Fundamentals of Environmental Pollution and Control
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Lecture No. # 07
Water Pollution Modeling – Surface Water (Contd.)

So to start with you know today we will begin with the discussion on this biochemical oxygen demand, biochemical oxygen demand, biochemical oxygen demand, biochemical oxygen demand you just write you know, you can write it carefully, right. Important, two important things that I have said earlier in the classes let us begin I mean let us, let us deal with this oxygen demand part as such.

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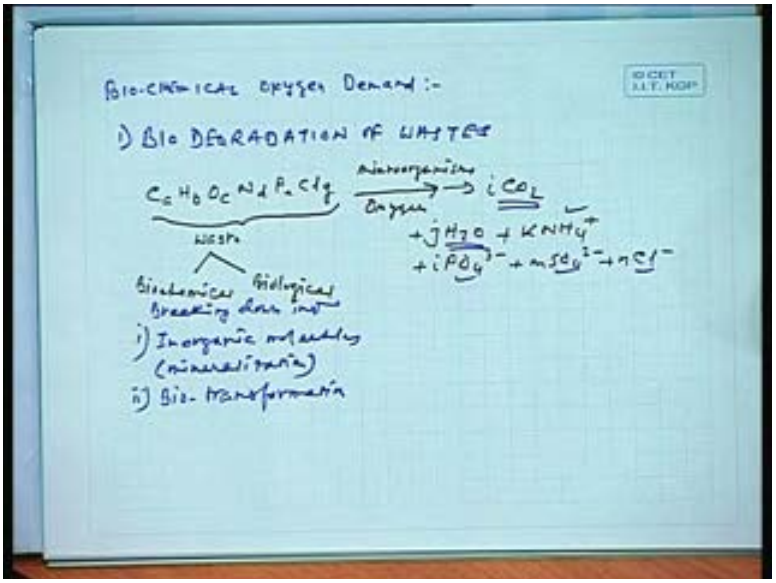

See here there are two, two differences, few differences to be made one is you know when your discussing biochemical oxygen demand before we go in to the detail of bio chemical oxygen demand I want to discuss about two things. This is number one is, this is very important for engineers outside or the environmental is working outside say civil waste or say sewage waste like this. Most in cases I in the last class also, classes also I discussed this biochemical waste is the nature of the bio chemical waste that I have said the human excreta say that the dead bodies then you know urinations, excreta then you know dead bodies, leaves, dead leaves, all these comprise of biochemical oxygen demand.

They are, these substances are mostly in the nature you know they call that they are, they are of biochemical origin and that is why since they have a very great demand in fact as I have said that mostly the environmental engineering started with sewage and sewage engineering. So, you say basically there is a, there is a strong correlation of biochemical waste so in environmental engineering but as such there are few things to know about this you know biochemical oxygen demand or oxygen demand as such.

What happens is there are one important part here is to this general biodegradation of wastes, you know this is what you would say biodegradation, degradation, biodegradation of wastes, biodegradation of wastes, right. The biodegradation of wastes you know this can be very well be you know we just try to see this from this plot here you know from this screen given horizontally, okay. So, mostly see this bio degradation first we can write on a particular say equation which should be incomposing that complete reaction that actually takes place say know C this is carbon being a very integral part of this kind of resources, this kind of wastes okay. A waste you see is basically the nature of this says a nature of, this is the mostly what you would find is C_a H_b O_c N_d P that is you know phosphorus and chlorine. This is a typical waste, this can be you know any waste or any organic compound that can be but this one is not necessarily a biochemical waste.

This is not necessarily a biochemical waste in a, in a sense is a typical waste, this waste, a part of this waste you know it can be a biochemical origin, bio chemical origin another is biological origin, right biochemical and biological origin. So, mostly the substances, this is what will be the waste would be generally made of this waste, this waste when it is, when it is being converted as a biodegradation it can be in the presence of oxygen, in the presence of oxygen or in the presence of other substances on microorganisms, microorganisms and oxygen and oxygen. It would form, it would form two important things. Two important things is you know i Co_2, Co_2, j H_2O, j H_2O, KNH_4 remember this, this is NH_4, this nitrogen in water would be mostly available as an ammoniacal radical Po_4 minus 3 minus plus M SO_4 2 2 minus plus n Cl minus, nCl minus. So you can see this would be the mostly, mostly the reactions that we generally observe in cases like this.

Here you know if we just see this you know in this place particularly that you know this is the decomposition taking place with the, in the presence of the microorganisms. Now, the two things to understand here, why these microorganisms do it? In nature nothing takes place; nothing happens without a cause, nature would always form anything that forms in nature. Nature is basically always takes something with a cause and nothing takes place as an accident or nothing takes place just as it is I mean without a cause, everything has a cause. The cause here the microorganisms need them because there are two things, first of all this waste here, this waste here would be mostly in the form of, mostly possibly in the form of solids or also they may be in the form of liquids dispersed in water, okay.

So, there is just like an urination is biochemical waste which is a liquid but it would be dispersed in water number one or it can be solid waste also. So in case cases like that if it is a solid waste, if it is a solid waste microorganism should have to break them down so that they remain soluble in water or at least you know at least even if it is not soluble in immiscible state in the water and in a liquid form, immiscible doesn't mix with water but remains in a liquid form or it remains as a soluble form in water, these two things are very important. Only because in such cases only a single or single microorganism cell, a single microorganism cell can draw it as a food by an osmotic method, understood. So the osmosis is takes place when there is a change in the potential from the, from outside, outside potential to from positive to negative potential it take place. Since there will be a potential difference, so the substance from the external environment would enter to the cell, enter the cell, okay.

So, this is where you know this is where the microorganisms need to break them down, this remains as the most important reaction I mean that is that can be, that can be exemplified as the possible as the cause for, as the cause for the total human life, total organism life or total organic say the population that you see is basically just because you know this has resulted into a wastes getting decomposed and this is how you know otherwise you just consider the thing. If the microorganism should not have been there, the waste should not have decomposed at all okay. So this is where the microorganisms play a very very important role and that is how it gets you know, gets decomposed in two ways. The first of all that this process should be known as one is called as the, one is called as you know into breaking down, breaking down, is breaking down into, breaking down into, breaking down into just see this breaking down into a say this inorganic molecules.

We called it as mineralization and the second one is, the second one is we would call this as biotransformation, transformation, biotransformation. See this one here, this one is, this one is inorganic molecules mineralization whereas this one is the bio transformation in a, see in the form of, in the form of ions in the, in the form of ions mostly forming in the place of sudden extent in biological materials. So, this would be mostly it is not in the molecular form, it would be in a radical form like this which should be or which should be mostly readed like this. So here you can see this is would be mostly in the biotransformation. So two processes essentially take place and this takes place only because there are the microorganisms are active, the microorganism, microorganism organisms are leading this reactions that is because you know they are agents of these reactions and they are taking place in the presence of oxygen.

So, this is one reason you know why oxygen gets depleted, why oxygen gets depleted in most of this in the, in the water body itself. Apart from this, apart from this if we just observe now, if we just try to observe it now you know here in a much better detailed now that I can see it you know here this the two things you know that it would be observe let me explain you little bit on this.

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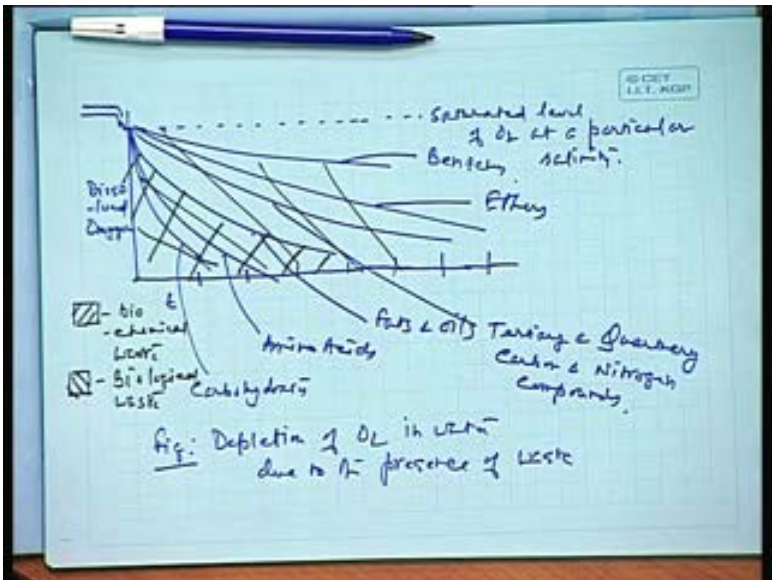

Say you know if a waste is introduced at say this is, this is if you just see the plot here, if the waste is introduced, if the waste is introduced just one minute, if the waste is introduced here we can see now this is where the waste is introduced. Suppose any, from any process or the waste is being dumped here say you know here it is waste is being dumped here, so here at this point the waste is being discharged here, okay. Now here as you can see this is the, this is the saturated level of oxygen in this water at this particular salinity. This is saturated level of oxygen at particular salinity right. This is, this is the water, the waste has been introduced in this. What would happen is that you know the saturated level of oxygen if you just say this dissolved oxygen, dissolved oxygen and if you say it time, time saying days if you just try to see you know in 1 days, 2 days, 3 days, 4 days, 5 days like that you know 6, 7 it can carry on, in fact it can carry on so it's if you just observe this curve now depending on the nature of the waste, depending on the nature of the waste you see this the depletion of oxygen in the water would take place I mean the rate of, rate of depletion of oxygen, rate of depletion of oxygen would depend on the nature of the waste, remember this nature of the waste.

So, you can observe a plot like this, you can observe a plot like this, you can see this is like this, you can see somewhere it is not going like this say this is, so if you just observe, if you just try to observe this some of the substances here or some of the substances like here you can see this is mostly, mostly you can find out, mostly this you know mostly if you observe this, this is mostly the, this carbohydrates. Carbohydrate should be forming this kind of, this kind of plot, right. This is just you know a notional I mean don't try to always try to say special kind of carbohydrates may remain, may follow a suddenly different curve, this is just to for a comparison. Say here this one is you know this is, this is say you know if you just closely seeing this, if you this be amino acids, amino acids okay this one would be, this one would be say fats, fats and oils, fats and oils. So this is, this is, this is say you know tertiary and quaternary, if this is say tertiary, tertiary and quaternary, quaternary, carbon and nitrogen compounds, okay.

Similarly you can see this would be ethers. If you see this, this may be, this is there mostly that you know benzenes. So this is what you know, this would be generally you will not find in any text book but this is what would be the mostly the nature of the plots, this is what would be the mostly you can see this would be the mostly the plots. So you know this figure is, this figure is to suggest, this figure is to suggest that that is depletion of, depletion of oxygen in water due to the presence of, due to the presence of, due to the presence of waste. We can see this, if we just try to observe this now here in such cases, in such cases interestingly here when we are talking about most of this biochemical waste, most of the biochemical waste, this mostly the biochemical waste should be around this region. This is mostly the biochemical region, you can see this, these are all the biological other waste, other waste should be here so mostly you can see this, this biochemical waste you know this, this would be primary level hydrocarbons, primary level hydrocarbons mostly this is would be the formation of the, this would be, this one would be showing the biochemical wastes.

So this is, this is about the biochemical waste, this is about this biological wastes, all right. Biological and biochemical waste, this you can see the relationship. Now for remember one thing I mean this is for most of the pollution engineering or in the waste water engineering that we generally discuss about, mostly we discuss about this region only. This is the hashed portion that we generally discuss that the other portion you know here you can say see of this if this, this can

be explained like this, this would be the total biological waste. So this would be biological waste, biological waste okay.

So this is what you know, this is what we generally observer at. This is a depletion takes place, this is how this, the behavior of different wastes in water. What is we are trying, what we are observing here in this case if there are no further addition of water or no further source of oxygen being supplied to water, the amount of oxygen in the water would continuously go down and go down till it reaches almost 0, almost 0, right. This is, this would be clearly you know if the waste concentration of waste is very heavy in such cases the oxygen, concentration of oxygen in the water would go down as much as 0, as much as to 0. So there will be almost no water, no oxygen available in the water. Hence this is one part that is you know of great significance for our work, for our study here. We would also see that this whatever we just see there are few things that I want you to, want you to understand this is the fats and oils, fats and oils are less biodegradable, less biodegradable than carbohydrates, fats and oils are less biodegradable than carbohydrates, carbohydrates.

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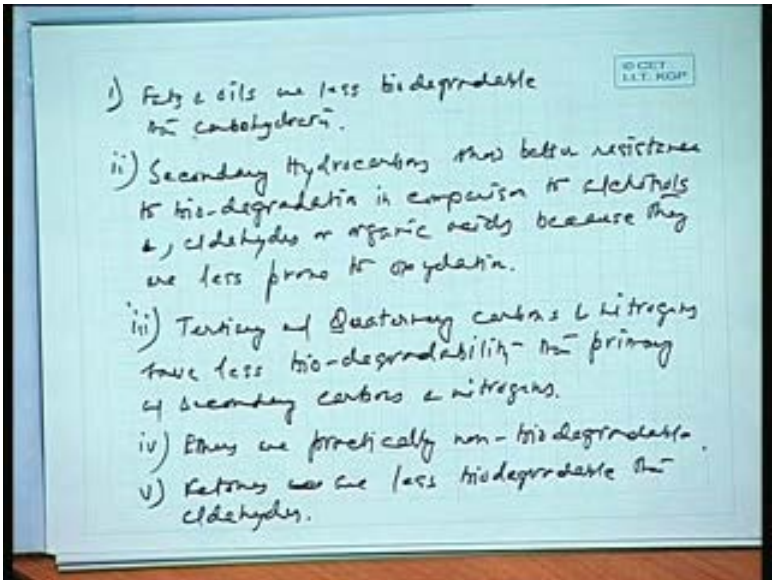

This is number one then this is secondary hydrocarbons, secondary hydrocarbons show better resistance, better resistance to biodegradation, biodegradation in comparison to, in comparison to alcohols, alchohols and aldehydes, aldehydes or organic acids or organic acids because they are less prone to oxidation, they are less prone to oxidation because they are less prone to oxidation. Third, if you just make this, this tertiary and quaternary, quaternary carbons and nitrogens have less ability than primary and secondary carbons and nitrogens, right. You can see this, this is as these are going for higher bounding, as these are going for higher bounding increased, it is going in the, in mostly if it you think of organic chemistry where you start with alkenes, alkynes right then hydrocarbon, carbohydrates, alkenes, alkynes and then you finally you go about this benzene ring and further then you go see say go particularly into high graded metal hydrocarbon complexes, all kind of thing wherever you are going from one stage to another, their biodegradability would be going to go down, would be less continuously, would be continuously

less. This is what is very important for us to understand and you say from say primary, the primary basis for environmental control, primary basis for environmental control. Ethers are practically non-biodegradable, so this organisms do not have almost any effect on ethers say this ethers are say this 5 ketones are less biodegradable, less biodegradable than, ketones are less bio degradable than aldehydes, than aldehydes right. Ketones are less biodegradable than the aldehydes, okay. So, you can see this you know the what I am mean to say here, remember one thing never I have said that all this substances came here of only out of biochemical origin, they can be outside also and primarily outside because most of this substances are outside the biochemical range.

They are not produces, produced by, mostly by this by biochemical substances, biochemical substances are mostly related you know to finally mostly related to organic acids, secondary hydrocarbons, primary hydrocarbons, secondary hydrocarbons some of them aldehydes, organic acids some substances like that but not in the higher organic groups okay. So, having said all those thing you know this is particularly, there are few process that actually reduces, there are biodegradation you say this is biodegradation. All this you know in the process of biodegradation that we have said you know mostly for all kind of wastes, this is one is something with the oxidation.

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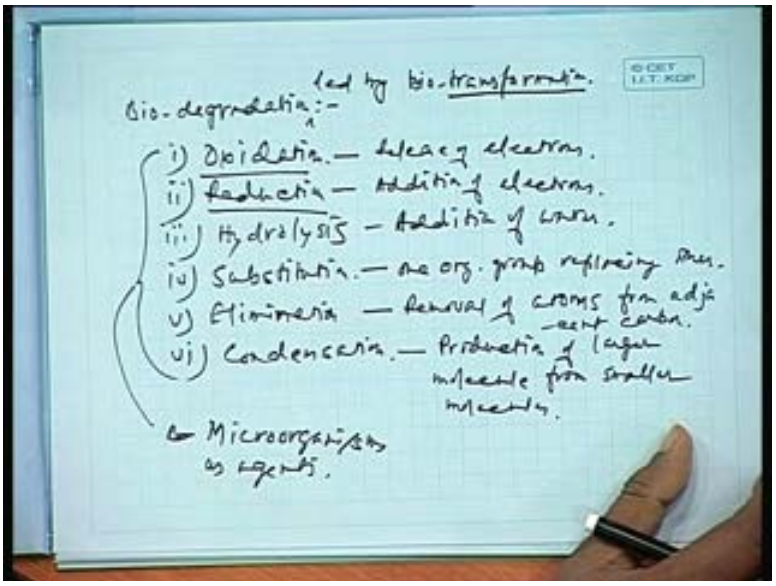

One process that leads biodegradation is oxidation, reduction, hydrolysis, substitution, elimination right. These are this biotransformation you know biodegradation, bio degradation led by, biodegradation led by biotransformation. So, biodegradation led by biotransformation I mean the transformations that take place it can be oxidized, it can be reduced, it can be hydrolyzed addition of water, addition of water, substitution, one group replacing other, one organic group replacing other, one organic group replacing other, elimination. Elimination refines is removal of atoms from, removal of atoms from adjacent carbon and condensation, you know condensation where you can see this production of larger molecule, production of, release of electrons as you know this oxidation and addition of electrons. In all these cases, in all these cases number of

several microorganisms can be an agent. This is microorganisms, microorganisms as agents so microorganisms not essentially does only you know only in the case as we have seen not only does, not only does decomposition of wastes, it can decompose it can transform also. The most important thing that is you know this more than bio decomposition, what we have been talking about biotransformation, this term is more appropriate because is not necessarily always oxidation would take place okay.

So having said all this you know there are, these are the most important things about this bio, this is when we are talking about the oxygen demand, oxygen demand and particularly the oxygen demand in cases of biochemical oxygen demand mostly. So a, remember one thing is so here we can say one thing here. This is biological, biological, biological oxygen demand would be here.

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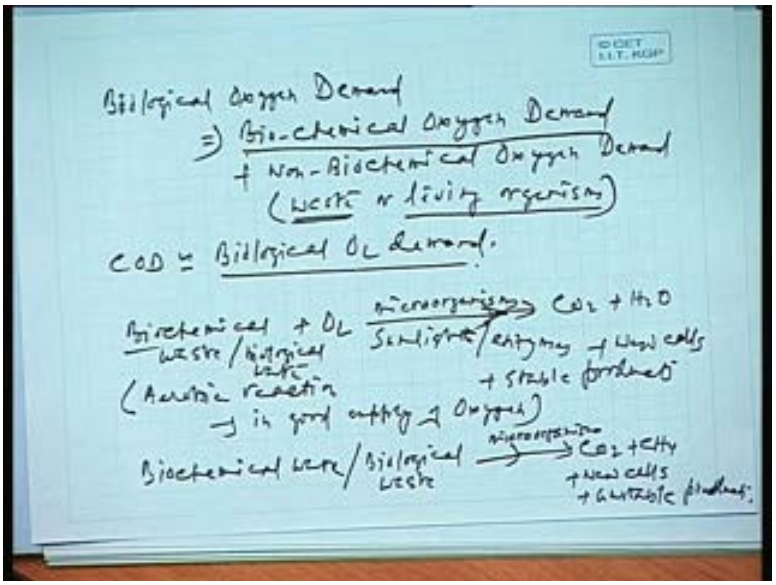

This is say biochemical oxygen demand, biochemical, biochemical oxygen demand plus non-biochemical oxygen demand, demand say from biochemical say this is waste, waste or living organisms, waste or living waste or living organisms. So, we can see this you know waste or living organism, we can observe that in this biochemical oxygen, biological oxygen demand would include this. So here a biochemical oxygen demand plus this non-biochemical oxygen demand wastes out of the source of biochemical, out of biochemical sources and also some of this living organisms plants and, plants and, plants species and animal species or any kind of species that you can think of.

So this would be, this is the total biological oxygen demand. In fact when we are, when we are finding COD we are finding COD mostly we are finding, mostly COD is almost similar to this biological oxygen demand, oxygen demand, biological oxygen demand. COD is essentially biological oxygen demand right. So here this is one, once we make a distinction, once we make a distinction like this you can see now that you know there are essential distinction that we have made you know in most cases as we have known for that you know most of this biochemical sources, most of the substances of bio chemical origin can and also a biological origin can be

easily decomposed into, easily decomposed into other hydrocarbons, other hydrocarbons and most of the very convenient way of saying this is that the biochemical waste plus oxygen is plus oxygen, this is microorganisms, microorganisms, microorganisms, is the microorganisms also you know sometime you know which must also need a source of energy. We need a source of energy, source of energy is also very important. So sunlight, sunlight I mean the sunlight or any other two substances, any other, any other sunlight or enzymes, different enzymes that we can generally find out, we generally find out that you know they can decompose into CO_2 plus H_2O plus new cells, new cells, new cells plus stable products.

This is mostly, this is mostly the aerobic reaction in oxygen. As oxygen begins to deplete, as the oxygen begins to go down, as the oxygen begins to go down the same reaction, it's a same reaction would be say this oxygen you say bio chemical waste. Remember this biochemical waste or biological waste, don't make any distinction biological waste, biochemical or biological wastes, biochemical waste or biological waste, biological waste getting immediately converted you know in the presence of this microorganisms remaining there but generally for all your information the microorganisms also change, microorganisms also change. These are aerobic microorganism they would be mostly anaerobic microorganisms right aerobic and anaerobic microorganism in, mostly in all this cases we find that CH_4 plus new cells plus unstable products, all right. We can see now, you can see here unstable product, unstable products, right.

So, we can see that you know how best, you know how best we can basically explain that you know this situation here that where it is when the water is having, when the waste is immediately dropped, immediately dropped and the oxygen is not yet depleted at this point of time we will find that first one. This the, this particularly the aerobic reactions taking place okay, aerobic reactions taking place. As the oxygen level would be deceased also the sources of energy would be decreased, sources of other source of energy, so sunlight getting decreased or we are not allowing another other energy source to go into in such cases generally in the deep of water, in the deep of water if you consider you know in the depth of water in the, if you see the top column of a pond would be mostly be, mostly the reactions that we generally observe would be aerobic reactions but as you go in the depth when there is a rays of sunlight and also the water is depleted of oxygen. In such situation we would find the second stage if the biochemical waste or biological waste getting depleted by this inorganic this by depleted by the microorganisms, anaerobic microorganisms in the absence of oxygen and sunlight to form carbon dioxide, methane, carbon dioxide, methane, new cells and unstable products. So this is how, this mostly this organic substances get decomposed in water okay.

Now having said this that you know there is a, in a very standard thing that we generally find out that you know 5 day BOD test say one, okay. The parameter in terms of reducing level of oxygen, the parameter that explains the nature of waste in terms of reducing level of oxygen with time is known as BOD, right biochemical oxygen demand, biochemical oxygen demand.

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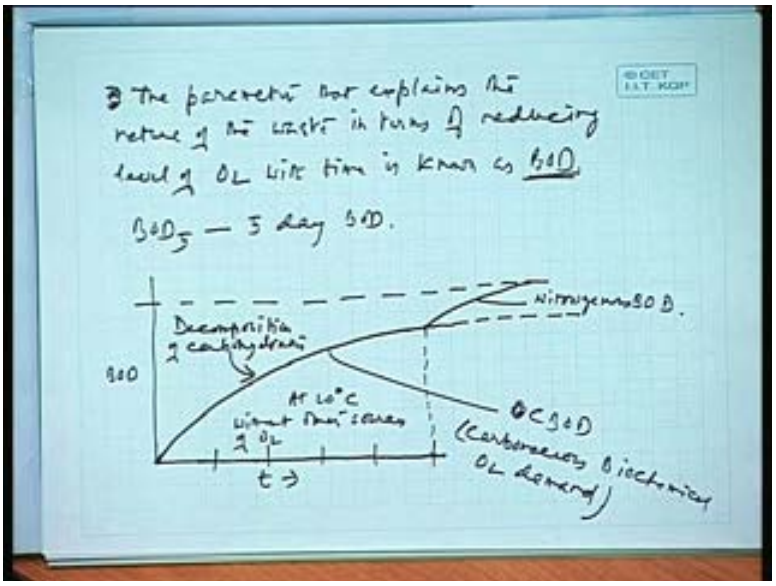

What is the demand of oxygen or in other words what is the demand of oxygen by the waste, what is the demand of oxygen by the waste, what is the demand of oxygen by the waste. One very conventional way of using this 5 BOD, this is BOD is this called 5 day BOD is called BOD 5 or 5 day BOD. Why BOD 5, let me explain this here itself. This is what you know if you just observe a particular waste, if it is a biochemical waste mostly a typical biochemical waste, remember this, this is a typical biochemical waste.

This is biochemical waste so this is you can see this biochemical oxygen demand, this is what is in relation to time. If you just observe you know first most for say five days if you see 1 2 3 4 5, mostly if we are trying to observe this, this DO as soon as it is dropped in the water before till that time water does not have any oxygen demand. As soon as the waste is dropped into that the oxygen demand is rising but at a increasingly flatter rate right. The rate would be, the rate would go down, the rate would go down like this. The rate would go down but it would still, the demand of oxygen would be higher, the oxygen would be, so demand of oxygen would be like this.

So what is what happens now is here in such cases it is, it is observed generally mostly at 20 degree centigrade, at 20 degree centigrade, at 20 degree centigrade without other sources of oxygen, without other sources of oxygen with thereby making sure, making sure that there are no other sources of oxygen supplied or given to the water. In such cases what happens is this is what would be, this is what is this you know this is how this BOD would increase, biochemical oxygen demand would increase. And then finally what happens after 5 days, this is, this zone, this is particularly what is observed is this particularly is basically the decomposition of the, this, this decomposition of, decomposition of hydrocarbite, hydro carbohydrates like any, for any kind of waste carbohydrate say you know if it is a, if it is a dead body say you know it is a dead body. If the dead body is generally thrown into water or if it is ratting in the water first 5 days we observe that this oxygen, the requirement of oxygen is just to oxidize this hydrocarbons. This carbohydrates, this carbohydrates would then this carbohydrates would then what we observe

now is after 5 days at 20 degree centigrade, we generally observe that this particular the demand of the, demand of this, this carbohydrates this call this carbohydrates or we call them carbonaceous products would remain almost constant but here we would find another increased value of you know we will find that there is another demand increasing at this point of time. At this point of time we are finding another demand increasing. See this would be mostly this is, this demand, this demand can continue for a long time, this is called nitrogenous, nitrogenous substances, so nitrogenous oxygen demand.

And this is, this part is this, this is a nitrogenous biochemical oxygen demand NBOD. This one is known as CBOD, okay. This would be known as carbonaceous, carbonaceous, biochemical, biochemical oxygen demand, carbonaceous biochemical oxygen demand okay, this is carbonaceous biochemical oxygen demand. So what we find out in BOD 5 essentially is carbonaceous biochemical oxygen demand all right. We find out mostly this carbonaceous biochemical oxygen demand. This oxygen demand would take place till what time? Till the time the, that all the, all till the time this, the oxygen is completely depleted out of water after that there would be decomposition would almost go down very slowly unless there is a source of oxygen or anything like that till that point of time the decomposition would not take place okay.

I think you know say we will stop at this point right one minute. We will stop at this point I mean there may be the, I have asked for two classes in fact. So this is we are just you know now at this point of time, so here we can see now that you know if we are given a class we will take the same class otherwise you know we will just be off here because all right.

Preview of next lecture:

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So, we were discussing about this BOD that the biochemical oxygen demand and then let us find out you know initially the, in the beginning you know that we have said say this determination of

one important thing that is determination of BOD, determination of BOD. The standard let me go it by, do it by step by step.

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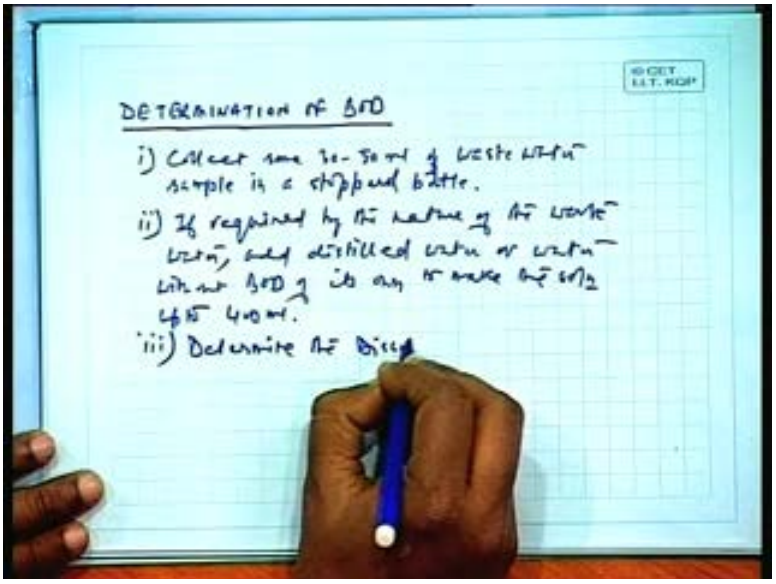

Say this is number one collect, collect some 30 to 50 milliliter of waste water sample remove this, waste water sample in a stoppered bottle, in a stoppered bottle, in a stoppered bottle. If required, if required by the nature, nature of the waste water, waste water add distilled water or water without BOD of its own to make it, make the solution up to 400 ml, 400 ml, up to 400 ml, 400 ml. Determine the dissolved oxygen otherwise if the BOD is very low in a sample waste water, if the BOD level is very low in sample waste water suppose you generally have a water which is having a very low BOD of its own. So, in such cases you might find that at the end of the fifth day there is no depletion of oxygen because the reaction rate is so slow that in no discernable change has taken place no observable change has taken place.

So, if you put BOD as seeded BOD if you just use, if you just use some water having its own BOD then in that case you find out that the reaction takes place very at a faster rate and we will observe that the oxygen, the depletion of oxygen is at a faster rate and we will find a considerable decrease in the oxygen, decrease in the level of oxygen in the water okay. So this is why this is called seeded.

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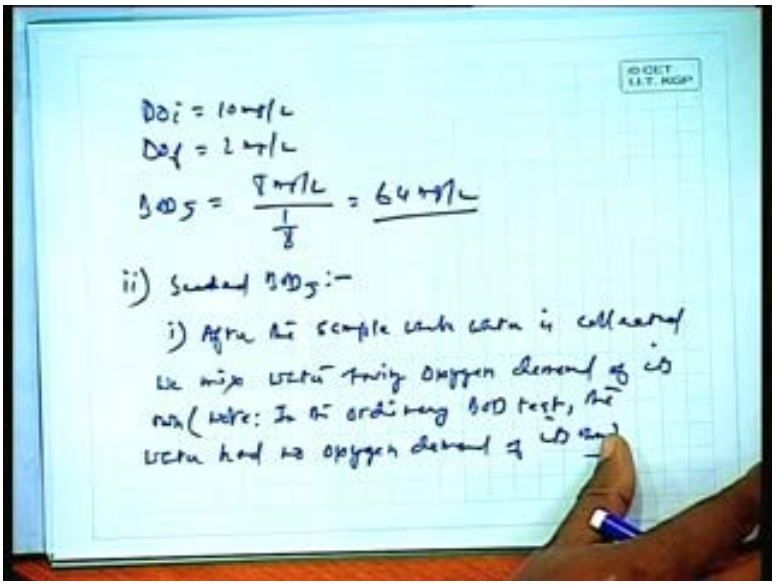

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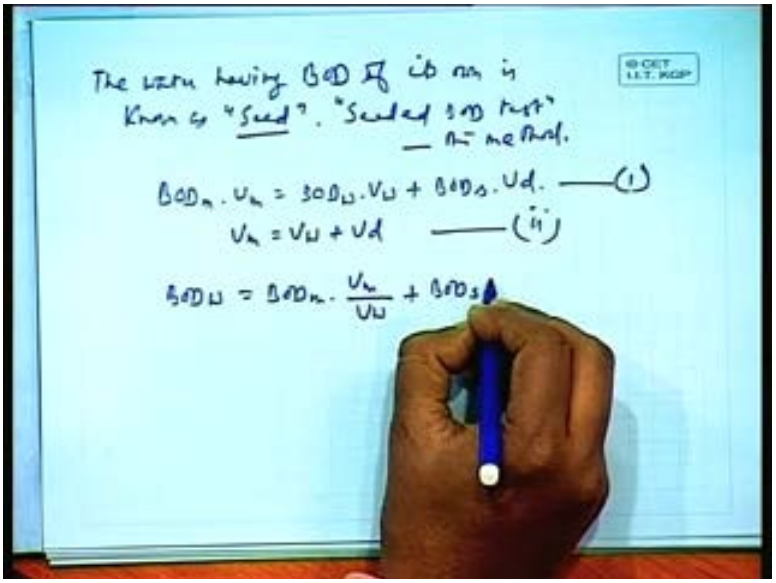

This is the water having, the water having, the water having BOD of its own is known as the water having BOD of its own is known as seed and the method is known as seeded BOD test. This is known as seeded BOD test, the experiment the method seeded BOD test. So in such cases what we find out is we can very well write is like this BOD of the mixture into the volume of water, volume of water that the mixture volume of, the mixture is equal to BOD_w waste water, volume of the waste water plus BOD of the seed BOD, BOD okay, BOD of the seed and BOD of the, BOD of the seed and volume of the seed right. So in such cases there are other things that we can find out is V_m is equal to V_w plus V_d, so we can find out one way of this thing here, two here and as you can find out from here this is if you just can find out like this. We can say this BOD

of the waste, BOD of the waste can be written like BOD of, BOD of the mixture divided by V_m divided by V_w plus BOD_s as an integration here it is just it would begin from L_0 into t, Lt L_0, L_0 into t when there is no demand, when there is no demand this is say this should begin from here and this one is minus k k_t as you can see here.

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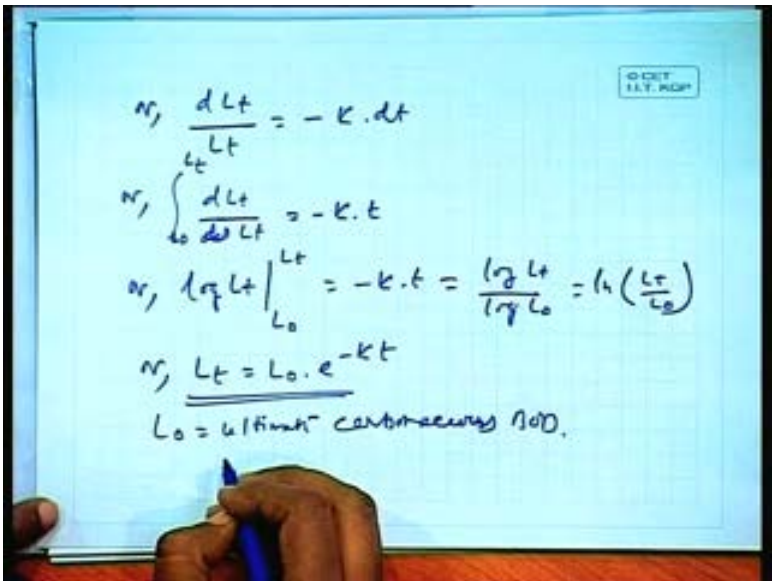

So here it is log, log, log Lt, this is L L_0 to Lt and this is 1 minus k t or you can find out that this would be essentially this is what we can find out L_t is equal to L_t would be, L_t is equal to L_0 into e to the power minus k_t, minus so it comes L_t log L_t divided by log L_0. So this one is if L_t by L_0 is would e to the power minus k_t, so L_0 your bringing in there, so L_0 into e to the power minus k_t. So this one, this one is it says that that at any point of time L_0 is known as, L_0 is known as the ultimate, ultimate carbonaceous, remember this carbonaceous, ultimate carbonaceous BOD.

This is known as ultimate carbonaceous BOD which is nothing but as you can see log, log as say L_t, this is log L_0 or say this one is e to the power so you can find out this, so this is, this is, this is log L_t divided by L_0 so you can find out like this. So, here as you can see this one is the ultimate carbonaceous biochemical oxygen demand, ultimate carbonaceous biochemical oxygen demand so you know in case if we are just plotting it now this you know this you try to see this.

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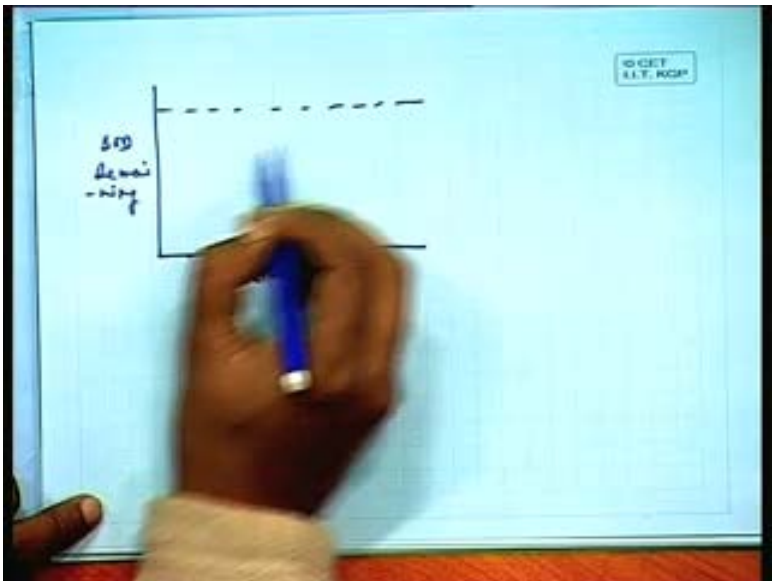

BOD remaining and if we just put time here, BOD remaining and if we put time here this we can see that may not require to decompose with the help of oxygen or in the presence of oxygen. So in such cases this is not absolutely what is more important in cases of this are the metal solubilities.

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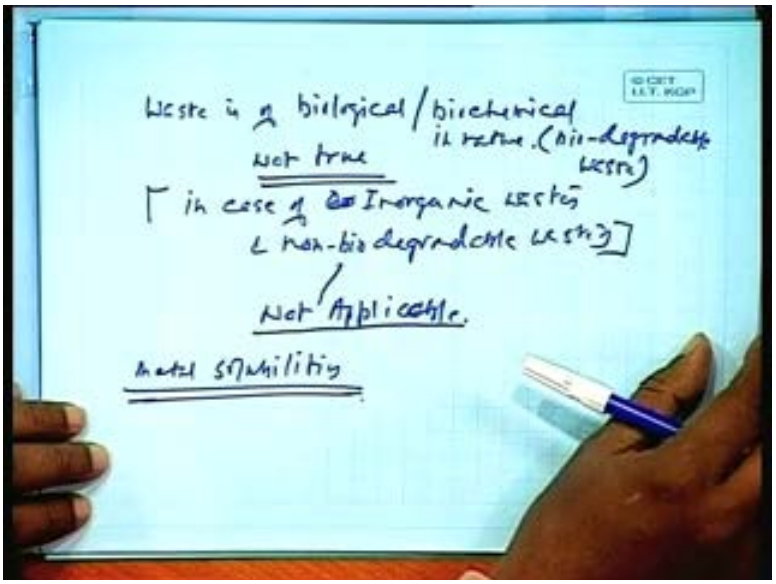

We would see this you know in one of these classes metal solubilities, this metal solubilities deal with, metal solubilities deal with you know this particularly the, when the soluble you know partial pressure conditioning in water how one metallic ion gets released in preference to another metallic ion right and in what, in such situation we would see this as I have said in many cases

the spacious becomes different, you know just let me give you a simple example here just give you, give a simple example here you know where we could observe this. This particularly this metal solubilities if you just see this metal solubilities here you can see this say as you can see you know mostly dissolved molecules, dissolved molecules, molecules of inorganic substances, substances break into, break into charged ions, charged ions, ions break into charged ions right, break into charged ions.

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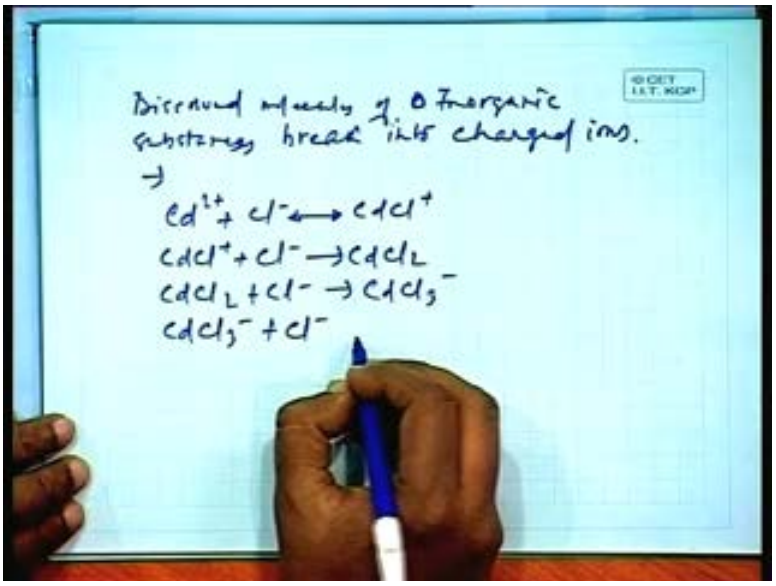

This charged ions you can see this, this is you know charged ions you see is cadmium, this is quite interesting to observe that cadmium in the presence of chlorine iron is this can form a reversible reaction of cd cl, see this cd cl plus it can also cd say cd cl, cd cl, this cd cl plus would be then cl minus can form cd cl_2, cd cl_2, cd cl_2, cd cl_2 plus cl minus, cl minus can cd cl cl_3 minus this cd cl_3 cd cl_3 minus can form with cl minus.