Integrated Waste Management for a Smart City.
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Lecture-31.
Biological Treatment of Waste (Continued).

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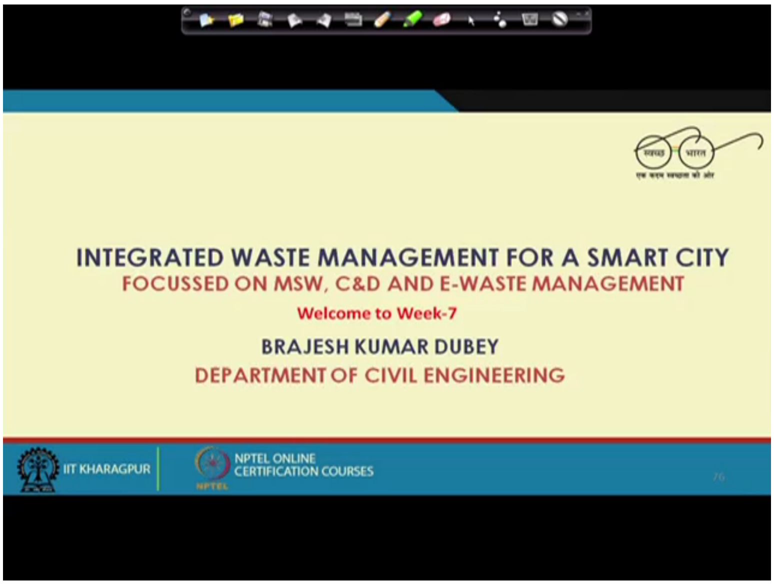

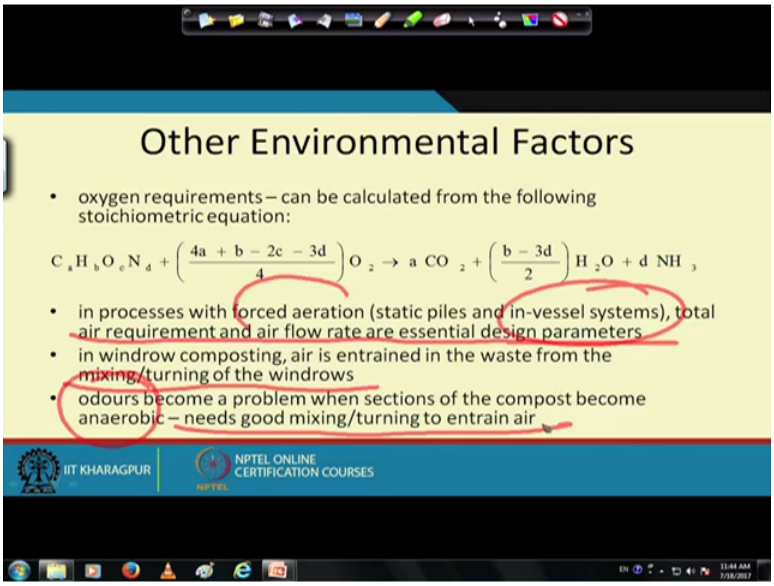

Okay, so welcome, we are going to start our week 7 from this particular module, so we have already finished half of the course, so remaining half is left and I hope you are enjoying the course so far. If you have any, again any questions, any concerns, feel free to contact us through the discussion board. So we will continue our discussion from where we left in the last week's last video where we were looking at composting, different factors, environmental factors which affect composting, if you remember we were talking about the temperature, we were talking about the pH, so we will continue the discussion further and look at some other factors which is out there.

So in terms of the other environmental factors, some of the important stuff, see composting is an oxidation process, so when we see oxidation process, we have to calculate the amount of oxygen required. That is what I am trying to, this is what the slide is trying to say, that we have to find out the amount of oxygen required because that is what, when you are, it says oxidation, so you are supplying oxygen, so oxygen , when we would could supply oxygen, we supply air. And oxygen is part of air, it is around 23 percent. So that is, we will be supplying air to the system so we have to find out how much air is required.

So for that 1st we will find out how much oxygen is required and then we know what and if this much amount of positive is required, what is the is proportionally, how much air is required based on percentage of oxygen present in air. So we have to calculate the oxygen and that can be done using following stoichiometric equation. So here you have the formula of the waste and now here, what is, what is this, if you remember from that slide that we had earlier, this is, this will be the biological volatile solid. So it is the B VS, if you remember that pie chart we had where you had , you had the B VS portion, you had some water, so we had water here, we have inorganic fraction over here, then we had this R VS residual volatile solids and then we have BV S.

So not a great, it is B VS, it is biological volatile solid. So we have to find out, this formal actually relates to this part of the pie, because that is what is going to react, other things will go into the system or it will be, it will become part of the compost or will, it is not going to react in the system. So what is going to react is the B VS portion, so since we are writing the equation here, like what is going to react and how much oxygen we are supplying and these are the products that are being formed, so we have to take the fraction which is going to react, which is the B VS fraction, so it is the biological volatile solid fraction.

So for the waste material which is coming to your plan, so if you are designing a compost plant for whatever city you are working for, you are designing a compost plant, you should know what is the B VS fraction, you should know what is the composition of the B VS fraction and so that you can come up with this equation and we will do a math to see how these equations, to see how the formula can be derived. And you can have, if you have the, you do the CH ONS analyser or if you do the carbon hydrogen oxygen nitrogen how much is there, you can always can come up with a formula for that, so we talked about that.

So it is, so we are, then there are different ways you can add air, so by using this equation, we can find out, we know the formula, so we can, once you know this formula, because based on the B VS fraction we can do that analysis of the, analysis of the waste sample and can get this formula. Once we get this formula, we can, using the stoichiometry, here what we are doing, we are assuming that entire fraction of B VS is going to react. So the entire fraction of B VS is, it is an ideal scenario, it is 100 percent reactions conversion which normally does not happen but for our calculation purpose we can use it because we can use always a factor of safety here anyway because once we get this oxygen will apply a factor of safety, so this is an additional factor of safety you can think about.

So once we know this formula, we can find out how much oxygen is required. So once we know how much oxygen is required, the different ways you can have this oxygen added to the system. You can have a forced aeration system, you can have forced aeration where you can have the static piles and then you add to it, you are forcing air through or you have in-vessel systems, you can have the in-vessel systems. And then here the total air requirement and airflow rate, these become essentially design parameters. So if you have to design that system, your air requirement and the airflow rate, at what rate you need to pump the air, that becomes one of the essentials design parameters because then you need to that your essentials design parameter for doing the design system.

And so and then you can do wind blow composting, in wind blow composting how we add air, we keep on turning the waste, we turn the waste from time to time. We bring our waste Turner and return the waste, while we are turning the waste, air is getting into the waste pile. So that is how mixing and turning of windrows, that is done in terms of composting. And if you do not do the mixing properly and if the air does not flow really well, the anaerobic, anaerobic pockets gets built up, what happens is you will have the problem of smell, you will have the odour problem.

So the good mixing and turning to entertain air and good air circulation system is one of the critical factors in terms of the compost design, because if you start compost, if you have the odour issues, if you have the smell issues, if see your neighbouring industry or neighbouring area, if you have residence neighbourhood, they will start complaining and then you will have issues with that as well. Actually in London Ontario which is, there is a London in Ontario in

Canada as well, so there is in London Ontario, as well as they had Orga world is one company which is a very big company, they, I think the parent company comes from Netherlands, not 100 percent sure but I am 99 percent sure.

So I think it comes from Netherlands and then this Orga world was having a plant in London Ontario, the nearby residences complained against the odour issues coming from the plant and they had to shut down the plant to setup an odour removal system. So there are odour removal systems in a landfill, sorry in a compost plant as well. And with the time Permission we will talk about that, I had a mass student did a thesis on odour removal technologies, techno-economic, techno-economic as well as life-cycle analysis on these odour removal technologies are from a compost plant.

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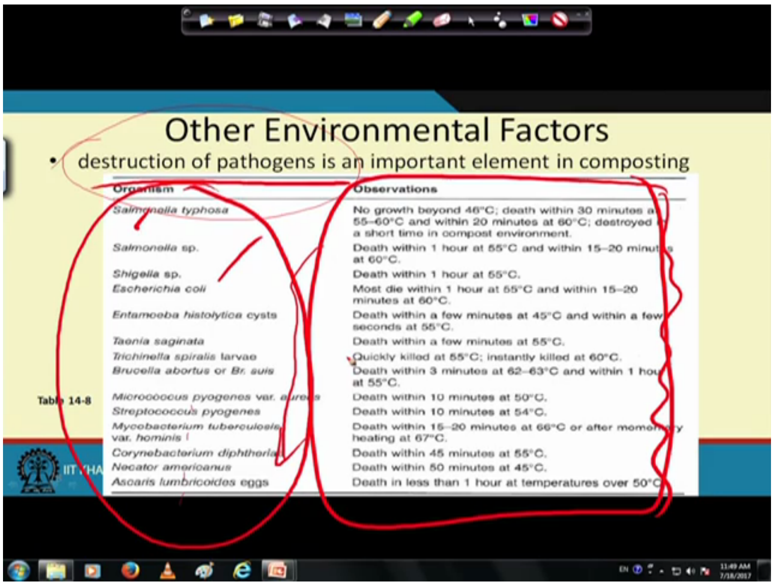

So if time permits, we can talk about that particular research if we get the, if otherwise you are interested, send me an email, I can send you the paper that we published on that. So odour does become a problem, so good mixing of air, good mixing, good circulation of air is very very important in terms of a compost plant. So that is other factors. Then other thing, you do not have to memorise things from this particular table. I am not going to ask any question, any memorisation kind of questions from this particular table but the bottom line that you need to get out of this is that we have to destroy the pathogens. Destruction of pathogens is an important element in composting, so we have to destroy the pathogens.

And that is one of the important factors that we have to do, we have to destroy these pathogens. And how we do that, so there are different types of organisms present, you do not have to remember, it is not in my, it is, you can have some ideas, you hear about salmonella from time to time, this is 2 types of salmonella, E. coli and there are other bacteria out there Coryne bacterium, Necator bacterium and there are different types of bacteria which is out there, which has, like if you improve, if you increase the temperature, especially if you look at on this side, if you look at from top to bottom on this side, you see that if you have a temperature of around 60 to 65 degrees centigrade and if you keep it for around an hour, most of these bacteria will die.

So that is because, once you make the compost, the compost has to meet the compost standard, there should not be, that should not be any pathogens in the compost, otherwise people will get sick, people handling the compost will get sick and then it can come into our fruits and vegetables. Because when we apply this compost in the agricultural field, these pathogens can come to the fruits and vegetables as well and which you do not want it to happen. In that case what you need to do is you need to, as part of the composting process, once the waste has degraded quite a bit, almost towards the end of the composting process there is a phase when we increase the temperature to around 65 degrees centigrade.

We do not want to high of a temperature because if you go beyond 70 degree, what happens is that the bacterial, the good bacteria, the earthworms who are, they start dying. So we do not want that to happen, the aerobic set of bacteria which we need for composting process, we want, we do not want that to die. So that is why we do not want it too high, it is around, we try to keep it around 65 degree centigrade because above 70, many of these good bacteria start to die which, actually bacteria does the work for us, is not it, the composting is aerobic aerobic exercise where these microorganisms, these bacteria are working on our behalf and doing that the gradation of organic matter.

So we do not want those bacteria to die, so we just keep it at around 65 for one hour as you can see from this part here that if you keep it at 65 degree centigrade for 1 hour, all these all these pathogens, they die away. As you can see no growth beyond say 46, after destroyed, after 60 degree, that within one hour and 55, 5 to 15 to 20 minutes at 60, if you keep it above 60 to 65, most of these pathogens will die and you will have a cleaner compost from pathogens perspective.

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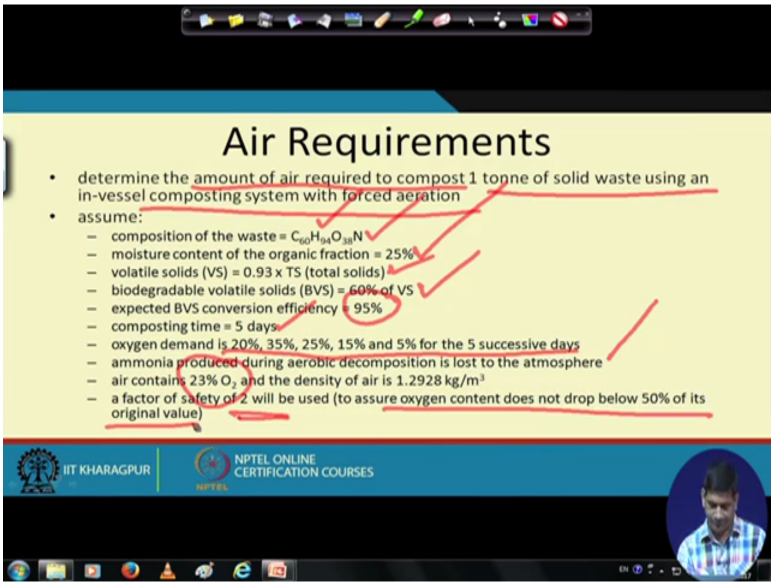

Then air requirement, so we will try to do a math now in terms of how to calculate air because that is one of the most important parameter that you need to do in terms of, when you try to go for compose design. One of the important parameters that we need to do is to have a aeration system. So for the, for development of the aeration system we need to know how much air we need to add. So here, so one example is given, if you are, if you have amount of air required, so in this problem, it says amount of air required to compose to 1 tonne of solid waste using an in-vessel composting system with a forced aeration, so we are trying to add air to it.

So we have been given composition of the waste, so the formula of the waste is already given, how this was derived, the composition as you can see C 60, H 94, oxygen 38 and nitrogen, for certain type of waste, certain types of agriculture waste be done the People's research done earlier, there are some composter books out there, from there you can get the formula directly. But in, for many cases what you need to do is you need to take the sample, get and analyse, then you know how much carbon, hydrogen, oxygen, nitrogen is there, you do an ultimate analysis, CH ONS analyser and then you can come up with this formula. The moisture content is given of the fraction in 25 percent.

VS is 0.93 of the total solids, 93 percent of the total solids, now the biological volatile solid is 60 percent of the volatile solid. Expected efficiency is 95 percent, so here it tells you not 100 percent but 95 percent is actually reacting. Composting time of 5 days is given, oxygen demand is given like how the oxygen that is required is distributed over 5 days. So 1st day 20 percent, 2nd day is the highest which is 35 percent. Then ammonia, we are assuming that ammonia producing the aerobic decomposition is lost to the atmosphere. We are assuming that, it is a fact, we are, air contains 23 percent oxygen by weight and the density of air is 1.2928 KG per metre cube.

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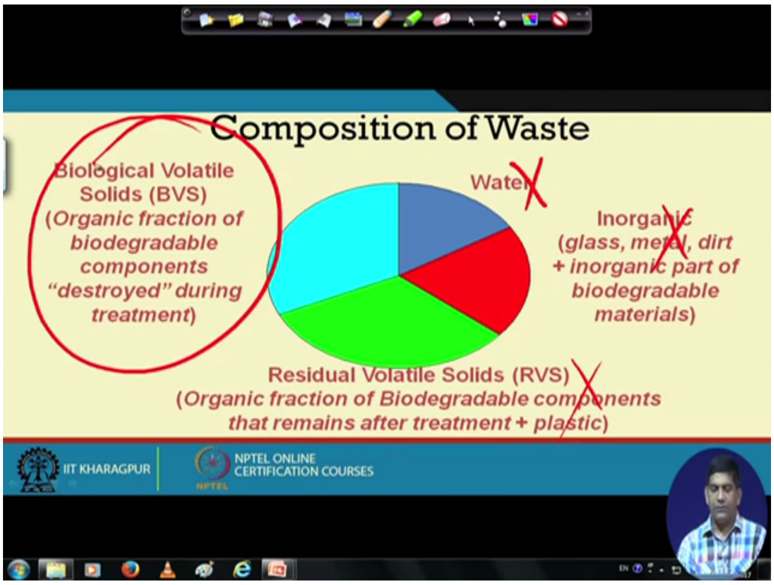

And then we will use a factor of safety of 2 to assure that oxygen content does not drop below 50 percent of its original value. So we have a factor of safety of 2 here as well. So this data is provided to us, so using this data if you have to do the math, then as I said earlier, solid waste maths is not that difficult, again now here if you look at the composition just to remind you, this is what I was trying to draw few slides back. You have the water, you have been organic, you have residual volatile solids, sorry, you have residual volatile solids, so this, this is not going to react with the compost system, what is going to react if this part.

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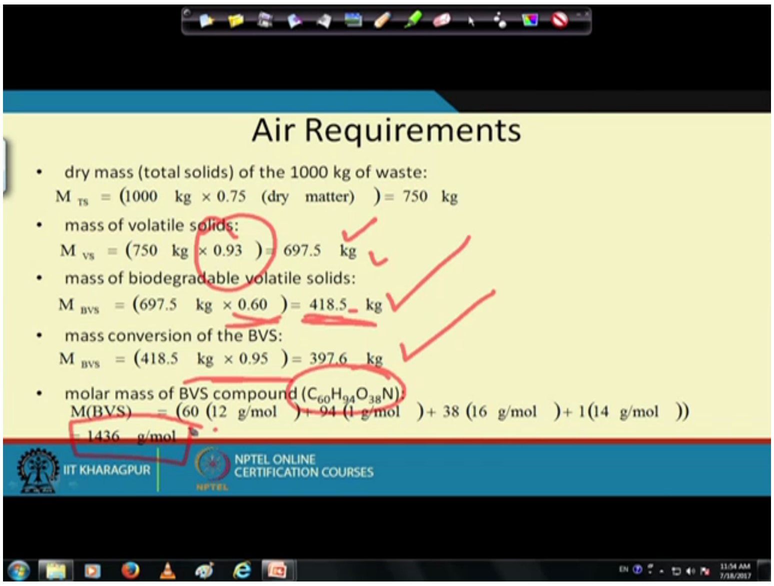

So this biological that equation that we have for the formula that we have is actually for the BV VS fraction. So that formula is already provided to us. So we have to calculate the air requirement, so 1st thing to do is to find out the total dry mass of air, if you remember from the previous slide, it sells 25 percent moisture, 25 percent much means 75 percent dry. So if you have 1 tonne, 1000 KG, so what is the mass of total solids? Why we need total solids? Because we have been told that volatile solid is given in the form of total solids, it is 93 percent of the total solids. So we have 93 percent of total solid here, so that is why we are using 93 percent. 93 percent we got the volatile solid.

Now once we know the volatile solid, we have been told that a logical volatile solid is 60 percent. So we take this number, then 60 percent, so we got that number like a mass of biological volatile solid. Now out of the mass of volatile solid, B VS, 95 percent is what is going to react. So conversion is 95 percent. So what this number, 95 percent, we get 397.6 kilograms, so that is the mass of B VS. Now this is the mass, if you remember from the equation, if you write an equation, you have one mole of this, you add these many moles of this to produce these many moles of this product. So we have to convert things in moles.

So how will convert the things in malls, we will take the B VS, we have already had the equation for B VS fraction, so we can find the molecular weight of that B VS fraction, so mass of molecular weight based on C 60, H 94, oxygen 38, so for this particular if you look at the mass, so 60 times 12 is for carbon, hydrogen is only 94 times 1, oxygen is 38 times 16 and nitrogen is one. So once you add this up, you get 1436 grams per mole. So this much gram per mole is there in terms of the molar mass of the bio, of the B VS compound. So once we have this molar mass, we can calculate what is the total amount of , so once you have the molar mass, so this is this much moles, we can find out in terms of amounts of moles of oxygen required.

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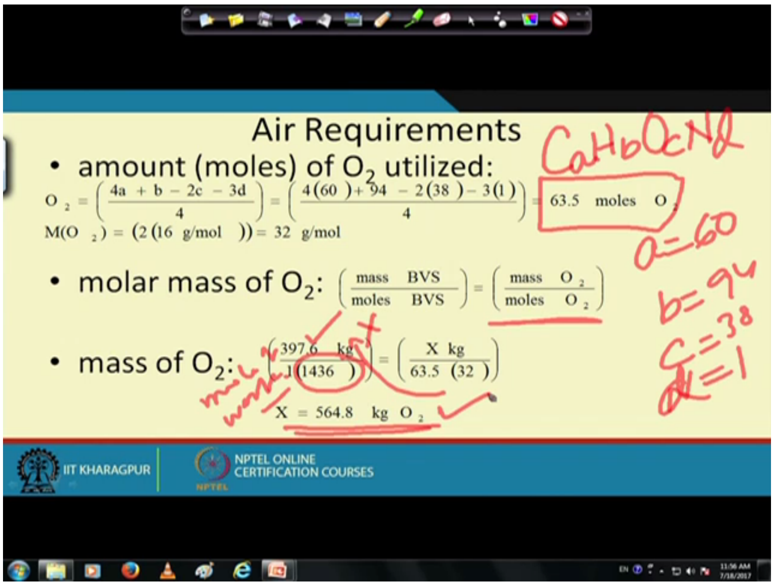

Some amount of moles of oxygen required is for 1, say one mole of this, we can just plug the numbers here, 4A plus B minus 2C minus 3D upon 4, that is like how much do one mole of that particular material will require these many moles of oxygen. So A, B, C, D, we can get from this, here, A is 60, so A, B, C, D is essentially coming from your CA, sorry you have CaHbOcNd. And if you remember, that is how we have defined in the previous equation. So for the previous slide if you see that a is 60, b is 94, hydrogen is 94, oxygen is 38 and nitrogen is 1. Sorry, d, that would be nitrogen, d is 1.

So we can plug these numbers over here, so 60, 94, 38, 1 and then you get 63.5 moles. So for one mole of this particular material we need 63.5 moles of oxygen. So we know 397.6 kilograms was the mass, this is the molecular weight, so this divided by this gives the mole of the mole of waste. So that is the mole of waste and then you may multiply by, for one mole we needed this much, so for these many moles you need how much, you will get, you will get that ratio of that and then you get X which is actually this will go over this side and then become multiplication. So X will be, you get 564.8 KG of oxygen. So you need these many KGs of oxygen for one mole of sorry, not for these many KGs of waste based on one tonne of waste coming in.

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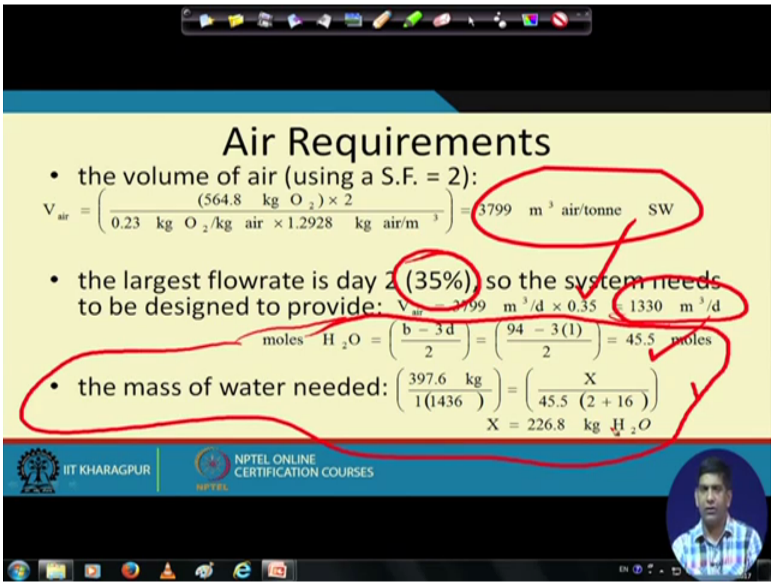

So this is the amount of oxygen is required, so it is expressed in kilograms and we are talking about flow rate and all that, so we have to put it in meter cube in the volume. So we will do that conversion. So to convert that way we will have , again before that, sorry, before that we will convert this to a factor of safety of 2. So there is a safety factor 2, so volume of air is 564.8 KG of oxygen, then we have 0.23 KG of oxygen per KG of air, then air has the density of 1.2928, so that way we can find out how much amount of air is required including the and the amount of a required, here we have included the factor of safety as well.

So factor of safety of 2 has been taken care of in this over here. So that is the amount of air that is required and if you remember from the problem statement, if we go back to the problem in a minute, if you remember from the problem statement, it says, oxygen demand is 20 percent, 35 percent, 25 percent, 15 percent and 5 percent for 5 successive days. So these are on 5 successive days we have this is the oxygen demand. So the maximum is 35 percent on day 2, so why this information is important because once you have, once you come back and have this number, so, okay, once you come back and have this number where you have this much metre cube of air is required per tonne of solid waste.

Now this much metre cube of air is required over a five-day period because we have been told that composting, this particular process is a five-day, five-day process. So if you, but on day 2 we require 35 percent of oxygen, so most of the oxygen is actually required on day 2. So when we buy the blower, when we buy the blower system which blows the air through, the blower has to say that if we have a total requirement and we know it is over day 5, so we cannot just take the total requirement, divide it by 5 to get individual day's requirements, that is not the case because on day 2 it requires much higher, it is 35 percent.

So it is not, we cannot take the average here, so the pump blower system has to make the requirement of day 2. If it meets the requirement of day 2, that is it anyway. So that is the constraint is the design constraint is having that day 2 scenario where you can supply 35 percent of oxygen. Based on that, so volume of air is 3799, so on day 2 you will require 35 percent of that, so you have 1330 metre cube per day. So that much is what is needed, so you can so that is the volume of air that needs to be provided. If you can, other problems that you can look at, you can look at how much is the mass of water present, do we need to add some water because sometimes the compost also require some water requirements, so those things can also be looked at as well.

So that is how much mole of oxygen, like water present there and then mass of water that is needed in terms of having a how much based on the number of moles, that is will be there. So based on that you can find out how much like oxygen requirement, water will be there and even you can find out how much water will be produced. So basically this is some illustration of you can find other information associated with that too. So that is present on that slide.

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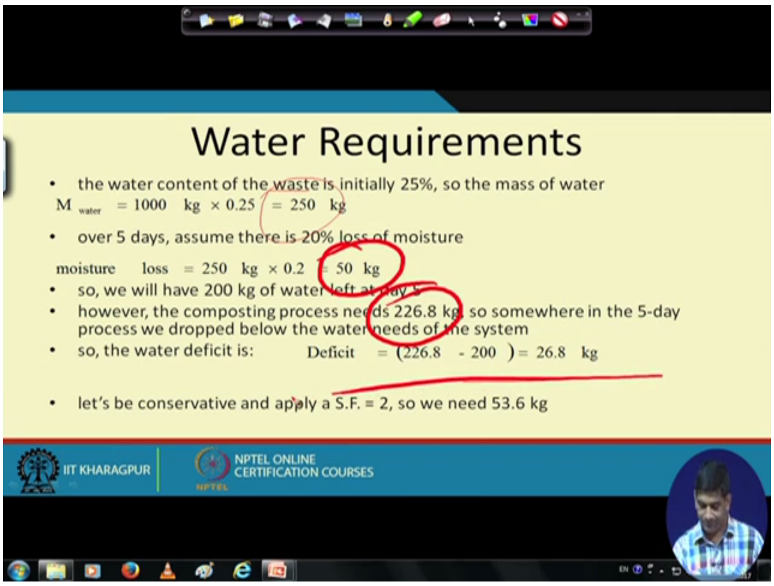

And then you have, you can also find out how much the water is required, like what is the mass of water which is required because in the aeration process, you will also be losing some moisture. There is a loss of moisture over a period of those 5 days. So initially you had 25 percent and over 5 days if you have 20 percent loss of moisture, so you are losing around, from 250 grams that you had initially, in terms of 25 percent, you are losing around 50 grams, so you are down to 200 grams. So if the composting process requires 226.8 kilograms, so somewhere in the five-day process we dropped below the water need, so we need to add water.

So the water deficit usually is there, which is you can calculate that as well. And, so to be conservative and apply factor of safety, so you have, water deficit in terms of the compost plants. So that can be, like a look into and work into, worked as well.

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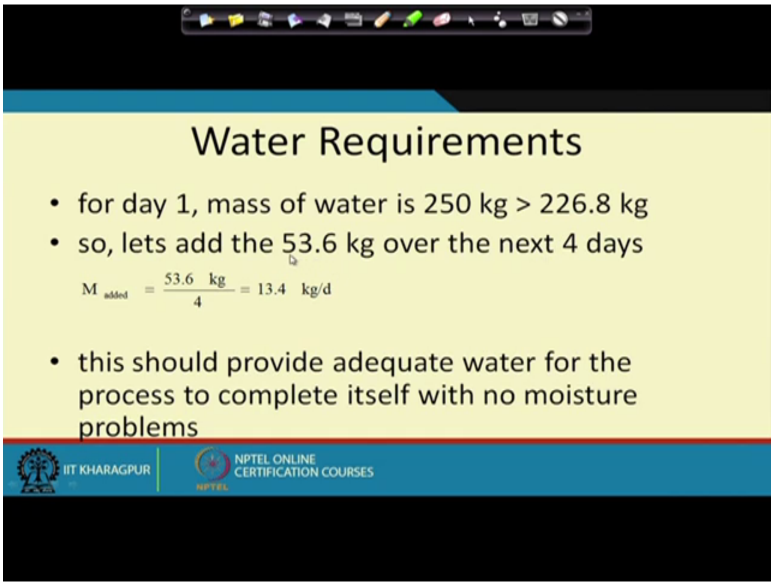

So that is in terms of the water requirement and then for, so you can add water, for day one the mass of water was actually more than what is required, so you can add over the next 4 days. So this should, this should provide adequate water for the process to complete itself with no moisture problem. So you have to look at the air requirement, the other thing is that how much moisture is required, whether we have enough moisture and all those things needs to be looked into.

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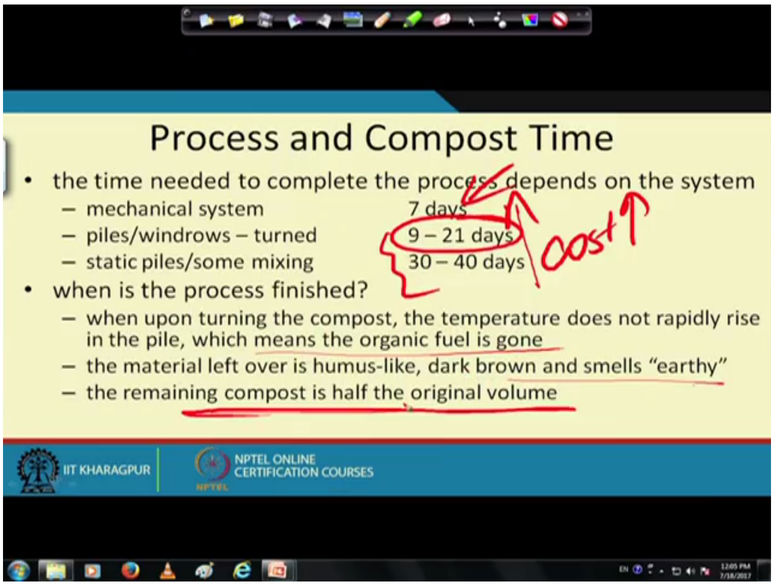

Now there are different types as I said earlier there are different types of composting process, there are some mechanical system, there are some Pile windrows and turned system, there should be some static pile, static as the name suggests, it is static, it does not move, so things are not moving over there. Some mixing could be done but not too much there as well. So based on what system you go for, there are different time duration. The one that we just, the maths that we just talked about was kind of a rigorous mechanical system, because we were talking about just 5 days.

So but here, typical the system is around 7 days, when you go for Pile and windrows, turning is around 9 to 21 days and then static piles with some mixing goes up to 30 to 40 days. So again it all depends on how much space you have, how much money you can spend. So if you have a bigger space and you can, you do not want to spend that much money, go for static piles with some mixing, you will go over 30 to 40 days, but that is okay, if the land is not an issue, if you have sufficient land available, then cost will be less and you can operate that compose that way.

In terms of windrow where you are turning piles and windrows where you are doing the turning exercise, 9 to 21 days, so it is like around slightly over a week to 3 weeks is what is required. If you go for a highly rigorous like a mechanical system, you can even bring it down to a week. So you can get the composting done in a week. So there are different systems, more, as we go up, the cost goes up as well. As you go for the system, your cost also goes up. So you have more cost as you make (())(25:03). But sometimes the cost of land is so much because if you have to do it for 9 and 21 days, that means you need a storage space for garbage.

You need to have, when you do this pile, that also takes, you have the area occupied for 21 days. So if you, if the land is cheaper, then , then this too can work but if the land gets really expensive and then it may work out that you will, you may have to go for a mechanical system because that is how it can get done quickly. But when we will know when the process is finished, so that is another part, like how to find out whether the process is finished or not. So when you are turning the compost, the temperature does not rapidly rise, so what does that mean, so when you are doing the compost turning and you do not see, that you do not see because compost plant we do have temperature probes and all that there to measure the temperature.

So you do not see a sudden like a rapidly rise of temperature, that means most of the organic degradation has taken place because organic degradation is an exothermic reaction, it releases heat. So once the things releases, once the reaction releases heat, the temperature has a tendency to go up. But if you do not see a temperature increase, you do not see substantial temperature increase, rapidly temperature increase, that means most of the organic fuel is gone, things have been degraded. The material left over is like a humus like dark Brown, it smells earthy like the smells of soil, the remaining compost is half the original volume.

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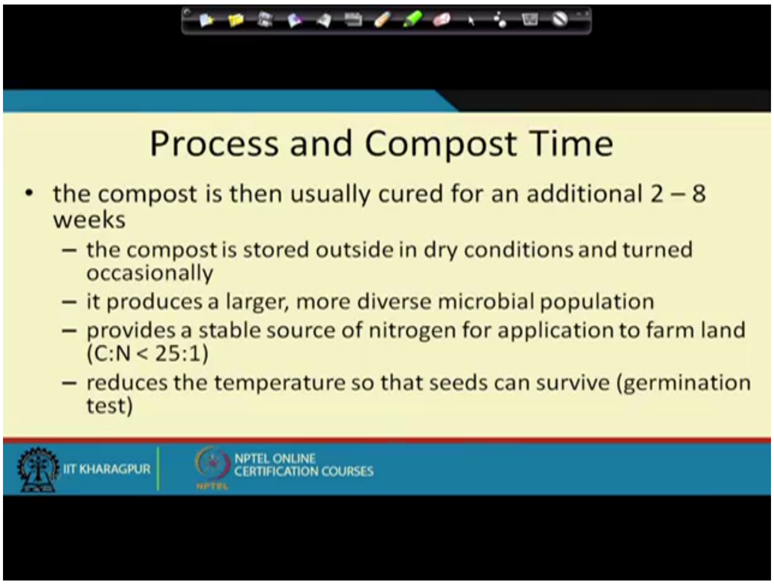

So it is around up to 50 percent of the initial mass that you put in there. So that is, that needs to be sold off or used for different applications. And then compost is usually, then cured for an additional 2 to 8 weeks, once you have done with this initial exercise, you will let it do the curing, what the curing does, it produces a large more diverse microbial population. So it, you basically what you are doing here is you are putting it in a favourable condition, you are putting favourable compost pile now in a favourable conditions for it to get matured to get to some moisture, to have the microbial activity going on, some even, like trees planted and all those kind of things could be done on that too.

So it just helps in like in compost, having a larger, more diverged microbial population and it does provide a stable source of nitrogen for application to farmlands. So with the carbon nitrogen ratio of less than 25 is to 1, reduces the temperature, so that seed can survive. So the germination test we can do to find out whether the seeds are going to survive, whether it will, or if it does not survive, then there is the point of this compost, is not it. So the seed has to survive, so that this is what, we have to reduce the temperature for that as well.

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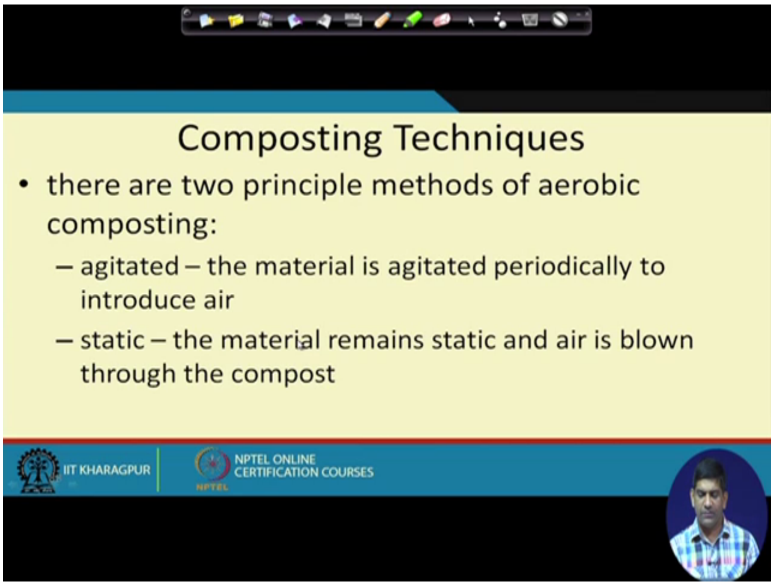

So in terms of composting techniques, there are 2 principal methods of aerobic composting is agitated and static. Agitated is, the material is agitated periodically to introduce air and static in the material remain static and the air is blown through the compost. In the 1st part the material is agitated periodically when we are adding the air and the 2nd one, material remains static, so we do not, they are not moving the material but air is blown through the compost, we are producing, that is how the air is added to it.

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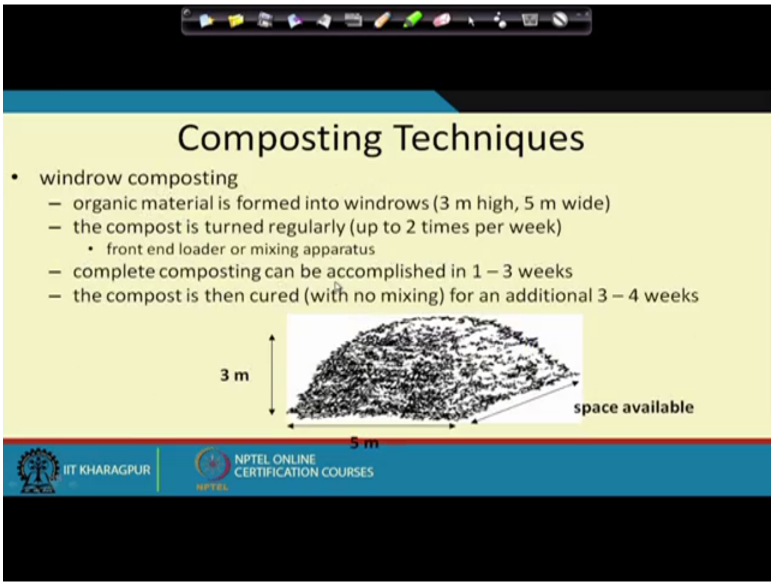

So composting techniques, windrow composting, it is the typical windrow, organic material is formed into windrow, you have a 3 meter height, 5 metre width and then the length will be based on your location that is available to us, then you have a front-end loader or mixing apparatus where it will go and then it will keep on mixing, mixing and turning. Complete composting can be done in 1 to 3 weeks and then you do another curing where you do not need to do the mixing for additional 3 to 4 weeks. So that is how windrow composting is done which is one of the very popular way of doing compost in many parts of the world.

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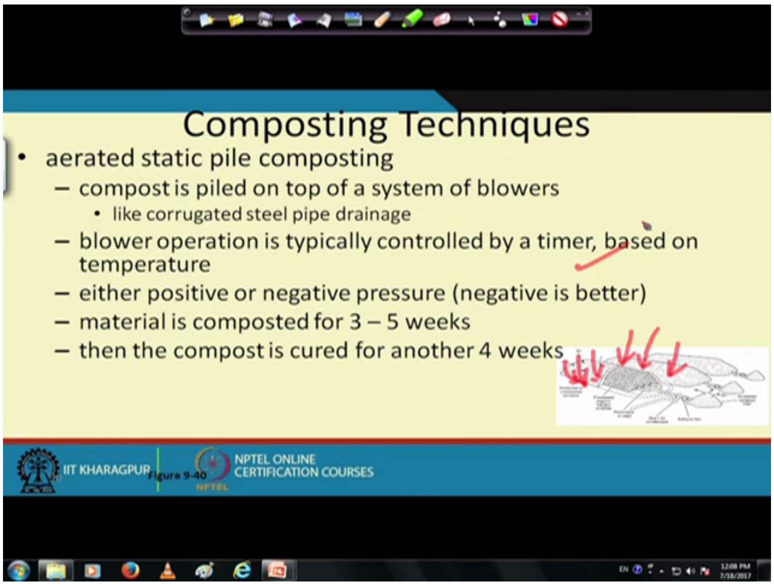

And the other one could be the Aerated static file where you have, where you have blower operation. So this is, you have in case of here, you have some sort of windrow kind of structure, you have some pipes and you can either inject air or you can apply vacuum. So when you apply vacuum, there will have a tendency to try to go in there. This material, these days are , you have a like a daily cover kind of material, so that is also, this kind of material is used. And then it has some perforation so the air can potentially pass through. So what you are doing here is essentially applying vacuum, you are applying vacuum and let the air go in there.

So that is one way of doing it, you can also apply positive pressure. So blower operation is typically controlled by a timer, so be the temperature, you do not want temperature to go too high because there will be some fire issues as well. So based on temperature you increase the blower, you start the blower, once the temperature starts getting too much you stop and then the cycle continues. So you can do positive or negative, both pressure, like vacuum you apply, material composted in 3 to 5 weeks, slightly less, then compost is cured for another 4 weeks, so that is used for composting in static pile.

So that is in terms of the composting techniques, so there are 2 different types of techniques we talked about. And let us based, I think we have to wrapup this video now and then we will continue with our 2nd video and where we try to do some more maths calculation for this composting exercise and then we will move to anaerobic digeter. So again right now we are focusing on biological treatment of waste, we started this discussion in the previous video, we are continuing in this video and then we will most likely it will get completed in the subsequent video. So again if you have any questions, feel free to contact and then we will be always be ready to help you. Thank you.