends on the availability of microbial consortia and the bio-availability of organic matter present in the waste.
- The wastewater disposal in groundwater has relatively lower mobility and much lesser chances of natural transformations compared with that disposed in surface waters.

If it is being disposed in the ground water, so, again the ground water has relatively low mobility has suppose to the surface waters and there are lesser chance of natural attenuation and natural transformation. Also, because in the ground water, there is no type usually there is no oxygen. So, natural oxidation process becomes very difficult. Some reductive reactions can take place, but oxidative environment is are not there. So, typical oxidation of the compound is a limited. Then the another important part is there is a lack of microbial consortia ok. As we go into the deep drawn waters or that way, so, there is not enough microbial activity there.

So, if there is not enough microbial activity, so those biodegradation is also almost inhabited and that way the decomposition of the organic matter becomes very difficult if you inject waste into the surface or into the ground water into the deep ground water, particularly so, those.

However, the ground water also flows and the contaminant will flow along with the ground water depending on what is the speed of ground water flow which is governed by the Darcy’s law and various other hydrostatic or hydro dynamic conditions in the sub surface. So, these are the sort of some of natural process which works upon when the contaminant is released in the environment and we will conclude this discussion here. And next class, we will take up some practice problems on the discussions happened so far this week.

Thank you.