Municipal Solid Waste Management
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Lecture - 04
Sampling and Characteristics

So hello students. Today we will continue model 2; sources, types, and characterization of solid waste. So in the previous class, we talked about different sources and based upon the different types of solid waste. Now today we will continue the same module based on sampling and characteristics of solid waste. So this is the most important discussion before the discussion about collection, treatment, or disposal.

And the characterization is very important and along with the sampling also is very important. Like for water and wastewater, we need not understand much about the sampling. Most of the students in the colleges take it the drinking water bottle for collection of water wastewater because is homogeneous most of the cases.

And if you collect the water samples or even wastewater samples from different areas, I think most of these are homogeneous sampling and very easy to collect. But for solid waste is a highly heterogeneous waste. So very difficult for the sampling as well as characterization.

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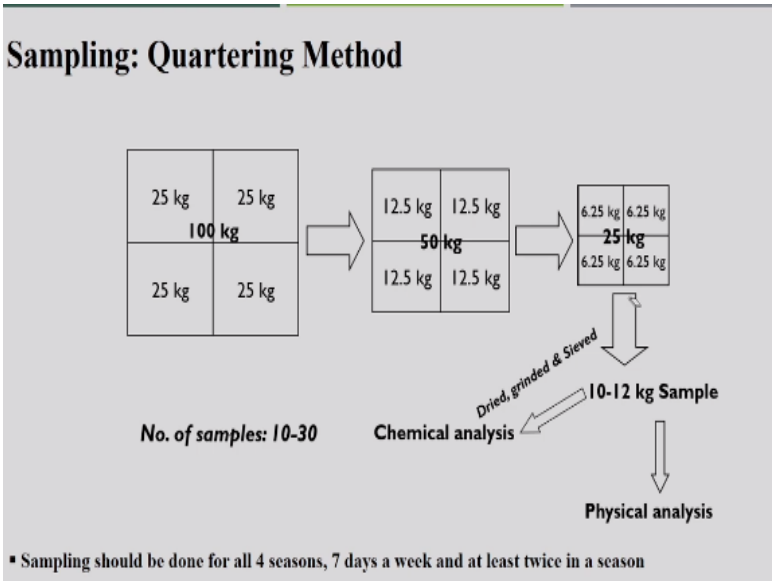

So normally sampling we do by the quartering method. This method is given by NEERI, National Environmental Engineering Research Institute, Nagpur. This method is called as a quartering method. So normally samplings will be done in the four-season, whatever the four seasons in the entire year. So is sampling itself is very difficult for solid waste.

If you want to understand the entirely different type, physical or chemical characteristics of the solid waste need to collect a sample from the four seasons and normally in a week entire seven days because weekdays and weekends are the different way the waste is getting produced and at least twice in a season. So that characterize sampling itself is very difficult.

If you locate, if you want to do the characterization study for the city, you locate out the different location and this entire area also you segregated by high-income group, low-income group areas, commercial areas, these kinds of different locations you can find it out and in that location collect the waste. I gave one example. Suppose 100 kg of waste, we put it like this, and now we will go for the quartering method.

With the entire waste will quartering in the four quarters and these two quarters, we will again put it in the same way, is a 15 kg waste. And likewise, we will go by quartering the different waste and we will get finally almost 10 to 20 kg of waste that is a sample final. And from that, we will grind it like this waste will dry it, grind it, sieve it and which will go for the chemical analysis and final the same waste will go for the physical analysis.

This is the way we can collect 10 to 20 or 15 kg of waste. That will be your sample. And the major idea about the quartering method is a need to get it the homogeneous waste, not heterogeneous waste so that and number of samples could go up to 10 to 30 different numbers of samples from the different locations. So now first we will talk about the physical analysis and after that chemical analysis.

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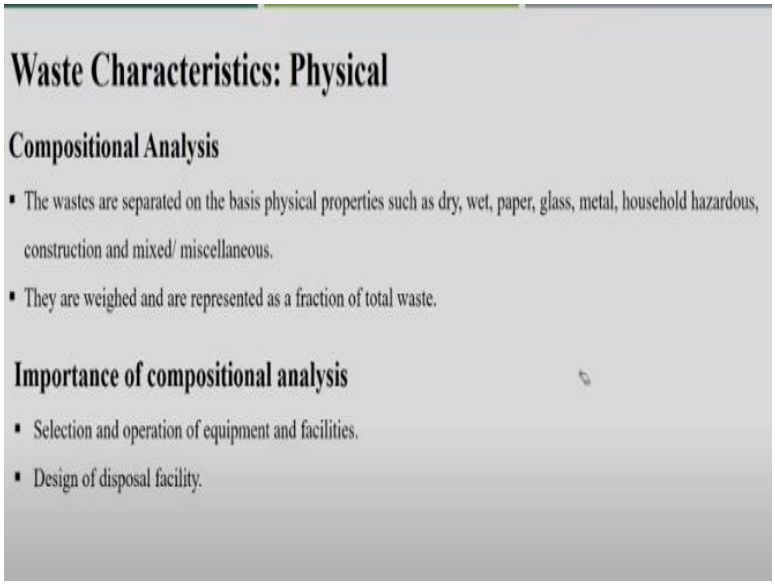

So in physical analysis, normally we do the composition analysis. We know that the waste is separated different physical properties such as dry, wet waste; how much amount of paper, plastic, or different kind of waste is available. This normally this composition analysis we will do manually. We will weight it and represent the fractions of the total waste.

This is very important for the selection operation of the equipment, facility, and disposal facility. Suppose, without knowing the composition of different waste, a physical composition like a wet waste, very difficult to design the composting plant or biological treatment plant.

And suppose if you are planning for the incineration facility and if you do not know how much amount of combustible matter or majorly combustible matter, like paper quantity, plastic quantity, rubber quantity these very important combustible materials which required for the incineration facility.

So for the not only the treatment process but also for the disposal facility need to know the how much amount of leachate is getting produced or what kind of waste is available in the entire, what kind of waste is coming to the disposal site based on that we can design the disposal facility.

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Municipal solid waste (MSW) characteristics of few cities in India as per Central Pollution Control Board (CPCB, 2000)

City	Paper (%)	Textile (%)	Plastic (%)	Glass (%)	Metal (%)	Inert materials (%)	Biodegradable matter (%)
Ahmedabad	6	1	3	-	-	50	40
Bangalore	8	5	6	6	3	27	45
Bhopal	10	5	2	1	-	35	45
Mumbai	10	3.6	2	0.2	-	44	40
Kolkata	10	3	8	3	-	35	40
Coimbatore	5	9	1	-	-	50	35
Delhi	6.6	4	1.5	1.2	2.5	51.5	31.78
Hyderabad	7	1.7	1.3	-	-	50	40
Indore	5	2	1	-	-	49	43
Jaipur	6	2	1	2	-	47	42
Kanpur	5	1	1.5	-	-	52.5	40

We will give one example like this is one study has been done by the CPCB in 2000, municipal consisting of few cities in India in 2000. If you see these entire data, you will see the paper and plastic quantity is very low. You see the plastic quantity was in 2000 was 3%, 2%, and a very small quantity. Paper quantity is also a maximum of 10%. But if you see the inert quantity and the biological quantity was more than 40%, 50% most of the cities.

And even the inert content which is not dry and wet is a different the soil content, more soil content that was very high was around 50%.

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City	Paper (%)	Textile (%)	Plastic (%)	Glass (%)	Metal (%)	Inert materials (%)	Biodegradable matter (%)
Kochi	4.9	-	1.1	-	-	36	58
Lucknow	4	2	4	-	1	49	40
Ludhiana	3	5	3	-	-	30	40
Madras	10	5	3	-	-	33	44
Madurai	5	1	3	-	-	46	45
Nagpur	4.5	7	1.25	1.2	0.35	53.4	30.4
Patna	4	5	6	2.0	1	35	45
Pune	5	-	5	10	-	15	55
Surat	4	5	3	3	-	45	40
Vadodara	4	-	7	-	-	49	40
Varanasi	3	4	10	-	-	35	48
Visakhapatnam	3	2	5	5	-	50	35

If you see the other cities like the other cities also like in Madras 10% paper quantity, plastic is only 3% inert content is 33% and biodegradable concentration was almost was more than 50%.

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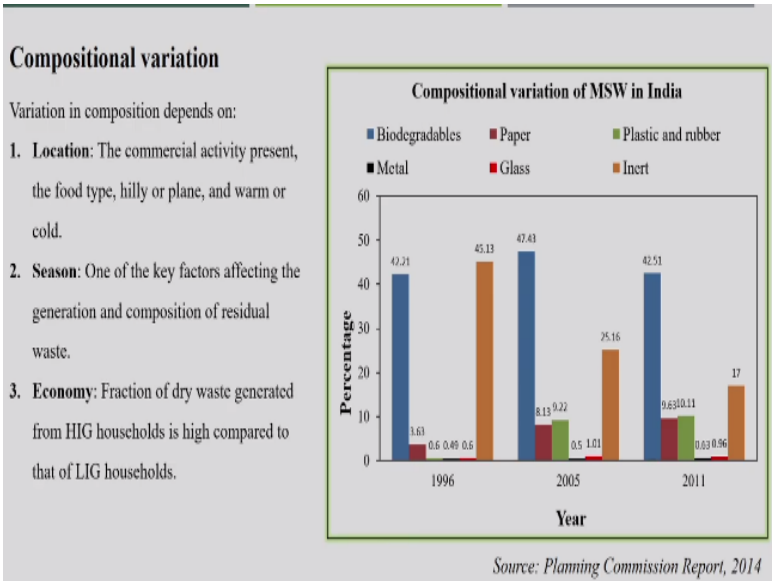

But, if you see in the this is another report by the Planning Commission in 2014. If you compare with these data with 2000 you will be surprised that the plastic quantity was very 3%, 1% was increased in 2000 was more than 10%. And even the inert content was very high in 1996 or around 2000 about 45% was reduced to only 17%. And **by** but see the very surprisingly the biodegradable quantity was 42%, 47%, and even in 2011 2014, 15 42%.

Still currently in 2020 also you see that the biodegradable fraction is almost 50% and the paper and plastic quantity was increased to the 15 to 20% and inert content was reduced to 30%, 35%. One more waste is added construction and demolition waste. That quantity with the day with the industrialization and developing the into the city that quantity is also increasing now.

This composition variation depends upon the different parameters like first is the location. So is the location wise, what kind of commercial activity in that particular location and simply with the plane areas and hilly areas, these compositions, the entire physical composition will change. Even in the warm and cold areas, these physical compositions are getting changed. And the season.

Now that is why when I talked about the sampling, I said that the sampling should be in different seasons. Because the season-wise the entire waste or commercial facility, commercial materials also availability is different. So the season also is one of the important parameters to know about the different components of solid waste.

Now another the economy. So that is why when you do the sampling, I asked you if you collect the sampling from the city area, we need to the entire area has to be separate into the high-income group, low-income group, and commercial areas market areas, vegetable market. So that based on that with the time and with the economy is getting changed different waste compositions.

So it is very important to know about the waste composition. So when you are planning for the sampling also needs to be planned every after 10 years, 15 years. You need to do the sampling and to know about the different physical compositions are changing with the time so to design the recycling facility or any disposal facility.

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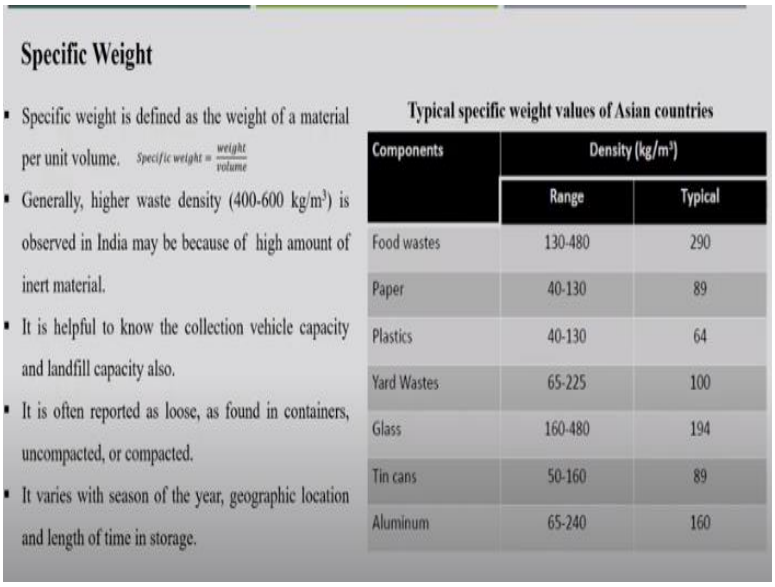

Now another parameter in the physical characterization is the specific weight or density. This very important to know about how much volume. I think normally when you talked about the solid waste we normally talked about in the weight, but the volume is also very important to know about how much area will be required into the disposal site. So that in the disposal site how much land will be required.

For that, we also need to know how much what will be the density or the volume of the solid waste. And this specific weight or density is calculated by weight by volume. Normally in India or the developing countries have very high-density waste that goes to 400 to 600 kg per meter cube. Is because of inert content, more inert content. And more I also told about the construction and demolition waste.

That is also because of that, we are getting a very high density of waste. So if more density means your collection facility will be different based on that. This is one of the data for the specific weight values of the different Asian countries of mostly Asian countries. If you see that food waste, especially for food waste the density is very high. Likewise, for paper and plastic, the density is very low.

Like just 100 kg per meter cube. So is also changing with the different season because the compositions are changing. Based on the composition density will also change.

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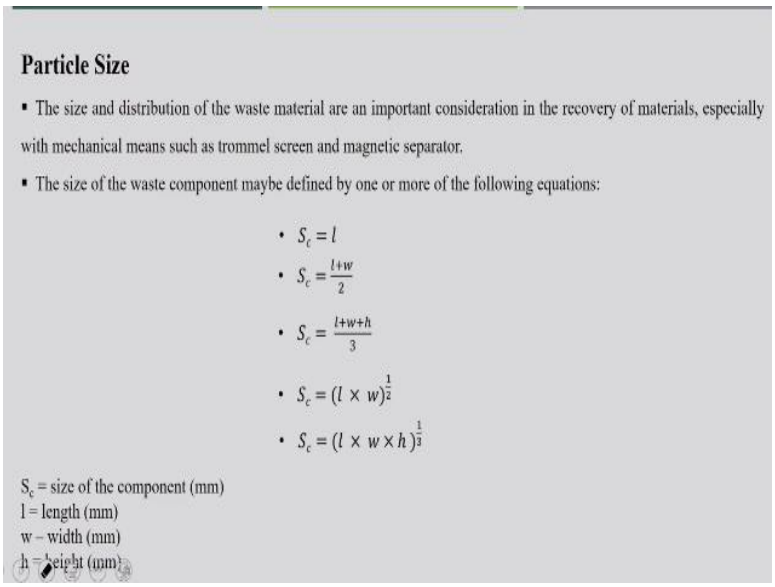

Another parameter is called particle size. These parameters normally are important for the recycling facility because there we need to know what kind of size. Even for the degradation process also we need to know the particle size. There are different ways of calculation of particle size like there are different ways based on the length and width or height of that particular material.

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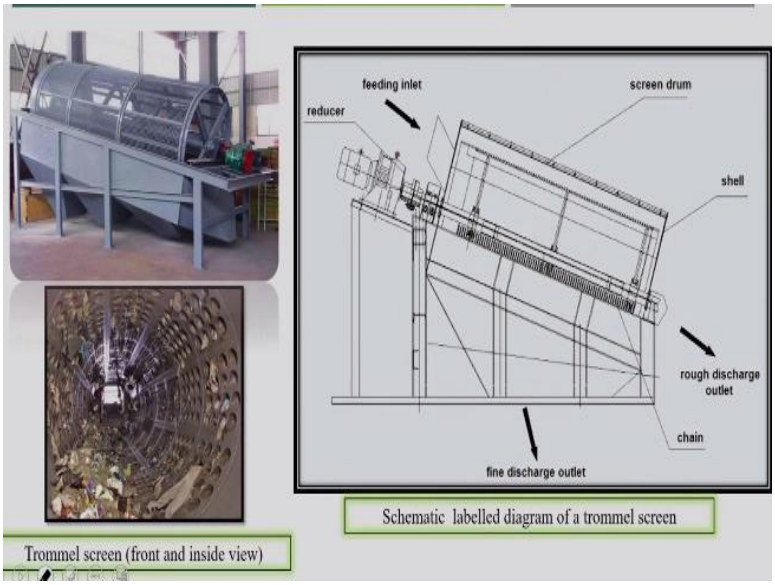

So and these are the few machines normally or equipment we use to separate the different sizes of the particle. Like this is Trommel. This is simply one of the other Trommel screens.

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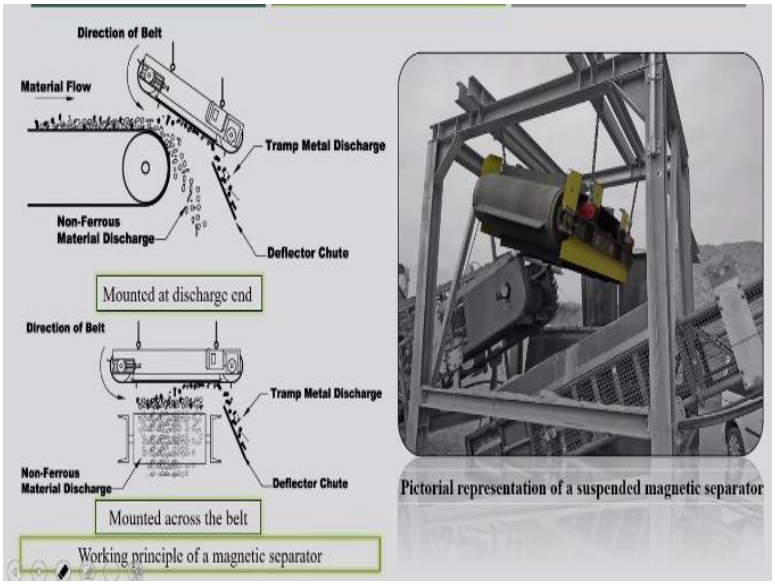

This is a magnetic separator. Like here one another magnetic separator. So from that, the magnetic particle is getting separated from the main waste.

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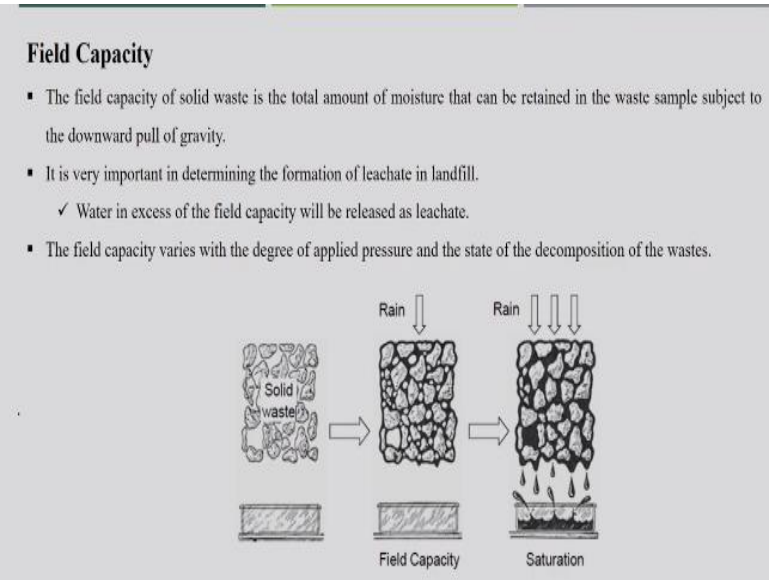

So this is another physical parameter is the field capacity. This field capacity is the total amount of moisture that can be retained in the waste sample subject to the downward pull of gravity. This parameter is very important to know about how much leachate is getting produced once the waste goes to the disposal site. So is an excess of the water over the field capacity will be released as leachate.

Normally this analysis you can understand by this photograph, the solid waste. Once the rain onto the disposal site will get the leachate production. That is called the field capacity.

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So I will show you some of the photographs. So these are the leachate. Is the leachate produced after the rain onto the solid waste? This is also another photograph of

leachate. These normally if you know this quantity before the waste goes to the disposal site, we will be able to design the collection facility and treatment facility of the leachate.

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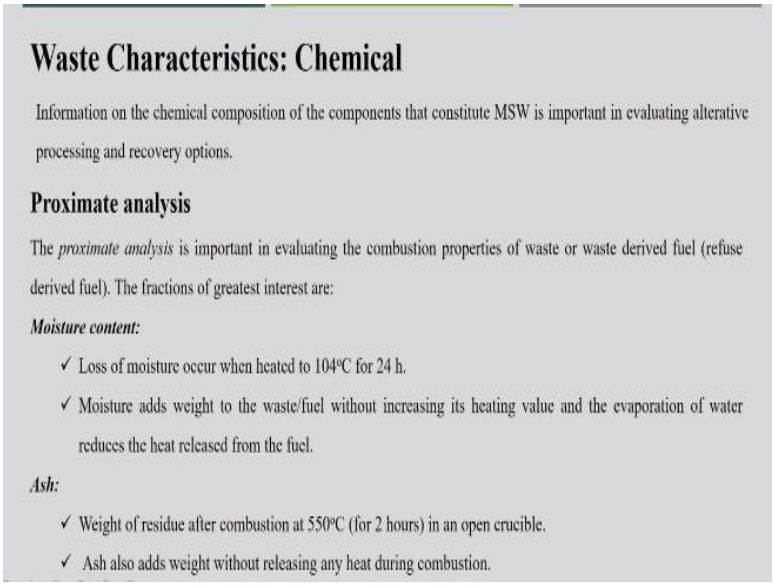

Now the chemical characteristics. This chemical characteristic is very important, especially for the treatment processes. Now the first is the proximate analysis. The proximate analysis normally analyzes to know about the combustion property of the solid waste to design the incineration facility or combustion facility of the solid waste. Normally it analyzes the four parameters. The first parameter is the moisture content.

Moisture content normally is analyzed by 104 degrees centigrade in a hot air oven for 24 hours. Normally this moisture adds weight to the waste without increasing its heating value. So once the way you are designing for the incineration facility is very important to know the moisture content.

If more moisture content will be required, so more this unnecessary adding the weight into the waste and there would not be any increase in the heating value with having the moisture content into the waste. Another parameter is called ash. These analyze at 550 degrees centigrade for two hours in the open crucible. Is analyzed and this also added the waste without releasing any heat into during the combustion process.

This is also a very important parameter. After conversion, if the waste is producing a large amount of ash, it is very difficult to dispose of such kind of ash material.

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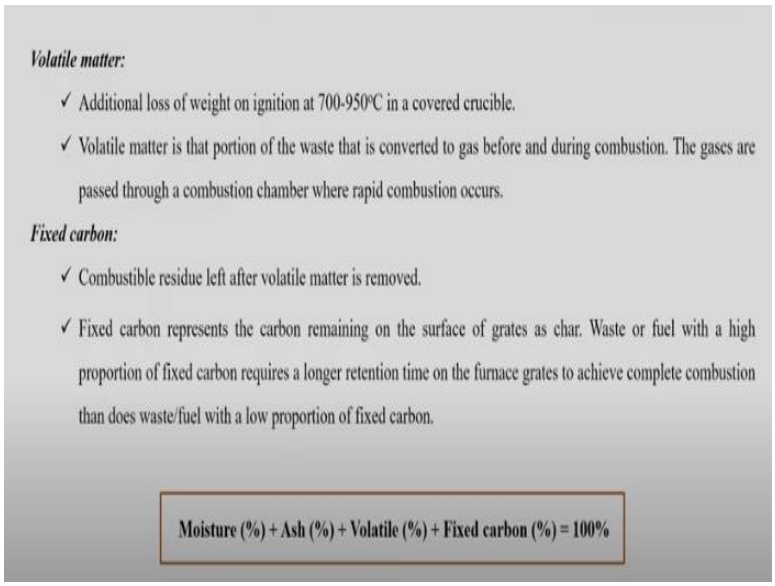

Another parameter the third parameter is the volatile matter. This was also analyzed by 700 to 950 degrees centigrade in the covered crucible. Volatile matter is a portion of waste that converts to gas before and during combustion. This is a very important parameter for the combustion facility. If for incineration facility more volatile solids are there more will be the heating value of the waste.

More energy could be possible to produce. So another parameter is a fixed carbon. These fixed carbon represent the carbon remaining onto the surface of the grid where the waste is getting incinerated in the incineration facility as char and this is unnecessary waste is getting produced in the while combustion of the solid waste. Normally this fixed carbon is calculated by all these four parameters should be 100%.

So you can calculate the moisture content, ash content, volatile and also we can calculate the fixed carbon. If more fixed carbons are there in the waste, very difficult to go for the combustion facility.

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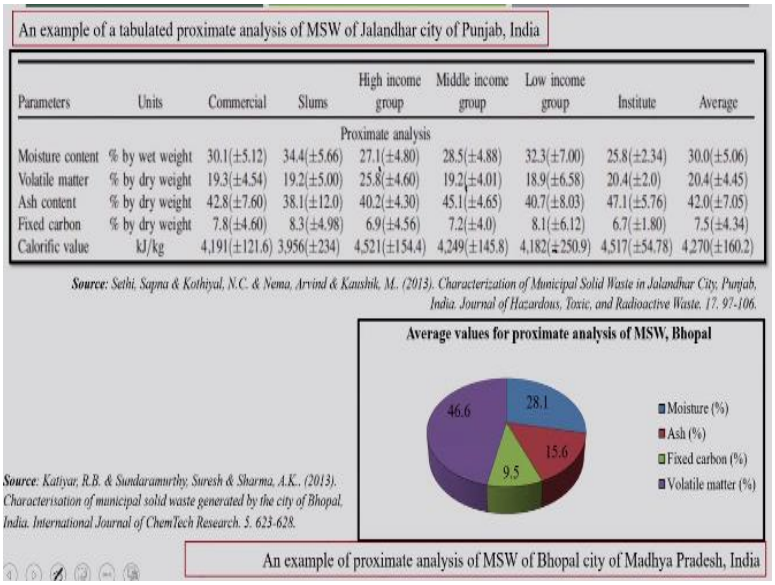

This is one example of one study that has been done for Jalandhar city in Punjab by few authors. And you can see here the approximate analysis of the different high-income groups, middle-income groups, and low-income group areas. And you will see you see the data of volatile solids, volatile solids data for the high-income group is 25%, middle-income group 19%, and the low-income group is 18%.

So with the different areas, we did that sampling in different areas. Based on that your entire the proximate analysis is getting changed and you see the fixed carbon 6.9, 7.2, 8.1. It is getting an increase in the low-income group area compared to the high-income group area. Similarly, the moisture content also is very low in the high-income group area and more into the low-income group area.

Likewise, with the different areas of different proximate analyses, we will understand what will be the even you see the calorific value of the waste is getting changed in the different areas. So this is another data of Bhopal, where you will see the volatile solid is 46% and moisture content is 28%. So based on that we can understand whether the waste can get combustible or can go for the combustion facility.

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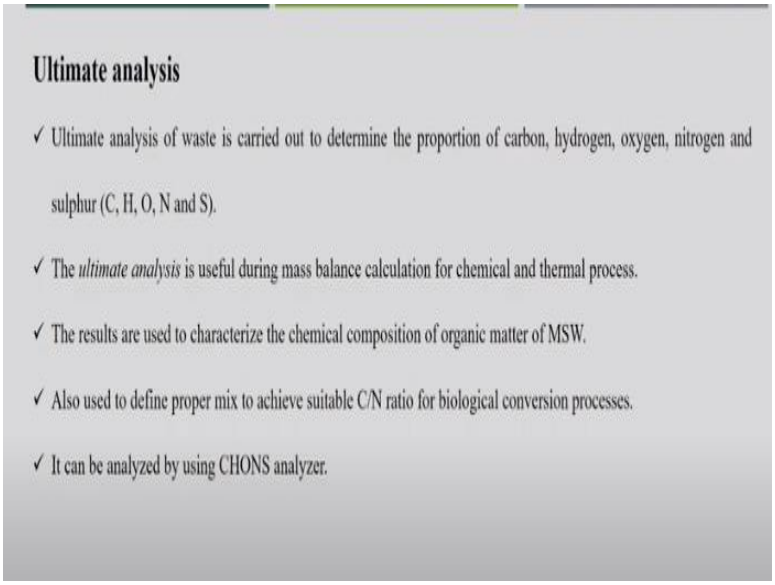

Now the ultimate analysis. Normally the ultimate analysis of the waste is carried out to determine five different parameters like carbon, hydrogen, oxygen, nitrogen, and sulfur. These are the five components normally analyzed for the waste to know the ultimate analysis. So these data like here, if you know the hydrogen concentration is very good for the combustion facility, even carbon concentration is more very good for the combustion facility.

If you know the nitrogen concentration is very good to know the biodegradability of the waste or if you want to design the composting plant anaerobic digestion plant, if you know the carbon to nitrogen ratio, that is very good for the designing of such kind of biological treatment facilities. And it is analyzed by a CHONS analyzer. This is one particular instrument where we can analyze these five different components.

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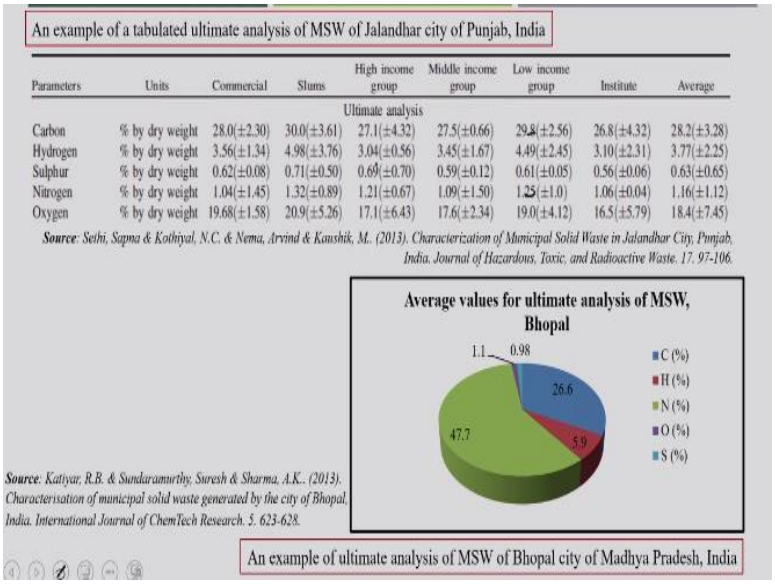

So for example, again I got some data for carbon, hydrogen, and sulfur. If you see here the hydrogen concentration is 3%, 3%, 4% hydrogen concentration. The carbon concentration is 27 to 29%. So based on that we will come to know even nitrogen also 1.21% is good for the degradation facility. And this is another data where carbon concentration is 26% and nitrogen is 47.7% means more waste is good for the biological treatment facility.

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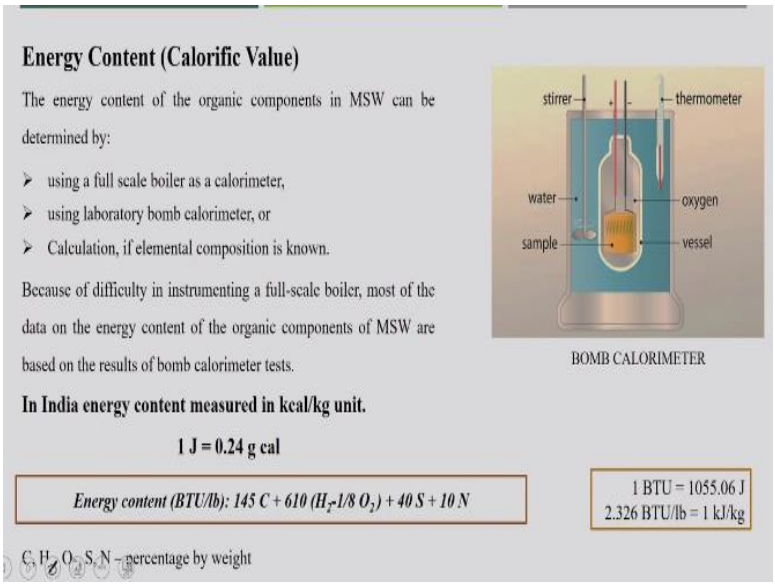

There is another parameter called energy content or calorific value. This is normally designed by a full-scale boiler as in calorimeter or laboratory one bomb calorimeter. This is one small diagram of the bomb calorimeter. In a vessel, the waste is getting combusted. And normally this energy content we calculated by this formula having the concentration of carbon, hydrogen, oxygen, sulfur, and nitrogen.

But in India, we analyze by the bomb calorimeter and in India, we analyze the energy content measured in kilocalorie per kg unit. This is one unit we are using in India kilocalorie per kg. So one Joule is equal to 0.24 grams of calories. So just for understanding.

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Calorific Value and Moisture Content of MSW in Indian Cities (Source: CPCB:NEERI, 2006)

Cities	Net Calorific Value (kcal/kg)			Moisture Content (%)		
	Min	Max	Mean	Min	Max	Mean
Cities with population less than 1 lakh	1234	3414	2149	42	65	52
Cities with population of 1-5 lakh	591	3766	2162	24	63	50
Cities with population of 5-10 lakh	591	2391	1481	17	64	48
Cities with population of 10-20 lakh	520	2762	1411	25	65	41
Cities with population above 20 lakh	834	2632	1772	21	63	47

So this is some data we collected from CPCB NEERI 2016, where they characterize the entire waste based on the different populations of the city. So cities with a population less than one lakh the calorific value are 2149 kilocalorie per kg and with the moisture content 52%. Like if you compare with the same, the cities with the population are above 40 lakhs your calorific value is less 1772, and moisture content is 47%.

So if you see the entire data calorific value is very high maybe because of paper and plastic or combustible matter, but because of more food waste, more biological matter, the moisture content is very high is 47, 50%. So such kind of waste is very difficult for the combustion facility. So is good if it is getting segregated, the biological waste will go to the composting plant and the dry matter will go to the combustion facility. That is the best thought of this kind of data.

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Calorific Value of Different Fractions of Waste (Source: ISWA, 2013)

Faction	Net Calorific Value (kcal/kg)
Paper and cardboard	3821
Organic material	955
Plastic	8359
Glass	0
Metal	0
Textile	4538
Other materials	2627

So another table you see that it was given by the International Solid Waste Association in 2013. The different fraction of waste what will be the net calorific value? If you see the paper, plastic, and textile, how very high net calorific value. But if you see the order organic material is very low concentration, is just 900 kilocalorie per kg. So such kind of waste is not good for the combustion facility.

If you get separated like paper, cardboard, plastic, textile, this material is highly combustible. Will easily get the net calorific value more than 3000 to 5000-kilo calorie per kg and metal and glass do not have any calorific value.

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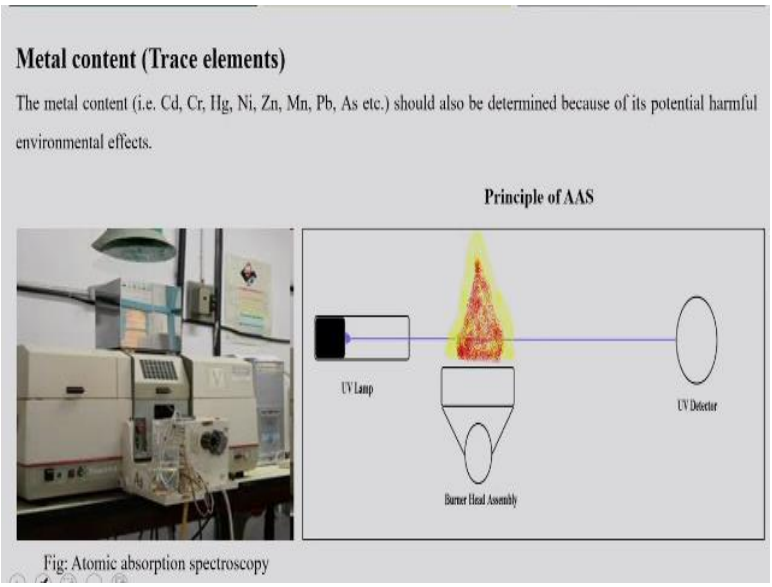

Fig: Atomic absorption spectroscopy

Now another parameter is metal content. Also is very important to analyze once the waste is going to the disposal site. Once the leachate is getting produced in the

disposal site, these metals are adding into the leachate and getting polluted the groundwater. So for that also is very important to know the metal analysis. These analyses normally we do by atomic absorption spectroscopy.

This also I think because is a solid material, the powder material, dried, ground to powder material has to be digested and converted into the liquid sample and get it analyzed by atomic absorption spectroscopy instrument.

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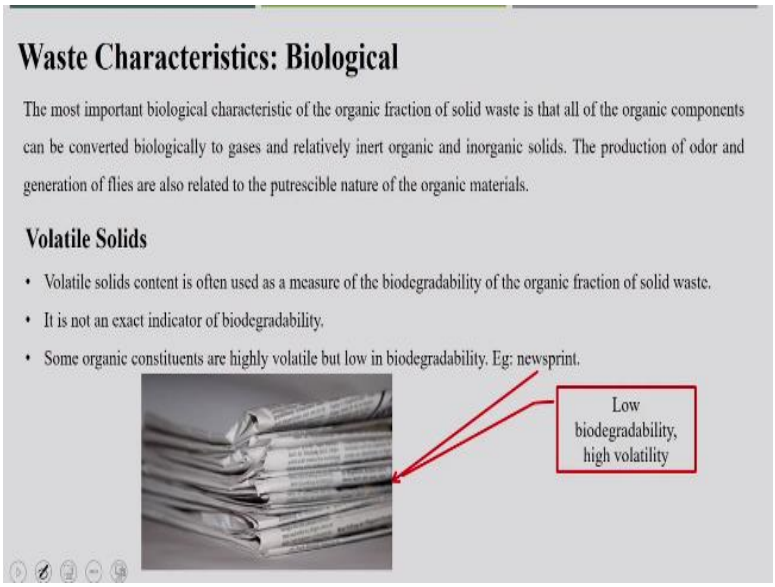

Now the biological characteristic. This is one of the very important characteristics also to know that the biodegradable fraction of the solid waste. This normally we do by volatile solids the same way, the way we analyze the solid waste for solid volatile content. This is not the exact indicator of the biodegradability.

But if you know the volatile quantity both way for the incineration facility and biological treatment facility both these parameters are very important. Just for one example, like paper, print newspapers are highly volatile matter. Is a very good combustible material. But it is not biodegradable. Is highly volatile, but is not biodegradable.

So it needs to be understood that both the dates are not the same as every volatile material is not biodegradable material. But every biodegradable matter is volatile in nature. So I think for this paper and plastic, even plastic also volatile matter, highly volatile matter but is not degradable matter.

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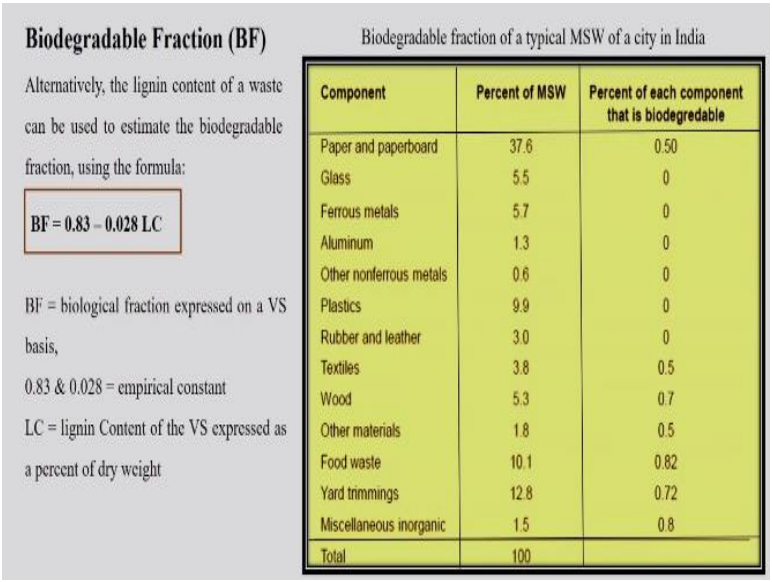

So for degradable fraction we normally we analyze by one equation like biodegradable fraction is 0.83 - 0.28 lignin content. So if you know the lignin content of the waste, is easy to calculate the biodegradable fraction of the solid waste. If you see the one particular data of India, the percentage of MSW of the different data like food waste is 10%. The glass is 5.5%, plastic is 9.5%.

But the biodegradability of this particular percentage is very low except the food waste having 10% in the MSW is having 0.82% of the biodegradable fraction. So and this yard trimming is also highly biodegradable. So from this, we can easily understand how much is the biodegradability of the particular fraction.

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So another few more parameters normally we never analyze such parameter but need to understand that. The breeding of flies. Normally it will take one week to two weeks. Once it is getting through that particular location. This is very important to know while designing the dustbins inside the city. If waste is getting stored for the longer period I think the breeding of flies is possible in such kind of locations.

And the odor also. This is very important. This odor normally is come from the two major gases like methane and ammonia gases. Normally methane is a very low concentration of methane is getting produced, but ammonia because the wastes contain a lot of biodegradable matter so nitrogen content is very high.

And these organic nitrogen is converted into the during degradation process or anaerobic condition this organic nitrogen is converted into ammonia and that creates the odor issue. Thank you. So with these characteristics, we will easily understand the different characteristics of the solid waste. Based on that we will be able to design the collection facility and also treatment facility. Yeah, thank you.