Course on Integrated Waste Management for a Smart City
Professor Brajesh Kumar Dubey
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Module-03 Lecture-11
MSW Characteristics – Thermal Properties and Chemical Composition

Okay. Welcome back to this course and today we will start the third week of this course. So again we will have five modules of around 30 minutes each. So, you will have five lecture videos and then followed by the quiz as we have been doing in last two weeks. So we will start where we left in the previous week. If you remember we were talking about the waste characterization. So we will start from, the continuation from the previous week in terms of the municipal solid waste characteristics.

We looked into physical characteristics, we talked about some of the chemical characteristics. We looked at why a solid waste could be hazardous waste, just to start that would be regulatory characterization. And then today, we will kind of continue that discussion and we will look at if you do a thermal characterization.

If you remember from the previous video, we were talking about biological characterization which is needed if you are trying to design a compost plant or anaerobic digester plant, biomethanation plant, anything that you can talk. There are different names, there are different technologies out there. Essentially what they do is they take biodegradable waste and convert that in a stabilized form either make a compost or will produce gas, methane or should be other gases as well.

These days even hydrogen and other things, those different fuels are being produced. So that is for whether a waste is suitable for that purpose. We do, we find out by doing the biological characterization of waste. Again it is very, very critical before you decide the different components of your integrated waste management. As you know the course is on integrated waste management.

When we say integrated waste management, we are talking about the different components, of course, starting from the source generation, source separation, transportation, collection, maybe need for transfer station. And then when we talk about the different components in terms of the management and disposal whether you go for composting or anaerobic digestion or a waste-to-energy plant. When we say waste-to-energy, we are talking about whether we are trying to go for like incineration plant or pyrolysis, gasification whatever.

And so there are different technologies out there but to choose the technology, first of all, you need to understand the waste that you have. And as a part of this Smart Cities initiative that we are taking in the country, we have to be really careful in terms of the deciding what components will really work for us, whether the anaerobic digestion is going to work here, whether the thermal treatment in terms of incineration is going to work here.

And one of the critical point, kind of the starting point of those thing is doing this characterization. So we will, we did that discussion last, I started towards the middle of last week and we continued that. And we will, so looking at the thermal characterization which is essential, as you know the Government of India is also trying to, is promoting waste-to-energy. When waste-to-energy, even biogas energy is waste-to-energy. When we say waste-to-energy in the solid waste field, mostly we kind of talk about waste incineration thermal treatment plants.

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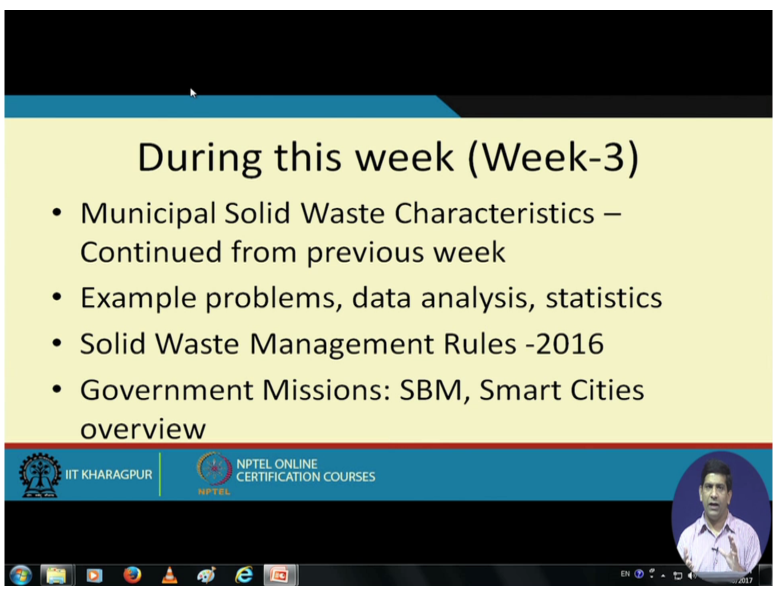

So those, we will kind of continue that, look at the thermal treatment characterization and then some other, we will do some example problems. We do some data analysis, we will talk about some of the statistics collecting data. Again data, data, data, always you talk about that. Because of the lack of good data, our design systems are failing. We have been trying to do lot of things in last I think maybe a decade or so in the waste management field but we have not been that successful as we would like to be. And the reason for that is many times we do not have good data. Our design is based on flaw data I would call it. And I tried to explain that in the previous videos and you will hear that more in coming weeks as well.

So we will talk about that in this week and then we will look at the Solid Waste Management Rules 2016 as the new, the oldest we had in solid waste management rule which came in 2000. Last year, we had a revision of that, so we will talk what is new in solid waste management rules. And then there are certain government initiative which is very unique initiative, very good initiative I would say in terms of the Swachh Bharat Mission, Smart Cities and they all relate to waste management.

So it is, without having a proper waste management, we cannot have a Swachh Bharat or we cannot have smart cities being made. So we will talk about how these missions kind of goes into the waste management plan, and how the waste management contribute towards success of Smart Cities program as well as the Swachh Bharat Mission. So that is in the nutshell, we will try to cover in next five videos and so let us get started from where we left in the previous week.

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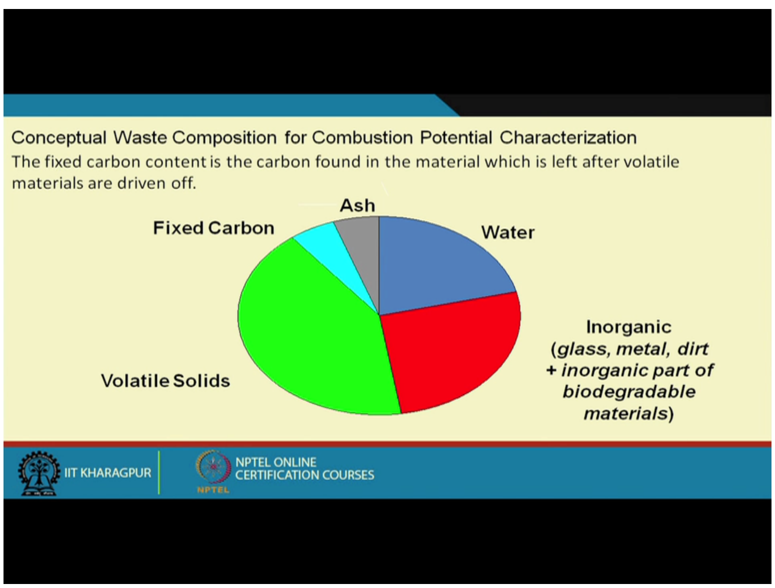

We were looking at the waste characterization. So here this particular pie chart, very similar to the pie chart that you saw earlier where we were talking about, we were looking at the characterization from the biodegradable like from biodegradable perspective. Similar pie chart we can come up with from the thermal perspective.

As you can see here, this is the conceptual waste (com) like composition for combustion potential characterization. When we say combustion potential characterization, here we have a like the green bar that you see over here is that, is like our volatile solids. So this is the green is the volatile solid part. Then we have the red which is the inorganic. Glass, metals, dirt, those are the inorganic fraction. We have some moisture content. There is some ash and then fixed carbon. This ash and the fixed carbon is essentially which is not going to contribute towards combustion process.

Combustion is an oxidation process. So when we talk about the waste incineration, we are essentially talking about burning of garbage in the presence of oxygen. When we say burning of garbage, as you know waste when it is, when we talk about the any combustion, combustion if you remember from your high school or even from before that, we had a concept of fire triangle.

Fire triangle means something which will burn. And something we need to have, one component of that is we need something which is combustible. Then there has to be a fire source and then there has to be a supply of oxygen. So that is why when we say combustion, it is an oxidation process. It happens only in the presence of oxygen and then we had to supply oxygen. So here again, we will combust the material but as we know not entire things gets burned.

If you had a waste material which is or any material for that matter, if 100 percent of it burns off, like if you think about the camphor or in Hindi we call it Kapur. That camphor, if you have, if you burn, when the camphor is burned during our religious activity, you do not see any ash being produced, so that is like 100 percent combustible. If then, if it is a 100 percent combustible, you will not have any residual there. But that is does not happen. When you burn the coal or you burn any wood, there is certain ash that is being produced. So those are non-combustible part. So here in this pie chart, the green part is the combustible part and we call it volatile solids or VS.

So that is the combustible part which will burn and then the red part is the inorganic fraction which is a glass, metal, dirt or inorganic part of biodegradable or the combustible material which is not going to react that much. And your blue part of the pie chart is the moisture content and that water. And as you know more the water, bad it is for combustion. Why? Because when you have more water, if remember from your high school like a science book, there is something called latent heat of vaporization. That latent heat of vaporization means it consumes energy for converting the water from water phase to the gaseous phase which is the vapor phase.

So when the water gets converted at 100 degree centigrade from the water, from the liquid to the vapor phase, it consumes lots of energy. So if it consumes lot of energy, that means you have to supply more energy in the combustion process or so that is more the moisture, bad it is for like a combustion process. And this, what is in terms of all these different components, which component really takes part in the reaction, it is the volatile solid, the green pie chart, green part of the pie.

That is the pie that we have, the green pie is that which is taking part in the reaction. So when you, when we try to find out how much air will be required, we need to know the composition of this green part so that we can use that equation and I will show you those examples. We will work through some examples in the class, in this particular as part of these different lecture modules and you will see those being worked into.

So this kind of composition is needed. So why? Again I showed you similar, we started with having a pie chart where we had the different waste components. Then, I showed you a pie chart which was for the biodegradable fraction. Today I am showing you a pie chart which is for the thermal treatment fraction. So why we need to produce this kind of pie charts? Again, why is very important as I have been telling again and again.

So why? Because this is, this we have to have understanding of this before we go and decide whether to have a thermal treatment plant or not, whether we have enough volatile solids present so that we can really make a good thermal treatment plant, whether we can generate some energy from that, whether we can have this energy generated and then make electricity or heat or whatever is needed from there. So that is where this concept of calorific value comes.

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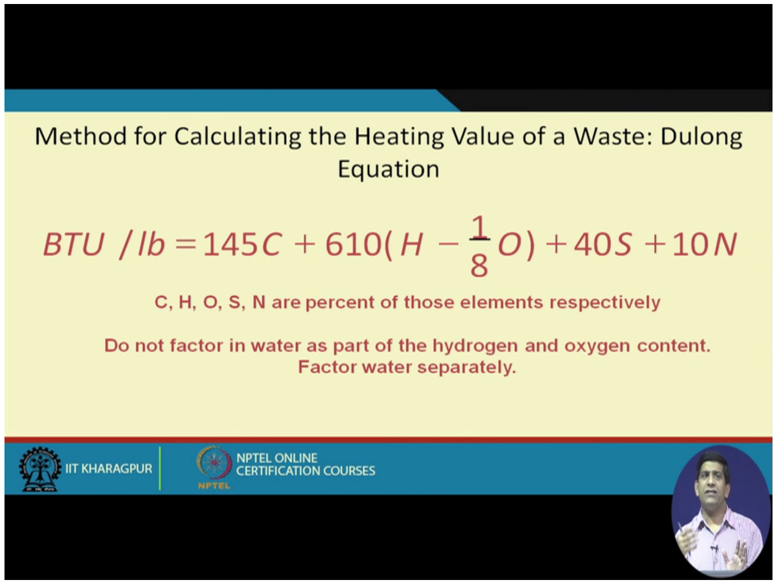

And that is, other name for the calorific value is the heating value. When we say calorific value, what does that mean is if you are burning, if you are doing this thermal treatment or incineration of a certain waste material or for that matter any combustible material, if you burn one unit say 1 kg, 1 pound, whatever you decide the unit, how much energy will be produced, how much heat will be generated. So that is why it is called heat value as well.

Calorific value or heat value both are, calorific because calorie is the unit of energy, is not it? So that is why calorific value is also used the term or many times we use the heat value because we are talking about the heating. That is the heat energy, that is the heat that is being produced. So for that, there is a empirical equation. And this equation was developed in the western world where they were using this British thermal unit and pound was used as a unit for weight.

So it is this particular equation is actually developed in terms of that, in that unit and it is developed by Dulong. So it is called Dulong Equation. So we can calculate the heating value of a waste by using this Dulong Equation. And how it is done? It is showing in terms of, if you have a waste material or you can do this BTU per pound. BTU is the British Thermal Unit. So much BTU will be produced per pound?

1 pound is around 400, is at a 453.6 grams. So we can always convert this to kilogram and I will show you that conversion as well. Do not worry about it. But since this original equation is developed in using BTU and pound, that is why it is being produced in this particular unit.

Usually we will use SI unit. So here in terms of the BTU per pound, we have 145 times carbon, 610 times hydrogen minus- one eighth of oxygen, plus+ 40 Sulfur, plus+ 10 of nitrogen.

And so this is we need to know how much carbon, how much hydrogen, how much oxygen, how much sulfur, how much nitrogen. So that is, that gives us the heating value. How we will get this carbon, hydrogen, oxygen, sulfur and nitrogen? Remember we are talking about ultimate analysis, proximate analysis and the ultimate analysis. So this is when we do this ultimate analysis, we get the CHONS and there is actually a lab equipment which is called CHONS analyzer anyway. So that is we can use that equipment and get these carbon, hydrogen, oxygen, nitrogen and sulfur.

So when we have those numbers, we can plug these numbers over here. One thing we need to be careful, these are expressed in percent. So these are in, carbon, hydrogen, oxygen, they are expressed as percent. And this is we can plug in those and get the heating value. And here the water is, we do not factor water as part of the hydrogen and oxygen. We take the water separately. So it is and this carbon, hydrogen, oxygen, nitrogen is for that green part of the pie that you saw in the previous slide because that is what is going to combust, that is what is going to produce energy. But other things is we will just go into the system and will come out of the system like that, it will not react.

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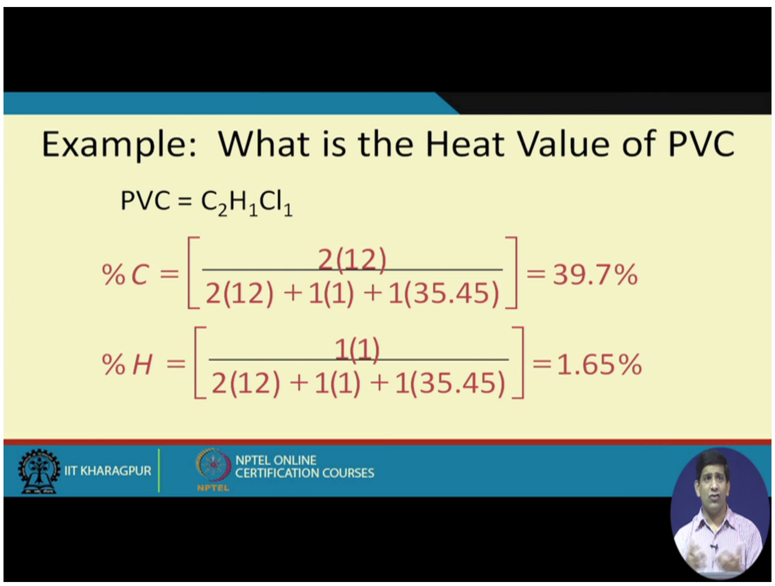

So how we calculate? Like it is a very simple example. Suppose our PVC, PVC pipes we use a lot. So if you have to find out heat value of PVC, this is just to illustrate an example how we do, go about that. First of all, we need to know the heating value, sorry, the equation, the formula of that particular waste component. So, PVC is C2H1Cl1. So that is the formula for PVC. So we calculate percentage carbon, percentage hydrogen, and other things in there.

So in terms of the percent carbon, using the molecular formula that is given to us, we can find out the percent carbon. It has two carbon, so you see two times 12 and then in the denominator, you have two times 12, 1 hydrogen and 1 chlorine. So that is all added up in the denominator, so that is a total mass. And in terms of the mass here, we have the two times of the carbon. So that is gives around 40, 39.7 percent. Similarly for hydrogen, you get 1.65 percent.

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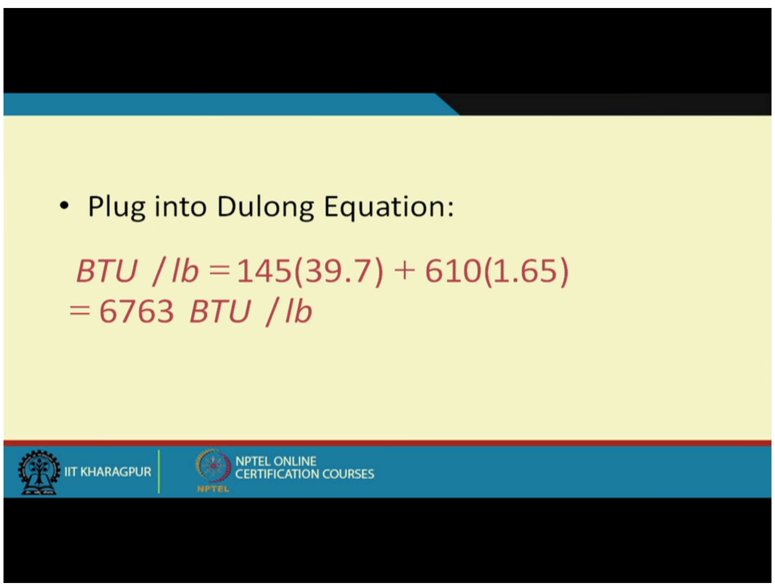

And you can plug since no other components are there. Chlorine does not, chlorine was not there in the Dulong Equation, so we do not have to factor the chlorine in. You just get your carbon and hydrogen, plug in there and you get 6,763 BTU per pound which is a very good number actually. Since anything above 5,000 is very good BTU per pound, it is a good energy source. And PVC is, can burn and can produce lot of energy. So what does this mean? If I burn 1 pound of PVC in a thermal treatment plant, in a good, and we will talk about some more details about that. In a thermal treatment plant, that will produce heat energy of 6,763 BTU.

That is the theoretical amount of energy that will be produced. Whether we will be able to capture this much energy from that, that is a different question. That is, we have to look at what is the energy collection efficiency. So we have to look at because there will be some losses. There will be, they are bound to have some losses. So up to what extent we can, whether it is a 60 percent collection, 70 percent collection, that is a different matter. But in theory, it will produce around 6,763 BTU per pound.

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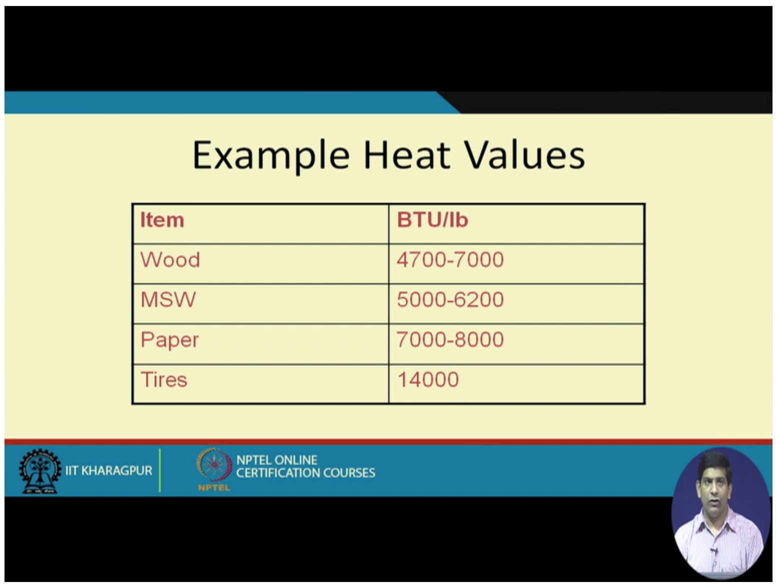

So if you look at some other examples here, wood, municipal solid waste, paper, tires and these are some of the ranges. For wood, it is 4,700 to 7,000. For MSW, 5,000 to 6,200 and again this MSW is MSW from the western world. Most of this data is from US and the western European countries. So their MSW is way different than our MSW. So we do not think that MSW in India will have 5,000 to 6,200 BTU per pound. It will not have as of today. In some pockets of India maybe, if you go to say south extension in Delhi or something very high posh area where people are, they do not care about plastics or paper being sold from their houses, it may be possible.

But since our plastics mostly gets picked up by these kabadiwalas, paper gets picked up by the kabadiwalas, you do not have, we lose some of those and then whatever is left from the secondary collection point, the rag-pickers take it away. So if you look at the calorific value of the waste which is reaching the landfill or which is reaching the dump sites today, it will be much much less. So again, it has to be very, very careful.

So when you try to come up with a, say if you are trying to convince the government or to be honest actually to say that whether it is really calorific value will be there, it is we should not try to put a rosy picture and try to present something which we all know, we know that it is not really true because we are not going to get rid of those kabadiwalas at least in the near future. So they will be there. The rag-pickers, they will be around.

So we have to be realistic in terms of what will be the real calorific value of the garbage when it comes to the landfill site. So still there are technologies out there which works even with low calorific value. So it is not that we cannot do waste-to-energy but we have to be realistic. We have to understand that calorific value of Indian waste is much lower than the calorific value of the western world. And here the number is for the western world. So do not code this number in Indian context.

And paper, 7,000 to 8,000. Again paper, depending on whether it is an office paper, newspaper, number changes. Tires, which is a 14,000 BTU per pound, so tires are a very, very good candidate for waste-to-energy plant but tires are also, they create lot of air pollution. So we have to be, but there are techniques out there in the world today to take care of those air pollutions. So it is not that tires cannot be burned and cannot be used for energy, many places around the world, they are doing it.

And tires have a very high BTU value, so they will produce lot of energy. We have to only make sure that we do not pollute. We do not, we take care of the air pollution issues associated with the tire burning. So that kind of just in nutshell, some thermal characterization. Again when we go into the thermal chapter, we will cover little bit more in detail and then do some math problem associated with that.

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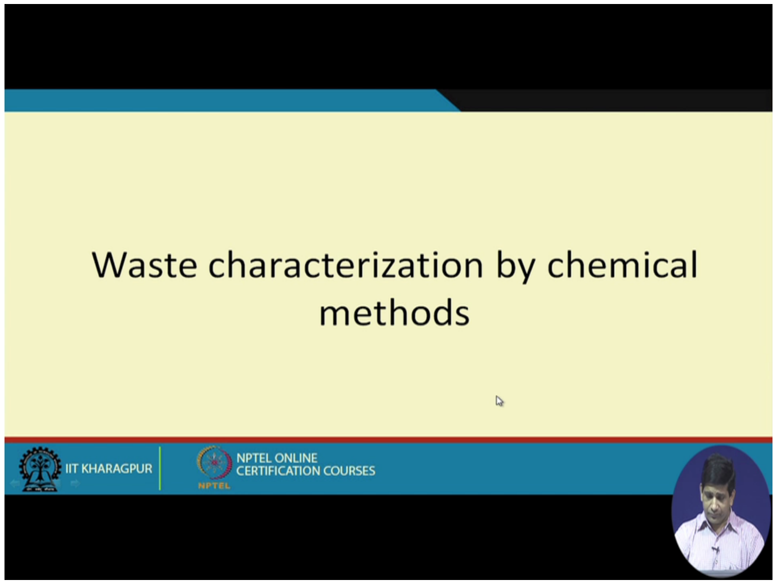

So this, so far we have been looking at how to kind of manage it. So in terms of the management side, one aspect also is we have to look at what are the different chemicals present. Say when we are talking about compost, we have to produce good quality compost. So if somehow some of these waste material gets mixed up and then we have this chemical showing up in our compost or in our waste-to-energy ash or even anaerobic digester sludge, so these chemicals will be of concern. So we have to, what are those different chemicals showing up in our waste stream, how these chemicals are measured, so we will talk about those kind of stuff.

And that is basically, that is how we look at the environmental risk associated with waste management. So when we talk about environmental risk and then when you try to do this chemical analysis, of course you have to go and do sampling. So we will talk little bit about the sampling or QAQC, Quality Assurance Quality Control statistics and all that.

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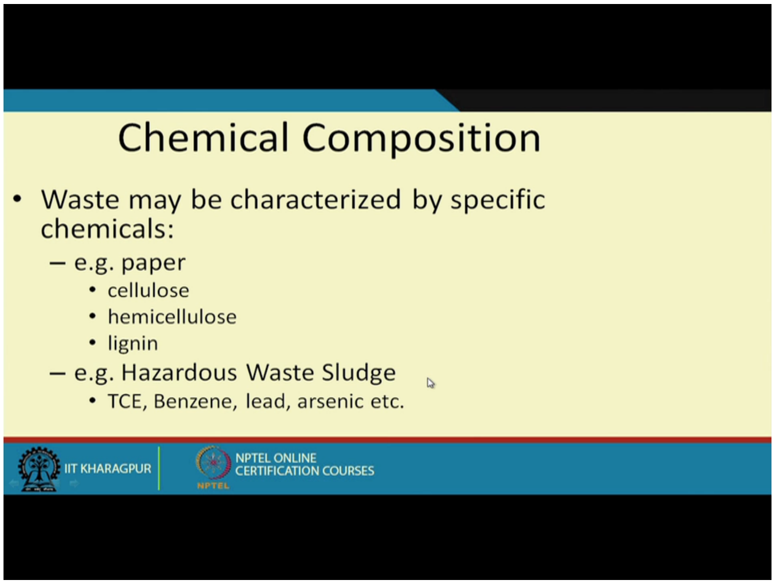

So let us get started on that part. So when we talk about the waste characterization by chemical methods, they are different methods out there. The waste may be characterized by, there we can look for specific chemicals or specific components like paper for example. In paper, we can look for cellulose, hemicellulose, lignin. We know that higher the lignin content, less is the biodegradability, we talked about that.

And if based on how much cellulose, hemicellulose are easy to degrade, lignin is hard to degrade. So if you have more the lignin content, we may have to design our digestion system slightly differently so that the lignin gets treated. And we may have to go for some pretreatment to make lignin more convenient to digest. So those things can be done. But before you do that, you need to know how much lignin is there. So we can do some analysis to find that out.

Or even for the hazardous waste characterization, when we have a TCE, Trichloroethylene, you have benzene, you have lead, arsenic. How will you measure them? So if you have a waste sample, how you measure how much lead is present? How much arsenic is present? So and those kind of things, we will talk about that.

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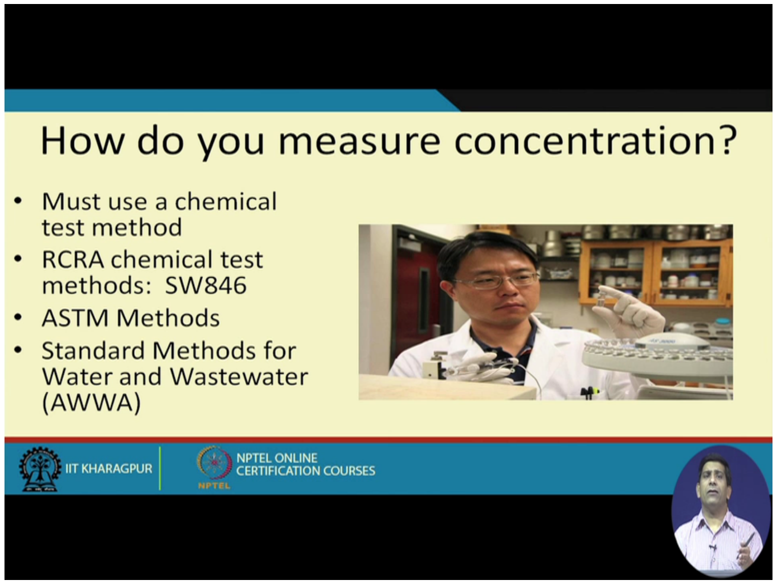

So how do we measure concentration? We use a chemical test method. Now why we use a chemical test method? Because we have to be uniform globally. These days, we have a standard methods of doing things. We do not, say if somebody is sitting in West Bengal here in Kharagpur, we do a certain way in terms of analyzing a particular parameter. Somebody in say Chennai does it in a separate, different way. Mumbai, does in a separate way. Outside India, does it in different way.

So when we get together, we cannot really compare our data together. So we have to follow a standard protocol. That is why for everything these days, there is a standard protocol. So we use a standard, there is a chemical test method. So there are methods out there, which tells you how to do this, how to measure this concentration. So for the solid waste methodology, since as RCRA which is a Resource Conservation Recovery Act of US EPA, they started the solid waste characterization in more elaborated way and more I would say consolidated way. So they have come up with a list of characterization methods or chemical test methods which is under SW846.

So if you go and Google and type SW846, you will see, in second or third link you will find this solid, SW stands for solid waste. So these are SW846 online, you will find all the test is available online. You can download those test protocol, it is available for free. It is based on the taxpayers' money of US government. So it is available for free around the world and then that really helps. You can go there, you can get those methods.

There are some ASTM methods and there are standard methods for water and waste water. If you walk into any good environmental lab anywhere in the world, you will find this standard method book. It is usually, it is either like a light green or dark blue, those kind of bounded cover book which I am pretty sure if you have gone into a lab and try to do some analysis in environmental lab, you must have seen that book. So those things are available which you can use for measuring the concentration.

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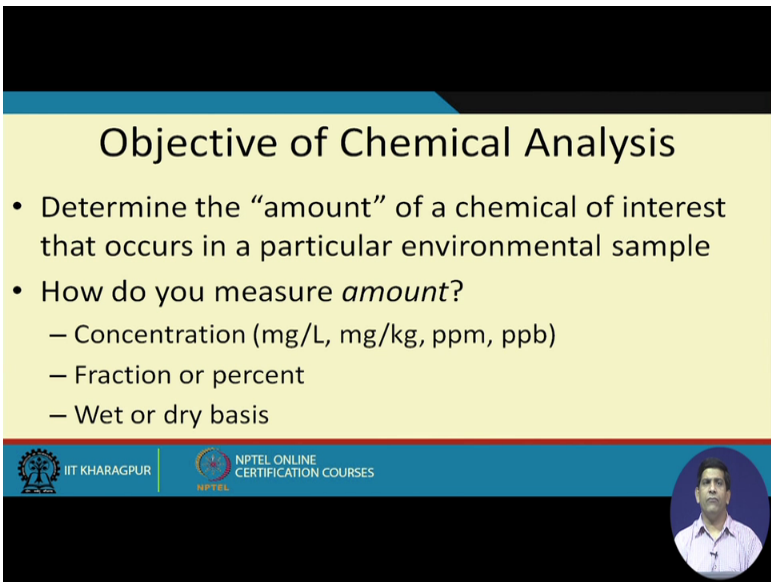

So what is the objective of the chemical analysis? Why we want to do this chemical analysis? We want to find out what is the amount of chemical of interest that occurs in a particular environmental sample. If you are worried about arsenic in water and this part of the discussion, this like last few slides and the coming maybe 8 to 10 slides, they are not just on solid waste. You can, this is true for water, waste water, air, soil, any environmental analysis that you do.

It is a very general discussion and many times our students struggle to have this kind of, so I thought it will be better for them to get some, and it is very, get some idea of how this analysis is done. And there is a difference especially if you are a master student or a PhD student. You need to realize that there is a difference between just producing data and then that is not enough. If you are a master student or a PhD student, you have to understand that data. Do not come and tell your supervisor that this is what I got from the machine.

You have to make sense of the data. Machine will give you some numbers but that does not mean anything. Unless you understand that data, you have to convince yourself that the data is correct, compare that with the literature, follow the QAQC protocol, do some statistics on it, get comfortable with that. And then you kind, of course you can come and discuss with your supervisor anytime you want depending on how arrangement you have with your supervisor.

But in general, do not just say that that is what the technicians will do. We have some lab technicians, we will give some samples and they will analyze that sample and they will give us the number without thinking too much about it. But you guys are getting masters in PhD degree, so that is does not, it is not acceptable from you guys that you will just focus, just do the analysis and give us the data. You have to understand and you have to convince us why this data is correct or why is, if you think it is wrong, why it is wrong.

And those kind of things you need to really make sure. So in terms of the objective, we have to determine the amount of chemical of interest that occurs in a particular environmental sample. And that is any sample for that matter. And we measure the, how do we measure the amount? We measure the concentration either in milligrams per liter, milligram per kilogram, ppm, ppb. So milligrams per liter and milligram per kilogram, both are ppm. But this ppm, we are trying to avoid using the term ppm because it gets confusing. When we talk about the liquid sample, we say milligrams per liter. When we say solid sample, we say milligram per kilogram. Just to kind of make it more clear because ppm stands for both. It is parts per million.

Then ppb is your micrograms per liter or microgram per kilogram. So again it states for both. Then you can express things in fraction or percent. You can do on the wet basis or a dry basis. That is also very, very important. Wet basis means when you are not factoring in the moisture content, when you are doing the sample as it is. TCLP test that we talked about is a, it is based on the wet basis. The 100 gram sample and 2 liter of leaching solution that we use, that 100 gram sample is the sample as it is. Even if as 20 percent moisture content, we are not factoring the moisture content there. So out of 100 grams, we are getting 20 grams of water but that is okay because that is how the sample will be disposed into the landfill.

And so we are just trying to simulate the landfill conditions. Worst case leaching scenarios, we are just taking the 100 gram, not factoring in the moisture. So that is called wet basis. If we had dried the sample, then it would be on the dry basis. Many times, you will see it is, especially when you look at the standards, for example the soil standard, compost standard, they are on dry basis.

So I do not know whether you have tried to thought about why they are on dry basis, what is the, what is rationale behind putting that in the dry basis. If you think about it little bit, that is pretty simple. Say, if you have two different compost, they may have different moisture content. If you are looking at different types of soils, different soils from different places, the moisture content will vary.

So if you do not, if you take it on wet basis, it is very difficult to compare because you have, one place you may have 5 percent moisture, one place you may have maybe 30-35 percent moisture depending on how much rainfall that area gets and what kind of soil they have. So that is why to avoid that problem of variability in moisture content for standard, when we say that your soil has to meet standard of say less than 0.5 milligram per kilogram of arsenic. I am not sure whether 0.5 is the correct number but just for example, less than 0.5 milligram per kilogram for arsenic or less than this x milligram per kilogram of cadmium, less than y milligram per kilogram for lead.

So when we talk about that, when we say those numbers, they are on dry basis because if it is on wet basis, since the moisture content keeps on changing in different places, these numbers we cannot have a, we have to then specify the moisture content. That means at moisture content of this like we do it for, when we talk about the ideal gas, we say at a standard temperature and pressure because things do keep changing.

Similarly here, with the moisture content, that concentration will change. So that is why we put them in the dry basis. So you have to understand and then the numbers really makes a lot of difference. But you have to be careful when you look at a data, make sure you understand whether it is on wet basis or a dry basis.

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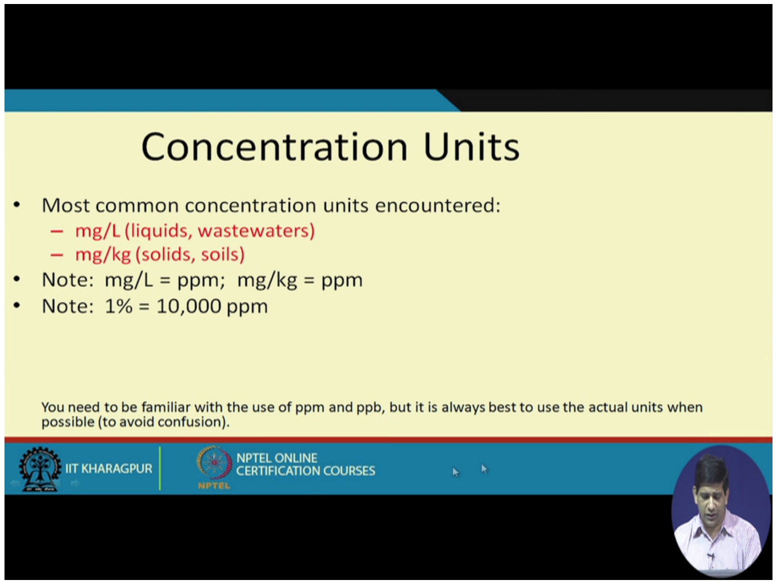

So concentration units, there most common is milligrams per liter, that is what the liquid and the waste water. Milligram per kilogram for solids, these both are called ppm. And then, 1 percent is 10,000 ppm. So 1 percent is 1 out of a hundred. When we say ppm, we are talking about 1 out of a million. So that is why if you do that math, you will say that it is a, 1 percent is actually 10,000 ppm. So it is always better to use actual unit, so you should be aware of ppb, ppm, ppb and those things. But it is always better to use the actual units, milligram per kilogram or milligram per liter.

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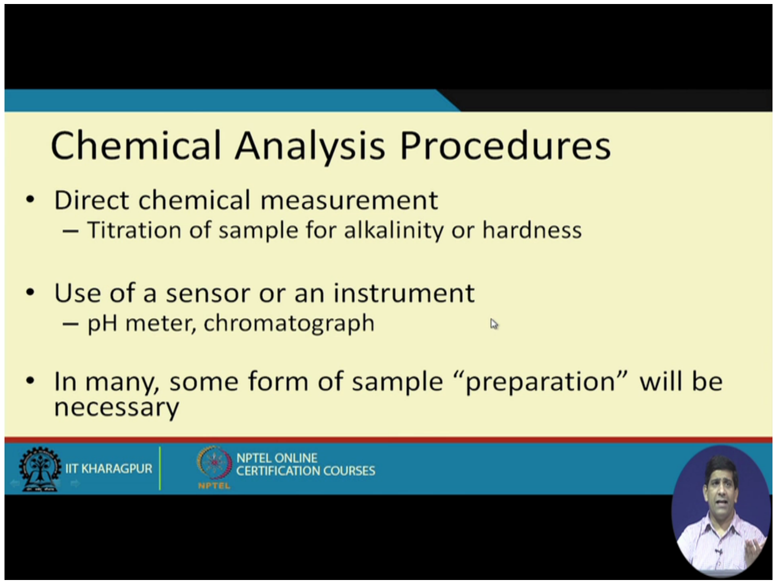

So there are different chemical analysis procedures. You can do direct chemical measurements, you can do use of a sensor of an instrument, you can do, but for all these, you need some sort of sample preparation. So sample preparation is needed before you go for the chemical analysis. So we will kind of continue this discussion in our next video as well.

So in terms of the wrap up of what we have covered in this particular video, we looked at the thermal characterization and then because that is important when you try to go for waste-to-energy plant to understand that. Then, we also started looking at that how we get this chemical analysis done because ultimately the focus that we have, the big picture if you look at is to have less environmental impact, less human health impact.

So when we talk about environmental impact and human health impact, we are worried about the pollution. So when you are worried about the pollution, we need to measure the level of pollution. So when you are trying to do this level of pollution, you have to look at the chemicals present in the waste and what is being released and how to take the sample, how to analyze these different chemicals. So that is what we have been discussing towards the end of this particular video.

So in terms of the, there are different chemical analysis procedures are there. You can do certain things, you can do direct chemical measurement like titration. We, all of us have done (())(30:43) hardness, so those, this is a titration method. You can use some sort of sensor, very simple one is pH meter. I hope that each one of you have used pH meter at some point of time. We use ion chromatograph, Gas chromatograph and I will give you some like common instruments. I will kind of give you a very quick overview of that. And then in the next video, we will start with, before you start doing this analysis, you need to do some sample preparation. So what do you mean by sample preparation and all that, that we will continue in the next video.

So again thank you. Keep enjoying this and if you have any questions, feel free to put it on a discussion board. We are keeping eye on that and we will be happy to respond to any query that you have. Thank you.