Water and Wastewater Engineering
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Lecture - 6
Water and Wastewater Characteristics (Continued)

Last class we were discussing about the characteristics of water and wastewater. We have seen that the characteristics of water can be classified into three groups; one is physical characteristics, another one is chemical and third one is biological parameters. And to decide what treatment process we have to adopt will depend upon the characteristics of the water. So it is essential to know the characteristics of water or wastewater.

We have seen; what are the important physical characteristics. They are turbidity, colour, odour, temperature and pH. And we were discussing about chemical parameters and we have listed them as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Theoretical Oxygen Demand (ThOD), nutrients, toxic compounds, alkalinity and hardness. We were also discussing about Biochemical Oxygen Demand in detail.

Biochemical Oxygen Demand is nothing but the oxygen required by the microorganisms for the degradation of biodegradable organic matter present in the wastewater. We have seen what are all the requirements for a BOD test. That means there should be microorganisms to do the work and there should be dissolved oxygen present in the system and the environmental conditions should be conducive for the microbial growth that means they should have enough nutrients available.

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For example, we were discussing about the BOD test we want to conduct for industrial wastewater where there is no biological matter or microorganisms present. At that case we have to add some external seed to the system then only we will have microorganisms to do the work. Then we were discussing about how to find out the biodegradable organic matter concentration and how the BOD or the biodegradation rate depends upon.

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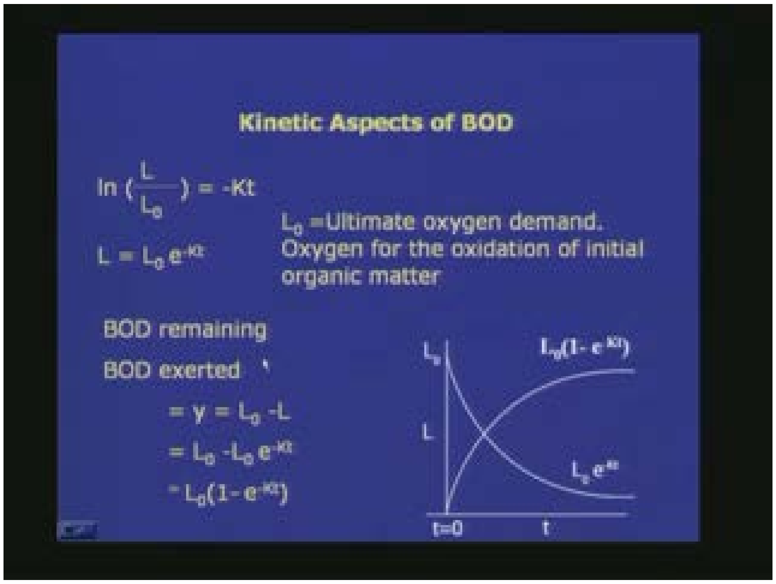

We have seen that it's a first order equation and we can represent it as L is equal to L 0 into e raised to minus Kt. L is what is the organic matter left over in the system and L 0 is the total organic matter present in the system. L is whatever is leftover at time t. So whatever is consumed by the microorganism we can get it by taking the difference of L and L 0 and that is nothing but the BOD exerted. So we have seen that the BOD is exerted at any time, y is nothing but L 0 minus L where L 0 is the original organic matter present and time t is what is the organic matter present in the system and L is the organic matter left over in the system at time t. So y is the difference between whatever is present and whatever is left over so this is the BOD exerted.

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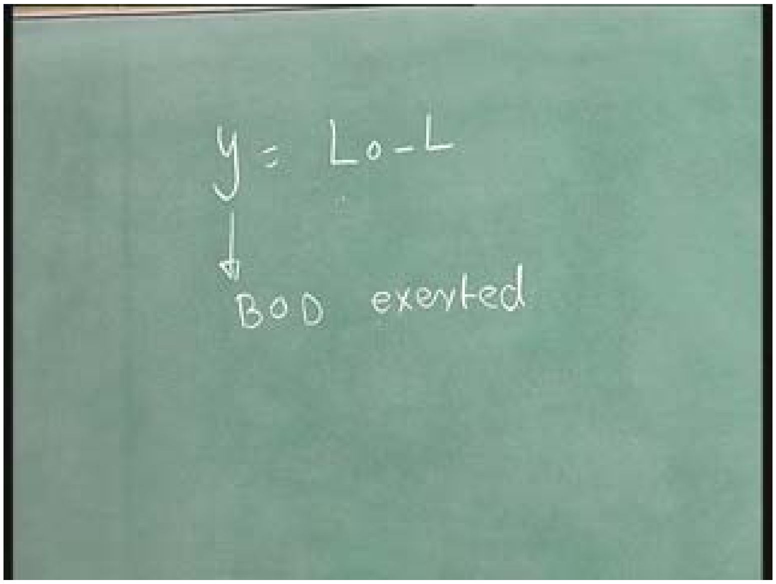

And we have seen that, when we conduct a BOD test at least 1 mg per liter of dissolved oxygen should be left over in the system after 5 days otherwise we cannot be sure whether the oxygen whatever was available was sufficient for the degradation of the organic matter. So the value whatever we are getting may be correct or may not be correct so that is why we are telling that at least one milligram should be left over and the consumption should be more than one milligram or two milligram whatever, we were discussing in the last class, the reason is because of the dilution the error should not come into picture.

Now we will see the importance of this equation: L is equal to L 0 into e raised to minus Kt and we have seen that this we can represent in this way (Refer Slide Time: 5:17) here this is the profile of organic matter whatever is remaining in the system with respect to time and this curve shows how the BOD is exerted. This is nothing but L 0 into 1 minus e raised to minus Kt. So we will see how to find out this L 0 and k.

We have already discussed that L 0 is nothing but it is the ultimate oxygen demand. Ultimate oxygen demand is the equivalent of organic matter present in the system and it is a constant value at any temperature or at any microorganism. That means the system organic matter content is not going to change, only thing is the rate at which the organic matter is consumed will be changing with respect to temperature and microbial nature or microbial consortium present in the system because we know that all the microbial activity are temperature dependent because there will be an optimum temperature, if the temperature is above the optimum temperature or below the optimum temperature the rate will be increasing or decreasing.

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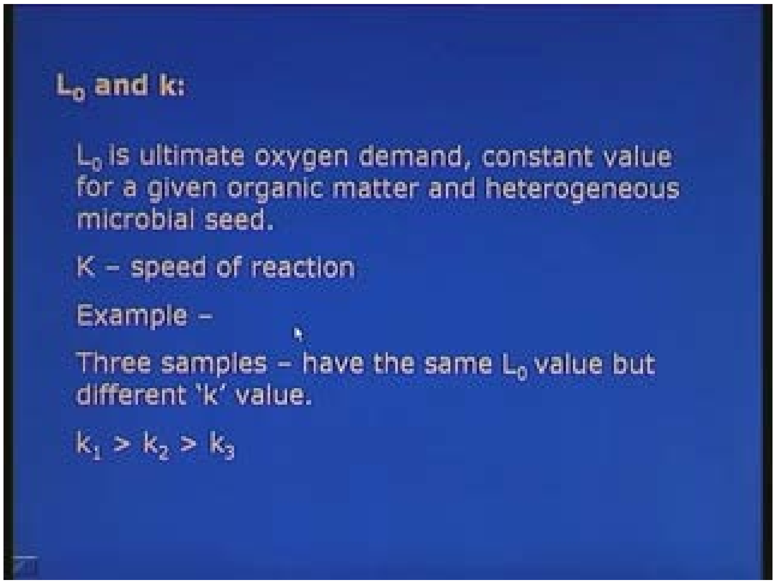

So this k we can call as the speed of reaction that means speed at which the organic matter is getting degraded or the speed at which the oxygen is consumed in the system. For example, if you take three samples have the same ultimate BOD. That means the three samples are having the same L 0 value. That means for example you have L 0 equal to 200 milligrams per liter and we are going to do the BOD test for this one and if you plot the graphs it is coming something like this:

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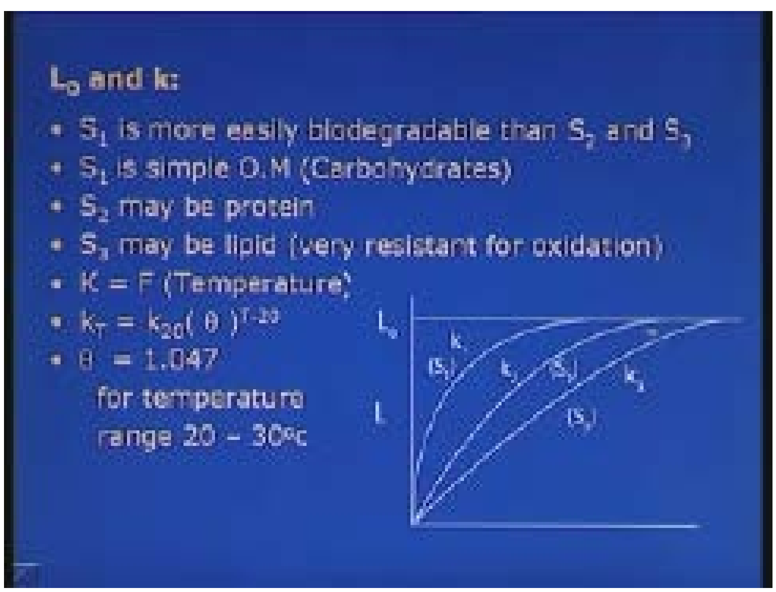

This is the L 0 that means the maximum value we are going to get and this is we have plotted with respect to L and time. So we can see that this is the profile for k 1 and this is for k 2 and this is for k 3 and k 1 was for a substrate, S 1 and k 2 for another substrate or another organic matter S 2 and k 3 for the third organic matter which is S 3. So from this graph we can make sure that the S 1 where the k 1 value was very high or the speed at which the organic matter was getting consumed is high. That means S 1 is more easily biodegradable than S 2 and S 3 that means it may be carbohydrates. We know that the wastewater may contain carbohydrates, lipids, proteins etc. So, if carbohydrates are present it is very very easy to biodegrade. So S 1 may be carbohydrate and S 2, here you can see that the speed is reduced from k 1 to k 2 this is the profile you are getting.

So here we can assume that it may be a protein because protein is less biodegradable compared to carbohydrate and S 3, in S 3 we can see that k 3 is much less than k 1 and k 2 so S 3 may be either lipid or any other compound which is very very resistant for biodegradation or biological oxidation. Now we were discussing that this k 1 is depending upon……. k depends upon nature of organic matter present, k depends upon the nature of the organic matter. If it is highly biodegradable then you will be getting a very high speed and this k also is a function of temperature because what I was telling earlier that if the temperature is higher then you will be getting a faster rate that means the microorganism will work at a faster rate at high temperature. So we can represent this k in terms of a temperature function. That means K T is equal to k 20 into theta raised to t minus 20. That means the standard condition at which we were doing the BOD test was at 20 degree centigrade. But you know that the biodegradation will be taking place at different temperatures because the temperature will be varying.

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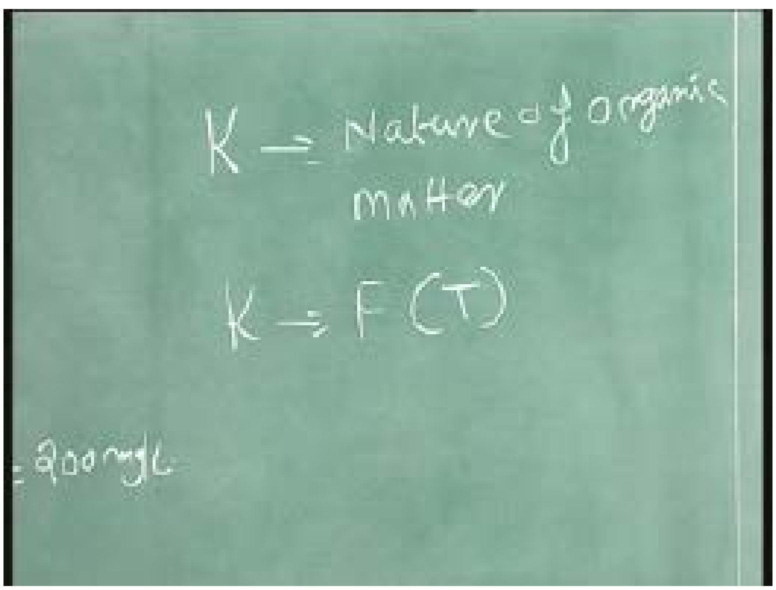

For example, if we take our country, the average temperature is 27 or 28 degree centigrade so naturally the biodegradation rate will be much higher than whatever we get by the standard BOD test. so we can correct this k or the speed factor using this expression k 20 into theta raised to t minus 20 where t is the temperature at which the biodegradation or the BOD test is conducted and theta is a constant and we can take it as 1.047 for a temperature range of 20 to 30 degree centigrade and this is the temperature range that usually comes in most of the wastewater treatment systems in our country.

Now we will see. We have seen that we are conducting the BOD test for 5 days and 20 degree centigrade and now we have discussed that if the temperature is different than that of 20 degree we can make the correction by using the formula whatever we discussed. Then what is the importance of these 5 days? Is it so important?

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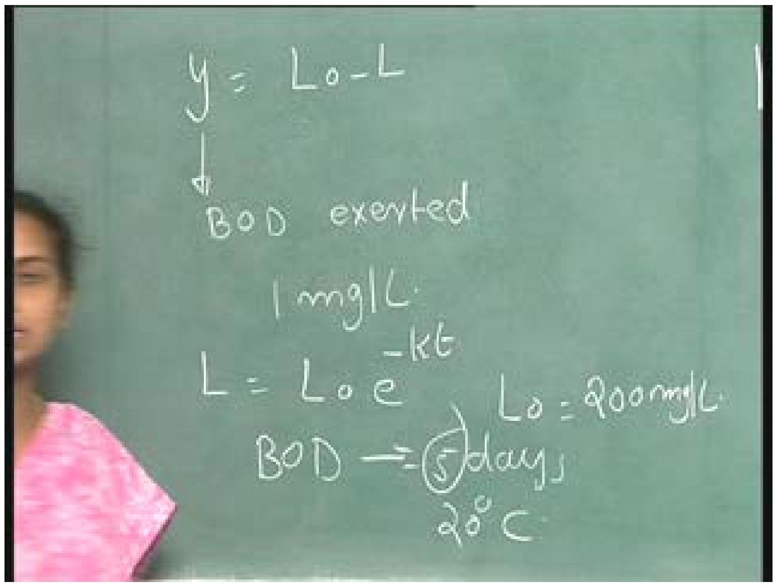

This graph (Refer Slide Time: 11:23) gives you some answer for that one. If you continue your BOD experiment with n days and if you plot the results you will be getting a graph something like this, this is the BOD left over and this is the time so we will be getting something like this. Initially it is going at a faster rate then it will be slowing down and it is becoming asymptotic and after certain time it is again increasing. This is the BOD consumption or the oxygen consumption. Why it is happening like this? The initial 5 to 8 days whatever is the organic matter present in the system is consumed by the microorganism and it is oxidized to carbon dioxide and organic matter is oxidized to carbon dioxide and water. So this is taking place initially.

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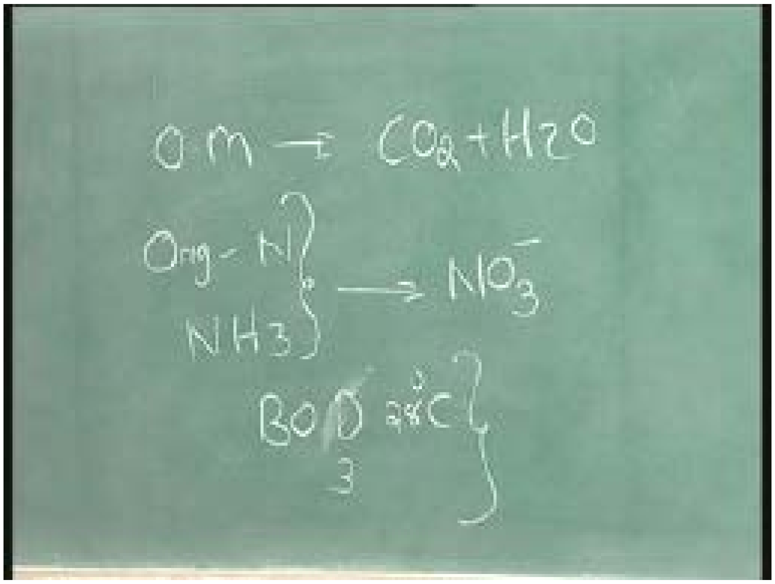

So this portion is known as carbonaceous oxygen demand. But we all know that the wastewater will be containing large quantities of organic nitrogen or ammonia. So when oxygen is available certain microorganisms are there they can convert this organic nitrogen and ammonia to nitrate. So here we can see that one nitrogen and nitrogen atom requires 1.5 molecules of oxygen or ammonium molecule requires 1.5 moles of oxygen for the completer oxidation of ammonia or organic nitrogen. So that much of oxygen is required for complete oxidation. That is why this hump is coming. So all the organic matter is getting exhausted first and whatever is left over namely the ammonia will be consuming the left over oxygen. Here the work is done by another group of microorganisms. So this is known as nitrogenous oxygen demand this portion (Refer Slide Time: 13:30) and this gives you the total oxygen demand.

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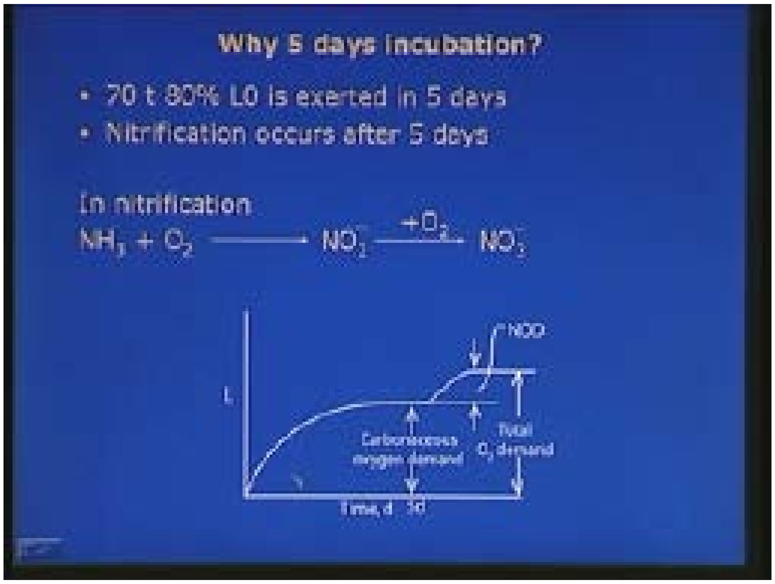

Why we are taking only the 5 days so within 5 days around 70 to 80 percentage of that organic matter will be getting oxidized so we will be getting the carbonaceous oxygen demand within this time so that is why we are doing the BOD test for 5 days. Nowadays because it is such a long time, nowadays people have developed BOD test for 3 and 28 degree centigrade. Because in India as I mentioned earlier average temperature is much higher than 20 degree centigrade so our average temperature is around 27 or 28 degree centigrade. So, as the temperature increase for every 10 degree rise in temperature the k value doubles that is the relationship between temperature and the k value. So, if you increase the temperature to 28 degree centigrade naturally your carbonaceous oxygen demand will be taking place within a short period of time so there is no point in waiting up to 5 days so the time can be reduced to 3 days.

In India people have developed this BOD test at 27 degree and 3 days. This will be giving almost the same value as your 5 day 20 degree BOD. This is all about the Biochemical Oxygen Demand and it is very very important to find out the BOD if you want to go for a biological treatment plant design because we can find out what is the biodegradable organic matter present in the system. But one disadvantage of this system is it consumes lot of time and it all depends upon the bacterial population present in the test. If you have large number of microorganisms in your test bottles your BOD exertion will be at a faster rate so it will be microorganism dependent. Other parameters also we have to control. So is it possible to find out the organic matter concentration by any other method? So people have developed another test that is known as chemical oxygen demand COD. Here the microorganisms and the dissolved oxygen which are the essential components of BOD test is replaced by chemical components.

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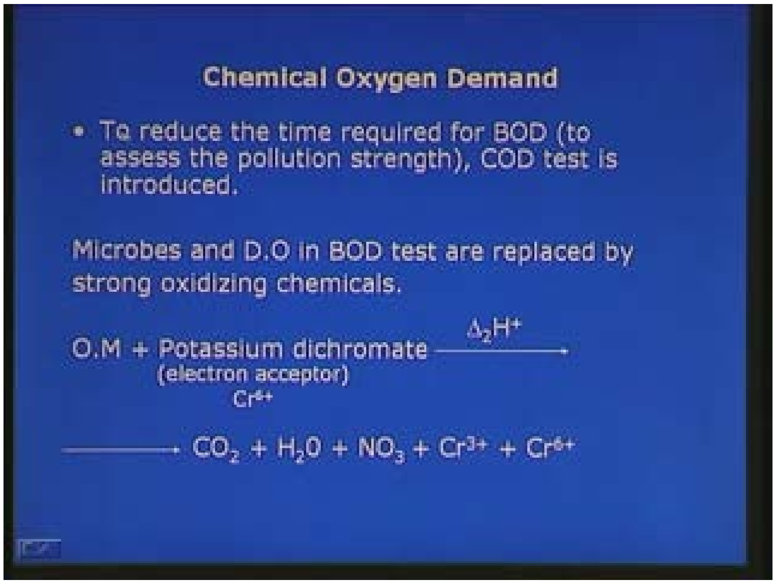

So, by going for this one we can reduce the time required for the BOD and we can assess the pollution strength at a faster rate. So here the microbes and DO are replaced by strong oxidizing chemicals. What we are doing here is we are putting the organic matter and we are allowing it to oxidize in presence of a strong oxidizing agent. We know what is the amount of oxidizing agent we have added to the system. After a certain time what we are doing is we are finding out what is the left over oxidizing agent in the system. So by taking the difference we can find out what is the amount of oxidizing agent consumed for the complete oxidization of the organic matter. From this one we can find out what is the strength of pollution of that particular water sample.

This is the reaction (Refer Slide Time: 17:14) organic matter plus potassium dichromate K 2 Cr 2 O 7, here we are putting organic matter plus K 2 Cr 2 O 7 this is potassium dichromate. So we are giving high temperature and low pH. So what will happen is your organic matter in the system will be converted to carbon dioxide and water, organic matter is getting converted to carbon dioxide and water and what will happen to this chromium, some chromium will be converted to………., here chromium valency is 6 plus it is getting converted to Cr 3 plus and some will be remaining as Cr 6 plus. This is the basic equation.

And, if the organic matter if ammonia or organic nitrogen is present that will be getting converted to nitrate. So complete oxidation of the organic matter is taking place and you are getting chromium 3 and chromium 6 plus. So what we are doing is, after the oxidation step we are finding out what is the left over chromium 6 present in the system. So we know what is the initial chromium 6 concentration and what is the left over chromium 6 concentration so we can know what is the amount of chromium 6 or the oxidizing agent consumed for the complete oxidization of the organic matter. From that one we can find out what is the oxygen demand or oxygen equivalence of the organic matter.

So how can we find out the left over chromium 6 here? So what we do is we titrate the left over chromium 6 using a reagent called ferrous ammonium sulphate. Ferrous ammonium sulphate is a reducing agent, it will be reducing chromium 6 to chromium 3 and it is an oxidization reduction reaction. So you can use ferroin as the indicator. So, by just doing the titration we can find out what is the amount of potassium dichromate actually consumed by the organic matter present in the water sample? You know the water sample volume, you know the amount of potassium dichromate you put initially and you know what is the left over potassium dichromate so you can find out what is the chemical equivalent of or oxygen equivalent of the organic matter present in the system.

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This is known as chemical oxygen demand. So, by comparing the COD and BOD we can make out whether the waste or the organic matter whatever is present in the water sample is biodegradable or not. So if you have a high BOD by COD ratio, if it is greater than 0.5; BOD by COD ratio is greater than 0.5 it means the organic matter whatever is present is biodegradable and if you take the domestic wastewater usually we get the value greater than 0.7 that means most of the organic matter present in the domestic wastewater are biodegradable so we can go for biological process. This ratio decides what type of treatment we have to select. Either you have to go for biological treatment or you have to go for chemical processes.

Another method to find out the organic matter present in the system is total organ by using Total Organic Carbon analyzer.

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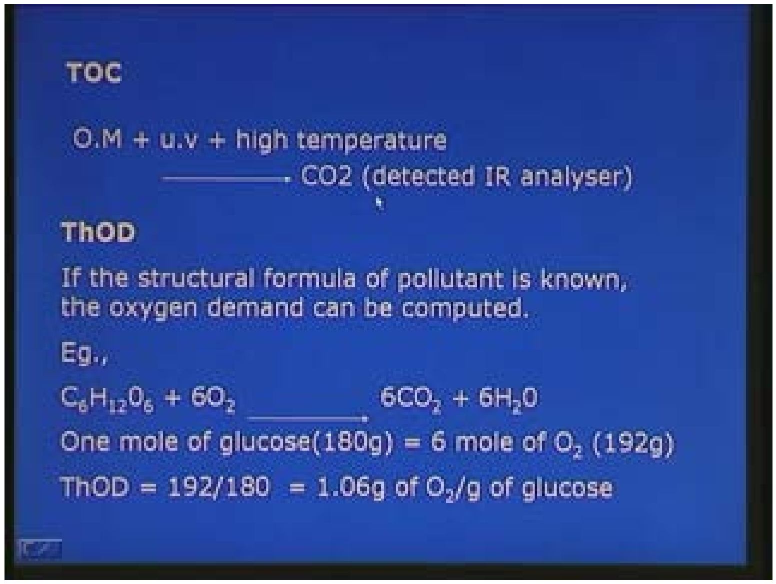

Here we are replacing the microorganism and dissolved oxygen in BOD test as well as the chemicals used in the COD test by UV radiation and high temperature. Here what we do is we just inject the water sample to the instrument so at high temperature, high UV this organic matter is getting oxidized to carbon dioxide and water and this carbon dioxide is detected by an IR analyzer in the TOC. TOC is nothing but Total Organic Carbon analyzer. So, by injecting the sample we will be directly getting the organic carbon present in the system so we can find out what is the strength of pollution in that wastewater.

Another method is theoretical oxygen demand. We don't have to go for either for the instrument or for the biological test or the chemical test.

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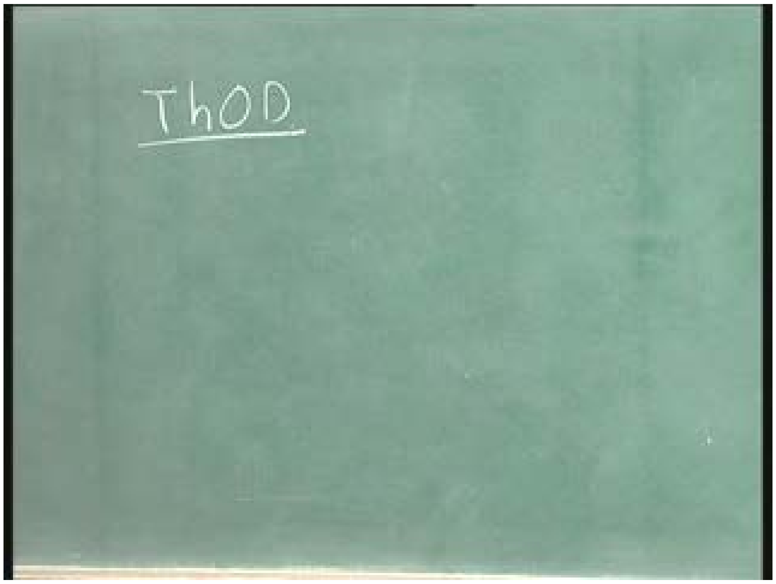

This is the theoretical oxygen demand. This is applicable if you know the composition of the waste properly. And composition I mean if it is composed of a well-defined organic compound. for example, you have a glucose solution, you have a glucose solution and you know the molecular formula of glucose and you know the strength of glucose present in that wastewater so there is no need of going for BOD test or COD test but you can directly find out, if you want to oxidize that one completely that how much is the oxygen required by stocumetric calculation. For example, this is glucose molecule $C_6H_{12}O_6$ and it is reacting with oxygen to give carbon dioxide and water.

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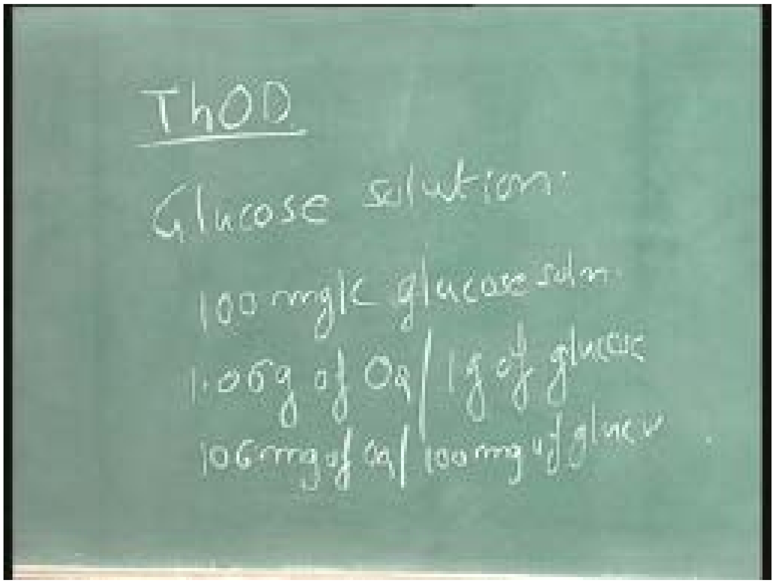

So one mole of glucose, if you take the molecular weight of glucose, that means 6 into 12 plus 1 into 12 plus 16 into 6 you will be getting 180 grams and this 180 grams requires 6 moles of oxygen. That means 6 into 32 that means 192g. So what is the theoretical oxygen demand for this compound? That means 192 grams of oxygen is required for 180g of glucose or 1.06g of oxygen is required per gram of glucose. So if you have 100 mg per liter glucose solution so from the stochumetry you know that it is 1.06g of oxygen for 1g of glucose. So, from here we can find out what is the oxygen required for 100 mg. It will be 106 mg of oxygen per 100 mg of glucose. So if you have 100 mg per liter of glucose solution its theoretical oxygen demand or its COD or BOD if you take, it will be 106 milligrams per liter. That means 106 milligrams of oxygen is required to completely oxidize the glucose present in that water or the wastewater. So, that is what it means.

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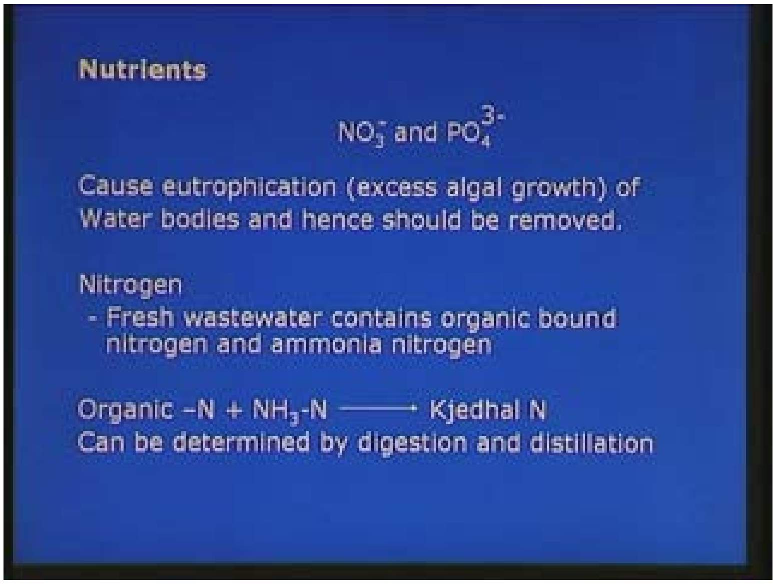

Now we will come to the other chemical parameter. We have seen how to find out the organic matter present in the water. There are four different ways we can calculate the pollution strength of the water with respect to organic matter. Those are: BOD, COD and TOC and theoretical oxygen demand. And what are all the problems associated with each one, we have discussed in details. Now we will see the nutrients.

Mostly the nutrients present in water or wastewater are nitrates and phosphates. So what is the problem if the nutrients are present in the system? If nutrients are present in the system or the water or wastewater are having these nutrients what will happen is it will cause utrification. Utrification means excessive growth of algae in the water bodies. So, if excess growth of algae is there in the water bodies what will happen? It will prevent the penetration of sunlight to the water bodies so that will affect the growth of aquatic organisms and moreover what will happen is this algae will be putrefying and that will be affecting the characteristics or the water quality. So it is not advisable to have high algal growth in water bodies. And especially if you are storing the water in a reservoir for water treatment or water distribution purposes and if there is plenty of algal growth, the chemical dose requirement for water treatment especially for the removal of algae will be very very high so these nutrients present in water or wastewater is not advisable at all.

How this nitrate is coming into the system? Nitrate can come into the system by three different ways: one is from the domestic wastewater because all the organic matter whatever is coming, food or food waste or whatever be the thing it will be containing organic nitrogen because organic nitrogen is a part of all the proteins so that will be coming from the wastewater. That is one source. And another source is…….. one is wastewater, another one is natural origin and third one is from agricultural lands and small amount of nitrate can come by nitrogen fixing also, nitrogen fixing by the microorganism.

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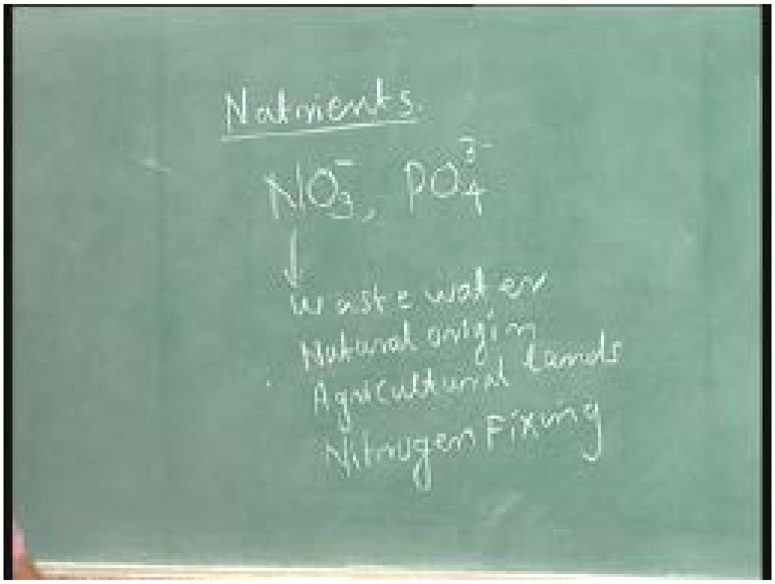

But among this the nitrate coming because of natural origin is very very insignificant. So we can associate the nitrate whatever is coming to wastewater, agricultural lands and nitrogen fixing. In wastewater how the nitrate is coming? As we discussed earlier whether organic nitrogen or ammonia nitrogen, organic nitrogen or ammonia present will be getting converted to nitrate and nitrate by the action of certain group of microorganisms that is known as nitrifiers.

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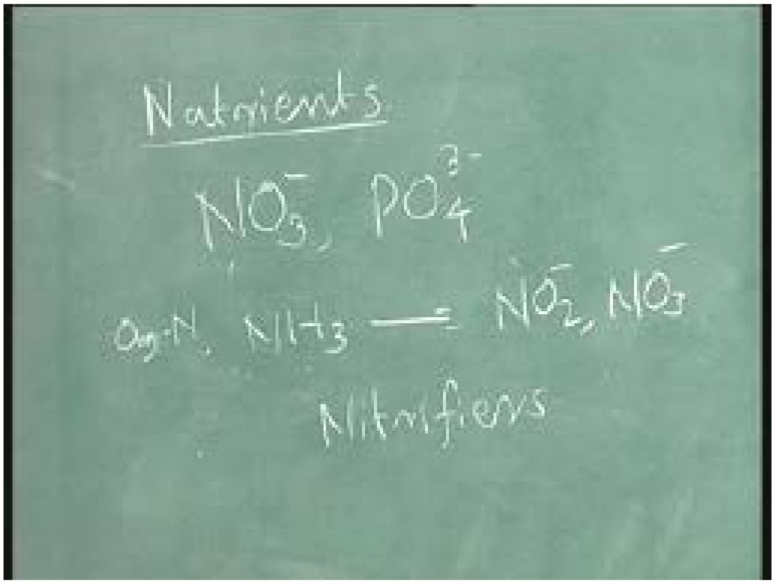

Nitrifiers are present in the system then they will be oxidizing this ammonia to nitrate and nitrate. So the nitrate will be present in the system and this ammonia is very very unstable because if you have a fresh wastewater you will be having organic nitrogen and with respect to time this organic nitrogen concentration will be reducing and you will be getting ammonia nitrogen and with respect to time this ammonia nitrogen is reducing and you will be having nitrate nitrogen and this nitrate is also very unstable so finally all the organic nitrogen and ammonia nitrogen will be present in the wastewater as nitrate.

So, even this concentration of organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen can be used as an indicator of whether the pollution is immediate or it was a past pollution. We can find this out based upon the concentration of organic nitrogen and nitrate nitrogen. That means if excess organic nitrogen is present that means it is an immediate pollution, somewhere the wastewater is directly entering to the system. If nitrate is present more that means pollution has occurred long back and everything has got oxidized to nitrate. This can be used as an indicator also.

How can we determine this nitrate? There are many ways to find out the concentration of nitrite and nitrate. And organic nitrogen and ammonia nitrogen we usually call it as kjedhal nitrogen and it can be determined by digestion and distillation. And nitrate nitrogen we can find out using spectrophotometric method.

This is the reaction I was explaining (Refer Slide Time: 31:03). Ammonia and a particular group of bacteria that is nitrosomonas in presence of oxygen is oxidizing ammonia to nitrite and nitrite is getting oxidized further to nitrate. And we all know that high concentration of nitrate in drinking water is not advisable because it can cause blue baby disease. That means if excess nitrate is present it is having high affinity to hemoglobin so the hemoglobin content of the blood is reducing and the babies will become blue that’s why the disease is known as blue baby syndrome or blue baby disease.

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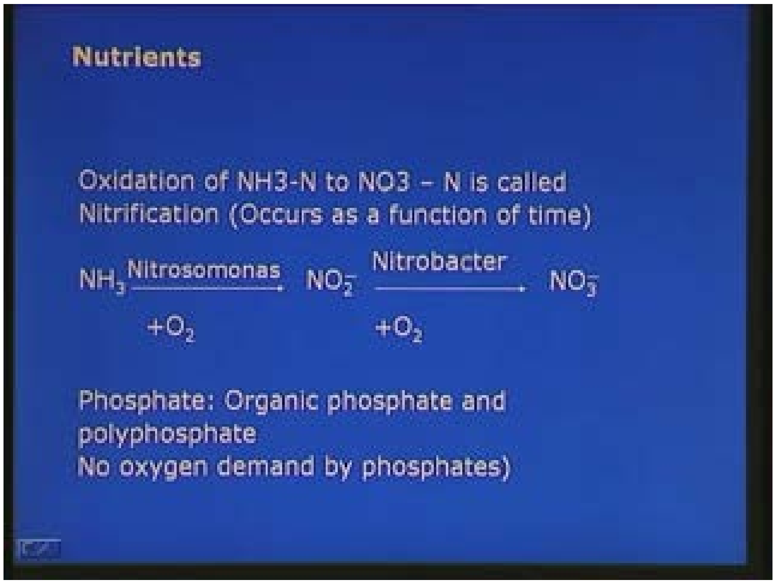

So here what is happening is the baby's intestine which is having more alkaline condition is conducive for these nitrifiers so what will happen is this nitrate will be formed and this will be combining with the hemoglobin and cause the disease. But in adults, as our intestine is more acidic this problem will not be there.

Now coming to phosphate, phosphate is also another nutrient which causes the utrification. But for phosphate one advantage is there, if phosphate is present in the water it will not be causing any oxygen demand or it will not be depleting the oxygen from the water bodies but it can cause utrification.

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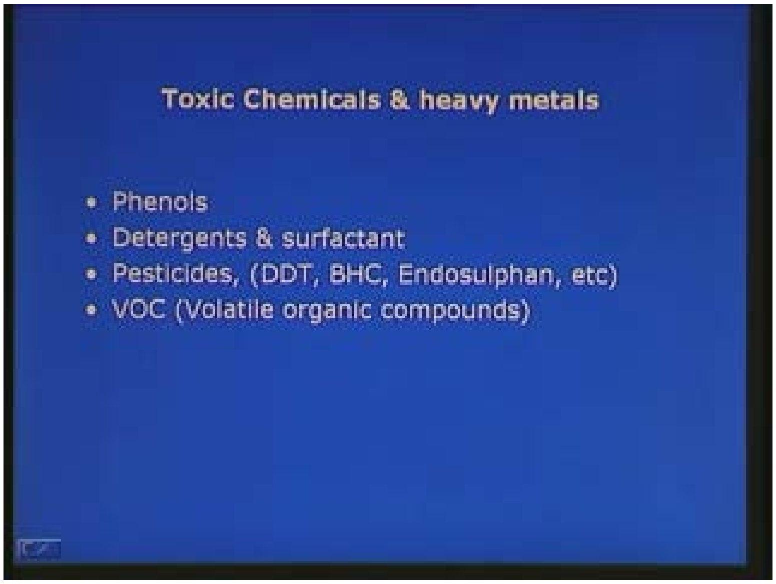

Now we will discuss about toxic chemicals and heavy metals. If you want to list few toxic chemicals present in wastewater we can list like this; phenols, detergents and surfactants, pesticides and volatile organic compounds. Where these phenols are coming into wastewater? Even if we take the domestic wastewater we can see lot of phenols present there because we use these phenols for cleaning purposes. And coming to detergents and surfactants they are also present in large quantities in wastewater. And pesticides, pesticides we use in domestic purposes to kill the insects as well as for agricultural purposes. So, from the run off, from agricultural fields etc causes the presence of pesticides. And volatile organic compounds are also being used in many industries as well as for domestic purposes.

So what is this pesticide? Pesticide is nothing but some organic compound which is chlorinated so they are highly toxic. So the presence of these toxic metals, why it is essential? It is because most of the toxic metals are non-biodegradable. Nowadays people have developed microorganisms which can degrade the toxic metals, toxic chemicals like; detergents, pesticides etc. But most of the time it is non-biodegradable or difficult to degrade. And moreover if these toxic chemicals are present it will be affecting the normal wastewater treatment systems because we are going for biological wastewater processes so it will be affecting the microorganisms present in the system so your treatment efficiency will be coming down.

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And if you discuss the adverse effect of these toxic chemicals in water, as all of us know these all are accumulative chemicals. Once they enter in the body it will be staying in the body and it will harm lot of harmful effect for humans and other organisms. So it is advisable to remove these toxic chemicals from water or wastewater before it is being sent for further treatment or put into the distribution system.

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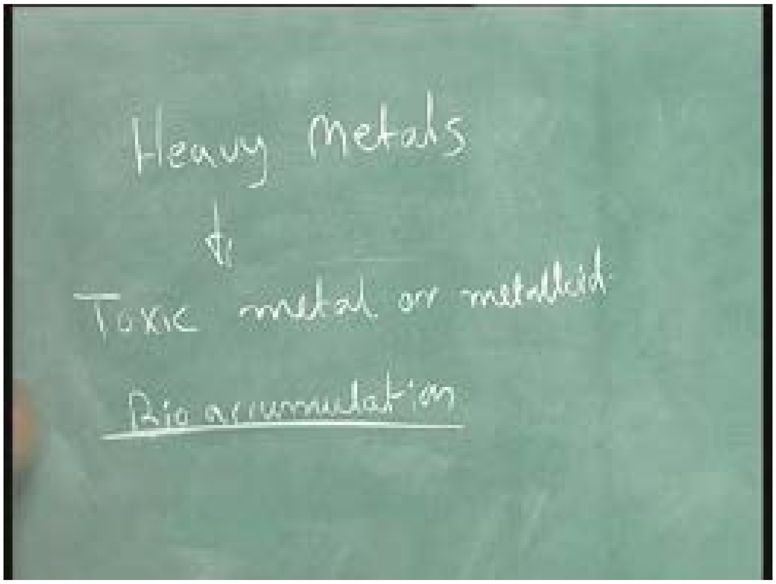

Coming to the heavy metals what is this heavy metal? The term itself is or the word itself is little misleading whether it is……., we can define heavy metal as any toxic metal or metalloid. so these heavy metals are being used extensively in industries and even some domestic purposes, for example, copper, cadmium, nickel, zinc, mercury etc are used in some someway or other in many of the industries especially electrochemical industries, tanning industry etc.

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What is the problem with this heavy metal? The major problem is they are non-degradable so we cannot destroy them. These heavy metals enter in the food chain and gets bio-accumulated or biomagnified. What is meant by this bio-accumulation or bio-magnification? For example, some wastewater is coming to a stream, some wastewater is coming and here you have your aquatic organisms and aquatic plants and you have heavy metal so what will happen is this heavy metal ions will be getting adsorbed biosorbed by this aquatic organisms or the aquatic plant so it will be getting concentrated there. Once they enter in the system it will not be coming out, it will be concentrating in that one.

We all know what food chain is. This aquatic plants or algae will be eaten by herbivorous fish that means fish which is surviving on plants and this herbivorous fish will be eaten by the carnivorous fish. So, compared to this aquatic plants the size of the fish is much larger and they will be eating so much of aquatic plants during their living period so whatever heavy metal is accumulated in this microorganism or the aquatic plant which is consumed by the fish, everything will be getting accumulated in this fish so this fish is eaten by some other big fish and that fish will be eaten by human beings and human beings will be consuming the fish for such a long time.

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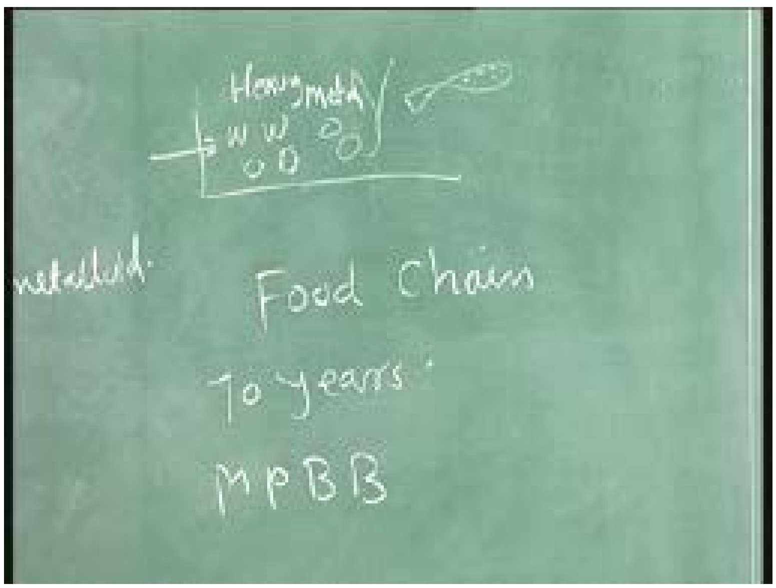

For example, our average life span is 70 years. So, over an year the person will be consuming so much of fish so whatever is the heavy metal present in that fish will be coming to our body and it is getting accumulated and accumulated and at a particular stage what will happen is the concentration of that particular heavy metal is going beyond the maximum permissible body burden. That means what is the maximum concentration our body can take without any adverse effect. So after sometime this concentration is going beyond the maximum permissible body burden and at that time we will have all the adverse effects.

So similarly it is not only because of eating fish. For example, if you are using the water for irrigating our vegetables so the same thing can happen, the heavy metals can get accumulated in the vegetables and we are consuming the vegetables on daily basis and whatever is the heavy metal present in that one it is coming to our body and it will be causing all the problems. So there are many many episodes because of this heavy metal accumulation.

One of the famous episodes is Minamata Episode which has occurred in Japan due to mercury. So what was happening? Mercury waste was being discharged in the Minamata bay of Japan. So, because of the environmental processes this mercury was converted to methyl mercury and this methyl mercury was getting accumulated in the fish. In this Minamata bay most of the people were fishermen so they were fishing and they were surviving. Since they were consuming lot of fish which was contaminated or polluted by this mercury so naturally the mercury concentration in their body was very very high than the permissible concentration and because of that mercury concentration many people died. This is the Minamata episode.

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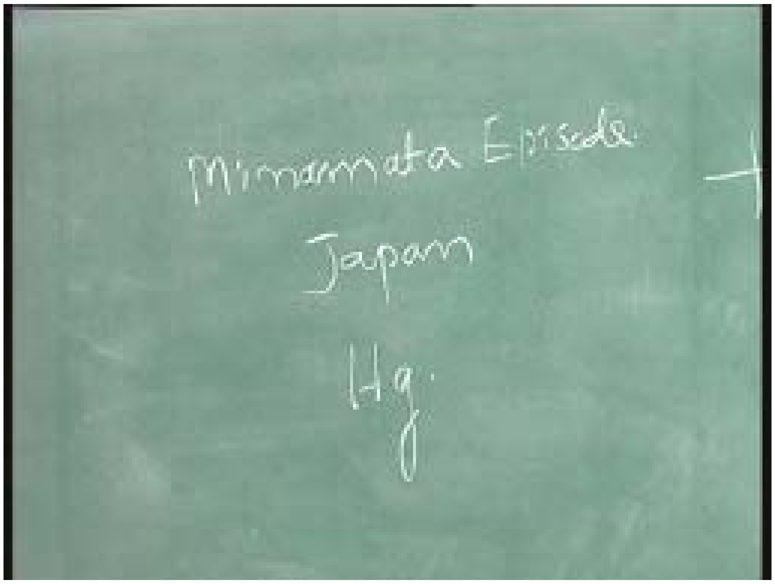

If heavy metals are present it will be bio-accumulating it is not getting destructed in the food chain so it will be accumulating and the final receptive will be getting affected because of the high concentration. So it is very very essential to remove the heavy metals from the system or it is essential to know what is the amount of heavy metal present and what type of metal is present. that is why there are…., if you see, whatever we were discussing in the earlier classes about the drinking water standards put up by Bureau of Indian Standards or Environmental Protection Agency or World Health Organization in all those cases we can see that there are specific standard for each and every heavy metal based upon their toxicity condition.

Now we will come to the biological parameters. Or before that one, I forgot….., we have to discuss about alkalinity and hardness. These two are also very very important chemical parameters. Especially when we go for any treatment plant design either it is water treatment plant design or wastewater treatment plant design this alkalinity plays a significant role. Alkalinity is nothing but the acid neutralizing capacity of that water. It is nothing but the acid neutralizing capacity of water. And in water, if you consider the alkalinity in water it is caused because of carbonates, bicarbonates and hydroxyl ions present in the system. The alkalinity is caused basically because of carbonates, bicarbonates and hydroxyl ions present in the system.

But if you consider the alkalinity in wastewater it can be from the carbonate carbonic acid system as well as phosphate. Phosphate can cause alkalinity because phosphate can be getting converted to HP O 4 2 minus and H 2 PO 4 minus and so on so it can cause alkalinity. Similarly, sulphide can cause alkalinity because sulphide gets converted to HS and H 2 S so the alkalinity…….. or we can tell that how much acid or base the system can take care without much change in the pH of the system so that is what is happening in alkalinity. so the most important thing we have to remember is it is basically because of the carbonic acid system or because of the presence of carbonate and bicarbonate present in the system but in wastewater there are other compounds also which can contribute alkalinity.

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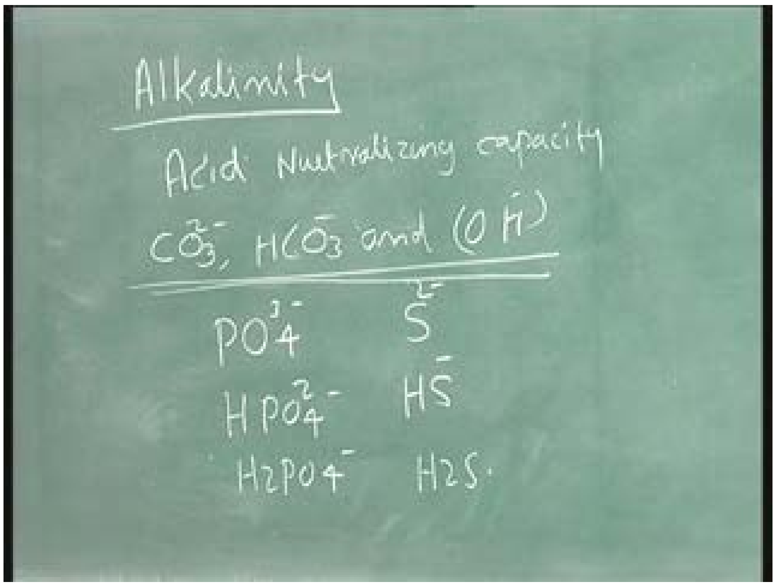

How can we measure the alkalinity?
Alkalinity can be measured by simple titration. What you have to do is take the water sample or the wastewater sample and by definition it is the acid neutralizing capacity so you take some diluted acid, for example 0.02 normal H_2SO_4 or Hcl, any dilute acid you take and titrate and use indicators. So we use phenolphthalein and methyl orange usually. So what you do is first you take the sample and add a few drops of phenolphthalein and titrate with the acid. Initially the phenolphthalein will be giving a violet color. That means you have phenolphthalein alkalinity. So you titrate it with the acid so the color will be disappearing at a particular point. So whatever is acid consumed up to that point that is the phenolphthalein alkalinity.

Usually the acid is required to bring down the pH up to 8.3 that is phenolphthalein alkalinity and after that again continue a titration so your methyl orange will be changing the color so that is your methyl orange alkalinity. Here the pH is 4.5.

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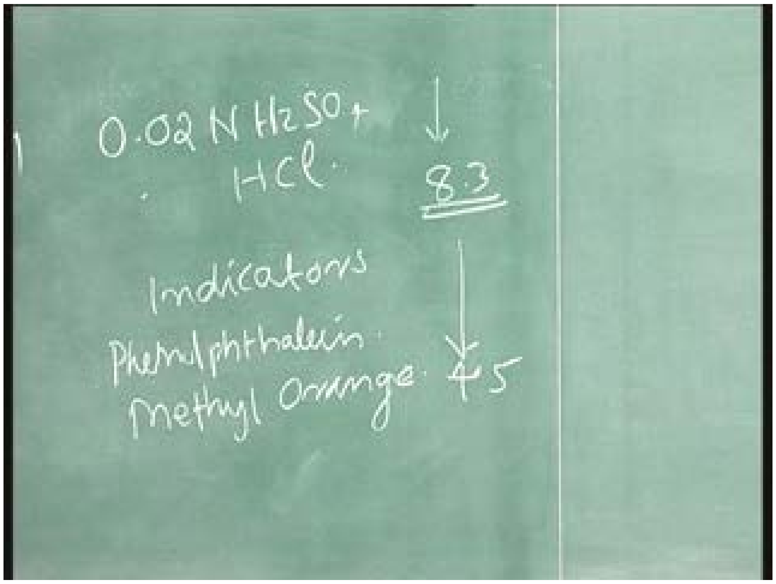

So your total alkalinity is what is the total acid consumed to bring down the pH of the water sample you have taken up to 4.5 so from this one you can find out the alkalinity.

Now we will discuss what is this hardness?
Hardness is nothing but the presence of multivalent metallic ions mainly divalent metallic ions like; calcium and magnesium. The presence of calcium and magnesium causes hardness. And you know what are all the problems with hardness. If it is present in water it will be forming scales in boilers or any water boiling facilities. Moreover, it will be causing scale formation in the water distribution system so with respect to time what will happen is your water distribution pipe will be getting thick calcium carbonate precipitates like this and the capacity of the pipe will be coming down with respect to time. So, excess harness is not recommended so we have to remove excess hardness. This hardness can be classified into two categories: One is carbonate hardness and another one is non-carbonate hardness.

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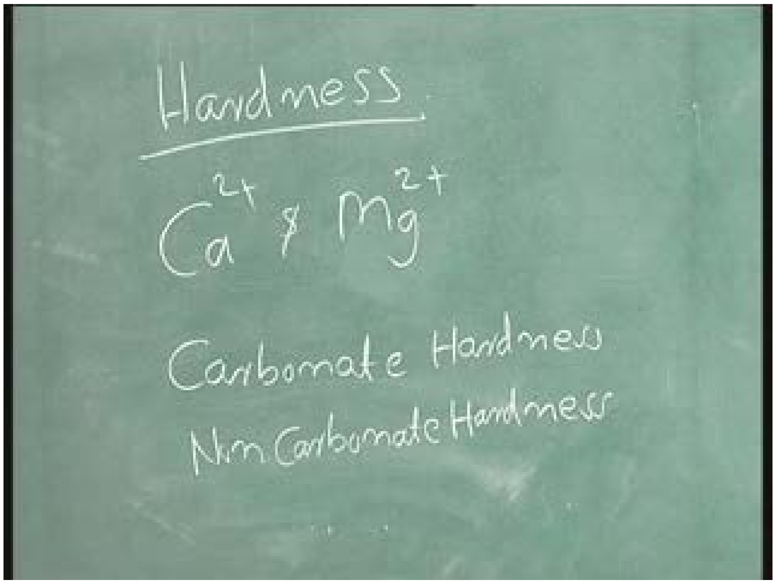

Carbonate hardness is nothing but the hardness equivalent to alkalinity. That means the calcium or magnesium present in the form of carbonate or bicarbonate that is known as carbonate hardness. This is also known as temporary hardness because this hardness you can remove just by boiling. Because what will happen is, when you boil the solubility of this calcium carbonate will be decreasing and this calcium will be precipitating as calcium carbonate so you can remove the hardness by mere boiling.

And non-carbonate hardness is nothing but the hardness or the amount of calcium and magnesium present in the form of either sulphates, nitrates or chlorides. This is non-carbonate hardness. Or in other ways we can tell that the hardness in excess of the alkalinity. That is known as non-carbonate hardness. So this hardness is also an important parameter. Now we will come to the biological parameters or biological characteristics.

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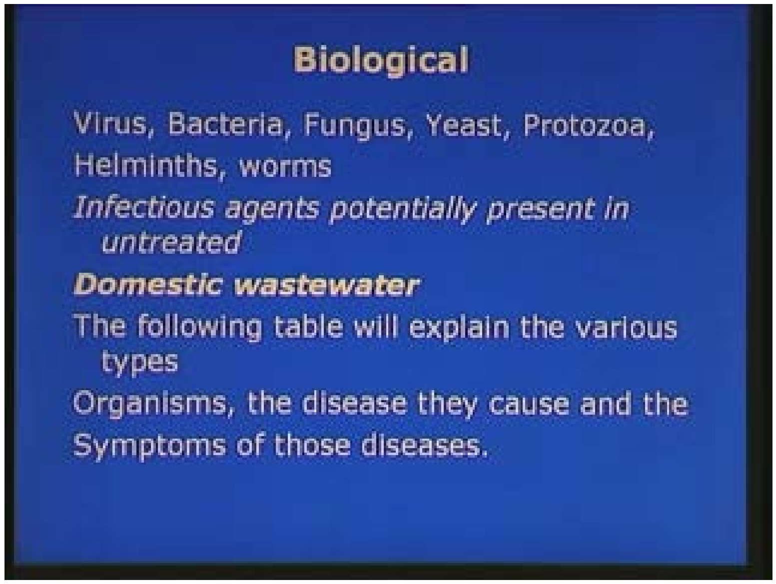

So, if you think about drinking water the most important water quality criteria is the bacteriological water quality criteria or bacteriological safety. Why, because if the water is not bacteriologically safe or if some pathogens are present there, there are chances of getting the disease immediately. But if the water is not safe chemically or physically you will not be getting the disease immediately. What I mean is if the chemical constituents, the toxicant present is at a lower concentration the effect will not be immediate. But in case of bacteriological pollution the effect will be immediate. If some pathogen is present you will be immediately getting the disease. So, in emergency cases this is the reason why people are going for only chlorination. Because you know that chlorination can kill the pathogens present in the water system. So emergency cases if you want to supply water to some places we won't bother about the physical parameter or the chemical parameter but we have to take care of the bacteriological parameter because it can cause diseases.

How can we find out whether the water is bacteriologically safe? The tests whatever we usually carry out is the M P N test. It is nothing but the Most Probable Number. According to the test what we do? We take the water sample in different test tubes and see whether the gas formation is there or the indicator organisms are present and depending upon that we can find out what is the Most Probable Number. And for drinking water this should be less than 1 per 100 ml.

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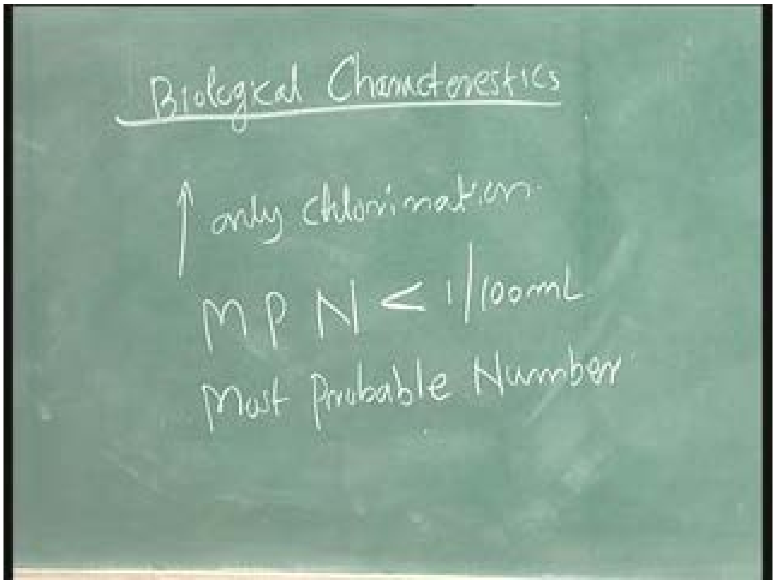

So biological characteristics when we discuss about wastewater we are discussing about whether the wastewater is having virus, bacteria, fungus, yeast, protozoa, helminthes, worms etc. these are the basic infectious agents potentially present in untreated domestic wastewater. So, when the domestic wastewater comes the following table explains the various types of organisms and the diseases they can cause.

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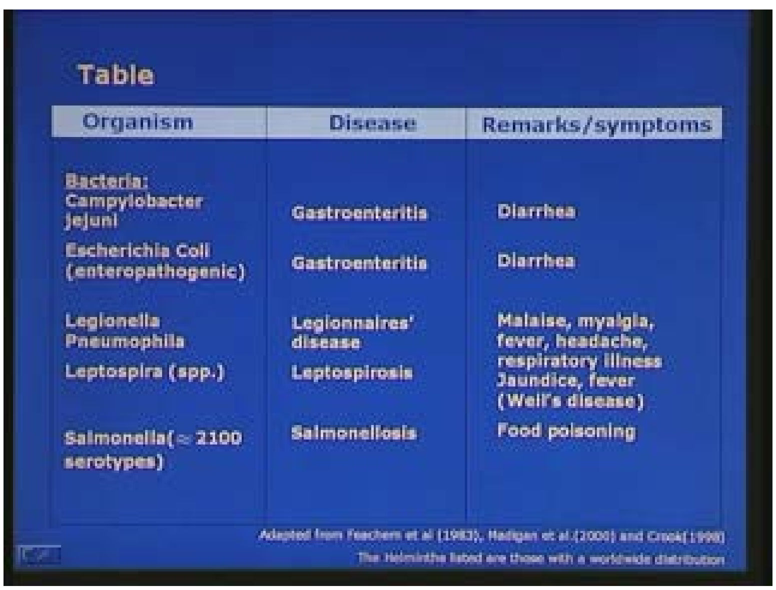

We can see here the bacteria. Most of us have heard about this Escherichia coli. I was discussing about this M P N Most Probable Number. Here we use this e-coli of the indicator organism. So, if this bacteria is present you get gastroenteritis that means diarrhea then salmonellosis, food poisoning etc. So this is the list of diseases caused by various microorganisms. And this is also bacteria; shigella, shigellosis and cholera it is caused by vibrio cholera. And protozoa diseases: giardia lambia giardiasis that is very common and amoebiasis. So these are the other diseases and helminths also can cause different diseases.

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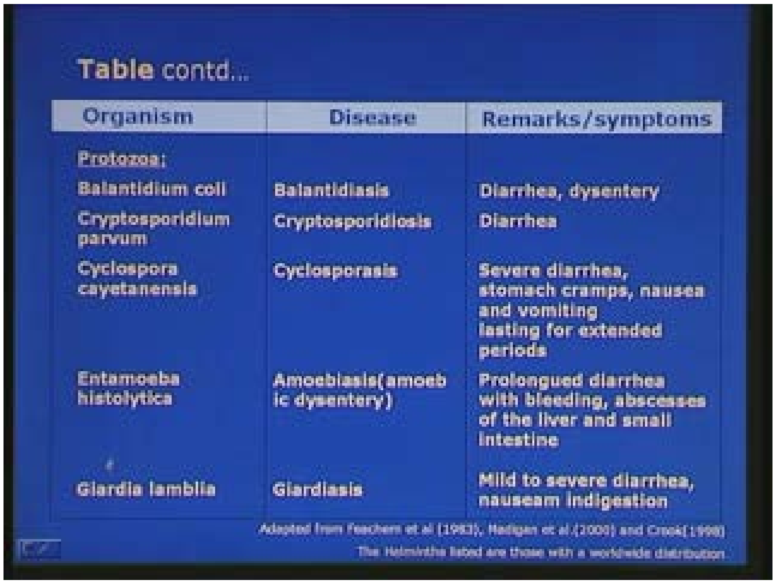

Organism	Disease	Remarks/symptoms
Protozoa:		
Balantidium coli	Balantidiasis	Diarrhea, dysentery
Cryptosporidium parvum	Cryptosporidiosis	Diarrhea
Cyclospora cayetanensis	Cyclosporasis	Severe diarrhea, stomach cramps, nausea and vomiting lasting for extended periods
Entamoeba histolytica	Amoebiasis(amoebic dysentery)	Prolongued diarrhea with bleeding, abscesses of the liver and small intestine
Giardia lamblia	Giardiasis	Mild to severe diarrhea, nauseam indigestion

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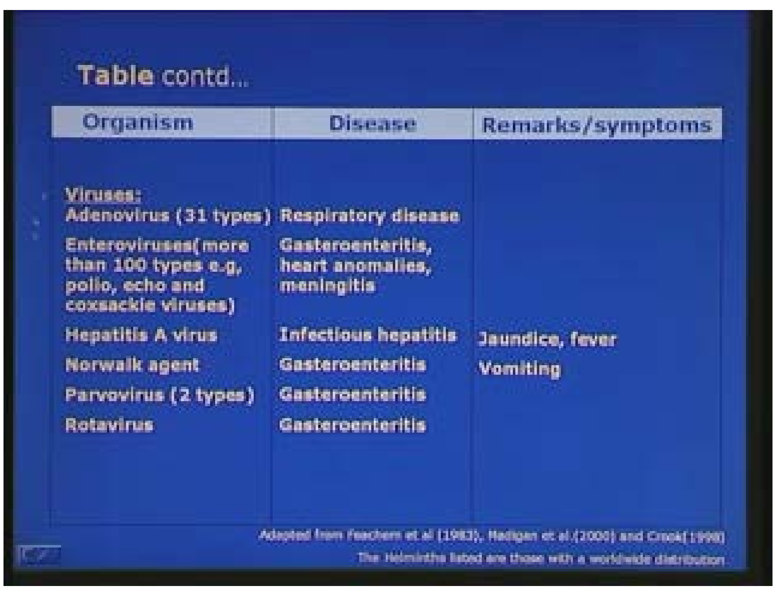

Organism	Disease	Remarks/symptoms
Viruses:		
Adenovirus (31 types)	Respiratory disease	
Enteroviruses(more than 100 types e.g, polio, echo and coxsackie viruses)	Gasteroenteritis, heart anomalies, meningitis	
Hepatitis A virus	Infectious hepatitis	Jaundice, fever
Norwalk agent	Gasteroenteritis	Vomiting
Parvovirus (2 types)	Gasteroenteritis	
Rotavirus	Gasteroenteritis	

And coming to viruses there are many types of viruses and they can cause various types of diseases. And this hepatitis A virus, we are all familiar with this infectious hepatitis. Usually because of the consumption of polluted water we get all these diseases. Or we can tell in other ways; almost all the diseases are having some relation or other relation with water or all the diseases can be classified into four categories. That means either waterborne diseases, or water wash, water based or in insect vector which is living in water. So, all the diseases are in some way or the other having some relationship with water. So if you can supply safe water then most of the diseases can be taken care of.

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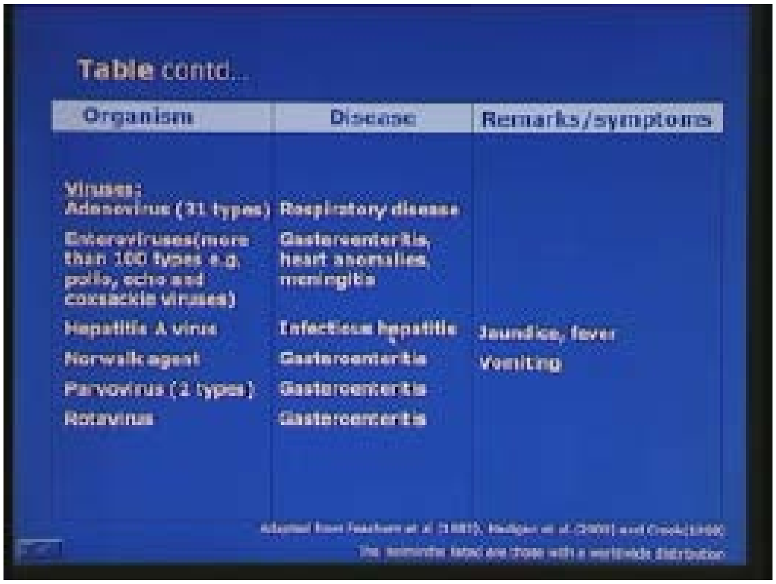

Now we will see what all things we have discussed in today’s class. We started with the chemical parameters chemical characteristics of water that include biochemical oxygen demand, COD and Total Organic Carbon, theoretical oxygen demand then we discussed about the nutrients, then toxic chemicals and heavy metals and alkalinity and hardness. Then towards the end we were discussing about the biological parameters which are important in water and wastewater analysis. So, coming to the chemical parameters we have seen that biochemical oxygen demand is very very important. It gives us the idea about what is the organic matter present in the water which are biodegradable so we are analyzing it in terms of the oxygen consumed by the microorganism in the laboratory conditions.

But the disadvantage with this one is it consumes lot of time and the quality of the experiment is depending upon the nature and the amount of bacteria present in your test. most of the time it is very difficult to reproduce your results so people were trying for a faster and more reliable analysis so they have come up with chemical oxygen demand.

In chemical oxygen demand what we are doing is we are replacing the bacteria and dissolved oxygen by some strong oxidizing agent at high temperature and at low pH. The pH is reduced by adding sulphuric acid. Like this we are creating a conducive environment for oxidation. All the organic matter whether it is biodegradable or non-biodegradable is getting oxidized to carbon dioxide and water. So we know the initial concentration of the oxidizing agent we are supplying and whatever is left over we are finding out and with that one we can find out what is the organic matter present in the system.

Third one is using Total Organic Carbon analyzer so we can find out what is the organic carbon present in the system. And fourth one is if the composition of the waste is known or the molecular formula of the wastewater is known then we can find out theoretically what is the oxygen requirement. So oxygen requirement will be giving you the organic matter present or what is the oxygen requirement for the oxidation of that one.

Then we discussed about the presence of nitrate and phosphate, what is the adverse effect of that one and how one can analyze the presence of this nitrate and how can we use it as an indicator. Then we discussed about alkalinity and hardness in water with respect to water and wastewater. And towards the end we were discussing about bacteria, virus, protozoa etc which is commonly present in domestic wastewater and which is having the potential of causing various diseases or if you can supply safe water that can take care of most of our diseases.