Water and Waste Water Treatment
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Lecture – 09
Water Quality: Do and Ways to Measure It

Hello everyone welcome back to the latest lecture session. Quick recap of what we have been up to in the last session. We started discussing about the different water quality parameters. Before doing that we also looked at why is it that we need to look at these parameters in particular lecture. Let us have a quick recap of what we have been looking at and we are talking about water quality parameters we are limiting ourselves at least in this course to a handful of parameters. There are a lot of parameters but with respect to the general wastewater treatment for domestic wastewater we are limiting ourselves to only a handful of parameters.

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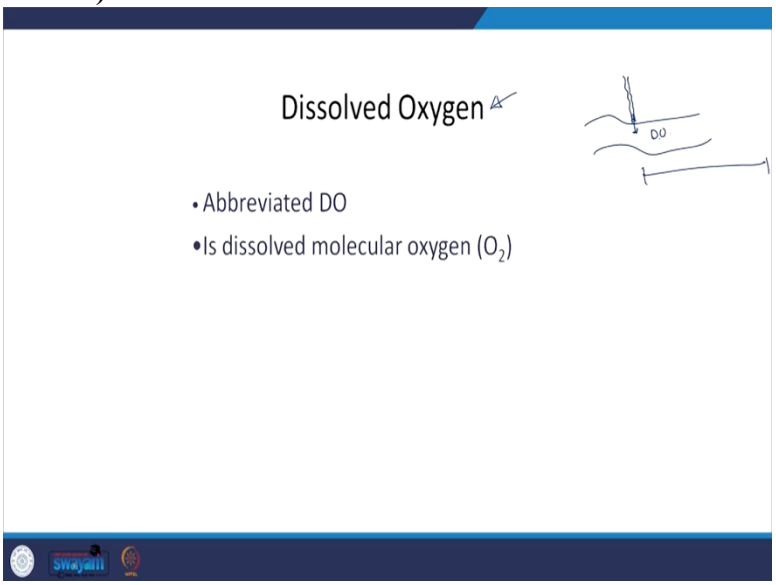

More or less, we are trying to ensure that there is enough dissolved oxygen or satisfactory levels of dissolved oxygen in the stream that is going to receive our waste or treated waste. This is the stream or the river and my treated or untreated waste is coming in. I want to see to it that the dissolved oxygen and this particular river throughout this stretch or throughout the relevant stretch is acceptable, why is that?

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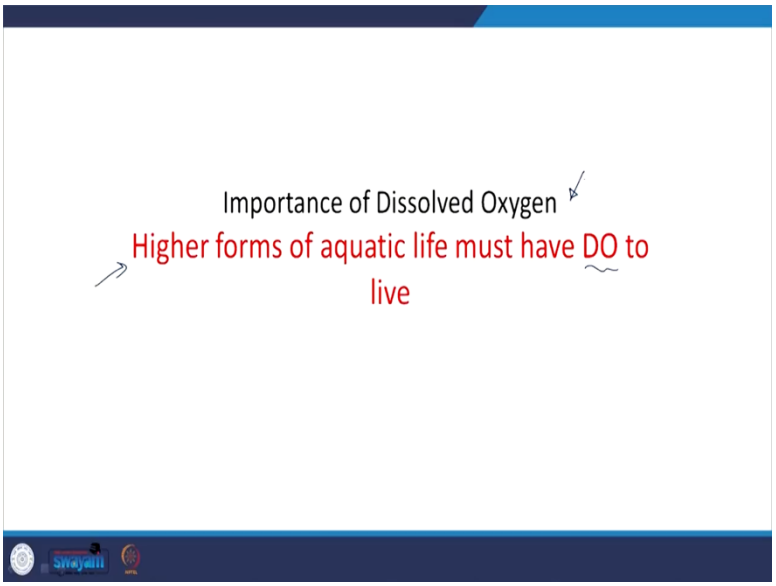

Why is that because higher forms of aquatic life must have dissolved oxygen to live and at relatively low DO levels are no or we know anaerobic conditions you are going to have septic what we say systems prevailing or septic conditions prevailing and you will have also pathogens prevailing during that time to the greater prevalence during that time. In general, high dissolved oxygen content is an indirect indicator of decent quality of water, decent not good .

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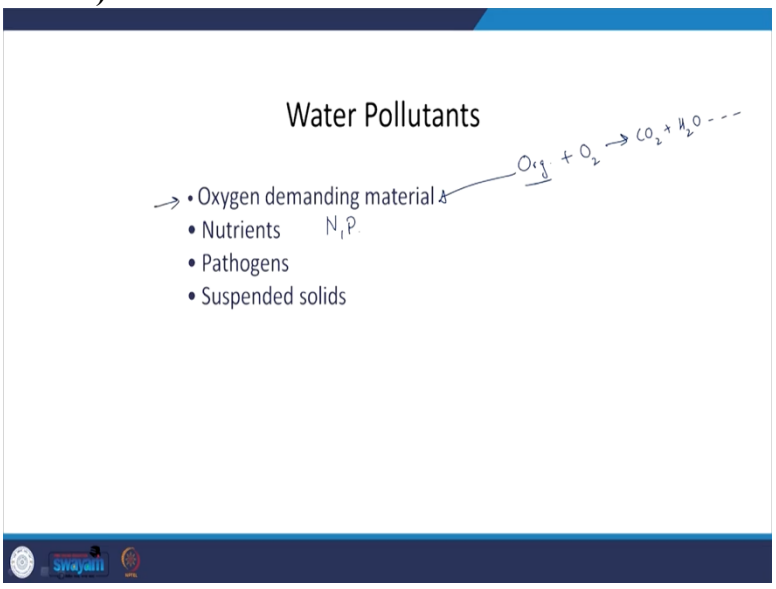

Water pollutants we talked about a few aspects organic matter. Organic matter can be oxidized by microbes in the presence of oxygen to CO_2 and water and other byproducts. We are concerned with organic matter but we do not directly measure it. There are ways to measure it but we directly we do not directly measure it we measure it in terms of oxygen demanding material. Then nutrients

typically we are going to look at nitrogen and phosphorus and pathogens. Microorganisms capable of causing disease and suspended solids. We will look at this we started looking at Oxygen demanding material.

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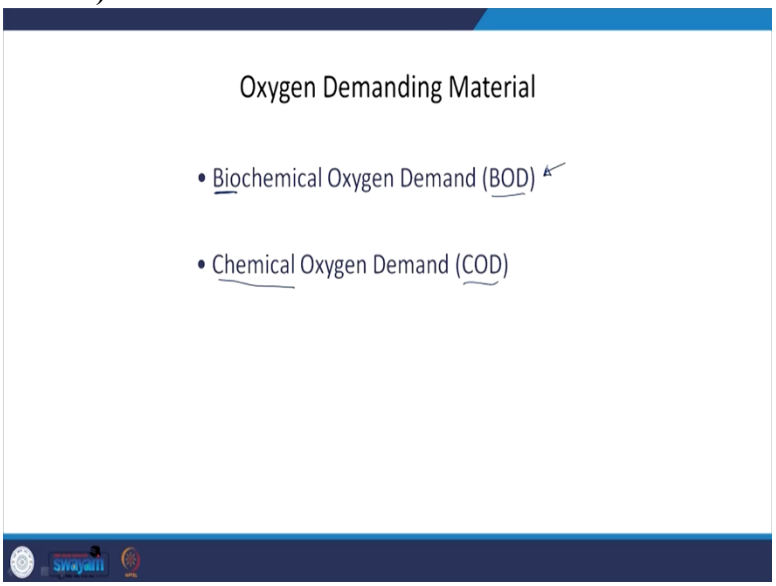

In that context we looked at 2 particular parameters. 1 is the biochemical oxygen demand BOD and the other one is chemical oxygen demand. Off the bat you can see that in 1 particular variable or parameter we have this addendum or biochemical oxygen demand, the other one is only chemical. Here we are going to look at the biodegradable fraction.

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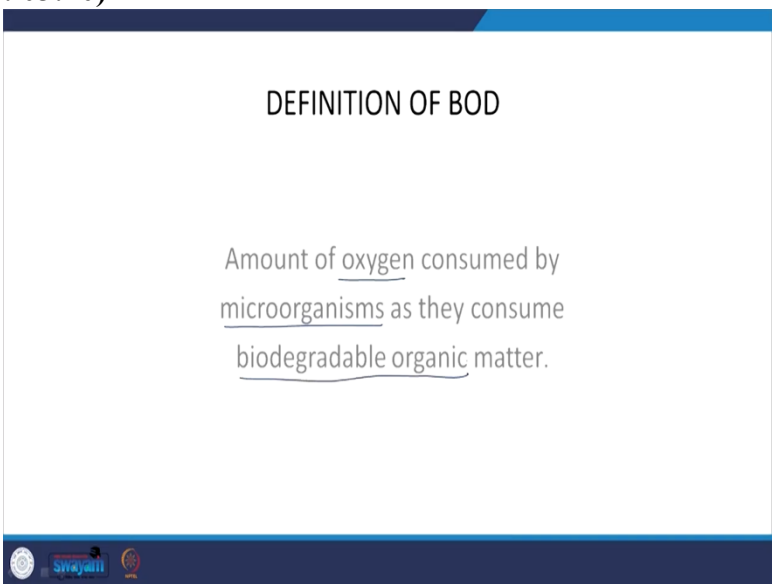

Here I have that amount of oxygen we are going to look at the amount of oxygen being consumed by the microorganisms as they degrade or consumed the biodegradable organic matter so 3 key aspects.

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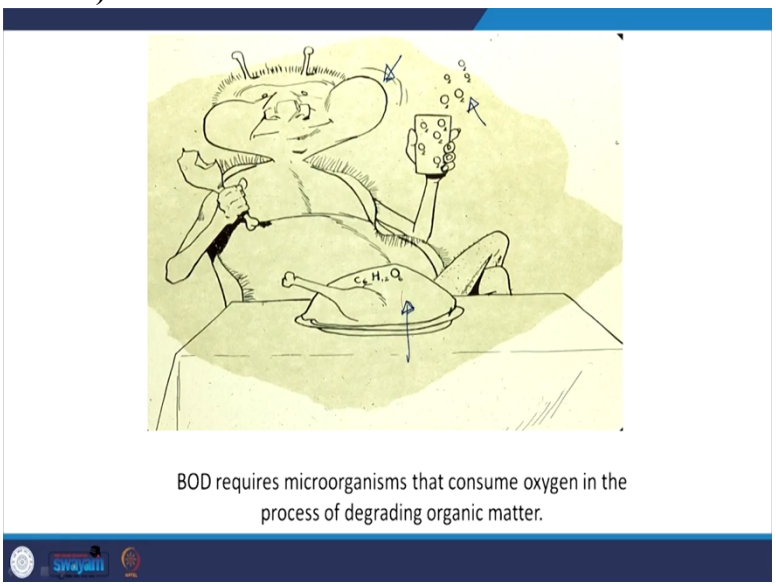

Generic example here we have the microbe about here. Here is our waste which is their food. Here is the electron acceptor which is oxygen.

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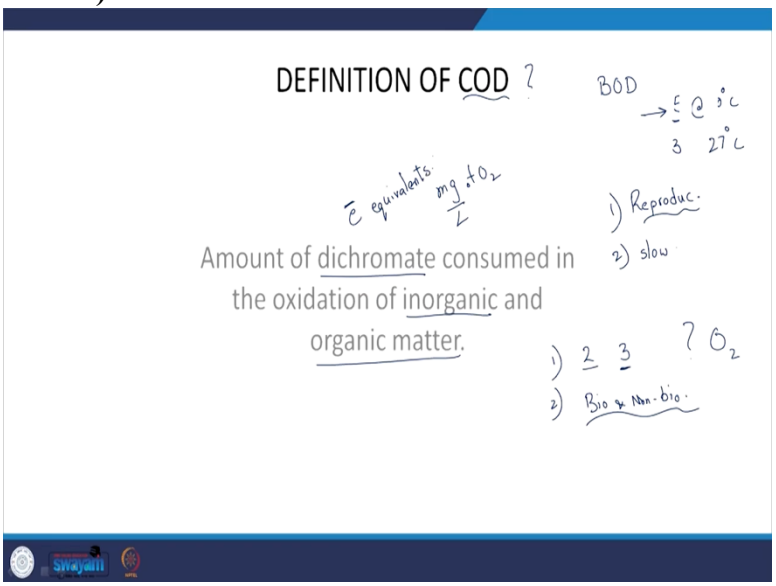

I already looked at this so I will move on. The second aspect is COD why do we want to go for COD, the BOD test typically 5 days at 20 degrees centigrade temperature or 3 days at 27 degrees centigrade. But typically, people go for this test. Also, it is not easily reproducible. The

reproducibility, of this particular test is pretty low depending upon who is what we say conducting the test and more importantly the kind of waste.

Why because the kind of seed bacteria that you are using as we mentioned with respect to the BOD test it is all about the microorganisms consuming oxygen, while degrading the organic content or biodegradable organic content. The kinds of microbes the kind of waste plays a role. If it is not domestic sewage or wastewater from our kitchens and toilets reproducibility will certainly be an issue.

As I mentioned 5 days so it is relatively slow ? Tells people would typically want to look at relatively faster methods. COD test typically 2 hours to maybe 3 hours. Relatively fast but here we are going to measure both the biodegradable and non-biodegradable organic content. That is something to keep in mind. How are we getting that done?

If I use oxygen for this test for COD it is going to take a lot of time context it is going to be very slow. We are going to use the oxidizing agent which will lead to faster kinetics. What is the strong oxidizing agent we are using here? Dichromate and we are going to look at the amount of dichromate consumed in the oxidation of inorganic and organic matter. That is something that you need to keep in mind. Then the units are though going to be in terms of milligrams per liter of O 2. It is not of dichromate because we are going to convert using electron equivalents. That is something to look at Stoichiometry.

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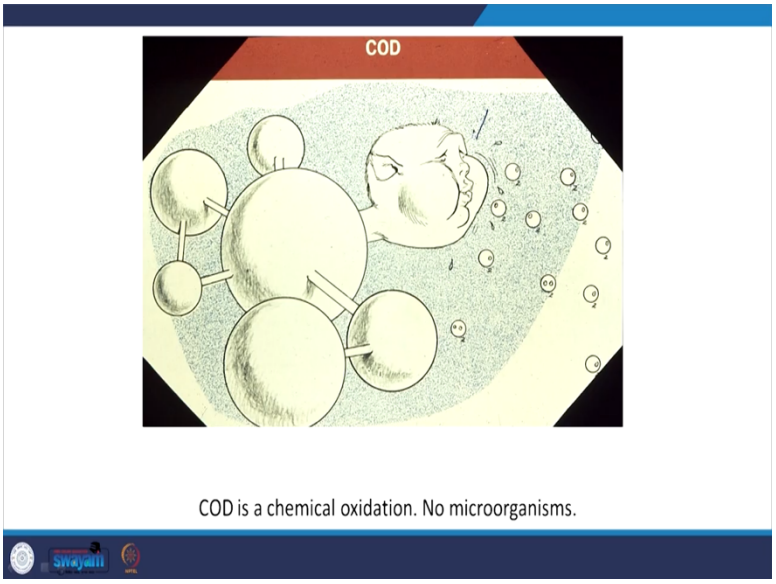

Most people should be pretty familiar by that now. You have a compound out here this is not a microbe and how much oxygen? Is it or oxygen equal? Says that it is going to require no microorganisms? That is the key aspect to keep in mind.

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Why is it that I need to be concerned about this BOD, COD and then think about spending money time resources to tackle this or remove this from the wastewater. Because you this is common in many regions in India or rather everywhere. You have a drain with untreated waste coming in and you have the river. Color changes do not say I am not really concerned about that fine.

Turbidity is high here relatively high but I am not sure how high the turbidity is here. I mean rate to turbidity is fine. Let us not bother about that. But I am a concerned citizen but a selfish citizen.

That is what the society is about now. But at the end of the day, I am just concerned about how is it going to affect me everything revolves around me the concern but selfish citizen now.

The issue here is that 1 example is of Delhi, Mathura, Agra, Yamuna flows and maybe a tower. Upstream of Delhi out here upstream the quality of water is pretty good. But by the time it passes through Delhi our the National Capital Region NCR the water quality is so poor that nothing survives and this water during, the summer season it is more or less a drain with little to no flow. It is drain because partially treated or sometimes untreated waste from the surrounding sometimes industrial areas comes into this river Yamuna.

That is what comes to Mathura and Agra and treated and you reused. But from what I know this water even after treatment is not good enough with respect to emerging contaminants which we are not going to discuss now. But people only use it for bathing or such purposes but not for drinking water or not for drinking. That is something to keep in mind.

As an even though I might not be concerned about the long term effects if I let this persist downstream of this junction of the river and drain remarkable levels of our septic conditions will prevail or remarkably anaerobic conditions will prevail and that is going to kill the ecosystem in that particular region. You are also going to affect the quality of life of the people around.

Also, you are going to affect the not habitats the fishermen. That is something to keep in mind. Whatever we discharge and sub being consumed by us or here we have the agricultural fields. This wastewater is used out here. We have this persistent organics which am now calling as emerging contaminants more of this later. For example, the pharmaceutical compound or antibiotic I taken only some of it 20, 25% will be used or consumed by me or my body.

The rest is going to be flushed out through the system urine or feces and it is going to reach the wastewater. Traditional wastewater treatment what we say plants with or when they run efficiently can remove them to some extent. Here I am just using a very generic term. Please note that I am just using emerging contaminants depending on the kind of emerging contaminant that will persist in even treated wastewater.

In untreated wastewater the levels of these emerging contaminants are going to be high. If they are used in these fields, I am going to end up consuming them. It is more or less a cycle. Whatever we put out there it is going to end up affecting us similar. This is similar to air pollution I am at what we say air pollutants I end up breathing them and my health is affected. These are aspects that we need to be concerned about. BOD tests how do I go about it?

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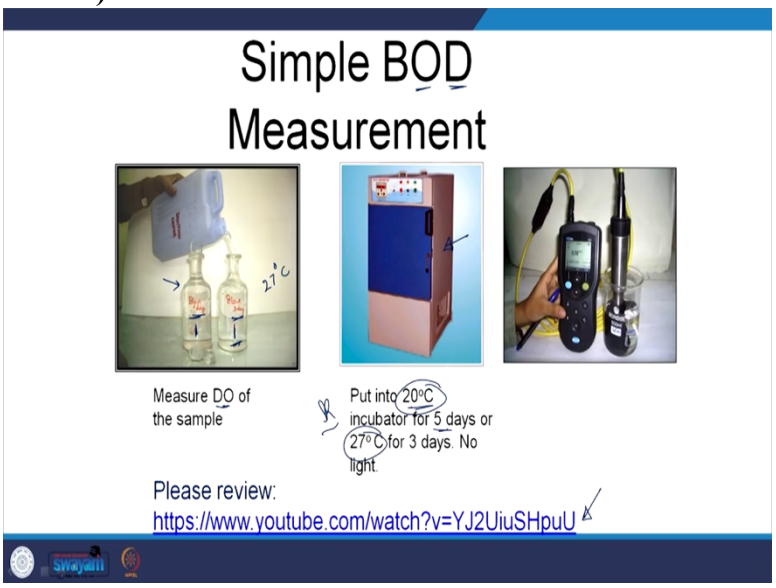

You can look at this particular video simple BOD measurement it is oxygen demand. Let us see how we are going to do it. Measure dissolved oxygen of the sample. These are the BOD bottles typically 300 ml are relatively standard sized. Measure the DO of the sample as you can see it is 0 day and it is 3 day at 27 degrees centigrade or 5 days at 20 degrees centigrade the kinetics turns out to be the same.

You will measure the initial DO. Then the DO after 3 days or 5 days as you see fit. But where will you keep the sample in that time you will put it in an incubator, why you want to maintain constant temperature so that the rate constant of degradation of organics is constant let see. As rate constant depends on temperature. You do not want the rate constant to vary a lot. That is why you are going to put it in an incubator and also no sunlight to prevent photosynthesis. After the relevant period you are going to measure the final DO? Measure the DO after 5 days or 3 days depending on the relevant temperature.

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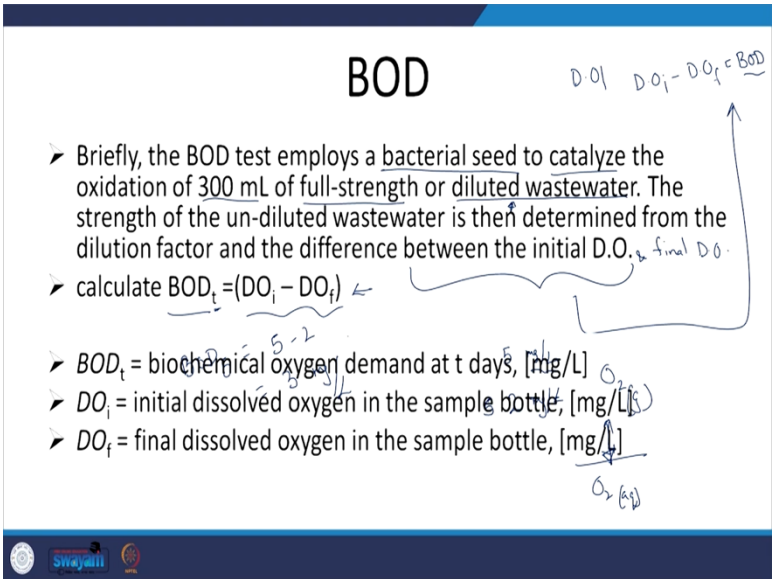

You are going to get the difference in DO levels DO initial minus DO final will give you the BOD biochemical oxygen demand. Here we are assuming that our sample which is domestic wastewater already has enough microorganisms which are assimilated to that particular kind of waste. We do not need to add any further microorganisms. But if it is toxic or industrial wastes where you presume that the microorganism content is going to be relatively low you have to add microorganisms.

Also add the relevant nutrients to allow for the growth of these microorganisms. That is something to keep in mind. Let us just look at what I have here briefly the BOD test employs bacterial seed. If we assume that there are no bacteria or microorganisms in the relevant sample to catalyze the oxidation of 300 ml of full strength or diluted wastewater, we will look at why we need to dilute the wastewater? The strength of the undiluted wastewater is then determined from the dilution factor and the difference between as I mentioned the initial DO and the final DO.

That is what we have out here. BOD with respect to either 5 days or 3 days as DO initial minus DO final for example initially because microbial action has not yet started the DO might be 5 milligram per liter. Then I put it aside I close it why do I close it? Because I do not want oxygen from the gaseous phase to replenish; the oxygen in the aqueous phase. If I let this happen then I cannot measure the change in are the oxygen consumed by the microbes accurately that is something to keep in mind.

This is how we are going to do it 5 milligram per liter initially and 2 milligram per liter after 5 days. I am going to end up with a BOD 5 meaning 5 day BOD is equal to 5 - 2 that is equal to 3 milligrams per liter in terms of oxygen demand. In which cases will this not work.

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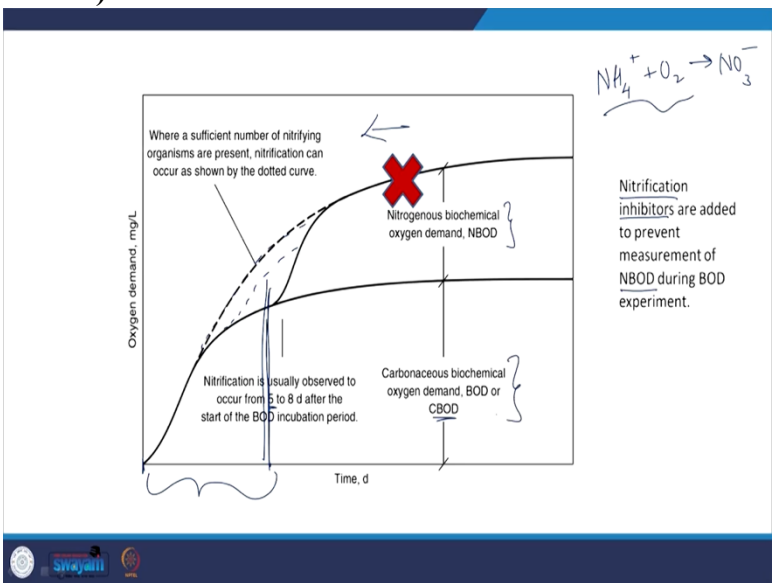

Let us look at this do I have that before I go further when I say we are measuring the BOD let us see what it is that we are actually measuring. On the x axis we have time on the y axis we have oxygen demand this figure is from the McGraw Hill book wastewater treatment oxygen demand. If we have a sufficient number of nitrifying organisms present nitrification can occur as shown by the dotted curve.

$$NH_4^+ + O_2 \rightarrow NO_3^-$$

Here we have 2 aspects or 2 types of oxygen demand 1 is the nitrogenous biochemical oxygen demand and 1 is due to the carbonaceous. Nitrogenous meaning, I have NH_4^+ in my solution let us see it can be oxidized to NO_3^- oxidized. This also will require some oxygen. Yes, but this will not take place when we have typically organic content or carbonaceous biochemical oxygen demand.

This will kick start or the kind of microbes that can lead to consumption of this nitrogenous biochemical oxygen demand will only take place or will only thrive in the absence of the microbes

that thrive in when you have these kinds of organic compounds. Typically, when we talk about BOD we are typically only talking about the CBOD. That is something to keep in mind. If I want to prevent this particular nitrogenous biochemical oxygen demand from being measured, what do I need to do?

I need to add nitrification inhibitors, I am going to add some compounds that specifically inhibit these compounds. Nitrification inhibitors are added to prevent measurement of NBOD during BOD experiment. In general, when will this come into play? Typically, as we see from here within the 5 day period we typically only capture the CBOD. But if the strength of the CBOD is less and my 5 day period is this.

This particular graph here will shift to the left and then even the nitrogenous BOD will be captured. In these cases, also you need to be careful and you will have to add the nitrification inhibitors. As I just mentioned nitrification is usually observed from 5 to 8 days after the start of the BOD incubation period. When sufficient number of nitrifying organisms is present, Nitrification can also occur as an NH_4^+ plus O_2. I will not balance in the equation here.

Finally ending up to NO_3 minus NO_2 minus and then and NO_3 minus. But I do not want this particular data typically only concerned with CBOD. That is something to keep in mind.

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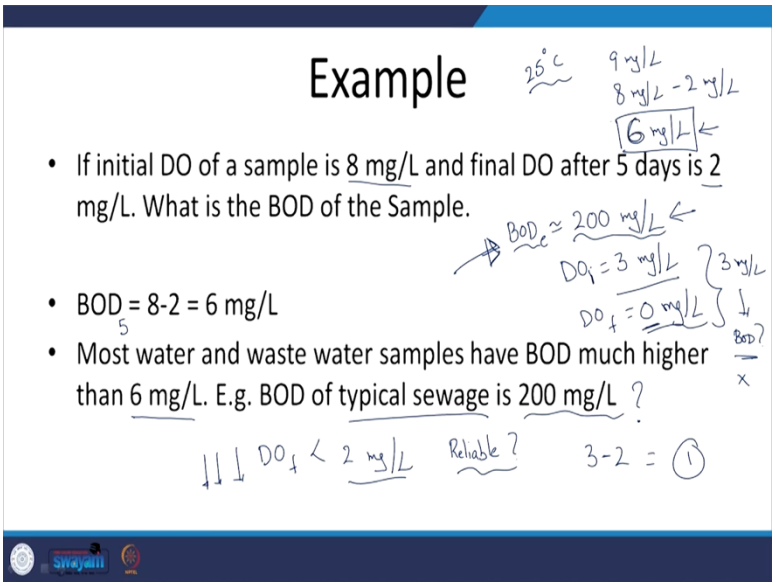

Example here that we have is initial DO of sample is 8, final DO after 5 days is 2 what is the BOD of the sample. Well, that is pretty simple. BOD 5 day is equal to 8 - 2 that is equal to 6 milligram per liter. But most water and wastewater samples have BOD much higher than 6 milligram per liter. Our sewage domestic sewage is around 200 or 150 milligram per liter. How do I measure this? Let us just see what the issue is if I try to measure it.

Before that I should have asked this question here. I would typically have a question here. I have my wastewater and BOD itself is pretty high 200 milligram per liter BOD. This is the estimated one. I do not know this I want to measure this. I know that the dissolved oxygen initial is already low because it is a sewage 3 it would not be typically as high as 3 milligram per liter.

If I conduct the test as I did previously, what do I do? I will take the initial measurement and after 5 days but because there is a lot of organic content the DO final will be 0, because all the dissolved oxygen will be consumed. Well, the difference which is going to be 3 is that going to be my BOD? Not. That is an issue? Also 2 aspects to keep in mind here is that if the DO final is less than 2 milligram per liter the test is not reliable.

Why is it not reliable? Because if the DO is too less the kinetics that we presume when we are looking at or analyzing our constraints are the assumptions, we make with respect to the growth of the microbes are not valid when the dissolved oxygen is so low the kinetics are going to be affected it is not going to be a pseudo first order loss it is going to be second order. Thus, your particular system is not reliable anymore.

If it is 0 that you cannot really estimate how much was left or how much of the organic content is left. Even if it is less than 2 we are it is not reliable. If it is the relabeled threshold is 2 milligram per liter. 3-2 only 1, I cannot really end up capturing the organic content here which is almost 200 milligram per liter. How do I do that? To do that I am going to dilute my wastewater as a 100 ml of my wastewater.

I am going to dilute it such that the change in the DO during my test is less than the acceptable value for example the maximum DO at a particular temperature 25 degrees centigrade.

DO maximum is around 9 milligram per liter let us be conservative and assume 8 milligram per liter is the maximum. I know that the lower threshold that I am fine with is 2 milligram per liter. The maximum change during my BOD test can be or maximum change in DO during my BOD test can be only 6 milligram per liter.

I need to dilute my sample such that sometimes it is certainly trial and error, such that the DO change is not too low if it is too low. You are going to have errors in your particular analysis. Or if it is too high you are going to have issues with reliability? You have to see to it that it is between 2 and 6 or 1 and 6 milligram per liter change in dissolved oxygen. Then you will be able to try to you will be able to back calculate and get the actual BOD.

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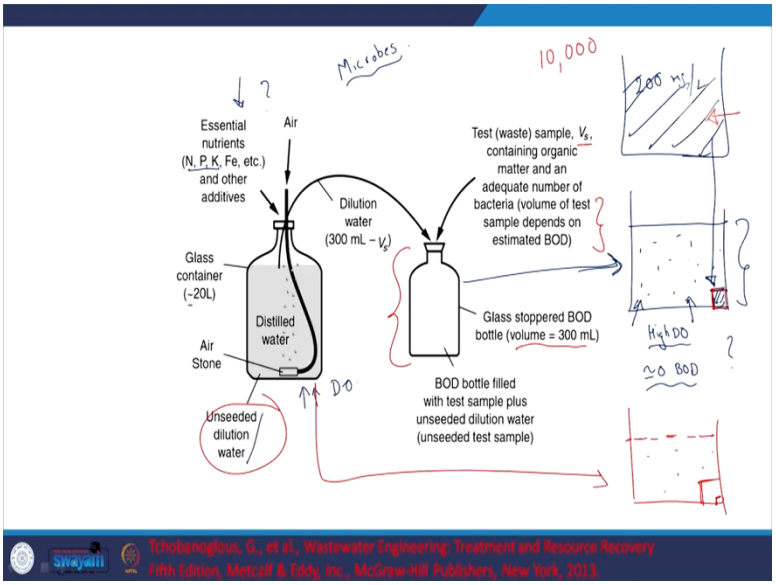

If the relevant compound or the organic compound is not in high concentration. Then I can get this done. Let me see what I have out here. I seem to have the one for the dilution water. First, I have to add microbes am I adding microbes out here? Let me see what I have. We have essential nutrients out here. Why are we adding the nutrients because you need microbes to thrive microbes in your BOD to test to thrive that is why you add these essential nutrients?

Air why are you adding air this is keep in mind the dilution water as I mentioned if my sample strength is pretty high what am I going to do and this is in this beaker let us see what am I going to do? I am going to diluted by bringing this out here add only a little of it that said this is my

sample actual sample and the rest of it I will fill it with dilution water which is what I have out here which will have high DO.

Almost 0 BOD that the total BOD in this particular sample will be relatively less, my high strength wastewater is now only a fraction of the total what we say diluted? Wastewater. For that I what do I need? I need this dilution water this dilution water, water part me which is high in dissolved oxygen has almost no BOD or no oxygen demand or no organics.

Also, I need to add microbes depending upon what we say the kind of wastewater. Here we are not adding the microbes unseeded dilution water. We are pumping air in why is it I want to increase the dissolved oxygen. That is why I am pumping air in and glass container and I am adding essential nutrients. Then this I will transfer it into my particular this is bottle into this container, then the test sample.

This is what we have out here the test sample the test sample V s containing organic matter and an adequate number of bacteria measuring that this wastewater already has bacteria. That is why I am not adding any bacteria. This high strength wastewater having adequate number of bacteria is added. Volume depends on the estimated BOD. For example, if the BOD is estimated to be 10000 I am going to add much lesser.

If the BOD is estimated to be 200 milligram per liter relatively higher. We will look at a particular calculation it should be clearer than and as I mentioned typical volume of this BOD bottle is 300 mL and then the rest of this 300 ml is made up by adding this dilution water as I mentioned and now I am going to have a sample that I can use to test for my BOD. How do I go about that? I have another particular case.

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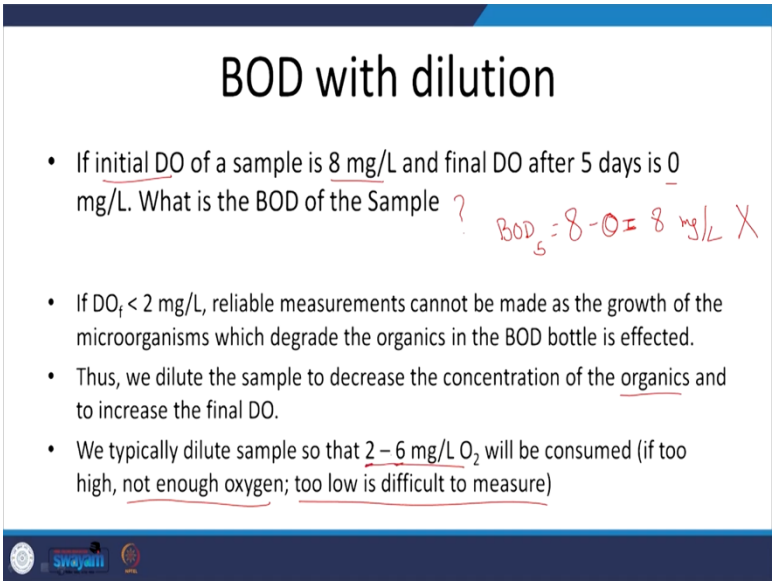

But this is what I already mentioned earlier. But I will just summarize here if the DO sample is 8 initial DO is 8 and after 5 days the final DO is 0. What is the BOD? As we know simple calculation says that the BOD 5 is equal to 8 – 0, 8 milligram per liter. But that is wrong. Because if it is 0 I do not know whether it is we still have organic content left or not say, it is not reliable.

As I mentioned earlier if DO final is less than 2 reliable measurements cannot be made as the growth of microorganisms is going to be affected. That is why as we just discussed we are going to dilute the relevant sample to decrease the concentration of organics or the BOD and to increase the final DO. We typically dilute the sample so that during the BOD test or after the BOD test 2 to 6 milligram per liter oxygen will be consumed. If it is too high not enough oxygen if it is too low it is difficult to measure? That is why we say we have thresholds of 2 to 6.

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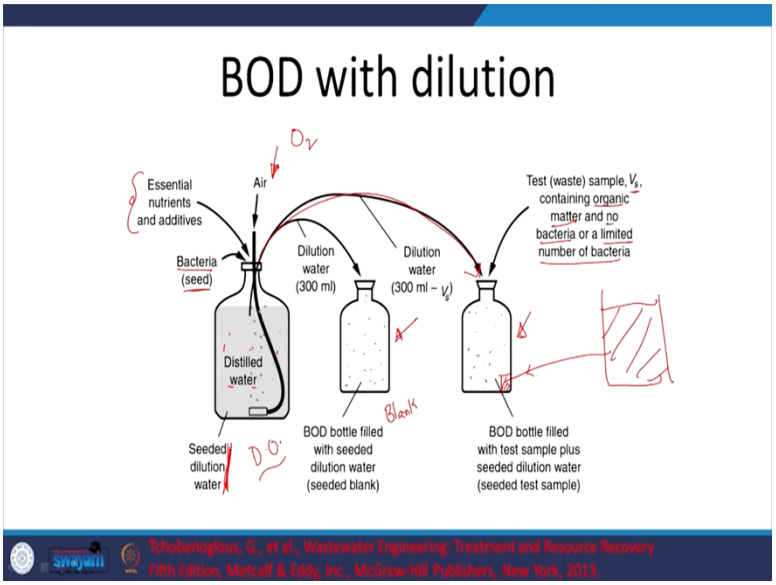

This is the case when I have to seeded. I am going to seeded with bacteria. Why is it because my sample from an industrial wastewater contains organic matter but has no bacteria or has limited number of bacteria. Thus, in my dilution water I typically I have to add seeded that are seeded meaning I need to see the relevant dilution water with bacteria that is why we call it as seed.

Then we add the relevant nutrients, we then purge it with air more or less we are trying to increase the oxygen or the dissolved oxygen in the water. As usual we are going to do this as if this is my actual wastewater sample. I am going to only take a little bit of it out.

Most of it I will fill with my dilution water from here let us see all of this will be my dilution water, because I am adding some seed that itself can lead to some BOD. That is why I will also have a blank which is only the seeded dilution water.

I will have to measure the BOD test for 2 samples 1 for this and also for this to check if there is any BOD In this sample also not in this sample in the seeded dilution water also.

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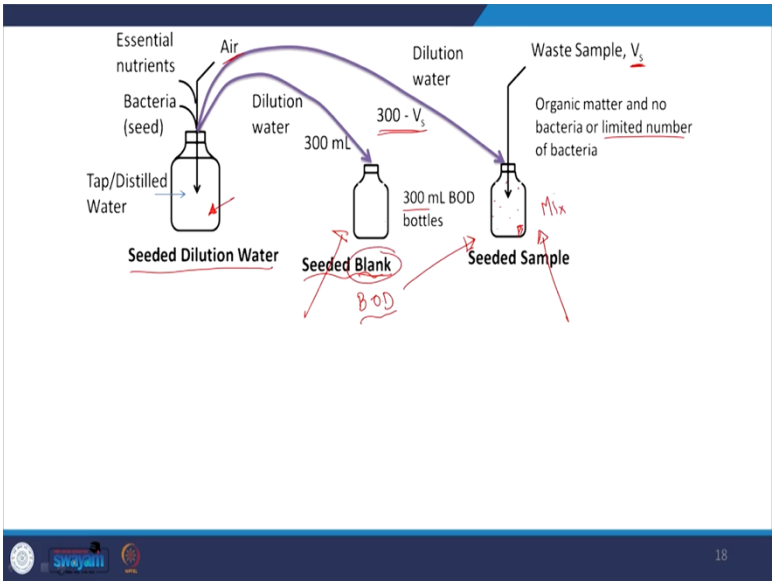

With an example it should be clear let us see what we have. As I mentioned, what are we going to do seeded dilution water we are going to what we say purge it with air and then add the bacteria and the nutrients. In the meantime, we are going to choose a particular sample volume based on the estimated BOD and put it into our particular BOD bottle of 300 ml. Why are we seeding because we have no or limited number of bacteria.

Then we are going to fill the rest of this particular BOD bottle with our dilution water. Because so what is the volume of the dilution water it is going to be 300 minus the volume of the sample. Then we have the seeded blank. To see if our dilution water itself has any BOD we are going to run the test on the seeded blank itself even though we call it blank we do not know if it might have any BOD which might affect this reading. That is why we have to measure the BOD of this particular blank to or the seeded blank to.

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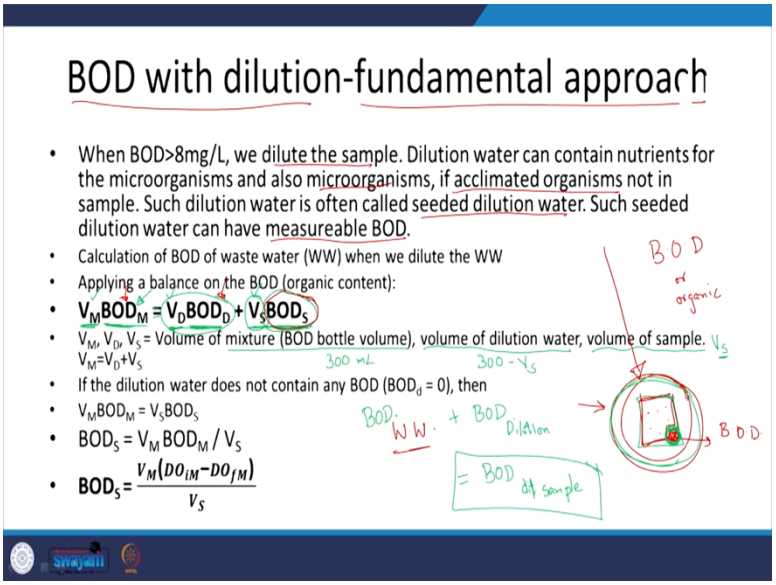

People typically look at what is it now dilution formula. But I am not one for mugging up formulas and search. I think 1 that floats around or the 1 that people usually use is based on the dilution factor or such. But we are people who are comfortable with using mass balance. Our approach is always about mass balance sheet. BOD with dilution we are going to look at the fundamental approach how to calculate the BOD of your particular sample.

For example, in this particular test what we were doing we were only getting or adding some sample and most of it was dilution water. But when I measured the change in DO, I am going to measure the change in Do for this dilution water. But I want to know what is the BOD of this particular wastewater that; I am concerned with? How do we go about that? A quick recap when BOD is greater than 8 we dilute the sample.

Dilution water itself can contain I mean will contain nutrients for the microorganisms and also microorganisms. If the wastewater sample does not have acclimatized organisms or microbes, such dilution water is often called seeded dilution water seeded dilution water can have some organic content or measurable BOD which will mess up our reading in this particular BOD test. Now I want to have or need to take this into account. How do I do that?

The aspect here that needs to be taken into account is that we can conduct the mass balance on BOD or the organic content let us see. The principle here is that or its mass balance. The BOD in

this particular sample plus the BOD in this particular dilution water will be equal to the total BOD measured in this particular seeded I mean diluted wastewater. 2 aspects what do we have? I have my wastewater.

Be with there is some contribution from this particular wastewater which is out here let me highlight it in a different color? Only some of this but there will be some BOD or the organic content mass but we will have to change the variables here from wastewater. Some of it will be due to this dilution water. But the total will be equal to the BOD in this particular diluted sample diluted sample it is.

More or less that is the mass balance out here. This is a batch reactor we are assuming that there is no mass coming in and going out. It makes our job easier. How do I get to this particular mass of the organics? It is not BOD concentration which always on the mass so volume of the mixture or the diluted sample into BOD of the mixture that what will that give me it will give me the total organic content in this system total system is equal to the contribution of the organics from the dilution water.

The contribution of the organics from the; what is this now sample now actual sample ? This actual sample is only a tiny fraction. That volume of sample is this into the concentration of the BOD in that sample is this. This will give me the mass of the organics in that particular sample. Similarly, volume of the dilution water into BOD of the dilution water will give me the mass of the organics in the dilution water.

But what is this going to be equal to this is going to be equal to volume of the mixture into the BOD of the mixture which is what I am typically measuring. What am I measuring? It is going to be the volume of the mixture into BOD of the mixture and I am measuring the BOD of the mixture. What do we have V M is the volume of the mixture BOD bottom volume which is 300 ml. Typically volume of dilution water and volume of the sample.

This is V_s this is what I know when I am conducting the test. Volume of the dilution water is going to be equal to 300 - V_s? What do I have? I already know V_M? I know V_D. I know V_S. That is what

I am going to start with. When I conduct the BOD test what else will I typically know? I will know the BOD of my particular sample not sample the mixture BOD my mixture is what I am getting it from the relevant test.

Because we are going to conduct the BOD test twice 1 on the mixture this is the mixture and once on the blank. From the blank I will get this BOD of this dilution water or BOD of the blank. From this you see that I have only one unknown which is BOD of sample so I will be able to get that. Let us me just look at a question if I have one out here.

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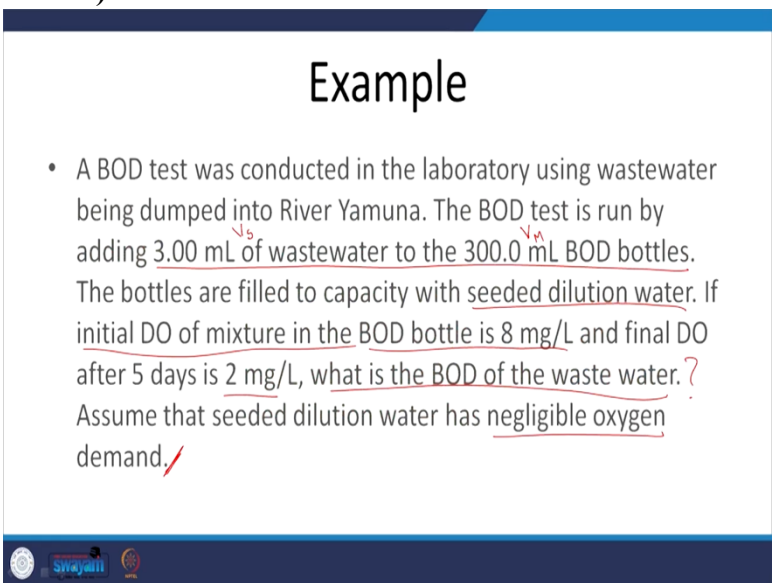

BOD test was conducted in the laboratory using wastewater being dumped into the river Yamuna. BOD test is run by adding 3 ml of wastewater to 300 ml BOD bottles, so what is this 3 ml it is the volume of the actual sample. The volume of the mixture total volume is 300 ml the bottles are filled to capacity with seeded dilution water. Initial DO was the mixture in the BOD bottle is 8. The final DO was after 5 days is 2 what is the BOD of the wastewater Assume that seeded the dilution water has negligible oxygen demand this makes the job easier.

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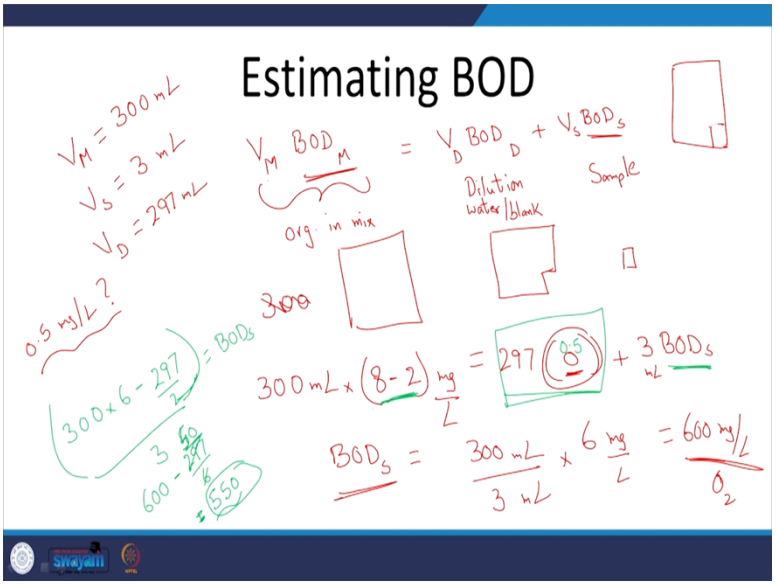

What do we have we know that volume of the mixture into BOD of the mixture. This will give me the organics in the mixture. It will be equal to the volume of the dilution water into BOD of the dilution water plus volume of the sample into BOD of the sample. This is what I am actually trying to get it. From above or from the question what do we have we know that volume of mixture is given as 300 ml.

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

We see that volume of sample was given us 3 ml volume of dilution water is then going to be the difference 300 – 3, 297 ml let me just check the numbers. BOD test is run by adding 3 ml of the actual wastewater to 300 ml BOD bottles. The bottles are filled to capacity meaning the remaining is filled with or made up with seeded dilution water and initial and final is given of this BOD mixture.

Volume of mixture is 300 ml this is for the dilution water or sometimes people call that the blank. This is for your sample actual sample as in here is the figure. If I have this and this let me set the sample is this fraction and the dilution water organic is this fraction. The BOD of the mixture is the entire thick. That should hopefully clear up the issue for anyone who is still confused.

300 ml volume into BOD of the mixture, what is it that we have? We know that it changed from 8 - 2 milligram per liter. This is the change in DO will change in DO was equal to the BOD. That is

what we have. Here I have 297 into the BOD of the dilution water. But what do I see we see that the seeded dilution water has negligible oxygen demand. It has negligible oxygen demand meaning it is 0 plus volume of the sample we know is 3 and BOD of the actual sample is what I am trying to calculate.

What do I have BOD have the sample or the actual wastewater is going to be equal to this is in ml. That is why I do not need to change the units 300 ml / 3 ml into 8 – 2, 6 milligrams per liter of oxygen. Here it is 100. It ends up being 600 milligram per liter of dissolved oxygen in terms of oxygen demand. The BOD of the sample is going to be equal to 600 milligram per liter.

I seem to be moving on to another aspect. I want to slightly change the previous question. Instead of saying that it is 0, if I say that the BOD of my particular dilution water is 0.5 milligram per liter. How will this system change? Let us also look at that. I will have to instead of 0.5 here I will have to put in instead of 0 here pardon me I will have to put in our plug in 0.5.

As you can see them the BOD of your particular sample is going to be lesser because this mass will go out here and we have to subtract it. 300 into 6 - 297/2 whole divided by 3 write so that is what it is going to be equal to the BOD of my sample. This we know is 600 – 297 / 6. I mean I should not make it 300. But let me try to calculate or if I make it 300 for easier calculation.

It will be 50, 600-50. I will end up with 550 or it is maybe 49.5. What do we have? I see that if the dilution water had some BOD, I see that my sample BOD will be lesser than when my dilution water had no BOD. But that is just a theoretical case assuming that the total change is still the same. That is just a theoretical aspect that I wanted to mention out here.

I am almost out of time with that title end the session. But to repeat we are not going to look at General formulas. Here the approach is mass balance I have a total that has dilution water some dilution water and some actual wastewater. Here our approaches the total mass of the organic content which are measuring by the BOD. This particular mixture is going to be equal to the organics in the dilution water plus organics in that small sample of your wastewater. That is the approach out here. With that as I said I am going to another session. Thank you.