Wastewater Treatment and Recycling
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Lecture – 14
Waste water Characteristics: Quality Parameters (Cont.)

Hello friends. Welcome to the next lecture of the week. And we have been discussing various water quality parameters. We did talk about some of the parameters in previous lecture as well the BOD, COD, DO all that we have covered we will try to cover of the remaining major parameters in this lecture.

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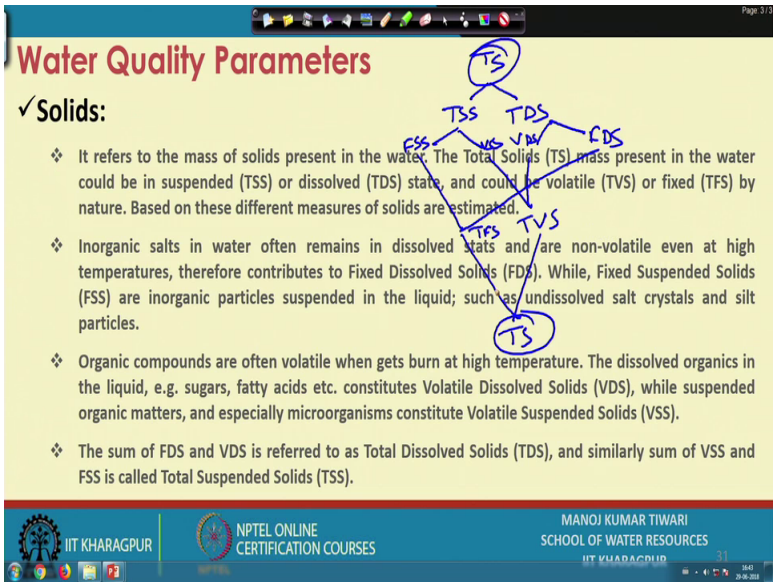

To begin with one of the other key parameter or a set of parameters other we can see a solids. So, solid typically refers to the mass of solids that are present in the water, ok. The total mass of the solid that is present in the water is typically known as total solids. Then the mass present in the water could be in different forms, ok, the solids which is present in the water could be either in the dissolved state or in the suspended states. So, depending on that we classify them whether they are dissolved solids or suspended solids.

Similarly, the nature of solids could be volatile or could be fixed. Now, this volatile and fixed because, something can be volatile at 100 degree something can be volatile at 500 degree, ok. So, there are there are set standard protocol to define what we should say

volatile in terms of the solids present in the water, ok. So, that is basically the one who gets volatile or who leaves the water phase or solid phase at 550 degree Celsius when heated at 550 degree Celsius for 20 minutes. The solids which evaporate are referred as volatile solids, and the solids which is still retains are referred as fixed solid. So, that way we have volatile solids and fixed solids, these are the different nature.

Now, if we see what constitutes these different solids present in the water. So, the inorganic salts typically remains in the dissolved state, and they are generally non volatile. If you have let us say iron calcium magnesium present in the water you heat it up to whatsoever temperature it hardly gets volatile, it hardly turns, it hardly gets vaporized. So, these are typically non volatile material or in terms of water quality parameters we call them as fixed solids, ok. So, therefore, now the inorganic salts they often remain in the dissolved state also. So, they are dissolved as well as fixed. So, we call them fixed dissolved solids, ok.

Then similarly we have fixed suspended solids which are primarily inorganic particles the because inorganic particle hardly evaporates who remain suspended in the water. So, for say you have sand silt particles all those things present in the water. So, they do not get dissolved in the water, they remain in the suspended form. So, undissolved salt crystal silt particles all that which remains suspended because they are not dissolved in the water so, they are suspended and they are fixed. So, they are called fixed suspended solids.

Now, organic compounds are primarily which are considered as volatile. So, if we heat up the solids, if we heat up organic matters at 550 degree Celsius most of them actually, most of the organic contents or organic compounds will evaporate. So, organic compounds predominantly are considered volatile, when get burns at high temperature. So, the organic compounds which are dissolved in liquid for say sugar fatty acids various carbohydrate other what is ever is dissolved in the liquid constitutes the volatile dissolved solids, because they are volatile in nature and dissolved.

So, they constitutes volatile dissolved solids while the suspended organic matter organic materials which are suspended and more over any sort of microbial impurities in the water present. So, for say there are bacteria presence, so bacteria cannot get dissolved in the water, bacteria remains in the suspension. And when you heat up at 550 the bacterial

cells will completely evaporate that way. So, this type of cellular mass, cell mass or bacteria or microorganisms they are the one which constitutes volatile suspended solids.

So, that way we have different type of solids fixed dissolved solids, fixed suspended solids, volatile dissolved solids, volatile suspended solids. Now, if we add the fixed dissolved solids and volatile dissolved solids we call that as the total dissolved solids. Similarly we had volatile suspended solids and fixed suspended solids we call them total suspended solids. Similar way we can add say fixed dissolved solids and volatile dissolved solids we can call that has total dissolved solids. We add fixed suspended solids and volatile suspended solids we can call that as total suspended solids, ok. So, that way the classification can be made.

Now, if we quickly see so the total solids which are there can be suspended can be basically total suspended solids and total dissolved solids split into two, right. Now, this total suspended solids can further be split into two we can have this it is suspended solids. So, we can have fixed suspended solids and volatile suspended solids. Similarly, total dissolved solids also can be split into two we can have volatile dissolved solids and fixed dissolved solids.

Now, this volatile dissolved solids and volatile suspended solids can give us the total volatile solids, and similarly fixed suspended solids and fixed dissolved solids can give us the total fixed solids. So, we can have various forms. And if we further add these two what we get is total solids. So, we started from total solids we can reach to the total solids by considering all these bifurcations, ok.

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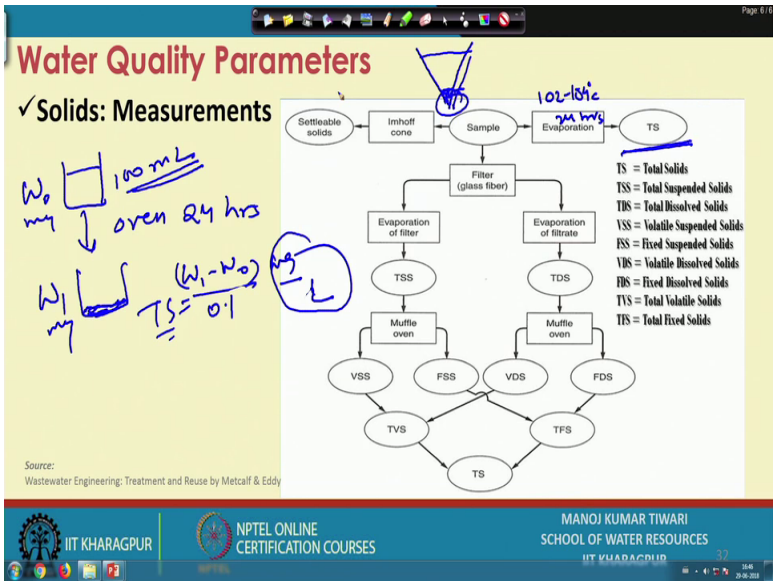

Now, let us see how the solids are measured in the water. So, there are couple of crude methods also, but the one which is most predominantly adopted is gravimetric analysis, ok. So, what we say, we have a water sample this is our water sample let us say, ok. So, if we take water sample and evaporate it in the oven at 102 or 103 degree whatsoever is prescribed. It is basically 102 to 104 degree. So, if you do it at say 102 to 104 degree for 24 hours all the water will get evaporate and what we get is we call that as a total solids, ok.

So, we can take in a let us say beaker we can take 100 ml of water for say, and put that into the oven for 42 hours at the temperature, and after 24 hours we will see that water has evaporated only some residue solid residues are left here. Now, let us say the weight of this empty beaker was W 0, ok. Now, the weight of beaker after putting pouring water in it and sort of drawing it is W 1. So, the difference W 1 minus W 0 is actually the weight of solids which were there in 100 ml.

So, if we divide this by 100 m l, we get this solids if let us say these are in milligram, ok. So, we get in milligram per ml or instead let us say if we divide it by 0.1 so we get in milligram per litre, which is typical unit gram per litre or milligram per litre are the typical units for solids, ok. So, that way we can get the total solids.

There is something called settleable solids which is a an approximation of suspended solids, because suspended solids can typically get settle, it is not the total suspended

solids, but a major part of suspended solids. So, that can be measured through imhoff cone also it is a basically cone like this and we put water in the cone allow it for sometimes the solids will get settle and we can measure there is there is marking over there. So, we can read how much volume is occupied by the solids. So, that way we can see how many settleable solids are there. For the purpose of determining other type of solids, ok.

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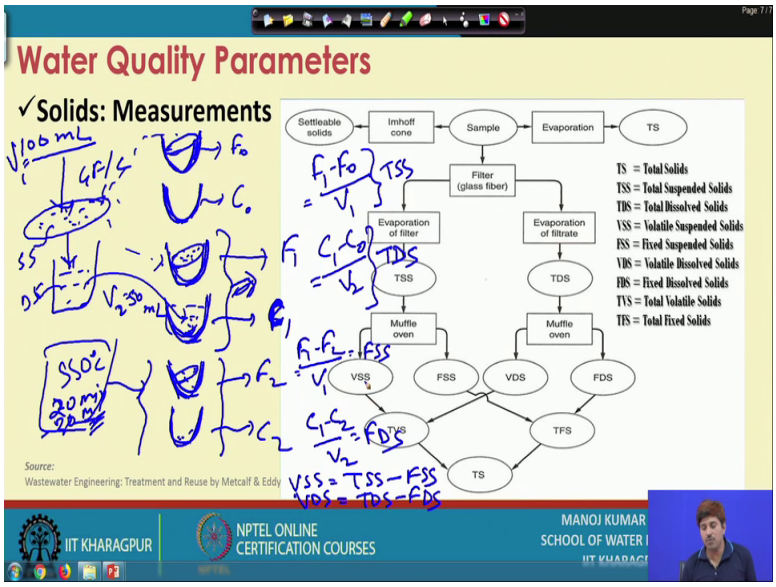

So, what happens that, let us say we take 100 ml sample of water, ok. Now, what we do? We filter this water, generally we filter it with a glass fibre filter paper GFC and the thing is that GFC does not lose weight when we put it in the oven or put it in the furnace, ok. So, we filter that water. Now, let us say this is the filter paper and through this filter paper we have filter the water. So, what happens? That suspended solids will get trap on the filter paper while the filtrate which will be collected will have dissolved solids. So, this will be containing dissolved solids part and this will be containing suspended solids part, ok.

Now, what we can do we can do this exercise like after filtration before that we can basically take a set of crucibles let us say we have these two crucibles, ok. Crucibles are generally made of (Refer Time: 11:00) materials which does not because glass we cannot keep at 550 degree Celsius, ok. For the purpose we need to put in a muffle furnace where

glass cannot sustain that higher temperature. So, we take silica crucible or porcelain crucibles which can sustain that higher temperatures, ok.

So, what happens, that we will take this crucibles and we will put maybe filter paper also in one of the crucibles blank filter paper and record the weight of this. So, let us say the weight of this is F 0 which is with the filter paper and the one which is not with the filter paper is C 0, ok. So, after that we will take this filter paper out do this filtering exercise and place this filter paperback. So, this filter paper is taken here after filtration it is placed back in the same crucible. So, now, this filter paper contain solid in it also, ok.

So, after that and in the next crucible that was there this next crucible will put filtrate. So, this filtrate we can put of the same amount or maybe a changed amount also, ok. Let us say you started with 100 ml and when you filtered you may not get the entire 100 ml because there might be some losses and all that. So, let us say you transfer 50 ml here. Now, what we do both of these crucibles are kept and set for the kept in the oven at 104 degree Celsius for 24 hours, then the water on this filter paper as well as water in this crucible will get evaporate and after that will take it out cool it down and then weigh them again, ok.

So, once we have cooled it down weigh them again let us say the new weight of this is say F 1, and the new weight of this is say C 1. Then what we do? After this after weighing this we again take this both this crucible and kept in a muffle furnace at 550 degree Celsius for 20 minutes, 20 to 30 minutes is recommended, ok. So, we keep it for that higher temperature, and then what we see that after again this furnace procedure we get these filter papers and crucibles and we again weigh them, ok.

So, the weight of this is let us say F 2 and weight of this is let us say C 2, ok. Now, what happens that the difference of F 1 and F 0, so F 1 minus F 0 is actually because of the solids which were suspended in here, the total solids which were suspended in here. So, if and this solids were there in how much volume, 100 ml which was actually filter. So, let us say this is V 1 100 ml. So, if you divided it by with the V 1 we get the amount of total suspended solids.

Similarly, if we take the crucible thing, difference of C 1 minus C 0 because this has the filtered water so the suspended part of the water has come on to the filter paper and this water which we pore in here has only dissolved solids. So, when water evaporates what

is left in the crucible is only dissolved solids part. So, the difference in the weight in C 1 and C 0 is the added dissolved solids in the C 1. So, C 1 minus C 0 by now because we have taken another volume let us say, if it is the same V 1 V 2 is same that is also fine otherwise we can take V 2 and this gives us the our total dissolved solids TDS, ok. So, that way we can determine the TDS and TSS, right.

After that you see the difference between F 1 and F 2 is what the F 1 has the total suspended solids while F 2 the solids which were of volatile nature has evaporated when we heat it when we heat that at this temperature. So, the leftover solids are the one which are fixed. So, the difference of F 1 minus F 2 F 1 is supposed to be higher because it is containing total solids while F 2 is containing only fixed solids. So, difference of F 1 minus 2 by V 1 which has come out of the V 1 volume is our these are the fixed solids and suspended part. So, these are fixed suspended solids. Similarly C 1 minus C 2 by V 2 is actually our fixed dissolved solids, ok.

Now, if you want to determine the let us say volatile suspended solids. So, we have total suspended solids minus fixed suspended solids will give us volatile suspended solids or if you want to measure volatile dissolved solids so similarly total dissolved solids minus fixed dissolved solids will give us volatile dissolved solids. So, that way we can basically estimate the different type of solids in this, ok. You can refer to this. So, we get we filter with the glass fibre filter paper, ok. The evaporate, through evaporation of filter what we get is TSS as we were discussing and through evaporation of filtrate what we get is TDS.

Then we put in the furnace out of furnace treatment we will be able to because whatsoever remain after furnace is our fixed suspended solids and similarly here fixed dissolved solids, and what has been evaporated out of furnace is our volatile dissolved solids and volatile suspended solids. So, once we get all this 4 species we can combine them accordingly and get TDS and TFS or TSS if it is needed, ok so, how the analysis of solids are made in the water.

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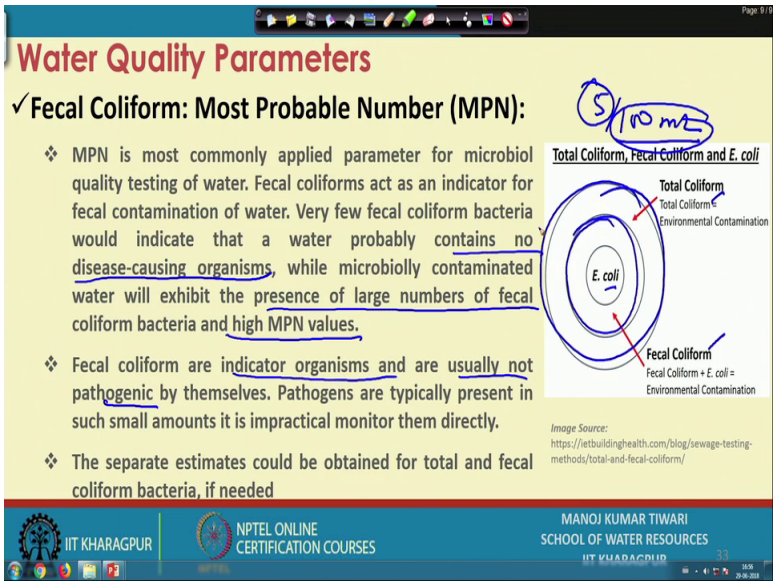

Another important parameter is the Fecal Coliform or which is typically represented through most probable number. So, most probable number is the commonly applied parameter it is typically referred as because it is a number, ok. So, it is referred as say whatsoever number, if 5 it is 5 if so we can refer it as let us say 5 per 100 ml. So, that would be the this kind of units are used. So, a number per unit volume is the unit for most probable number. How many possible colonies or possible indicator organisms are there in a unit volume of water is what it is measured, ok.

So, MPN is the most commonly applied parameter, ok. It basically measures Fecal Coliform, Fecal Coliform acts as an indicator for fecal contamination of water, ok. If the MPN is very low or Fecal Coliform count is very low though then water probably contains no disease causing organisms and is considered safe, while microbiolly contaminated water will exhibit the presence of large number of Fecal Coliform indicated through high MPN values, ok.

So, it is actually Fecal Coliform here is an indicator organism and may not necessarily be pathogenic by themselves. Most of the Fecal Coliform means Fecal Coliforms usually are not pathogenic by themselves, but they are used as an indicator organism. We are not able to measure pathogens precisely because they are typically present in a very small amount and it is impractical to monitor them directly and that is why we use this indicator organism.

Further, we can separately estimate the total Coliform or Fecal Coliform if needed, total Coliform is basically a larger set. So, a smaller set is E coli and then much larger set is Fecal Coliform or we can basically measure the total Coliform. It depends on how the what type of growth medium we presenting, it will depend on that.

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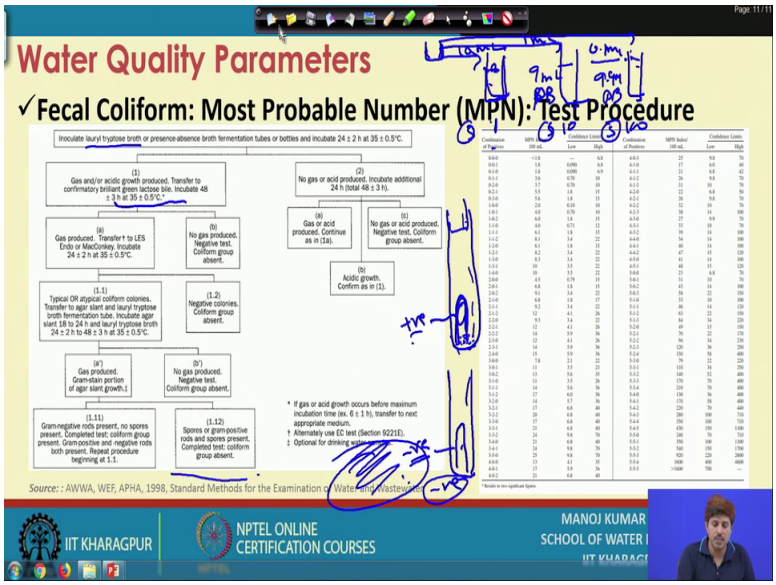

Measurement procedure is as the is basically available in the standard methods, of American water works association or American public health association. So, typically the we inoculate with lauryl tryptose broth, for the present of both fermentation tubes and bottle and incubate them at 24 degree. So, normally 5 sets are inoculated we prepare 5 different dilutions. So, we have sample let us say one sample for which we want to monitor, right.

So, we will prepare 3 different dilutions in 5 numbers, ok. So, how it is done? Let us say we take 10 ml of that and pour in here, pour in a pour in a test tube, then another we take 1 ml of that and pour in a test tube, and then third we take 0.1 ml and pour in a test tube, ok. Now, this 10 ml is kept at 10 ml only this 0.1 ml we add 9 ml of generally phosphate buffer is added, are we can add another nutrient solution in those kind of things as well though. And, in this in the next one we where we have added 0.1 ml we add 9.9 ml of the phosphate buffer for say.

So, you see this is undiluted or dilution factor is 1, this is 10 times diluted. So, dilution factor becomes 10 and this is 100 times dilution so dilution factor becomes 100. So, we

have 3 different dilutions and similarly we prepare 5 sets each for each of them. And then what is done, in each test tube let us say this is our test tube, so in each test tube we put a inverted smaller tube which is typically which is called durham tubes. So, we put this durham tubes in each test tubes. So, these tubes are filled with this either example or diluted sample in 10 ml range and then we put this inverted durham tubes, ok.

Now, what happens? That we prepare 5 such tubes for each of these dilutions, ok, and then we tend to monitor them we like after this we inoculate it for 24 hours and then after 24 hours we the inoculation is typically done at 35 degree Celsius 35 plus minus 5 degree Celsius for 24 hour and after that we monitor after 24 hours. So, what happens when there is microorganisms or pathogens present in this thing? They will respirate and produce gas bubble. Now, because there is a inverted tube present. So, this gas bubble will trap in this inverted tube, ok. The one which is case from here can escape, but whatsoever is there when it produces this gas will lift up and it is under inverted tubes. So, there will be a gas bubble travel in inverted tubes. So, this kind of test are considered positive and similarly the tubes which have no gas bubble are considered negative.

So, we will count the number of positive and negatives for all these 3 sets. The one which are not which are positive is fine, the one which are not positive we keep we inoculate them for we sort of put them in the put the we. So, we keep them for another 24 hours, in incubator. So, we incubate them for another 24 hours in order to get confirm. So, after even after 24 hours if let us say they are still negative, then we can that is almost indicator that there are no pathogenic organisms, but in order to be doubly sure we can plate them.

So, on a plate we take through streaking or through this thing we basically plate them and see if there is any growth on this or not if there is a growth it is suspected positive if there is no growth it is negative, certain negative. So, that way over all we identify the number of positive and negatives, for each subsequent dilutions. And then the standard methods suggest standard methods typically suggest a table based on which we can read the MPN. So, this is the there are different tables under different conditions, this is the 5 dilution table this may not be readable but you know the difference and you can basically get these details these images from this reference, ok.

So, this table typically suggest like the first point is 0 0 0. So, when none of them have shown any growth that indicates that m that MPN is less than one point 8 are almost negligible, ok. If there is one positive tube just of the third dilution this that there are 3 series. So, it is like number let us say n 1, n 2, n 3. So, this kind of numbers are there in this table. So, this indicates of no dilution, this indicates of 10 x dilution, and this indicates of 100 x dilution.

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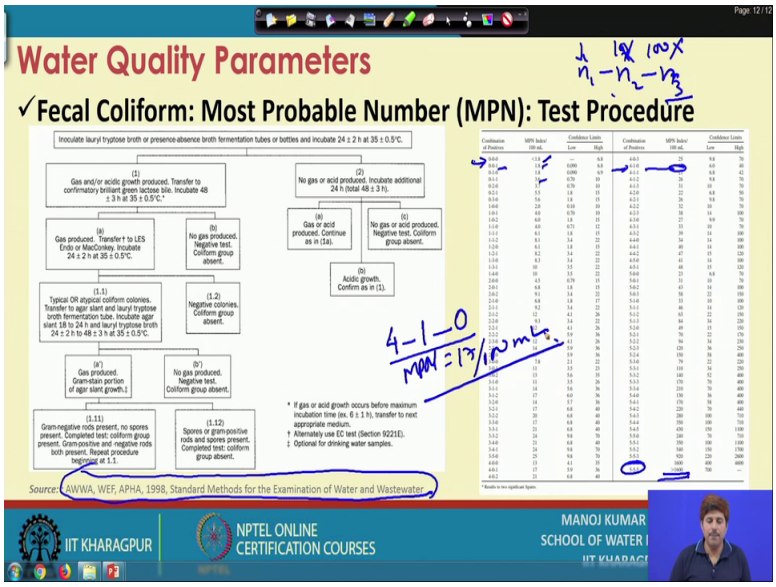

So, if you see just one positive in 100 x dilution your n p n is 1.8. If you see just one positive or one and one positive in 100 x and 10 x dilution your MPN is 3.6. So, that way we can basically keep on tracking this. If your all tubes are positive the last point where it says 555 means all the tubes are positive that indicates your MPN is greater than 1600, ok. So, that is how we get an MPN value. This is MPN index per 100 ml.

So, for randomly say like we did the test we found that in the first set our 4 tubes resulted positive, in the second set our just one tube resulted positive and in third set none of the tubes resulted positive. So, 410 if you want to see, so 410 is let us say somewhere here this indicate 17. So, your MPN counts become 17 per 100 ml. So, that is how the MPN are monitored. And this is one of the most widely used parameter for the measurement or for the knowing the bacteriological pollution.

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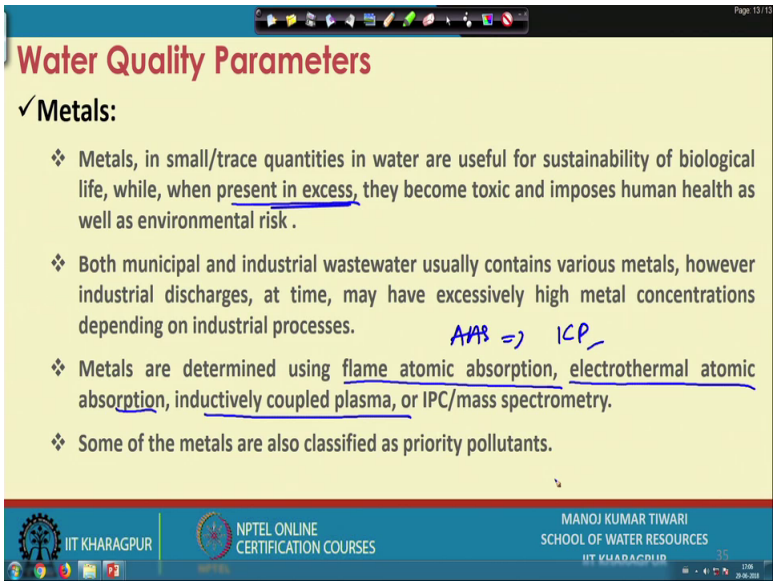

There are few other specific contaminants or parameters typically metals which are in small and trace quantities present in the water and is actually useful for sustainability of biological life. Means we should not drink the water which is completely demineralised, if there are no mineral or no metal present, ok. So, that is why we do not drink distilled water, because distilled water is not supposed to have any sort of minerals or metals in it.

So, in order to basically survival or sustainability or safety of ours or environment we need a little minerals, little metals in the water and they are not a problematic at all. But when these same metals present in excess they become toxic and imposes human health risk as well as environmental risk, ok. The both municipal and industrial wastewater contains lot of metals, ok. Generally the concentration in municipal wastewater is lesser as supposed to the industrial wastewater, industrial wastewater depending on the type of industry will actually can lead to excessively high concentrations of metals in their waste, ok. Particularly some of the toxic waste like chromium, cadmium, mercury all this things often comes from the various industries in their effluent.

Now, these metals are typically measured through flame atomic absorption particularly for alkaline metals electro thermal atomic absorption, ok. Atomic absorption spectrophotometry which is typically the equipment is referred as AAS is the one which is one of the most popular equipment used. And nowadays there is inductively coupled plasma or ICP which has come which can actually a step ahead and can monitor or

measure the metals to trillion levels very precisely. So, that way we can monitor these different metals. Some of these metals are also classified as priority pollutants, ok.

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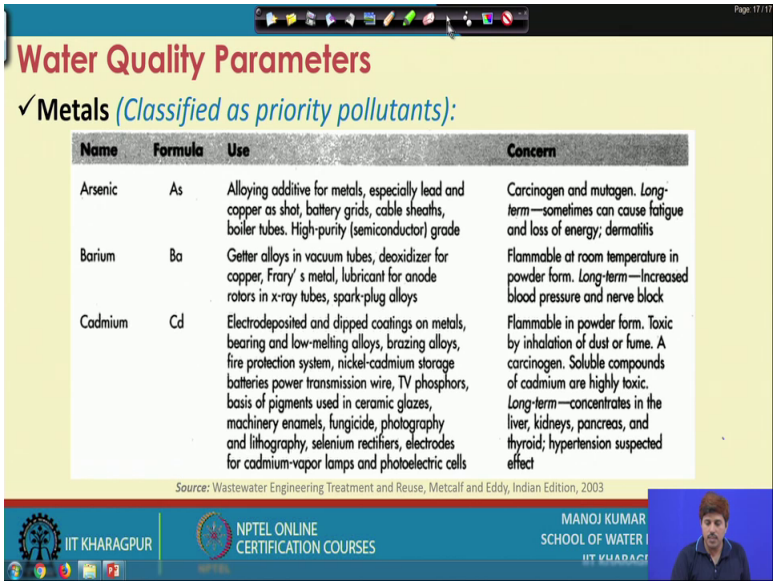

There is a list of priority pollutants in terms of metals. So, these are the arsenic arsenic, barium, cadmium there is different uses from where they come and their concerns are listed. So, we will not be going into the detail of all these points though.

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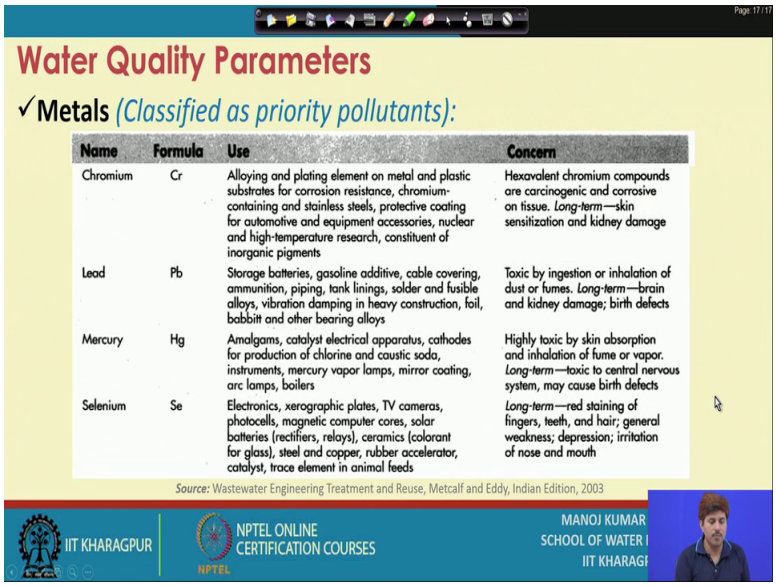

So, these are there are similarly chromium, lead, mercury, selenium, silver. So, these are the these are the priority pollutants or the metals which are classified as priority pollutants.

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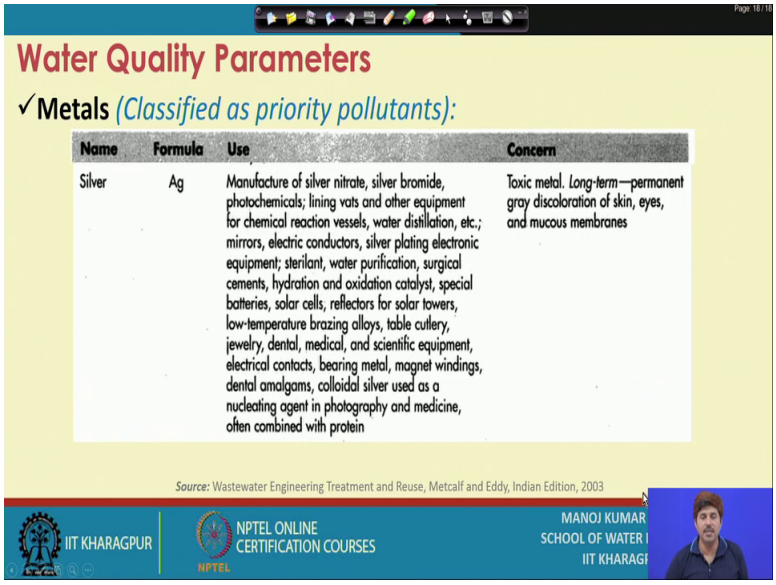

The measurement of all this is done typically through AS or ICP methods there are some chemical titrimetric methods are also available, but AS and ICP equipments are more popular and more common for determination of these metals and can actually monitor to very low levels.

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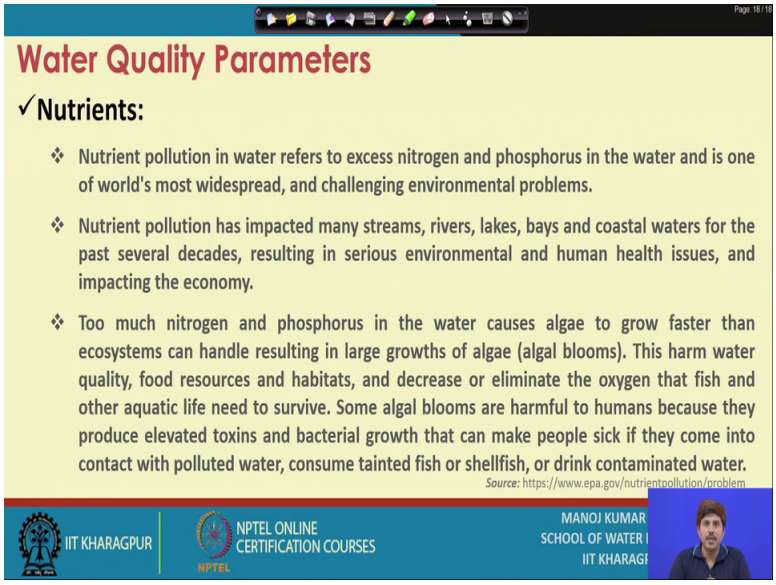

The next set of pollutants is nutrients nutrient pollution in water is typically refers the axis of nitrogen and phosphorus. So, nitrogen and phosphorus are they generally referred as nutrients when they are present in the water. They are nutrients for plant, herbs and all that so that is why they are referred as nutrients.

However, this excess nutrient leads to various severe environmental problem and is one of the most challenging problems which are spread worldwide which leads to deterioration of so many water resources, ok. This has infected rivers, lakes, streams, coastal waters, even a tanks, for several decades and this eventually results in serious environmental issues as well as human health issues and impact the economy also, ok.

The too much of nitrogen and phosphorus will cause algae to grow much faster in a ecosystem and typically there is the capacity of ecosystem to handle this kind of biomass. But if it is going much faster so the large growth of algae takes place and it covers the entire water entire surface of the water body. Many places of I am sure all of you might have seen here and there that many small ponds or lakes are turned green, ok, the entire top is green and covered mostly by algae. So, this kind of phenomena is called eutrophication or we call them algal bloom. So, this harm the water quality, food resources, habitat, and sort of the major problem is it decreases oxygen present in the water and which completely deteriorate the aquatic ecosystem, ok.

Your fishes cannot survive, your aquatic plants cannot survive, the water below may turn completely anoxic, so this kind of things and can in breed various toxic or those kind of impurities or even microbial impurities. So, this can cause variety of issues, the toxic levels toxicants levels can get elevated in this in such systems and the people may feel sick if they come into the contact of this polluted water or consume this tainted fish or shellfish which are grown on such waters, or drink this kind of waters. So, that is the issues primarily issues with the primary issues with the nutrients.

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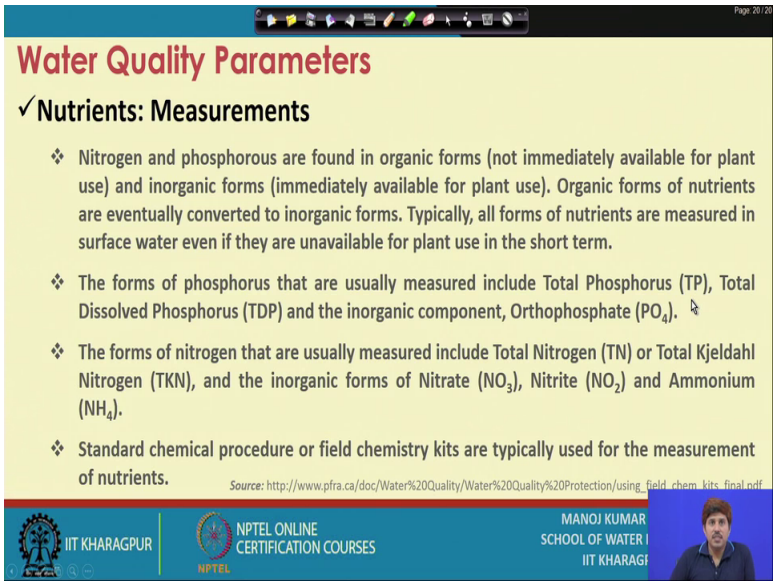

Then measurement we are means we are talking about measurement of nitrogen and phosphorus these are the primary nutrients, ok. So, these are found in the organic form as well as in organic form. Organic form is not immediately available for plants generally well as in organic forms are immediately available to the plant. So, however, this the form convergence also takes place organic can get converted to in organic forms, ok. Typically all forms of nutrients are measured in surface water even if they are unavailable for plant used in the short span of time because of the possibility of interconversions.

So, the forms of phosphorus that are usually measured include your total phosphorus, total dissolved phosphorus and inorganic component which is orthophosphate. So, orthophosphate is the one which is most crucial and readily available for the biota to uptake. Similarly, nitrogen is measured as Total Nitrogen, then Total Kjeldahl Nitrogen which is popularly known as TKN, which is a mixture of ammonium nitrogen plus organic nitrogen present in the system. And the inorganic form such as nitrate, nitrite and ammonium, ok. So, these are the different forms.

There are laboratory standard procedure titrimetric procedures we are not going into the detail of that as well as field chemistry kids are also available for the measurement of nutrients. There are some advanced equipments also are there in the market which can directly measure the different species of nitrogen and phosphorus these nutrients.

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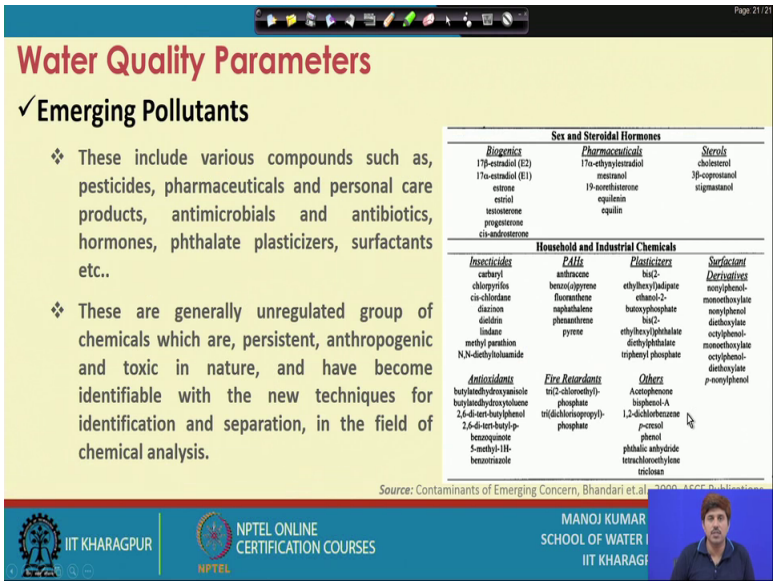

The pollutants that we have discussed so far are the parameters that we have discussed so far are the more common parameters. Apart from that if you recall we discussed in the beginning itself of this week, that this list is numerous and there are many more pollutants keep on adding to that and a set of such pollutant is referred as emerging contaminants or emerging pollutants which are various compounds such as pesticides, pharmaceuticals personal care products, various surfactant. So, the one which are not earlier present in the water many of actually this compounds were not synthesized earlier. Many new pesticides coming in the market the industries are synthesizing newer and newer pesticides compounds personal care products, cosmetics. So, when they are synthesizing when they are getting synthesise now they have started people have started using them and they have started coming in the waters.

So, these because they are not detected earlier they are not concerned earlier we call them as a emerging contaminants. These are generally unregulated group of chemicals. Most of the places in the world there are no regulations for these set of compounds some now because of the environmental concerns, many countries are coming forward and started having regulations for such or at least known set of these compounds, ok. These compounds are typically persistent anthropogenic and toxic in nature most of them are organic in fact, ok. And they have sort of since they have started coming their new technological development new technological methods are also being devised in order to measure monitor and quantify that quantifying them.

So, these compounds are quantified based on their nature, ok. Many of these needs advance equipments including GCMS, LCMS for those kind of equipments for the precise detection separation and quantification of these compounds. A list of these compounds some compound summarised in a paper is given here. So, these are the steroidal hormones the different compounds over there, household and industrial chemicals including insecticides antioxidants fire retardant PAH, plasticizers surfactant and other compounds these are there.

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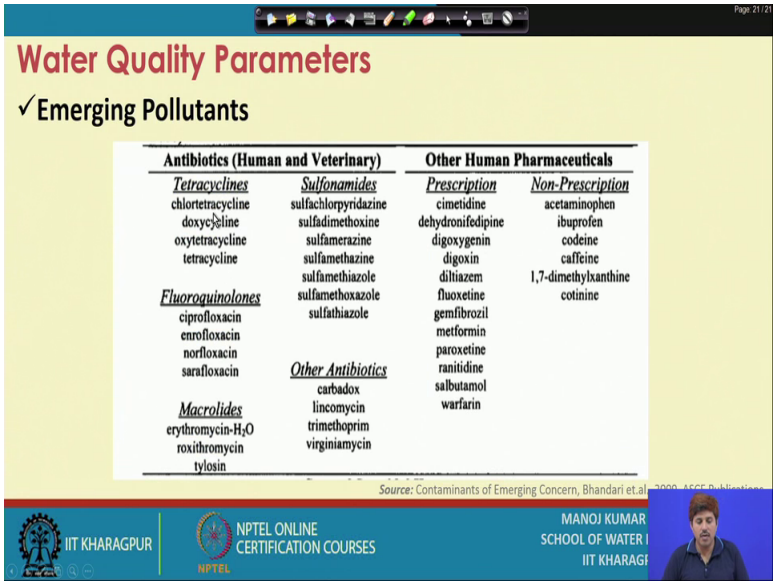

Then medicinal or pharmaceutical compounds including antibiotic humans and veterinary antibiotic or other pharmaceuticals which are coming in the water these days; So, this kind of, these set of such emerging contaminants or emerging pollutants have sort also started coming in water. Some countries has started having regulations also for these, even our BIS bureau of Indian standards now have for pharmaceutical compound some regulations over there for pesticides, it has some regulations.

However, not compound a specific and as you see the list there are various compounds in each group and these each compound may have a different method for detection, may have different effect also at time health effects and all that. So, things are under development lot of research is going on the measurement, quantification, standard development and control of these emerging contaminants in the water, ok. So, that are there.

Apart from that as we discuss that the common list of this water quality parameters are used to recognise how is the quality of a water. Once it is recognised we see whether it is highly polluted, less polluted or moderately polluted what kind of water it is and how far it is from being fit for certain reuse purpose, ok.

So, we and, this discussion here and in the next lecture we will comprehensively try to see how the different, means typical characteristic of some of the industrial wastes or the common domestic effluent or domestic waste water what we get. And we will try to; further will try to take up some practice problems on the quantification measurement or calculation of the water quality parameters that we discussed today.

Thank you.