Biological Process Design for Wastewater Treatment
Professor. Vimal Chandra Srivastava
Department of Chemical Engineering
Indian Institute of Technology Roorkee
Lecture: 05
Wastewater Characterization - II

Good day everyone and welcome to this NPTEL online certification course on Biological Process Design for Wastewater Treatment. So, in the previous lecture, we started understanding how to determine the characteristics of the wastewater. So, as to further determine whether how to go ahead with the treatment of the wastewater itself. So, we learned in the previous lecture that there may be different constituents which may be present in the water, which makes them unusable for various applications.

And these characteristics include the presence of biologically treatable organic molecules, untreatable molecules, including heavy metals, refractory organics, as well as other types of pathogens etcetera, which may be present in the water. So, overall the water wastewater maybe characterized in different parameters, and these parameters may be clubbed together as physical water quality parameters, chemical water quality parameters, biological or biochemical water quality parameters and pathological water quality parameters.

So, in the previous lecture, we studied regarding the physical water quality parameters including temperature, specific conductivity, then colour, turbidity.

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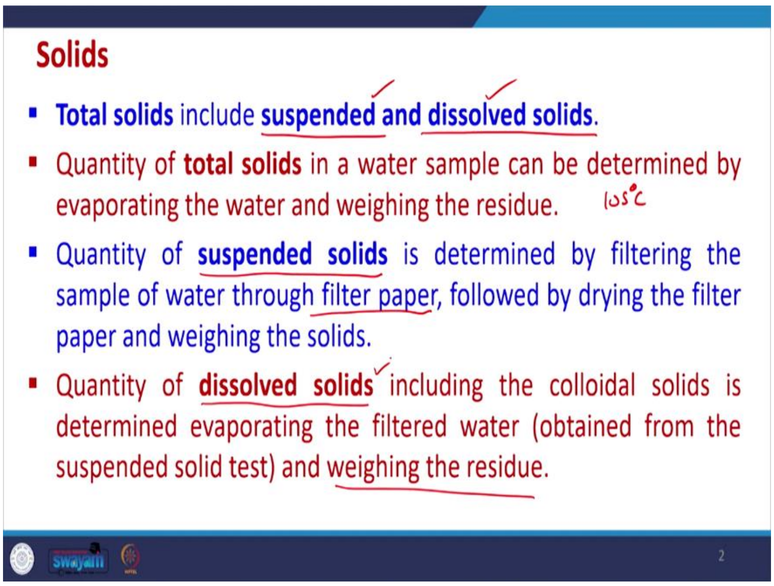

In today's lecture, we are going to start with another physical water quality parameter which is called as solids the total solids is one of the important parameters which is evaluated for any water sample and the total solids includes the suspended solid as well as the dissolved solid. So, total solid is one of the parameters the quantity of total solid in a water sample can be determined by evaporating the water and weighing the residue this is very simple technique and the evaporation take place at 105 degrees centigrade and thus we can determine the residue and from the residue we can find out the total solid now, total solid will include both suspended solid as well as dissolved solid.

So, that means, we should be able to find out the suspended and dissolved solids also individually. The quantity of suspended solids is determined by filtering the water sample through filter paper followed by drying the filter paper and weighing the solids. So, this is that means, we can find out the suspended solid via filtering the solid in the water through a filter paper. So, these filter paper characteristics surface generally this is whatman filter paper number is also fixed for this and what after filtering we measure the solid which is actually being filtered.

Thus we can determine the suspended solid. Similarly, the quantity of dissolved solids including the colloidal solid is determined by evaporating the filtered water obtained from the suspended solid tests. So, whatever filtrate we are getting we again evaporate that filtrate and weighing the residue. So, we can find out the dissolved solid which was actually not filtered by the filter paper. So, that this way you can find out the dissolved solids also.

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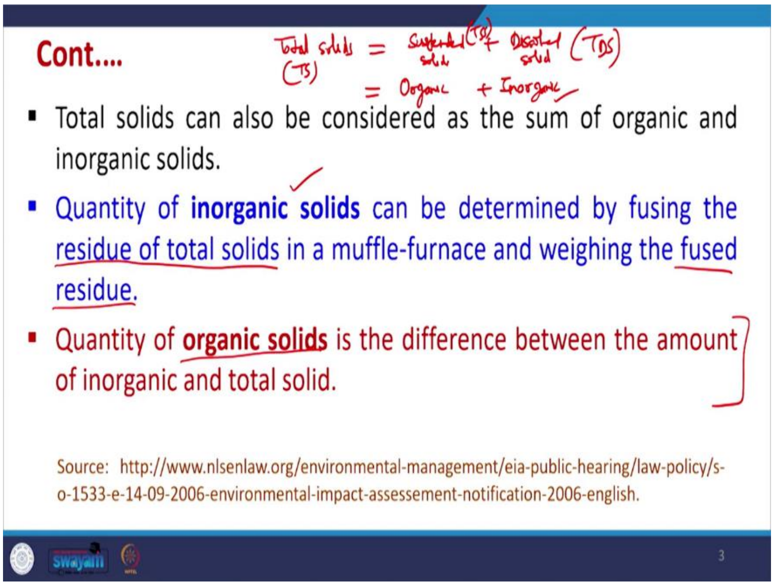

So, we can find out total solid suspended solid dissolved solids now further the total solids can be considered as sum of Organic and Inorganic solids also, there are 2 ways of total solids. Now total solids one way is total solid is equal to some of suspended plus dissolved solid. So, this is one classification and then there is another classification is that total solid is equal to organic solid plus inorganic solid.

So, this is another classification. Now, the suspended solid this is called TS, the suspended solids are called TSS, the dissolved solids are called TDS. So, this also we must know the quantity of inorganic solids inside any water or wastewater sample can be determined by fusing the residue of total solids in a muffle furnace and weighing the fused residue. So, what are the steps first, we have to evaporate the water. So, total water will be evaporating.

So, we will be getting total solid after that the total solid has to be fused in the muffle furnace at some particular temperature. So, organic content of the total solid will go off and only inorganic content will remain inside the muffle furnace. And by weighing the fuse this residue we can determine the inorganic solid and by the difference between total solid and inorganic solid we can get the total amount of organic solid and this organic solid is highly helpful.

Because this organic is solid will be easily biodegradable. And depending upon that what is the amount of total organic solid presence inside the water sample per litre of the sample or anything, then we can know beforehand that whether we should go for biological treatment of wastewater or not, if suppose the inorganic content is very high that means. We have to go for physico chemical treatment of wastewater more as compared to biological treatment of water. And also we can tentatively determine that what is the amount of sludge and other things which will be reduced when we are going only for physico chemical treatment of wastewater.

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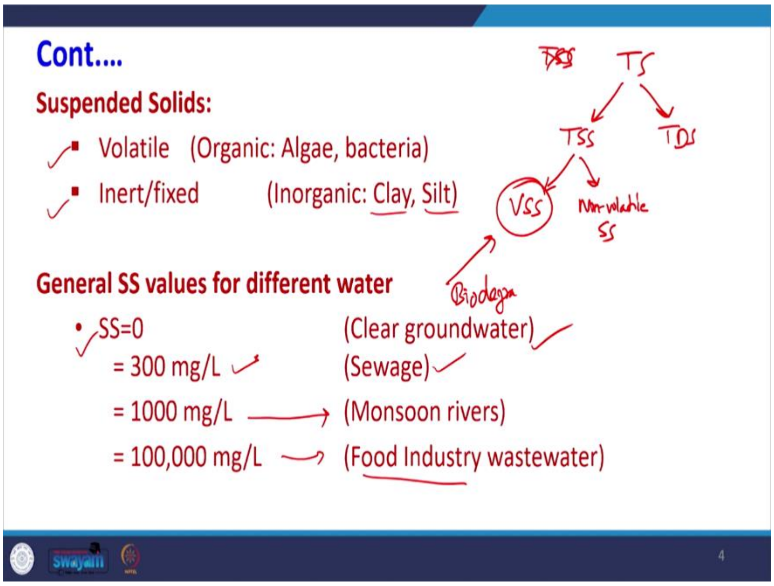

So, the suspended solids or the total dissolved solids, they can be classified into different categories, suspended solids themselves can be classified as volatile or inert oblique faced. So, volatile solids are those like algae and bacteria which are organic in nature and within suspended solid maybe we may have inert and fix also inert material may include Clay, Silt etcetera, which will not be biodegradable.

So, within the total solid or TSS we have first total solid then we have total suspended solids, total dissolved solid, total suspended solids, maybe volatile suspended solids and non-volatile means, inert suspended solid. So, this is non-volatile, SS. Now, this VSS actually is the one which can be biodegradable. So, this gives an idea that whether we should go for biological treatment of biodegradable fraction of this total suspended solids.

So, this VSS is very important General SS value for different water sample is like if the suspended solid is 0 it is clear groundwater, if for sewage it may be up to 300 milligram per litre. For monsoon river the amount of suspended solids is very high 1000 milligram per litre or more also, for food industry wastewater the solid sample may be up to 1 lakh milligram per litre also. So, different types of wastewater may have different values of SS inside them.

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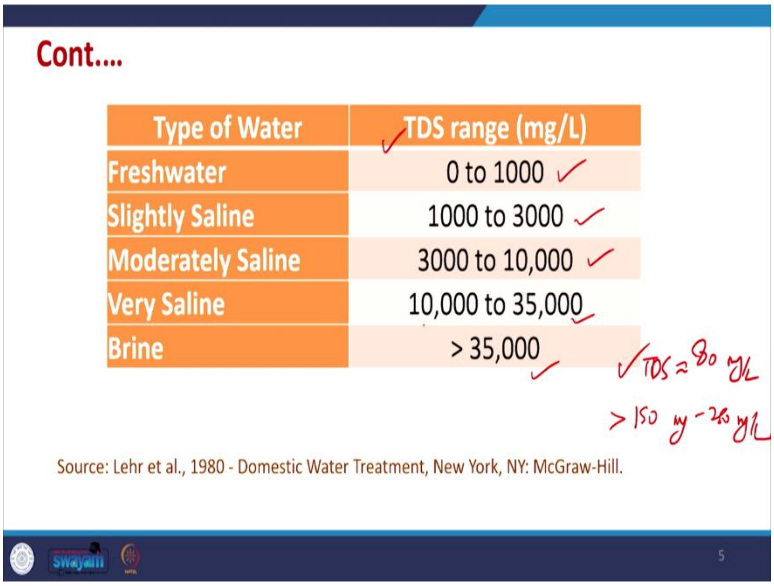

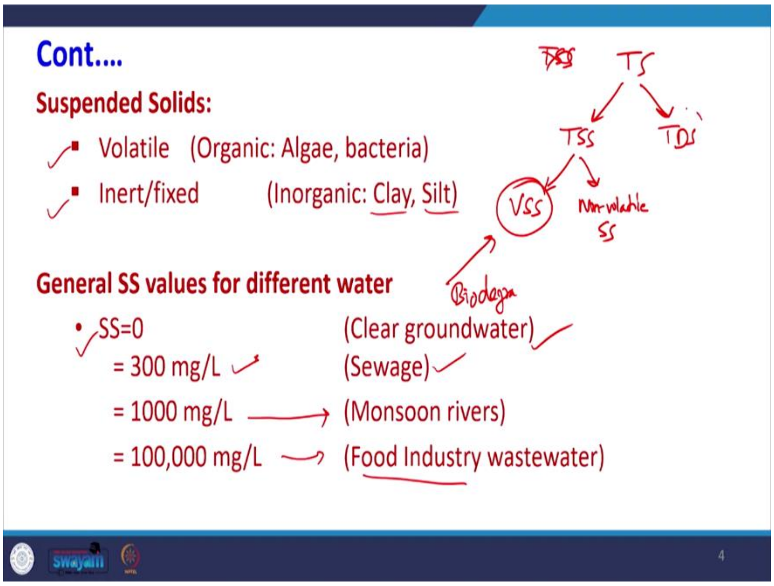

Now, this is again it characteristics with respect to TDS. The total dissolved solids which was given here that total dissolved solids range may also vary for different types of wastewater. Now, for freshwater the TDS may be up to 0 to 1000 milligram per litre, for slightly saline water that TDS is 1000 to 3000 milligram per litre for moderately saline water, it is 3000 to 10,000 for very saline water 10,000 to 35,000 and for brine or for like seawater it is 35,000 or greater.

So, TDS value is very important for our drinking purpose like we use measurement of TDS generally people measure TDS only via measurement of specific conductivity. We can drink water up to TDS range of 250 milligram per litre very easily. And in fact, we should drink water which should have a TDS of around 150 to 200 milligram per litre but the RO water that we drink generally has TDS of around 80 milligram per litre which is not good for our health.

So, we should always try to use water sample which has TDS of more than 150 milligram per litre maybe up to 250 milligram per litre for our drinking daily and it will help in maintaining the nutrients inside our body up to a optimum level otherwise, if we are using TDS of 80 milligram per litre, the minerals we are not getting and then we have to eat other types of pharmaceutics for maintaining those level of minerals inside our body.

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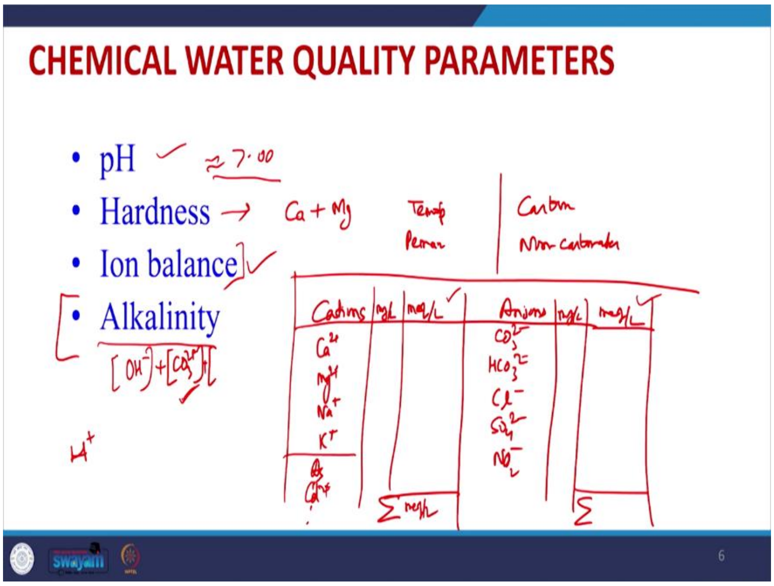

Going further there are chemical water quality parameters also there are different types of chemical water quality parameters, and few of them are listed here. And then further they there are other water quality parameters also. So, first and foremost is the pH, pH is the most important parameter and for water quality and the pH affects the solubility of various solid compounds inside the water sample. Similarly, pH affects the solubility of gases inside the water sample.

So, pH is the most important parameter generally we wish to have the treated water pH around 7, which is the neutral pH, but wastewater which are generated industry may have pH up to 0.5 also. There are some industries which generate water having pH 0.5. Generally, they will be generating wastewater in the pH range of 5 to maybe 10. But some industries generate water which is highly acidic, highly basic, but after treatment, we always the water to be at pH 7. So, pH has a lot of importance, you will have to refer to my other lecture for understanding this which has been given in the another course on physicochemical treatment of wastewater.

Now, hardness is another parameter which is comes under the category of chemical water quality parameter. Now hardness may be temporary and it may be permanent. And this may be because of calcium and generally the hardness is because of calcium and magnesium and this calcium magnesium or cation but certainly anions will also be associated with this. So, calcium along with calcium magnesium, the carbonate whether it is carbonate hardness or non-carbonate hardness, that will also be there.

So, we have hardness which can be defined in various categories, that means, it includes temporary hardness then it includes permanent hardness. So, that is there, then it may be carbonate hardness and non-carbonate hardness. So, there are various chemical water quality parameters that can be determined within the hardness through this. For doing these parameters assessment we need to find out the ion balance and through ion balance we can check.

So, what is done basically is that we try to find out different types of cations inside the water. And similarly, we tried to find out that different types of anions present inside the water sample. The cations which are generally found out very commonly are calcium, magnesium, then sodium these are potassium there are many other cations to be found. Similarly anions also are different types may be found, like CO_3^{2-} HCO_3^{2-} then we have chloride which has to find out sulphate, then nitrate.

So, different types of Cations and anions are determined. After their determination their values are will be generally in milligram per litre, the both the values will be in milligram per litre, later on what we do is that we convert the value in milli equivalent per litre using the valency approach. So, if we find out in milli equivalent per litre, we tried to measure the amount of cations in milli equivalent per litre total amount of cations and total amount of anion.

Also, the difference if there is more than 5 percent error is there in the balance between cations and anions then, that means we are missing either some cation or anion and we have to determine other major content it may be possible that water may contain maybe arsenic, maybe cadmium and in higher concentration, but we are missing that. So, we have to make ion balance, then only our chemical water quality parameters have been properly determined and all the different types of cation and anions have been determined. Once we have determined all these concentrations of cation and anions in detail in terms of milli equivalent per litre, we can determine many other parameters related to irrigation and other things.

Similarly, the determination of alkalinity is another chemical water parameter that has to be determined properly. Generally people perceive that alkalinity measures only OH minus concentration, this is not so, this is not directly related to pH it is related to pH but it is not only related to pH, alkalinity, measures all other anionic parameters, which can actually neutralise the H plus ions if they are added inside the water and these parameters may include carbonate ions, bicarbonate ions, etcetera and all these anions.

So, all some of these anions minus H plus ion actually gives an idea that how much acid added to the water will be neutralised. So, alkalinity is a parameter which actually measures the tendency of water not to change its pH when, acid is added because when acid is added H plus actually reacts with other types of anions presents in the water. And thus the pH does not decrease though we are adding the acid, but this acid is getting reacted with carbonate ion or bicarbonate ion to form the as respective acid.

Thus the concentration of H plus is not increasing and that the pH value will not change. So, it is alkalinity is like a buffering capacity of water with respect to change in pH. So, determination of alkalinity is very important. Also alkalinity helps in certain reactions, which happened during coagulation and flocculation and if alkalinity is not present, the coagulation reaction will never happen. So, under those conditions, we have to add alkalinity from outside. So, then only we can treat the water via coagulation flocculation.

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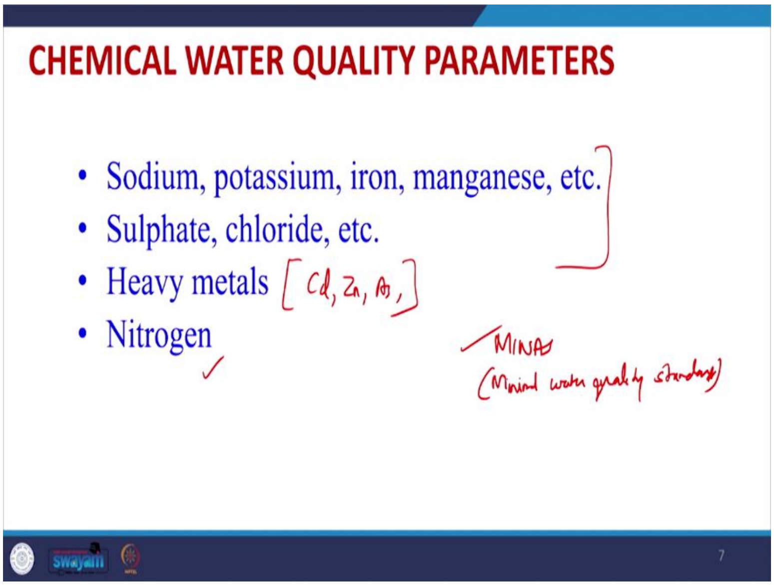

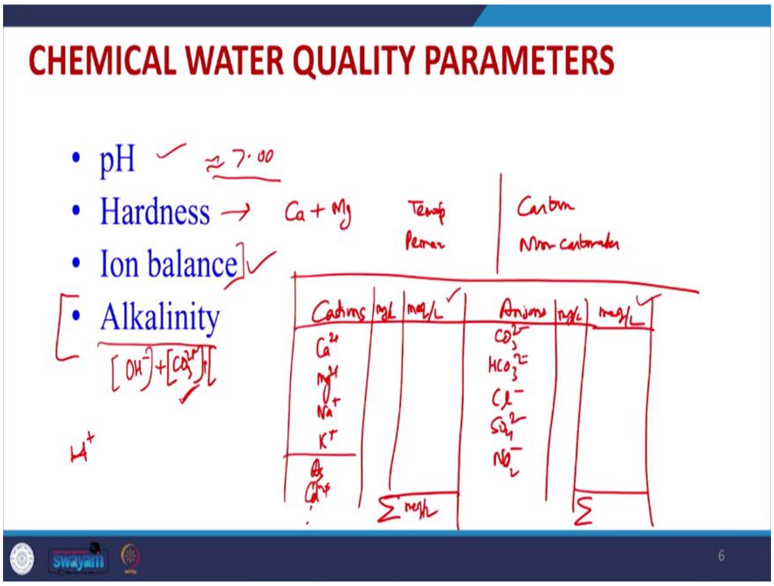

So, alkalinity is important parameter that needs to be determined under chemical water quality parameter. Similarly sodium potassium iron and manganese etcetera. sulphate chloride already discussed here that all these parameters have to be determined for essentially totally determining the water quality parameter and if the ion balance is not matching, we have to go on determining other ions which we may be missing and these ions may be any of the heavy metals also say it may be cadmium, it may be zinc it may be arsenic, it may be other toxic parameters, which may be missing and when we determine all these parameters, then only we can tell that all the water quality parameters have been properly reported.

Now, within beyond this nitrogen is also an very important element that has to be determined and this the nitrogen may be determined in terms of various parameters. One is like total nitrogen, then total organic nitrogen, total ammonical nitrogen the nitrogen which is present in the form of ammonia etcetera.

So, there are different types of nitrogen parameters that have to report it for various water samples including those for wastewater generated from fertilizer industry in particular. So, we have to determine various nitrogen parameters for understanding the chemical water parameter of a fertilizer industry where urea, ammonia etcetera. are being produced. Going further, there are chemical water quality parameters n number of chemical water quality parameters, but all are not reported until unless they are asked by the person concerned.

We generally determined few only water quality parameters which are reported here like pH, hardness etcetera, but other water quality parameters may be determined may not be determined depending upon that from which source the wastewater is getting generated, which is the industry because for various types of industries, the central pollution control board a sector have specified already for industry specific which water quality parameters have to be essentially determined.

So, this is like for tannery that cadmium has to be determined, whereas, it may not be necessary to determine it from a textile effluent. So, depending upon the effluent, which is generated from different industries, that chemical water quality parameters vary also as per the MINAS there is a one MINAS standard which is called minimal national standard for various water quality parameters which are industry specific. So, this is MINAS standards. So, minimum water quality parameters.

So, what is the quantity it is reported under this MINAS and we can determine the MINAS for different industries within India and there also it is reported which chemical water quality parameter have to be determined. So, we can go and understand and determine all those water quality parameters. Now, going further biological water quality parameter is the third category of chemical water quality parameters that we have to understand and this is more important for us of wherever we are going for biological treatment of wastewater.

So, the biological water quality parameter is essentially because of the presence of organic matter inside the water, when these organic matter is present, certainly this organic will degrade with time and when the degradation happens inside any water, then the oxygen which is present inside the water actually used for degradation and thus the oxygen depletion happened. So, we want to know beforehand that what will be the total oxygen demand of the water sample are the organics present in the water sample.

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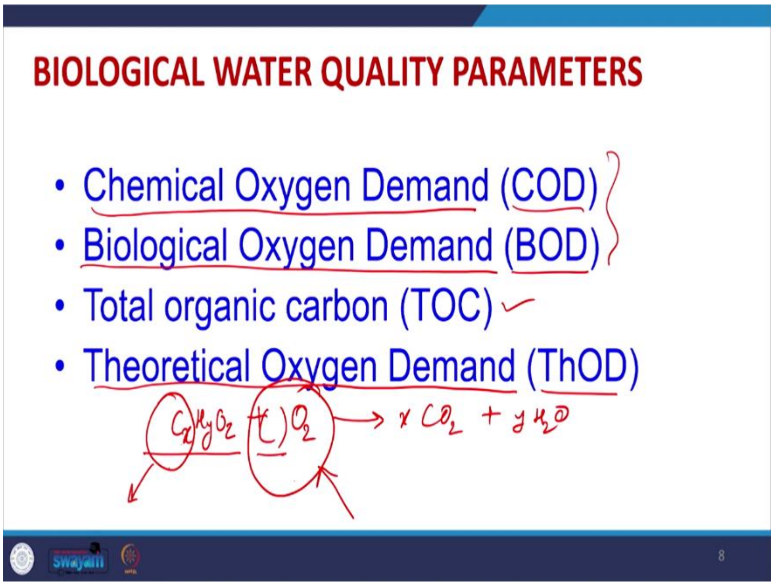

So, there are three different types of ways in which we can measure the oxygen demand one is called chemical oxygen demand another is called biological oxygen demand, which is also called our BOD, chemical oxygen demand is called COD, then there is theoretical oxygen demand which is more theoretical in nature, they no need for any determination via any other testing methods, which is called THOD and in place of that, we can also determine the Total Organic Carbon because if that Total Organic Carbon is known to us, we can know that what will be the oxygen demand.

So, through that way, we can measure the amount of any of these parameters. Now, the basic logic here is that here supposes any compound is there $C_xH_yO_z$ this is some organic compound. Now, when the degradation will happen actually this will under aerobic condition this will degrade into CO_2 and H_2O now via balance we can do some alliteration to find out like x is there, this will be y and we can easily determine what is the coefficient here. Now, in the oxygen demand actually we are measuring this, that what is the oxygen demand that will be there for degradation of this compound ultimately inside the water.

When we are measuring organic carbon, we are essentially measuring this, that what is the amount of organic carbon inside this. So, certainly there may be essential some relationship between oxygen and this organic carbon. So, this is TOC is like a pseudo parameter of oxygen demand. So, total organic carbon can also be determined and reported. So, now we are going to study all these parameters in detail. And because this is determination of all these parameters is essential for understanding whether we should follow the biological wastewater treatment or not.

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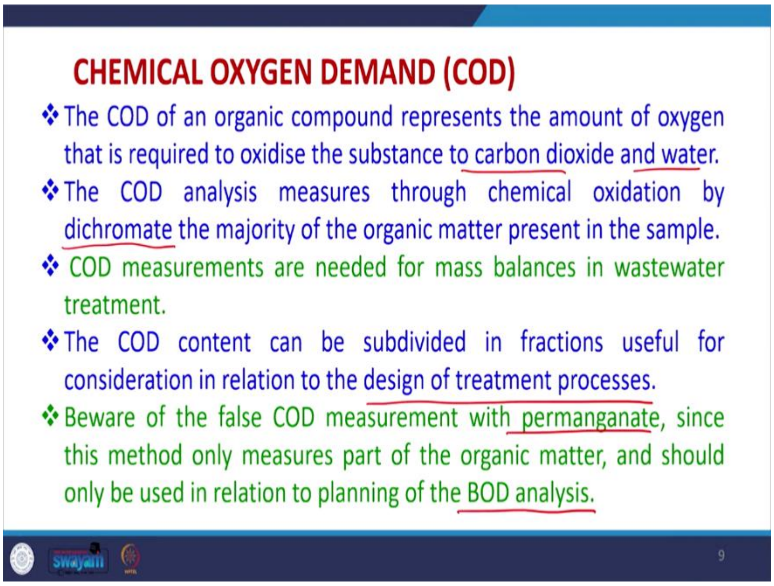

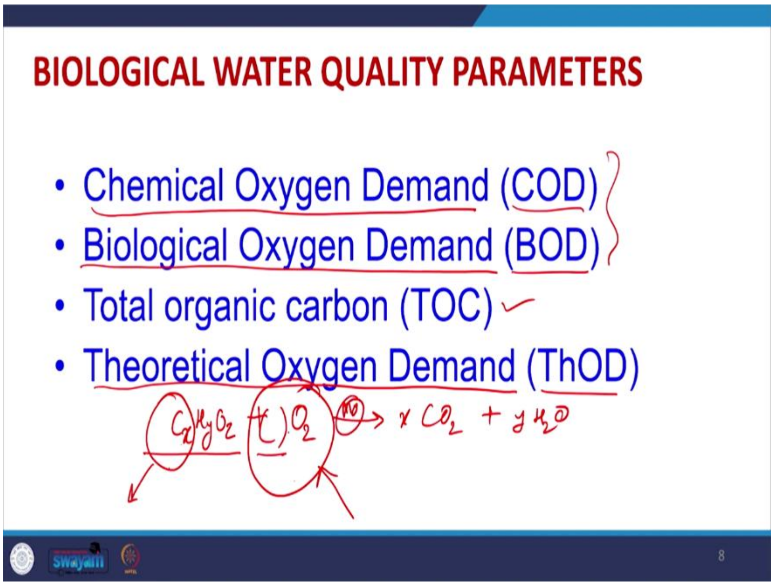

So, we will start with the COD first. The COD of an organic compound represents the amount of oxygen that is required to oxidise the substance to carbon dioxide and water. This is the same reaction that was given here. The difference between COD and BOD is that in the BOD only microorganisms are involved for degradation. Whereas in the COD we assume that we can use some highly oxidising chemical for oxidising that compound into CO_2 and water. So, CO_2 analysis through during COD analysis, we measure the chemical oxidation by dichromate.

So dichromate is highly oxidising compound. And this the majority of organic matter present in the sample will be oxidised. COD measurements are needed for mass balance in wastewater treatment. We will understand that further. The COD content can be subdivided in fractions useful for consideration in relation to the design of treatment processes will understand this. COD measurements with per magnate measures a part of the organic matter and should only be in relation to planning the BOD analysis.

So, when we are measuring with dichromate we are measuring all the oxidation whereas when we are measuring with per magnate it tentatively gives in relationship fast COD with respect to BOD analysis.

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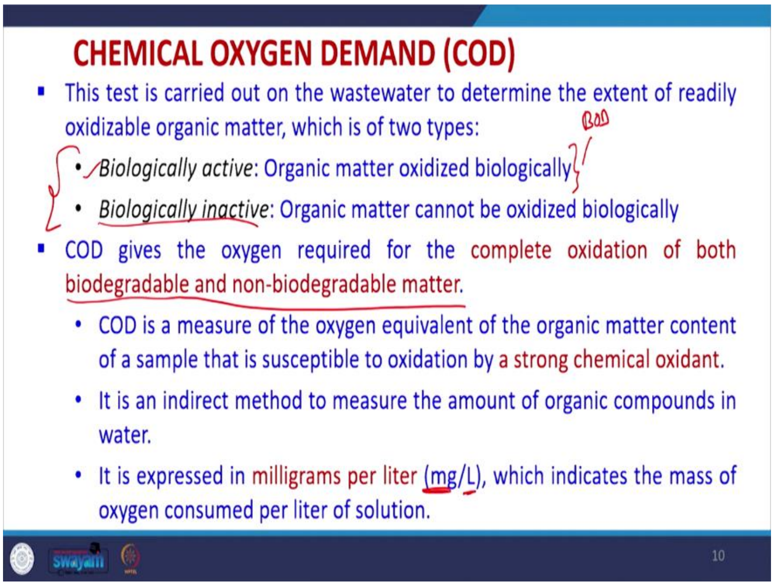

Now, how the COD analysis is performed, this test is carried out on the wastewater to determine the extent of the readily oxidizable organic matter and which may be 2 types it may be biologically active and biologically inactive. So, organic matter which is can be oxidised by micro-organism is called biologically active which cannot be oxidised biologically via micro-organism is called biologically inactive.

So, at least COD will determine both. Whereas, if we are measuring BOD that will be understanding then later on, it will be only focusing on this it cannot determine the biologically inactive organic compounds. So, this is there. So, COD gives the oxygen required for the complete oxidation of both biodegradable and non-biodegradable matter, whereas BOD gives only the oxygen required by the biodegradable matter.

So, COD is a measure of oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant like this dichromate, we can use the per magnate also, but it will be giving the false COD it is an indirect method to measure the amount of organic compounds present in the water and generally it is expressed in milligram per litre, which indicates the mass of oxygen consumed per litre of the solution. So, this is the mass of oxygen consumed per litre as the solution.

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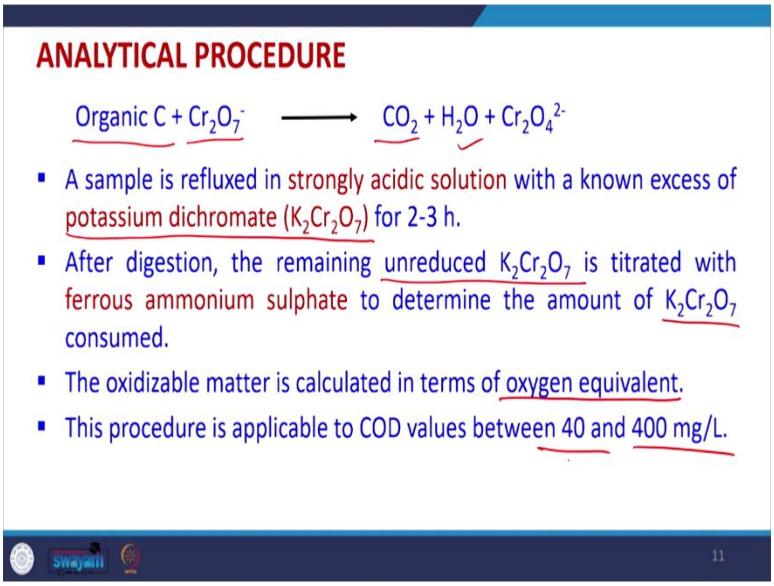

$$\text{Organic C} + Cr_2O_7^{-} \rightarrow CO_2 + H_2O + Cr_2O_4^{2-}$$

Now, this analytical in the analytical method what we do is that organic compound in depending upon the oxidising agent, it will convert into CO_2 H_2O etcetera. So, dichromate a sample is reflected in a strong acidic solution within known access. So, what we do know we know beforehand what is the potassium dichromate we are using, after digestion the remaining unreduced potassium dichromate is titrated with ferrous ammonium sulphate to determine the amount of the potassium dichromate which has been consumed and this oxidizable matter is calculated in terms of oxygen equivalent.

This procedure actually, the titration procedure or the refluxing and titration procedure is applicable for COD values in the range of 40 to 400 milligram per litre it gives very good results, if the values are higher, we have to dilute the sample to keep them in this range.

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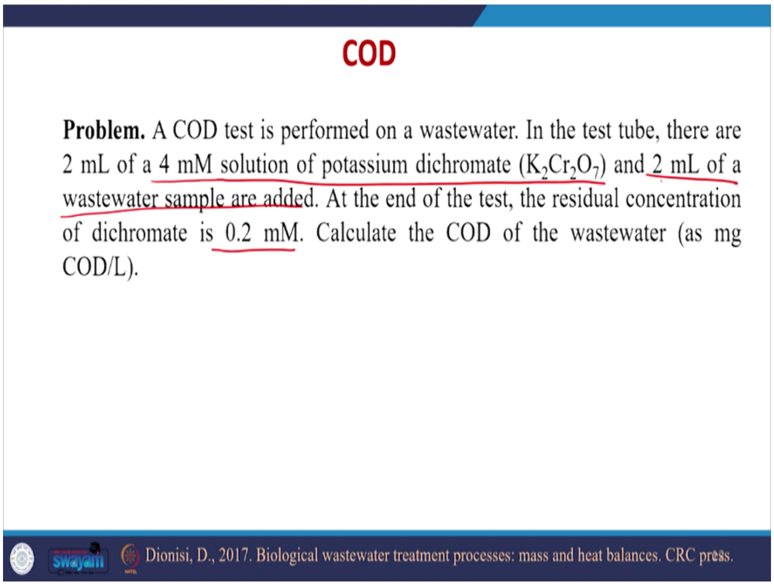

So, through this we can determine the value of COD. Now, let us take an example to further understand the COD. A COD test was conducted on the wastewater sample. In that test there are 2 ml of 4 milli molar solution of potassium dichromate and 2 ml of a wastewater sample are added. So this. At the end of the test the residual concentration of dichromate was found to be 0.2 milli molar, earlier before that it was 4 milli molar after that it was 0.2 milli molar calculate the COD of the wastewater as milligram COD per litre.

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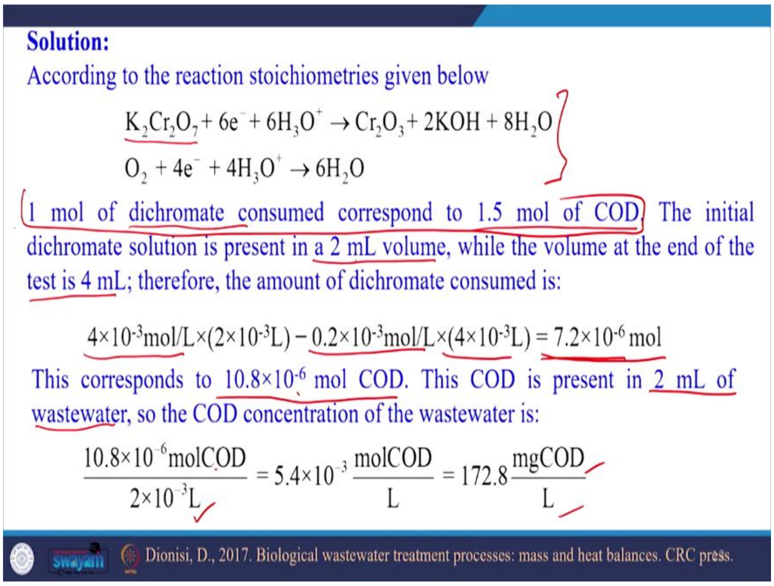


According to the reaction stoichiometries given below

$$K_2Cr_2O_7 + 6e^- + 6H_3O^+ \rightarrow Cr_2O_3 + 2KOH + 8H_2O$$

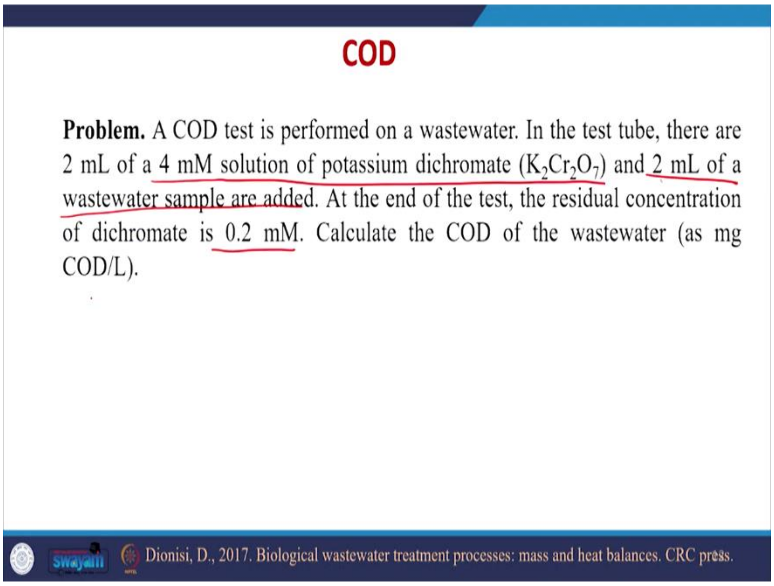
$$O_2 + 4e^- + 4H_3O^+ \rightarrow 6H_2O$$

The amount of dichromate consumed is:

$$4\times10^{-3}\ \text{mol/L}\times(2\times10^{-3}\ \text{L}) - 0.2\times10^{-3}\ \text{mol/L}\times(4\times10^{-3}\ \text{L}) = 7.2\times10^{-6}\ \text{mol}$$

The COD concentration of the wastewater is:

$$\frac{10.8\times10^{-6}\text{molCOD}}{2\times10^{-3}\text{L}} = 5.4\times10^{-3}\frac{\text{molCOD}}{\text{L}} = 172.8\frac{\text{mgCOD}}{\text{L}}$$



So, this is the process via which we can determine it is explained here. So, according to the reaction, so, the same reaction we can write in detail which was given earlier, we can see here that the one mole of dichromate consumed corresponding to 1.5 mole of COD. So, we can easily calculate. So, from this 1 mole of this and we can determine the initial dichromate solution is present as 2 ml volume, while the volume at the end of the test is 4 mL. Therefore, the amount of dichromate which is consumed is 4 into 10 raised to minus 3 mole per litre, because, it is milli molar. which was given we can see here 4 milli molar. And this is multiplied by the volume of sample this is 2 ml and after the sample again the molarity was only 0.2 milli molar, and but the sample volume taken was 4.

So overall, the difference is coming out to be 7.2 into 10 raise to 6 mole this corresponds to 10.8 into 10 raise to minus 6 mole of COD because this is already known to us that this is the particular 1.5 times the COD. Now, this COD is presenting 2 ml of wastewater because we had taken only 2 ml of the COD concentration in the wastewater sample can be determined because, this 1 mole of dichromate which was, actually we had 7.2 into 10 raised to 6 molar dichromate, which was consumed, and which is equivalent to this much COD.

Now, this much COD is present in only 2 ml sample. So, that we can determine 2 5 into 5.4 into 10 raise to minus 3 molar COD per litre and which is equal to 172.8 mole of COD per litre. So, through that we can determine the value of COD. So, this wastewater sample is having a COD of 172.8 milligram per litre. Next lecture onwards, we will go further and understand how to determine BOD, TOC and THOD. So, we will continue further. Thank you very much.