Water and Wastewater Engineering
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Lecture - 5
Water and Wastewater Characteristics

Last class we were discussing about the design period, design population, design flow etc. The water and wastewater treatment systems consists of massive units like dams, reservoirs and treatment units so it is very difficult to construct them very frequently. The reason is, they involve lot of cost and modification is difficult and moreover the pipes and conduit pass through the main roads so it causes so much of inconvenience so it is better to construct this master units for a long period of time so that’s why the design period concept is coming in. And the design period for various plants are decided based upon various factors such as the longevity of the unit and how easy or difficult it is to make modifications and what is the rate of population growth in that particular region and what is the ongoing interest rate etc. So once we find out the design period then we have to find out what is the population at that time.

We have discussed what are the various population forecasting methods. And we have also seen that the logistic method is the most scientific method. But people are using geometric method for the design purpose because it always gives an over estimate and our design will be always safe. And we have seen how to find out the water demand and what are all the different components involved in this one. And once you get the water demand you can find out what is the quantity of flow required for the water treatment unit or what is the flow coming into the system when we design wastewater treatment units.

We have also seen that the flow whether it is water flow in the distribution system or the wastewater flow coming to the treatment system it is not uniform, it will be varying daily, monthly, seasonally, yearly so we can find out what is the average flow, what is the minimum flow, what is the maximum flow, what is the peak factor and depending upon the units whatever you are designing you can find out which one we have to use for the design of that particular unit. These are the things we have discussed in the last class. So now you know what volume of the treatment unit required. The next one is, what process we have to select. In order to select the process we should know the characteristics of the water or wastewater. So in this class we will discuss what all are the characteristics of water and wastewater.

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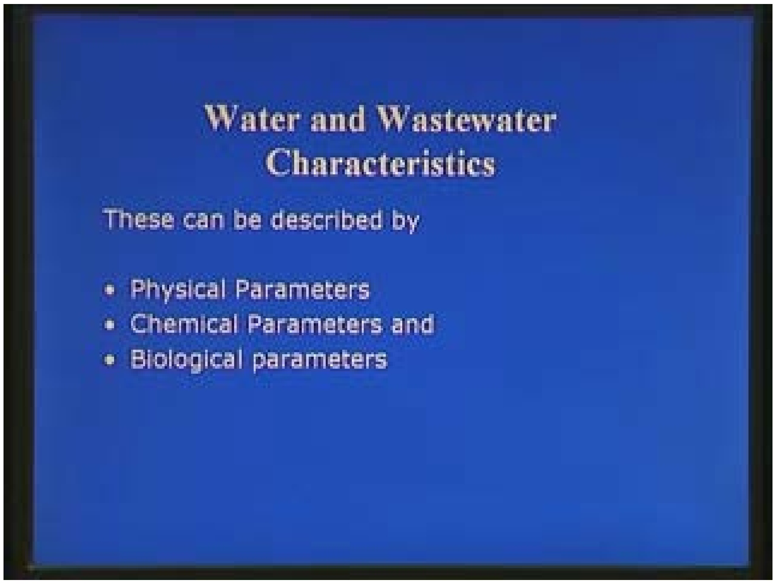

The characteristics can be basically divided into three categories; physical parameters, chemical parameters and biological parameters. This class we will discuss each in detail. Coming to the physical parameters it involves whatever we can physically feel. The parameters can be classified into solids, turbidity, colour, odour, taste, pH and conductivity.

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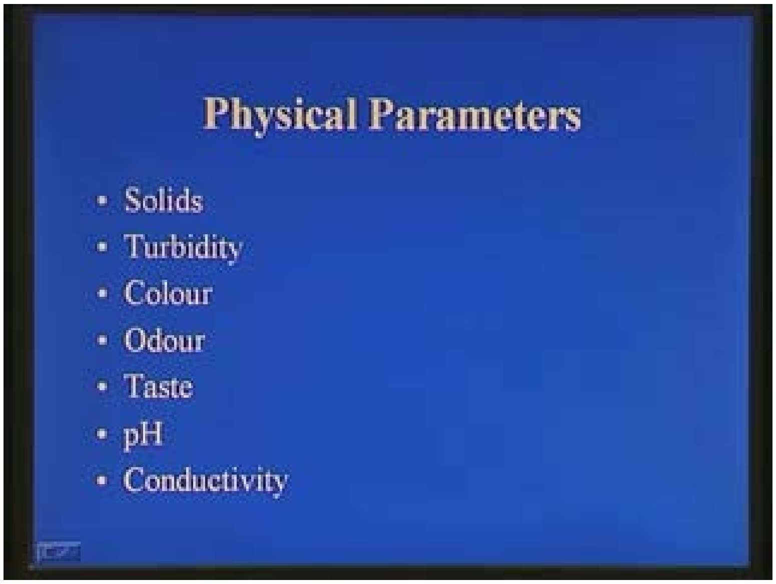

In case of wastewater usually we won't measure taste, odour etc but when it comes to water supply or especially for drinking water colour, odour, taste etc are very very important. And moreover the solids present in water and wastewater are entirely different. In wastewater mostly the solids are organic in nature whereas in the raw water whatever is coming to the water treatment plant the solids may be mostly inorganic originating from clay silt and soil particles. And sometimes biological material also may be coming like plant fabrics and microorganisms. So we have to separate these characteristics for water and wastewater because most of the time the characteristics will be different.

First we will discuss about the solids. Solids can be classified into various categories depending upon the size of the particles. As we all know the particle size will be varying from nanometers to few micrometers or millimeters.

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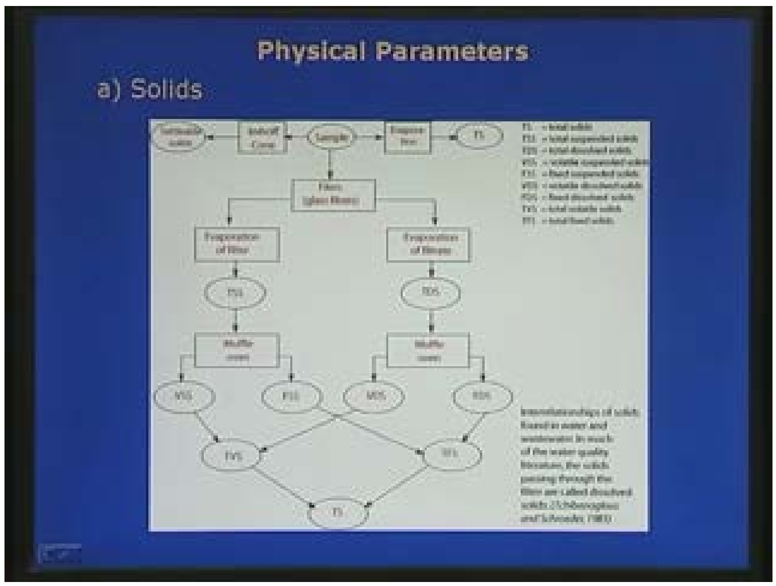

So, if the particle size is very very small if it is completely dissolved in the solution we can call it as dissolved solids. If the particle size is in between 0.01 micrometer to 1 micrometer we can call them as colloidal solids because these colloidal solids are very very stable that means they will not be settling down in the liquid or in water so they will be always in that Brownian motion so it is very very difficult to remove them especially from water and wastewater.

Next one is the suspended solids. Suspended solids we can find out or remove by settling. Then another category of solids is settleable solids which is easily settleable. In wastewater especially domestic wastewater around 60 percentage of the total organic matter is in settleable form. So first we will see how we can classify the solids or how to find out what is the fraction coming under each category. So what we have to do is first take the representative sample of the water and put it in an Imhoff cone. Imhoff cone is like this (Refer Slide Time: 06:56) a conical glass vessel. So what we have to do is take the representative sample of the wastewater of about 1 liter and pour it in the Imhoff cone and allow it to settle for 1 hour and after 1 hour whatever is settled in the Imhoff cone you find out what is the volume. It’s a graduated cylinder so we can find out the volume directly from here. So we will be getting the settleable solids in terms of ml per liter. This is the procedure.

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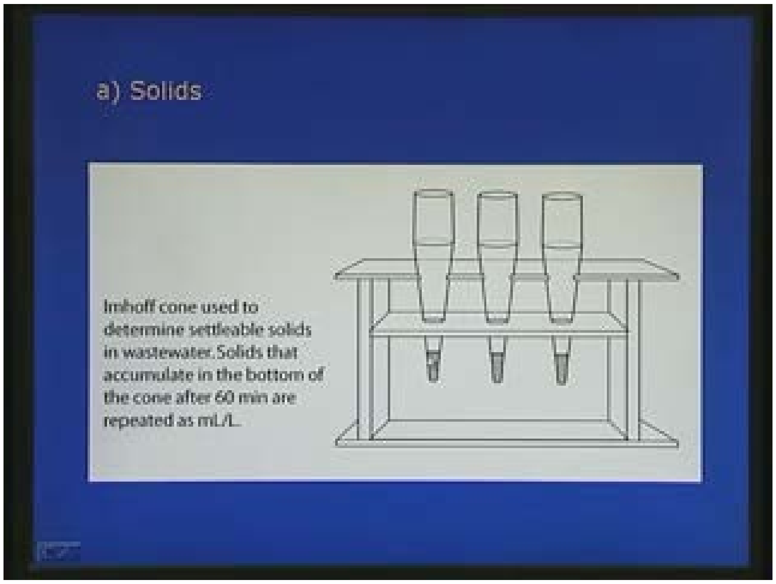

Imhoff cone or these settleable solids measurement usually we do it in the case of wastewater. Now, coming back if you want to find out the total solids either it is water or wastewater what we have to do is take, again the representative sample of the water in a container and evaporate the water completely so that all the solids present in the water will be remaining in the container. So take the weight of the water before pouring the water and after complete evaporation…….. then what is the weight difference we get, we can find out what is the total solids.

For example, if you have the initial weight, initial weight equal to W 1 and after evaporation of xml of water the weight is W 2 so total solids equal to W 2 minus W 1 into 1000 divided by x and this one (Refer Slide Time: 9:04) we will take it as milligrams, this also we will take it as milligrams then you will be getting it as milligrams per liter. This is the way to find out the total solids.

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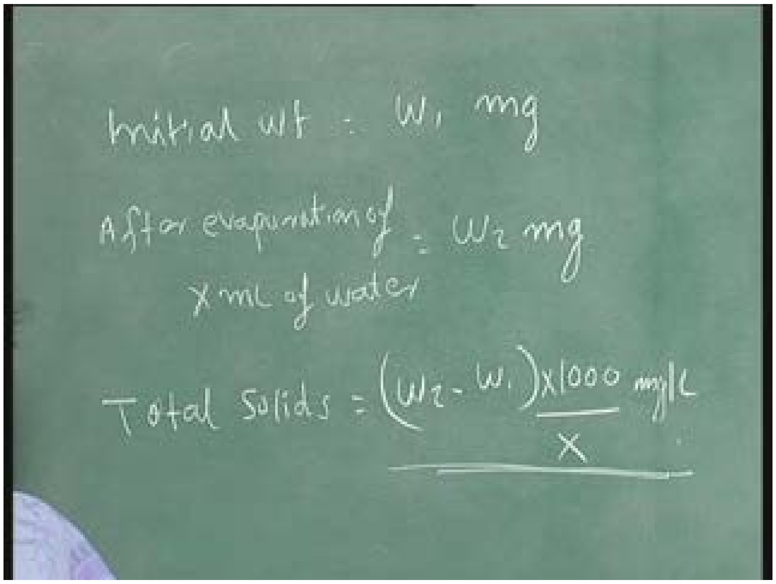

And if you want to find out the suspended solids what we have to do is take a non-volume of the representative sample of the water and pass through a glass fiber filter. The pore size usually used in wastewater according to standard methods is, as per standard methods pore size of the filter is 2 micrometer to find out suspended solids. So what you have to do is before doing the filtration you have to find out the weight of the filter paper and while doing this experiment we have to be careful.

Sometimes the filter paper may be having some soluble components so before doing the analysis or the experiment first soak the filter paper in distilled water and allow the soluble part to get dissolved in the water again try it in the oven, put it in the desiccator, cool it back to room temperature and take the weight then use it for filtration and after the filtration again put back it into the oven, allow it to dry at 104 degree centigrade then take the weight. So this is the way we can find out the suspended solids.

We have got total suspended solids and total dissolved solids and in the total suspended solids and dissolved solids as I have already mentioned in wastewater most of the solids are of organic nature so if you want to find out what is the organic fraction and what is the inorganic fraction present what we can do is we can heat up the sample at a high temperature then what will happen is that the organic component will be reacting with oxygen and forming carbon dioxide and water and this will be escaping from the system.

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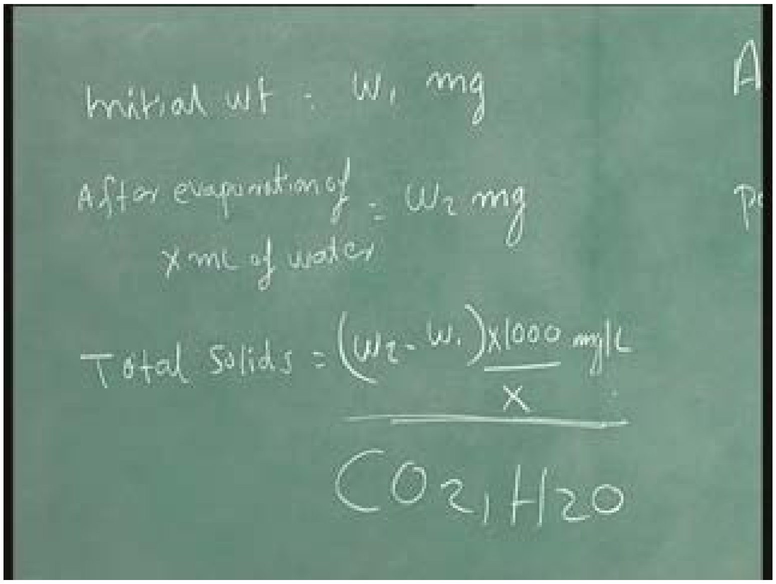

So if you want to find out what is the volatile suspended solids if you want to find out the volatile suspended solids what we have to do, we have already filtered the water and you got the total suspended solids, put that filter paper in the oven or in the muffle furnace at 500 plus or minus 50 degree centigrade. At this temperature what will happen is all the organic matter will be volatilizing and all the inorganic components will be remaining. So you take the weight before and after putting in the muffle furnace so the difference will give you what is the volatile compound present in the filter paper that means total suspended solids minus whatever is left over you will be getting volatile suspended solids.

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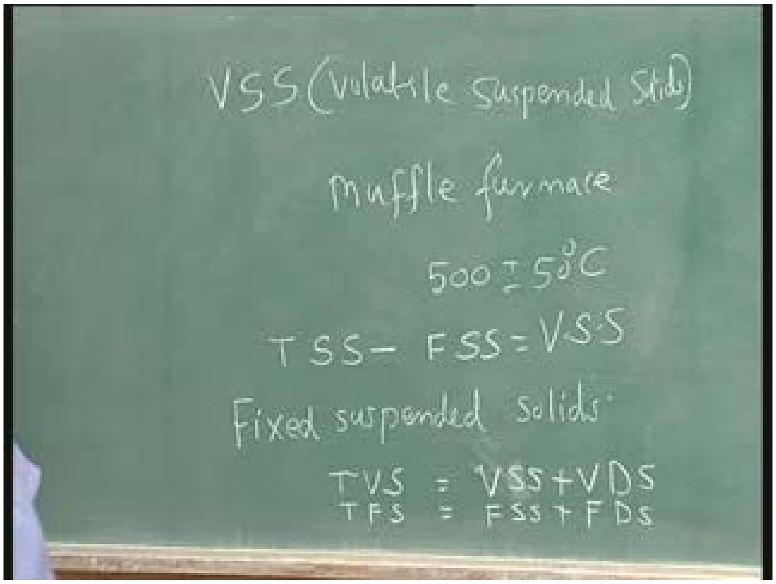

So whatever is leftover in the filter paper that is nothing but the inorganic component. So we call them as fixed suspended solids. So now we have seen how to find out the total solids, total suspended solids, fixed suspended solids and volatile suspended solids. In the similar way we can find out what is the volatile dissolved solids and fixed dissolved solids.

Volatile dissolved solids how can we find out? What we have to do is, the container what we have used for evaporating the total sample, you have to keep it in the muffle furnace. So usually we use platinum crucibles or silicon crucibles for this purpose silicon crucibles or platinum crucibles which can sustain high temperature so usually the evaporation and other processes are carried out in silicon crucibles.

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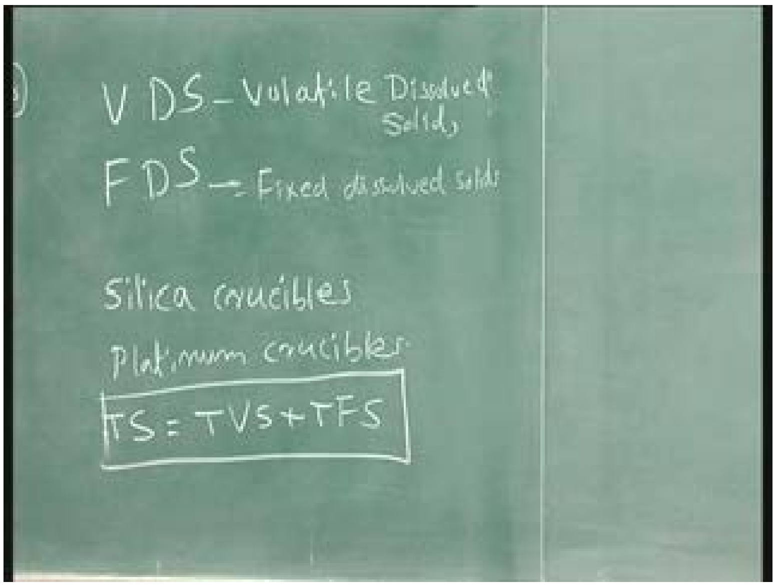

So what you have to do is take the sample, evaporate it in the oven and afterwards put it in the muffle furnace, take the weight before and after so whatever is lost in the muffle furnace that will give you the volatile dissolved solids. This is volatile dissolved solids and the left over is fixed dissolved solids. So we have seen what is the volatile suspended solids, fixed suspended solids, volatile dissolved solids, and fixed dissolved solids. Now from this one we can find out what is the total volatile solids and total fixed solids.

Total Volatile Solids TVS is nothing but volatile suspended solids plus volatile dissolved solids so this will give you total volatile solids and total fixed solids is equal to fixed suspended solids plus fixed dissolved solids and total solids TS will be equal to total volatile solids plus total fixed solids. So we can find out all the components of the solids from the water or wastewater.

Why we want to find out all these components is because when we design the treatment units we have to know what is the component present as suspended part, what is the component present as colloidal part and what is the component present as dissolved solids because the treatment process for various particles for various particle removal are entirely different.

For example, the suspended solids we all know, will be settling very fast so we can go for some physical unit just like sedimentation for the removal of suspended solids whereas colloidal particle removal is very very difficult so we may how to go for physical chemical processes and for the dissolved solids removal you have to go for chemical processes or adsorption, ion exchange etc in case of water treatment whereas in case of wastewater treatment if you go for biological processes also the design criteria will be changing depending upon the nature of the solids.

This picture shows (Refer Slide Time: 16:45) how we can find out the different components of the solids. This I have already explained, I will once again explain. this is the sample, so in evaporation you will be getting the total solids Imhoff cone and allowing it to settle then you will be getting the settleable solids, then evaporation of the filter, the total suspended solids then put it in the muffle oven or muffle furnace and you will be getting fixed suspended solids and volatile suspended solids and whatever is the filtrate coming out, from that one you will be getting total dissolved solids and put it in the muffle oven so you will be getting volatile dissolved solids and fixed dissolved solids. So you take the sum of fixed suspended solids and fixed dissolved solids you will be getting total fixed solids and for volatile suspended solids plus volatile dissolved solids you will be getting total volatile solids. And if you take the sum of total volatile solids and total fixed solids you will be getting total solids.

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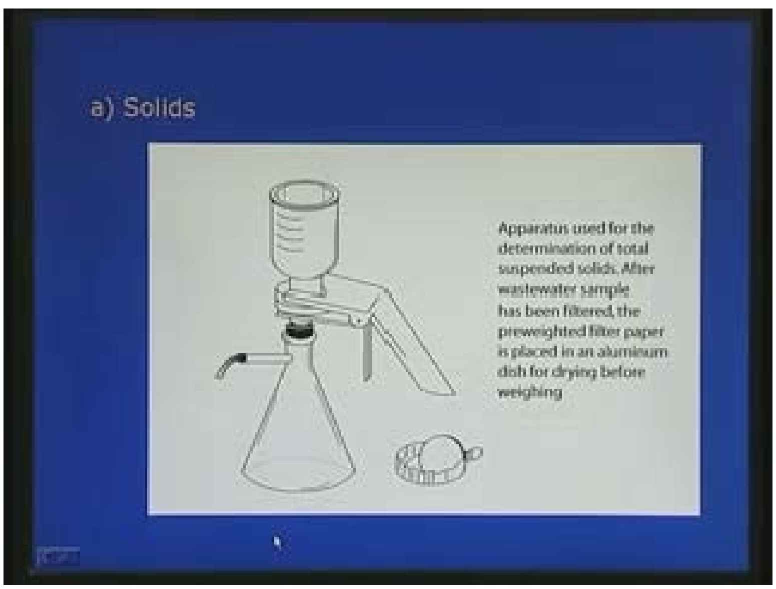

This is the filtration assemble we usually use to filter the thing. Because if you take the 0.2 micrometer filter paper and if you pour the wastewater or water then the filtration will take lot of time. So, if you want to increase the rate of filtration what we can do is put the filter paper here and attach it to a vacuum pump so what will happen is the vacuum pump will be sucking the air from here so the filtration rate will be much much faster. And this is the filter paper (Refer Slide Time: 18:25) usually we use for this purpose and this I have already explained to you.

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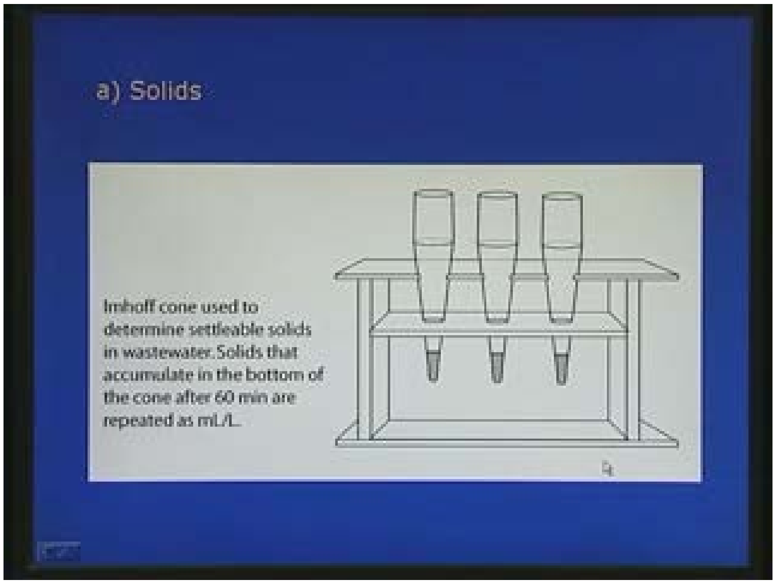

Now we will come back to the next physical parameter that is turbidity. Turbidity is a qualitative measurement. Turbidity is a qualitative measurement of solids. It will not give you any quantity. For example, if you have clear water in that one if you put a pebble a small pebble what will be the turbidity the water will be very clean and you will not be getting any turbidity there. But if you crush that pebble into fine particles and put it into the water what will happen is the turbidity will be very very high. So, if you take the total solids in both the cases you will be getting the same value but the turbidity will be entirely different in both the cases. So this means turbidity is depending upon the nature and size of the particles present in the water sample we are considering. So this is what I told that it is a qualitative measurement not a quantitative measurement.

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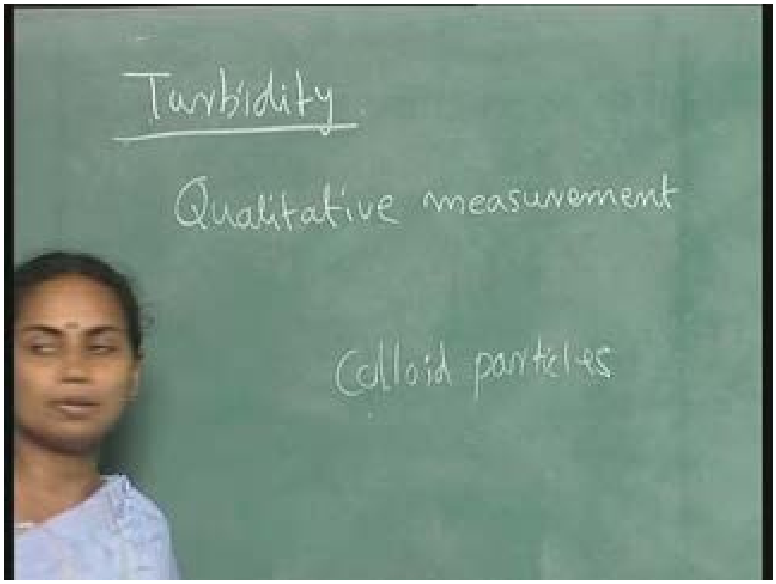

How the turbidity is caused?
The turbidity is caused basically due to colloidal particles. So what will happen, if the particles are present in the water or the wastewater what will happen is it will not allow the passage of light completely. So if you want to find out the turbidity of the water so how can we measure it. By measuring the absorbance of light through that water sample we can find out the turbidity. And if turbidity is there in the water how it is going to affect.

Turbid waters are not pleasing. So it is essential to remove the turbidity. Moreover, if you consider the drinking water when we go for disinfection and so on this turbid particles will effect the efficiency of disinfection because the colloidal particles whatever is present will be acting as a shelter for the microorganisms so it will not be getting exposed to the chemical dose so most of the time the disinfection will not be effective.

Another reason is this can be acting as the adsorbents for many dissolved chemicals and that will be harmful to us. And in case of wastewater treatment if you go for oxidation ponds and if the turbidity water is there the passage of light will not be proper and it will be affecting the aquatic system.

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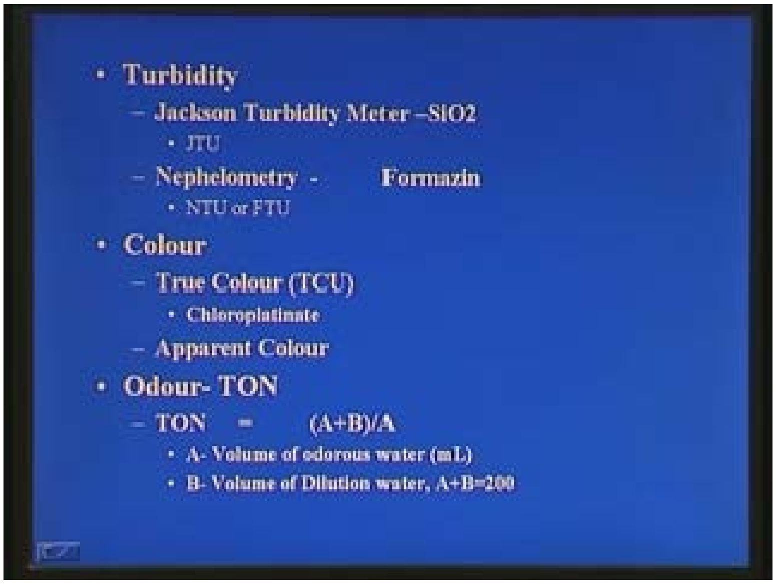

So how can we measure the turbidity? There are two different methods. In earlier days people where using Jackson turbidity meter. Here the meter was consisting of a graduated cylinder and a standard candle. The standard candle was put it in a black metallic shape so that the light can be visible only from the top of the arrangement. And if you want to measure the turbidity of a particular water sample what one have to do is pour the particular water sample in the graduated cylinder which is placed above the candle and see the candle light through the water and pour the water up to that level in which we cannot see the candle light so that mark will give you the turbidity. It was something like this. Here there is a standard candle and here we place the graduated cylinder and see the light from that, see the light from the top and this portion will be filled with water. So depending upon the water level which can completely obstruct this light coming from the candle gives the turbidity (Refer Slide Time: 22:52).

And in Jackson's turbidity meter 1 turbidity unit that means 1 Jackson's turbidity unit is equivalent to the turbidity coarse by 1 mg per liter of silica oxide SiO_2 so this was the standard used in earlier days. But as we know it is very difficult to measure because we have to have the standard and carrying this instrument is very very difficult so nowadays people are going for nephlometric turbidity meter this is working on the lights scattering principle.

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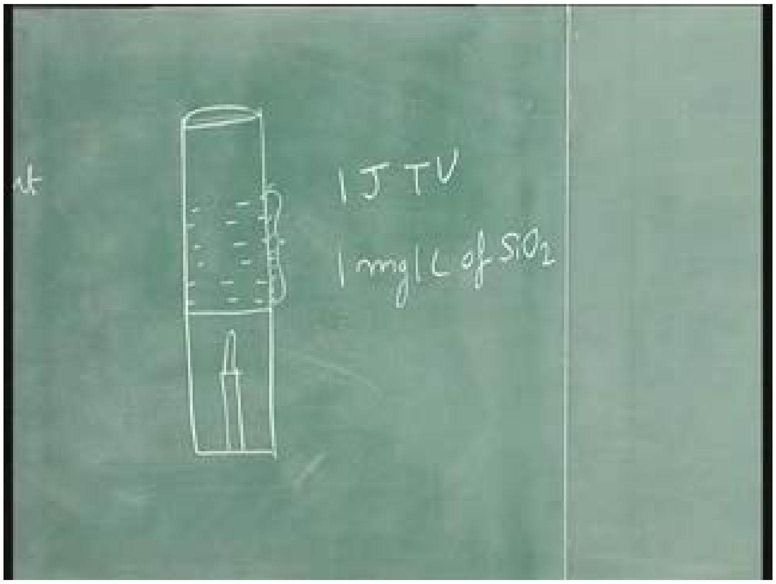

So what is happening is, light is coming from a particular source and you have your sample here and the light will be coming in this direction and whatever light is getting scattered by the turbid particle present in the sample we observe from here at 90 degree angle.

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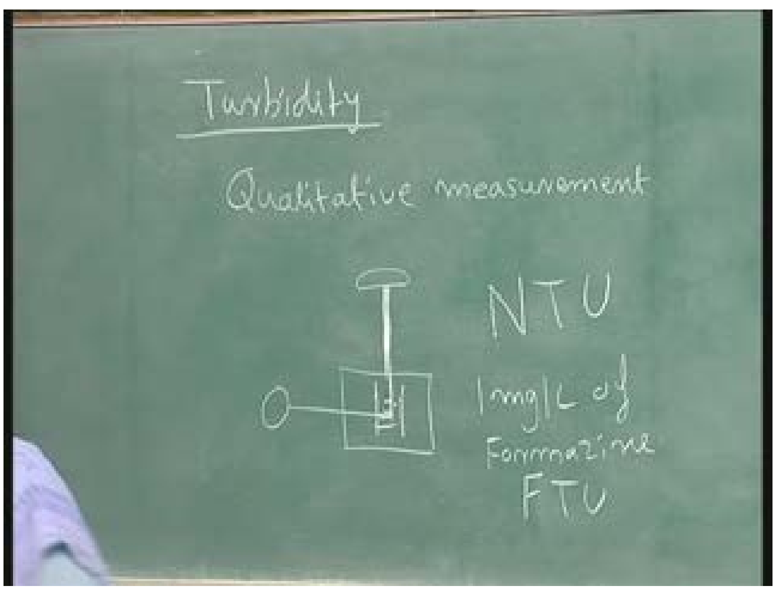

So we can get the amount of light that has got scattered and it gives you the turbidity of that particular water sample. So, the turbidity is exposed as NTU that means Nephlometric Turbidity Unit and 1 NTU is equivalent to 1 mg per liter of formazine. The turbidity generated by this formazine is much more stable compared to this silica oxide that's why silica oxide is replaced by formazine. So, since formazine is used as the standard this turbidity unit is sometimes called as FTU also. NTU or FTU both are the same so drinking water as per EPA the turbidity should be less than 1 NTU.

The next parameter under physical classification is colour. Colour is caused in water or wastewater due to the presence of dissolved or colloidal particles. So the colour can be divided into two categories: One is true colour and another one is apparent colour. Apparent color can be removed by removing the colloidal particles but true colour is caused by the dissolved solids.

How the colour is coming in water is because when it comes in contact with various chemicals or biological components the coloring material may be leaching from those substances gives colour to the water. How can we find out the colour.

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So usually we compare the colour with some particular standard. The colour standard usually used is or the colour scale usually used is platinum platinum scale so here chloroplatinate is used as a standard. So what we have to do, if you have a particular sample you have to take the standard chloroplatinate solution and dilute your sample and compare the colour with the standard solution and the dilution you have to continue till your standard colour and the sample colour matches. So, from the dilution number you can find out what is the true color unit. And if the colour is entirely different from the colour which is given by this chloroplatinate then usually people go for spectrophotometric method.

The next one is odour. None of us like to have any odourous water for our use. So how we can measure this odour? Whether any standard method is there? We all are aware that this odour the intensity will be varying from person to person so it is not a true measurement. So the odour is usually represented as threshold odour number and this will be again varying from person to person depending upon their sensitivity to the odourous compound. So, how to find out this threshold odour number? What we have to do is take the odour of sample and dilute it till you won't get any odour.

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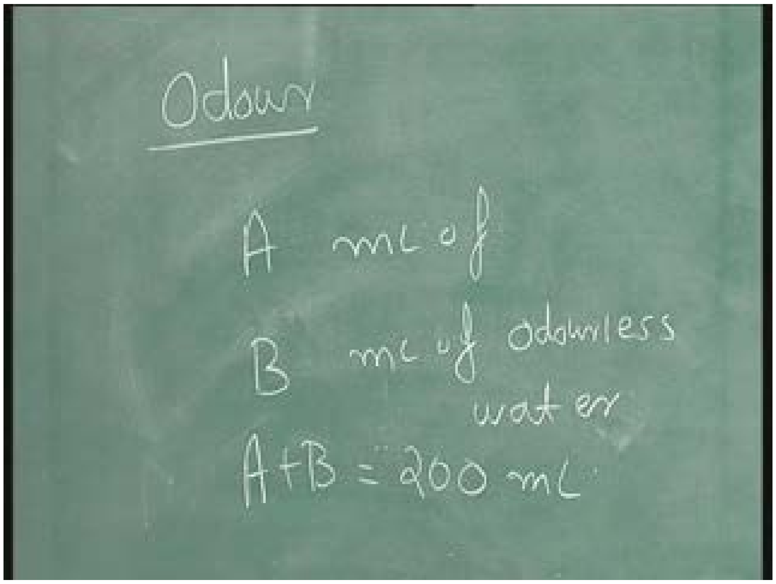

So what we have to do is, say we have A ml of odourous sample and we are diluting it with and total with B ml of odourless water and another condition is A plus B is equal to 200 ml.

So for example if you take A as 1 ml you add it to 199 ml of dilution diluted water or distilled water then smell the sample and find out whether any smell is coming. Or what you do is start from the higher level. Take 50 ml of your sample and add 150 ml of the dilution water then you can find out whether the odour is coming. so the odour number at that case is A equal to 50 ml and B equal to 150 ml so your threshold odour number will be equal to A plus B divided by A so this is 200 divided by 50 equal to 4.

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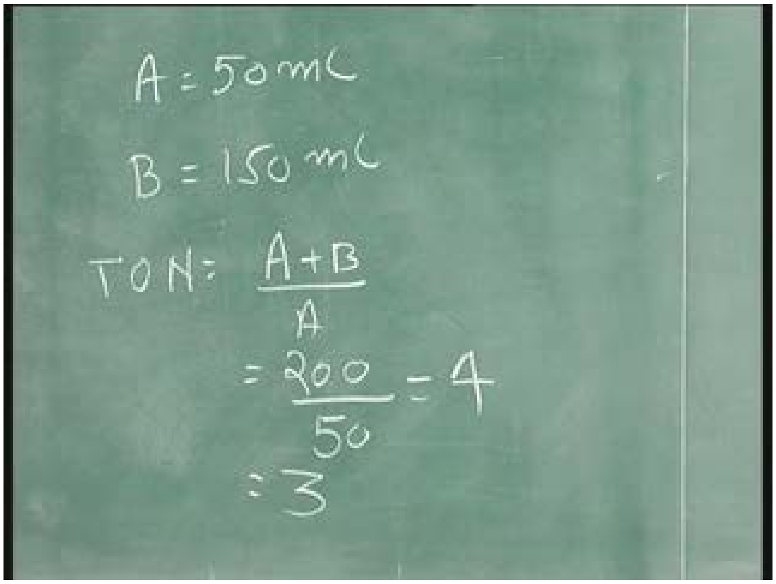

So, as the volume of air decreases your threshold odour number will be increasing. That means you have to dilute it more times to get odour free sample. And for drinking purpose it is recommended that the threshold odour number should not be more than 3. So, if you supply any water more than 3 there will be objection from the people because people can recognize the odour very easily.

Now, coming to the colour of the wastewater, till now, we were discussing about the colour of the water sample. The colour of the wastewater will be either gray colour or black colour. So, if gray colour means the water is non-septic and black colour means it is septic sewage.

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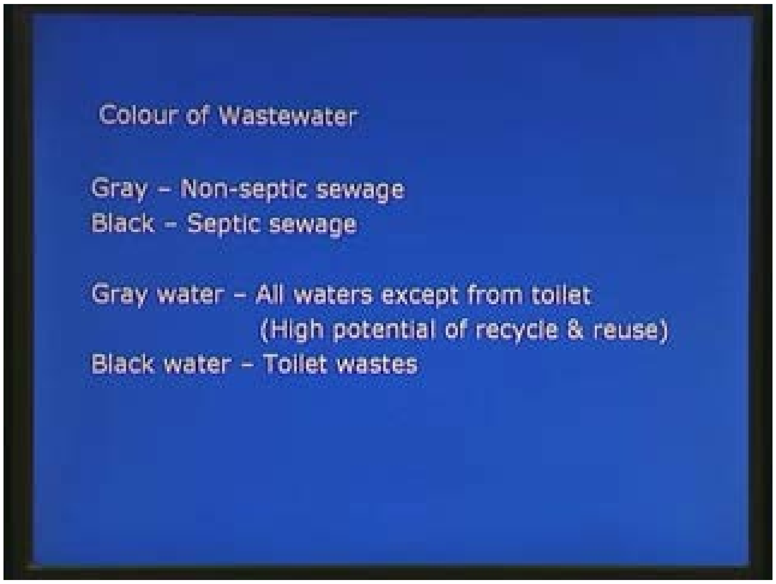

What we mean by gray water?
Gray water is all the water collected except from the toilet and the gray water is having high potential for recycle and reuse because we know that nowadays so much of water scarcity is there in all the places so this water we can recycle and reuse for gardening, flushing, etc and black water is the water coming from the toilet waste. So we have seen other parameters like pH conductivity etc. This is applicable for both water and wastewater.

What is this pH?
pH, as all of us know it is nothing but negative log of hydrogen ion activity. This is same as the concentration in dilute solutions and in concentrated solution the concentration and activity will be different. So what we have to remember is it is the negative logarithm of hydrogen ion concentration present in the system.

And coming back, what is conductivity?
The conductivity measurement of water or wastewater sample can be indirectly used to find out the total dissolved solids present in the system. Because you know that especially in case of water most of the solids are inorganic and when it is present in the water what will happen, it will be dissociating into ions so when the electrolytes are present it will be conducting the electricity and if more electrolytes are present the conductivity will be more. So, by measuring the conductivity we can find out the total dissolved solids present in the system by using this formula; 2.5 into 10 raise to minus 5 into TDS. Here the TDS is expressed in milligrams per liter.

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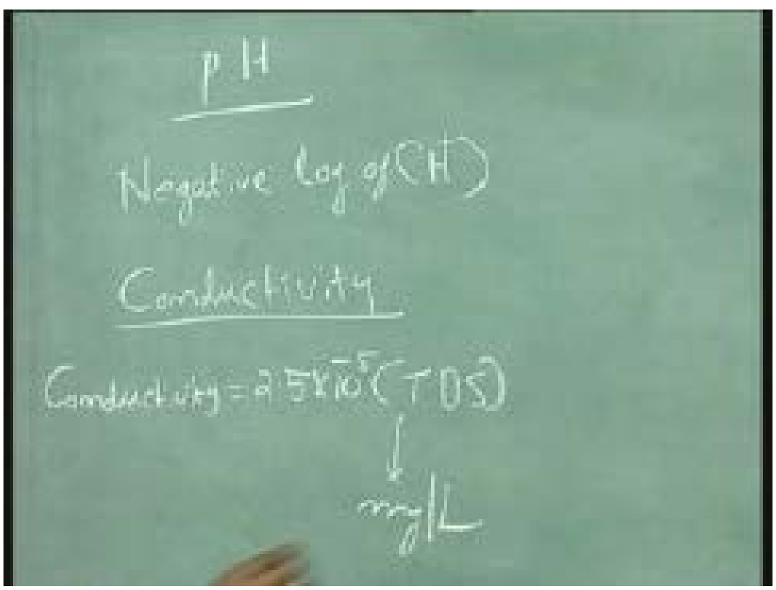

But when we come to the wastewater what will happen, the conductivity will not give you the total dissolved solids properly because most of the solids are organic in nature so mostly it will not be dissociating those are not electrolytes so what will happen, the electrical conductivity of this water will be much less but the dissolved soils will be very very high so we have to take into account the ionization of the compounds present in the system.

For example, if you take distilled water and put glucose into that solution you know that the total dissolved solids present in the system will be very very high. But if you find out what is the conductivity of that water you will be getting almost nil, that doesn’t mean that the system is not having any dissolved solids. But if you put 1 gram of sodium chloride in the same water instead of glucose what will happen, the electrical conductivity will be increasing significantly. So, depending up on the nature of the solids the conductivity will be varying.

So we have to have an idea about what is the type of solids present in the system. Till now we have seen what are all the physical parameters or physical characteristics of water and wastewater. Mainly those are; solids, turbidity, colour, odour, pH and conductivity and we have discussed how to find out each and every parameter. Now, the next classification is chemical parameters.

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Chemical parameters involve biological oxygen demand, chemical oxygen demand, total organic carbon, theoretical oxygen demand so all these give you the organic components present in the water or wastewater. Then other things are; nutrients, toxic compounds, alkalinity, hardness. Now we will discuss one by one in detail.

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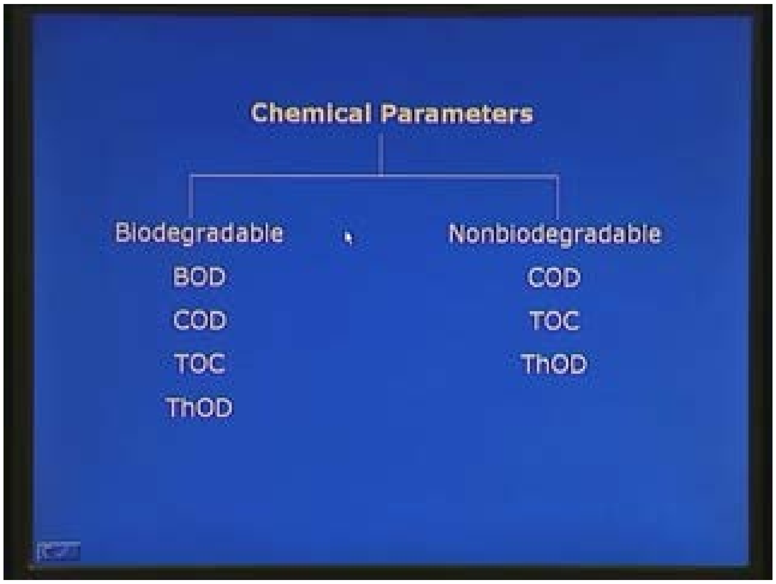

So chemical parameters we can again classify into two categories. Especially this is very very important in the case of biological wastewater treatment systems because when you decide to go for a treatment unit we have to decide what type of a treatment you have to provide, either it is a biological process or a physico chemical or the combination of biological and physico chemical, how can we find out that one. It will be decided based upon the characteristics of the wastewater basically the chemical characteristics of the wastewater whether the components or the pollutants present are biodegradable or non-biodegradable. If you want to find out the biodegradable components we can go for either BOD that means biochemical oxygen demand, COD that is chemical oxygen demand, TOC it is total organic carbon and thOD theoretical oxygen demand. The pollutants contain organic components and they are non-biodegradable so we can measure the concentration by chemical oxygen demand, total organic carbon or theoretical demand.

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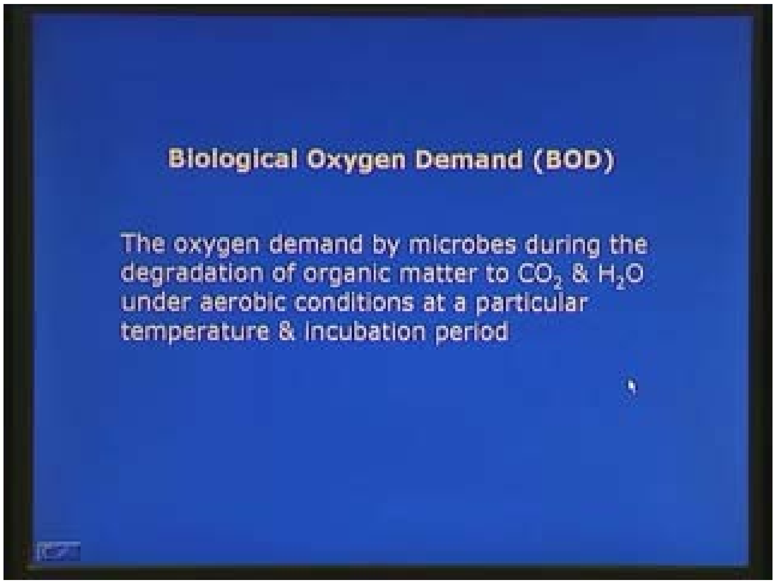

First we will see what is this biochemical oxygen demand or biological oxygen demand. this is nothing but the oxygen demanded by the microorganisms during the degradation of the organic component present in the water into water or wastewater into carbon dioxide and water at a particular temperature and a particular incubation period.

So once again I will tell the definition: The oxygen demand by the microbes during the degradation of organic matter to carbon dioxide and water under aerobic condition at a particular temperature and incubation period. That means this temperature is important, incubation period is important and aerobic condition is important and microorganisms are important. If all these parameters are there or all these components are there then only you will be able to measure the biochemical oxygen demand.

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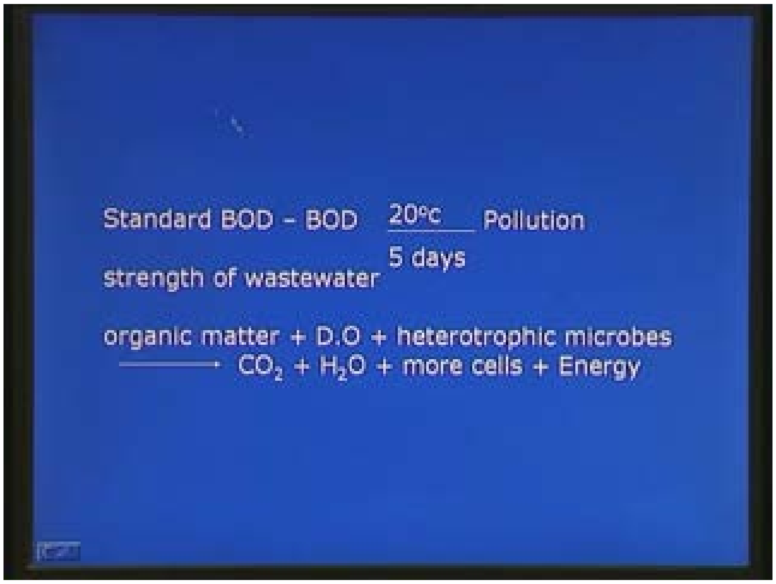

This is what is happening in a standard BOD. Standard BOD we measure at 20 degree centigrade and 5 days and it gives the pollution strength of the wastewater. That means basically this was used to find out the pollution status of streams. Because what is happening, the wastewater whatever is generated in the cities or the towns situated along the river…., what will happen, after proper treatment it will be discharged into the streams. And you know the stream water will be having a particular dissolved oxygen and it will be having its own flora and fauna. So when the wastewater comes to the river stream what will happen, it is adding some organic matter to the system and the microorganisms present in the stream will be utilizing that organic matter and as a result what will happen, the dissolved oxygen present in the stream will be coming down. So, if the dissolved oxygen comes down beyond a particular limit what will happen, the aquatic organisms present in the stream will not be able to survive.

So in BOD experiment what is happening, organic matter plus dissolved oxygen plus heterotrophic microorganism, the microorganisms which use organic matter as their food and enough source, that will oxidize the organic matter into carbon dioxide plus water plus more cells and they will be getting energy from this reaction. So, if you want to conduct the BOD test in the laboratory how can we do it?

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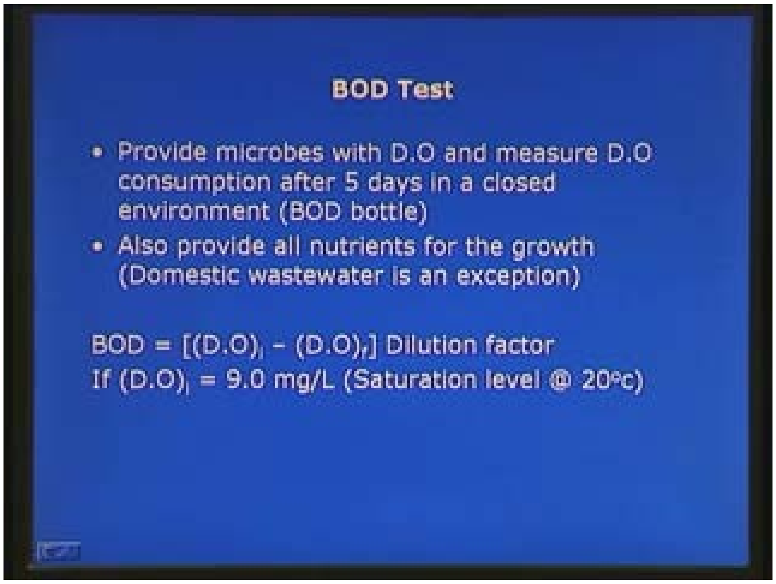

We have to provide certain conditions. There should be microbes and there should be dissolved oxygen in the system and the dissolved oxygen should be sufficient for the consumption of microorganism for the decided incubation period.

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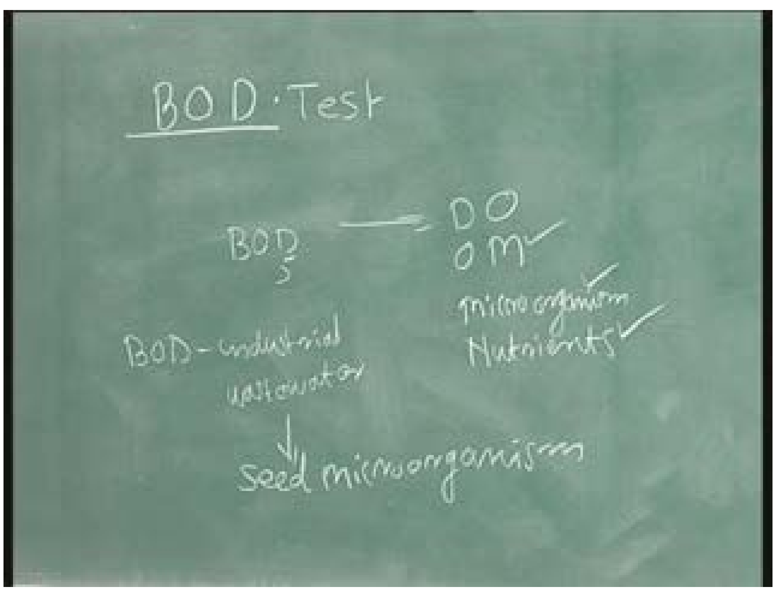

For example, if you want to find out the BOD 5 that means 5 day BOD so the dissolved oxygen present in the system should be sufficient for the microorganisms to sustain for five days. And you know, we are providing microorganism, we are providing organic matter and dissolved oxygen and the microorganisms has to grow. So what is the other requirement? The microorganism should get enough nutrients for the growth. So whenever we do the BOD test you should have dissolved oxygen, organic matter, microorganism and nutrients. These are the essential things to get a proper BOD or to do a proper BOD test. And if you want to find out the BOD we can find out what is the dissolved oxygen of the sample present initially and what is the dissolved oxygen present finally. That means after the incubation period, here it is five days into the dilution factor. Usually the initial dissolved oxygen is 9 mg per liter; this is the saturation level at 20 degree centigrade.

And if you want to do the BOD test for domestic wastewater, you know the organic matter is already present in the wastewater and microorganisms are present in the wastewater and enough nutrients are also present in the wastewater so we don't have to supply them externally. But if you want to find out the BOD of industrial wastewater depending upon the industry there may not be any nutrients or they may not be any microorganisms. So in this case we have to add this microorganisms and nutrients externally. So what we do is we add some seed microorganism and nutrients to the dilution water then only you will be getting a BOD result.

Or another example I can tell you. You take a sterilized bottle with sterilized glucose solution. So glucose all of us know it is an organic matter and it is very very easily degradable. So if you put that solution in a BOD bottle and keep it an incubator at 20 degree centigrade for five days and after five days if you analyze the dissolved oxygen whether there will be any decrease in the dissolved oxygen there will not be any decrease. The reason is there is no microorganism to utilize the organic matter. So microorganisms are very very essential for the BOD.

Here I am going to give some cases for this BOD test. for example, in the first case, I was having an initial dissolved oxygen of 9 mg per liter, that is the saturation concentration because we usually dilute……., the dilution water will be aerated and we will be adding the seed microorganisms and the nutrients so most of the time it will be having very high dissolved oxygen in the rate of 8 to 9 mg per liter.

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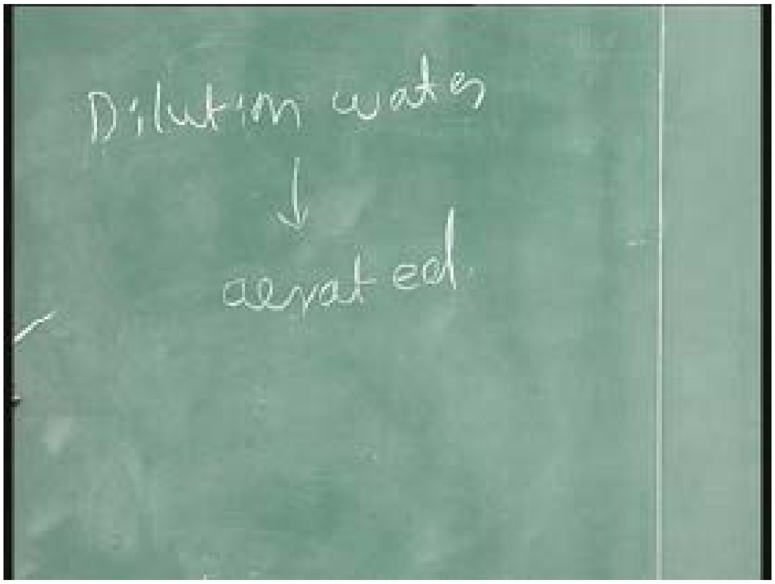

Here we are assuming we have initial dissolved oxygen of 9 mg per liter and final dissolved oxygen of 5 mg per liter and I didn't have any dilution, it is almost a pure water sample so my BOD is 9 minus 5 into 1 that is 4 mg per liter. And in the second case my dissolved oxygen final, after five days incubation my dissolved oxygen was 0 mg per liter so is it possible to calculate the BOD of that particular sample. According to the formula we will get BOD equal to 9 minus 0 into 1 that is 9 mg per liter but this result is invalid.

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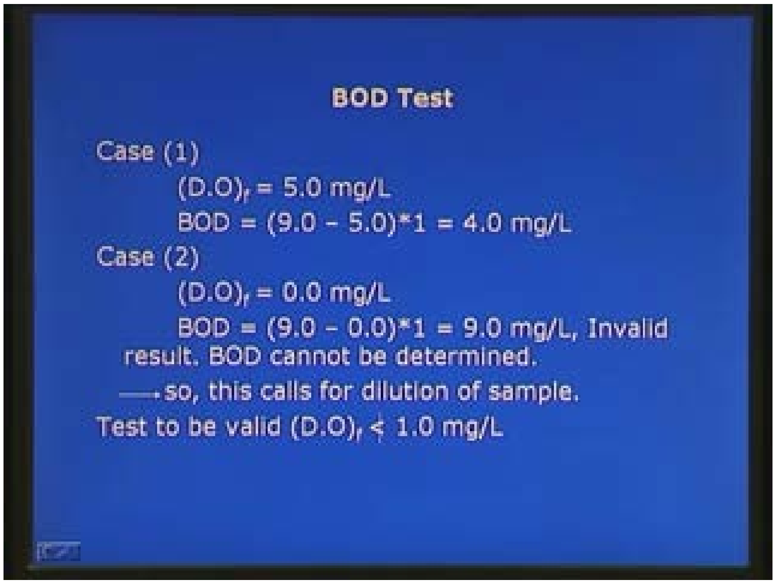

What may be the reason, what is the reason for this?

Initially DO initial was 9 mg per liter and after five days DO final was 0 mg per liter so we don't know whether the dissolved oxygen whatever is present in the system was sufficient for the microorganisms so there was no enough dissolved oxygen present for the microorganism that's why the entire dissolved oxygen was conceived within five days. So whatever result we are getting here will be under estimating the BOD biochemical oxygen demand because we don't know what was required by the microorganism. So we cannot use this data at all.

In that case what we have to do, we have to dilute the sample so that the organic matter present in the water will be getting diluted so the oxygen requirement will be produced. The reason is this is the maximum amount of oxygen we can provide in the dilution water, we cannot get a concentration more than that. So within five days they can consume maximum; 9 minus 1 milligram per liter so this is the condition we have to dilute the sample. And for any BOD test to be valid the dissolved oxygen final should not be less than 1 mg per liter. That means after five days at least 1 mg per liter of dissolved oxygen should be left over in your BOD bottle then we can make sure that the DO whatever we have provided was sufficient for the microorganisms.

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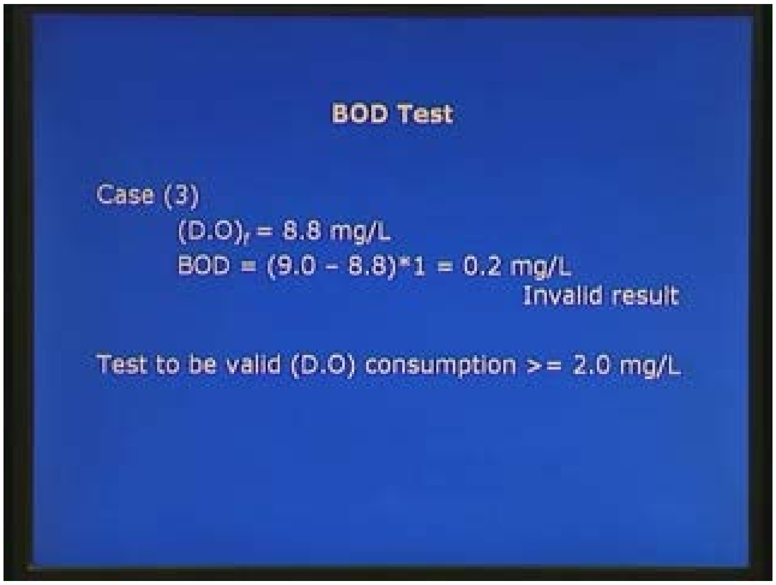

This is the third case. Here the dissolved oxygen final was….. DO initial was 9 mg per liter and DO final was 8.8 mg per liter, whether we can use this result for the calculation of the BOD. This also cannot be used because your dilution is too high so the organic matter whatever was available in the system was too less for the microorganism. So we cannot be sure that this 0.2 mg per liter was because of the consumption of the microorganism but it can be because of the experimental error also.

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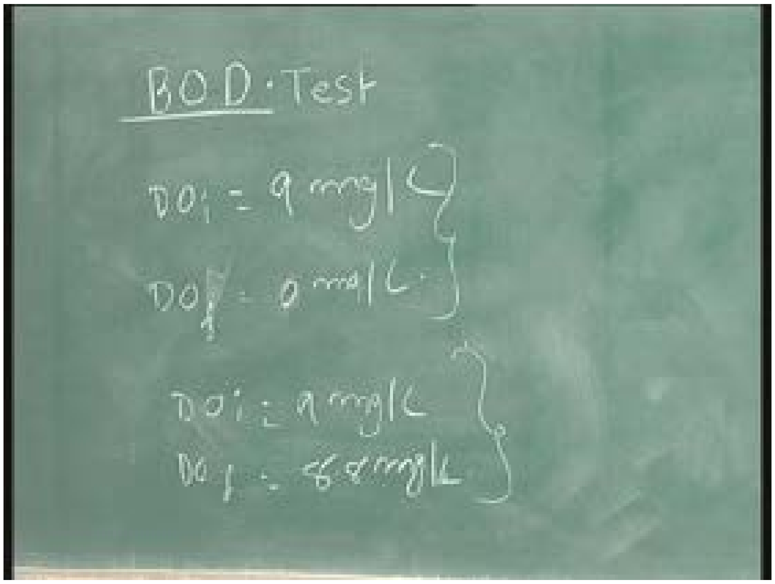

These are the points to be kept in mind. For the test to be valid DO consumption should be greater than or equal to 2 mg per liter. That means the DO final should be at least 7 mg per liter or less than 7 mg per liter so that as per the test within five days the microorganisms have consumed at least 2 mg per liter.

I will repeat the conditions for the BOD test once again.

You have to provide enough dissolved oxygen. If that is not there what we have to do is we have to dilute the sample. Second one, microorganisms should be there. If microorganisms are not there we have to add the seed microorganism. What is the seed usually we do use? It is nothing but the settled domestic sewage because the domestic sewage will be containing around 10 raised to 6 to 10 raised to 7 microorganisms per milliliters. So if you use that as seed you will be getting enough microorganisms in the system. Then third one is nutrients. This is not required for domestic wastewater but for industrial waste we have to add externally the nutrients. Then fourth one is the dilution. When you select the dilution the DO consumed during the 5 day period should be greater than or equal to 2 mg per liter and DO final should be greater than or equal to 1 mg per liter.

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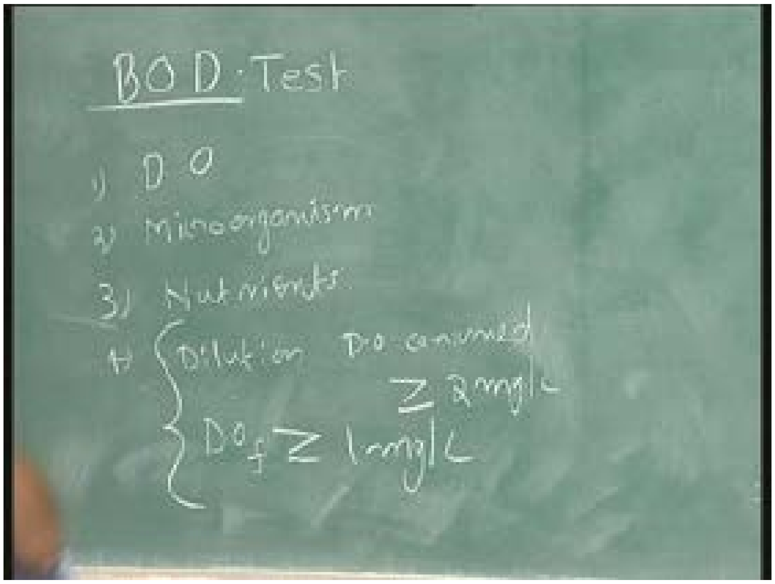

So, if you can satisfy these conditions your BOD results are valid otherwise you have to repeat the experiment. Now, as you got the BOD result how we can calculate what is the total organic matter present in the system and how can we use this data for the design purposes.

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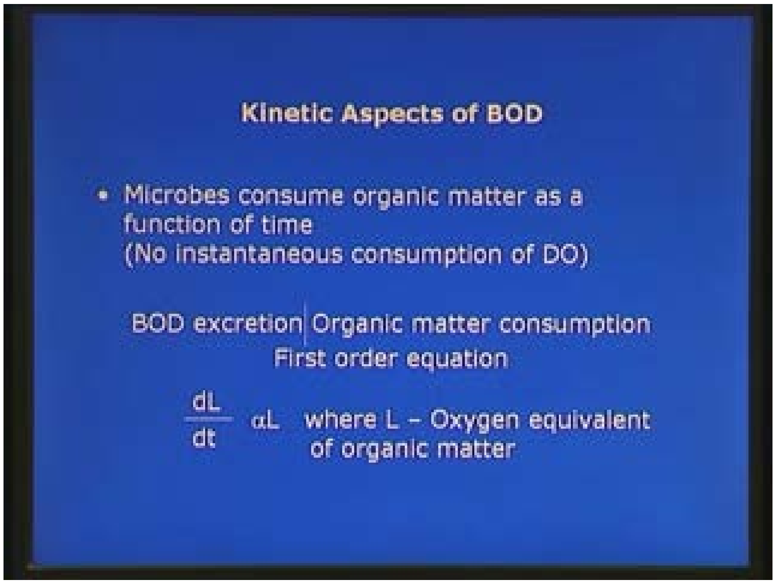

In any case, in the microorganisms you have the organic matter and you have the microbes. These microbes will be consuming the organic matter with respect to time or with respect to time your organic matter concentration will be coming down and your microbial concentration will be increasing. So what we assume is this organic matter consumption is depending upon the availability of organic matter or the rate of change of the organic matter concentration. The rate of change of organic matter consumption or the removal will be proportional to the total organic matter present in the system or BOD exerted or organic matter consumption is assumed to be a first order reaction.

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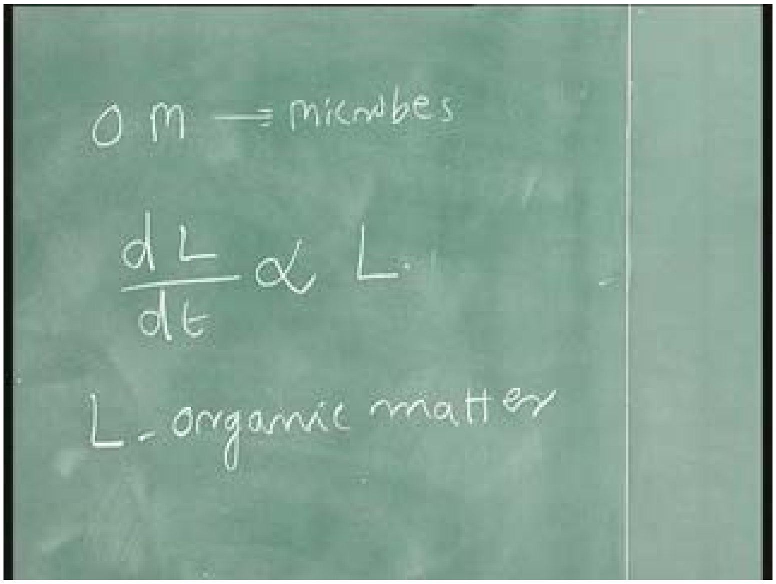

So we can write like this; dL by dt is proportional to L where L is the organic matter present and t is the time, the rate of change of or rate of change of organic matter concentration is proportional to the organic matter present in the system.

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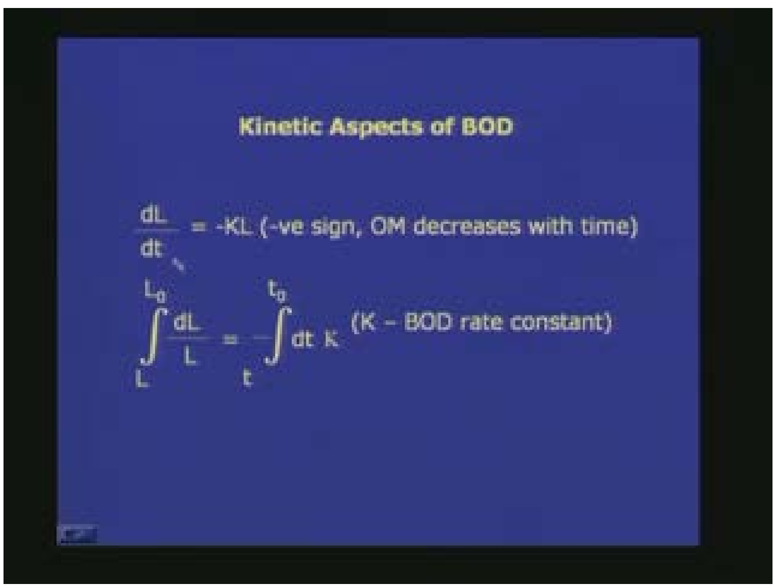

So, again we can write this one as; dL by dt equal to a constant into L. Here we are giving a negative sign, the reason is, with respect to time the organic concentration is decreasing because microorganisms are consuming the organic matter so whatever is left in the system is decreasing. So if you want to get the equation what we have to do, we have to integrate this equation and see how it will be coming. We can integrate this one; dL by L equal to minus Kt this is the thing. So here I have done this one. So we have to put the limit from L to L 0. That means what is present to the ultimate organic……. that means the organic matter present at time zero equal to……. like this where K is the BOD rate constant, it will it is the property of the microorganisms present in the system.

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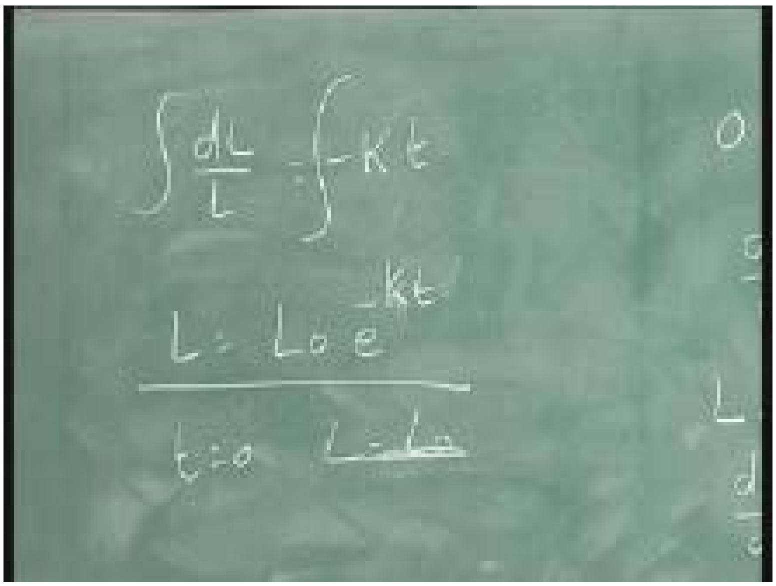

So, if you integrate this one we will be getting L is equal to L 0 into e raised to minus k into t. L is equal to L 0 into e raised to minus Kt where L 0 is the ultimate oxygen demand for the oxidation of initial organic matter. Because when time is equal to 0 t equal to 0 L is equal to L 0 that means the initial organic matter. With respect to time this one is decreasing and at anytime the organic matter concentration is L. So if you want to represent that one pictorially then we will be getting something like this:

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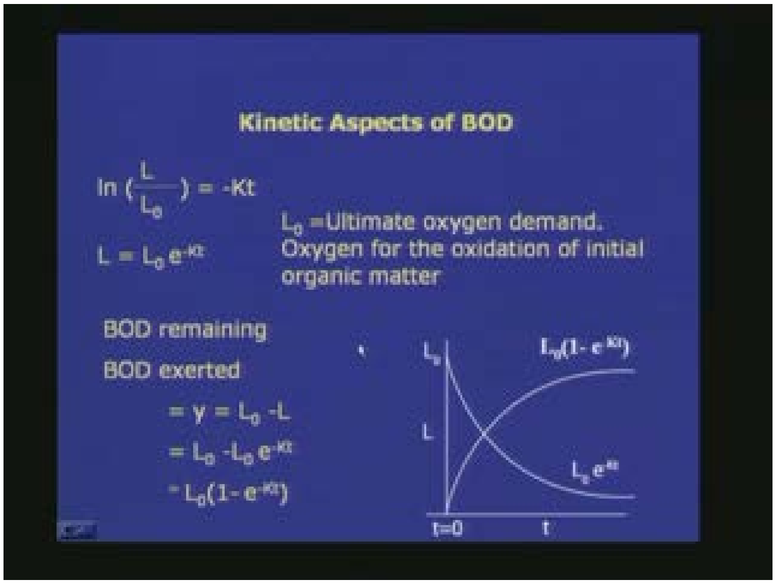

This is the BOD decreasing with respect to time (Refer Slide Time: 52:41) and this is the BOD that is exerted with respect to time. That means the amount of organic matter removed from the system is equivalent to the oxygen removed from the system. Y is nothing but the BOD exerted. It is nothing but what was your initial organic matter minus what is left over. So we can write this one as L 0 minus L or it is nothing but L 0 minus L 0 into e raised to minus kt because we have seen what L is, it is nothing but L 0 into e raised to minus Kt so the BOD exerted or the oxygen consumed at any time can be found out using this formula; L 0 into 1 minus e raised to minus Kt.

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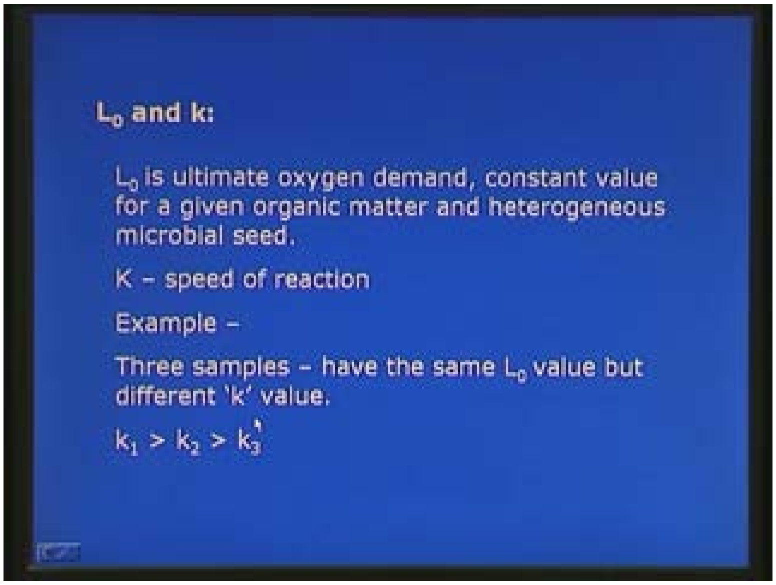

So if you want to find out L 0 and k, so this portion we can discuss in the next class. So I will summarize what we have discussed today. So we were telling that for the treatment plant design we should have the quality aspect of the wastewater or water and the quantity aspect of the water and wastewater. For the quantity aspect we have seen how to find out the design period, design flow, design population etc and coming to the characteristics of the wastewater that will be deciding the process or treatment processes. So the characteristics can be divided into physical, chemical and biological parameters.

Under the physical parameters it can be classified into various categories like; solids, turbidity, colour, odour, pH conductivity and taste. So solids, solids are very very important. The reason is that decides the treatment process more or less. So in solids we have seen what are all the different categories. We have suspended solids, dissolved solids, fixed solids, fixed suspended solids, fixed dissolved solids etc. And turbidity also we have discussed in detail. Turbidity is caused by the colloidal particles present in the system and it affects the treatment processes. Especially in water treatment if you go for disinfection etc these dissolved turbid particles hinder the disinfection process and moreover it can be acting as an adsorption site for many pollutants. Then we have discussed how to measure colour, odour etc and pH is also very very essential for the water and wastewater treatment. Now, coming to the conductivity this is a parameter which gives the dissolved solids concentration indirectly.