Integrated Waste Management for a Smart City.
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Lecture-30.
Biological Treatment of Waste (Continued).

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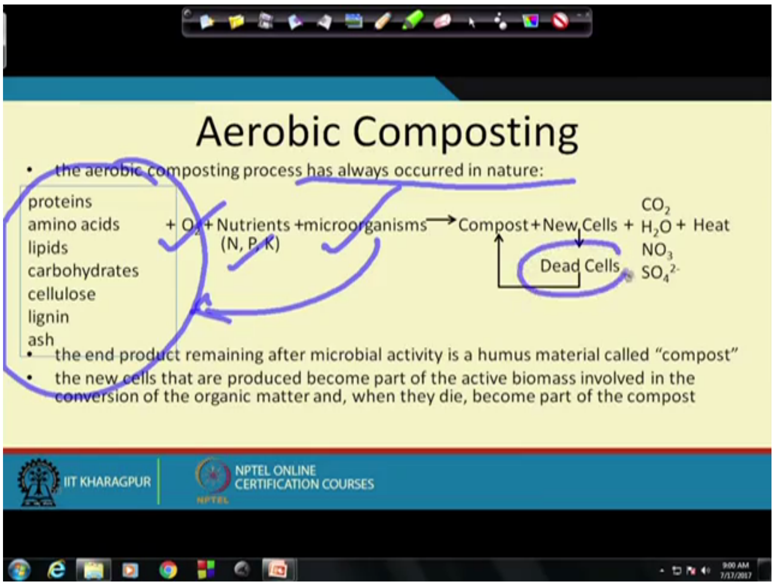

Okay, so welcome back this is the last module for week 6, we will continue our discussion on the biological treatment. So we were talking about some of the basics of biological treatment in the previous model. So let us continue that discussion. So in terms of our logical treatment, what I mentioned to you that there are essentially 2 aerobic and anaerobic and in the aerobic we call it a composting process. So what is the composting process? So in this particular slide we will try to explain what is composting like the very basics of composting. So the composting process, it has been happening in nature always, it is going on in nature. If you go on outside , there is always some sort of biodegradation happening, you go in the woods, you will go into the forestry kind of area, you see lot of biodegradable, you see a lot of biodegradation and other things going on.

So but in terms of the composting that we talk about in terms of getting into the food waste, agricultural waste and those kind of waste stream, essentially what we are doing is we are taking this waste stream which is which has this proteins, amino acids, lipids, carbohydrates, cellulose, lignins, some ash contents, then you supply us into it, you supply some nutrients if needed, microorganisms needs to be there. So what this does is these microorganisms use this as the food source and that is your main, like the Carbohydrate kind of main food source over there, carbohydrates, protein and other things are there as well.

And so they, they use it as a food source, they produce new, they produce new bacteria, they produce new microorganisms, the old cells die, so they produce new cell and then old cells die and then the old cell also becomes a part of the compost. So it is basically a set of microbial activity, at the end of the microbial activity you get a humus material called compost and the new cells that are produced become part of the active biomass. So you have the active biomass which is involved in the conversion of organic matter. And when they die, they become part of the compost. So that is how the situation, the cycle works, you produce CO_2, you produce some water, nitrate, sulphate, and then some heat is also released. Aerobic composting is an exothermic reaction, it is not endothermic, exothermic is when the heat is released.

So that is why many times the compost systems, especially in the summer months we have an issue of sometimes compost piles catching on fire. Because usually these gases, none of these gases actually catch fire easily but they do get catch fire because there would be some pockets of anaerobic activity going on and so some methane will be produced and that methane when it gets at a very high temperature and then because of the exothermic reaction the temperature goes up and when it goes to flammability range of methane you start seeing some fire coming out. So that is how you many times you see that the fire going on top of the dumps on top of the compost piles, that is the reason why it happens.

So compost is essentially like a very simple way, you have old, you have your food waste or organic fraction of municipal solid waste, supply oxygen, supply nutrients, some microorganism and then you get your compost produced, new cell produce then there would be some dead cell that would become part of the compost and gas released and it is an exothermic reaction, so you have some heat released as well. So that is in terms of some, like a very simple discussion of how this composting is done. Composting, when (())(2:36) how the composting is done.

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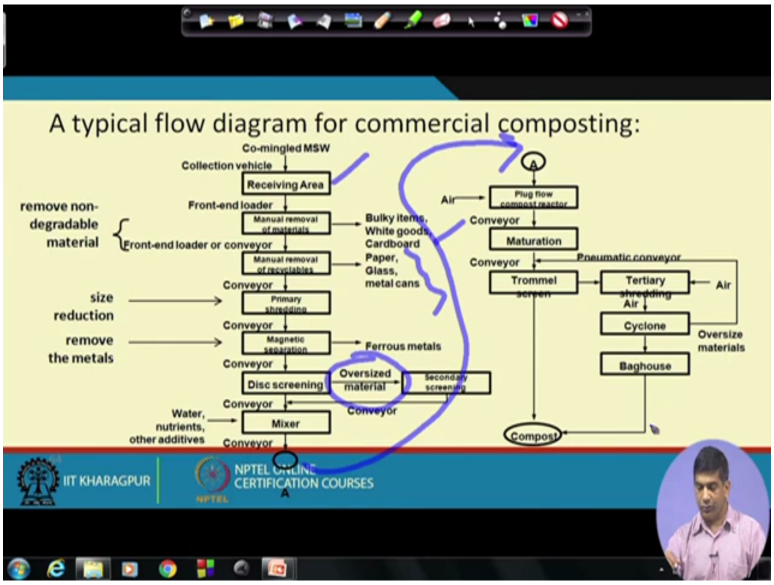

Typical flow diagram for a co-mingled commercial composting where you have everything co-mingled MSW coming in, so there would be collection vehicle which will, waste will be coming in in the receiving area, then you have a front leg loader, then you have manual removal of material, you have bulky items, white goods, cardboards can be taken out, then there would be another manual removal of recyclables where this paper, glass, metals, cans can be taken out. Then you have conveyor where it goes to the primary setting, it gets broken down into smaller pieces, then it goes for magnetic separation where they remove the metals, then to disc screen where you take the oversize materials or magnetic separation.

And mixture, you mix with water, nutrients and other additives just to make it good enough for your compost. Then from this point you basically come over here and then you have plugged flow compost reactor where the reaction will take place there will be some maturation time use of Trommel screen to save it and then you have pneumatic conveyor in terms of tertiary, cyclone, Baghouse in terms of air-pollution control system. So this is a typical, this is a typical flow diagram for commercial composting. And depending on what kind of face to have, if you have a source separated organics only coming in there, so you can skip many of these steps in the over here because you are just working with source separated organics, you do not have these, you do not have these ferrous metals, you should not see any glass showing up and all those kind of stuff.

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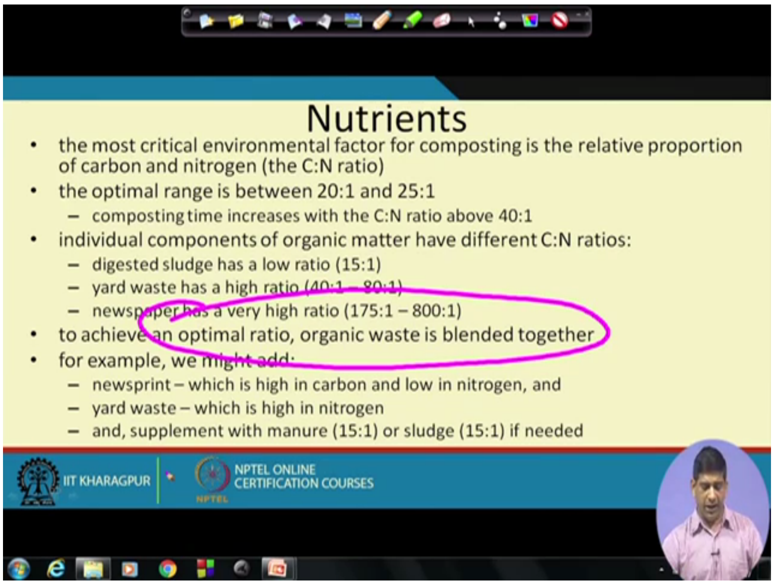

So, so this is again a typical flow diagram for commercial compost. Then we have nutrients, nutrients are also very important, nutrients are kind of vitamins that we take it helps into keeping the system running. So the most critical environment factor of composting is a relative portion of carbon and nitrogen. You do not want too much of a carbon and nitrogen ratio. The optimal range is between 20 is to 1 and 25 is to 1, so that is a range in which it works, 25, 20 is to 1 to 25 is to1. And then composing time increases with increase in carbon nitrogen ratio. If you have 40 is to1, it becomes really difficult, there are, there are some, so if you look at the individual components of organic matter, they have different carbon nitrogen ratio, some sludge has lower ratio 15 is to1 but yard waste has very high ratio, newspaper again has a high ratio.

So what we do is, to get the optimal ratio to get the optimal ratio many times the organic waste is blended together. So you will have few of the organic waste which is blended together to make the waste in carbon nitrogen tissue between 20 to 1 and 25 is to1. For example we might add newsprint which is high in carbon, low in nitrogen, yard waste which is high in nitrogen and supplement with Manure which is if needed in the range of, they have the carbon nitrogen age of 15 is to 1 or sludge again 15 is to1, so they can be, they can be added to get the optimum carbon nitrogen ratio.

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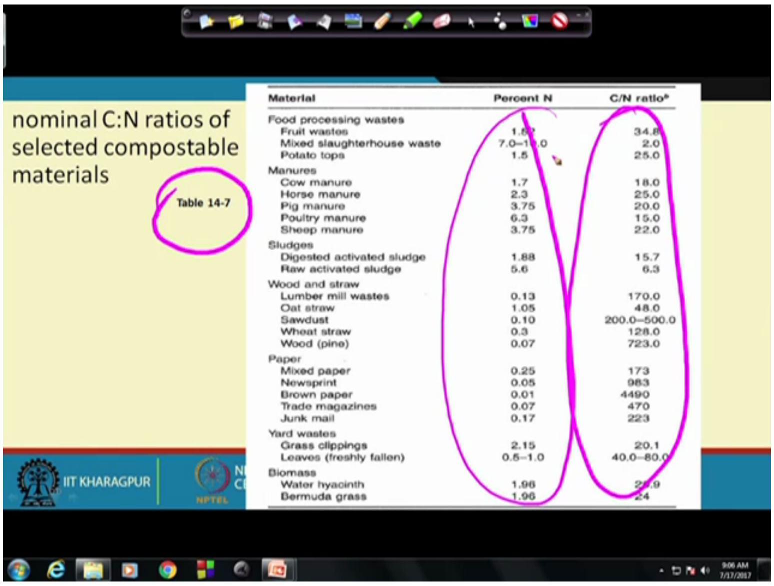

Material	Percent N	C/N ratio[a]
Food processing wastes		
Fruit wastes	1.52	34.8
Mixed slaughterhouse waste	7.0–10.0	2.0
Potato tops	1.5	25.0
Manures		
Cow manure	1.7	18.0
Horse manure	2.3	25.0
Pig manure	3.75	20.0
Poultry manure	6.3	15.0
Sheep manure	3.75	22.0
Sludges		
Digested activated sludge	1.88	15.7
Raw activated sludge	5.6	6.3
Wood and straw		
Lumber mill wastes	0.13	170.0
Oat straw	1.05	48.0
Sawdust	0.10	200.0–500.0
Wheat straw	0.3	128.0
Wood (pine)	0.07	723.0
Paper		
Mixed paper	0.25	173
Newsprint	0.05	983
Brown paper	0.01	4490
Trade magazines	0.07	470
Junk mail	0.17	223
Yard wastes		
Grass clippings	2.15	20.1
Leaves (freshly fallen)	0.5–1.0	40.0–80.0
Biomass		
Water hyacinth	1.96	20.9
Bermuda grass	1.96	24

So that is again a very important point. Next is our in terms of carbon and then ratio, this is just a carbon nitrogen ratio of selected compostable material. Again this table is coming from the same book that we mentioned yesterday, sorry in the earlier videos where this is from the Sumangulash integrated waste management, very old book but again has a lot of information there and these numbers does not change that much anyway. So in terms of the food processing waste, manure, sludge, wooden straw, paper, yard waste, biomass, this is the percentage nitrogen and this is the CN ratio given to us.

So if we know the CN ratio, we know the percentage nitrogen, of course we can calculate carbon. So that is kind of to give you just and illustrate that there are carbon nitrogen ratio, or CN ratio is available for many of the waste, many of the food waste component, many of the food like a, many of the components from the from the organic fraction of municipal solid waste. So it is this data can be used for doing our mat exercise and all that and we will do that when we do some maths associated with this chapter.

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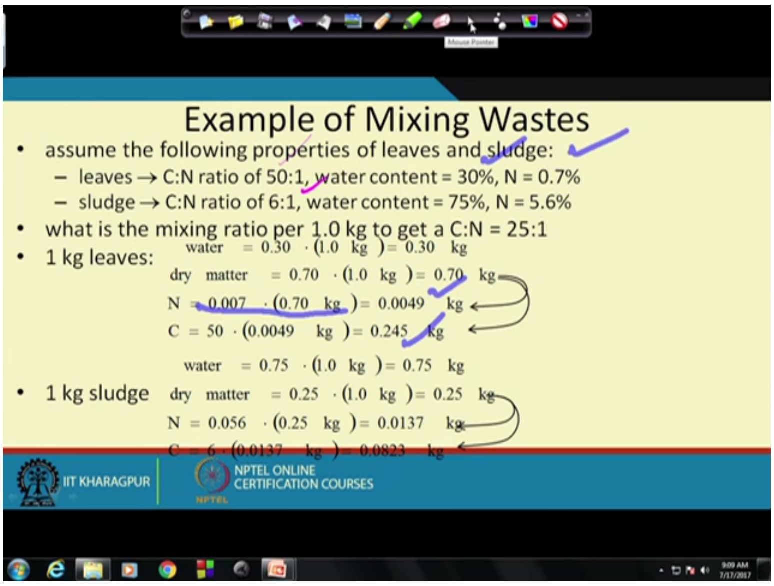

So in terms of some of the maths problem now. So in terms of, say if you working with different waste streams, so if you are running a compost plant, you will not be only dealing with one type of waste because many times you will have people bringing different types of waste. And now you are trying to find out that is what ratio you should mix them so that you get an optimum carbon nitrogen ratio. So if you look at the, so if you have leaves and sludge, you have leaves from from certain part of the, if suppose there is a big storm and lots of leaves came down and so you have this big truck full of leaves.

And then you have some sewage sludge, carbon nitrogen ratio for relief and sludge has been provided, 50 is to1 and 6 is to1 and the water content as well as nitrogen content is also given. Once we know this, nowadays asking that what is the mixing ratio per 1 KG to get a carbon nitrogen ratio of 20 is to 25 is to1. So if we take 1 KG of leaves, moisture content is 30 percent. So the dry matter would be 0.7, because 1 - 0.3 and nitrogen so it is nitrogen is what it says 0.7 percent, so 0.007, so that is what you see over here. So 0.007 times 0.70 and then you get a nitrogen value of this much.

So once you know the nitrogen value, we know the CN ratio is 50, so 50 times the nitrogen will get us of the carbon. So this is how the carbon nitrogen ratio can be calculated. Same thing for the sludge, water is 0.75 KG, so the dry matter is 0.25, nitrogen has been given as 5.6 percent, so based on that we can calculate how much nitrogen, how much carbon, so that also gives us like a carbon, percentage carbon present, percentage nitrogen present, so that we can use those in our calculation.

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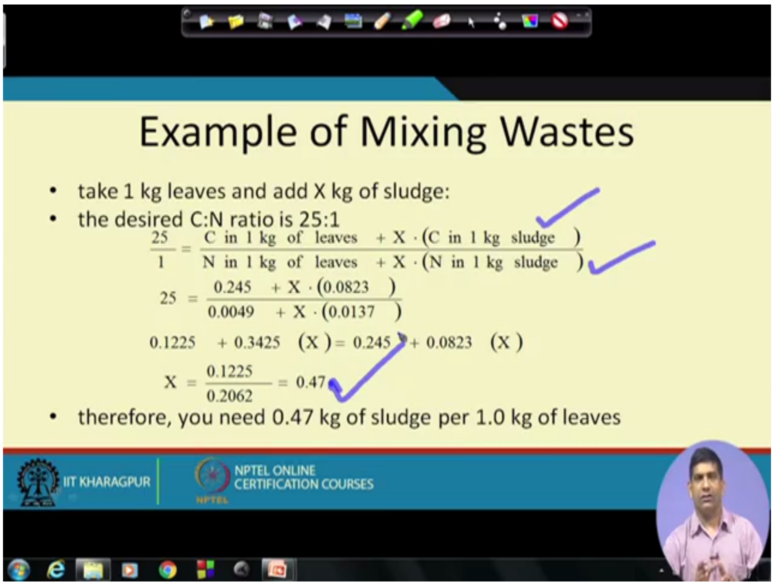

So this is like one example of that and then if you continue, take 1KG of leaves and X KG of sludge, we do not know yet, so much sludge, how much leaves will be needed. So let us take 1KG of leaves and X KG of sludge, the desired carbon nitrogen is 25 is to1, so we can, so we are doing, what we are doing here is just simple mass balance. So all the carbon is in numerator and all the nitrogen is in the denominator. So carbon in 1 KG of leaves plus X times carbon in 1G of sludge, so that will be like a much sludge needs to be mixed, and then for the nitrogen it is nitrogen in 1 KG of leaves plus X times nitrogen in 1 KG of sludge.

So if we do this maths and then you come up with X equal to 0.47, so what does this mean? It means that you need 0.47 KG of sludge past 1 KG of leaves to get optimum carbon nitrogen ratio of 25 is to1. So this is, this was an example to illustrate that you can calculate, if you know the individual carbon nitrogen ratio and individual quantity, you can calculate the carbon nitrogen ratio of the mix. And you may have to do it when you try to do your compost or anaerobic digestion or all those in terms of treatment method using bio or, bio or microorganisms.

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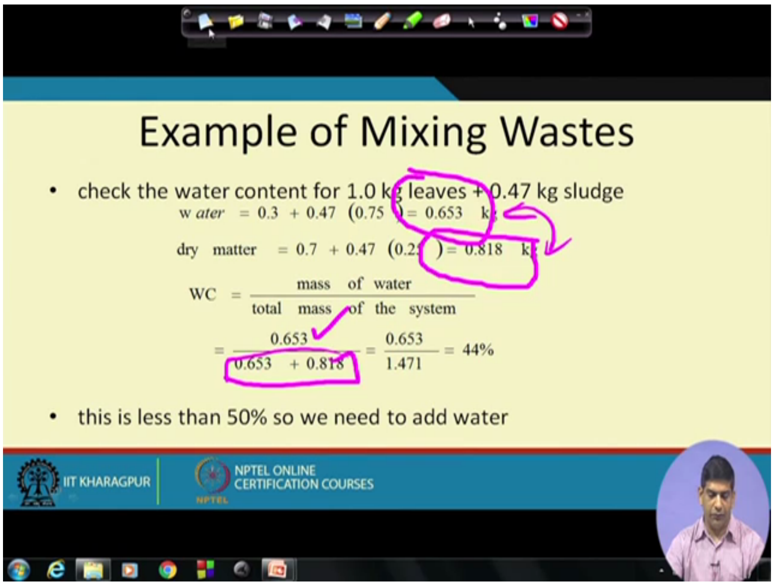

So that is, so that is kind of important on that part. Then check the water content, once you have this , the carbon nitrogen ratio you know that when you need 0.47 KG of sludge per 1 KG of leaves, so but what about the water content because we need certain amount of water as well. So check the water content for 1 KG leaves + 0.7 + 0.47 KG of sludge. So water we get around 0.653 KG water is there. And the dry matter is 0.818 KG. So in terms of the water content, mass of water divided by the total mass of the system. So mass of water is 0.653 and total mass is 0.653 + 0.818 which is these 2 numbers, which came from there, so this is, this number and this number, these are the 2 numbers we have.

And there is numbers, so we add these 2 up, that gives us the total mass, the total mass of the system and this is the mass of water which is present there. So based on that if you look at, it is around 44 percent, so 44 percent is the moisture. For the compost, typically it says that you try to have around 50 percent, 50 percent because the microbes, they really love moisture, they do love moisture and they do their work much better if it is moist. So for the 50 percent moisture content, we need to add some water. So we can also calculate how much water we need to add and those are very straightforward.

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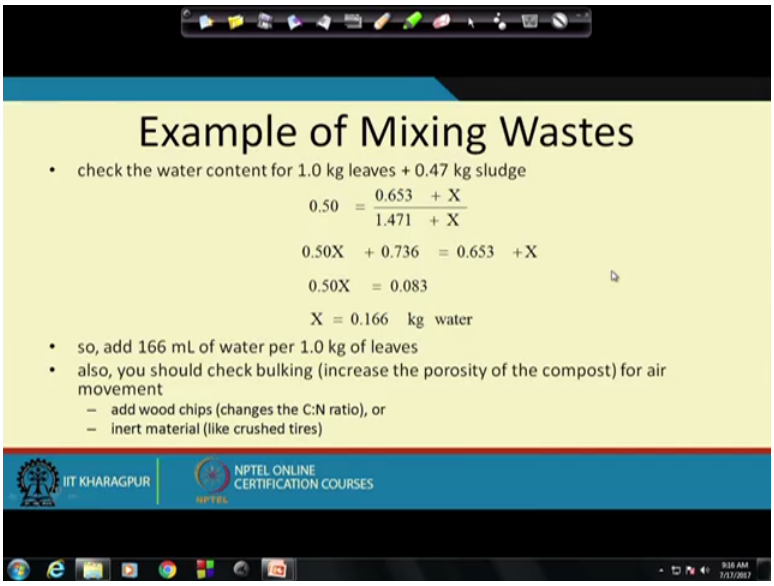

So for the water that you need to add, check the water content for 1 KG leaves + 0.47 of sludge, so here we are 0.5, that should be the water content. So here total, so if we are going to add X amount, so the weight of water will become 0.653+ X and total weight would become 1.471 plus X because that is the. So just based on that we can calculate X and X is 0.166 KG of water. So we can add 0.166 ML of water per KG of leaves. So that is what we can do. Also we can look at bulking agent we can look at, do we need to add woodchips, do we need to add some crushed tyres, inert material, bulking agent for the porosity, increasing the porosity of the compost for a movement, calculate the air pollution control system. Those things needs to be done as well.

So in terms of bulking agent, bulking agent we use to increase the porosity of the compost. Why we need to increase the porosity of the compass, because we are supplying air, so when we are supplying air, the air has to pass through the compost to get the reaction done. So for that for the airflow, good porosity, good porosity will help actually in terms of the airflow. So that is where it is important to have a good porosity. So these are some of the calculation that can be done on that aspect. So that is in terms of the math on this part. So this is just to give illustrate, so this is again how as a as a compost, if you are running a compost plant and you are interested in, you are running a compost plant and you are interested in getting various waste stream.

Because many times you will not be working with only one waste stream. So you will have municipal solid waste, you may get some garden waste, you may get some agricultural waste, so how to calculate an optimum carbon nitrogen ratio for this variable, like different type of waste stream. For each of the individual waste stream you will know carbon nitrogen ratio, if you do not know it, you should find it out using that CH O N S analyser, as most of the labs in good universities have it. So that gives us the carbon and nitrogen content. The once we have this carbon and nitrogen content for individual based on optimum carbon and nitrogen ratio that we require, we can always do our proportion of, in what proportion we need to mix our different components.

So that is, that is basically tells us that if you are running a compost plant, how to go about that. So these and again very important , when we do any composting, in India we have several compost plants were built and some of them are still working but many of them actually could not work for a longer period of time because of some problem or the other. So that is why we need to be really very thorough in terms of the design of the compost plant, at least from this point onwards. Compost as a technique is being used globally, it is popular, it is more popular in the rural areas than in high density urban area but again if you want to go for this composting, if we have the sauce separated organic, it is actually very good, that helps us a lot.

But if we cannot have a source separated organics, then of course the compost quality will be bad and we have to come up with ways of how to get these inorganic fraction, those plastics and other things out of the compost. Otherwise your compost quality goes down, it will not sell at a higher price and if it does not sell at a higher price, this will, your plant will not be self-sufficient for a long period of time. Again the subsidy can only get things started, the plant has to be self-reliant and then we should look at it, and these things can be made self-reliant, it is just that we have to do it properly. And these kinds of calculations should be done in terms of , when we try to go for design of these compost system.

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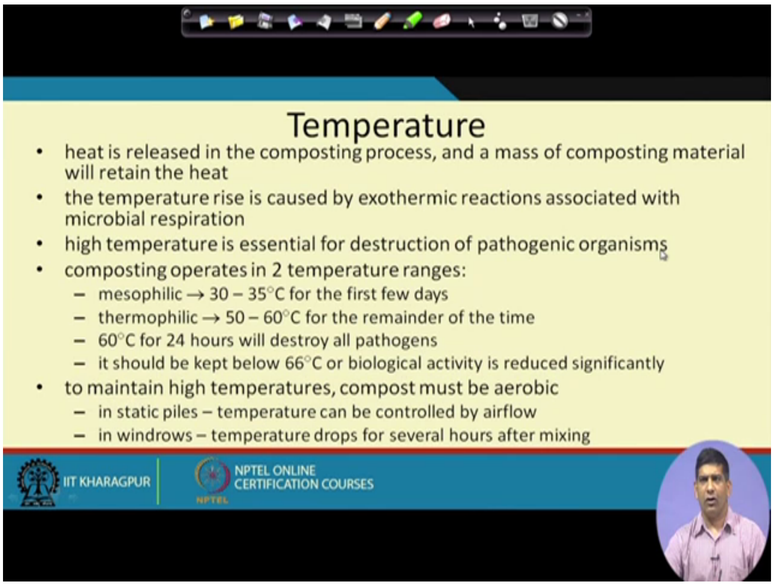

So being said that, there are the parameters are there as well. We will talk about some of those other parameters where temperature plays a major role in terms of , in terms of degradation as you know the bacteria they work at a certain, they like certain temperature, they do not like too cold and they do not like too hot either. So that is why, if you remember from your BOD test, that the BOD test is done at 35 degrees centigrade. So there is a reason for doing it at 35 degrees centigrade because that is the set of bacteria which we want to do our job in the BOD test, they are very active around 35 degrees centigrade temperature. So we have to be careful in terms of temperature.

And heat is released in the composting process, so when the heat is released the composting process, the mass of composting material will retain the heat, it will get warm, the temperature is caused by the exothermic reaction which is associated with microbial respiration, high-temperature is essential for destruction of pathogenic organisms. So in high-temperature you have pathogens getting destroyed. Composting operates in 2 temperature ranges, mesophilic and thermophilic, mesophilic is 30 to 35 degrees centigrade, so we try to work at 30 to 35 degree centigrade in the 1st few days to get the things are working in a mesophilic range. And then we take into a thermophilic range, that is around 50 to 60 degree centigrade for the remainder of the time.

In the thermophilic range, around 60 degree centigrade, if you keep it for 24 hours, it will destroy all pathogens. Remember you are working with waste, so when you are working with waste, you may have some pathogens present and those pathogens needs to be destroyed before you sell those compost. So it has to and we test for those as well. So it should be kept below 66 degrees centigrade, we wanted above 64, sorry above 60 but we do not want it above 66 because if you take it above 66, your most of the biological activity reduces significantly because the bacteria starts to die.

You do not want it above 66 degree centigrade. So in but so that is, to maintain the high temperature, the compost, it can be controlled by airflow, if we, in static piles the temperature is controlled by airflow, in the wind blow the temperature does drop for several hours after mixing and then it again picks up because of the exothermic reaction, it is also produced as part of the reaction process.

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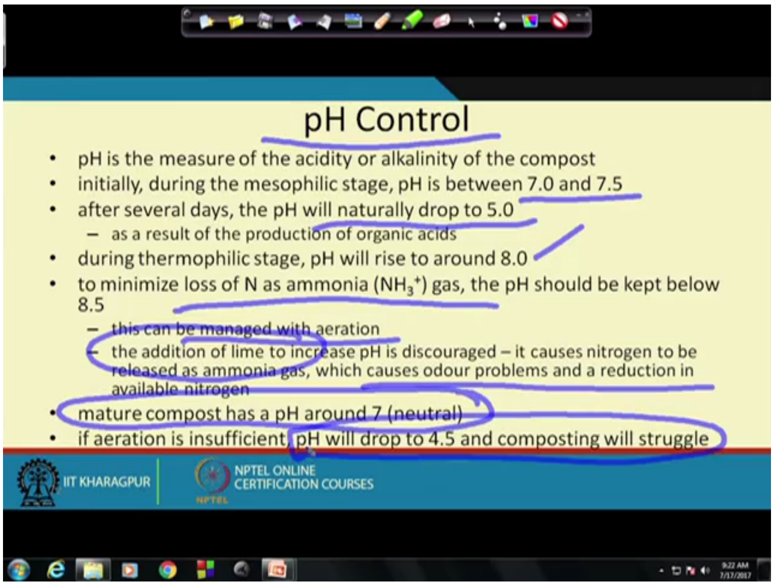

Then the other most important, other important factor is to do the pH control, we have to do the pH. Why to control the pH because mesophilic range pH is around 7 to 7.5 which if you initially was like after you try to keep it at a neutral pH, was the waste starts degrading, if it starts producing some organic acids, the pH will naturally drop to 5, it will go down to 5 because of the organic acid. But and then during thermophilic range, pH will rise to around 8, so pH does do fluctuate. During thermophilic stage pH will rise to around 8, to minimise but we do not want it to go to further beyond 8 because if it starts getting beyond 8.5, this nitrate, the nitrogen, remember we have this, getting to have a optimum carbon nitrogen ratio, nitrogen is needed in our fertiliser as well in the compost.

So if you have too high of a pH, so if the pH goes beyond 8.5, what is going to happen is your nitrogen, it gets converted to ammonia gas and this ammonia gas escapes the system. So we do not what that to happen, otherwise we are losing nitrogen and we need nitrogen in our compost. So we try to keep our pH below 8.5. Again as I was telling you in the previous video, do not try to memorise these things, these things are everything without there is there because of some reason. So try to understand the reason, why we need to do the pH control because there is this bacteria, they like the, they like the neutral range, neutral range.

But once the acids produced, the pH will go down little bit, but you do not want it to go down to below, see below 4 or below or even below 5, too much below 5, that also becomes problematic for any of these bacteria. And then we do not want it to go beyond 8, there will be some, in thermophilic there is a reaction the pH will go back up but we do not want too much beyond 8, otherwise we are losing nitrogen as ammonia gas. So we have to manage this pH and that is done using some sort of, we do the aeration. And then we do not like to add lime because if you try to add lime, it causes nitrogen to be released as ammonia gas because lime is , it is a basic which causes and then ammonia will be released which causes the smell problem and reduction in available nitrogen.

So your compost quality is going down. Mature compost, once the composting is done, when the reaction has been taken place, they have a pH of around 7. And but if you do not have a proper air supply, if the, if it is anaerobic system gets developed, your pH may drop to 4.5 and then once it drops to 4.5, it is the, the pH, your compost system will struggle. So it is not easy to keep it like working, so you may have to sometimes restart the whole composting process. So that is, you do not want that to happen. So you do not let pH go below 4.5 in a compost system.

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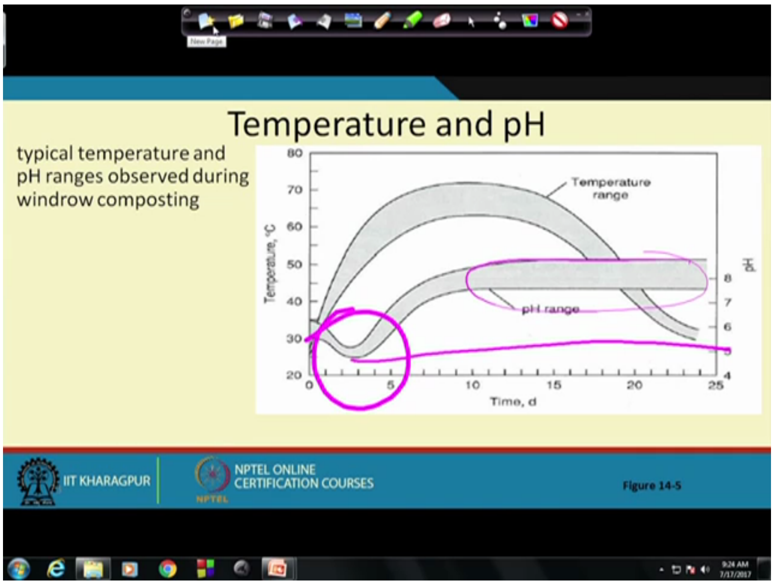

So temperature is important, pH is important, moisture content is important, amount of organic fraction which is there is important and then the temperature and pH also have certain relationship here as well. So as the time of the day, once you start this composting process, you see that this is a kind of temperature range like how based on the reaction that is happening, you start seeing a buildup of temperature and then the temperature goes down. There are 2 lines at the bottom and the top and the one in the middle is showing us like, it is basically the range, the grey, the grey portion is the range of temperature range and the pH range.

PH again as you can see over here, we have certain trip in pH and that drip in pH is because of the acids that is being formed, like the acetic acid. So here if you try to kind of drag a line, it is around 5 point something. So it is not a perfect line but you can put a scale and do it, it will be around, something around 5, 5 point some will come up. So it is, so pH does go down but then it starts, will start back up, so this is, this range will, this pH is around 7.5 to 8.5, there is a pH range which the bacteria really likes. And once the composting is done, we will have the pH kind of goes down to around 7.5, that is what the typical pH you will see. So this is just showing you a temperature and pH profile of a typical composter, of a wind blow composting and that is in terms of how the temperature and pH will change over a period of time as a composting process is taking place.

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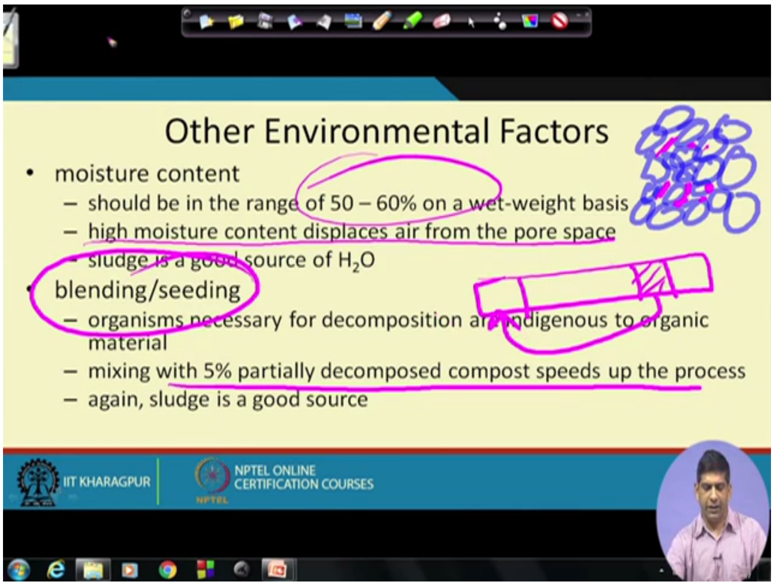

So there are some other environmental factors, the moisture content, we kind of talked about that, I will keep it here, it should be in the range of 50 to 60 percent, on wet weight basis. When we say wet weight, it means taking the moisture content into consideration. So when we are talking about it is, in the wet wastes, wet weight is basically mass of water divided by the total mass, total mass by the mass of water is also included. So that is your wet weight basis. So high moisture content, you do not want to much moisture content because if it is, if all the pores have been filled up, if all the pores have been filled up with this water, we will not be able to pass air through it.

So for, if you remember, say if these are the, we have this is a waste, different components and so in between we have this void spaces, so say this is like, not a great artist but in between as you can see there are some, let us use different colour. So in between we have these void spaces here, these are the void spaces, now if we fill these void spaces with moisture, now next we will not be able to pass air through these. So it will be a already saturated, that is why we do not want high moisture content displaces air from the pores spaces. So we do not want too much high but around 50 to 60 percent is what is helped in terms of because the bacteria likes water, without water bacteria will not survive, it does need water to survive.

Then you may do some blending and seeding, blending means where the organisms are necessary, so if we do not have, so what we do is we mix 5 percent of partially decomposed compost, so it is a partially decomposed compost, it is a good, good population of the bacteria present, so we take that 5 percent partially degraded compost and mix it at the front. So if this is your composting process to buy the waste is actually coming in here and you have some partially degraded compost over there, so we take part of it and put it back here and that, that helps in terms of bacterial population coming back here. Again sludge is a good source, sludge is also used for getting a good bacterial population.

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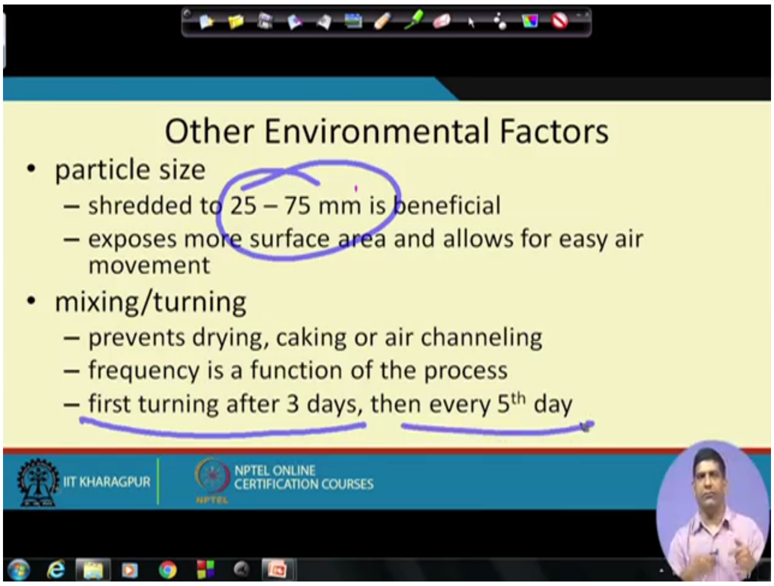

Particle size, again if it is too big of a particle, it becomes difficult, so we try to shred it to 25 to 75 MM, so that is the particle size for this 25 to 75 MM. Exposes more surface area, allows for easy airflow, so it helps in that. Then you do the mixing and turning, prevents drying, caking or air channelling, when you try to do the mixing and drying. Frequency, it is again you do it in a certain interval. 1st turning we do after 3 days, then after every 5 days we do the turning. So while doing turning, essentially what we are doing is we are trying to add air, we are mixing as to the compost part. So these are some of the environmental factors which goes in there.

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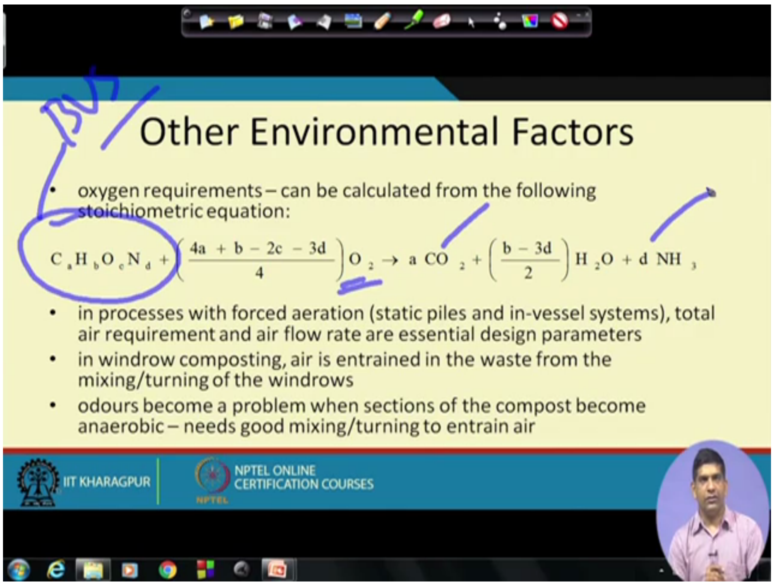

So there are some other environmental factors in top of the oxygen requirement which can be calculated from the following stoichiometric equation. So we will, we will continue this discussion from this particular slide because this slide will take little bit of time for us to talk about and we are kind of end of this video, around 30 minutes duration. So but essentially what we need to do is 1st we will talk about that in terms of how to get this equation and this equation is for the B VS portion. So we need to get this equation 1st, so once you get this equation from the stoichiometric, how much oxygen will be required, how much CO_2 will be produced, how much ammonia will be produced and all those calculations can be done.

So we will talk about that in more detail in the next in the next video, so that will be naturally week 7 video number 1. So with that let us conclude this particular module and we will start from this particular slide again. So again, we have been the emphasising everytime that use the discussion board for any problem you have, anything we can help you with and do the quiz and you can take the exam at the end of the class. So any questions, anything, feel free to contact us through the discussion board and I hope you are enjoying the course and I look forward to continuing the next half.

Now actually this is the end of week 6, so half of the course is done, now we have another half left. So which will cover these treatment systems, landfills, disposal part and then we will go into C and D and E waste component for last few weeks. Okay, so thank you and looking forward to seeing you again.