Fundamental of Environment Pollution and Control
Prof. J. Bhattacharya
Department of Mining Engineering
Indian Institute of Technology, Kharagpur
Lecture No. # 09
BOD Modelling - Part – II

We were discussing about BOD modelling in static water. Remember yesterday if I have not mentioned say this, this has to be, this is you know BOD modelling, BOD modelling in, BOD modelling in static water, static water.

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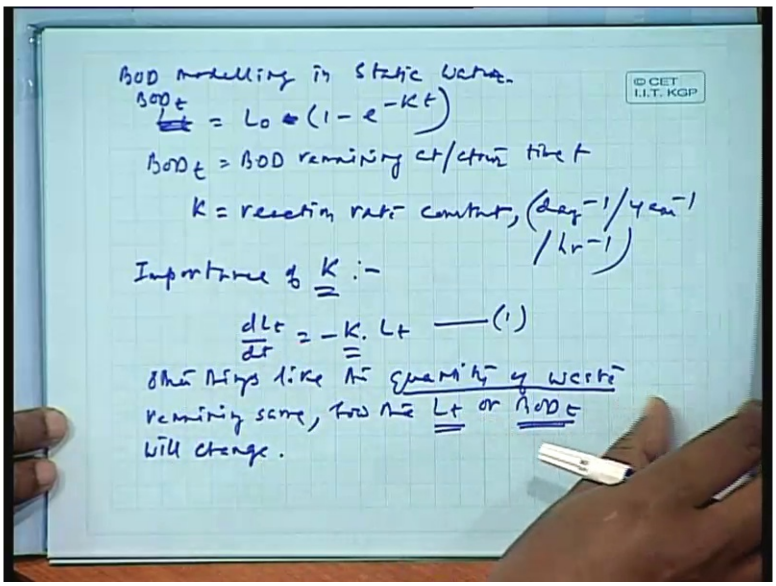

We'll continue discussion, we'll continue this discussion today also and we'll further move on to you know in the next class or so we'll move over to you know where is moving water. So, at present we are at BOD modelling in static water. Remember this, whatever we have discussed yesterday is basically relates to BOD modelling in static water. Those of you who could not hear this lecture please read them in this in the video course as such. So this is you know we have lastly we have found out that you know this is we have also found out a relationship whereby we have said that you know L_0 e to the power, L_0 1 minus e to the power minus K_t, e to the power 1 minus K_t which is which is shows that you know this is the, this is what is the, this is what is the BOD_t, the BOD remaining BOD_t, BOD remaining, BOD remaining at or after time t and this is what is this L_0 we have already explained as ultimate carbonaceous oxygen demand, biochemical oxygen demand and this one is you know 1 minus e to the power minus K_t where K is known as the reaction rate constant.

Reaction rate constant is generally in the form of you know the unit that we have seen now is would be day inverse or year inverse or say you know say hour inverse like this. This is how the unit should be in the inverse of time, in the inverse of time. So, you see, here you can see this so depending on that the t would also change, the t would essentially would also change and so you know what you find is a basically an unit dimensionless, dimensionless parameter K into t which is essentially reduces e into e to the power minus K_t and also.

So is basically reduces this and so as a result of this you know there would be L_0 would be a, L_t would be BOD modelling we can very well find out like this. So having said all this, having said all this we can now find out, we can now find out that you know what is the importance of K, importance of, importance of K. If you observe in this function, if you observe in this function you know when you began first is that dLt by dt is equal to minus K L_t this where from we have actually derived this, L_t is equal to L_0 into multiplied by 1 minus e to the power minus K_t. What we can see here is this K, this K essentially other things remaining same, other things like other things like the quantity, quantity of the waste, other things like quantity of the waste remaining same, remaining same, how L_t, how L_t or how you know this BOD_t, how L_t or BOD_t would remain.

I think we make a correction here this is BOD_t right, this is BOD_t, please make a correction BOD_t. BOD_t is equal to L_t L_0 minus 1 minus e to the power minus K, K_t that is what BOD and this is L_t is that you know the remaining the quantity of the oxygen demand left, demand left at the end of, so at the end of the time t. So here remaining same, how the L_t or BOD_t will change. So here you see this quantity of the waste, if it is quantity of the waste is same this would show a nature of the, nature of this functions, nature of this function would essentially guided by this parameter K, okay.

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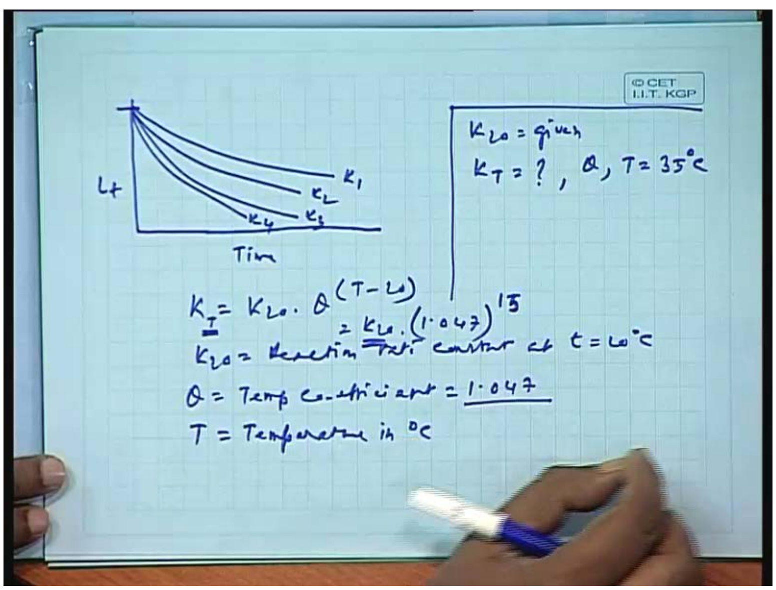

So, whenever even if, even if a waste is actually starting from, even if a waste is actually starting from a, even if the waste is starting from say you know BOD, the same waste even if that you know that it would have, it would have a, it would have different values would basically because of K_1 K_2 K_3 K_4 okay. This is what is BOD remaining, so this is L_t, then is and time, right. So how, how this function would be, would be influenced, L_t would be influenced would be largely be guided by parameter K_1 K, K, parameter K what it is known as a reaction rate constant which is known as the reaction rate constant. This particularly you know if you just trying to observe it, experimentally it has been observed it, experimentally it has been observed that this K, K can be written as K_{20} into theta T minus 20 where this K_{20} is the reaction rate coefficient, reaction rate constant at t is equal to 20 degree centigrade. Theta is a, theta is a constant, theta is a, theta is a temperature coefficient, theta is known as the temperature coefficient, temperature coefficient and which is known to be equal, which is known to be equal to zero point, 1.047 and this one is a T is, T here is the temperature at which this K is being measured. So you can see this K_T, if you can write K_T here, this K_T is equal to T is the temperature, temperature in degree centigrade so its degree centigrade.

So, you can find out so here in most cases suppose if you are, if you are given the value, if you are given the value of say, if you are given the value of say K_{20}, K_{20} is given to you, is given, you can find out K_T, you can find out K_T when you know, theta is known to you and also this the temperature say you know temperature is at temperature say T is given say at say 35 degree centigrade or 35 degree centigrade like this. This would be, this you can find out. One important thing that one can be seen here is having said 1.047. So you can see now this one is essentially reduces to 1.047 into say a certain value which is not a certain value say more than T, more than say 35 minus 25 say here in such cases you can see this, this one is 15, so 15.

So you can find out that with increasing temperature, with increasing temperature the reaction rate coefficient also reaction rate also increases. I was telling you other day that you know with this means that you know more and more oxygen would be consumed as the temperature increases. As the temperature increases more and more oxygen would be consumed. As a result of this you know we can find out for different kind of wastes particularly this is a general function I mean as I have said for any kind of typical waste at different, two different temperatures, the higher temperature would show higher reaction rate and the lower temperature would show lower reaction rate, all right. Now having said this, having said this for you can now find out that this one then this one is you know you can find K_{20} of, K_{20} of some of the wastes that is already experimentally known, this is K, K day inverse, we can say it’s a raw sewage, raw sewage it would be about 0.35 to 0.70.

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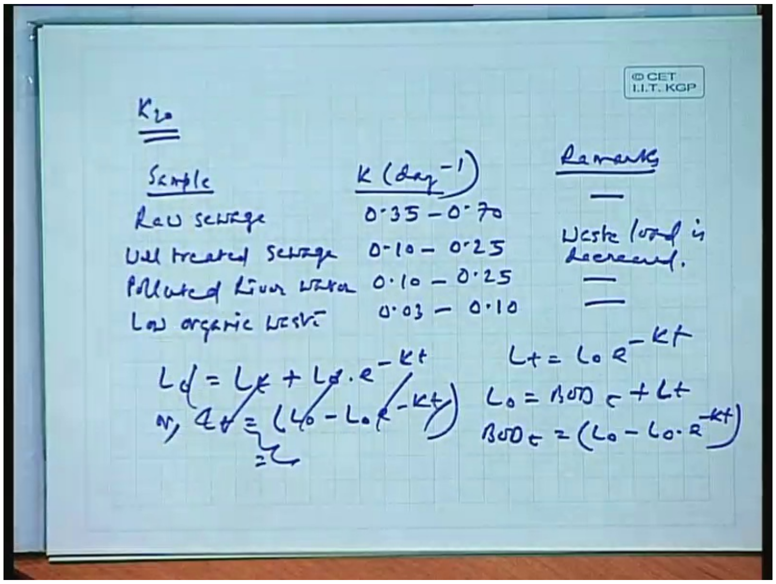

Then well treated sewage, treated, well treated, well treated sewage 0.10 to 0.25 that is you know here as remarks, if you just put here remarks say this waste load is decreased, waste load is decreased from the earlier raw sewage, okay. So this is polluted say polluted, polluted river water, polluted river water. We can find these value between 0.10 to 0.25 again this value, this is polluted river water but in cases you know say a particularly low organic, low organic waste, low organic waste this value can further be sometimes it can be as low as say you know 0.03 to point say between 1.

So, you can see this a wide range if there is a low organic waste I mean it's a low organic waste particularly in many cases say a mining waste is basically water river is discharged is basically very low organic waste or say you know in various industries like civil industry. Suppose you know road construction or say building dams I mean wherever they are discharging some of the pollutants to the stream, some of the pollutants to the stream it will mostly be characterized by low organic waste, it will be low organic waste but there may be higher inorganic waste but it should be generally low organic waste in such cases the depletion of oxygen if you observe this depletion of oxygen the rate is very slow, the very slow rate.

So, you can see you know the slow means you know if you are measuring oxygen suppose you know you have started with the measuring of as soon as it is meeting the stream, at the point of the meeting of the stream if you take a sample at that point and if you observe the oxygen and you observe the oxygen in 3 days, 4 days, 5 days like this you will see that the rate of depletion of oxygen is very slow. That is you know if in the first day you find tenth, a 10 milligram per liter in the oxygen level you are likely to get say about in 5 days' time you might as much as get you know 9.5 or 9.6 like this or even at best 9.

So, this is how you know very slowly the oxygen would be depleted in low organic waste. Remember this low organic and low biodegradable waste, I have also characterized that not all organic substances are biodegradable. There are many organic substances like ethers are almost completely non-biodegradable in nature, there are many substances. So this would also include non-biodegradable organic waste all right, excuse me. So here this one you can see this is a, this is what you know we can observe that K_{20} as this. So whatever, whenever a particular temperature is given, try to modify the K_{20} into find out K_t, K_t and then use that function to find out say the BOD remaining or say as we have said L_0 is equal to L_t plus L_0 into e to the power minus K_t. So here we would find out that L_t we just I mean just to you know recapitulate the whatever we have learnt L_0 e to the power minus K_t and that is how we found out that is you know is, it's okay just one minute L_0 L_t it should be like this, only L_t is equal to this is wrong. We have L_t, we have found out L_t is equal to e to the power minus K_t, this L_t, L_t plus L_0 would be BOD_t plus L_t. So this L_t if you just put that this BOD_t is, BOD_t is L_0 minus L_0 into e to the power minus K_t.

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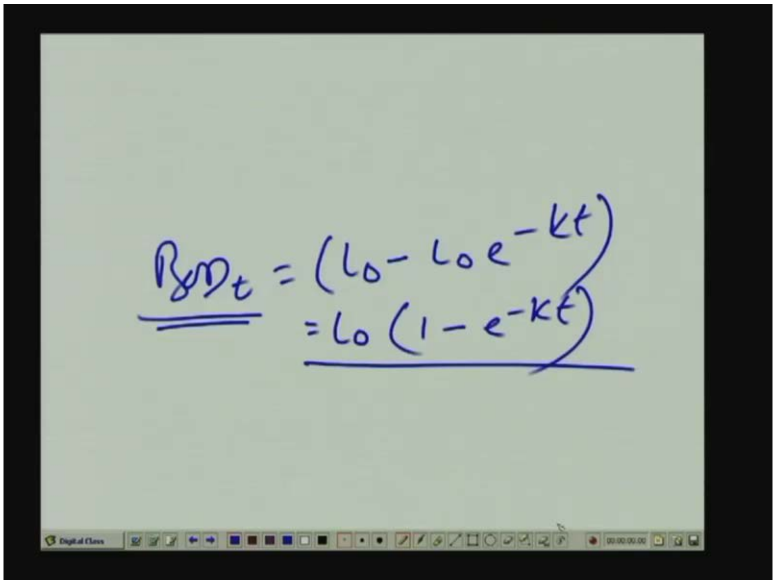

So this, so if you can write it like this, so here we can find it like this here that BOD_t, BOD_t is equal to L_0 minus is L_0 e to the power minus K_t that we have already know, so L_0 common taking L_0 as common, so its you'll find e to the K_t. So BOD remaining at time t would be essentially ultimate carbonaceous oxygen demand multiplied by 1 minus e to the power minus K_t. So we have derived that only just to recapitulate in the, from the yesterday's class, okay. This is one thing, this is one thing you know this is what we have learned so far. So this is how the reaction rate and the reaction rate how the calculation of the reaction rate would be done is generally can be shown like this. Then there is another important aspect you know is called the nitrification you say nitrification, nitrification.

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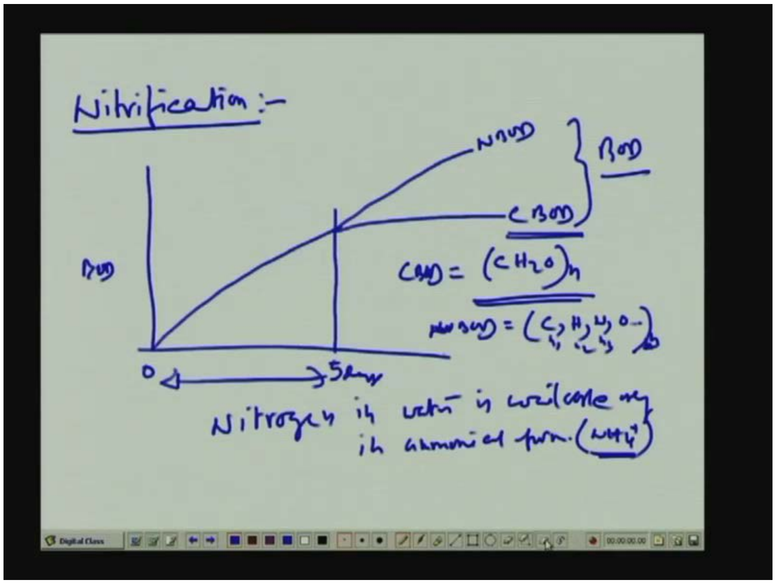

The word nitrification here you know this, this particular part of nitrification is one important thing you know as I have said if you remember, if I have said that you know this first 5 days, first 5 days are basically in a, in as I said about first 5 days there is no, there is no decomposition of nitrogenous compounds but as such as we see after that this is a, the nitrogenous oxygen demand actually begins to increase. This is N BOD, this is C BOD and this is, this is total BOD. This would be total BOD, this is generally what I have said if you just remember once again that is you know this is BOD, this is BOD, so this is BOD right.

What I have said in that class is that you know till about 5 days, till about 5 days is generally observed that the, this the amino acids, amino acids, amino acids which form you know mostly the tissues of the body, tissues of the bodies are generally formed of amino acids. These amino acids do not decompose for about 5 days. Till that time we only find the decomposition of carbonaceous biochemical oxygen demand that means carbonaceous biochemical oxygen demand mostly you can write it like this. One, one representative this thing is CBOD would be mostly this, mostly this. When we can in a, in a NBOD, this is CBOD, NBOD what you find in NBOD is essentially C, H, N, o right and say O is from O then there may be, there may be some other substances like chlorine and all this thing each this can be prosperous all this can be linked and we can find out NBOD as a, is mostly you know all these things are C_1 N_1 HN_2 N N_3 like this so you can find out this is NBOD.

The complexes, organic complexes which have, which have a nitrogen component which has a nitrogen component. Now interestingly, interestingly this is has to be found out that nitrogen is not freely available in water, just say nitrogen is available, nitrogen in water is available, available only in ammoniacal form, ammoniacal form. So, ammoniacal form this is basically as an NH_4 plus radical yes, AI NH_4 ammoniacal form in NH_4 plus radical. This is, this is what you know this is what is NH_4 but when NH_4 begins to decompose, this NH_4 begins to decompose.

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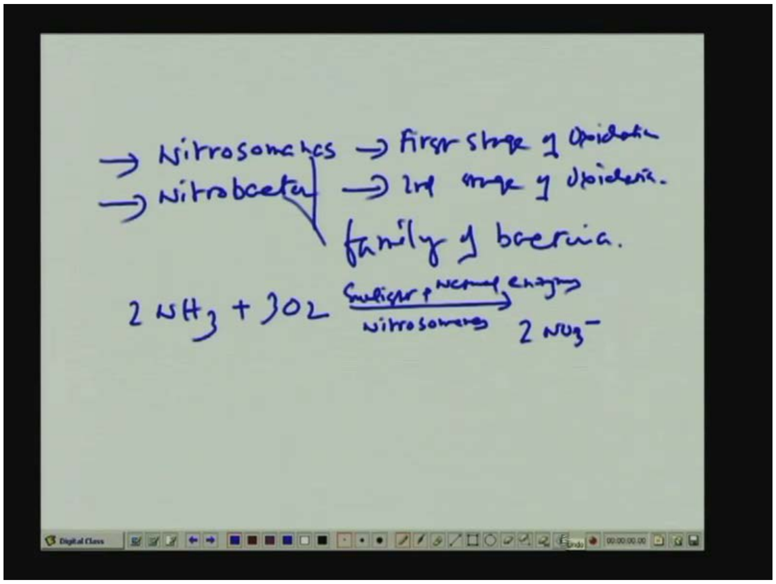

When NH_4 begins to decompose what happens is the first things there are two bacteria's at two different stage essentially carries this. One is called nitrosomonas, this is you have seen the first stage of, first stage of oxidation, right. Say remember we are talking about NBOD, we are talking about NBOD here so nitrosomonas is the first stage of oxidation and then the nitrobacter, nitrobacter. This is a second stage, second stage of oxidation nitrosomonas and nitrobacter these are, these, this is, these are this, these are the microbial group the essentially the bacteria, essentially the bacteria’s. It’s basically a family of bacteria’s, it’s not a single species remember this family of bacteria. These are the family of, these are the families of bacteria’s, this two kind of bacteria’s essentially convert the, this nitrogen locked as nitrogen locked as ammonia, locked as ammonia to decompose into, to decompose into nitrate.

Let me write down this equation here, NH_3 let us consider this to be say deionized 3 O_2 converted by nitrosomonas. Nitrosomonas essentially in the presence, in most cases in the presence of sunlight right plus other natural enzymes, nitro sunlight plus other natural enzymes which actually spar the reaction you know they provide the energy of the reaction most cases you know is many cases the energy of the reaction is very important unless and otherwise the reactions would essentially not take place. So, there should be a source of energy so that source of energy is basically from sunlight or any other natural enzymes or due to the, due to say the latent energy obtained from the water body itself, okay. So, here this particularly thing, this can be particularly this is what we see is you know two sorry. Okay, let me take off all this. What is this happening, it doesn’t go off, okay. Anyway let me start here so you know here if you can see this so here as we have, we have been explaining this reaction let me write it again.

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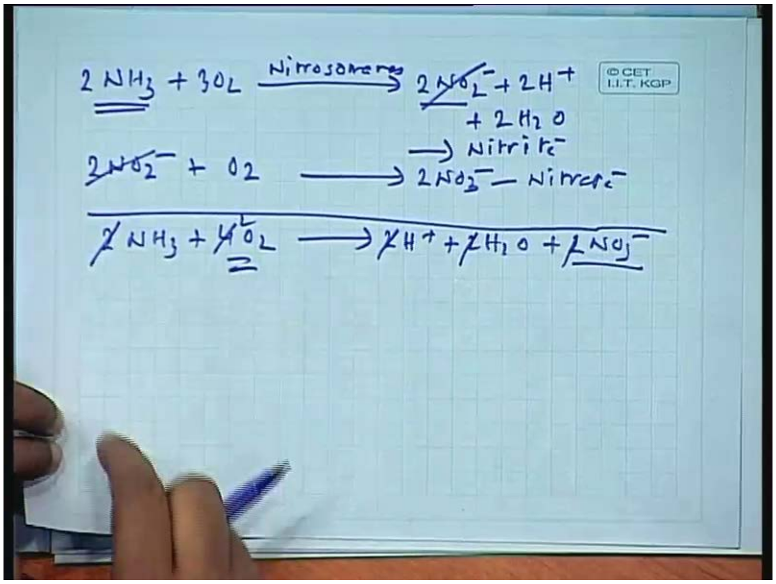

So, here this one is $2NH_3$, $2NH_3$ plus $3O_2$, $3O_2$ this one is nitrosomonas, nitrosomonas forms 2 No_2 minus plus 2 H, this is hydrogen ion released 2 H_2o. This is one stage, you can see this is, this is called you know this is nitrite, formation of nitrite. This is one stage of oxidation, this is one stage of oxidation that is taken place. The second stage of oxidation that takes place is converting this No_2, No_2 minus plus O_2 into a nitrobacter, this is 2 No_3, $2No_3$. If you just add this, if you just add this two reactions, if you just add this two reactions you can see this, this one cancels, this one cancels here. So another thing that is finally being produced is if you can just see 2 NH_3 plus $4O_2$ converting into 2 H plus 2 H_2o plus $2No_3$. Is it right, okay? So you can very well two, two you can cancel it out.

This is essentially it forms a, so this is what is, this, this is how this, then this is how this, this is what is nitrate, nitrate ion, nitrate ion, nitrate ion. So this is, this particularly, this nitrate now, this nitrate is now amenable for, amenable for, amenable for acceptance I say the plant medium can be you know in the form of a solution in water, it would be mostly in the form of a solution in water, this would be, this would be available. So here there is you know here it is, it just a part of the famous nitrogen cycle. That is what we generally know of the nitrogen cycle. Just let me take a little bit on this, the partly you know what happens is this is how the mechanism actually takes place, this is how the mechanism essentially takes place.

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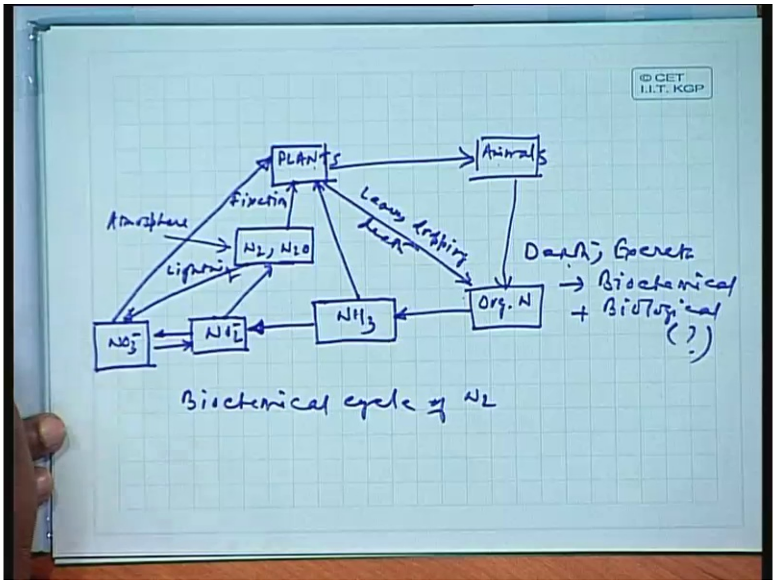

This is the plants, this a plants, plants, animals, animals then from the animals coming the organic, organic nitrogen, organic nitrogen, death, excreta, death excreta. So, you can see here these are, this can be, this, these are possibility of two sources one is the biochemical. biochemical sources, there may be, this mostly there may be some biological sources also some with or without biological sources, some biological sources, biological sources okay some biological sources. This is essentially biochemical source you can see death by death you know animals by death you know supplying organic nitrogen, excreta is also supplying organic nitrogen. So here this is what is the plants are also contributing by you know different types of leaves dropping, leaves dropping death all right.

This particularly would be then we find out ammonia, this is what is essentially what is generally being converted as such is amenable anyway at the same time as I have said after 5 days, after about 5 days of decomposition you find NH_3, this NH_3 would be finally formed as nitrate, nitrate then it is, then it is nitrate. There would be some kind of nitrogen in this, this is denitrification. So you can see this, this is the simplified biochemical cycle of, biochemical cycle of nitrogen, this is biochemical cycle of nitrogen, all right.

So, let me explain this plants and animals you know by their leaves dropping and death and all those thing death, excreta then other means of decomposition whatever other means of decomposition is supplying organic nitrogen. This is organic nitrogen as I have said would be bonded you know C H N O phosphorus P, all these you know in a particular bondage which would be available for oxidation at about fifth day that I have said, at about fifth day when it is available it is available in the form of ammonia. These ammonia can be directly, directly some of this ammonia can be directly taken by the plants, directly taken by the plants and the other most of the ammonia most of the ammonia would be first converted into a nitrite and then into a nitrate and this from this nitrite also it can form in N_2 and N_2o or otherwise this one is, this would finally go for after a fixation would go the plants say you know there are leguminous plants which can fix nitrogen in their plant roots and this would be fixated in the plants and then finally this one is when it is by lightning you just write this is lightning you know this particular N_2, N_2o which is released from this No_2 one of them would be in the atmosphere. This is all in the atmosphere, atmosphere, atmosphere due to lightning may be fixated as nitrite and this nitrite whenever coming out in the rain, coming out with, coming in on the ground with the rain they may be again, they may be again absorbed and can be turned back, can be absorbed by the plants. So, the nitrogen one cycle, one part of the nitrogen cycle is that by which you know by the decomposition by the leaves dropping or say other biological sources, this biological sources where nitrogen would be, nitrogen would be generally supplied.

This is one source of nitrogen coming in, one source of nitrogen coming in, another source of nitrogen is, from this nitrogen whichever is getting released in the atmosphere some of them due to lightning, during lightning particularly during this the rainy season, a most of the nitrogen in the upper atmosphere would be, would be, would react because you know there would be energy of reaction for nitrogen. We should convert it to nitrate ion. This nitrate, this, this nitrate and this nitrate would essentially be used by the plants for the fixation of, for the fixation and for the fixation as, for the fixation for to develop amino acids. Amino acids are mostly, these amino acids would be used by, some by the plants and their formation of tissues formation of say cellulous, this cellulous structures all this would be formed by this nitrogen. So nitrogen is an essential element for tissue formations.

So tissue formations, so these tissues and all these you know plant tissues and the plant related things would be essentially supplied from two sources. One is atmospheric nitrogen getting converted into nitrate and the biochemical oxygen, biochemical nitrogen sorry biochemical nitrogen converted into nitrate and then being absorbed. This is a typical nitrogen cycle that we know of. So here say this is particularly if you see you know this there are the way we generally find out how this nitrogenous oxygen demand, nitrogenous, nitrogenous oxygen demand.

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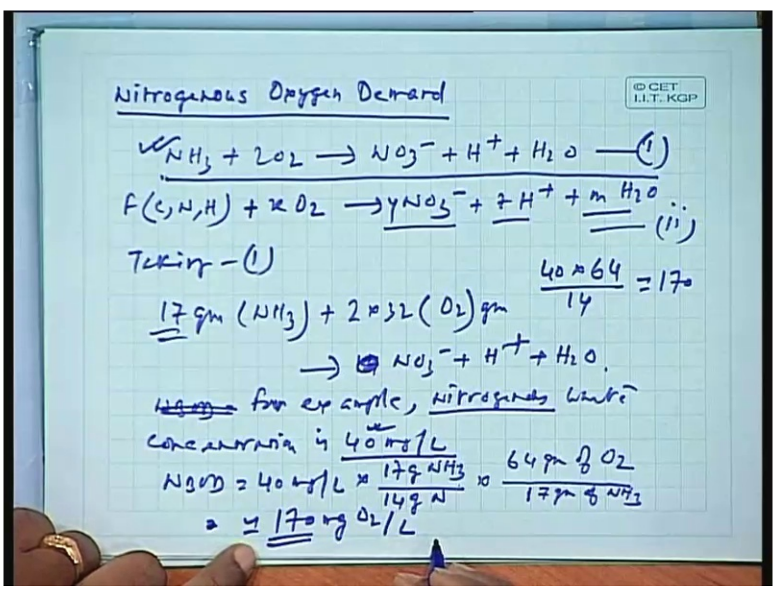

So in the nitrogenous oxygen demand we generally try to find out as you have seen, if you have seen this last reaction, in the last reaction you can see this this one is here, the oxygen is being used. What is the demand of oxygen, what is the demand of oxygen that can be found out nitrogenous form of a waste, of a waste. The same can be found out but suddenly with certain assumptions I mean I'll explain you how these assumption take place but you can see physically the oxygen would be consumed. This oxygen would be supplied from the water, remember this this oxygen would be mostly supplied from the water so not only, not only CBOD but NBOD is also taking oxygen from the water.

So this would be, this particularly when you see this, this particularly this nitrogen oxygen demand we generally is say you know what we generally find out you know if the essential important thing that you know is one important, one typical reaction that we generally use of is that NH_3 that is you know that we have found out is that $2O_2$ is equal to No_3, No_3 plus H plus H_2o.

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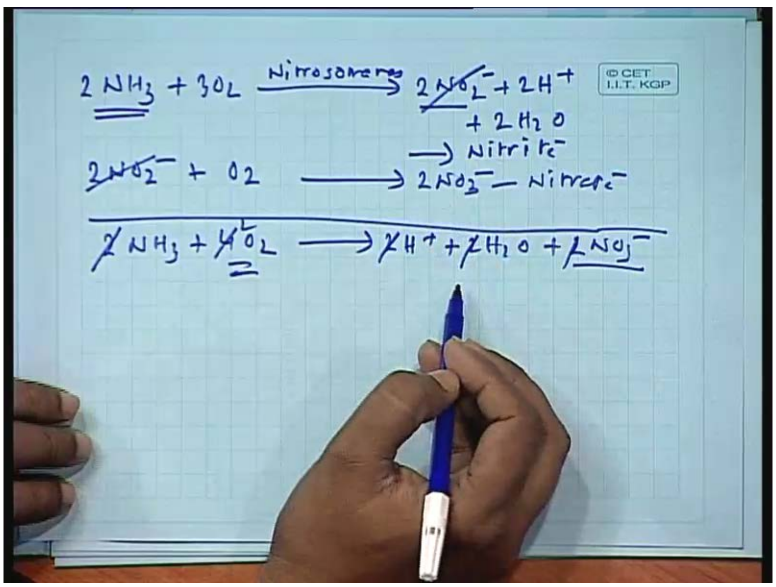

If you remember in the last case, so this is nothing but if you just take out this one into 2 and 2 2 2, this is the typical reaction that we have just, just found out rather than by which nitrosomonas and nitrobacter convert ammoniacal nitrogen into nitrate, into nitrate. The same where you can see this you know here only you can very well find out that this is, if this is one relationship, this is one relationship but you can sometimes remember this, this is one relationship but this not necessarily only relationship, this is not necessarily the only relationship there can be other substances of nitrogen say you know if we find out other say as a function, as a function of C N H any reactant, any available substances which are readily oxidisable combining with nitrogen in such cases you see this one is if we can establish x O_2 into say No_3 say this is y No_3 then z H plus xyz say m H_2o. If you can establish a relationship, we can also find out you can also find out say the oxygen demand, we can also find out the oxygen demand. This is, this is try to understand this. This is a, this is a basic equation that we have just found out right how this nitrosomonas and nitrobacter uses but this is not necessary the only relationship only, only function, a only reaction explaining how the nitrogen in the water would be converted.

Nitrogen may be, may be if locked up in the any different forms also which is possible that you know they also, they would be oxidisable, they are oxidisable and when they oxidize they might form this substances as well. So if we know, if we know this you know this, if we know the characterization of this C N H this function plus if we know this x, how much of x is required we can always derive what would be the reactants, what would be the products of the reaction, what would be the products of the reaction. So, having known that we can also find out the typically the relationships. So here you can see here one thing for this relationship here, if we taking, taking one, taking one we can see that, we can see that 17 gram this is in terms of 17 gram of, 17 gram of ammonia, 17 gram of NH_3 plus this 2 into 32 that is you know 2 into say 2 into 32, 2 into 32 oxygen would give rise to, would give rise to say this, this N NH_3, this 14, 14 gram of this is will give rise to 14 gram, 14, not 14 gram actually this is what it is producing, this reaction is being produced.

So here you can see this H plus, this is you know in a ionized form, so you know so not necessary that we write this reaction here. So NBOD, NBOD can be very well say now if the milligram of the waste is given, so nitrogenous waste. Now say for example say nitrogenous waste, waste concentration is, concentration, nitrogenous waste concentration is, nitrogenous waste concentration is say 40 milligram per liter, right. We have identified that, in the waste we have find out that whether the nitrogenous waste. We have found out carbonaceous waste, we have found out nitrogenous waste and we found out that the nitrogenous waste concentration is 40 milligrams per liter. If it is 40 milligrams per liter NBOD can be found out as 40 milligram per liter multiplied by 17 gram for every 17 gram of NH_3 that would be formed from this 14 gram of nitrogen, 14 gram of nitrogen multiplied by 64.

So here, so you can see this 17 gram, it is 17 gram of NH_3 would require 64 gram of oxygen, 64 gram of oxygen. So, 17 gram means you know it would be basically 14 gram of nitrogen, for every nitrogen this is for every gram of nitrogen this one is 17 gram of NH_3 for every, every 17 gram of NH_3, for 17 gram of NH_3 we would require 64 gram of oxygen, this multiplied every 17 gram of NH_3 would essentially form 14 gram of nitrogen. So here we can see this nitrogenous biochemical oxygen demand that we found out to be, how much it should be? Say it is about, say how much it is coming out, can you can you find it out for me. So this one cancels out, so 40 into 64 this is 640 into 4. That is 286, 256 are you sure 256, okay 250 divided by 14 so it is basically you know 40. 70, 40 into 64 divided by 14. Isn't it? 170. Okay, you just you say 170, 170 milligram oxygen per liter right. This is because, this is the waste that we have said is 40 milligram this is the unit, this if grams are getting canceled only this milligram per liter remaining. So you can see this would be finally in the form of 170 milligram per liter.

What we are finding out is you know here just case if you just see this equation here, for 40 milligram per liter what you are say? For every 17 gram of nitrogen would provide 14 gram of, for 17 gram of ammonia would provide 14 gram of nitrogen. That is, that is clear that is for 14 gram of nitrogen, if it is converted into free nitrogen. So this 14 gram of nitrogen it should produce and say for every 64 gram of oxygen, this 17 gram of nitrogen would use 64 gram of oxygen. So, this one is that is how we are finding out, for every, for every nitrogen, for every,

every gram of nitrogen what would be, what would be the requirement of, a requirement in case of in in, in the, in the you in the requirement, the amount that would be required is 170 milligram of oxygen per liter would be generally known. This is, this is what is how this we generally found out this NBOD. Remember one thing if you some cases if you find that these reactions has been changed, the reaction has been changed, so in such cases you also have to automatically change the, Muller value has to be found out, from the Muller value you can change the parameters for calculation. Is it clear okay?

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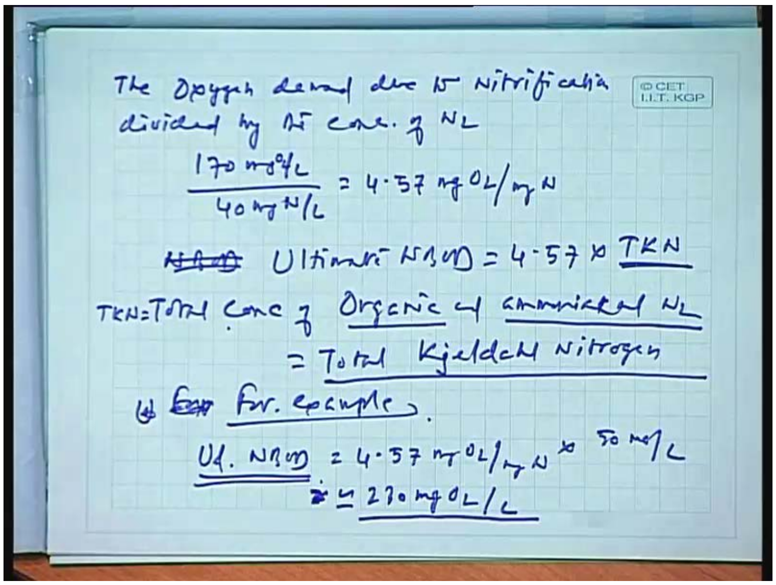

Now this is, this one, this particularly that is that the value that you generally get is the oxygen demand, the oxygen demand say the oxygen demand, oxygen demand right oxygen demand due to nitrification, oxygen demand due to nitrification divided by, divided by the concentration of nitrogen, concentration is 170 milligram say milligram of O_2 per liter divided by say 40 milligram, per milligram nitrogen per liter. So this one is we find out for, we would require for 4.57 milligram of oxygen per every milligram of nitrogen present in the water. This is known as, this 4.57 is known as, so ultimate this is known as total Kjeldahl nitrogen, this is TKN. So this is known as, this that total concentration of organic and ammonia nitrogen, so NBOD this ultimate NBOD, ultimate NBOD, ultimate NBOD would be generally know as you know this is say you know about 4.57 into total Kjeldahl nitrogen TKN. This is total concentration of organic and ammoniacal nitrogen, ammoniacal nitrogen is known as total Kjeldahl nitrogen.

See this total concentration of organic and ammoniacal nitrogen, organic and ammoniacal nitrogen is a total, this is known as a TKN. This is what is, this is total TKN, this is total Kjeldahl nitrogen this is what is TKN. For every, for say, for, for every gram of or every gram of milligram per liter of organic nitrogen, for every milligram per liter of organic, so you can see this for example, for example, for example ultimate, ultimate NBOD, NBOD is 4.57 milligram of O_2 per milligram of nitrogen. This TKN, if this TNK is generally say, say if you find out say 50 milligram per liter, this 50 milligram per liter then you can see this you know about 4 is say total is four point say 4.5, so it is 4.6 say 4.6 into 50, 4.6 into 50 is 230 right 230, about 230, about 230 milligram of oxygen per liter, 230 milligram of oxygen per liter would be required.

So the ultimate NBOD can be found out like this. Is it clear? If it is not I mean you can always read it again, see it again if it is not you know you can again discuss in the next class but till that time you know this part is almost complete. So we'll move over to the stream BOD or this is so far is a fixed and still water. So we'll move into stream now from, if there is no other question to discuss okay all right. We stop the class now and this is where you know today's class will be stopped, so we'll move over to the next class with a stream BOD. Thank you.