Course on Integrated Waste Management for a Smart City
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Module No 07
Lecture 35: Thermal Treatment (Contd.)

Okay, welcome back. So we will get start where we left yesterday.

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If you remember, like in the previous module, we were looking at this overall like how to go about doing a integrated waste management plant, I think we have spent enough time on it. So just to give you a quick recap, this is what we were talking about in the last video towards the end of the video like how to go about developing a integrated waste management plan.

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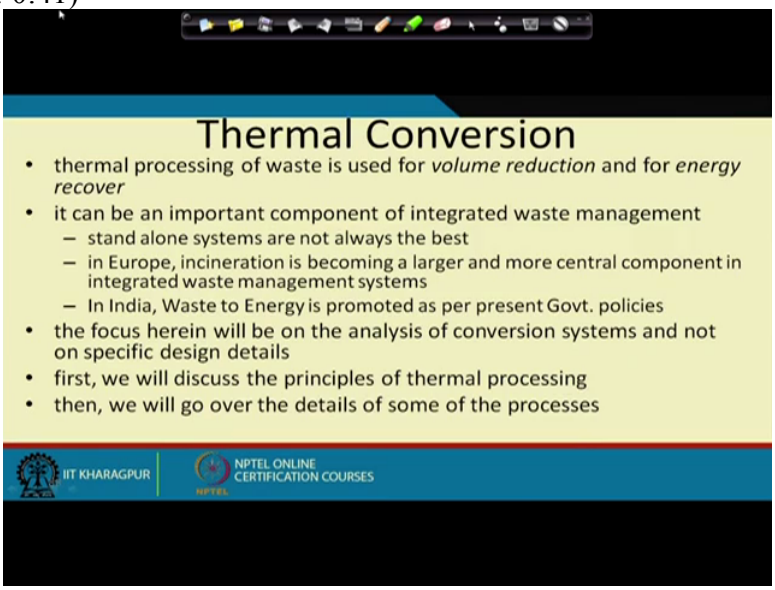

And now today we will go into talking about more in detail about the thermal conversion. I explained to you how this thermal treatment fits into the integrated waste management plan as part of our discussion yesterday. So now let us look at this thermal conversion in the details of like the technical aspects, the technical details of this thermal conversion. So thermal conversion we used to it can be done if you think about thermal treatment or waste combustion, we have been torching our garbage, we have been putting our waste on fire since a long long time.

There has been a practice in agriculture that at the end of the harvest season, some of those agricultural waste which is left, which is left on the field itself, the farmers will put things on fire. And then that burns and that also adds some nutrient value of the soil. So there is a benefit of doing that and of course, there is a problem of doing that too in terms of the air pollution and all that.

But since in the old days we were not that much aware of our air pollution, not much aware of that the burning will cause some this particulate matter and all those dioxins, furane and those agricultural waste actually will not create dioxins and furane unless they will create mostly shoot particle, PPM, and some may be some if sulphur is there, nitrogen is there, some Sox and NOx may be created. But in most part, those dioxin, furane, polycyclic aromatic hydrocarbon and those things happens in the presence of chlorine.

And in the , so plastic actually creates. So because of the plastic coming to our waste, this waste incineration, uncontrolled burning of garbage or open burning of garbage as we see it in many places. In our country, in India if you just drive around the countryside, drive around the near the dump site, you will see many times the waste is put on fire. And the reason it is put on fire is to just to reduce the volume of garbage so that the volume of garbage is reduced and you can use that as a part of, the space that is created on the landfill can be used to put more garbage on top of it.

So that is the reason why many times you see the uncontrolled burning. And many times people burn garbage on the backyard as well. So those relate to a lot of air pollution issues and there has been documented research now which documented report done by United Nations Environmental Program, a UNEP so if you do not believe me, you can believe the UNEP report which says that uncontrolled burning of waste, uncontrolled burning of garbage is the number 1 cause of dioxins and furanes in the world.

And dioxins and furanes are one of the like most nasty air pollutant that we can think of. It is considered as a carcinogen and it can lead to different type of disease. So that is and of course there are other pollutants out there as well. So we have been burning garbage for long time, uncontrolled burning of garbage has been going on since many many many many years, probably centuries and then still continuing in many in several parts of the world.

But from time say, for last few decades, we have been focusing on doing a what is known as the waste incineration in a thermal treatment plant. So where we are treating the garbage. So we are basically taking the waste and thermal treatment part, treatment is more we have got that name from hazardous waste because the hazardous waste thermal treatment is very popular. There the focus is not that much on energy recovery. Their focus is more on collecting, make this hazardous waste less harmful.

So when you burn this hazardous waste or even for biomedical waste, so as even for as for the biomedical waste to rules of India, the government our Indian rules, it or even that is pretty much everywhere in the world, it requires that big hospitals should have their own incinerator. And when we say incinerator, it is basically a thermal treatment unit and it has a air pollution control system. So it is a highly engineered system.

And so they will have their own incinerator unit where they should burn this garbage and if they do not have their own, they should have a tie-up with a waste incinerator where this biomedical waste is sent and then biomedical waste is burnt on those, in a controlled environment with all this proper air pollution control system and this ash that is produced, is no more harmful because all the pathogens, bacteria and other stuff will be burnt and it is whatever is coming out, it is not harmful and that can go to a landfill and things could be recovered from them, from that as well.

So that part that treatment name came from there. And for the municipal solid waste what we are doing is, we are essentially trying to generate energy from this. So that is, we use more of a term waste to energy. Although when we say waste to energy, even the anaerobic digestion is also waste-to-energy. When we talk about anaerobic digester which is different is the biogas and then you use the biogas for energy purpose, landfill gas to energy is also there.

Like if you operate landfill and then you collect the gas, these days there is a concept of bioreactor landfill as well where you operate landfill as a treatment system and then you collect the gas and then you use that gas for energy purposes. So those things are also done but when we talk about waste to energy from a waste incineration point of view, we are talking about essentially the like either incineration, there are different types of incineration we will talk about.

And so and the more broader term is thermal conversion. So where we are trying to do some conversion, we are trying to convert the material as is as I have been telling you several times that whatever material is there, we cannot really destroy it. We are only converting it. We are converting it to one form or another form. It is a, you may have heard me saying several times that anything on the periodic table, we as a human does not have the power to destroy those essentially.

We can only change its form either from one form to another form, something less useful form to more useful form, less leachable to more leachable or vice versa, more leachable to less leachable but they cannot really destroy it. So thermal conversion it is a where we are trying to do the volume reduction, one of the major aspect here is to do this volume reduction. So what is this volume reduction?

If you start with 700 tonnes of garbage, you are end up with 10 tonnes. So your almost 90 percent volume reduction happens if you go for a waste incineration process. And also we are looking at the energy recovery. So when we are talking about the energy recovery, the calorific value becomes very important. So calorific value is very important of the garbage and that is what I was trying to tell you in the previous video that we have to be really careful with this calorific value.

We need to really assess the calorific value very carefully and for the waste which is coming at the dump site which or at the waste to incinerator because the waste composition especially in developing countries, is keeps on changing. Like what is produced at my home and what will end up at the waste incinerator gate is different because the Kabadiwalas, the ragpickers and there are other animals eating some of those organic, so the composition keeps on differing and we need to be careful in terms of where we collect the data from.

And it is an important component of integrated waste management plant which I was trying to explain earlier. Standalone are not always the best. You cannot just have waste to energy system. So if somebody comes to you and tell you that they will send up a waste-to-energy plant say for like for a small, let us take a small city, example, for example say even for Kharagpur where there is, I am sitting at IIT Kharagpur campus.

Just outside the campus, we have a very I would say important city from point of view of air pollution, from point of view of railway, and so it is important for the Kharagpur town or Kharagpur if somebody says that we will set up a waste incinerator and we do not need anything else, we do not need a composting plant, we do not need anaerobic digester, we do not need any waste management, only waste incinerator will do your job, no. I think that person is just trying to fool us.

So it is not going to work on its own. Of course, it can be part of the solution. So that is why, integrated waste management plant, then name is the integ you have to have the different components in there and waste to energy or this is this could be an important components specially for the part of the waste which has high calorific value, relatively high calorific value which can be used for the treatment in the system. In Europe, incineration is becoming a larger and more central component.

Why? As if you go to any country which has less land, high population density, less land, does not, cannot have landfill. They cannot just put all the waste into the landfill. Waste-to-energy, you will see more there. Other thing is the regulation also supports. In the European context, the regulation actually supports waste to energy. In in US, it is not that much because the US is depends on which state you are but most of the state still relies on landfill as a major way of disposing their garbage.

Although there is a lot of popularity these days on doing anaerobic digestion and (())(10:10) can we go for composting, there is also waste-to-energy plants are coming up. Same thing in China, lots of waste to energy plants are coming up but usually they are in combination with other systems there as well. But in Europe, you see more and more waste to energy plant. Again China, it is trying to build more and more waste to energy plants as well.

And say some countries like Sweden and other places where they have even this, they are importing garbage from other European countries. They are importing garbage so that they can have this waste-to-energy plants running. Many places in Sweden, specially those cold countries what they are using, the energy produced from waste-to-energy plant is used for district heating. When we say district heating, it is the heating of the homes in the surrounding areas.

So since the winter is there every year, and with more and more recycling happening in these western European countries, they do not have enough garbage to feed those big incinerators they have built. So they import garbage from those European countries which cannot meet the European Union target of diversion. Like diversion means how much waste should not, is away from the landfill.

We talked about that earlier, diversion is a term used for waste which is not going to the landfill. So to meet the diversion targets, some of these countries like Poland, even UK, they send their garbage to Sweden and it gets burnt in Sweden. So Swedish people use that as energy for their home heating and it is kind of win-win for both but it is again, the waste is travelling, we should do a life-cycle analysis to find out what is the real footprint because of the transportation does release with the use of fossil fuel and other stuff, transportation will release carbon dioxide and other gases.

In India also, even for last several years, like I would say almost 5 or 6 years now, since the time of our I think few years back when honourable finance minister was P Chidambaram, he 1st announced where we were trying to promote waste to energy in India. That was in budget. There was a specific provision for waste to energy. And waste-to-energy plants are being built up. In Delhi, now we have two, then other places from time to time I do see RFPs, request for proposals or DF DPRs being requested to do a waste to energy plant.

So waste to energy is becoming a talk of the town. Like in Indian context, we did had some poor experience with waste to energy, I was talking to you about the Timarpur plant earlier. But Timarpur is passed now. Things are much better and as long as we do things properly again, we need to design our plant properly, make sure we collect the real data. And if the calorific value is low, so be it. What we can do?

Like our Kabadiwalas does a great job, rag pickers also collect some of those stuff. So our calorific value will be always low and if you compare us with US and other Western countries, but we have to work with those calorific values. There are companies now which claim that even with low calorific value, things are going to work. Of course, we need to check those claim but at the same time we 1st have to realise that our calorific value is low and then we how to make waste to energy work with this low calorific value.

And so that is what but there are in terms of the government policy, the waste to energy is promoted as per the present government policy as well, even in UPA 2 it was there and present government is also is promoting this government policy on waste to energy. So in this particular section that we will be covering in this course, the focus will be more on analysis of the conversion system, like which conversion system is best to use where and what will work in what context.

We will talk about design but we will not go into like nitty-gritty detail about the design because that itself kind of become like a course for a few weeks. So we will not go in very detailed design and if you are interested can contact me separately and then we can, I can provide you some information on how to go about that but in the in the course we will be more in terms of design we will do some design but we will just do some basic design, we will not go into the detailed design as you saw in for the composting, anaerobic digestion as well.

So we will discuss the principles, what are the principles of thermal processing, then we will go over the details of these processes so that you understand and which process to choose based on your waste composition because that is the number 1 thing you have to do. Once you have figured out which system is going to work for you, there are companies out there which could provide you the technology and if you need help, there are people like me available in the country who can help you to choose choosing the best technology that will work for you for that particular process.

But 1st you need to understand, like to make waste to energy work, what things should be there and what mistakes we should not make because, so that we have a good waste-to-energy plant working.

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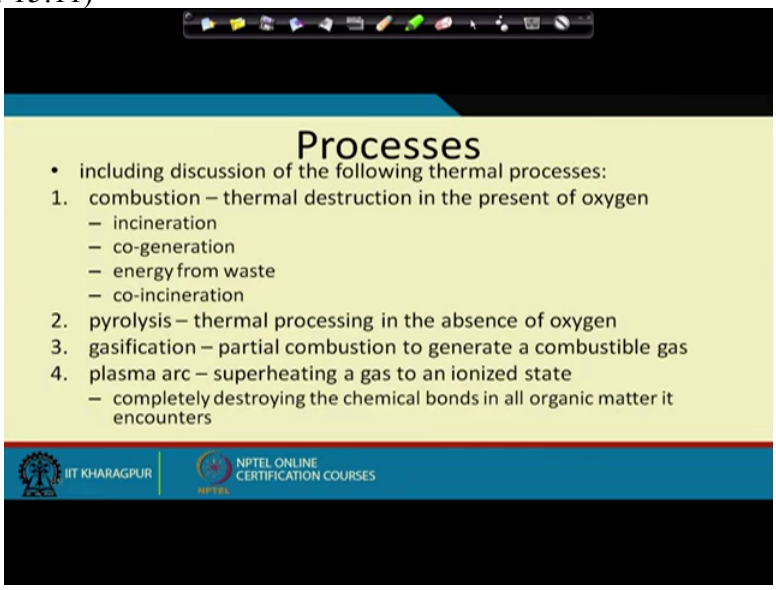

So in terms of the process, there are essentially there are 3 or 4 more, there are 4 listed over here, reason I said 3 or 4 because last one is mostly for hazardous waste. But let us talk about them. It is in terms of the process, combustion which is you hear the most and combustion means essentially you are burning and you are burning in a controlled environment. So that is the combustion part. So combustion is thermal destruction in the presence of oxygen.

So you need to have oxygen. So if you remember the fire triangle where you need some, you need oxygen, you need a ignition source. I am not very good writing with this but that is the

ignition source. You need oxygen and then you need something which will burn. So this is your like a combustible material. So we have combustible material, we have the ignition source and then we need oxygen. So these 3 is needed. Otherwise you must have heard about fire triangle or in your any class earlier.

So essentially what it does is what is happening here, it is in the presence of oxygen. So what? It is an oxidation process. So combustion is an oxidation process. And what will burn? It is all those volatile solids. The volatile solids is what is going to react and we will talk about that with the pie chart again. So volatile solids how we how we identify volatile solids?

You take the sample, you put it in the muffle furnace at 550 degrees centigrade over a period of I think 72 hours and then you look at the loss of mass before, you weigh the initial mass with the Crucible and after you take it out from the that the bottle and had furnace, you weigh it again, the difference gives you the volatile solids. So that is the (())(17:12) what is going to react in this particular process. And in terms of this, what is there in terms of if you go to the individual element, is mostly carbon, hydrogen, oxygen, nitrogen, those sulphur, those things are present.

And once they react with oxygen what they will produce? They will produce carbon dioxide, they will produce moisture vapour, they will produce sulphur dioxide, they will produce nitrous oxide, Nox, Sox, Nox, N2O, NO2 depending upon the reaction, it could be carbon monoxide or carbon dioxide again depends on the reaction. So these are the things which will so if you know again we have to know the formula of this volatile solid which which we will go there.

So but in terms of the process, in terms of the we have combustion which is essentially a oxidation process. There are different names given to the combustion, we have incineration, cogeneration, energy from waste, or co-incineration. And most of them actually, incineration is you have the waste coming in, you are putting into incinerator and then the waste is is burning, it is producing energy, your the heat, that heat is used to feed the boiler and the boiler makes steam and steam generates the electricity so that is with the turbine and all that.

So that is how things work and that is the basically here rather than using so if you if you compare this with the coal-based thermal power plant, rather than using the coal, you are using waste as a energy as the fuel. So that is what it is. Then cogeneration is when you are actually

trying to mix something together. Energy from waste is which is essentially you have you in the incineration plant you may not be just you may not be able, you may not be collecting any energy.

You are just incinerating it for the sake of thermally destroy it but when you try to do energy from waste, your focus is on energy generation. so you are trying to make energy out of that garbage. Co-incineration is when you are mixing with something else. So those are your co-incineration. So all those things are essentially it is a combustion it is a combustion process. That is what it is. And then in terms of combustion since we have to supply oxygen.

And as part of this particular course, we will do some calculations like how to find out how much oxygen will be required to be supplied and all those things. Now the 2nd part is, what we talk about is is the pyrolysis. The 1st part combustion is in the presence of oxygen, pyrolysis is in the absence of oxygen. So you have, you do these things in the absence of oxygen. It is in terms of the municipal solid waste like a general municipal solid waste, you do not see that much pyrolysis plant.

Pyrolysis plants are there which are operating for kind of specific waste, for certain specific waste stream pyrolysis works and pyrolysis is used as a process for thermal treatment. But for in general municipal solid waste, you do not see that much of pyrolysis plants out there. Gasification where you are, you do partial combustion. You do the partial combustion to generate a combustible gas. So you do not do 100 percent combustion.

You do a partial combustion and you you produce a combustible gas and that combustible gas could be used as a fuel source to so that is another thing that is done in terms of in terms of the process. Then plasma arc, plasma arc is actually you are super heating a gas to an ionised state. So plasma arc what you do, you take the waste and heat it all the way to almost like 10,000 degrees centigrade. So it is a highly energy intensive process.

If you remember, in the beginning I said usually we do not see plasma arc plant for municipal solid waste. The reason for that is its it is a highly energy intensive process and if you think about in in Indian context, when our calorific value is already low, and if I want to use energy intensive process, what are my actually we will have a net net energy will be negative. When I

say negative means, rather than producing energy, it will be actually consuming energy because to make something, to up to 10000 degrees centigrade, it is not a joke.

Even if some technology works from around 5000, 6000 to 8, so it ranges from 5000 to 10000. So it requires a lot of energy to do that. And so if this plant has to really work sustain like in a on a long-term basis, it should produce energy at least, it should be at least self-sufficient on energy so that you do not have to supply energy from outside. So that is I do not think it is really work specially from Indian garbage perspective.

You do not see I have a hard although there are some vendors out there which will which are trying to promote plasma arc as a municipal solid waste treatment system but I have my strong reservations on that that is really going to work. We have to be really, if we are going for that, if any ULB in the country wants to go in that route, they should actually do this energy balance calculation, they should be really sure about the energy and because that is where later on there will be a problem.

So it is a super heating you put it all the way, you completely destroy the chemical bonds and then what happens is it actually takes it to all the way to what is known as the vitrified slag and then you can use that slag as a construction material and all that. Of course, you have to look at any heavy metals present, potential leachability issues, and all those things needs to be done but those are not that difficult, some tests need to be done in the lab and people can like several labs can do that.

And so that is can be tested and to find out whether it can be potentially used as a construction material. But for hazardous waste management, plasma arc is used. In many parts, plasma is used for hazardous waste because hazardous waste treatment is much more costly. It is sometimes even 100 times more costlier to manage the waste as a hazardous waste than a nonhazardous waste.

So economics works in terms of hazardous waste for to go for plasma arc. For municipal solid waste, I have, I am not sure. Like I have not seen any like a full-scale working municipal solid waste plasma arc facility which is which has been operating for quite sometime. So it is it it

could be that the if energy required is much less now because of some improvement in technology which which I do not see like it could be possible but I have not seen any.

So that is so we we still have to look at this plasma arc. So that is basically (())(23:37) down to essentially for the waste to energy, we mostly focus on this part, in general for municipal solid waste. For municipal solid waste, we are focusing here. For some of the specific to waste, there is pyrolysis and gasification is also done. So these are the processes which is out there.

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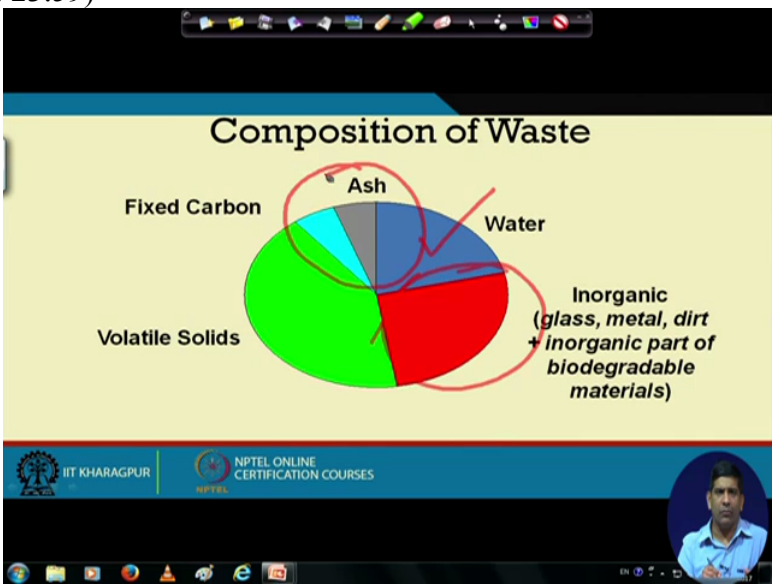

Now so in terms of the process now what fraction of the waste which will react in this process, whether you use one or the other, as again if you take the pie chart, if you take the composition of the waste and put it as a pie chart in form of like a from the combustible characteristics, so here you already seen this slide way, I think in the 1st week or the early 2nd week. So any waste stream you pick up and do this composition, you will have some moisture , then there will be some in organic fraction.

Some of the inorganic will be there. Then we have some ash and fixed carbon which is always there, fixed carbon is the amount of carbon has really it does not react. And then we have this volatile solid part. So this is the volatile solid which we just explained 3 minutes back. This volatile solid is what is going to react in your, in your combustion system. So for calculating the air requirement and other stuff, we need to know the formula for this particular fraction.

We need to know the formulae for this particular fraction, this volatile solid fraction, this green faction that you see over here. So we need to find out the information for that and that we can use it in our equation.

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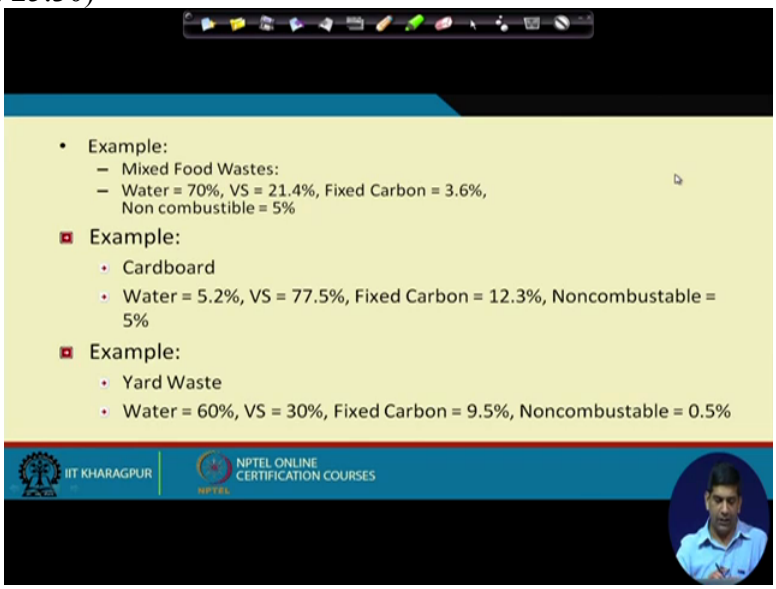

So some example, say if you look at the mixed food waste, it has water is 70 percent and more water, bad it is for waste incineration. Why? Of course water does not have much of a, it does not have the calorific value. In fact water will consume energy because when you heat the things up, usually the waste to energy plant works at around 1100, around 1000 to 1200 degrees centigrade just to not have some of those air pollutants in terms of PAH, polycyclic aromatic hydrocarbon and some of the dioxins and other stuff.

They are produced at low temperature, so we try to work at high temperature to reduce the amount of air pollution coming out. So for that to happen, we need to heat it up at a very high temperature. So when you take the waste, with lots of moisture, you are heating it up, so when it reaches 100 degrees centigrade, of course, you are you have a huge consumption of latent heat of vaporisation if you remember from your high school physics class, as latent heat of vaporisation, the energy is consumed.

So energy will be consumed and then that is becomes your negative in terms of the heat value. So with mixed food waste, 70 percent moisture, it is very difficult as a, it is not a good candidate

for waste to energy. VS is 21 percent, fixed carbon is 3.6 percent and this noncombustible is 5 percent. Although things here will combust but the heat value will be very low, the calorific value will be very low.

We use heat value and calorific value kind of interchangeably. Sometimes we call it heat value, sometimes we call it calorific value but they are the same. Then we have a cardboard. Cardboard here you can see, the moisture is much less, only 5.2 percent, volatile solids is 78 percent. So cardboard is a very good candidate for waste to energy. And that is also the very good candidate when we go for the recycling.

That is why there is always a debate that if you most of the recyclables like the cardboard, paper, those, only these 2, cardboard and paper, they are very good in terms of waste to energy because of a good calorific value, low moisture but still, they are good for recycling to. So if you take it out from the recycling and put it in waste to energy, are we really doing an environmental good? Or the other way, if we are taking this cardboard or plastics and papers and then take it to to travel it around several kilometres before it goes it gets recycled, it may make more sense to directly put in a waste-to-energy plants. We have to to find out which one is better for my men. So again this whole concept of life-cycle comes in picture where you can do those type of calculation. So volatile solid, fixed carbon is there some and there are some noncombustible still but there is a good amount, the VS is pretty high, moisture content is low, so can be used there

Yard waste again, a lot of moisture. So may not be a good candidate. Has a good, like one third of volatile solid, fixed carbon and noncombustible is also there. So some of those are good, some of them may not be good. Tyres are actually pretty good in terms of calorific value but the problem with tyres is it also creates some air pollution issues. There are some like chlorine is there, dioxins, furane production from tyre burning issue.

There is heavy metal issue is there as well. So in fact very recently, there is a there was a in (()) (28:53) in Canada, just couple of months back, I think it was in July of this year, they were looking at in terms of, try to burn tyre for energy and people are resisting that because they already had some issues with that almost 20 years ago when they were trying to do it for the 1st time and then there was a matter permission issues.

Air pollution issues has improved a lot since then, it is becoming more stricter, things are becoming more cleaner but still, if you have a bad experience with certain certain technology, even if the technology has improved really well, it gets really difficult to convince the people. That is really difficult to convince the public to go and use that technology again in future.

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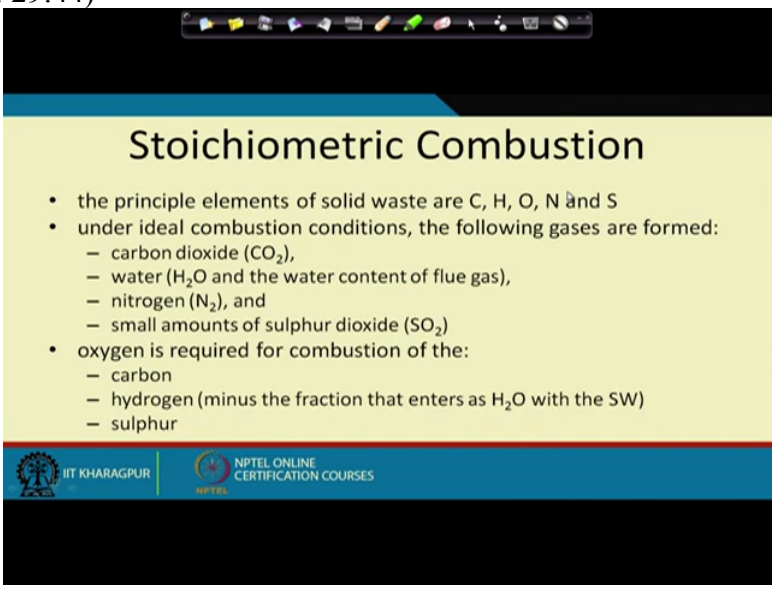

So let us think let us we can we stop at this particular point for this particular video and then in the next video, we will continue our how to do those stoichiometric calculation and all that. Since so in terms of the thermal treatment, there are different types of thermal treatment. For hazardous waste, biomedical waste, thermal treatment is used quite extensively. For municipal solid waste, and specially from the Indian context, we have some waste to energy plants now, we had some bad experience earlier that is why we did not had any for several like almost 2 decades.

And then we are building some of the new waste to energy plants. And one thing we need to be careful about to have a realistic assessment of waste calorific value so that when we design our waste-to-energy plant, we are designing it in a way so that it works rather than if we have a faulty calorific value to start with for design, it will it will have problem in terms of its operations. So with that, let us close that video and then we will come back again and then do detailed calculations in the next one.

And again, if you have any questions, feel free to put on the discussion board. Discussion board is the only forum where we kind of response to your questions. We do not entertain any other forum. So put it on discussion board, we will be more than happy. Every evening, we are looking at it and we are trying to reply to any query you have. So thank you and look forward to see you again in the next video.