Wastewater Treatment and Recycling
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Lecture – 12
Waste water characteristics: Quality Parameters (Contd.)

Hi everyone. So, the last lecture, we were discussing the wastewater characterization and we started basically discussing the water quality parameters which are typically used or determined for assigning certain water or waste water in terms of its quality. We did discuss a few parameters in the previous lecture we will continue though discussions. So, the next parameter that we are going to discuss is turbidity.

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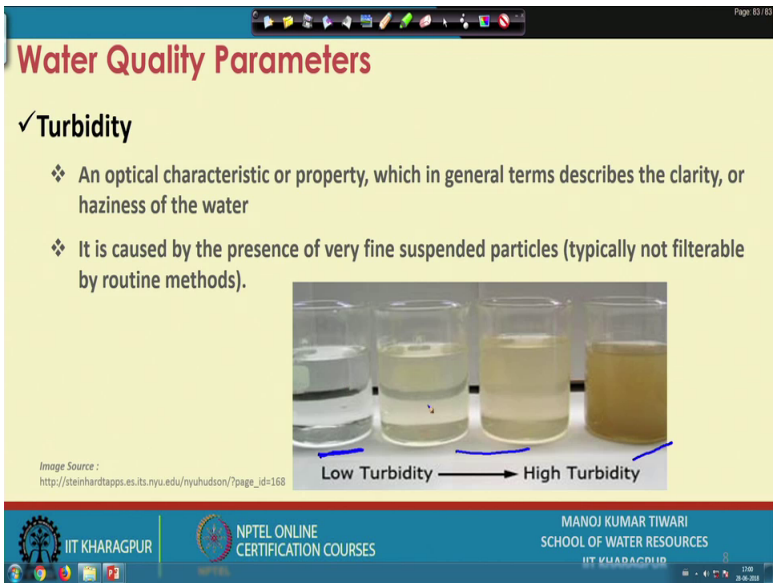

Turbidity actually is an optical characteristic or optical property which in general terms describe how much the clear the water is or what is the haziness in the water the water as the water which is very clear is perceive to be have very low turbidity. So, like this is a low turbidity water and as the sort of typically, we call water gets more and more dirty, the turbidity actually increases. So, the water which looks dirtier or which looks more hazy is more turbid as supposed to the water which is clean ok.

Turbidity is typically caused by the presence of very fine suspended particles and these particles are generally not filterable by routine methods. So, the things; you can see here this water which is far more clear is not having too much of suspended particles here,

there are very fine suspended particles, the concentrations keeps on increasing and the turbidity is keeps on increasing that way. So, that is what turbidity is.

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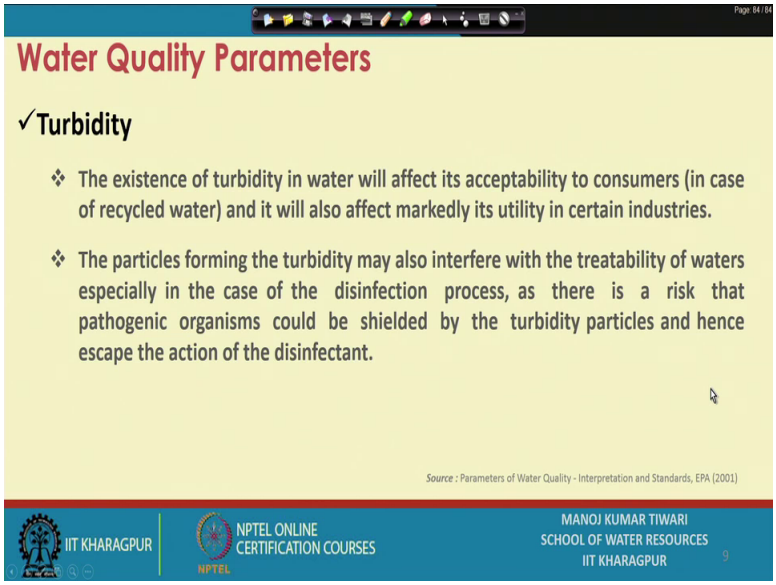

The existence of turbidity in water actually affects; its acceptability to consumer, the water which is looking more turbid people will not be happy to accept that water for theirs domestic uses. A little turbid water may be for irrigation purpose for say, but for industrial applications or for domestic applications one needs a low turbidity water.

So, that is how basically it needs to be understood that the suspended particles which are there may or may not be that unhealthy from health perspective although in water we do not want suspended particles at all, but there is a perception as we were discussing in the previous lecture about colour ok. So, colour also has more to do with the perception turbidity the particles which are there which can be actually clearly seen. So, this can be considered as a sort of physical property because, it is because of the very fine suspended particles which are physical entities.

So, this which can be seen can be observed and that is why people are more aware about such they may not be knowing the term turbidity, but they can easily assign that this water looks not good not of good quality or this water looks dirty. There are certain other implications of turbidity it hampers various treatment processes we will discuss that once we go into the detail, but particularly like this certain process for say disinfection or the light or this kind of based processes are greatly affected by turbidity.

If there a lot of suspended particles bacteria may get sealded by the suspended particles and what is ever disinfection we are providing, let us say, you are using UV for disinfection purpose. Now, UV light cannot even touch the bacteria because it is sealded by the these fine suspended particles. So, in that case, your process becomes ineffective or less effective.

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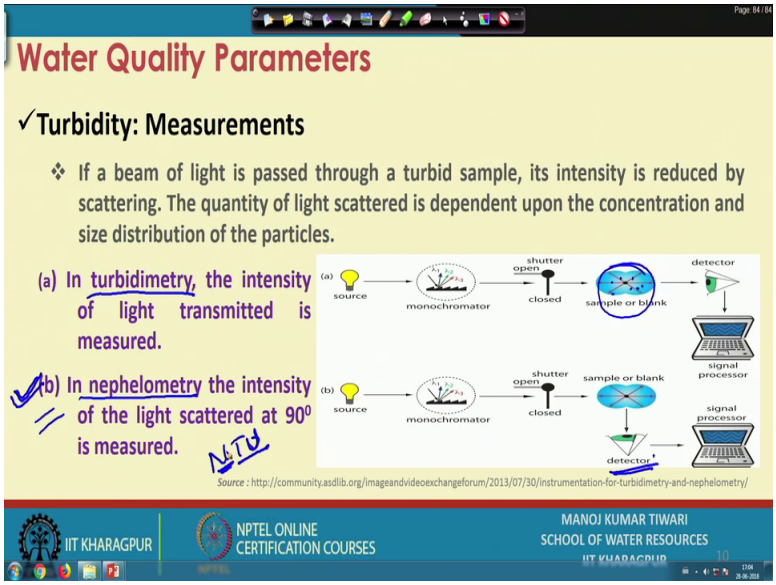

So, those are some of the terms related to the turbidity measurement, it is as we said that it is an optical property. So, it is measured by incidenting a light beam. So, there are basically 2 principals for the measurement of turbidity, one is called turbiditymetry. So, in turbidimetry there would be a source and there would be a monochromator. So, the monochromatic light goes on to the sample and then what is ever light is transmitted is measured. So, if the particle has a lot of suspended particles ok, the lot of light will get scattered and very little light will get transmitted, right. So, we can correlate the light which is getting transmitted with the amount or number of the particles present in the sample and that is how we can basically assign turbidity.

There is another principle which is called nephelometry which is more common and more frequently used. So, here things remain same only detection part changes we do not detect the transmitted light, but we detect the light which is scattered at right angle or ninety degree. So, the light which is scattering at ninety degrees gets detected in the

detector and then signals are processed and the value of turbidity is given to us normally a very stable compound pharmacien is used as a standard for turbidity.

So, we have different pharmacien solutions of different turbidity value and the typical unit for turbidity is NTU which is nephelometric turbidity unit. NTU stands for nephelometric turbidity unit and that is this is the principle which is nowadays used commonly for the measurement of turbidity. So, since, it is mostly detected by the nephelometric procedure, it is called it is expressed as NTU where N stands for nephelometry and T U is the turbidity unit.

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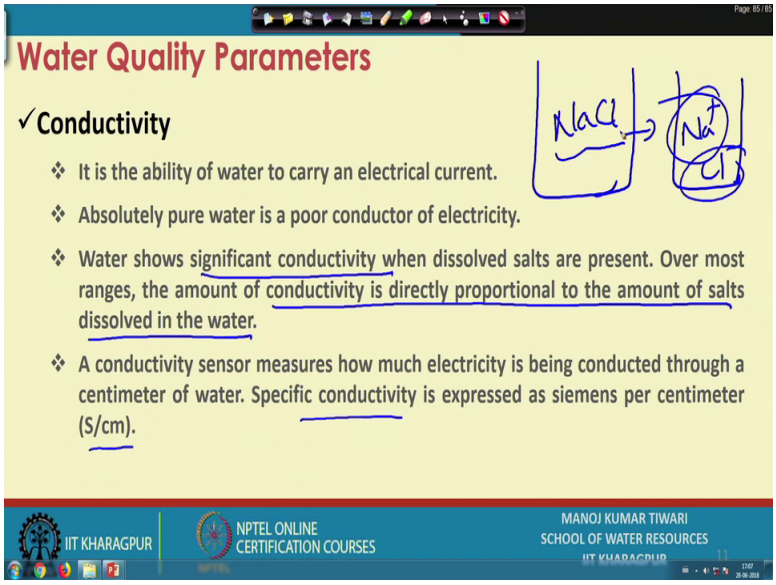

Then we have another parameter conductivity. So, conductivity is the ability of water to carry an electric current, this is pretty well understood, it is there in most of the places in higher secondary syllabus as well. So, absolutely pure water is a poor conductor of electricity because absolutely pure water does not, cannot transporter cannot carry an electrical current what carries an electrical current, if there are some ionized salt present.

So, when there are salts present in the water they often remain in the dissolved state or ionized state. So, like if you put NaCl in the water, if you try to put NaCl in the water this is actually going to remain in the form of sodium ion and chlorine ion so, because these are ionized element. So, they are the one who actually can carry the electricity. So, the dissolved salts if water is if water is having some amount of dissolves salts or

significant amount of dissolved salt. So, then the salts are able to carry electricity or carrier current through the water and that gives the water a significant conductivity.

So, essentially because if we exclude other things normally the conductivity it is because of these dissolved salts. So, it can be nicely correlated with the amount of salts dissolved in the water. So, in most cases or in often this conductivity is directly proportional to the amount of salts that are dissolved in the water more the amount of salt higher is the conductivity ok. This conductivity is measured through typical conductivity sensors and how much sort of electricity it can carry through one centimetre of water and the specific conductivity is typically expressed as Siemens per centimetre which is the unit for the conductivity. So, that way conductivity is measured.

Often this conductivity sent sensors also give the value of correlated value of salinity because salinity is also because of the salts only. So, conductivity can be indirectly measured can be directly estimated through the how much amount of dissolved solids are present in the water. It is often also correlated with the TDS which is total dissolved solids because most of the bearing few organic solids the inorganic constituents of salts when they are dissolved in the water they remain in the ionic state and they carry the charge. So, when they carry electricity, they will impart conductivity and conductivity can be correlated with that.

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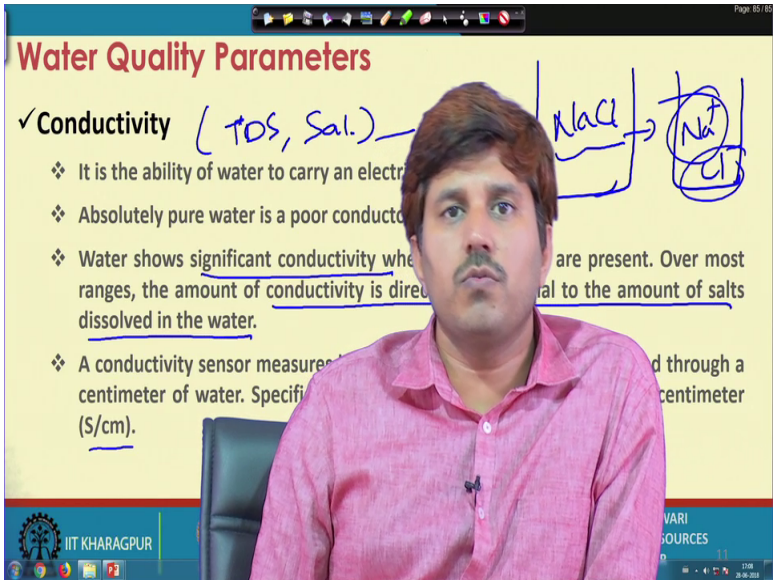

So, that is why the conductivity the typical conductivity metres that we get will give us several other values including total dissolved solids, then salinity. So, all those values can also be obtained from the conductivity sensors by the sort of indirect correlative assessments.

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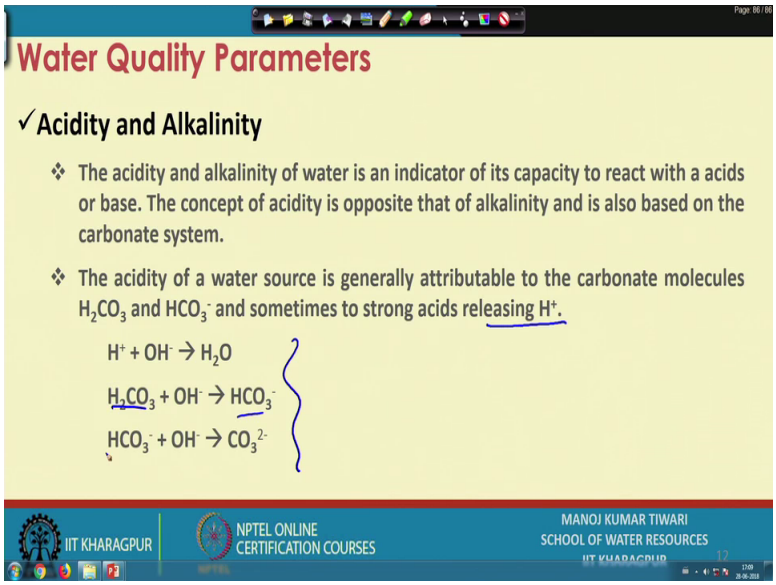

There are other parameters acidity and alkalinity. So, acidity and alkalinity of water are indicator of its capacity to react with the acids or bases in case of acidity, how much it can react with the base or in case of alkalinity that way the concept of acidity is opposite to that of alkalinity and is based on the carbonate system. So, the acidity of water sources generally attribute to the carbon molecules that are the carbonate and bicarbonates.

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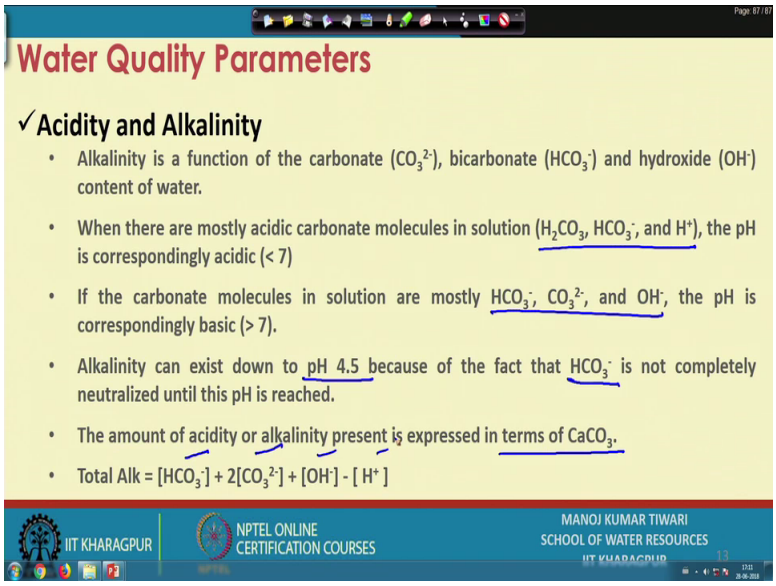

Hydrogen carbonates and bicarbonates and sometime even the strong acid that is released in the form of H. So, these are some of the reactions which govern; how we can get the carbonates and bicarbonates interchanged in the system and imparting acidity or alkalinity of the different types. If we see the alkalinity is a function of the carbonate bicarbonate and hydroxide content of the water. So, how much is the carbonate bicarbonate and hydroxide will give a fare estimate of the alkalinity where there is a mostly acidic carbonate molecules in the solution. So, carbonate bicarbonate or hydrogen and the pH corresponds to the acidic range.

So, that is less than 7, if carbonate molecules in the solution are mostly in the bicarbonate or these ions the pH corresponds to the basic range. Now, alkalinity normally there is a perception that above pH 7 the solution is alkaline or below pH 7, the solution is acidic, but when we estimate alkalinity and acidity, it is not that a way means because it is the presence of these ions which actually imparts acidity or alkalinity to the system. So, based on to pH these ions can exist we have to determine the acidity or alkalinity up to that range.

So, that is why this alkalinity can exist down to pH 4.5 up to pH 4.5, it can exist because the fact that bicarbonate is not completely neutralized until this pH and the total amount of acidity or alkalinity present in the system is again given in terms of milligram per litre of calcium carbonate. So, total alkalinity will be because as we said that alkalinity

corresponds to these ok. So, total alkalinity will be this bicarbonate ions carbonate ions hydroxide ions summation and minus H ions. So, that way, we can actually estimate the alkalinity.

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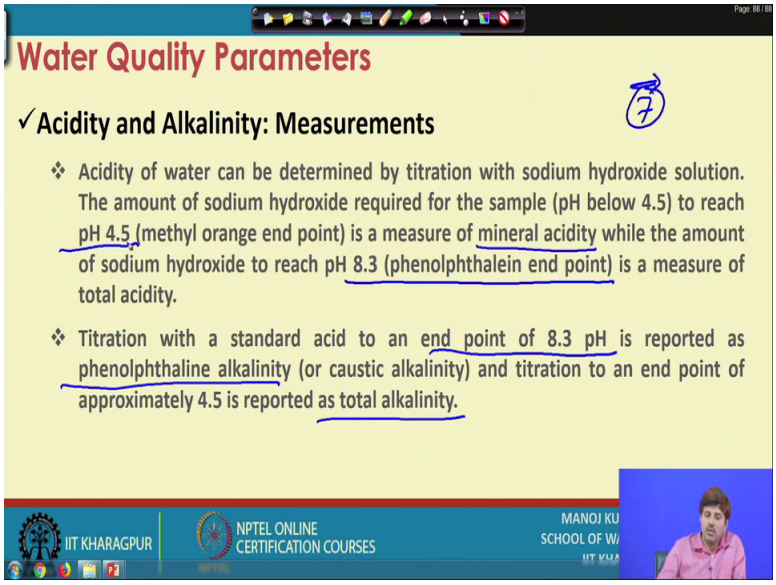

And similarly, we can estimate the acidity; the acidity of water is determined by titration with sodium hydroxide solution ok. This typically is a like depending on the starting point there are 2 end points. So, if our starting point is below say 4.5 then our first end point is 4.5 which is called methyl orange end point and that measures the mineral acidity. So, when we titrate it with sodium hydroxide solutions. So, amount of sodium hydroxide consumed to bring the pH up to 4.5 or methyl orange end point means if you add methyl orange it changes colour at 4.5.

So, up to 4.5 that amount is when that is represented as milligram per litre as CaCO 3 that is referred as mineral acidity while if we keep on further titrating it till the pH 8.3 which is phenolphthalein end point this is what measures the total acidity. Similarly for alkalinity purpose again like we do a titration. So, if let us say pH is pretty high if pH is say around 10. So, our first end point is that methyl orange is the phenolphthalein end point. So, we titrate it at pH 8.3 and report that as a phenolphthalein alkalinity or this is also referred as caustic alkalinity and then we keep on further titrating it till pH 4.5 and then we get the total alkalinity.

So, if our sample is having let us say pH of 7 for say and we want to determine the total acidity and total alkalinity. So, for alkalinity purpose we cannot bring it down to 8.5 by adding the standard acid ok, it is already below 8.3. So, from 7 we will titrate it to 4.5 and report that as the total alkalinity where as phenolphthalein alkalinity or caustic alkalinity in that system is 0.

Similarly for acidity purpose, if you want to titrate the same determine the same sample for the acidity. So, we will titrate it with sodium hydroxide and raise the pH till 8.3 and what is ever we get will be called as total acidity while the mineral acidity because it is already above 4.5. So, there is no mineral acidity or the mineral acidity which is methyl orange end point is actually 0. So, that is how we can determine the acidity and alkalinity in the system.

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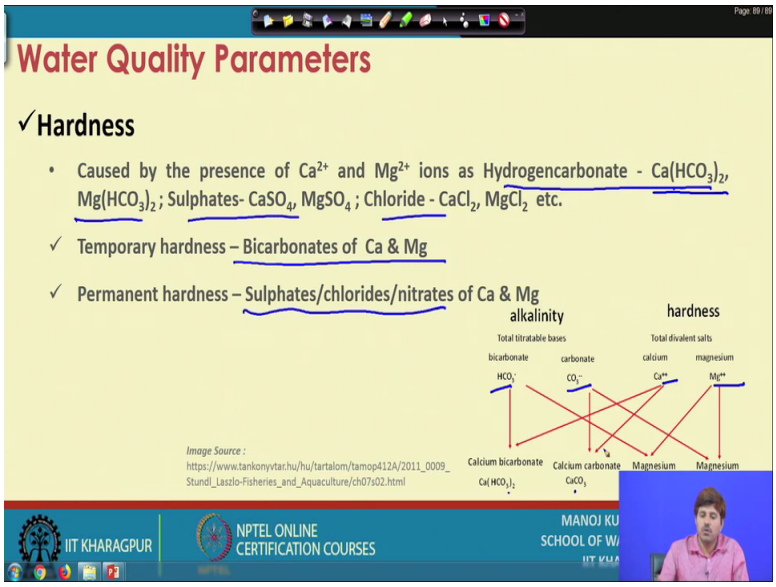

The, another quality parameter is hardness which is caused by the presence of calcium and magnesium ions this calcium and magnesium ions could be present as bicarbonate or what we call hydrogen carbonate ok. So, it could be there is calcium bicarbonate or magnesium bicarbonate could be there, it could be present in other forms also like in the form of sulphates chlorides or even nitrates. So, based on which form this calcium and magnesium ions are we assign the hardness whether it is a temporary hardness or permanent hardness.

The temporary hardness is actually due to the bicarbonates of calcium and magnesium and when we boil actually this temporary hardness can go off where as permanent hardness is because of the other ions sulphate chloride and nitrate ions of calcium and magnesium. So, that is what gives the permanent hardness which is not that easy to remove.

So, if we see the alkalinity we already discussed could be because of bicarbonates or could be because of carbonates and hardness is because of calcium and magnesium ion. So, when this calcium and magnesium ions are with the carbonate or bicarbonates they form calcium carbonate and calcium bicarbonate when these bicarbonates. Similarly, with magnesium, it forms magnesium carbonate and magnesium bicarbonate and this way the alkalinity and hardness can be basically linked or correlated.

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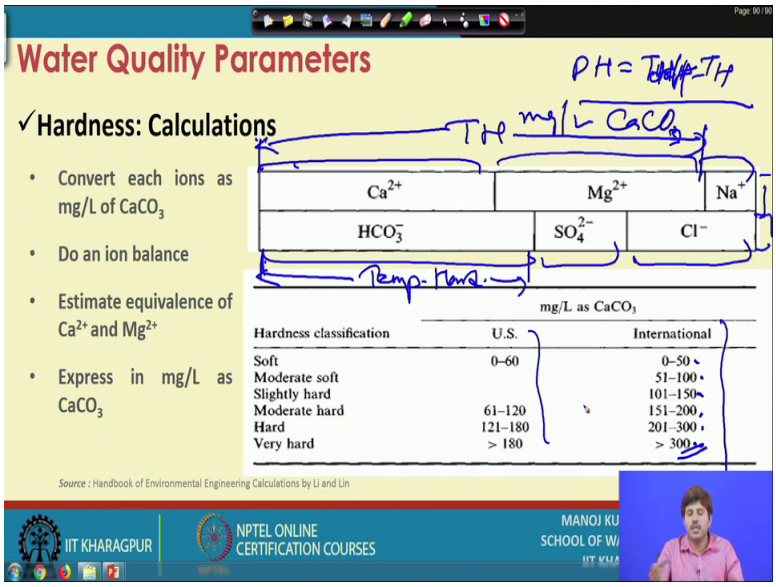

Now, if we sort of want to estimate or calculate the hardness of the system ok, there has a EDT titration procedure through which we can actually get the hardness ok, idea of how much calcium ion present in the system through complexation process. However, this standard high school chemistry is there for calculation purpose the each ions are converted to the milligram per litre as calcium carbonate all the ions all the cations as well as anions and then an ion balance is done like you see an ion balance here.

So, in sample, let us say for this much is the calcium ion this much is the magnesium ion this much is the sodium ion towards anions there is this much is a bicarbonate this much

is a sulphate this much is a chloride for say or there might be let us say other ions also at times or unknown ions. So, that possibility is also there. Now, once this ion balance is done, we can actually estimate the equivalence of calcium and magnesium and calculate or express the hardness as CaCO 3. So, all these are expressed as a CaCO 3. So, in this case if we ask total hardness. So, total hardness is because of calcium and magnesium ions. So, summation of this becomes your total hardness of course, expressed as milligram per litre CaCO 3.

Now, if you ask for a temporary hardness. So, temporary hardness is because of the bicarbonates. So, whether it is either with calcium or magnesium we can refer this as bicarbonates as the temporary hardness and in this case because of there in no carbonates or nothing. So, this will actually be equal to the alkalinity as well; so, temporary hardness becomes equal to the alkalinity of the system and if we see the permanent hardness. So, we know the total hardness and we know that temporary hardness or bi bicarbonate hardness carbonate hardness. So, we can subtract this for permanent hardness we can subtract the total hardness we can subtract temporary hardness from the total hardness. So, that will give us the permanent hardness.

Based on hardness the waters water can be qualif sort of categorised in different groups. So, if it is there are U.S. norms there are other international norms different agencies different countries can have their own norms as well. So, internationally less than 50 is considered soft, from 51 to 100 is considered moderately soft, from 100 to 150. It is likely hard, from 151 to 200, it is moderately hard, greater than 200 up to 300, it is hard and greater than 300, it is very hard U.S. have their own classification of course.

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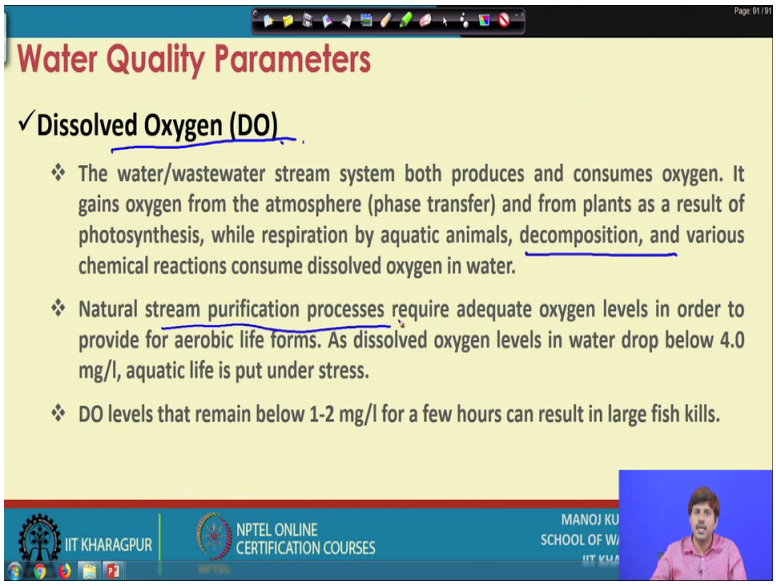

Then we have another parameter which is dissolved oxygen. So, the water or waste water streams both producers as well as consumes oxygen now the oxygen is gained how oxygen comes into the water body it comes through the phase transfer that is the prime way of getting oxygen into the streams. So, we have our rivers flowing they are exposed to the atmosphere there is oxygen in the atmosphere. So, by Henry's law, the oxygen remains in the equilibrium. So, oxygen will actually some of the atmospheric oxygen will transfer into the water through the interface of a through this air water interface and that is how the atmospheric oxygen comes into the water phase and remains soluble in the water which is typically referred as dissolved oxygen.

The, another route of getting a oxygen in the water is photosynthesis. So, the aquatic plants the plants which are there in the water they do photosynthesis activities and in the process they produce oxygen and since they are in the water. So, oxygen is produced within the water and it gets dissolved in the water. So, that is another way, through which oxygen can come into the system. However, there has to be basically plant algae or this kind of things present for photosynthesis normally, in flowing water in river. There are not much of these vegetative things are present in the system and that is why this route of the oxygen in flow to the water is a have very little contribution. The major way through which the flowing water or rivers get oxygen is through the atmospheric oxygen transfer.

Now, how oxygen gets consumed oxygen can be consumed by the respiration of the aquatic animals or the decomposition of a various organic matters various chemical reactions that consume dissolved oxygen in the water. So, the chemical reactions which consume oxygen will consume certain amount of oxygen the decomposition of organic matter consumes oxygen. So, that will be a consuming lot of oxygen from the water and of course, the respiration of the aquatic animals if there are there are any. So, that will do some consumption of the oxygen.

Now, so, there are ways through which oxygen comes in the water. So, there are ways through which oxygen goes out of the water at any given particular point of time what is the level of oxygen dissolved in the water is typically referred as dissolved oxygen. So, dissolved oxygen is the oxygen which is dissolved in the water. Now, naturally stream purification process needs adequate amount of oxygen level why because naturally streams how naturally streams get purified. There are inherent aerobic life forms, there are inherent aerobic microorganisms present in the water and when there are organic matter comes on the form of waste in the let us say you are disposing one somebody is disposing a city's sewage into a river.

Now, what happens when that sewage enters the river sewage is carrying lot of pollutant and organic pollutant also along with it because our domestic sewage carries significant amount of organic matter and industrial sewage is even higher. So, when this organic matter enters the when this organic matter present in the waste streams enter the river what happens that the inherent microorganisms either present in the waste stream or present in the river will attack the organic matter and try to decompose it for the purpose of extracting food and energy out of it.

We will talk about the detailed process later on, but quickly. So, in that process they need oxygen and they need oxygen. So, they consume oxygen that is what we said the decomposition of organic matter is also a way of consumption of the oxygen. So, in the process, they consume oxygen and your waste your naturally stream should have sufficient or adequate amount of oxygen level present. So, that they can utilize that oxygen, otherwise, they would not be able to degrade these compounds and if they are not able to degrade these compounds the naturally stream purification process hampers.

The dissolved oxygen level in water should be adequate the level should actually be generally higher than 4 for aquatic life survival, below 4 the aquatic life comes under stress. And if DO level decreases up to 1 to 2 milligram per litre for even a few hours, it can result in a large fish kills because fish is do their respiration based on the dissolved oxygen. For us for our breathing in for our respiration atmospheric oxygen is the source, but for aquatic culture the oxygen which is dissolved in the water is the source. And if that oxygen depletes, they would not get oxygen for their respiration or breathing in and that leads to basically very severe detrimental effect on the population.

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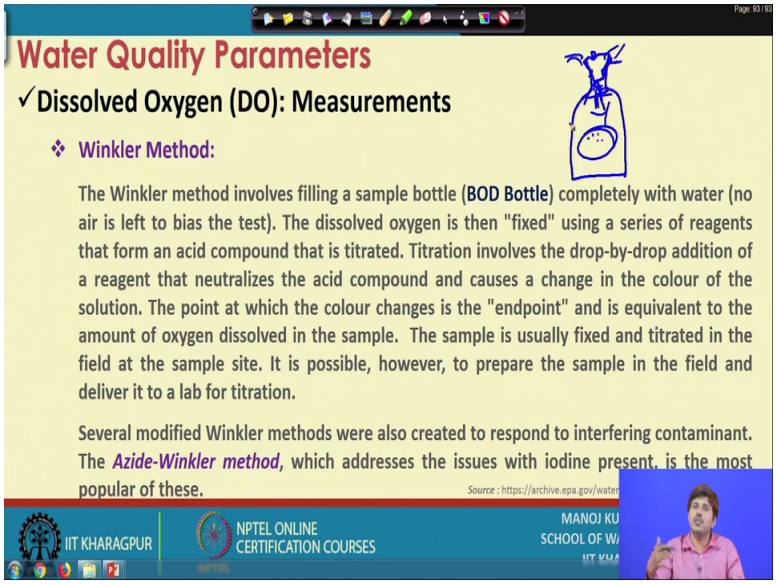

If you see the measurement of oxygen, there are some traditional methods like Winkler methods which is a titration based method a chemical method. So, the in Winkler methods; basically, it involves that we fill the sample bottle completely with the water, there should not be any air left in the water for biasing the test because we are trying to measure here the oxygen dissolved in the water. So, for that a particular bottle which is typically referred as BOD bottle comes and this bottle is used, it typically has the neck like this. So, that a cap can be fit in here very nicely and preventing any air entering into it.

So, when we sample for dissolved oxygen fill this bottle right till the neck and then we put the cap. So, that a little water can spill from here that is fine, but there should not be any air bubble or any air in this we are trying to monitor oxygen dissolved in the liquid

and if we leave some air space for say here. So, then it is going to the concentration in liquid is going to change because there will be exchange with the air. So, we will not be able to get the actual concentration in the water. So, that is why it is fell to the neck.

Then it is fixed dissolved oxygen typically using a series of regents that sort of form an acid and which is later on titrated titration involves drop by drop addition that neutralize the acid compounds. And change the colour of the solution the point at which the colour changes that is endpoint is actually the equivalent to the amount of oxygen dissolved in the sample. The sample is usually fixed and titrated at the spot because, we should not allow any form of oxygen entering here and there.

So, we if we can titrate this sample as fast as possible or even in the field that is the best way even if not that it is possible like it is not possible many time to carry this tradition equipments or this kind of laboratory setups to the field. So, we that is possible that we can go fix the sample in the field itself the fixing part is must and that should be done immediately as we sample. Why? Because, if we do not fix there are microorganisms there are other things.

So, they will keep on consuming the oxygen and they dissolve oxygen level in the water will keep on changing. So, that is why we as soon as we take the sample we fixed it with the fixative reagents and put it in the acidic conditions of that all microbial activities are stopped we prevent any contact from the air and that is how the samples are fixed and then if it is fixed we can bring it to laboratory and we can analyse it there.

So, this is a typical titration method Winkler method which has been which was under use for a very large period of time there had been several modifications came for this method. And one of the most popular modification was Azide Winkler method where, an Azide reasons were added in order to compensate for the interference from the iodine present so that way like it was traditionally used to be monitored in the laboratory.

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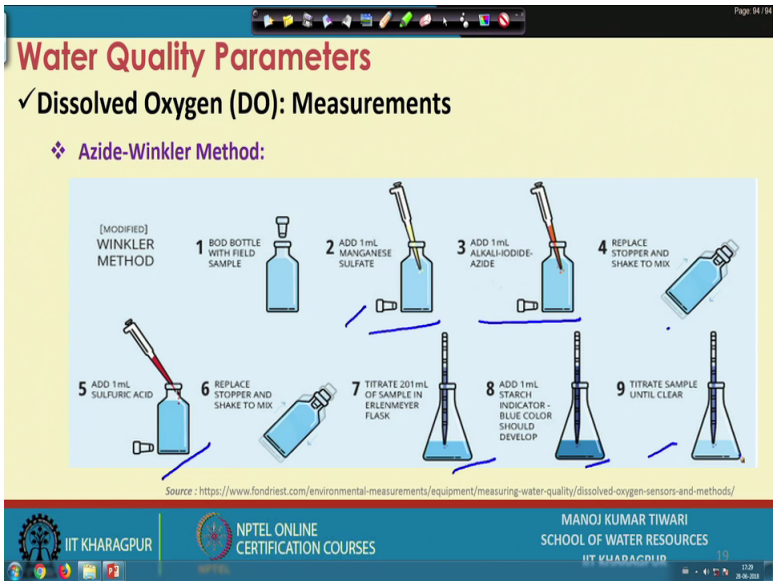

This is a schematic of how the procedure was there we take the sample we fill it with the sample first then we add certain reagents. So, 1 mL magnesium sulphate is added 1 mL alkali azide is added, this azide modifica modified method and then we replace the cap we add 1 mL sulphuric acid in order to drop the pH and control all possible in any possible microbial activity. We replace this stopper shake it completely and then titrate it sample, then add starch indicator and titrate until the colour is cleared. So, that is how we were able to determine the amount of oxygen present in the water.

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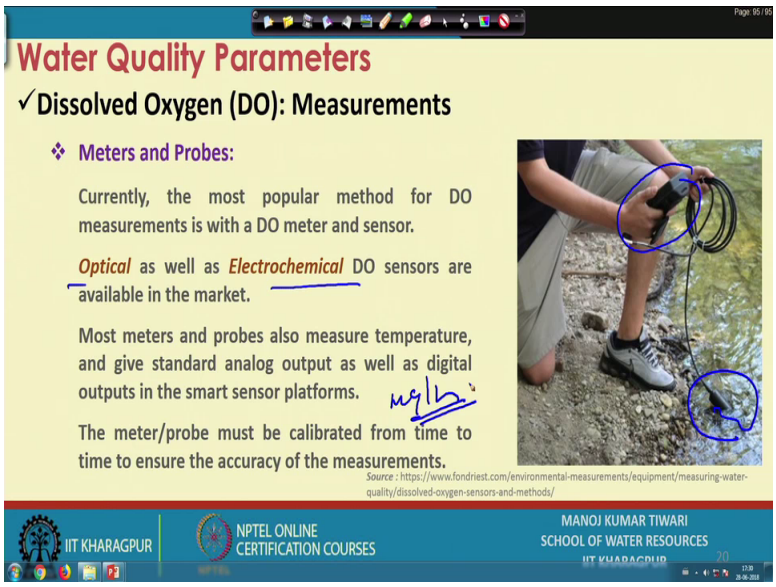

However, these days this methods are not that used and actually the metres and probes have come which are far more handy for users. So, currently the most popular method for DO measurement is based on the metres and sensor. So, we have a probes and sensors like this and connected to typically handheld or a tabletop devices.

The sensors could be of optical or could be electro chemical in electrochemical further we have 2 3 different type of sensors the galvanic based sensor then and there are like couple of different type of sensors and then there are optical sensors. So, these sensors measure temperature as well and give analogue output as well as these days we have smart sensor platforms on which we can get the digital output also in the milligram per litre which is a unit of dissolved oxygen.

However these metres and probes should be calibrated from time to time because we are measuring based on a say optical or electrochemical sensor which is passing through. So, we must be sure that the value it is giving is correct and that is why because titration is a simple procedure what is ever is there how much titrant it is consuming. So, based on calculation, we can determine, but here signal is getting converted to the dissolved oxygen. So, we must calibrate the equipment from time to time. So, that the through way which signal converts to the milligram per litre is appropriate. So, that kind of that is kind very important precautions for using such metres.

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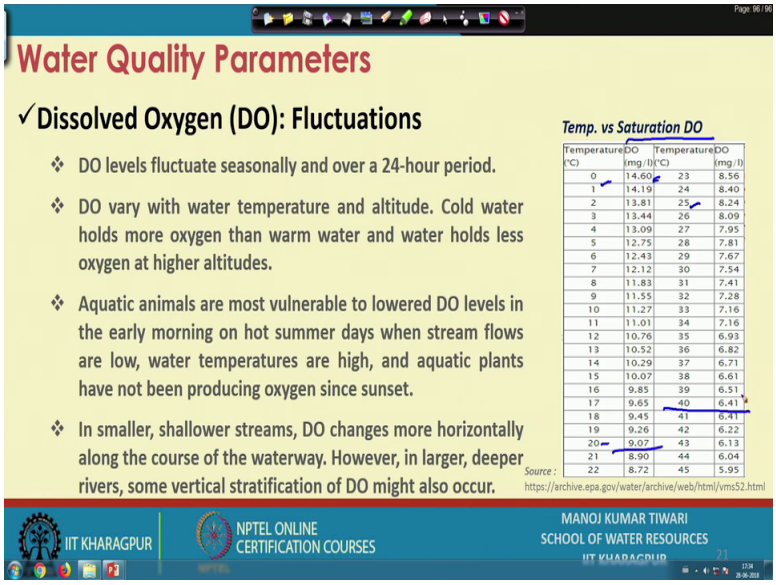

Now, if you look at the fluctuations in the dissolved oxygen DO levels fluctuate seasonally and over a 24 hour period ok. So, in season to season there will be fluctuation and within a within a day also there is a lot of fluctuation why there is fluctuation because, it varies at the temperature it varies at the altitude it varies at the sort of what kind of biochemical processes taking place within the water. So, cold water holds more oxygen typically and warm water will hold laser oxygen similarly the sort of water which is at higher altitude because of the pressure will hold less oxygen as supposed to the water which is at lower altitude.

The aquatic animals which are most vulnerable to lower dissolved oxygen particular in the early morning on hot summer days because the stream flows are low on summer days; we know that rivers run very narrow or very little flow is there and that results in the water temperature are high. So, when water temperature are high the dissolved oxygen or saturation dissolved oxygen level itself is low and then the aquatic plant sort of have not being producing oxygen because of the sunset.

So, what happens during the daytime since photosynthesis occurs if there are significant aquatic plants and all that. So, if photosynthesis is occurring the oxygen is getting produced in the system and that is why many times, if you see, if you sample a dissolved oxygen in a river at 3 pm, you will see very high level of dissolved oxygen if you sample at 3 am in the morning, in the night time there would not be any photosynthesis. So, you will see much less dissolved oxygen level.

In sort of water courses this shallower streams smaller streams DO changes more horizontally as supposed to the vertically because in vertically, it is becomes sort of well mixed system, but if it is a very larger or deeper rivers. So, then there is a possibility of vertically stratification means DO could vary vertically as well. If we see how the DO changes with the temperature. So, this is the saturation dissolved oxygen levels at different temperature.

So, at around 0 degree water the saturation dissolved oxygen level is 15 milligram per litre at around normal temperatures around 25 degree Celsius or 20 degree Celsius. So, at 20 degree Celsius, it is 9.07 or 9.08 kind of that at 25, it is 8.25 and as temperature increases at 40 degree, you will see the dissolved oxygen the saturation oxygen level is 6.41 only.

So, as it is a function of temperature and it is a function of altitude function of lot many other things. And dissolved oxygen is one of the very critical and important parameters of the water quality estimation just by measuring the dissolved oxygen in a river. It may not be it is actually not a very important parameter for drinking purpose, but for a natural waters if we see a water which is exposed to the atmosphere and still having low dissolved oxygen level. That means, it is a polluted water because there are certain organic matter present in the system which are consuming the dissolved oxygen which should not be there. So, that that is a simple indication from the dissolved oxygen values.

So, we will and this lecture here and in the next lecture, we will talk some more water quality parameters especially the BOD and COD.

Thank you.