Course on Integrated Waste Management for a Smart City
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Module-02 Lecture-07
Municipal Solid Waste Characteristics and Quantities

Okay. So welcome back. And so this is the second module for second week. So after completing that overview that we just finished, in this particular module, we will start looking at in terms of, as I said we will start looking at the municipal solid waste characterization as well as the quantities, those two part. So in terms of the characterization, every country, every place wherever you go, we will have a, there is a solid waste characterization.

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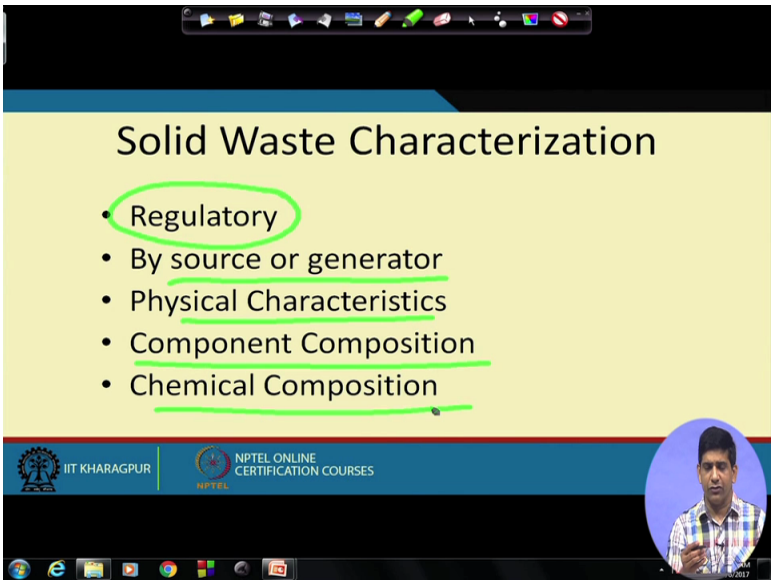

In terms of solid characterization, you have the regulations out there, so you have to follow certain regulation. In the Indian context as well, we have Municipal Solid Waste Management Rules 2016 now, we had MSW Rules 2000 which was passed almost 15, 16 years back. There are different way of characterizing the waste. In this particular module, we will try to understand that, what are the different ways of characterizing the waste.

So one is the regulatory characterization, so we will talk about what is the regulatory characterization. Regulatory characterization, then we will talk about the source or generator, what is the source of the waste, how to characterize in terms of the physical. So we have the

source, generator, physical characteristics, component composition and chemical composition. So one by one, we will go over each one of them.

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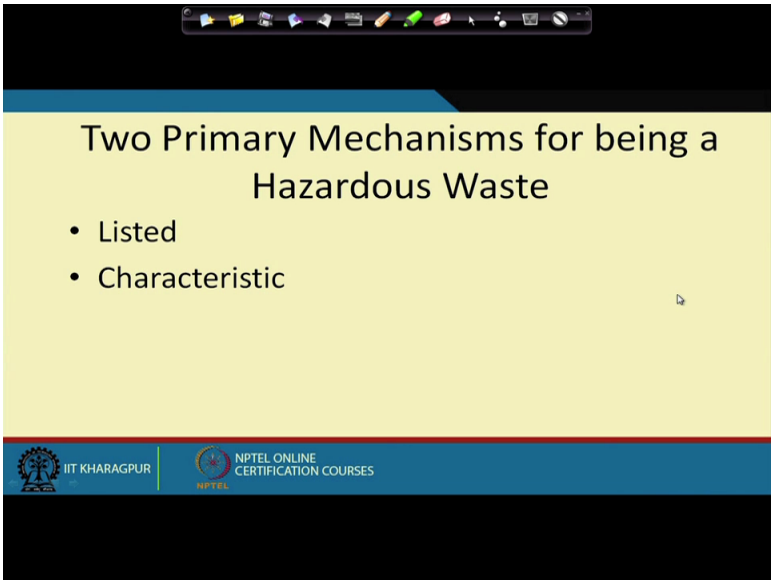

So in terms of the regulatory characterization, the most important things that we when we talk about the regulatory characterization is to find out whether the waste is hazardous waste or not. So when we say whether the waste is hazardous waste or not, it is, so because the hazardous waste, so when we talk about, again kind of go back and like if you go back and think about little bit, solid waste is the bigger umbrella.

So within solid waste, we have municipal solid waste, we have hazardous waste, we have construction and demolition waste, we have agricultural waste, we have mining waste. So all these are the different types of waste out there. So hazardous waste is something which is more dangerous than typically municipal solid waste or construction and demolition waste.

There could be things from municipal solid waste which could be hazardous. There could be things from C&D waste which could be hazardous. So how we know, say if you are running a company or if you are running a factory or even if you are a solid waste engineer in a city, how will you know whether your waste is hazardous waste or not? Or you are running a landfill, you are in charge of a landfill and somebody brings a garbage to you, how will know when that garbage is not municipal solid waste? How will you know whether to accept that garbage or not

to accept that garbage? Whether that garbage which is coming in could potentially be a hazardous waste or not?

So there is certain regulation to classify waste to be a hazardous waste. There are two ways, two primary mechanism in which it is done. And that is, it does not matter these days wherever you are in the world, the hazardous waste management rule is pretty much similar well throughout the world including in India because just to have a uniformity among the different countries, we are trying to have similar rule for hazardous waste.

For municipal solid waste, the rules do change from place to place and then based on how the city geography is and what is the population, what is a demand over there and all that, what is land availability and all that. But in terms of hazardous waste, rules are pretty much the same. It is, it is throughout the world. So for a waste to be a hazardous waste, there are two predominant way. One is the listed, one is the, other is the characteristic.

So this part of the video, I would, my sincere advice would be that you watch it very carefully and you watch it again and again to make sure that you understand this concept. Otherwise, this is, this does get confusing a little bit and since this is a regulatory aspect, regulatory aspect many times is not very interesting. Any regulations you may have, you may have signed many times while you are installing a software in your computer, you sign 'I accept' button without reading those, all those stuff there. Same thing for your cellphone. When you buy anything, you just click on 'I accept terms and condition' and you sign. Something similar here. It is a, regulations are pretty dry but we try to, we will try to explain it in a simple way so that you can understand that.

So for a waste to be a hazardous waste, there are two ways. Either it can be hazardous waste because it is a listed hazardous waste or it could be hazardous waste because it has certain characteristics. Now what is listed hazardous waste and what is characteristics, we will talk about that. So in terms of the listed, as you know listed means what? It is on a list. Very simple, if you think about from English, just from the English language, listed means it is on a list. Now how it got in the list and what are these list, we will talk about that.

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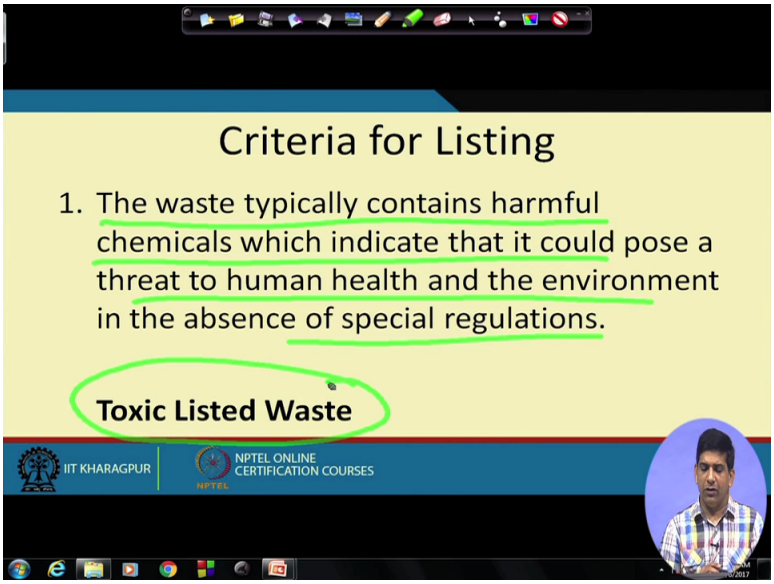

This list, in any regulation, if you take out the hazardous waste management rules of India or hazardous waste management rules of US EPA or European Union, you will see there are certain list. And that list is from our experience we have come up with that list. Now what is that experience?

After Second World War, we have started having lot of industrialization throughout the world at a different level depending on which country you were in. So with the industrialization, we started producing lot of chemical based waste or lot of waste which was being produced from these factories and we did, we have studied those waste. And we have find out that some of these waste are harmful to us and they are harmful because of certain criteria which we will talk about that.

And since we found out it is harmful, we have put it in a list and so that is what is listed hazardous waste. So for any part of (comp) like a industrial setting which is like a normal industrial setting if it based on coal based thermal power plant, electroplating industry or lot of industry which is certain that, we know that these industries produce certain kind of waste and there are certain kind of contaminants present there in terms of the heavy metals and organics and all that.

So once we have these heavy metals, organics presence there, we know we have put it in a list because of we know that this will be harmful to the environment, harmful to the humans. So that

is the reason for the list. So how these things got listed, here again this language herein next few slides, so the language is directly from a regulation.

So it is the criteria for listing is where you have waste typically contains harmful chemical which indicates that it could pose a threat to human health and environment in the absence of special regulations. So that is your toxic listed waste. So it is a list, it is listed because it contains harmful chemical. Harmful chemicals could include arsenic, could include lead, could include certain organic chemicals, could include dioxins and all that.

So those are, if there are harmful chemicals present, it could pose a threat to human health and environment in the absence of special regulation. We put it as a toxic listed waste. So among the listed waste also there are different categories. So this one, this would be put under toxic listed waste.

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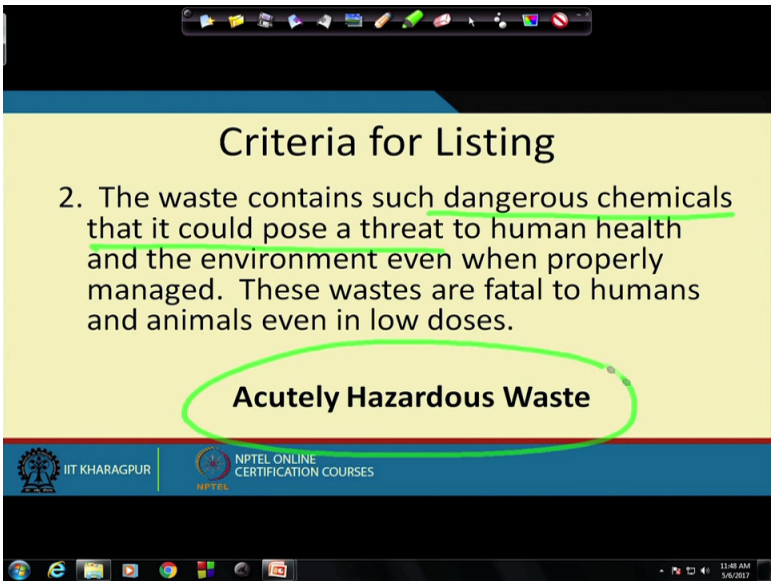

And then other criteria is the way waste is containing acutely dangerous chemical. All, it is, not only it is a toxic, it is acutely dangerous. It is acutely dangerous, such dangerous chemical that could, it could pose a threat to human health and environment even when properly managed. Something like methyl mercury or methyl isocyanide. If you remember, those of you who are familiar LTTE, Liberation Tiger of Tamil Eelam, I do not know whether it is true or not but there have been a saying or there have been some media reports that most of these LTTE like people, the fighters they used to carry a cyanide capsule.

And they will take that cyanide capsule and they will, if they are caught, if they fear that they will be caught, they will take that cyanide capsule and take their own life because they do not want to be captured and being tortured and all that. So that is, it is, that was, that is a very lethal. You take that, if somebody takes that, you are gone. It does not give you much time to do anything else.

Similarly, methyl mercury is very dangerous stuff. Methyl, there was instance few years back where one professor in one of the universities in US, she was working with methyl mercury, unfortunately she was wearing a wrong set of gloves and the methyl mercury did penetrate through the gloves, got into her skin, got into her palm. And by the time paramedics team came, as some, as if you have watched the Hollywood movie, you know that paramedics do come there pretty fast. Within five minutes, doctors and everybody, at least the first respondents will be there. But within, even during that time period, she could not survive. So it is those are very dangerous chemicals. So even in a very low dose, even with accidental exposure, you are gone.

So those are called acutely hazardous waste. So they are put under acutely hazardous waste. These waste are fatal to humans and animals even in very low dose. Those are our, so these are put under acutely hazardous. So the regulations would be more tougher for these type of waste so that they, it is, it can be handled more properly.

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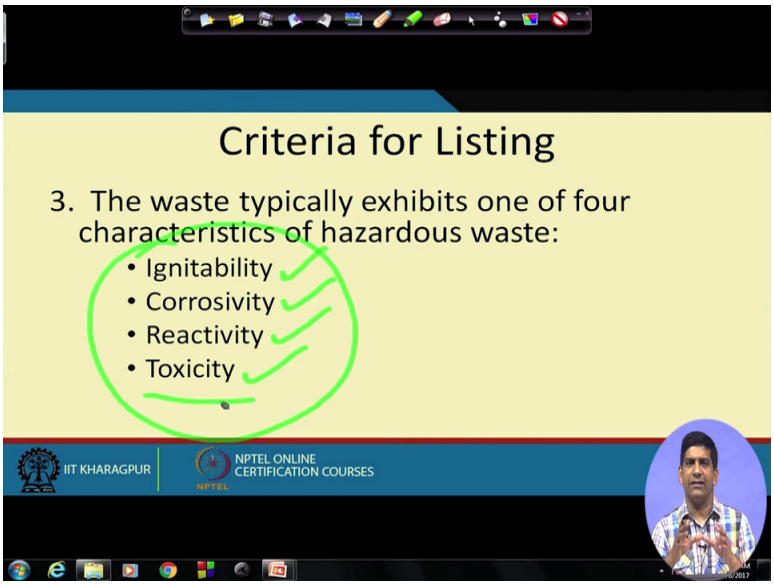

And then if they have certain characteristics, if the waste typically say scientific, one of the four characteristics of hazardous waste, now what are those four characteristics? It could be ignitability, corrosivity, reactivity and toxicity and we will talk about each one of them in a little, in a one by one. Ignitability means something which can catch fire spontaneously. There is a difference between ignitability and combustibility.

Combustibility means something which can burn. But you have to put a, you have to use your lighter or a matchstick to have it like we start the burn, we have to give the fire. Ignitability, at a certain pH, sorry, at a certain temperature, it will start burning by itself. So it will get ignitable and it will start burning by itself. It will catch fire by itself. So that is the ignitability type of waste.

And there are testing for all of these. Since this course is not, if you have been teaching a course on hazardous waste management which I do teach in MTech and PhD level at here at IIT Kharagpur but since in that particular course, we go in for each of these characteristics and we kind of look over what are the test being done, there is a test. There is a regulatory prescribed test for each of these categories. We will talk about one of the category here but the other categories, we will not talk much about this test because we do not have time for that and that is a hazardous waste class. That is, and this course is focused on municipal solid waste.

But I just wanted to give you, you should have an understanding of when how this hazardous waste listing is done because it, that is also, it is linked with municipal solid waste so that we are just trying to do some whatever is the little bit of overlap there. So based on these characteristics, ignitability we talked about, rest is the corrosivity. If something is corrosive, corrosive means very low pH and very high pH. So then, typically at a very low pH and very high pH, things are corrosive.

Very strong acid, very strong waste, so that is the corrosive. So if that kind of waste is there, again that is a hazardous waste. Reactivity, if something reacts violently, there is a reactive and there is it reacts and then creates an explosion, so those kind of, that is your reactivity. And if you, things, there are (comp) compounds, so there are chemicals out there which does, say if it gets into sunlight or gets into some favorable conditions, it will explode by itself.

And you, if you have a, there was, you may have watched it in certain videos or movies as well but there are certain chemicals out there. And so that is which is highly reactive and that is who creates a some sort of explosion with a, in a favorable condition. The last one is the toxicity. And toxicity here, we are not talking about the toxicity as we know for the biological organism.

Here the toxicity, we are talking about the toxicity characteristic which is, which means that there are, in a favorable condition when the moisture gets into that, it will leach enough chemicals out there and that chemical, in a landfill setting if that (chem), in MSW landfill if that is used and if the liner breaks, that chemical will cause a like a contamination of groundwater. And we will spend more time on these toxicity characteristics. For the other, we have kind of already talked about the different criteria. So that is the criteria for listing.

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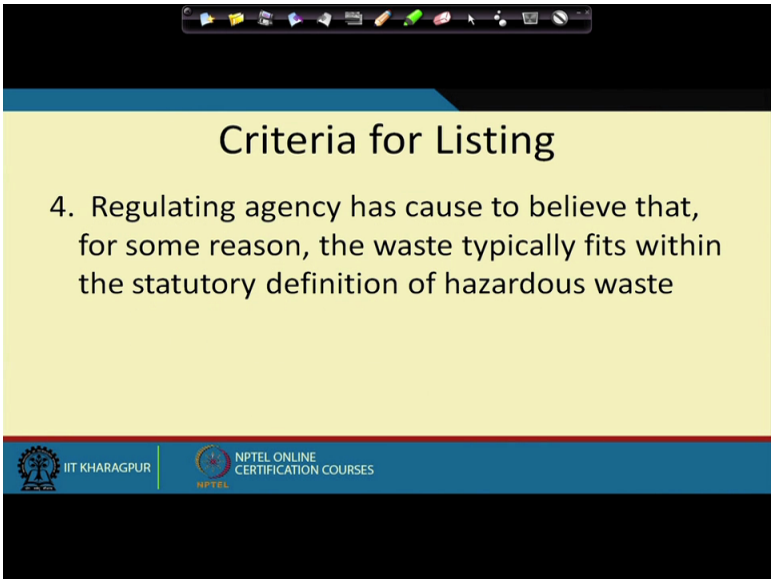

Then other than that, if the regulatory agency has cause to believe for some reason that the waste typically fits within the statutory definition of hazardous waste, so if they have some reason to believe that something, waste is could be hazardous waste, so then they will put it under hazardous waste.

Many times, we do not know if there is a newer waste categories. Recent example is on nano-waste. Certain nano-particle containing waste in country such as Australia, they have started managing it as a hazardous waste because still research is going on, we do not know whether it is a hazardous waste or not, research is not conclusive yet, there are argument on both sides of that.

Some claim that it is a hazardous waste, other claims it is not. But once the conclusive evidence is reached, until that time as a proactive approach, they are, this regulatory agency in Australian EPA is putting this nano-waste as a hazardous waste. So that is one situation. So those kind of situation do come from time to time and that leads to list, putting things on the list for hazardous waste.

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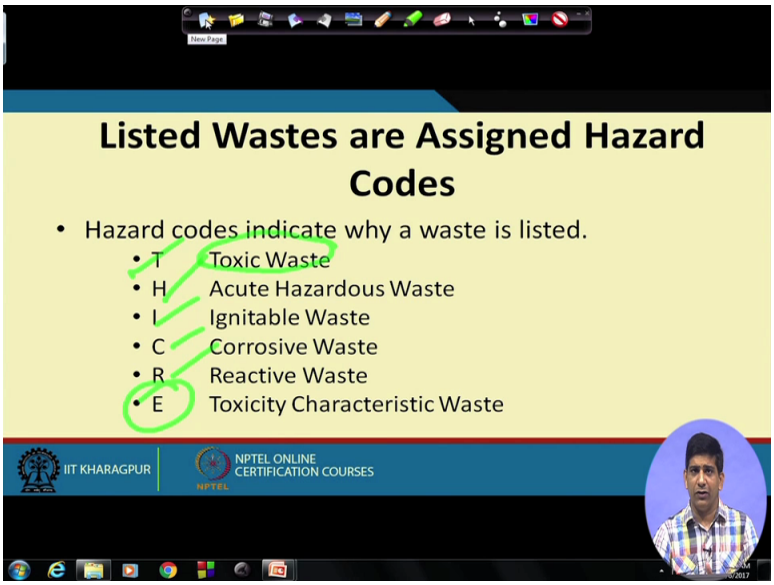

So for the hazardous waste, there are Hazard code is assigned. And again, this code may change from country to country but this is a, essentially the bottom, I would say the essence is the same. The bottom line is the same where we talk about different types of waste. T is your toxic waste. T is the toxic, H is the acutely hazardous, I is ignitable, C is corrosive, R is reactive.

Since toxic waste has been taken over there by T for the toxicity characteristics, we use the code E which is for the toxicity characteristic waste. So this is, so what are these code? So when you look at the regulation, when you go towards the end of hazardous waste management rules, you will see several list out there. For the list, there will be, this hazard code will be a sign to those list. You will see T007 or H004, so those and that is H004 means it is acutely hazardous waste, or C007 mean it is a corrosive waste. And then depending on type of waste, just like 1, 2, 3, the numbers will come along with that. So that is in terms of the hazard code.

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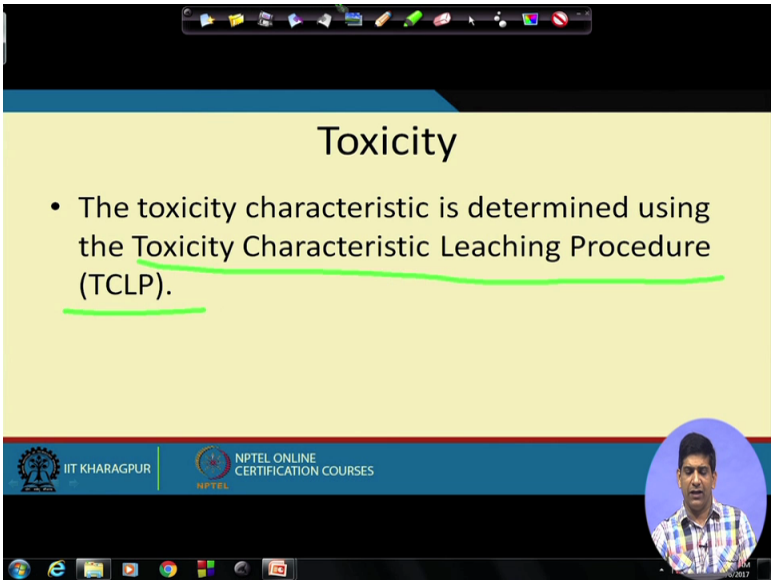

So toxicity characteristic which we said that we will try to explain a little bit more further, this toxicity characteristic is determined by a test which is known as the toxicity characteristic leaching procedure. And this test is one of the highly used and I would say highly abused test in waste management system.

Now this toxicity characteristic leaching procedure, TCLP, what is this test? As we, as I said earlier to you, it is a test for characteristic of the waste and what characteristic? Toxicity characteristics. When we say toxicity characteristic, what we mean? Essentially what we are, the regulation as this test was developed was to find out, say if we have a pile of waste and we want to find out whether that waste can be disposed in a MSW landfill or not, when we say MSW landfill, is the typical landfill that we make for municipal waste. So that is your, or the sanitary landfill that you hear, it is a non-hazardous landfill where we do not, we accept non-hazardous waste.

So if you have a pile of waste which you want to find out whether the waste can be safely disposed in MSW landfill or the sanitary landfill. That, so we want to, this test, TCLP test was designed in late 80s, in that particular time period to find out that in the event, this waste goes to MSW landfill, whether they, the leachate that is produced, in case there is a liner breakage, if the leachate produced from the waste will cause any harm to the groundwater in case of any liner failure.

So this TCLP test, the rationale of TCLP test was to find out if I have a waste stream, can I put that waste stream in MSW landfill or not? If I cannot put in MSW landfill, that means I have to put it in a hazardous waste landfill. And hazardous waste landfill is more stricter than a municipal solid waste landfill. So that was the basic, that was the basic concept behind this TCLP test. These days, as you may have seen in environmental reports, solids waste reports, we have been using TCLP kind of for everything and that is not true.

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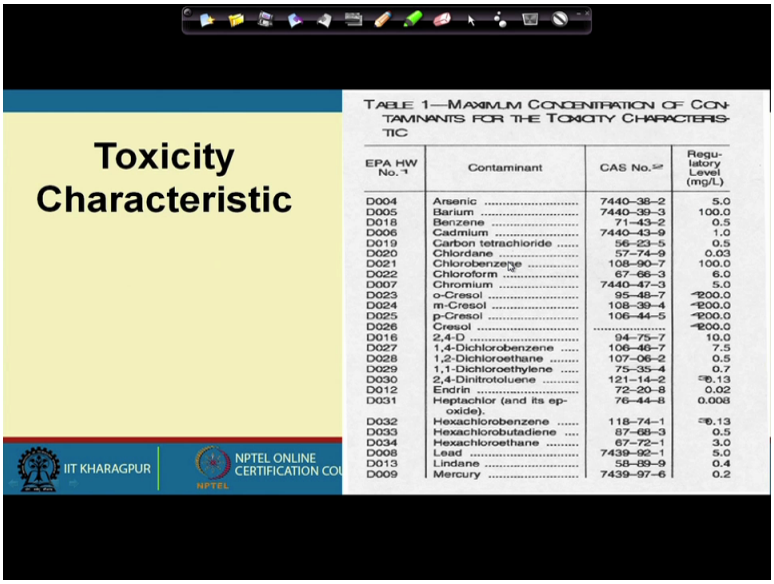

TABLE 1—MAXIMUM CONCENTRATION OF CONTAMINANTS FOR THE TOXICITY CHARACTERISTIC

EPA HW No.[1]	Contaminant	CAS No.[2]	Regulatory Level (mg/L)
D004	Arsenic	7440-38-2	5.0
D005	Barium	7440-39-3	100.0
D018	Benzene	71-43-2	0.5
D006	Cadmium	7440-43-9	1.0
D019	Carbon tetrachloride	56-23-5	0.5
D020	Chlordane	57-74-9	0.03
D021	Chlorobenzene	108-90-7	100.0
D022	Chloroform	67-66-3	6.0
D007	Chromium	7440-47-3	5.0
D023	o-Cresol	95-48-7	[3]200.0
D024	m-Cresol	108-39-4	[3]200.0
D025	p-Cresol	106-44-5	[3]200.0
D026	Cresol		[3]200.0
D016	2,4-D	94-75-7	10.0
D027	1,4-Dichlorobenzene	106-46-7	7.5
D028	1,2-Dichloroethane	107-06-2	0.5
D029	1,1-Dichloroethylene	75-35-4	0.7
D030	2,4-Dinitrotoluene	121-14-2	[4]0.13
D012	Endrin	72-20-8	0.02
D031	Heptachlor (and its epoxide).	76-44-8	0.008
D032	Hexachlorobenzene	118-74-1	[4]0.13
D033	Hexachlorobutadiene	87-68-3	0.5
D034	Hexachloroethane	67-72-1	3.0
D008	Lead	7439-92-1	5.0
D013	Lindane	58-89-9	0.4
D009	Mercury	7439-97-6	0.2

TCLP test is only to find out whether the waste can be safely disposed in a MSW landfill or not. So when we say it is safely disposed, there has to be certain limits. So there is certain limits for whether the waste can be safely disposed or not. So when you produce this leachate, you compare with this regulatory level. And we will come back and talk about this regulatory level in a little while more but this is not an exhaustive list, this is just an example list for you.

So we have the, having some, we have like inorganics and we also have the organics and these are the regulatory concentration. So if I do a TCLP test and if I find that my leachate concentration for these compounds are less than this, so I have no problem. If it is more than this, then I have a problem because then it becomes a hazardous waste. So we have to, and we will come back and talk about this table in a minute more.

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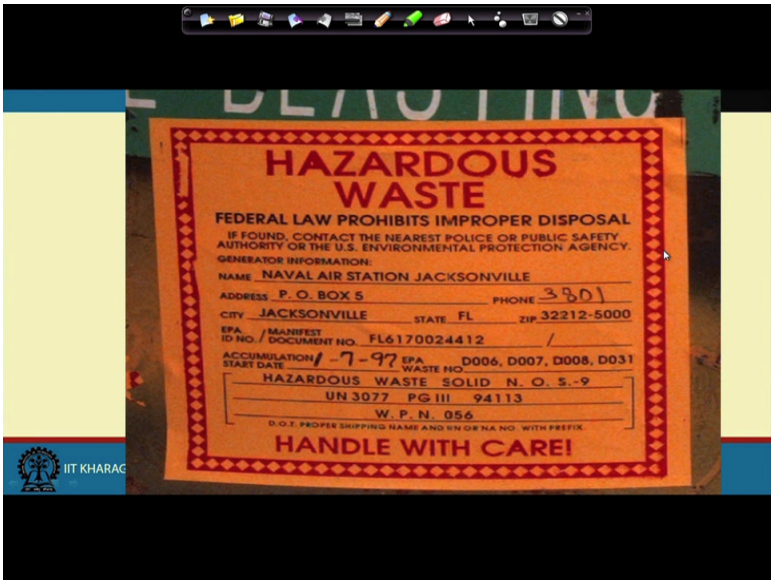

So hazardous waste, if it is a hazardous waste, it has to be managed separately, it has to be putted in a separate bottle, it has to be labelled properly and then what type of waste is there and all that, and then you will call and people will come and pick it up. It is a, and then they take it to a hazardous waste landfill or hazardous waste treatment facility. So that is typically what is done.

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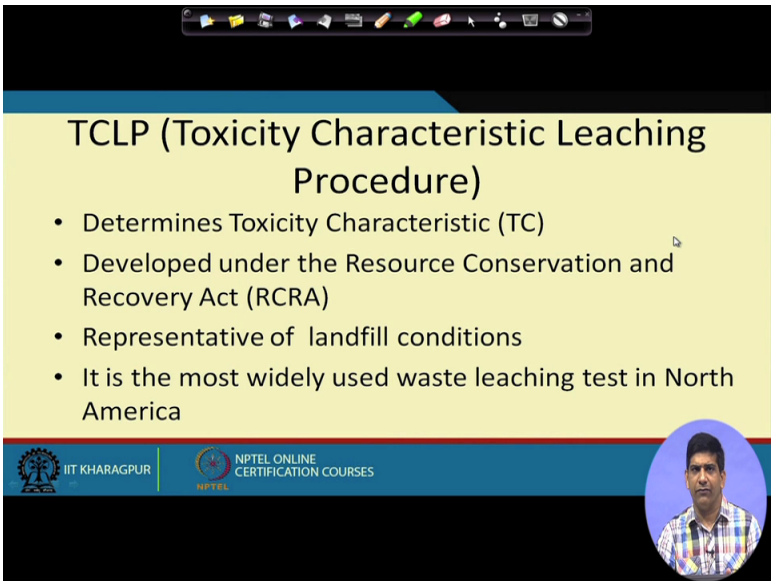

So in terms of the TCLP test which we are talking about, it is determines the toxicity characteristics, it finds out the toxicity characteristics of the waste. It was developed by US EPA under RCRA which is Resource Conservation and Recovery Act. And what it does? It represents

the landfill condition. Why it represents landfill condition? Because it is what it is supposed to do, is not it? It was supposed to find, TCLP was designed to find out whether the waste can be safely disposed in a MSW landfill. So it does create landfill situation, so that is representative of landfill condition and it is the one of the most widely used leaching test not only in North America, actually throughout the world. It is, that is a number one leaching test which is used throughout the world. How it is done?

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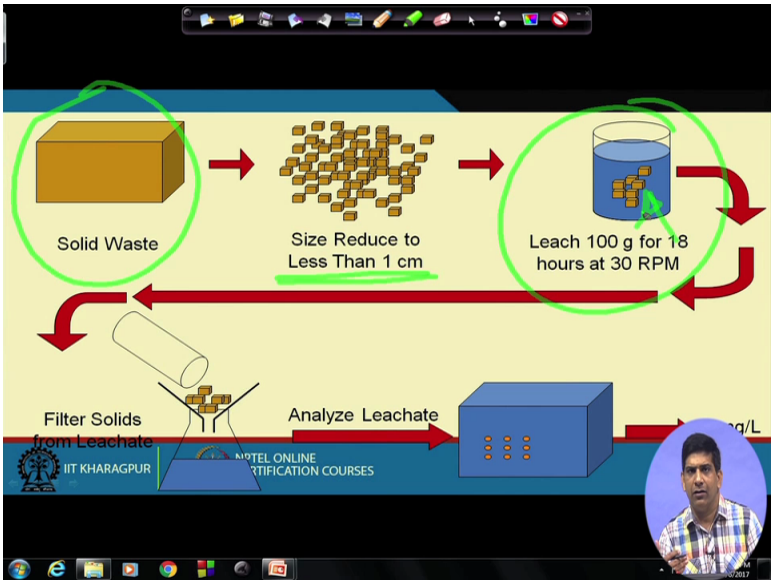

As you can see in this particular sketch, we have the steps. So you have certain solid waste, you size reduce it to less than 1 centimeter. Now why less than 1 centimeter? You can always make an argument. So when I, say I have electronic waste, I dump it in a landfill. This like I have a CPU, dump it in a landfill. That CPU will not get crushed down to less than 1 centimeter, so that is true. But it will get crushed down in a compacted but it will never be less than 1 centimeter. That is totally understandable. But then why we do it less than 1 centimeter? The reason for that this is a leaching test, this is a test where we are trying to be more conservative.

Electronics is kind of little bit an odd example here because the site is a big and it is difficult to, difficult to kind of size reduce them. But there are certain other ways where the size reduction does happen with the compact and other stuff. Or you may, so that in that case, so our goal here is to have a size less than 1 centimeter because smaller the size, more the surface area. More the

surface area, more the reactivity. That means it will be in a more conservative scenario in terms of the leachate.

So you have the size reduce less than 1 centimeter. Then you take 100 gram of the sample and put in the beaker for 18 hours at 30 RPM, and then let us leach for 18 hours at 30 RPM. Then you put a liquid here and this liquid is what is known as TCLP leaching fluid. And that TCLP leaching fluid, what is trying to simulate? It is trying to simulate worst case leaching scenario of a MSW landfill.

What is there in MSW landfill? Acetic acid. Remember in the just previous module, we talked about that. That, all the big acid, smaller, big molecular compound, lower molecular compound and finally to acetic acid, so acetic acid is present there. So this solution will have acetic acid and we add some sodium hydroxide. Why sodium hydroxide? To make it more like a buffered solution. So it is a buffered system, it is pH will not change that easily so that pH is maintained and the pH is maintained at 4.93 plus+ minus- 0.05.

Now why 4.93? Again, as like I have been trying to highlight this why, why and why for you, you should also like I would, I think I already said few times that for any topic, always try to understand why this topic is needed, what is the importance of it. Once you know that why, you will figure out the other part for sure.

So why we add sodium hydroxide? To make it a buffered, to have a pH so that pH is more stable because in a landfill system, pH is a (())(22:49). Now we are using a pH of 4.93 plus+ minus-05 which is more at a lower range. Why again? Then why lower range? Because we wanted to be more conservative because that is the worst case leaching scenario. And the worst case leaching scenario of, for heavy metals and some of these organics as well, it is at very low pH.

So what is the lowest pH? That is where you will see more leaching coming out. So we are accelerating that particular condition. So once this leachate it is being leached, you put it in, you filter it. You filter solids from the liquid and why, we are not that much interested in the solid phase, we are interested in the liquid phase. Because our concern is that waste will, it is the leachate will percolate through the soil and it will get into the groundwater.

So that is what based on our concern, we are focused on the liquid phase, we are not focused on the solid phase in this particular situation. So you filter the solid from the liquid. You take the liquid, you do the digestion or do whatever is needed for that and then you analyze this leachate and then you get the concentration and say X milligram per liter. Now taking this concentration, what we will do? We will compare it with, after taking this (concen) this concentration, we will compare this with regulatory standard which we talked about just earlier.

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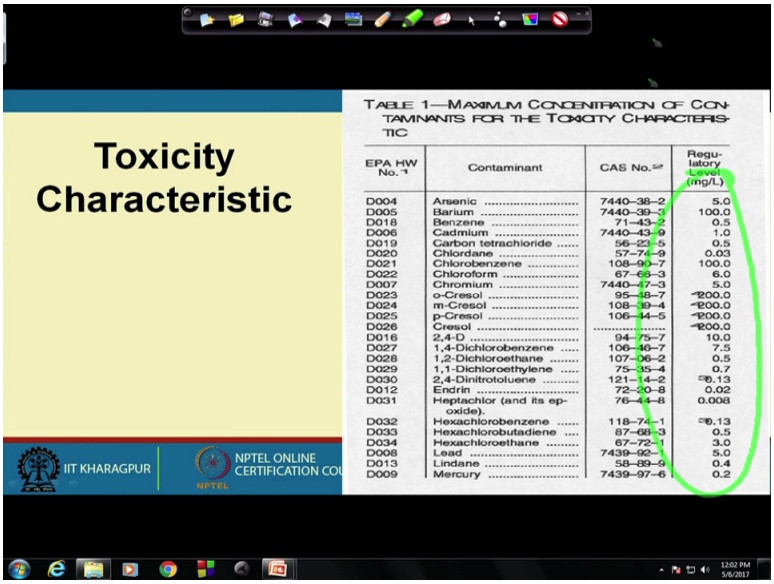

These are the regulatory standard which we looked at few slides back. So we can compare this X milligram per liter with these numbers and if any of these parameters are exceeded, then that waste becomes a hazardous waste for that particular, for that particular parameter. So that is in terms of the TCLP test.

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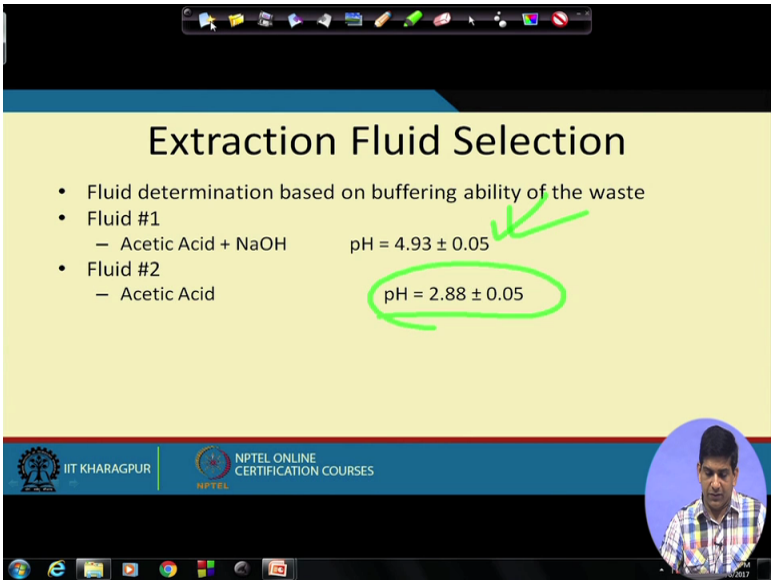

So in extraction fluid solution, we use acetic acid and sodium hydroxide which I already explained to you, pH, 4.93 plus+ minus-05. And in terms of, there is another fluid is used which is just acetic acid by itself but typically you will not see that, and usually it is done for a very high pH waste. So if you have a waste sample whose pH itself is more than 10 or 11, there is a, actually there is a limit for that, I think it is 11. Then we use the second leaching fluid, otherwise we just use the first one which is the most, almost 90 percent of the waste situation you will see the first leaching fluid being used. So once, this is the extraction fluid used for TCLP and then we had, remember we had this TCLP limit, the table that I showed you.

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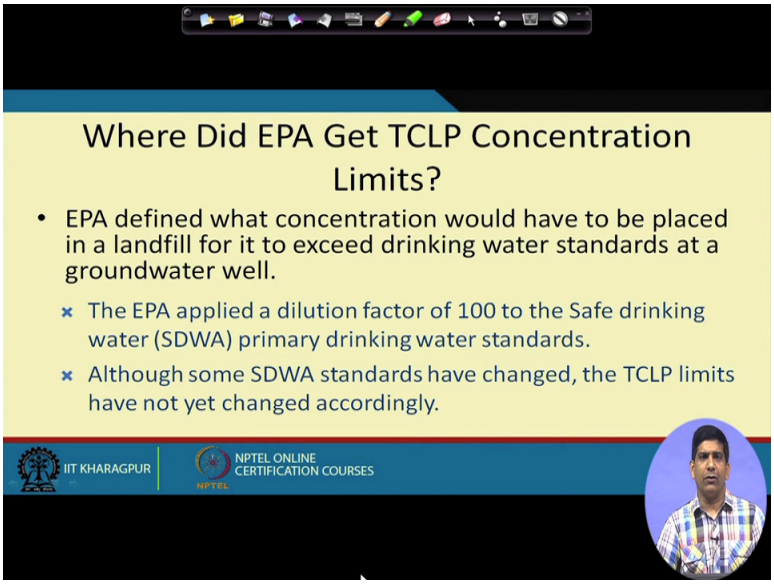

Now the question is, where did EPA got this limit from? How the EPA come up with these limits? What EPA did at that particular time? Because what is a concern? Concern is this leachate migrating through the liner, going to the groundwater and contaminating the groundwater. So groundwater should meet a drinking water standard because many times the groundwater is, groundwater is used for drinking purposes. So it should meet the drinking water standard. So what we are trying to do over here is we applied a dilution factor of 100 to the drinking water and of safe drinking water and then we got the TCLP limit.

So if at that particular time, if arsenic for example, the arsenic drinking water standard at that time was 50 micrograms per liter, today it is 10 micrograms per liter. So 50 micrograms per liter multiplied by 100, that gives 5 milligrams per liter, so arsenic TCLP limit is 5 milligrams per liter. Similarly, for lead and other stuff. So that is kind of gives you kind of how this number was generated. So there was the basis, it may not be a very good basis, we can always argue on that.

But that is how these numbers were derived. And I should do, I should also mention that there is a debate going on in terms of replacing this TCLP test with some other test, so which is more realistic, more but other test, because this test is mostly chemistry oriented, we want something which is not only chemistry, we want something which is actually biogeochemistry because that is what typically happens in a natural setting. But that is, it is very difficult to do something related to bio in a short period of time, so that is we need to talk about that as well.

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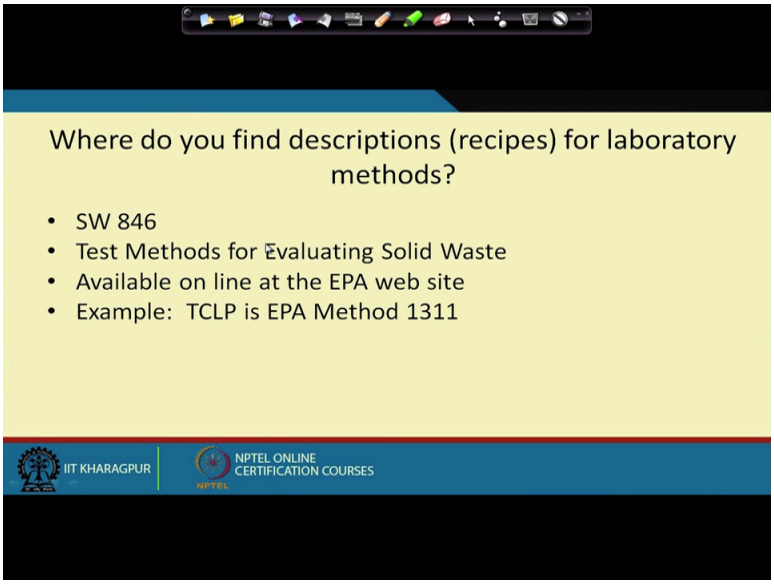

So in terms of the method for the TCLP, there is SW 846 online that is, if you google that, you will find the that TCLP method will be there. It is, there are lot of test methods for evaluating solid waste, it is available on EPA website and TCLP is the method number 11 which you can see it, check from there. So that is kind of gives you a idea about in terms of the regulatory, regulatory characterization.

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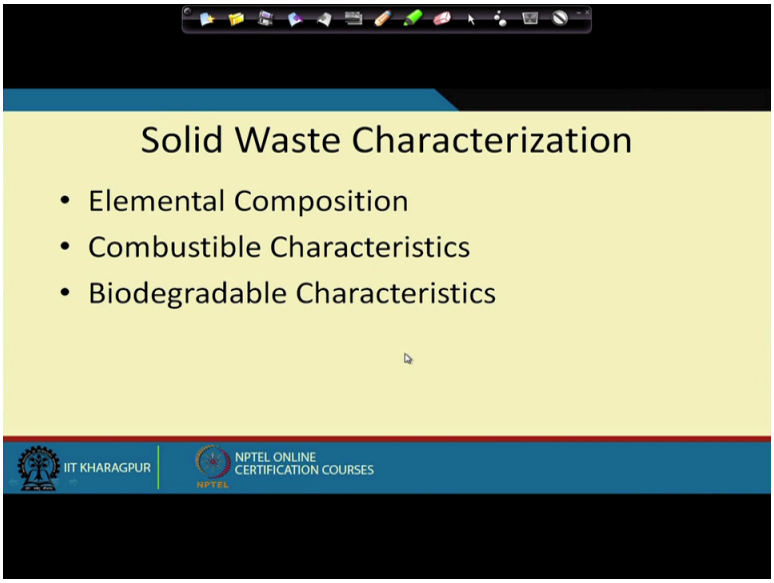

As I said earlier, we will talk about the regulatory characterization, we will talk about the elemental (comp), we will talk about the elemental composition, we will talk about in terms of

what is there in different chemicals present there, high calorific value, (degrada) whether it is easily degradable, less easily degradable, hard to degrade, all those things we will talk about as part of the characterization.

So regulatory part, we have taken care of that. It is, as I said earlier it is not always easy, it is I think it kind of gets boring sometimes as well but it is important. It is important for us to understand and I tried my best to explain that to you. And again, if you have any questions on any of these videos, you are confused, I would encourage you to post questions on the discussion board. We are, we will help answer those questions or clear any confusion you may have.

So let us close this module right here and then I will see you again in the next module where we continue this characterization discussion that we are having. Thank you.