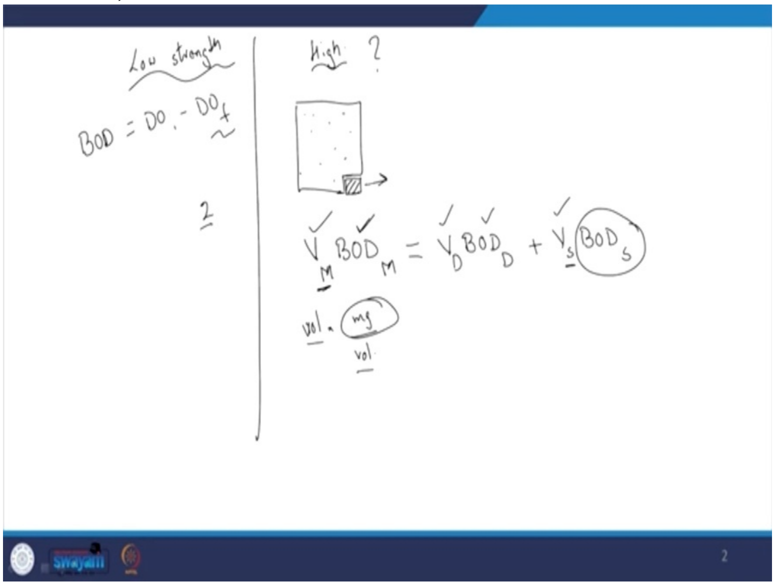
Water and Waste Water Treatment

Prof. Bhanu Prakash
Department of Civil Engineering
Indian Institute Technology – Roorkee

Lecture - 10
Water Quality – Nutrients in Water

Hello everyone, welcome back to the latest lecture session, we have been discussing about different wastewater quality parameters we are going to encounter in this course. First and foremost is BOD, Biochemical Oxygen Demand. That context we looked at measuring BOD. We looked at some of the different scenarios you would come across that we just summarize that.

(Refer Slide Time: 00:48)



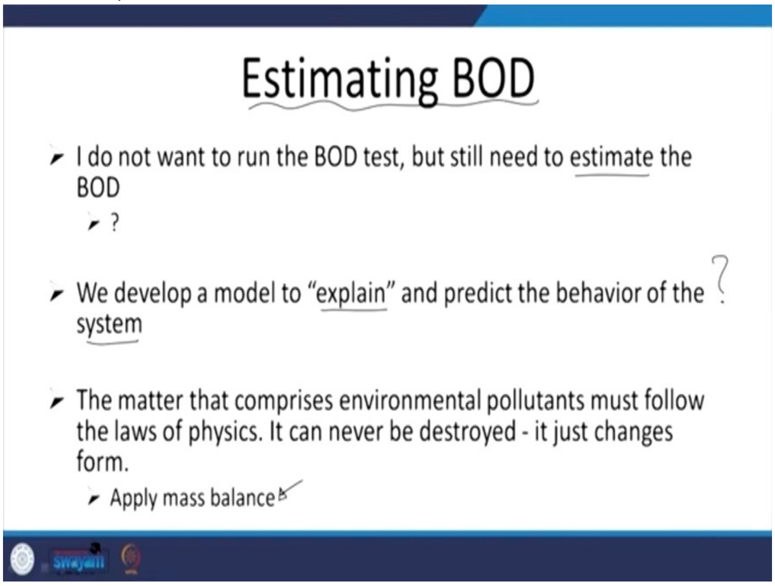
One case is when we have very low strength, wastewater, so I can just say the BOD = DO initial minus DO final and get it. But DO final cannot be less than 2 then I cannot get variable measurements. When the wastewater is high strength, how do I do it? What am I going to do? I am going to dilute the wastewater, by dilution water, this is the dilution water. Only a fraction of this is going to be my actual sample or the wastewater.

$$V_M BOD_M = V_D BOD_D + V_S BOD_S$$

What is the approach here in this case? We know that the volume of the mixture, total here in to BOD of the mixture. What will this give me an idea about volume into BOD, milligram per volume, or mass of oxygen demand per volume. It will give me an idea about mass of oxygen demand or the organic content, Volume, Volume cancel out. What is this going to be equal to? It will be equal to the organic content in these 2 parts.

One part is volume of the dilution water into BOD of the dilution water plus the other part volume of the sample into the BOD of the sample. Typically, what will we have, we will measure this, I mean, we know volume of the mixture is typically 300. We know how much wastewater I am adding or you are adding and we know the difference to be V D and BOD of the mixture is what you are measuring and BOD of the dilution water also you will typically measure. Third you can get this particular unknown which is your BOD of your high strength wastewater.

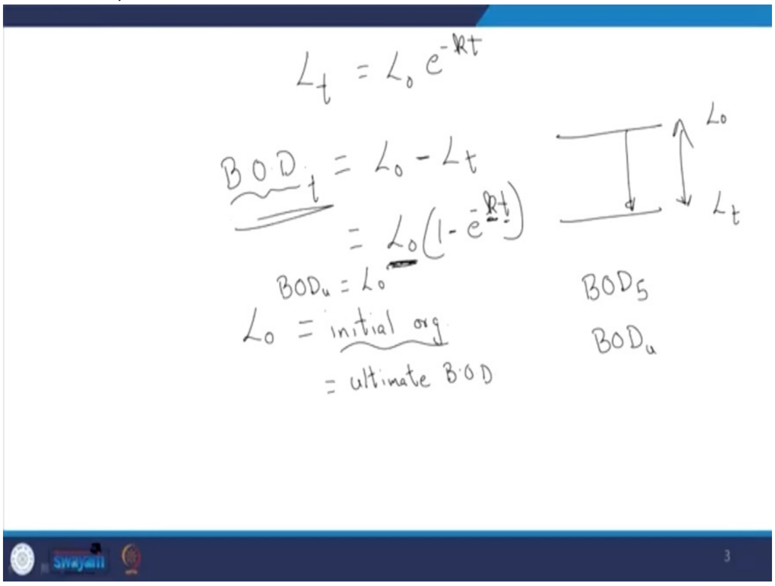
(Refer Slide Time: 02:39)



That is one aspect to keep in mind. Technical aspects and if I sometimes want to estimate the BOD without measuring it, I am short of time, but I just want to run a quick test based on the data that I already have. What do I do, I do not want to run the BOD test, but I want to estimate it. I developed a model to try to explain and predict the behavior of the system.

How do I go about doing that? Assuming that I know the different what, we see underlying variables and constants and assume I can make some reasonable assumptions. I want to be able to explain the system. If the BOD now is so and so and if the temperature is this assuming a rate constant of x I am going to see this BOD at the end of 5 days or 10 days or 3 days. How do I do that now? The whole aspect is based upon Apply mass balance. Let us just see what we have out here. In this BOD test, what is it that I am assuming.

(Refer Slide Time: 03:46)



I am assuming that the organic contents are going to products and the assumption here is that it is going to be done by microbes or being catalyzed by the microbes in the presence of oxygen and the assumption is that this is a pseudo first order loss. This is valid when the dissolved oxygen content or DO is greater than 2 milligram per liter otherwise microbes would not thrive. This is the case and s the case the rate constant.

To use the usual nomenclature L is the concentration of the organic content. Initially I have L_0 this is not L_{out}. In my sample, I want to be able to estimate it. This is my sample; this is a closed system, meaning it is a batch reactor. I want to estimate or predict the behavior of this organics and please note that I am applying the mass balance on this organic content and this is a batch reactor.

What is the mass balance equation? V dc / dt = mass coming in Q_{in}, C_{in} minus mass going out Q_{out} C_{out} plus volume into rate of formation minus rate of loss. Here it is a batch system, so no mass coming in and no mass going out and Volume, Volume cancels out. Also, here organics are not being produced the waste or our waste or the waste in that particular sample is only being degraded or being lost, it is not being formed. Rate of formation is 0.

Dc / dt = minus rate of loss. For first order, we know that it is equal to minus the rate constant times the concentration of the organics, not organics, concentration of the reactants. Here we have only one reactant which is the organics and we are saying that the concentration of the organics is being represented by L. This is also not C, dl / d t. Integrating , L_t is going to be equal to L_0 into e power - kt.

What will this give me an idea about? If this is the initial organic content, this will give me an idea about the organic content after time t, but if I am trying to measure the BOD, so what is it I have? I have the organic content at time t being equal to L_0 into e power - kt. But I want to measure the BOD. What is BOD? It is the biochemical oxygen demand and 5 day or whatever or that particular time t.

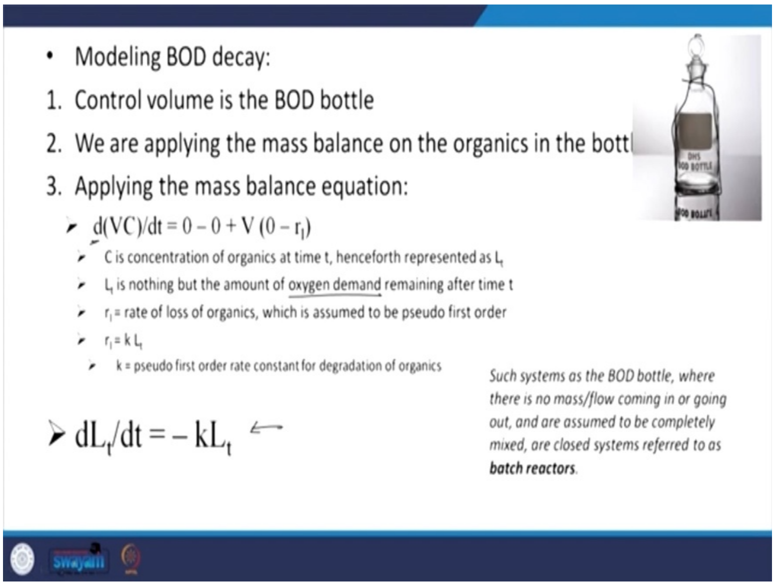
$$BOD_t = L_0(1 - e^{-kt})$$

It is the difference between the initial organic content and organic content after time t. The oxygen demand or the oxygen is consumed by the microbes in bringing down this organic content from L_0 to L_t. We are, when we say we are talking about BOD, it is the initial organic content minus the organic content at time t. BOD at time t = L_0 into 1 - e power - kt. That is something for us to keep in mind.

If I know the estimate for the organic content, so here there are 2 aspects to keep in mind L naught is the initial organic content. But how do I measure L_0? Typically, I am only measuring BOD_5, or after 5 days. But as within 5 days not all the organic content is going to be consumed, but I want to be able to, ? Measure all the organic content or ultimate organic, I mean ultimate BOD. Why do I say ultimate? Because it increased the time to a considerable value BOD ultimate.

What will that end out turn out to be? Time equal to infinity, our ultimate time, a lot of time then BOD ultimate will be L_0. That is what you see BOD ultimate will be L_0. L_0 is the initial organic content or if I measure it in terms of BOD, it is going to be equal to ultimate or called ultimate BOD. Assuming rate constant is more or less same for a particular kind of wastewater at a particular temperature, I can get an estimate for K. After a particular time, BOD 3, 5, 10 or such I can calculate the BOD. That is the principle out here.

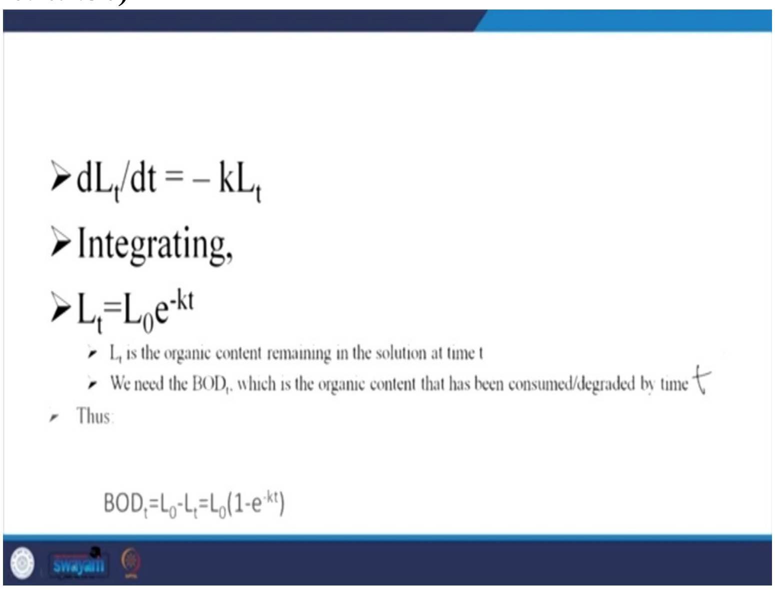
(Refer Slide Time: 08:40)



What did we do we just applied the mass balance. Let us just have a quick recap. Modeling BOD decay, what is the control volume? It is my BOD bottle, the 300 ml BOD bottle. We are applying mass balance on the organics in the bottle, apply mass balance, this is what we have. We already talked about these aspects, L_t is the amount of oxygen demand remaining or the amount of organic content remaining after time t.

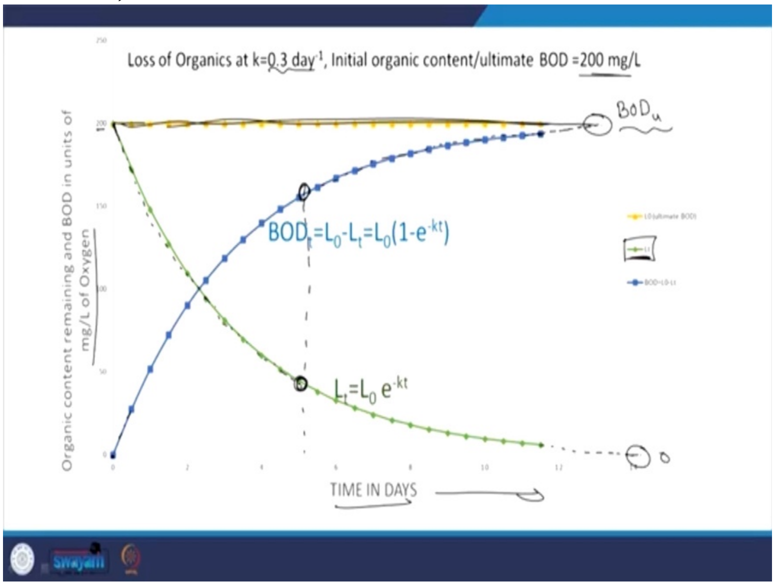
Please note that when we are talking about organic content in terms of the experiments or our calculations or measurements, we are measuring it in terms of oxygen demand. L_t is the amount of organics remaining after time t or the amount of oxygen demand remaining after time t and other aspects we already or I just mentioned. This equation simplifies to this particular equation.

(Refer Slide Time: 09:36)



Batch reactor, I end up with this. We need the BOD at time t which is the organic content that has been consumed or degraded by time t. Thus, BOD at time t = $L_0 - L_t$.

(Refer Slide Time: 09:51)



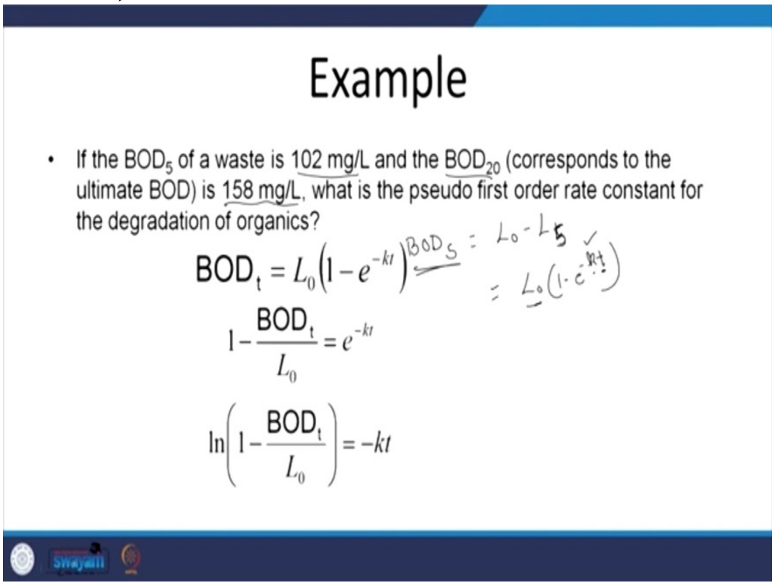
That is equal to L_0 into 1 - e power – kt. I just drew this graph and the rate constant I took was a typical rate constant for decay, kt = 0.3 D inverse. Initial organic content or the ultimate BOD is 200. That is why you see 200. Initial organic content or ultimate BOD, I am measuring it as or with, not measuring it, I am indicating it here 200, I took it to be 200. So here we have the test time and days organic content remaining and also BOD in units of milligram per liter of oxygen.

BOD test, I started here at 0 day. I see with time, what is happening? Some of the organic content is being degraded. When I say organic content is being degraded, some oxygen is being consumed. That is why the BOD increased. At 5 days, it ends up being the BOD is this. What happens to the organic content in this meantime? Organic content is the green particular region.

I have this organic content initially 200 and the organic content keeps on decreasing because the microbes are degrading it in the presence of oxygen. After 5 days, I only have a little of the organic content left. That is for you to be able to understand. If I run the test for longer, more of the organic content is going to be used up and after some or considerable number of days, this BOD consumed will be equal to the initial organic content.

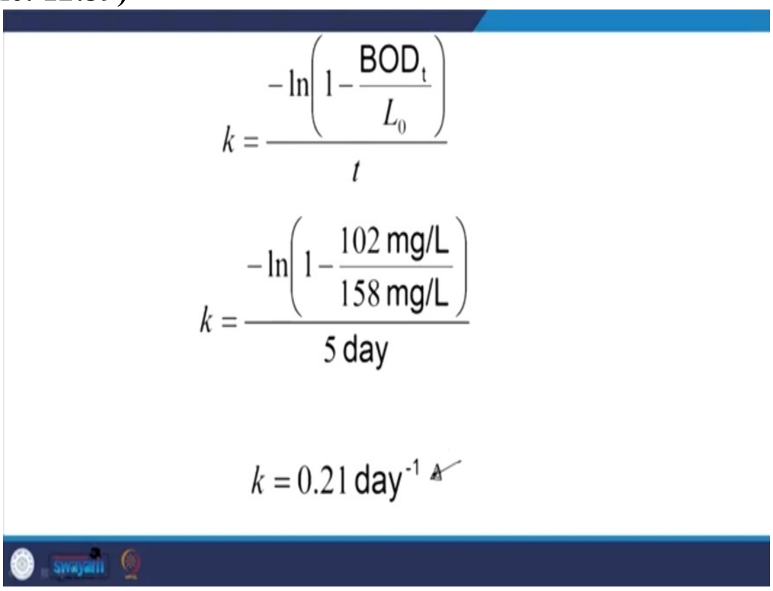
That is why we are calling that initial organic content as BOD ultimate. At BOD ultimate measurement day, how much organic content will be left? No organic content will be left. That is something for you to be able to understand.

(Refer Slide Time: 11:49)



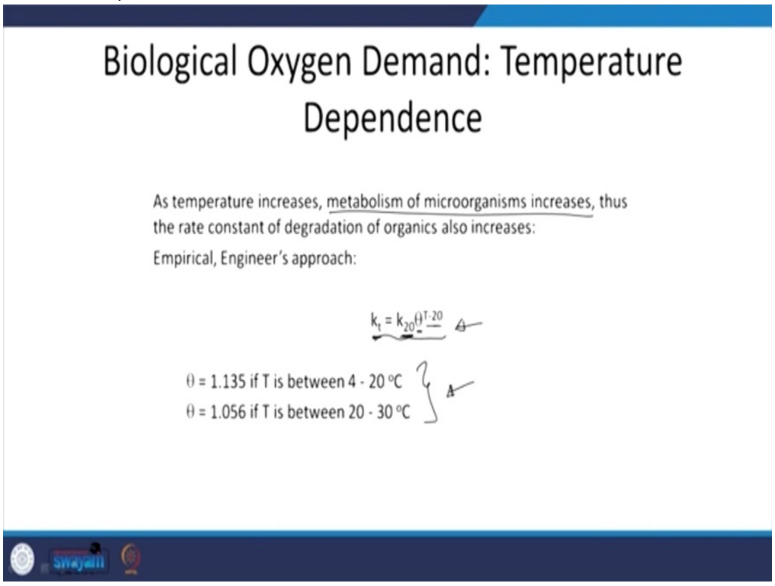
If BOD 5 of a waste is 1 or 2 milligram per liter and BOD 20 which we are saying corresponds to ultimate BOD is 158 milligram per liter. What is the rate constant? We know that BOD_5 is equal to the difference in the organic content, meaning, initial organic content minus organic content after the 5 day period or it is equal to L_0 into 1 - e power - kt. I have this BOD_5, is given here, time is 5 days. L naught is given us 158, so how to calculate k. This is not a great way because we have only one sample. But still for approximation that is not a bad way to go about it.

(Refer Slide Time: 12:39)



I plug it in and the k turns out to be 0.1 day inversely or per day, pseudo first order rate constant.

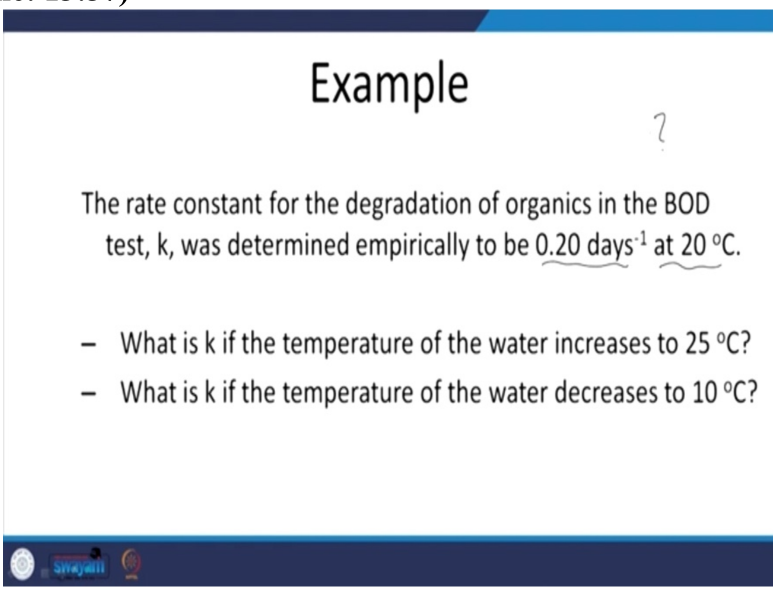
(Refer Slide Time: 12:46)



Temperature dependence, as we mentioned, rate constant is going to be dependent upon temperature. As temperature increases the metabolism of the microorganisms increases thus rate constant of degradation of organic salts increases, but it is not as if I increase it 100 degrees centigrade, it is going to, what we say? Ramp up the kinetics, because you are going to have the death of microorganisms after a certain threshold. We are talking about certain thresholds here.

Empirical approach quite widely used, rate constant at temperature T is equal to rate constant at 20 degrees centigrade into theta to the power of t - 20. Different values for theta? Typically, these will be given in the formula sheet, you do not need to mug up.

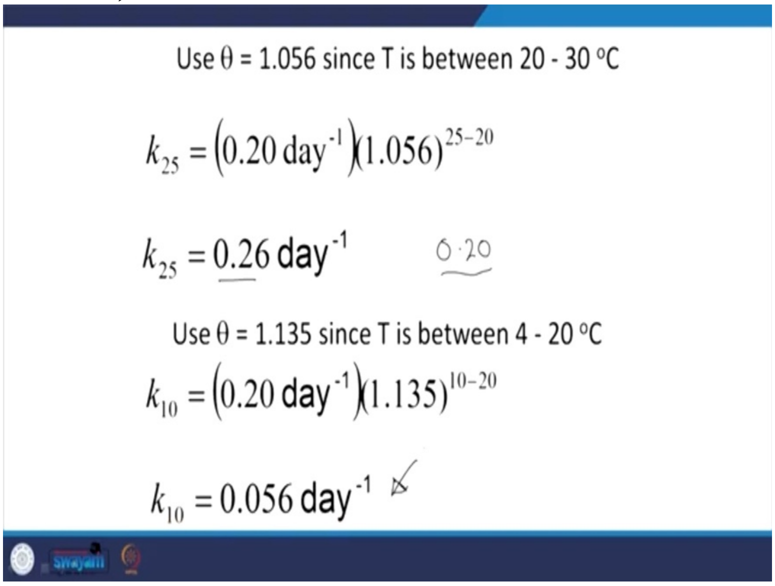
(Refer Slide Time: 13:37)



All these aspects now. The point is to not mug up aspects, but to understand the principles and the working of the system. The rate constant for the degradation of organics in the BOD test k was determined empirically to be 0.2 day inverse at 20 degrees centigrade. If I increase it to 25, what will the k be? If I decrease it to 10 degrees centigrade, what will the k be? Why is this relevant? I am on this information that we are going to gain by solving this.

Why is it relevant? As I mentioned in the summer, the degradation kinetics is going to be faster, and in winter or even in the colder regions, you are going to have relatively low kinetics, a slow kinetics partly. It is just plugging it in. We are not going to spend much time.

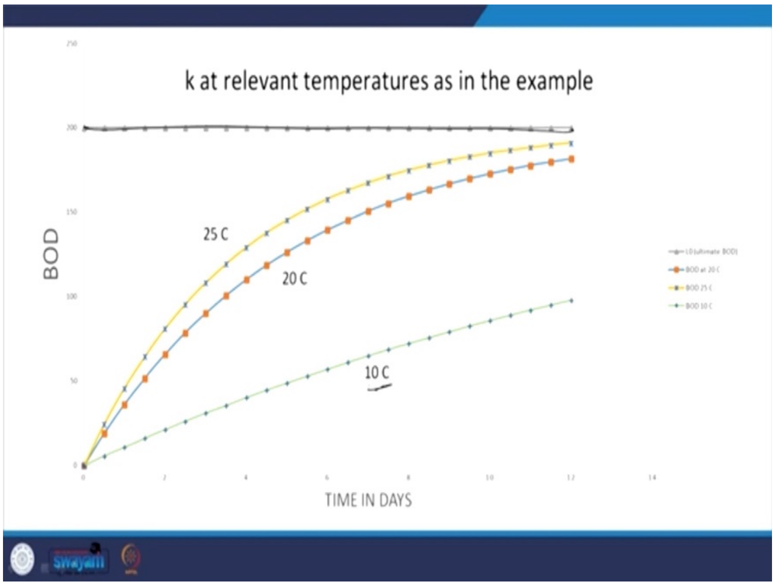
(Refer Slide Time: 14:28)



K 25 turns out to be 0.26. When at 20 degrees it was 0.2 and at 10 degrees, what is it going to be? It decreases greatly though, to 0.056. I think I have a graph out here.

$$k_{25} = (0.25\ day^{-1})1.056^{25-20}$$

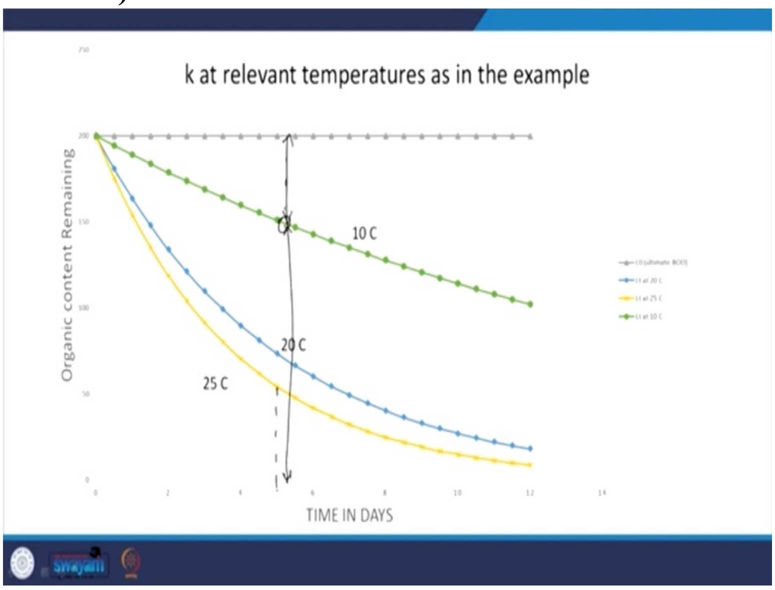
(Refer Slide Time: 14:45)



I have this graph so L_0 ultimate BOD, it is with 200. At 20 degrees centigrade this is what we have I think I took 0.3 or 0.2 does not really matter. Now I think I took 0.2 constant. At 25 we see that it did increase, but not by a lot. But it does, there is increase, but when I decrease the temperature, you see that there is a remarkable decrease in the consumption of the organic content. You can see that the degradation kinetics are going to be remarkably affected at relatively low temperatures. That is something to keep in mind.

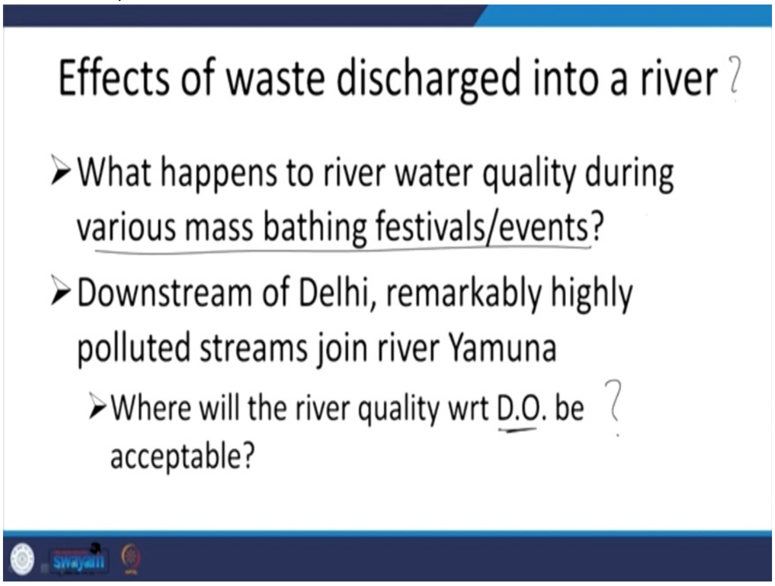
$$k_{10} = (0.20\ day^{-1})1.135^{10-20}$$

(Refer Slide Time: 15:23)



Organic content remaining, this is just representing this graph in a different way. If it is at 20 degrees or 25 degrees centigrade within 5 days, 50 / 200, considerable fraction, 75% is consumed. But at 10 degrees not much. At 10 degrees centigrade, not much has been consumed. Very little has been , consumed and a lot of it is still remaining out here.

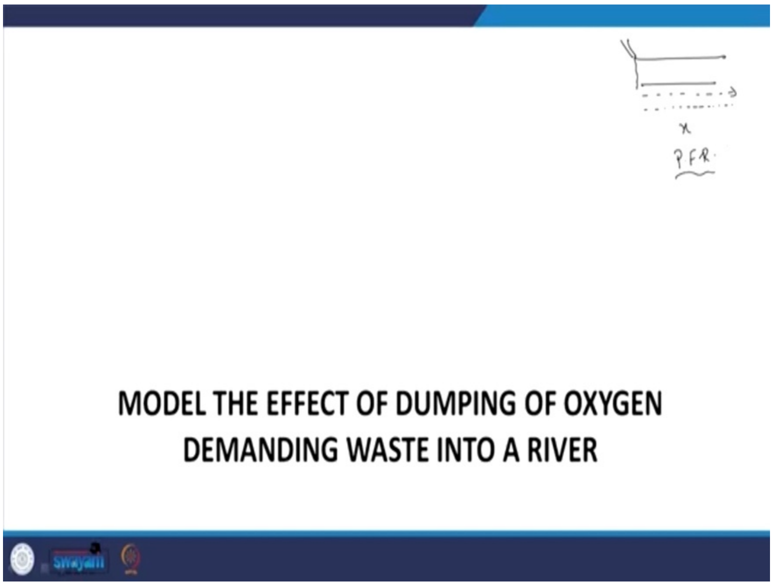
(Refer Slide Time: 15:58)



Let me not spend more time looking at the same aspect. What are the effects of waste being discharged into a river? We discussed this briefly earlier, but I have a decent picture out here. What happens to river water quality during various mass bathing festivals or events? For example, we have Kumbh Melas here and you are going to have a lot of organic content flowers being dumped or people immersing stuff or having birth.

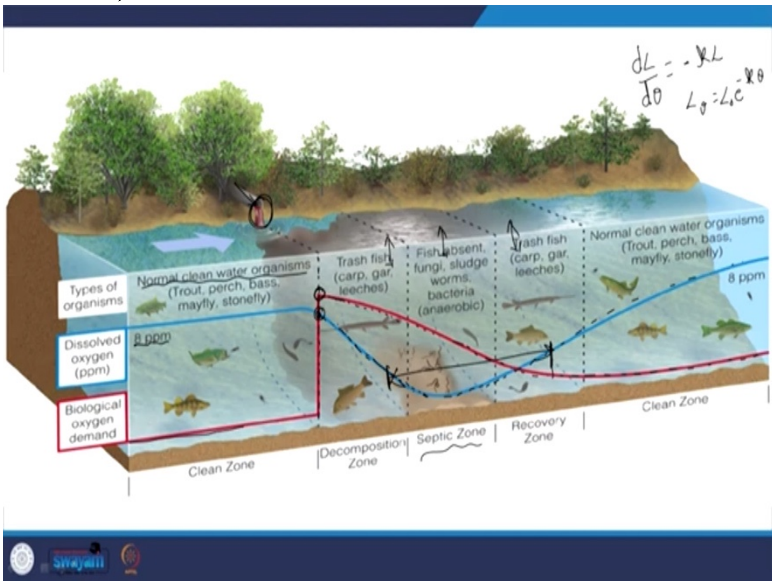
During that time, a lot of organic content comes into the river within a short period of time, though we say that the reverse are holy we do not let them be pure, we do not let them rejuvenate. There are other issues I am not going to go into that aspect now. Downstream of Delhi remarkably highly polluted streams join river Yamuna. Where will the river quality be acceptable with respect to DO?

(Refer Slide Time: 16:56)



How will we model it? Look at this, if this is the river, and this is the waste coming in, and assuming perfect mixing, understand that the concentration of the relevant compound, dissolved oxygen or BOD is changing with x, meaning we are going to use plug flow reactor, either with or without dispersion, so that is the best way.

(Refer Slide Time: 17:19)



To look at it . Here we have an example, we will just look at the holistic picture or take a holistic view and move on. Here I have my stream coming in, sub stream of that my dissolved oxygen is pretty good. The BOD is or the organic content is very low. Thus, the aquatic life or aquatic system ecosystem is thriving. But at the point of mixing, so BOD is very high in my particular wastewater. The organic content in the mixture of the river and the wastewater takes a huge jump.

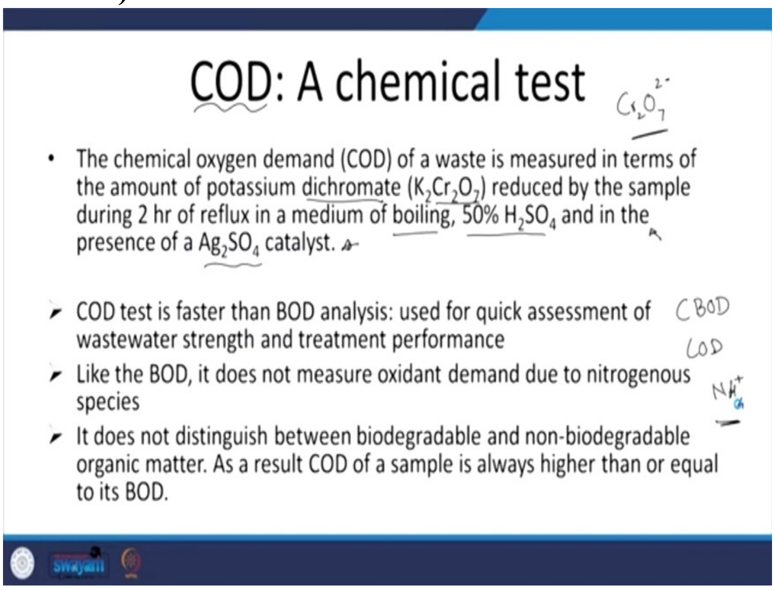
$$L_{\theta} = L\,e^{-k\theta}$$

DO does not fall immediately. It will decrease but would not fall immediately. But now what is going to happen? The DO is going to start decreasing. Why is that? Because the microbes are going to degrade this organic content in the presence of oxygen, so the organic content is going to be decreased. We looked at this graph earlier. Or even here if I want to dl / d theta = - k L. L theta = L naught into e power - k theta.

You see exponential decay that is what you see out here. But with respect to D O what is going to happen? It is going to decrease because organic content consumption or aerobic degradation takes place. Then you can have septic zone if you do not take care, you can have anaerobic conditions. But in the meantime, you are also going to have replenishment of oxygen from the atmosphere. That is why , you are going to have an increase in your, dissolved oxygen.

I am concerned about this stretch probably, when the conditions are so poor that the aquatic ecosystem will not thrive. These are the aspects I need to look at.

(Refer Slide Time: 19:17)

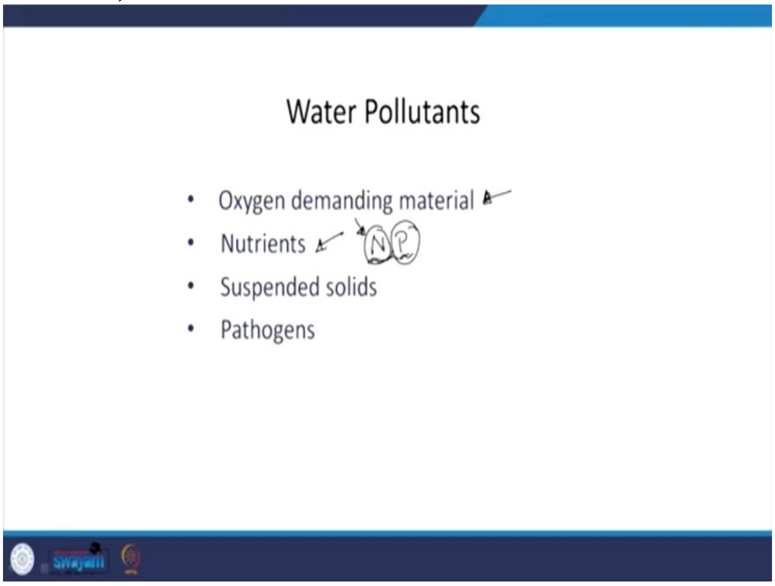


Let us move on. As I mentioned COD, relatively faster and relatively more reproducible. Unlike the BOD test which is slow, and depending on the kind of waste and whoever is doing it, you are going to have issues with respect to reproducibility. COD though not really such an issue, but it is relatively costly, because the ingredients are costly, but one aspect is the amount of lab space required is pretty much less.

COD of the waste is measured in terms of the amount of dichromate $Cr_2O_7^{2-}$ which is reduced or is used to oxidize the sample during 2 hours. Your 2 hour period in a medium of boiling and acidic conditions . In the presence of Ag_2SO_4 catalyst, sometimes you also add mercury. We are going to look at this reasons later . Mercury add to , complex the chloride so that it is not oxidized by $Cr_2O_7^{2-}$, Ag_2SO_4 we are adding it for, what is it now? As a catalyst .

Stiochiometry you can look at that, COD is faster than BOD. That is something that we already knew . Both biodegradable and non-biodegradable, but one aspect is similar to the CBOD test; even the COD test will not oxidize or lead to oxidation of your ammonia. That is something to keep in mind.

(Refer Slide Time: 20:54)



We have spent considerable time on oxygen demanding material. But that is worthwhile because during water and wastewater treatment, we are always concerned with oxygen demanding material. Let us now look at nutrients when I say nutrients; I am specifically concerned about nitrogen and phosphorus. Firstly, nitrogen and phosphorus, how do they come into the picture?

Nitrogen, we eat protein for muscle growth and such, now 6 packs, eight packs and what not are in fashion now or in vogue. But in general, even for muscle retention, if not for growth, you need to take in proteins, and amino acids and such. You are going to have sources of nitrogen. Similarly, we have different sources of our requirements for phosphates now. I am going to consume it and some of it is going to be coming out of my particular system or my system.

That is going to be present in the wastewater. If I need it, also understand that other, beings will also require it or will thrive on it. The issue with nitrogen and phosphorus is that all the other nutrients are typically present calcium, magnesium and such. But nitrogen and phosphorus are limiting nutrients they are not typically present in abundance in the natural waters.

If wastewater comes into play and joins that particular natural water, ocean or , inland water bodies, surface water bodies, what is going to happen, you have all the ingredients required for explosive growth of your algae. You are going to have algal bloom, or explosive growth of algae within a short period of time. After this particular bloom, what is going to happen to this algae when there is no more what we say nitrogen or phosphorus or any other nutrient, they are going to die.

When they die, they are going to increase the organic content of this particular lake or river typically lake, because that is relatively less turbulence, no flow of water. Then you have decaying organic content. Oxygen content in that particular lake will be very low, you will have septic conditions. Thus, we are typically concerned with nitrogen and phosphorus. Inland phosphorus is the limiting nutrient and in oceans, nitrogen is the limiting nutrient. That is something to keep in mind.

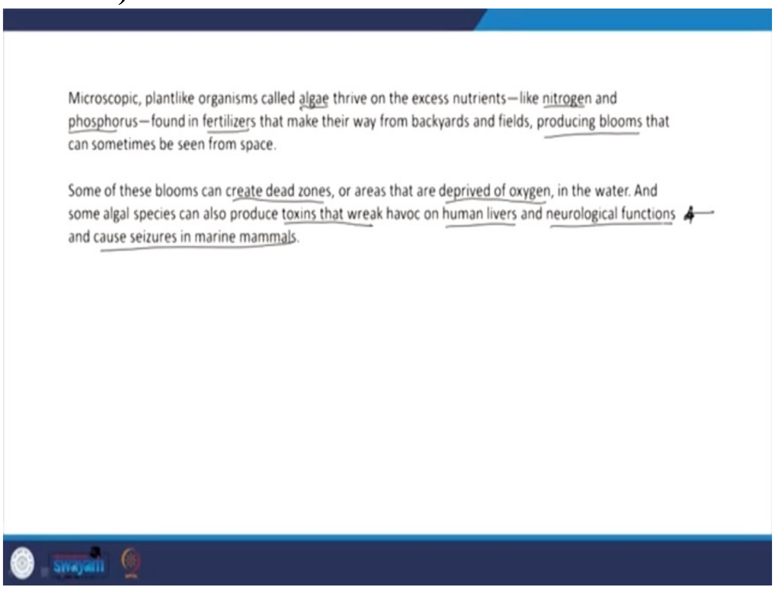
(Refer Slide Time: 23:11)

Let us just look at that. This, I give the relevant reference out here. This is from China; I am just looking at good pictures out here. We see people having fun. I mean seems like a good day to be out and people are having fun.

(Refer Slide Time: 23:27)

Here is the bigger picture. We see the people having fun out here. You see that this is nothing but an algal bloom from 2013. You see the scale and the extent of this particular algal bloom. Though in this picture seems like some people are having fun, I am sure at the end of the day, some people might have what we say observed remarkable adverse effects.

(Refer Slide Time: 23:56)



Because we will come back to that, so microscopic plant like organisms, algae, photosynthesis thrive on excess nutrients, as I mentioned, nitrogen and phosphorus. Where are they found in? They are found in fertilizers and also in our wastewater and they make their way from backyards, fields or septic tanks. They lead to producing or lead to algal blooms that can sometimes be seen from space, we will look at that.

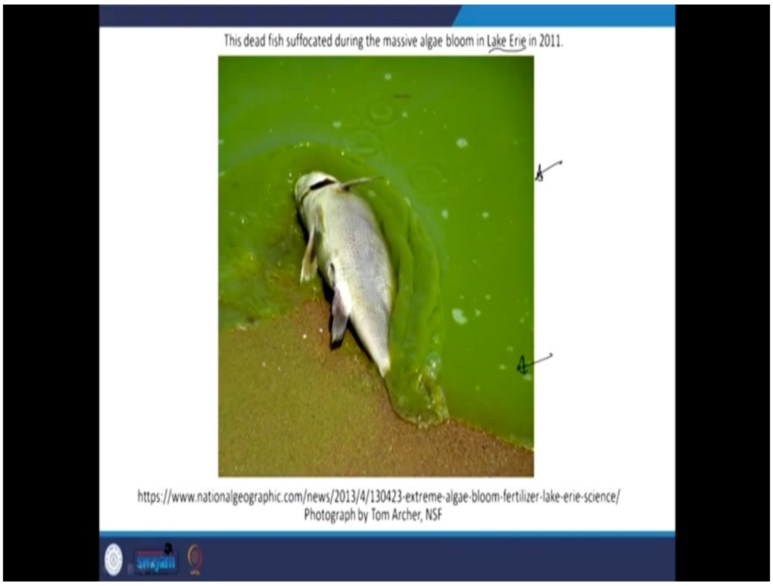
As I mentioned, this blooms can create dead zones or areas that are deprived of oxygen. Some algal species, as I was just about to mention earlier, can produce toxins that can wreak havoc on human livers and neurological functions and can cause seizures in marine mammals. Typically, we have issues not with just the aquatic ecosystem, when I say just it is because I am selfish, primarily selfish, but concerned citizen. Humans also have considerable or can experience considerable adverse impact.

(Refer Slide Time: 25:00)

As I said we can see it from space. This is from North America. These are the largest lakes in the world. I think we are talking about Lake Erie, North America, this is 2012. But this is always the picture you can see algal blooms. Any way you can see the algal blooms all out along this coast and on this lake, all along this coast. Caused by agricultural practices as when we add urea. We need to add nitrogen and phosphorus in different forms for our plants.

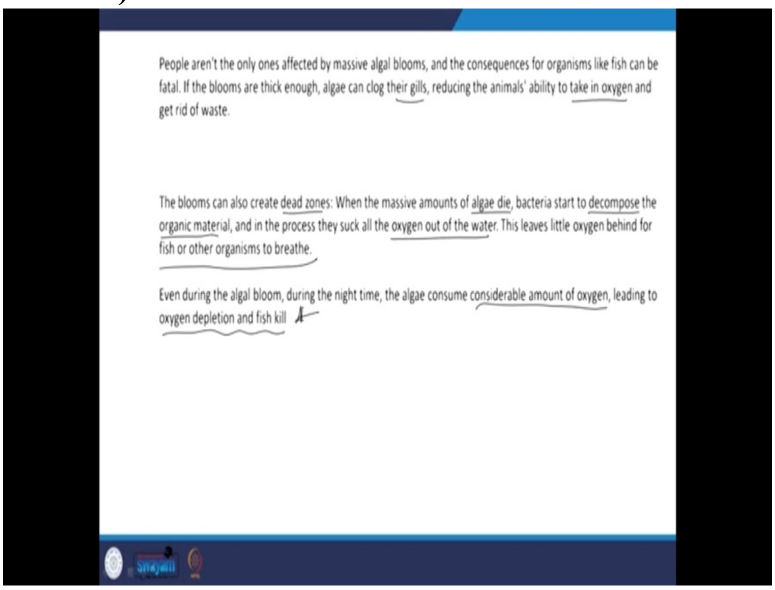
Sometimes we dump excessive fertilizers and you have rain and then run off from this agricultural land and settle in the lakes and that is going to lead to algal bloom. Not all algal blooms produce toxins, but for those that do in fresh water systems, the culprit is usually the blue green algae or cyanobacteria. They are very harmful to your liver. Neurotoxins that can shut down a person's heart or stop their breathing or caused them to lose their short term memory or send them into convulsions, these are common toxins.

(Refer Slide Time: 26:16)



Even though I am selfish, sometimes I need to be concerned and if not short term, long term issues, we see that aquatic life is going to be remarkably affected and devastated. This is from Lake Erie. These are you can see the level of algal bloom; I might not have what do we see eye catching pictures from India, but this is pretty common in Indian, lakes too. Indian lakes, people are encroaching upon Indian lakes left and, there are few lakes if any left. That is something to keep in mind.

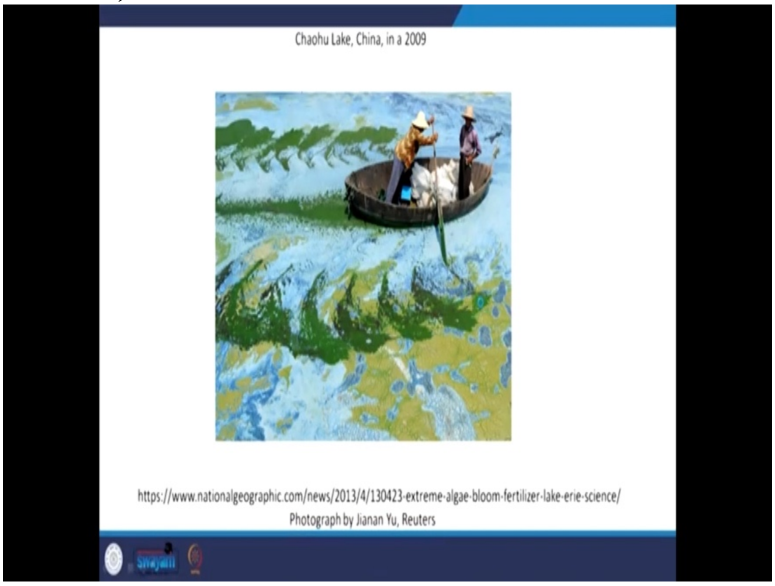
(Refer Slide Time: 26:53)



People are not the only ones affected. Organisms like fish can be I mean, killed a lot of times. If blooms are thick enough, algae can clog the gills reducing the ability to take in oxygen and get rid of waste. As I mentioned you can lead to or they can lead to dead zones, massive amounts of algae die and then they are going to decompose, because they are organic matter. Then they lead to decrease in oxygen.

You have oxygen depletion in your particular system. Even during the night time, the photosynthesis, the principle, algae consume considerable amount of oxygen, leading to oxygen depletion and fish kill. This was seen in Bangalore for all purposes seems like the lake was fine. But in the night or in the early morning you saw a lot of fish floating up, because they were dead. People were not sure. But the issue was oxygen depletion in the night due to algal growth rates. That is something to keep in mind.

(Refer Slide Time: 27:59)

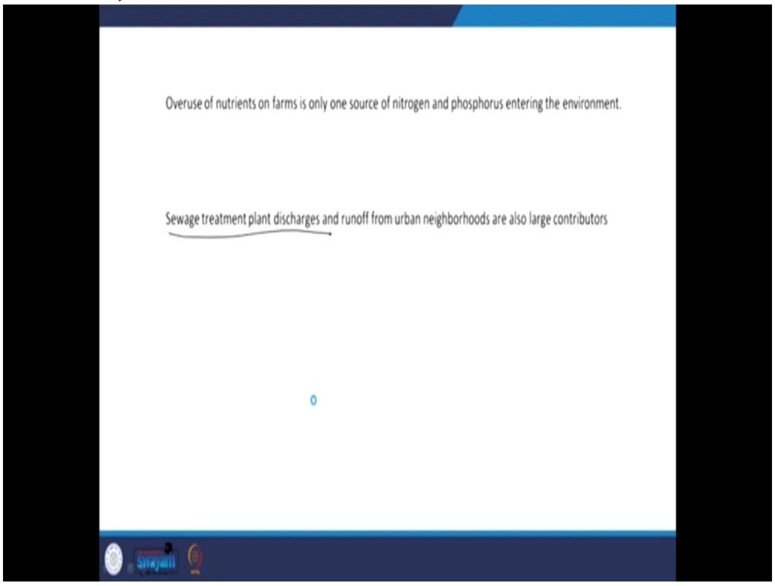


More colorful examples, but as I mentioned these are actual examples. China has spent billions of dollars but, here you cannot really.

(Refer Slide Time: 28:11)

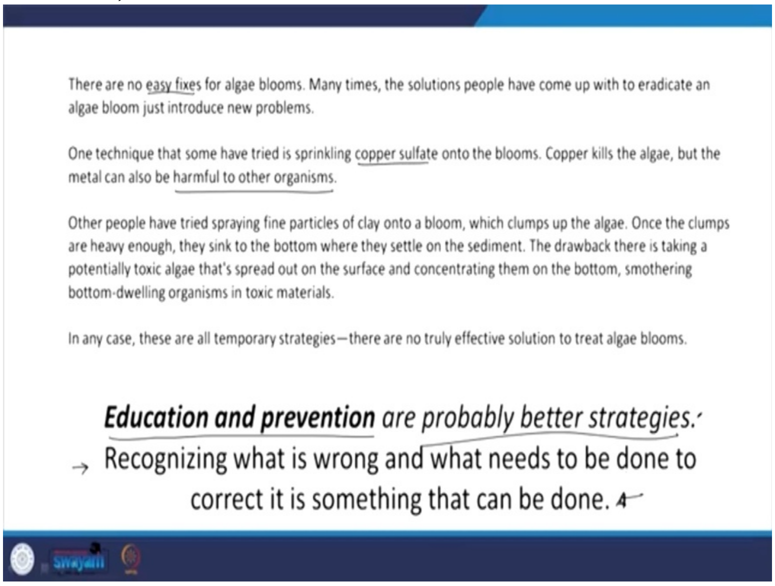
Tackle the issue once it is already underway, the only aspect is prevention . One aspect which is remarkably prevalent in India is fertilizers. There is a huge fertilizer lobby. People push for consumption of fertilizers.

(Refer Slide Time: 28:32)



One other aspect is sewage treatment plant discharges and also from septic tanks.

(Refer Slide Time: 28:44)

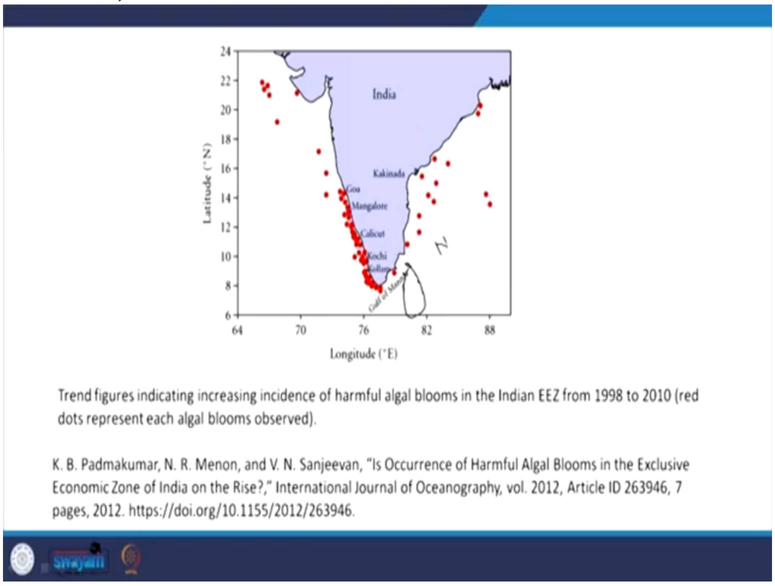


Now that is the reason why we are trying to treat for or remove nitrogen and phosphorus. As I mentioned there are no easy fixes. Sometimes people add or try to solve it and exacerbate the problem. For example, copper sulphate, though it kills the algae, because it is toxic to it, it is also harmful to organisms, heavy metals and general other aspects. But as I always say, education and prevention are the better strategies and that is what we are trying to do through this course.

While we do not do this, but I wanted to mention this, recognizing what is wrong and what needs to be done to correct it is something that we can do at least by word of mouth or , by just following decent example, setting the decent example Bangalore another lake, lake frothing was observed, you can type it up or Google it. Lake frothing Bangalore, you will see scenes as if you have ice out there, but it is due to excessive use of phosphorus in the detergents, a lot of detergent being used.

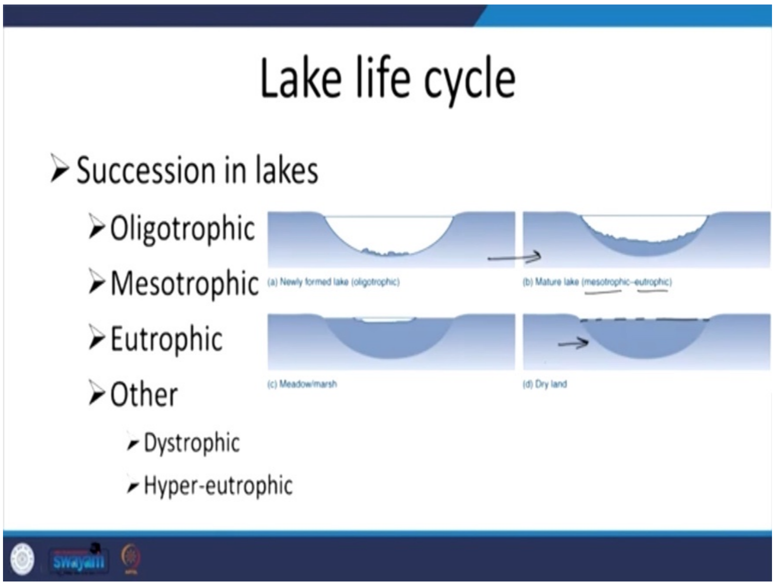
Then you have Lake frothing and , remarkable levels of phosphorus. The whole point is to be, to let the earth be sustainable, our life on earth be sustainable.

(Refer Slide Time: 30:00)



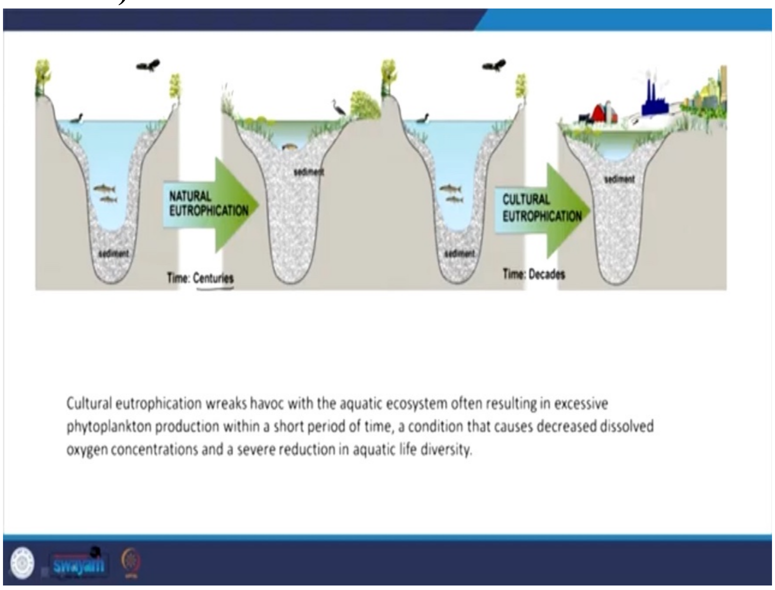
As I mentioned we have algal blooms. Various parts of India, I do not have the data for inland water systems. But in oceans too, we have it in oceans, nitrogen is typically the limiting nutrient.

(Refer Slide Time: 30:13)



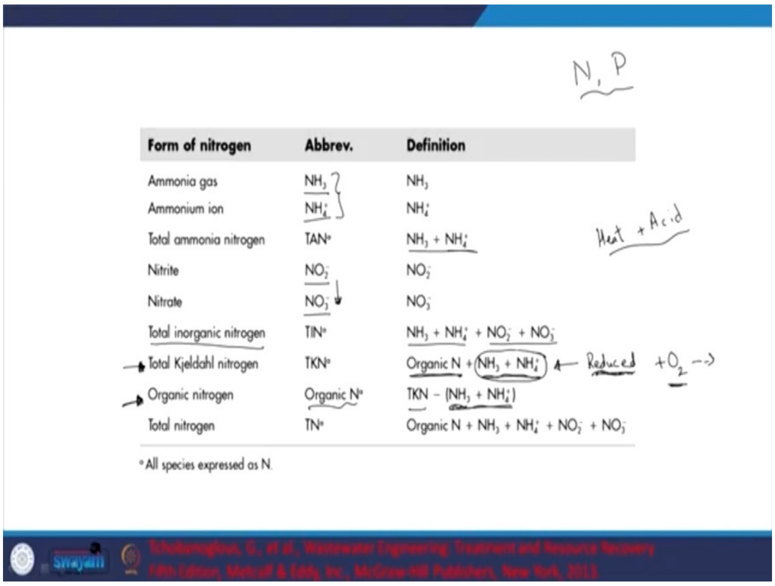
We see that it is exponentially taking off here we have the number of high algal bloom events and we see that it is taking off. In lakes, what happens is this algal blooms they fasten or hasten, this particular transformation of lakes and they become dry lands. You want it to be mesotrophic, but they end up being eutrophic. This is the final , stage when we let excessive nutrients coming into our water bodies.

(Refer Slide Time: 30:49)



Natural eutrophication takes centuries and it leads to or it supports the aquatic ecosystem. But cultural eutrophication hastens the process and we end up, cutting the tree branch upon which we are dependent. That is what we see out here, let me not spend too much time.

(Refer Slide Time: 31:08)



Form of nitrogen	Abbrev.	Definition
Ammonia gas	NH_3	NH_3
Ammonium ion	NH_4^+	NH_4^+
Total ammonia nitrogen	TAN*	$NH_3 + NH_4^+$
Nitrite	NO_2^-	NO_2^-
Nitrate	NO_3^-	NO_3^-
Total inorganic nitrogen	TIN*	$NH_3 + NH_4^+ + NO_2^- + NO_3^-$
Total Kjeldahl nitrogen	TKN*	Organic N + $(NH_3 + NH_4^+)$
Organic nitrogen	Organic N*	TKN − $(NH_3 + NH_4^+)$
Total nitrogen	TN*	Organic N + $NH_3 + NH_4^+ + NO_2^- + NO_3^-$

*All species expressed as N.

But we are talking about measuring nitrogen and phosphorus in the wastewater because I want to remove them depending upon their, what we say concentrations. Firstly, I need to know in what forms is nitrogen present in my particular wastewater. NH_3 or NH_4^+ ammonium ion or ammonia gas that is one aspect, so total ammonia, nitrogen nothing but the sum.

The oxidized forms of nitrogen or nitrite and nitrate, typically nitrite is unstable, it is usually oxidizing to nitrate. Then we have total inorganic nitrogen which as the name indicates and is self-explanatory, we have the reduced forms and the oxidized forms of nitrogen. Then we have a variable that is widely used to measure nitrogen, Total Kjeldahl nitrogen, and here we have, for the first time, both organic nitrogen and the reduced form of nitrogen I mean ammonia, though.

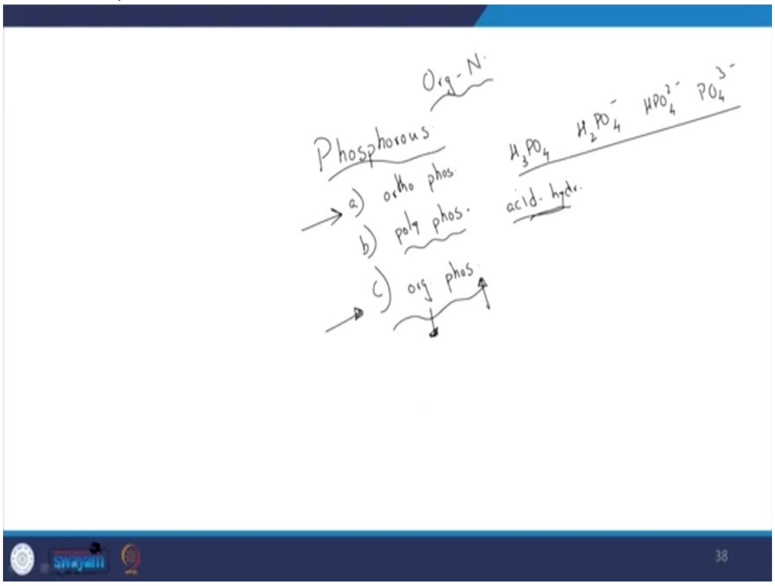
What is common out here, as I was just mentioning, and all these cases, the nitrogen is in the reduced form and organic nitrogen we are just talking about TKN minus ammonia, or total ammonia nitrogen. Typically, we look at this, why am I concerned about this? Because as you can see here, we say that this is the reduced form. This can take in oxygen and lead to oxygen demand.

Also, we are looking at the removal of nitrogen. How do I measure this TKN. Typically, I need to convert this fraction of organic nitrogen into ammonia. I am going to apply heat and acid, typically, as the conditions and I am going to this is called digestion. Then I will measure this particular NH_3 and NH_4^+ or the converted forms of ammonia.

How do I measure this organic nitrogen? It is not that I am going to take the difference or little reference of this 2 particular , parameters. But I can , see to it that the pH is changed. We know the pH, pK relationship, and I can see to it that I can , see to it that this ammonia changes phase from the aqueous phase to the gaseous phase. Typically, that is done during boiling.

First, I am going to boil it and then see to it that the conditions are such that ammonia leaves the aqueous phase and goes into the gaseous phase. Then I am just left with the organic nitrogen, which I digest, but in acidic conditions and then measure the nitrogen content and that will give me organic nitrogen. But in TKN, I am not going to boil it or see to it that I am not going to see to it that NH_3 and NH_4^+ leave the system. That is the primary difference.

(Refer Slide Time: 34:13)



Let me move on. In nitrogen we as I mentioned, organic nitrogen is a key component and microbes are going to break it down such that, are converted into ammonia before using it for cell synthesis. With respect to the other particular nutrient, we have phosphorus. There are 3 primary forms a, b and c of phosphorus or the phosphates.

When I am talking about this it is H_3PO_4, typically in it cannot be in H_3PO_4, typically pH is not so low, $H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}. Then I have the polyphosphates relatively more complex with 2 phosphorus or such or more. Then I have organic forms of phosphorus . But typically, microbes take a lot of time to make them soluble, so that they can be utilized. Unlike organic nitrogen, organic phosphates, they typically stay in the solution.

Poly phosphates, I think we call them acid hydrolysable. Typically, we are concerned with ortho phosphates, not acid phosphates, we look at ortho phosphates because they are readily consumed or assimilated by the relevant microbes. But organic phosphates, not really so they can persist in the sludge too. That is something to keep in mind. With that I will end my session and we will look at pathogens in the next session. As usual, I thank you for your patience.