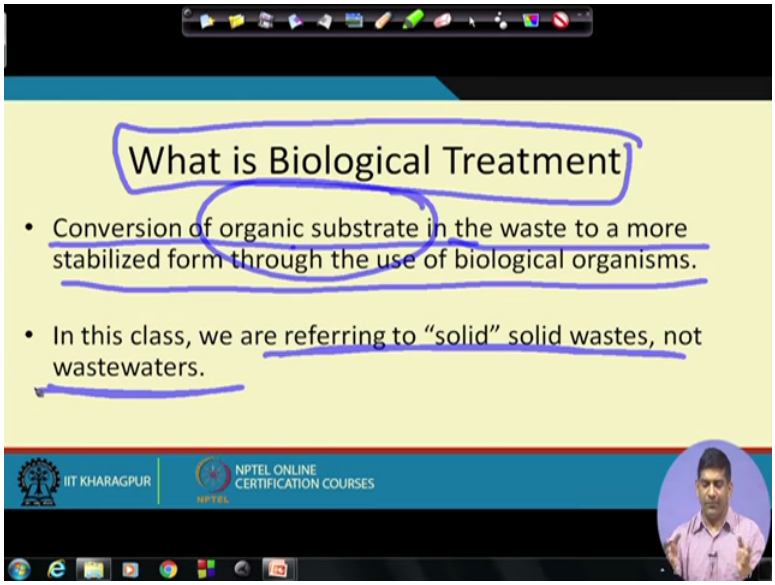
Integrated Waste Management for a Smart City.
Professor Brajesh Kumar Dubey.
Department of Civil Engineering.
Indian Institute of Technology, Kharagpur.
Lecture-29.
Biological Treatment of Waste.

Okay, welcome back and we will continue, this is the, we are in week 6, so today this is , this video we will be looking at model number 4 of week 6. So we will, as I said now we have finished our transport, collection, initially we started with, if you remember from the very beginning we started with waste quantity, like how to get the waste quantity, how to do the waste quality, then we also talked about what are the rules associated with that, municipal waste management rules, smart city initiative, Swachh Bharat Mission we talked about all that aspect, then we also, then we looked into how, we know how much waste is produced and what is the type of waste, how to collect it, what are the different ways the collection can be done, how to design a collection system, so we did a overview of that.

And then now we will look at, since now we have already collected the waste, we have to treat this waste. So from this video onwards we will be talking about the treatment and when we talk about the treatment, essentially when we say about the municipal solid waste, the most common treatment methods is used, these are the biological treatments or thermal treatment. So in biological treatment we have 2 aspects, one in the anaerobic and one is the aerobic. So aerobic treatment, we call it composting, when we see composting, it is essentially an aerobic treatment, we supply air, in some way or the other.

And then anaerobic is your anaerobic digester. So where you have the methane gas being produced which you can capture, landfills are kind of anaerobic treatment as well but it takes a longer period of time, we will talk about that in the concept of bioreactor landfill and all that will be there. So, so we will get started with the 1st is the biological treatment. Let us talk about biological treatment and some of the stuff that we covered in the very beginning in the 1st week, you will see some of those slides coming back again because if you remember we said that in the 1st week we covered kind of an overview, now we are going into deeper, into each of the each of the topics.

(Refer Slide Time: 2:45)



So you will see some of the slides repeating here but just to recap and so that you know if you are forgotten, you will remember now. So let us talk about the biological treatment of waste, so when we say biological treatment when we say biological treatment, what is biological treatment? So 1st of all the question, again at anything you say, what, what and why, those are 2 very important aspects, what is biological treatment, essentially what we are trying to do here is we are converting the organic matter, we are converting the organic of substrate in the waste to a more stabilised form through the use of biological organisms.

So essentially what we are doing is we are making use of the biological organisms, those biological organisms which is available in nature or if it is not present in that particular area, we provide biological organisms, we, and then essentially our, what we are trying to do is we make the condition suitable for the biological organism so that these organisms can do the work for us. And when we say do the work for us, we are saying that essentially that they will be able to degrade the waste. And when we say the degradation of waste, essentially what it means that it is the conversion of the organic substrate. So this is the organic substrate.

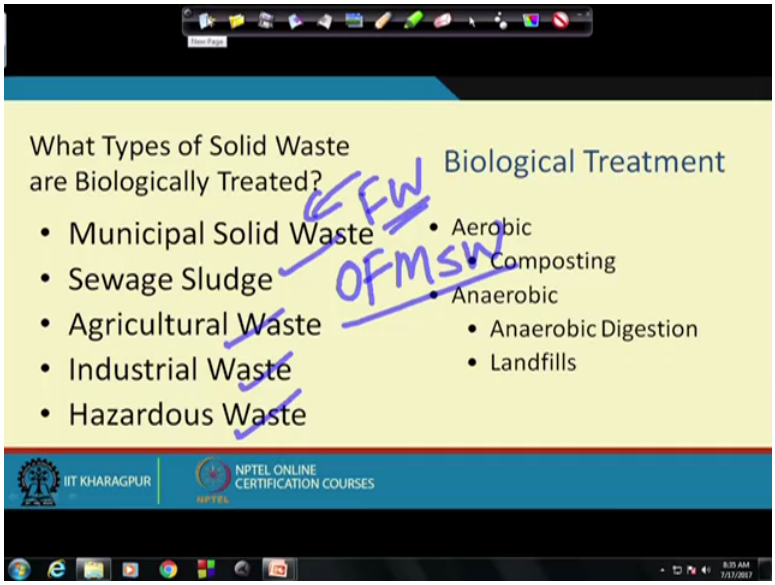
So the amount of organics present in the waste and that kind of dictates how much air you need to supply in aerobic system or how much gas will be produced in aerobic system. So whatever is the organics present, the organics will get converted to either CO2 in the aerobic system and or it will get converted to methane and CO2 in the anaerobic system. So that is conversion of organic substrates, organic substrates, when it converts, it essentially gets oxidised. So organic substrates will get oxidised and then something is to get reduced. Remember that Oxidation reduction equation, these things we talked about in chemistry.

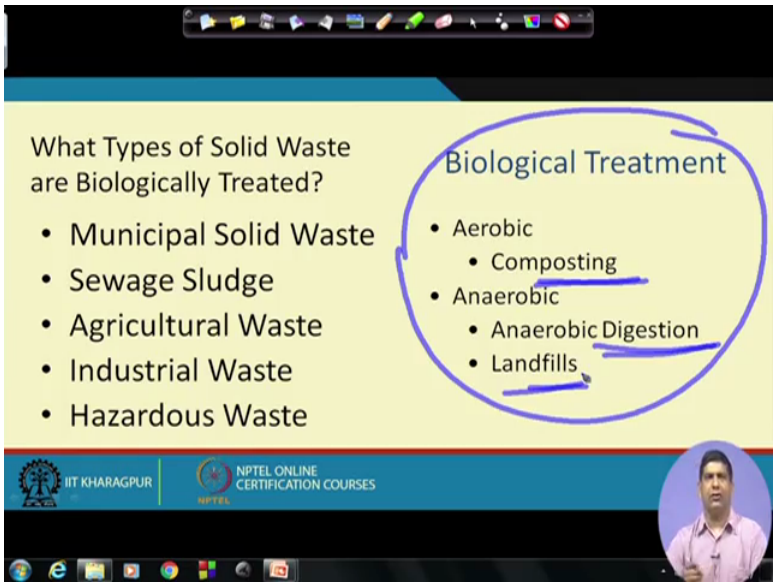
That is organic substance will get oxidised and in aerobic system and then something has to get reduced, so for something to get reduced in a more technical chemistry term we call it a, something has to accept the electron. Because when something is getting one element or compound is getting oxidised, one element, when things are getting oxidised, electrons are released. So electrons cannot just be , it cannot be just floating around, some, electrons have to go somewhere, so there are electrons except us. And those electronic acceptors are essentially those are the oxidising agent.

So we have oxygen, nitrate, sulphate, those are our electronic sectors because oxygen will will accept electron and get reduced, sulphate will get accept electron and get to sulphide and then nitrate to nitride and so all those things happen. So here the conversion of organic substrates in the waste to more stabilised through the use of biological organisms, so that is the biological treatment. So that is what we call biological treatment. Now here in this particular course we are referring to solid solid waste. Because if you remember earlier we talked about solid waste could be liquid as well, it could be but here we are essentially talking about solid solid waste, when talking about the wastewater.

There is a, if we have taken a wastewater course, this biological treatment of wastewater and the biological treatment of solid waste, the concept is essentially the same, here only we are looking at high solid content and then in wastewater we are looking at low solid contents. So that is the difference, otherwise the concept and all steps are the same as you will see as, if you have taken a bio wastewater course, you will you will see a lot of similarity, similar concepts which being talked about over here as well.

(Refer Slide Time: 6:24)





So what types of solid waste are biologically treated? Municipal solid waste, MSW, especially among MSW, these days are very, food waste, food waste is throughout the world, there is a push to collect this food waste separately and do biological treatment. And composting is popular but many, especially in semiurban areas or the rural areas, composting is going but in highly dense urban areas , composting requires more land and they of course, whenever you set up any plants, we talked about that, you need to do market analysis, you need to do the economic survey whether this plant, the product that is produced from the plant will be able to sell those products.

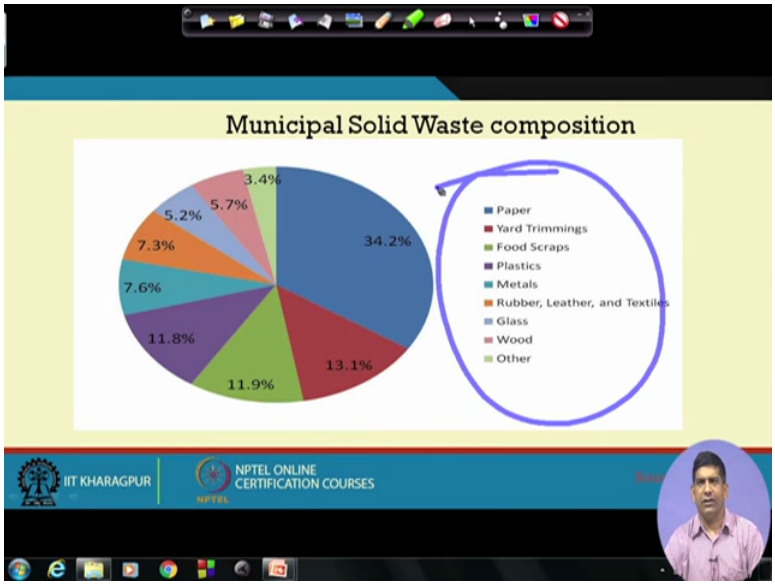
So if you are making compost in Delhi and if you cannot sell that compost in Delhi, then the plant cannot survive for a long period of time because it has to make money. So similarly in,

so in urban areas, globally, more popular is getting is is anaerobic digestion. So at least what, they collect the food waste separate, do the anaerobic digestion, produce the methane gas and that methane gas can be used as an energy source and then the sludge, which is almost down to say 30-30 percent of, so you take the sludge and you take I would do the composting on the sludge with mixing with other yard waste, garden waste and those kind of waste with that.

So what type of biological, coming back here, municipal solid waste, food waste specially the many organic, sometimes you also hear terms like organic fraction of municipal solid waste you will hear OFMSW, that is the organic fraction of municipal solid waste. That is, that is also term is used for doing the biological treatment. Then the sewage sludge, sewage sludge can be used, agricultural waste is done quite a bit, industrial waste is also done, you know events of of the contaminated sites with some of these industrial waste, is also biologically treated. Hazardous waste can also be done as well. So these are the different types of waste that could be biologically treated.

And when we say it is biologically treated, essentially hour microorganisms should be able to use that waste as a food source. So the organism, they should be able to use the organic fraction of that waste as a food source and if they can do that, it can be biologically treated. So what are the treatment types, we have in terms, here we are looking at the treatment times, we have essentially tube, biological treatment, we have aerobic is which is the composting and then we have anaerobic which is the anaerobic digestion, landfills are also anaerobic system.

(Refer Slide Time: 9:56)

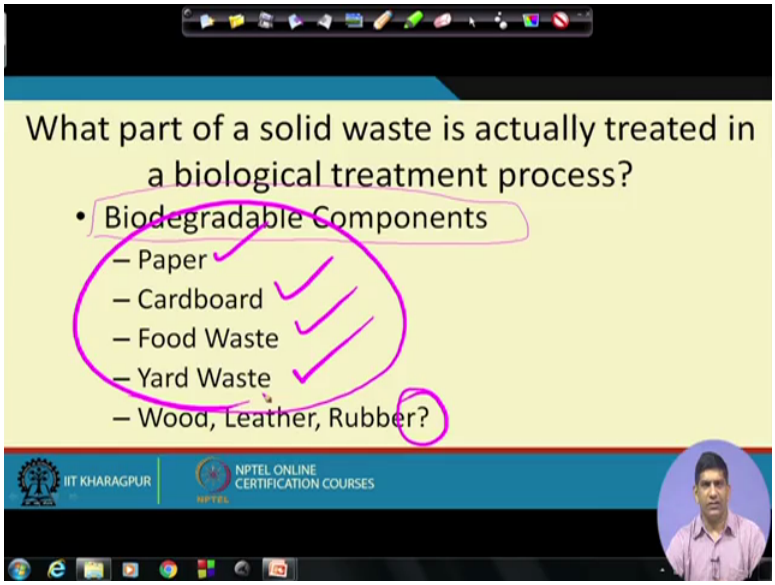


So this is, there are 2 types of biological treatment, aerobic and anaerobic. So in this video and the subsequent video we will be looking 1st aerobic and then we will go into the anaerobic system, so in terms of how they are done. Okay. So coming to like a municipal, this particular pie chart, we had looked at this pie chart earlier as well. This was done like a earlier you have seen this pie chart, long ago and now we will kind of just see one more time, just to recap, do the recap for you. So that you remember like what, what we are talking about earlier. So this is the typical municipal solid waste composition where we have a paper, this is again, this is coming from, this is a typical example of a Western world.

So, here you see more paper, lot of paper there, which is, paper is there, yard trimmings, yard trimmings is the garden waste, food scraps, plastics, metals, rubber, leather, textile, do not worry too much about the percentage is, if you put Indian waste here, we will have more food waste, less paper, some garden waste and then we have, plastic and metals will also be less, we will have lot of other materials like dirt and all those things showing up there as well. So essentially what I am trying to say is in terms of different, so if you look at these components, so that these kinds of components present in any waste stream.

The percentages will differ, if you go to any place in the world, the percentages differ from place to place but this is different, like the composition of like a typical components of municipal solid waste. So about, among all these, not everything will degrade in a biological system. For example glass or your plastics, metals, typically they will not degrade, there are some research going on in terms of biodegradability of plastics these days but most of the, for more, for most part this does not degrade that much in an anaerobic system.

(Refer Slide Time: 11:36)

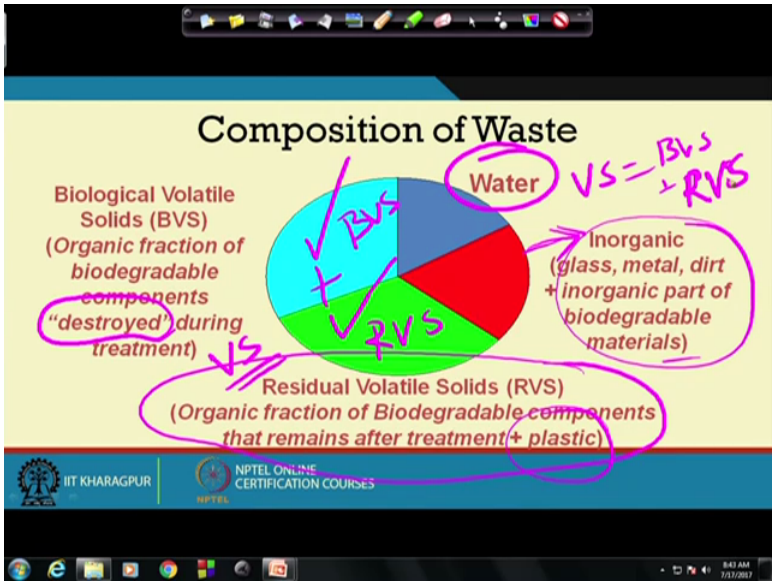


So what will degrade, that we have, it is what the stuff that will degrade is called biodegradable components. So we have these biodegradable components are the ones which will degrade, so that is biodegradable components. So now what are these biodegradable components? They are paper, cardboard, food waste, yard waste or the garden waste, wood, leather and rubber, I have put a question mark there because in theory they do but in practical they do not. So wood, leather and rubber actually takes a long period of time to degrade and in theory they do degrade but in practice you do not see much degradation happening to them.

So for most part you have paper, cardboard, food waste and yard waste, yard waste is garden waste. So these are the ones which will typically degrade in a anaerobic or aerobic system when you try to do this biological treatment. So in terms of the total, if you remember the progress pie chart, in terms of the total component that we have, we have to identify these components because these are the ones which will degrade. When we say these are the components that will degrade, that means when we are trying to supply air for the composting process, we need to supply air for the degradation of only these 4 components because others will not are not going to react anyway.

So when you are supplying air you need to know, essentially you need to supply oxygen but since we cannot supply oxygen directly, we supply air. So when you are supplying air, you need to know what is, what is the composition of this part. So this part composition is important. So we need to 1st identify this part of the component, that is called biodegradable component or biological volatile solids which we will talk about in a minute.

(Refer Slide Time: 13:21)



So this is again, you saw this slide earlier, so we had, this is a composition of waste like the one we had just few slides back, when we had paper, cardboard, steel, metals and all those, rather than putting the pie chart in this, if you put the pie chart in this fashion where you have of course there will be some moisture, so we have some moisture which is the water which will be there in the waste. Then we have in organic fraction, this we have this red pie is our in organic fraction which has glass, metal, dirt and then some inorganic part of biodegradable material.

So this is our inorganic fraction present there, then we have this position is your biological volatile solids. Now what is a logical volatile solids? It is the organic fraction of the biodegradable component which will get destroyed during treatment. Destroyed is actually kind of a, just to get your attention here, destroyed, I think destroyed me not be a very good word to choose in this particular but it is not destroyed, it basically changes its form. And I have said that several times that anything on the periodic table, we cannot really destroy it, we can only change its form from one form to another form.

So your organic fraction of the biodegradable component which is reacting during the treatment rather than using the destroyed term which should use may be reacting during the treatment or which will take part into the reaction, so those are the. So but this is the one which will do the reaction. And then we have residual volatile solids, residual volatile solids means that it is there but it is organic fraction but that remains after treatment. Certain, for example if you have , if you are doing composting or any like a biological treatment, something like lignin, it does not degrade very easily.

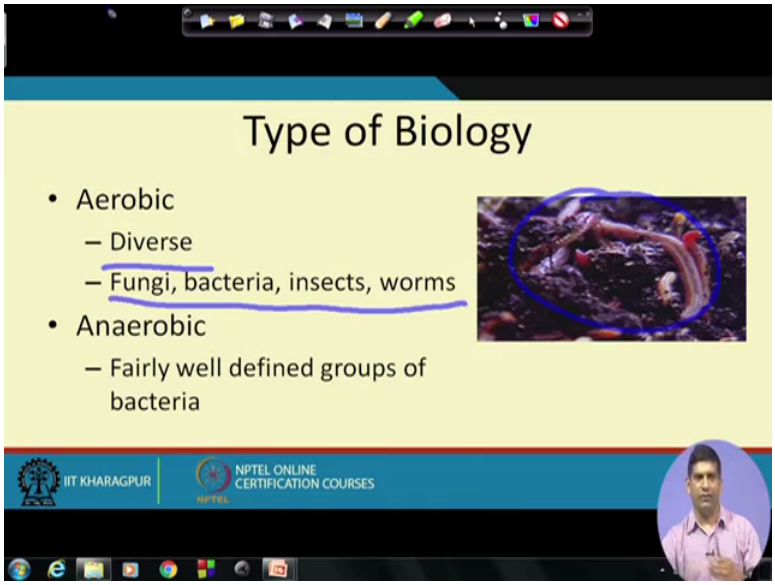
So although it is it is degradable, but will not degrade very easily. Other thing is that you have certain biodegradable component but the bacteria cannot really chew it, so bacteria cannot really eat that, so that will not degrade. And then next is plastics as well, plastics is part of the volatile solid, if you do a VS calculation, you plastic will become part of that but when you are talking about biological volatile solid, plastic is not part of that. So this plus this , these 2 together is what is known as VS, volatile solids. These 2 together is our VS. Now this part is the BVS and this is called R VS, so biological volatile solid and this is our residual volatile solid.

So B VS plus R VS is equal to VS, that is, the number that. So volatile solid which you can do, calculate in the lab is B VS plus R VS. So that is so this is your like a, that is just for, you should remember that it is, when we say VS, because when we do the thermal treatment we will talk about VS there again, volatile solids because that will do the reaction in the thermal treatment. For biological treatment, it is not the VS part but it is the B VS part, the biological volatile solid, the fraction of the volatile solid which will react, which , on which the bacteria will act on, so rather than which will, bacteria will act on and then do, we need to know that fraction.

So in terms of this BVS fraction, so this is what is taking part in the reaction, this particular pie chart, this particular pie chart is what is taking part in the reaction, so for any waste component, if you are trying to design a compost plant, we need to know the composition of this particular pie like the part of the pie and also like the amount the composition in terms of what kind of things are present and also what is the amount, like how much of it is present because this is what is going to do the reaction, others will, all the others, moisture may, moisture may help but this part and this part will just be there and then it will go into the system and it will go out of the system.

So it is not going to react, so if you think about a box, say if you think about a box here, saying that this is my compost system, as a box we have certain input and we will have certain output. So this fraction and this fraction, these 2 will actually get into the system and then they will just go out of the system, they are not going to react at all. What is going to react is this fraction. So we have to design our air injection system and all those things for for this particular fraction. At 1st we need to know the quantity of this fraction as well as the quality of this fraction. So when I say quality, it is basically the composition and we will talk about that, how to do those calculations.

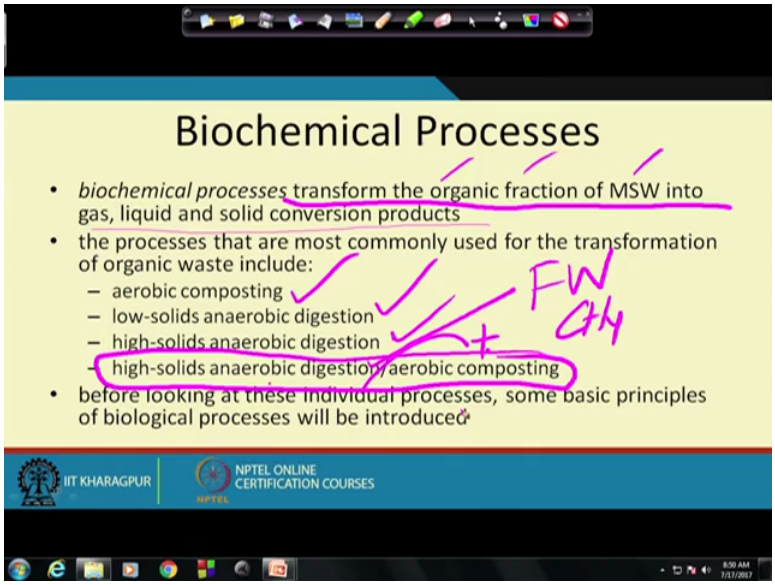
(Refer Slide Time: 18:13)



So in terms of the biology which happens in a biological treatment system, means aerobic as well as anaerobic, we talked about that. Aerobic, there are diverse set of bacteria, there are fungi, there are bacteria, insects and worms, and all those things are there in the aerobic system, as you can see some of those worms here as well. And then anaerobic is a group of bacteria, it is fairly well-defined. In this particular class we will not go in to detail about the type of bacteria, aerobic, the names, and type and family and all that because that, it is not a microbiology course and stuffs, we are focusing on in terms of how to design this compost system or how to design the an aerobic digester, that too from a big picture perspective.

So but for your information you should know that there are diverse set of bacteria in both aerobic and anaerobic system which has been identified, people have documented all that, fungi, bacteria, insects and worms, they also take part in composting like aerobic composting process. And for anaerobic again we have self reducers, we have methanogens, we have (()) (19:26) and we will talk about those as well. But those are also kind of present.

(Refer Slide Time: 19:34)



So the biochemical process, again as I said earlier, the process is to transform the organic fraction the process is to transform the organic fraction of MSW into a gas, liquid and solid conversion products. We have this OFMSW, so this is what OFMSW, so that is your organic fraction of MSW into either gets converted to gas or liquid or solid conversion products. So either of these is can come from either a gas, liquid or solid. Now the process that are more commonly used for transformation of organic waste is aerobic composting, that is your very commonly used, low solids and anaerobic digestion and high solids anaerobic digestion, those things are also used, low solids and high solids.

High solids anaerobic digestion followed by aerobic composting, so this is what is getting a lot of attention these days. Like can we do a high solids anaerobic digestion upfront? Because safe you collect the food waste, although just recently I saw some article, these days a lot of people are posting articles on Facebook and other places where in terms of the food waste, so amount of food waste that we generate and it says something around 40 percent of the food sold in North America actually goes into the waste. And think about that, 40 percent of the food, that is a lot of lot of food waste.

There had been a study which was done saying that a typical North American households which is a family of 4 like wife, husband and 2 kids, they are, they are wasting nearly 1000 dollars worth of food every year. So 1000 dollars food every year is just getting wasted. So that food waste that is being produced for people are losing around, every family is losing 1000 dollars. So think that, 1000 dollars is not a joke, it is a very decent amount of money, it

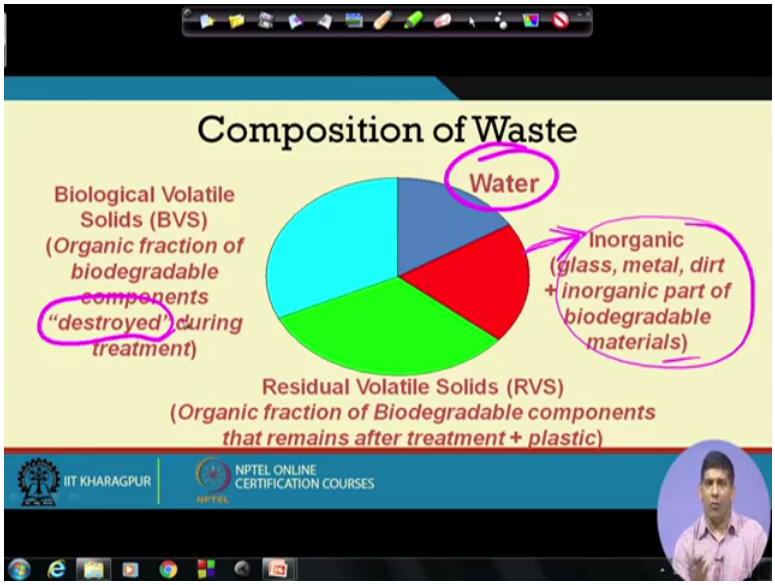
can book possibly buy good gift for 4 people, actually for all of them they can buy good Christmas gifts for around 250 dollars each.

But that around 1000 dollars amount of food is wasted, where there are a lot of hunger in the world. And even there is hunger in the United States too. So, this food waste, rather than sending to the landfill where the gas will be produced, not captured very well because it is the, these days focus is that 1st of all we should not try to produce, we should try to cut down the amount of food waste that is produced. If unless that happens, during this transition phase, unless that happens, was the food waste, the waste Wastage of food is really suppressed down, what we can do is at least try to recover some of the material, recover some of the energy from these food waste which is thrown away.

So that is where this biochemical process comes in picture very can use these are different techniques and one of the technique used is high solids anaerobic digestion followed by anaerobic composting. So here what we are trying to say is you take all these food waste, you have this food waste which is high solids and then you do the anaerobic digestion, you produce methane and you use that methane as an energy source and then whatever is the sludge is, you mix it that sludge over here with some other waste stream and then you do the aerobic composting. So that is what can be done as well.

And then, it again depends upon what that particular city or city requires, what will work in that particular area as well. So that is kind of , just quick description of what is the biochemical process, what are the different examples. Now we will go little bit into the basic principles of this biological process, so that you have a better understanding of that.

(Refer Slide Time: 23:35)

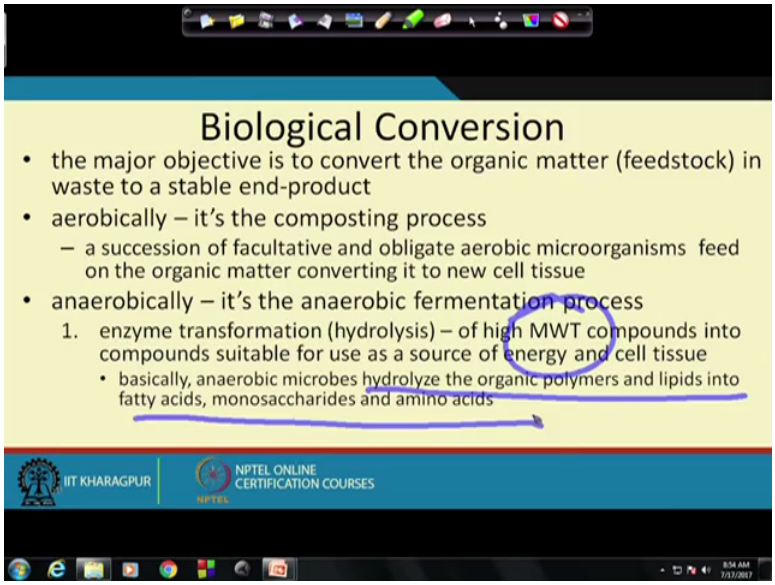


So in terms of the basic principle, let us get started on that, so there are different terminology you will see and which is used, which is, we need to get those data as well. So one of the important stuff is the organic matter, because it is the organic matter which is going to degrade it in, in the composting or and anaerobic process. So organic material composes nearly 30 to 80 percent of MSW depending on where you are. It is around 30 to 80 percent of municipal solid waste is organic material. And then in context the number is actually maybe around 60 to 80 percent or something like that or 50 to 80 percent.

So again we do not have a very good data, we need, really need to collect, these are all guesstimates when we say from the Indian data, it is many times it is a guesstimate, we do not have good quality Indian data and that is one thing we need to really calculate, we really get a good quality pan Indian data when we can have data from each major city, what is the type of waste and all that so that although the things may seem repetitive because when we do it at different cities, but we need to do that, we need to do so, so that there will be some differences as well, which will help in our design steps.

So proximate analysis, as you know proximate analysis will give you water content, volatile content, fixed carbon, non-combustible, and all that kind of stuff. So water content will trial combustible matter, fixed carbon, noncombustible residue, all these things can be measured using the proximate analysis. Then, and what are the principal components of the organic fraction, we have proteins, we have amino acids, lipids, carbohydrates, cellulose, lignin. So these are all different material which is there in terms of of what is the component present in MSW. So these are the components which is available there in the, in MSW.

(Refer Slide Time: 25:40)

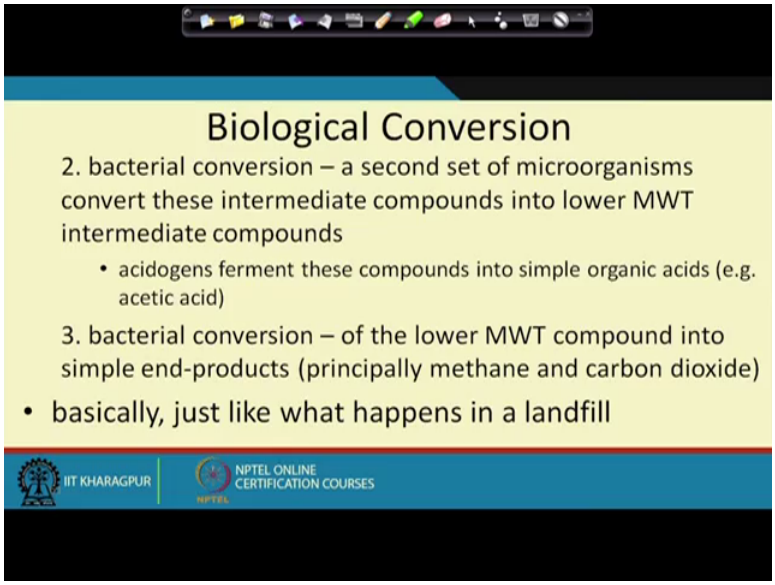


So, then in terms of biological conversion, conversion the major objective is to convert the organic matter in waste to a stable end product. So it can be done aerobically which is the composting process where we have a succession of facultative and obligate aerobic microorganisms, so it is a facultative aerobic, and there are obligate aerobic microorganisms, they feed on organic matter, converting it to a new cell tissues. So essentially it is getting converted to a new cell tissue, they reproduce, they produce more and more microorganisms.

So basically what is happening in a composting process in a very simple way, we have this food waste, we had this organic fraction of municipal solid waste, this is a source of food, this is a food source for these microorganisms. So microorganisms will come in, will try to eat this and then in the process of eating this, they oxidise the organic matter and then CO2 gas is produced. So that is and then when this organic matter has been stabilised, then it becomes more like a fertiliser kind of material because it has some nitrogen, it has phosphorus, it has potential and it has good soil like properties.

So it becomes a good quality compost as long as you keep the organic fraction of municipal solid waste separate. So that is in terms of aerobic, anaerobically it is the fermentation process, so there is enzyme transformation, so it is hydrolysis, so you have the high molecular weight compound, MWT is your high molecular weight, molecular weight compound into a compound suitable for user source for energy and cell tissue. So this high molecular weight compound is getting degraded and getting broken down by the set of bacteria into, into smaller chain compound. So basically anaerobic microbes , what they do, they hydrolyse the organic polymers and liquids into fatty acids, monosaccharides and amino acids.

(Refer Slide Time: 27:56)



So they convert these organic polymers and lipids into these relatively simple form where the microorganisms can have access to it, whether can use these as a food source and degrade it even further. So this is in the anaerobic system, you have that is happening and then you have the bacterial conversion where the 2nd set of microorganisms convert these intermediate products into lower molecular weight components, for example acidogens ferment these components to simple organic acids like acetic acid. So bacterial conversion of the lower the beauty compound into simple end products, principally methane and CO2. Basically what like say now what happens in a landfill.

So that is how this biological conversion happens in terms of biological treatment. So in terms of , well this is anaerobic, we will talk about that later. But in terms of this, in general biological conversion, you have a microorganism doing the job for you, what you are doing is you are making the life suitable for microorganisms to grow and to make, to degrade this organic material. So this is, in a kind of nutshell, terms of what biological conversion is, so we will continue this discussion in the next video and again this, this is a very common way of treating, composting has been very popular in India.

There are some compost plants which did not work out, there are some issues associate it with that, so we will talk about those things as well in this course as we make progress. As I said it will be more practically oriented course and again we want your feedback, we want your feedback, we want your questions, any confusion, any clarification you need, use the discussion board and communicate to us through that. Okay, thank you and then I will see you in the next video.