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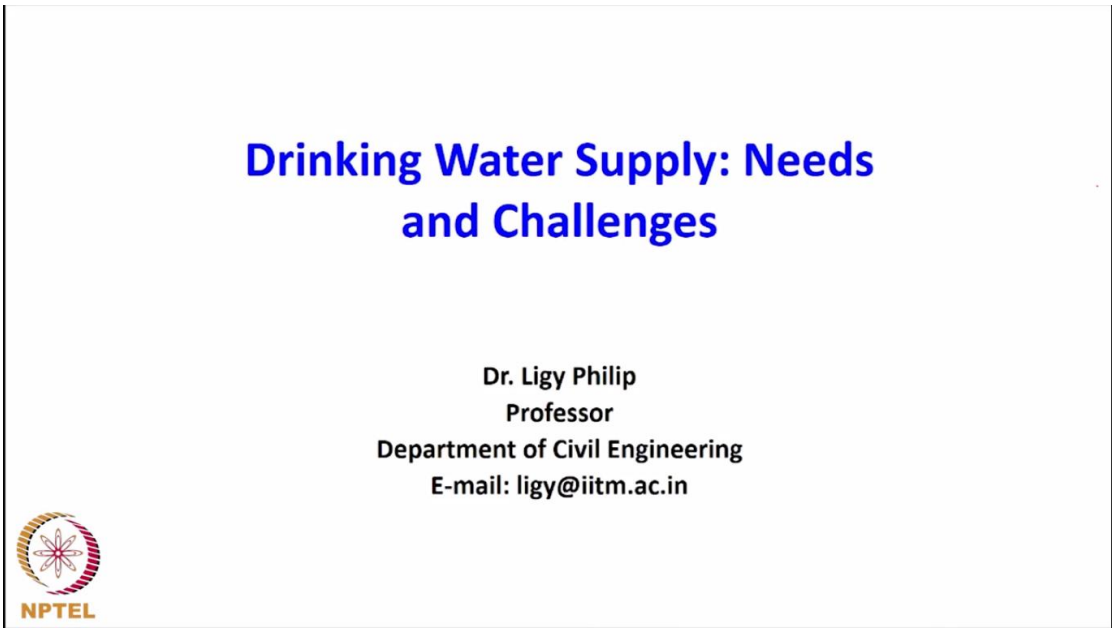
ECOLOGY AND ENVIRONMENT

Drinking Water Supply: Needs and Challenges

Lecture 2

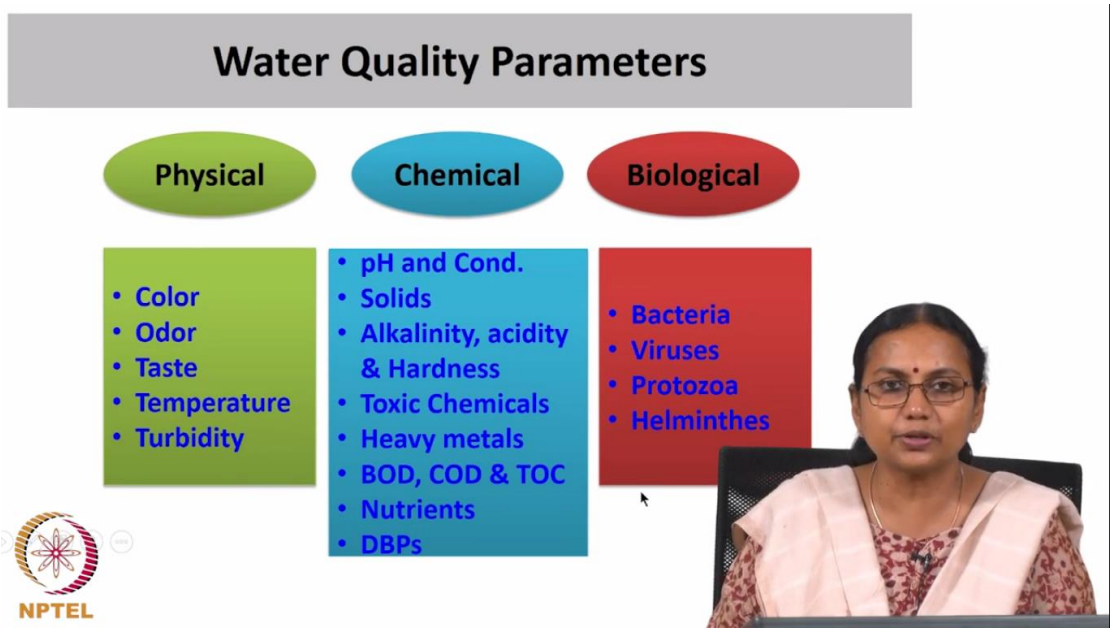
Prof. Ligy Philip

Department of Civil Engineering
IIT Madras



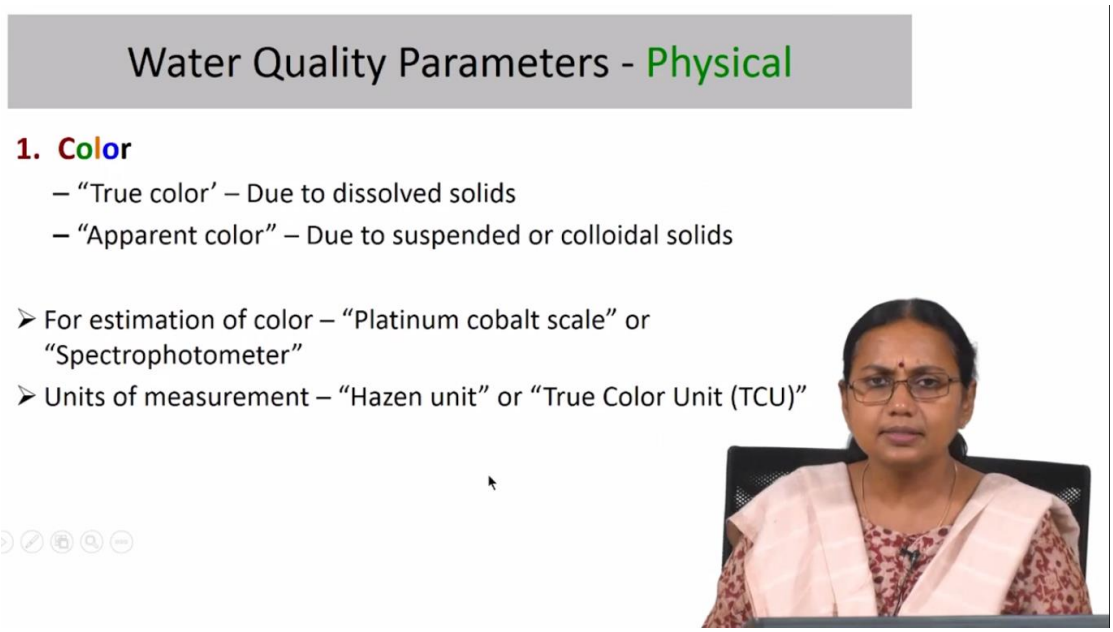
Welcome back to the lectures. In the last class, we were talking about the different sources of water and what are the attributes of a water supply system and how can we calculate the water demand, etc. Today we will talk a little bit in detail about water quality parameters.

When we talk about water supply, we have to be careful about the quality of the water. So, when we talk about water quality, we can divide them into three categories; physical parameters, chemical parameters, and biological parameters.

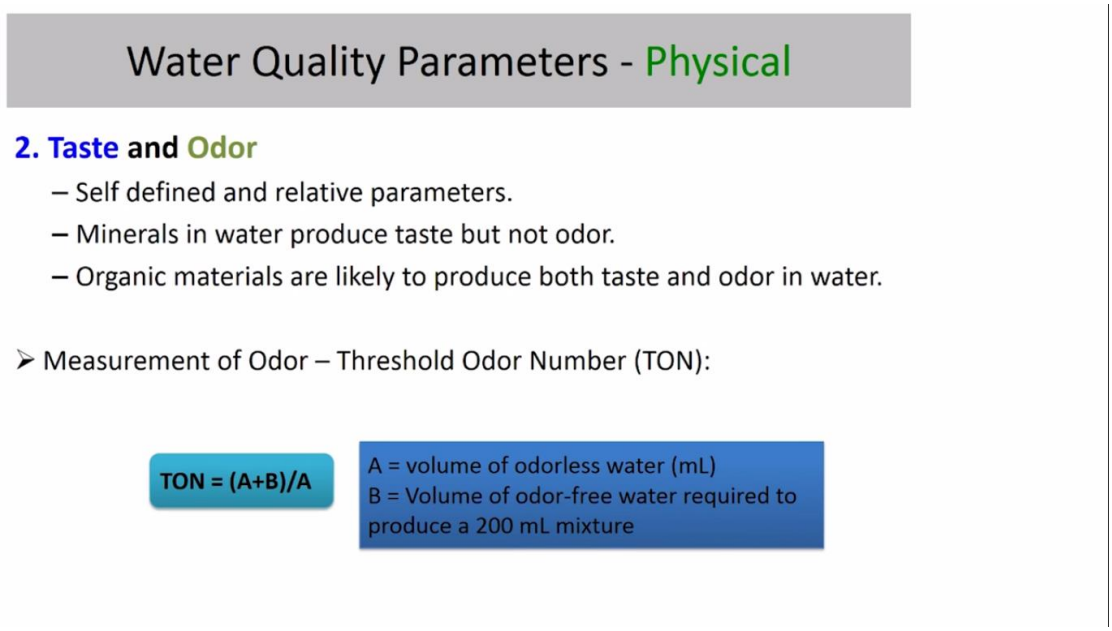


So, this slide shows you what are all the parameters coming under physical, chemical, and biological categories. Physical means which we can see, or we can perceive, those include color, odor, taste, temperature, turbidity, etc. We can immediately feel the feel

them, so that is why they are known as physical parameters. And the other one are chemical parameters, because of the presence of some chemical components, these properties are coming. One is pH, pH, and conductivity, then solids; solids can be dissolved solids, colloidal solids, suspended solids, etc., alkalinity, acidity, hardness, toxic chemicals, heavy metals, then organic compounds; organic compounds different ways we can express, those are biochemical oxygen demand, chemical oxygen demand, and sometimes we measure in terms of total organic carbon. Then we have nutrients. You you have many other complex organic compounds including DBPs, polyaromatic hydrocarbons, pesticides. Nowadays people are talking about emerging contaminants that means the pharmaceuticals, personal care products, etc. present in water. All those parameters are coming under the chemical category. And the last one is biological. That means these parameters are of biological origin; they include bacteria, viruses, protozoa, helminths. So, when we talk about water quality, we have to have one idea about what is the amount of this parameter present in the water and whether they are within the permissible limit.

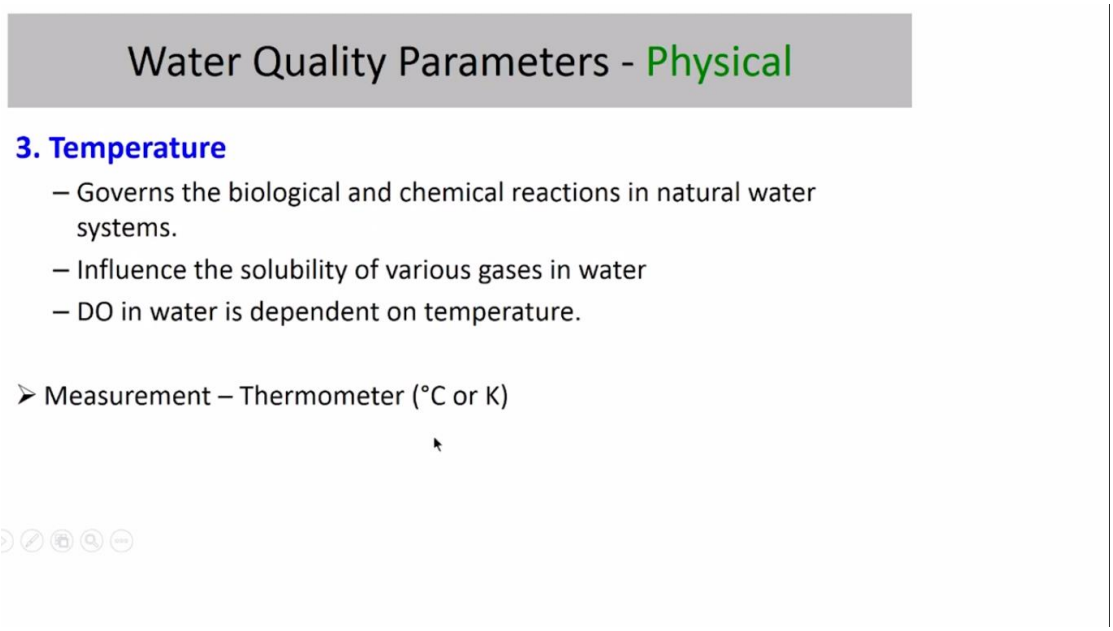


So, first, we will quickly see the physical parameters. One is color. Color is the presence of dissolved or suspended solids in the water. And it is divided into true color and apparent color, and if you want to find out or measure the color our eye is the best method but there are different scales, whether we can use Platinum cobalt scale, or we can use spectrophotometer to quantify the color. And units of color measurements are Hazen unit or True Color Unit. These are the units, we usually represent the color.

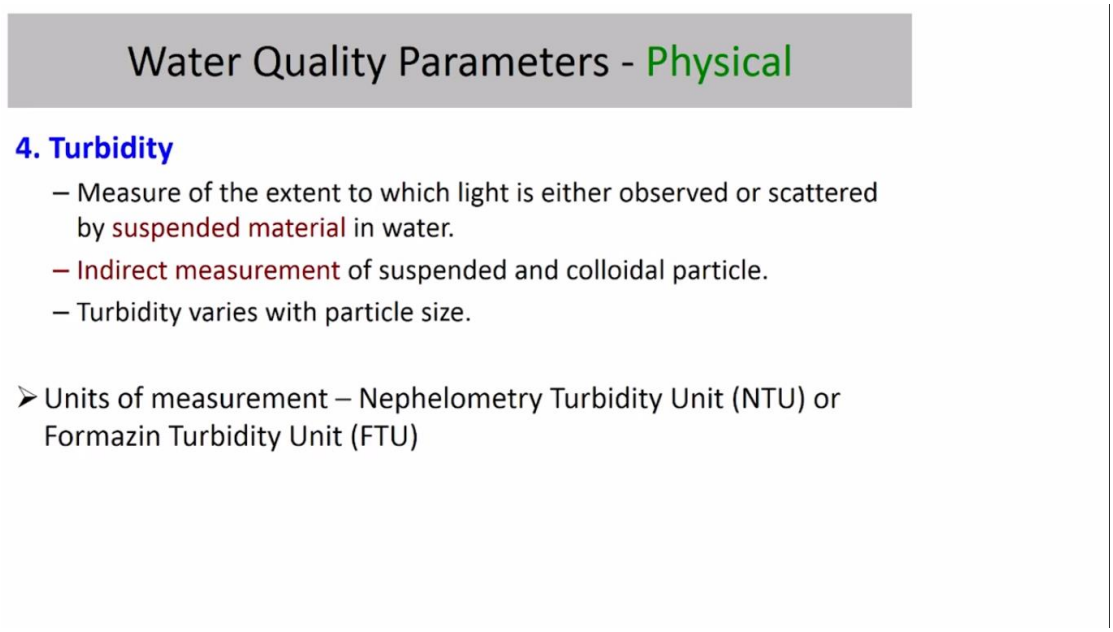


So, this is one parameter, and another one is taste and odor, and it is a self-defined and relative parameter because somebody may feel that the water is having some taste, other person may be thinking that it - feeling that it does not have. So, this is a parameter which will be varying from person to persons. And minerals in water produces taste but not odor. Organic materials are likely to produce taste and odor in water. For example, any decayed leaf is present in the water then that will create both taste and odor. And the measurement of odor is usually done or expressed in terms of Threshold Odor Number or TON. So how can we calculate TON? So, the formula is given here. (A+B)/A. Here A is you see the volume of odorless water in mL and B is the volume of odor-free water required to produce a 200 mL mixture. A is the volume of the water sample you have, and B is the volume of odor-free water required to produce a 200 mL of mixture.

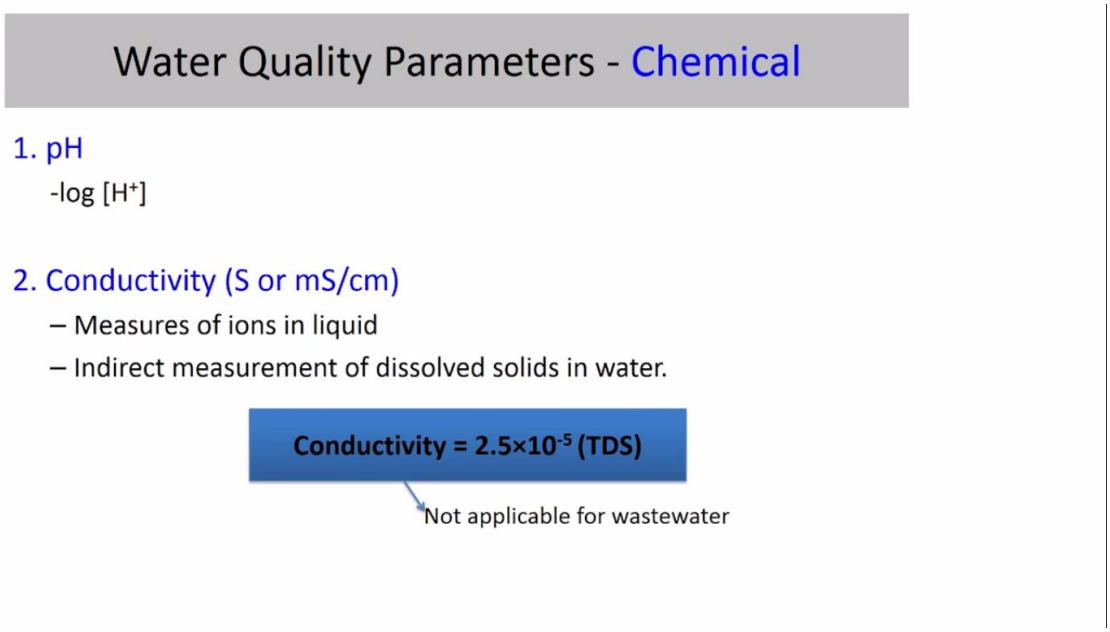
For example, you take one mL of your sample, and you are adding 199 mL of odor-free clean water then you A is one mL, and B is 199 mL. So, your TON is (A+B)/A.



And temperature all of you know how to measure the temperature. And the temperature governs the biological and chemical reactions in natural water and influences the solubility of various gases in water and dissolved oxygen water is depending on the temperature. So, that is why usually we measure the temperature but again what is the acceptable limit; it varies from person to person. Some people prefer cold water, some people will prefer hot water. So that is also a subjective parameter.



Now coming to turbidity. So, what is this turbidity? It is the measure of the extent to which light is either absorbed or scattered by suspended material in water. Again measurement of the extent of - extent to which light is either absorbed not observed, absorbed or scattered in suspended by suspended material in water. This is an indirect measurement of suspended and colloidal particle present in the water. For example, you take a beaker of water having a lot of suspended and colloidal particle, and you allow the light to pass through that one what will happen? The light will be getting scattered. So, it will give an indirect measurement of suspended and colloidal particles present in water and turbidity varies with particle size. For example, you take a pebble, and you put it in a beaker, and if you measure the turbidity, the turbidity will be very less. But imagine if you take the pebble and crush it into very fine particles and put it into the same beaker that means the same pebble, initially we have put it as a pebble, the next time what we are doing is, the pebble you take it, crush it into very fine powder and put it, so what will happen? The second time the number of particles are very very large. So, your light scattering will be very high, so, you will be getting a very high turbidity. So, what I am trying to tell is, it will not be quantitatively measure the total solids present in the system, it is indirectly measure the suspended and colloidal particles, qualitative measurement. So, most of the time the unit of the unit of measurement of turbidity is NTU or Formazin Turbidity Unit. Nowadays we usually use NTU units for measurement of turbidity.

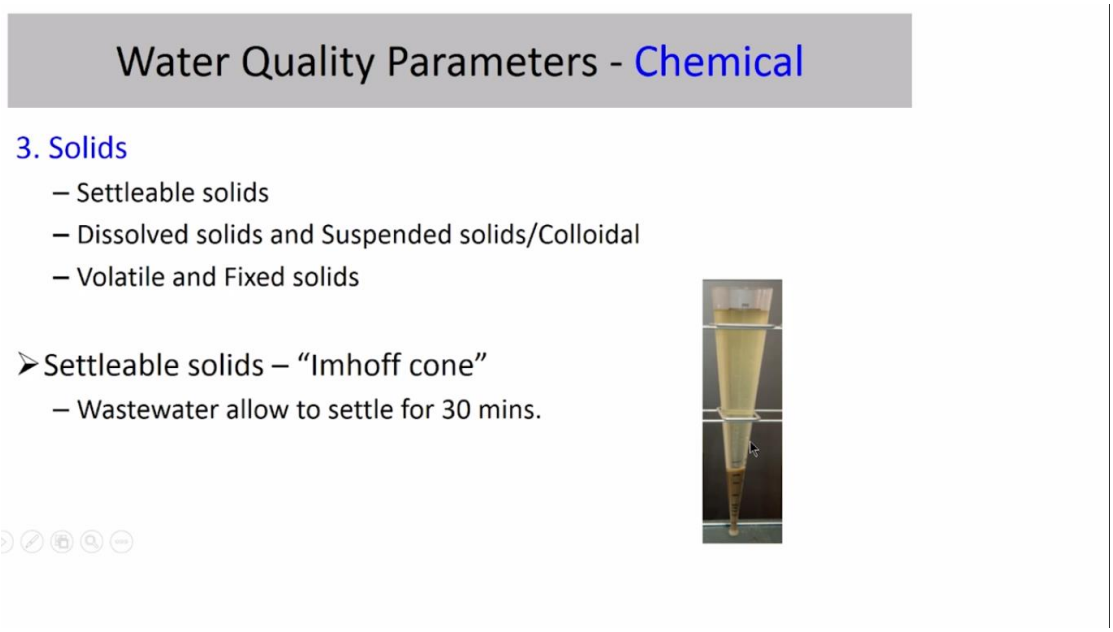


And pH, I know all of you know what is pH. It is the narrative log of hydrogen ion concentration, and this decides whether the water is alkaline or acidic. So, the water

should not be highly acidic or highly alkaline. It is not acceptable for drinking purpose. So, the pH around 6.5 to 8.5 is preferred for drinking water.

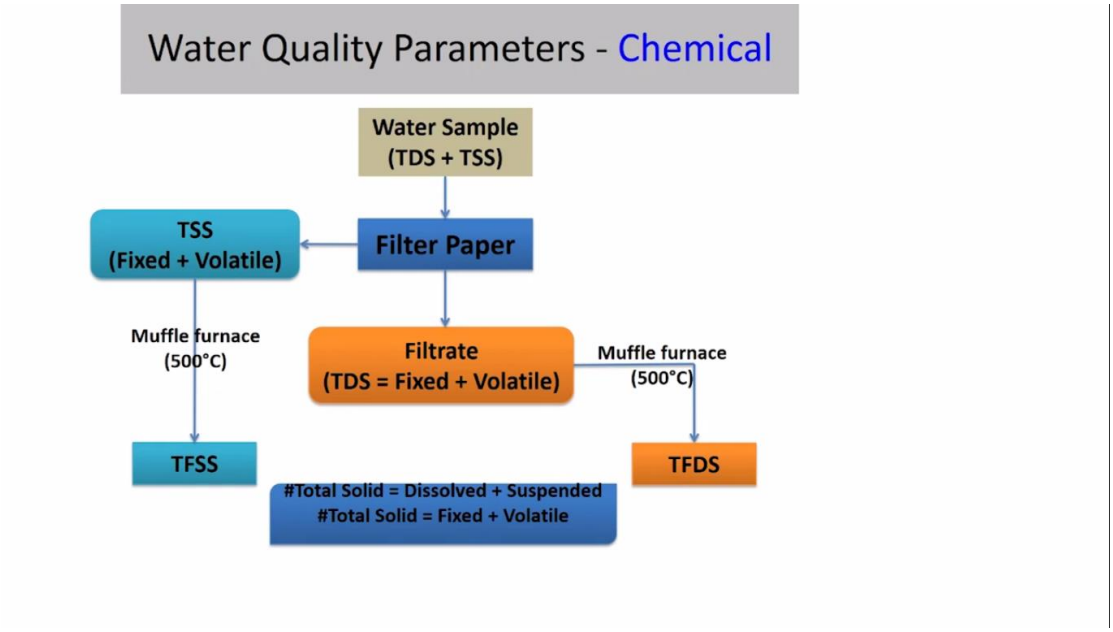
Now coming to conductivity, it is a measure of ions in the liquid. Mostly only ions, not the molecules because it will measure only ions. Indirect measurement of dissolved solids in water but conductivity cannot be used for measuring dissolved solids in wastewater because in water most of the solids will be in ionized form but in wastewater the solids maybe most of the solids may not be in the ionized form. Because for example, you take the organic matter, many of them may not be existing in ionized form. So, if you use conductivity to measure the dissolved solids in wastewater, it may not be giving a correct value.

So, this is the empirical formula we usually use to find out the TDS. Conductivity is equal to 2.5 x 10^{-5} (TDS). So, this TDS will be in milligrams per liter. So, so this is the empirical formula usually used for the thing.



And I told you, next parameter is solids. When we talk about solids, we can divide them into different categories settleable solids, dissolved solids and suspended or colloidal solids then volatile and fixed solids. When we talk about these solids, water supply system we will not bother about all these solids, we look into only total dissolved solids and total solids. But when it comes to wastewater treatment, we have to have a clear idea about all these classifications because the treatment system design will be depending upon the nature of the solids. So, what is this settleable solids? As the name indicates you allow the water to settle and whatever is settled inside the

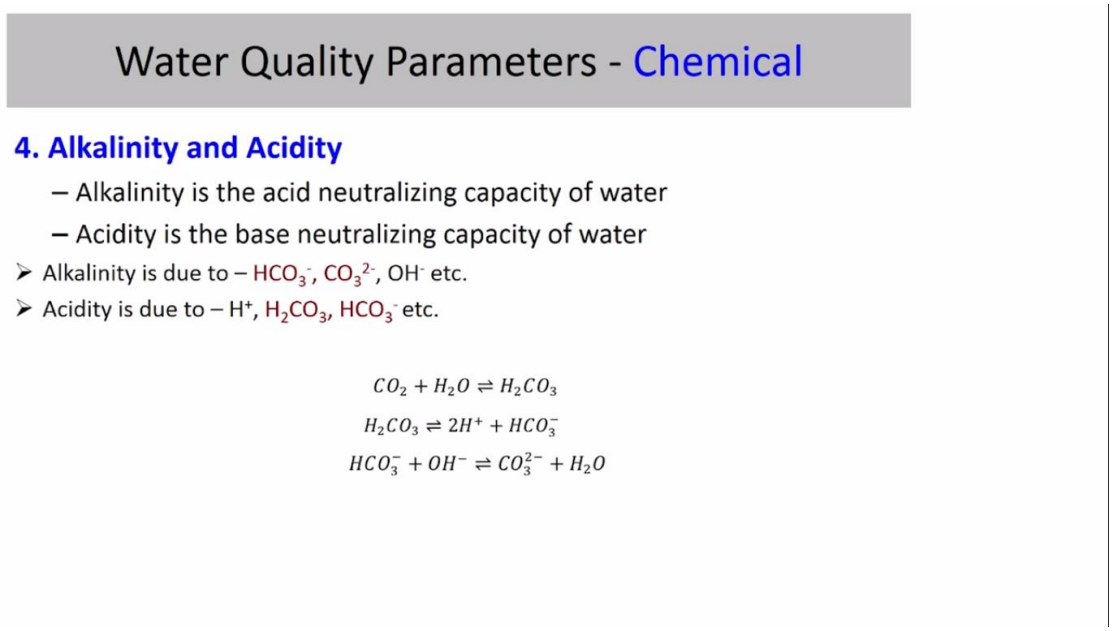
vessel, so that is the settleable solids. So, usually, we use Imhoff cone. This is the Imhoff cone. You can see that this cone the measurement is here.



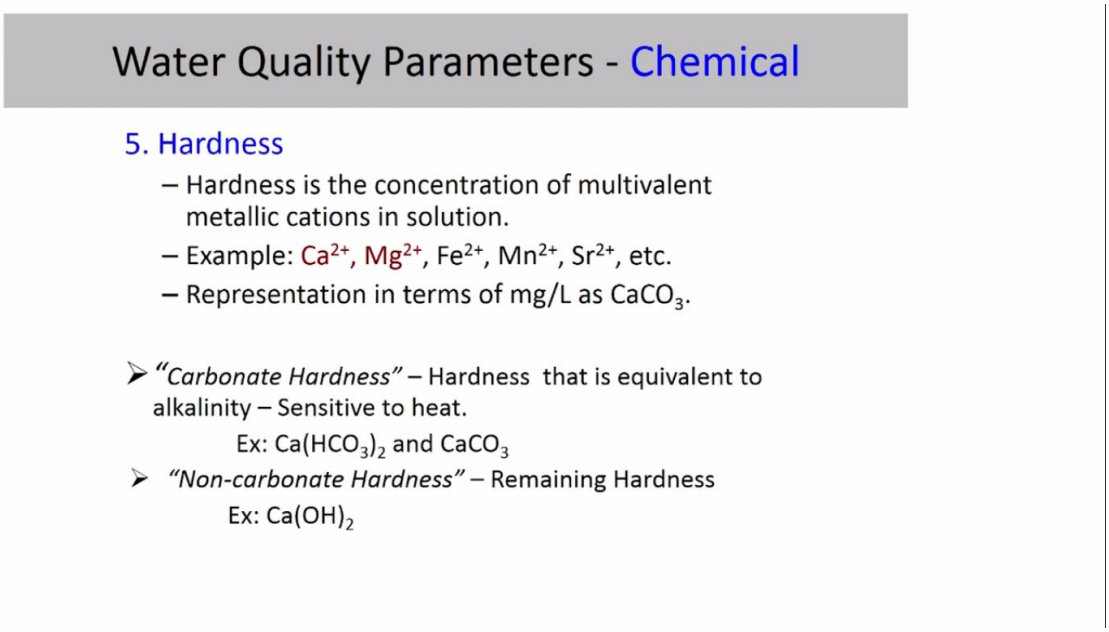
So directly we will be getting the volume of solids settled in the system, and the water is allowed to stand there for 30 minutes so that all the settleable solids will be settling.

Now, we will come to the other solids how to find out. So, I told you many different types of solids are there. Water sample will be having total dissolved solids and total suspended solids, so then you filter the paper, filter the water through a filter paper so and take the filter paper and dry it. So, the difference in weight will give you total suspended solids. This will be a combination of fixed solids and volatile solids. Then what you have to do, keep the filter paper along with the solids in a muffle furnace at 500-degree centigrade for 20 to 30 minutes. Then what will happen, all the volatile solids will be getting oxidized thermally to carbon dioxide and water then only the inorganic solid will be remaining in the filter paper. So, if you take the weight of the filter paper, you will be getting the total fixed suspended solids. So, after the filtration, if you take the filtrate and you evaporate the water completely and take the weight of the container having the solids, you will be getting the total dissolved solids. And here also it is the combination of fixed and volatile solids. Then again you put the container in a muffle furnace at 500-degree centigrade or the crucible under 500-degree centigrade; you will be getting total fixed dissolved solids.

So, if you add total fixed dissolved solids and total suspended solid you will be getting total fixed solids, and total dissolved solids plus total suspended solids you will be getting total solids, etc. So, these are these are the ways to find out different categories of solids, and I am telling you again, these solid classification this type of classification is usually done for wastewater, not for drinking water.

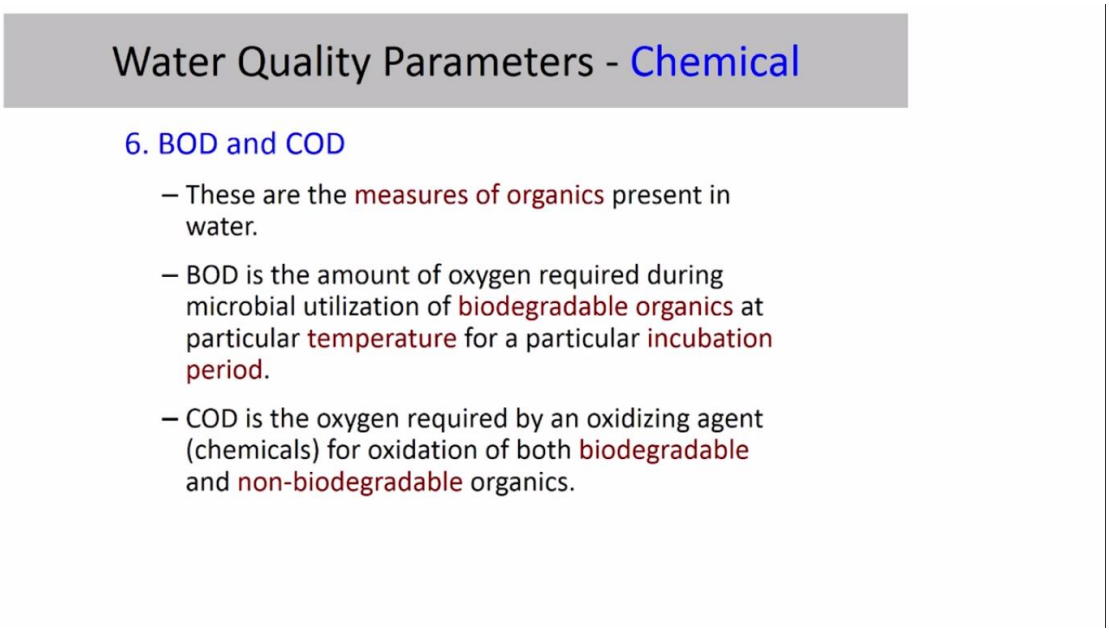


Now, what are these alkalinity and acidity? Alkalinity is the acid neutralizing capacity of water. Acidity is the base neutralizing capacity of water. Alkalinity is due to bicarbonate, carbonate, and hydroxide, hydroxyl ions present in the water and acidity is due to H^+, H_2CO_3 and HCO_3 because of, in water mostly it is because of the carbonic acid system. Because you know that carbon dioxide and water gives you H_2CO_3 and this H_2CO_3 can dissociate into HCO_3 and H^+ and then again to CO_3 and H^+. So, so this is the system, or this is the system which is giving the buffering capacity to water.

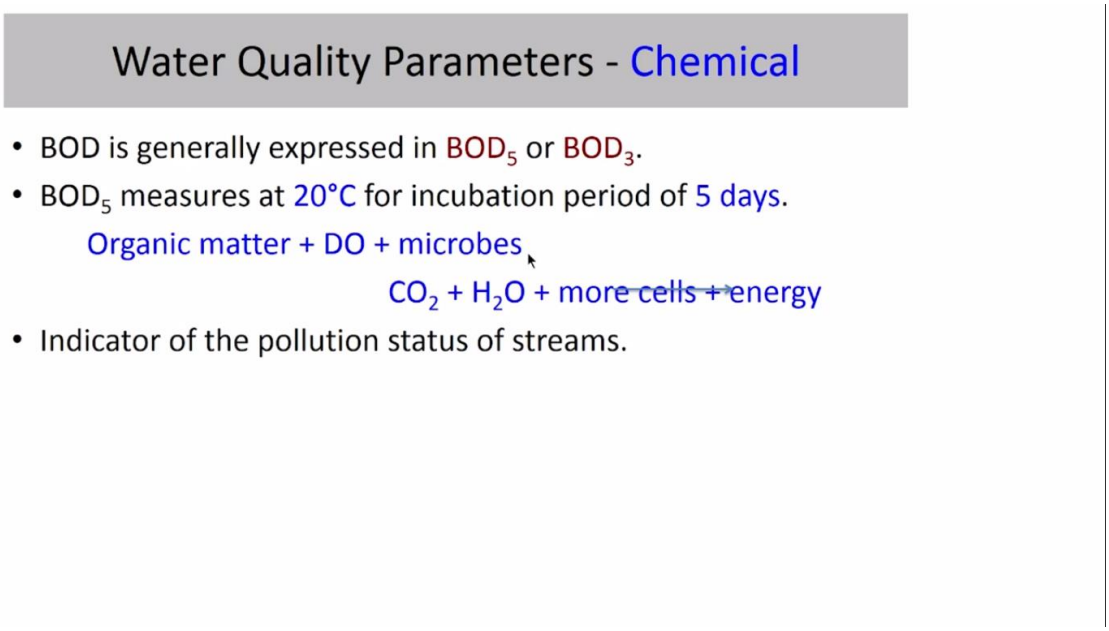


Now hardness. By definition, hardness is the concentration of multivalent metallic cations in solution. Again, hardness is the concentration of multivalent metallic cations in the solution. Examples, calcium, the presence of calcium, magnesium, iron, Manganese, Strontium, etc.

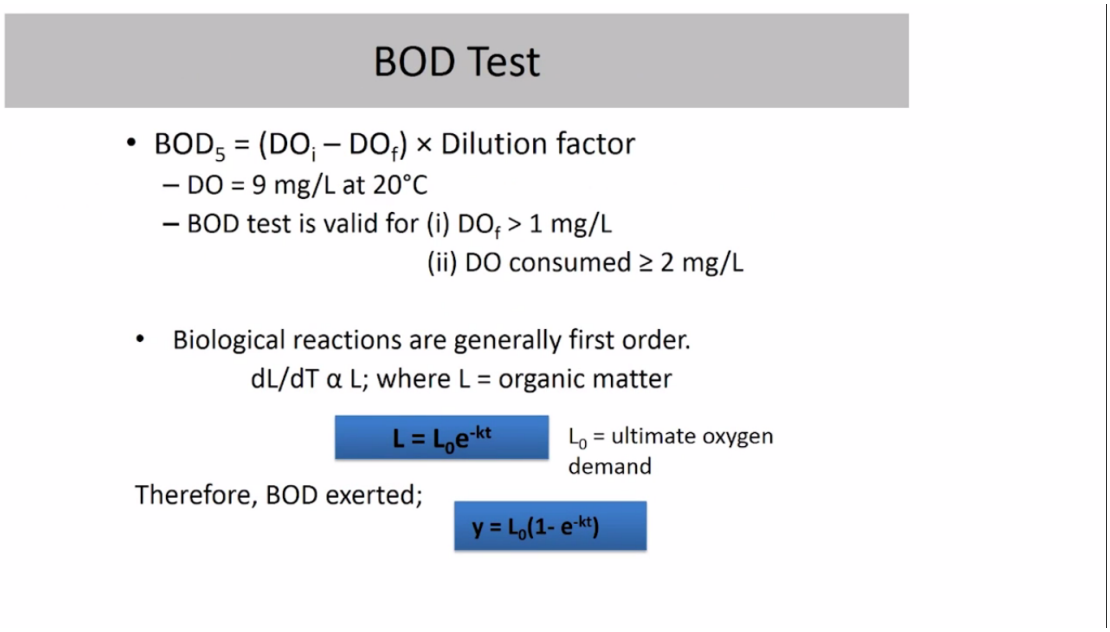
And in drinking water most of the time the hardness is caused because of calcium and magnesium because other ions are present in very low concentration. And most of the time the hardness is expressed as milligrams per, milligrams per liter as calcium carbonate. And when we talk about hardness, carbonate hardness is the hardness that is equivalent to alkalinity, and it is sensitive to heat, and non-carbonate hardness is, hardness remaining after heating or it is in excess of alkalinity present in the water.



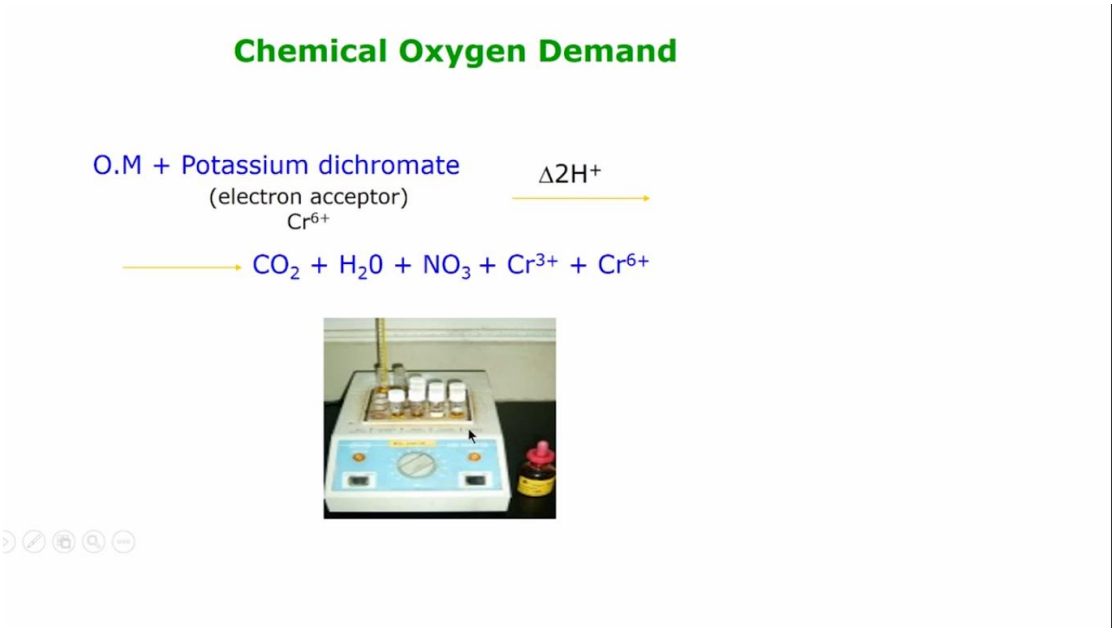
Now coming to BOD and COD. These are the measure of measures of organic matter present in the water. BOD is the amount of oxygen required during microbial utilization of biodegradable organics at a particular temperature for a particular incubation period. And COD is the oxygen required by an oxidizing agent for oxidation of biodegradable and non-biodegradable organics. These measurements are usually done for wastewater. Drinking water usually we will not do it because the drinking water we assume that mostly free from organic contamination.



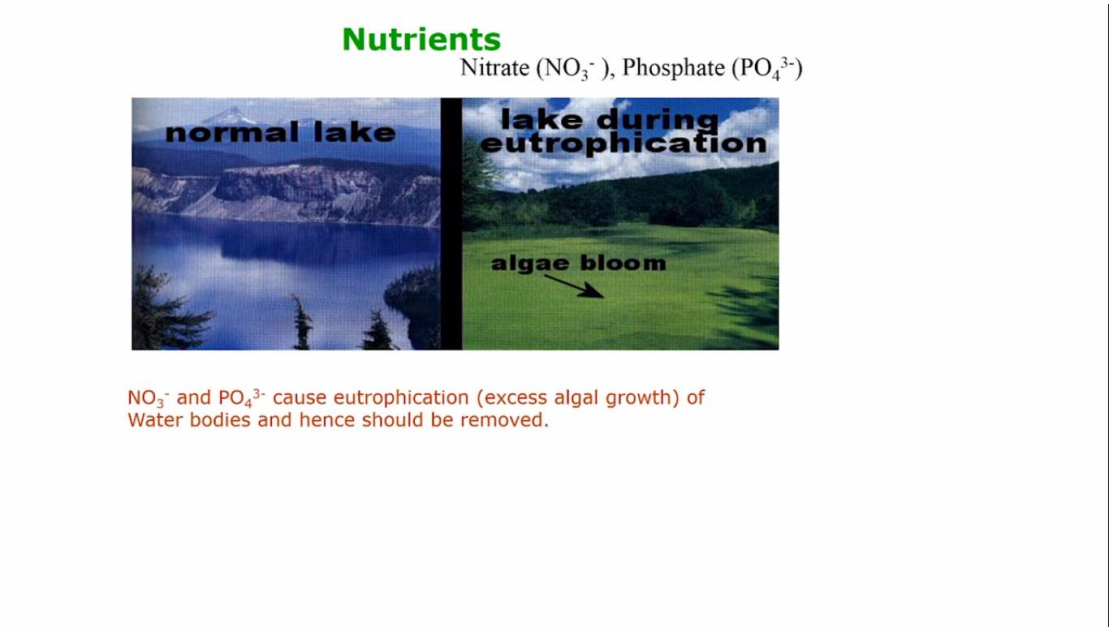
BOD is generally expressed in terms of BOD5 or BOD3. BOD5 measures at 20-degree centigrade for an incubation period of five days. So, what happens in the reaction is organic matter plus dissolved oxygen plus microorganism convert the organic matter into carbon dioxide, water, and more cells plus energy. And this is an indicator of the pollution status of streams.



So, there are BOD tests. I am not going to into the details, whoever is going into the specialized session, they can look into this one. So, BOD test usually, take the wastewater, dilute it sufficient times and keep it in an incubator at the desired temperature, mostly 20-degree centigrade, and we assume that the BOD exerted here follows the first-order reaction, so, you can calculate what is the organic matter present in the system.



And COD, chemical Oxygen demand because the biological process will take a long time. So, we can oxidize the organic matter chemically by using very strong oxidizing agent under conducive environmental conditions. So, this is the reaction what is happening in COD, organic matter and we are using potassium dichromate as the electron acceptor and at high temperature and highly acidic condition what happens this organic matter gets converted to carbon dioxide, water, and chromium present in the dichromate, the chromium six; Cr^{6+}, present in the dichromate will be getting converted to chromium 3; Cr^{3+}. So, by looking into the amount of Cr^{6+} got converted to Cr^{3+}, we will be able to find out what is the organic matter got oxidized in the process. So that is the way we measure the chemical oxygen demand.



And when we talk about water, the nutrients also will be present in the water. I already mentioned that the nutrients sources are either partially treated or untreated wastewater other otherwise it is the runoff from agricultural fields. Because agricultural fields we use a lot of fertilizers, so that contains nitrate, phosphate, etc. So that also will be contributing the nutrients to the system.

So, then you may be thinking that what is the problem if nutrients are present. If nitrate and phosphate can cause eutrophication of water bodies and hence should be removed.

Nitrogen

- Fresh wastewater contains organic boud nitrogen and ammonia nitrogen

Organic –N + NH_3-N ⟶ Kjedhal N

Can be determined by digestion and distillation

Nitrification

Oxidation of NH3-N to NO3 – N is called Nitrification (Occurs as a function of time)

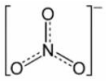
$$NH_3 \xrightarrow[+O_2]{\text{Nitrosomonas}} NO_2 \xrightarrow[+O_2]{\text{Nitrobater}} NO_3$$

Phosphate: Organic phosphate and polyphosphate

No oxygen demand by phosphates

Moreover, So, this is what is happening. If more ammonia is present in the system, it will be taking away the oxygen from the water body, you can see that ammonium ion in the presence of some microorganism and some oxygen get converted to nitrite then to nitrate. And phosphate exists in the form of organic phosphate and polyphosphate, but phosphate will not be exerting any oxygen demand.

Nitrate



If the water is high in nitrate level it leads the kids 'blue baby syndrome' disease.

The use of contaminated water for agricultural land, will contaminate not only water, also ground water.

Mostly for vegetation we are using toxic pesticides, because of this only the nitraate level in groundwater is increasing constantly

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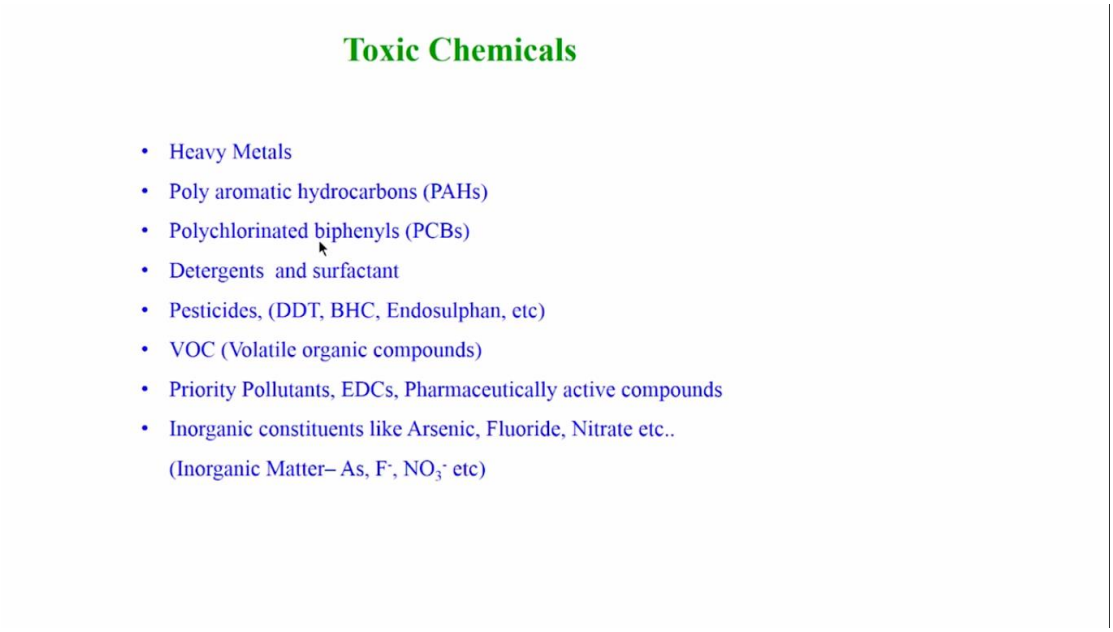
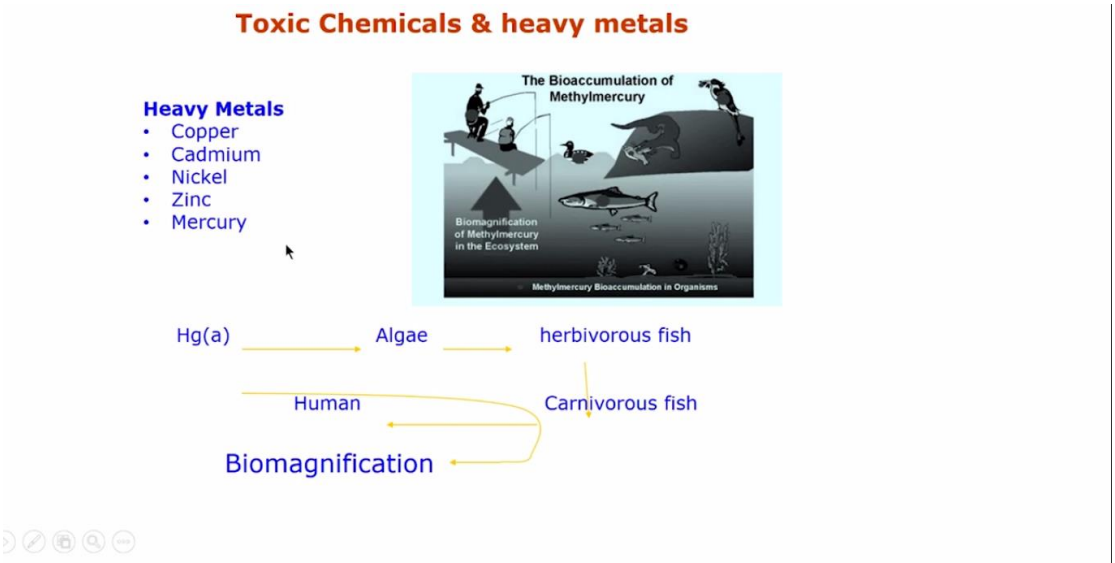
And they are nutrients. They are useful for a human being but what is the problem. Why are we bothered about the nutrients in the water? Phosphate as such it may not

be very problematic, but if you have excess nitrate present in the water, it can cause blue baby syndrome. This is in the kids. What happens? The oxygen-carrying capacity of the blood will be reduced, and what happens, the infants will be dying of insufficient oxygen. So that is why we have a standard for nitrate in drinking water, and around 45 milligrams per liter of nitrate is permissible in drinking water.

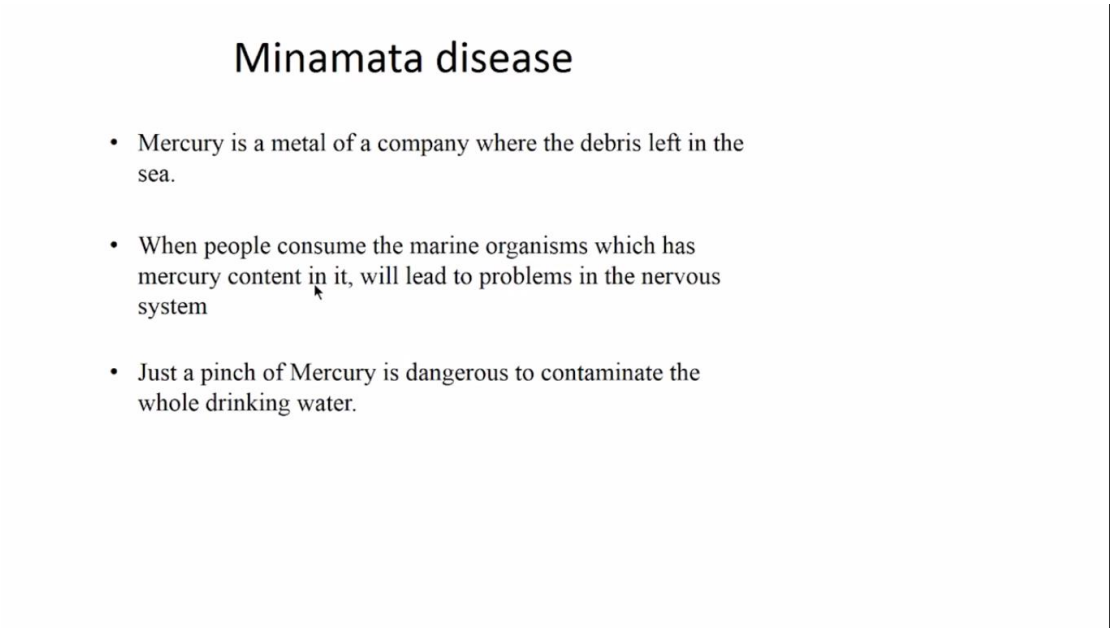


Then when we talk about toxic chemicals, there are a large number of toxic chemicals which can be found in the drinking water. So, those include heavy metals, polyaromatic hydrocarbons, polychlorinated biphenyls, detergents and surfactants, pesticides, we can name a large number, volatile organic compounds, priority pollutants, endocrine disturbing compounds, pharmaceutically active compounds, inorganic constituents like arsenic, fluoride, nitrate, etc. All these things can be present in the water. So, if you are identifying a source for water supply, you have to check the water for all these parameters, all these parameters. Otherwise, you develop the system, and finally, you are seeing that the water is not suitable for drinking purpose.

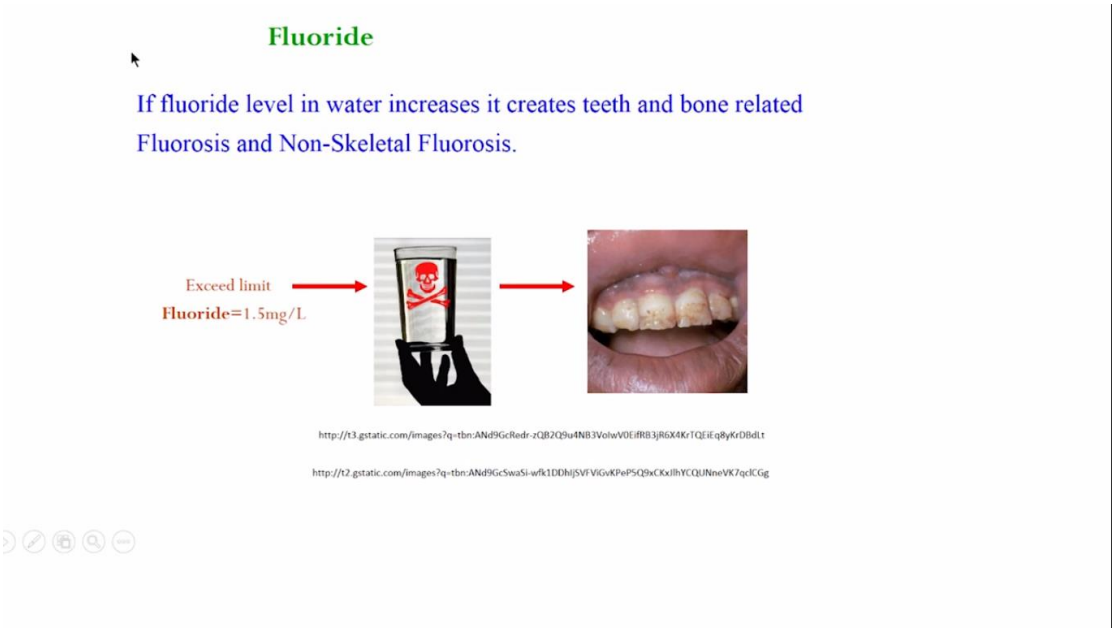


And what is the problem if toxic chemicals and heavy metals are present in the water? Because we know that many of these toxic chemicals are non-biodegradable or they are highly xenobiotic in nature. And similarly, heavy metals also.

So, what will happen if they are present in the water, for example you take a river, if the river water is contaminated with these compounds PAHs, PCBs, endocrine disturbing compounds, pharmaceutically active compounds, heavy metals, etc. and you know that the river system has a lot of flora and fauna. So, the pollutants are getting absorbed onto the small plants, and these small plants are eaten by the small fishes. So, since these compounds are not getting degraded or these ions are not getting degraded, what will happen the concentration in the plant that will be getting into the small fish and it will be staying there. And small fishes are eaten by big fishes. So, what will happen? All these pollutants will be getting into the big fish, and in the food chain, it will be bio-accumulating, or bio-magnification will be happening in the food chain. And finally, what will happen, you can see that first algae, then herbivorous fish, then carnivorous fish then it is coming to human. By the time humans eat the fish, a large quantity of this pollutants are accumulated in their body, and it can become highly problematic.



For example, most of you must have heard about Minamata disease. So, this was caused by mercury, and you know that mercury is a metal, heavy metal which is highly toxic. So here in Minamata what happened, mercury is a metal of a company where the debris left in the sea, when people consumed the marine organism which has mercury content in it, what happened all this mercury got into the human beings, and their nervous system got affected. And you know that just a pinch of mercury is dangerous to contaminate the whole drinking water. So, in Minamata bay what was happening, so many fishermen were living in that area, so they were consuming a large quantity of fish. So, that bay was contaminated by the mercury because of the discharge of the waste from the company. So, that is got converted to methylmercury, and it got accumulated in the fish and the people consuming the fish, a large quantity of mercury got into their body, and people were affected.

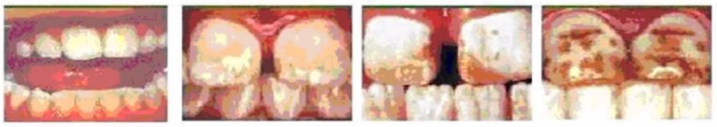


So that one, after that one, the awareness about heavy metal contamination become very very huge. So, another one is fluoride. Fluoride is also an ion present in the water; mostly it is coming from the natural origin. If fluoride level in water increases, it creates teeth and bone-related Fluorosis and non-skeleton Fluorosis. You can see here how the de-coloration or discoloration of the teeth is happening and you can see less than 1.5 milligrams per liter fluoride, there is no problem but if the fluoride concentration in the water is around 1.5 to 3, teeth Fluorosis can happen, 3.1 to 6 less skeletal Fluorosis and greater than 6, more skeletal Fluorosis. You can see that. These are the examples of fluoride affected people's teeth.

Effects when the level of fluoride increases in water

World Health Organization (WHO) guideline for fluorides in drinking water is up to 1.5 mg/L (WHO,1984).

Level of Fluoride (mg/L)	Symptoms
< 1.5	**No Problem**
1.5-3.0	Teeth Fluorosis
3.1-6.0	Less Skeletal Fluorosis
> 6.0	More Skeletal Fluorosis



Very Less Less High Severe

http://t2.gstatic.com/images?q=tbn:ANd9GcSwaSi-wfk1DDhIj5VFViGvKPeP5Q9xCKxJhYCQUNneVK7qcICGg

And World Health Organization guidelines for fluoride in drinking water is up to 1.5 milligrams per liter.

Water Quality Parameters - Chemical

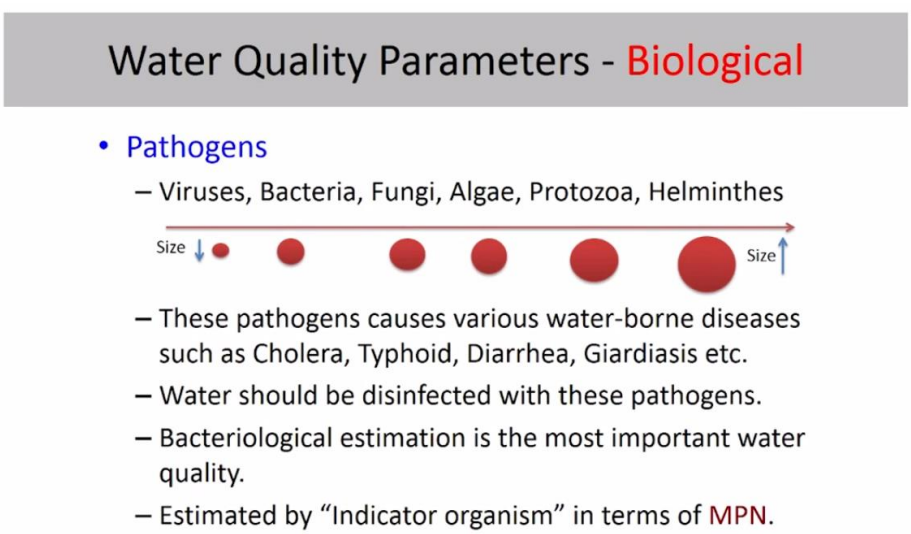
Disinfection by-products (DBPs)

- Reaction between oxidants (such as Cl and O_3) and naturally present complex organics such as humic and fulvic acids.
- Example : Tri Halo Methanes (THM), Haloacetic acids and many organo-chlorine compounds.
- These compounds are non-biodegradable, xenobiotic and carcinogenic in nature.

So, another thing when we talk about the water quality parameters we have to be bothered about disinfection by-products. When we do the, we add the disinfection, disinfectants to water, they can form organochlorine compounds or organo-halo compounds, and many of these compounds are carcinogenic. For example, Tri Halo

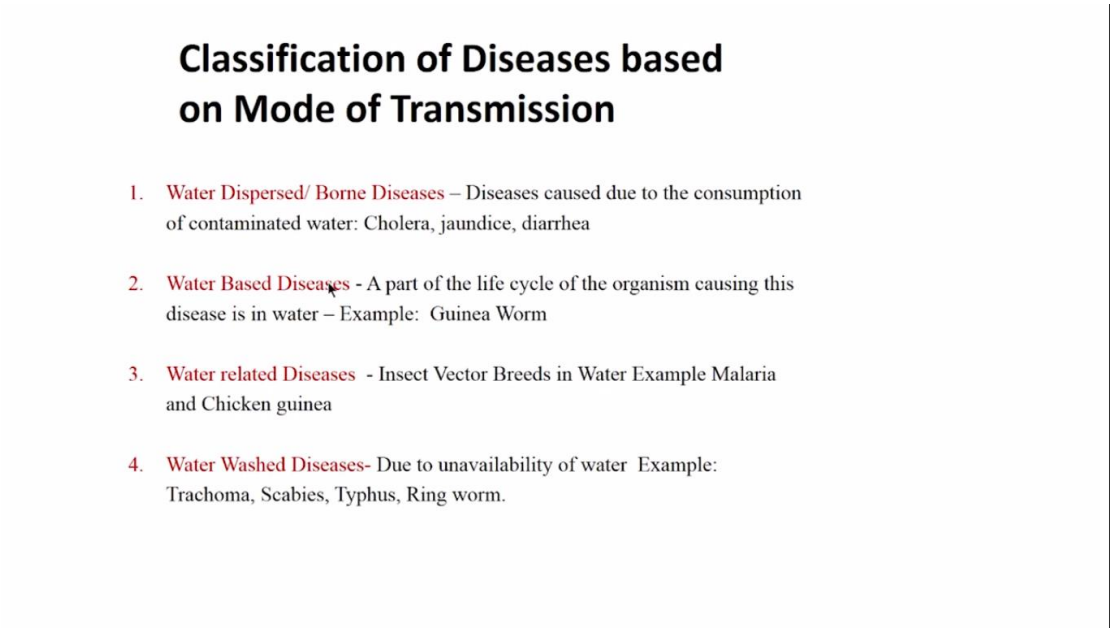
Methanes, Haloacetic acids, and many organochlorine compounds, these compounds are non-biodegradable, xenobiotic and carcinogenic in nature. So, we have to be bothering about that one.

So now, we will talk about bacteriological quality, and I told you they are most important, and because of the contamination, many diseases are there, for example, malaria, dengue, rat fever, chikungunya, vomiting, cholera, all these things are caused because of the pathogenic microorganisms present in the water.



So, pathogens can be viruses, bacteria, fungi, algae, protozoa, helminths and you can see the size variation.

These pathogens cause various water-borne diseases such as cholera, typhoid, diarrhea, giardiasis, etc. Water should be disinfected with these pathogens. The bacteriological examination is the most important water quality parameter. The water should be free from any pathogens and most of the time the water quality with respect to microorganisms are represented in terms of most probable number or MPN. So, here we are finding out an indicator, the presence of an indicator organism, how many numbers of this indicator organisms are present in the water, based upon that one we can tell whether the water is safe or not. For drinking water, the total coliforms, coliforms are used as the indicator organism, the total coliform number should be less than 1.8.

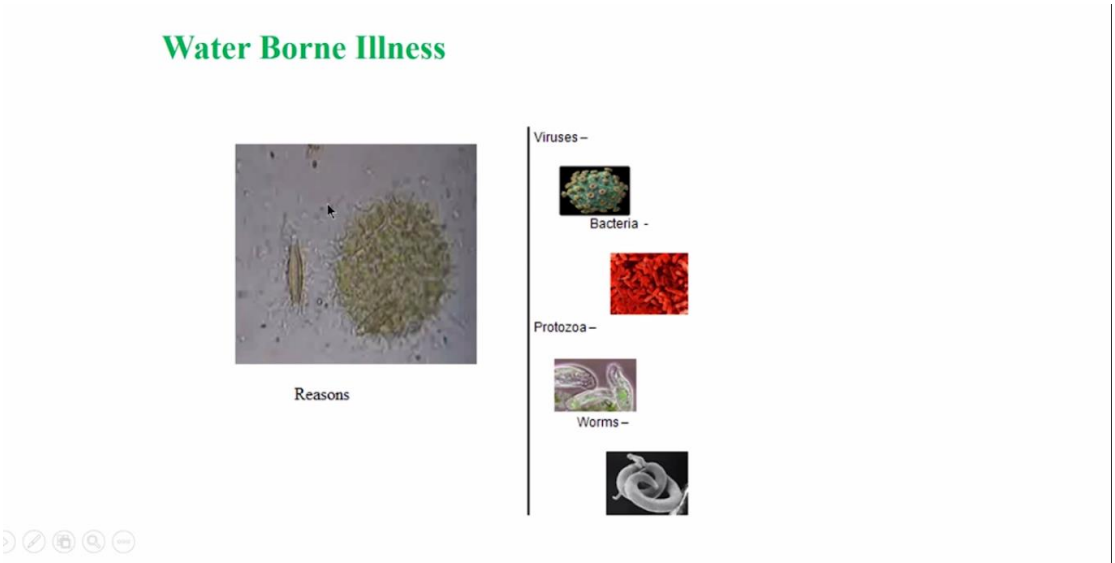


Then as I was mentioning earlier, if you give good quality and sufficient quantity of water the health of the people are assured, and it is, we can see that around 80% of the diseases are having some way or other related to water. So, we can classify the diseases based on their mode of transmission. Mainly they are classified into four categories; water-dispersed or water-borne diseases, water-based diseases, water-related diseases, and water-washed diseases.

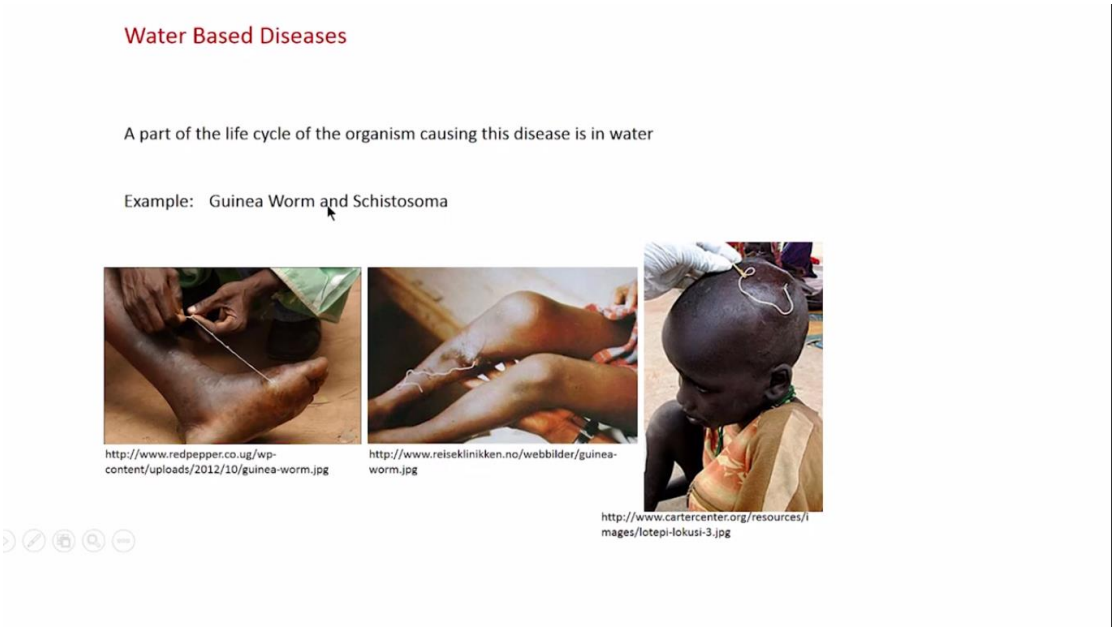
What are waterborne diseases? Diseases caused due to the consumption of contaminated water. If you consume contaminated water, these diseases are spread. Examples are cholera, jaundice, diarrhea, etc. So, if you want to control this disease, what should we do? We should give water free from these disease-causing microorganisms. So, that is first classification, waterborne disease.

Second is water-based disease, here a part of the lifecycle of the organism causing this disease is in water. Example, Guinea worms, any worm disease, the water – the organism spend a part of their life cycle in water. So, if you are coming in contact with contaminated water this type of disease can – the people can get this type of disease.

And the next one is a water-related disease. Insect vector breeds in water, they cause this type of disease. Examples are malaria, chikungunya, dengue, etc. So, the organisms or vector which spreads the disease stays in the water. And the last one is water washed disease due to the unavailability of water for hygienic conditions. Examples, typhus, ringworm, scabies, etc., come under these categories. So, these are water-borne.



I have shown the viruses and protozoa here.



And this is water-based diseases; you can see guinea worm. The worms are coming out.

And water-washed diseases, scabies, and eye diseases and all the things because the hygienic conditions are not met, that is why this type of diseases are happening. So, I will stop here. Next class, we will see water quality standards and a little bit on the treatment.

Thank you very much.