Course on Integrated Waste for a Smart City
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Module 12
Tutorial I

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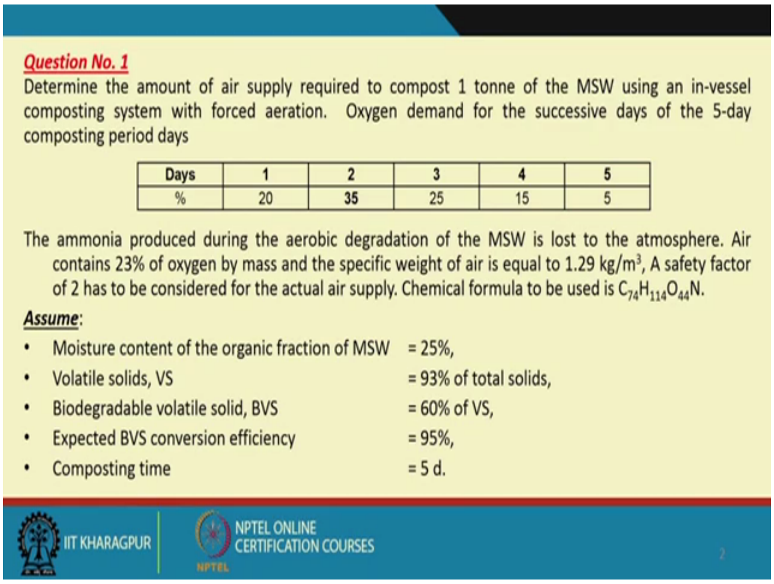

Welcome to the NPTEL course on integrated waste management for smart city. So we will be doing a tutorial on the air calculations and anaerobic digestion and incineration in this session. Now we will just look into the question number one, so we will to determine the amount of air supply required to compost 1 ton of municipal solid waste using an in-vessel composting system with forced aeration.

So the oxygen demands for the successive days of the 5 day composting periods have been provided in this table. The ammonia produced during the aerobic digestion degradation of MSW is lost to the atmosphere and air contains 23 percent of oxygen by mass and the specific weight of the air is equal to 1.29 kg per metre cube. The safety factor of 2 has to be considered for the actual air supply.

And the chemical formula to be used is given over here and we will be assuming moisture content of the organic fraction of the municipal solid waste is 25 percent, the volatile solids is 93 percent of the total solids, and biodegradable volatile solid BVS fraction is 60 percent of the volatile solids, and expected BVS conversion efficiency is 95 percent, the composting time is the 5 days.

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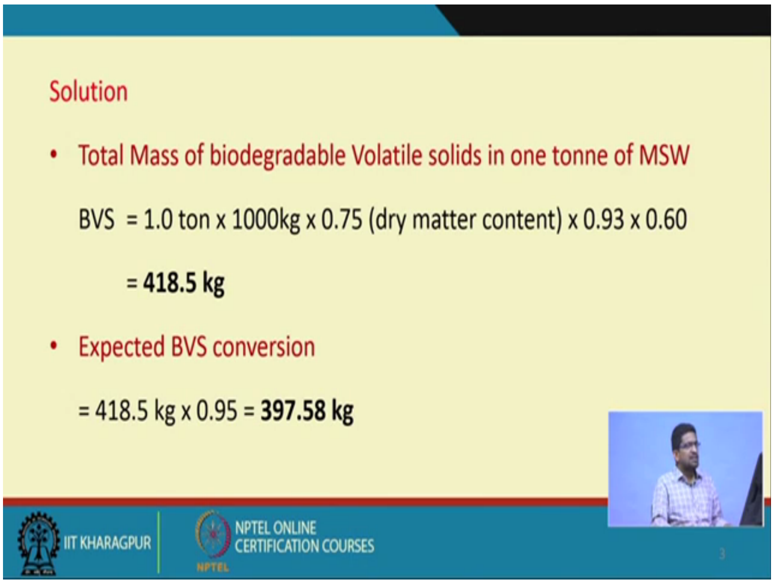

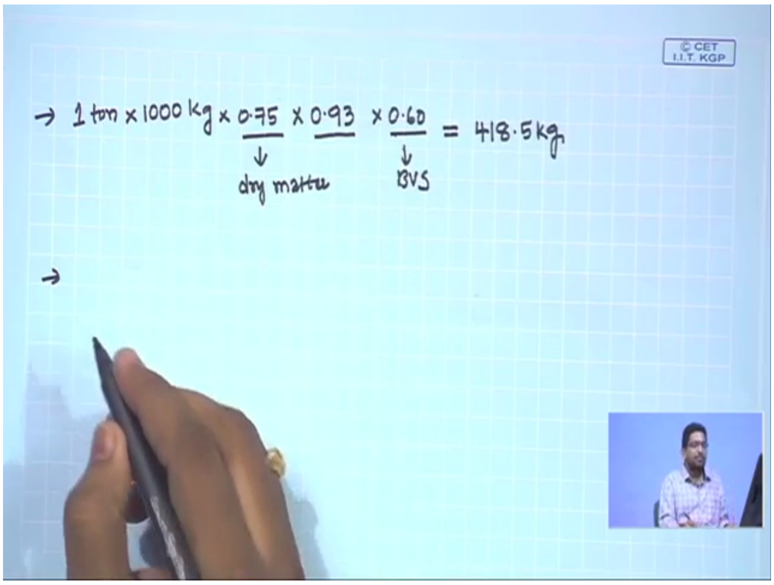

And come to the solution, the initial step of solution we have to calculate the total mass of biodegradable volatile solids in 1 ton of municipal solid waste. So here the 1 ton, so we have one ton so when we are converting it to the KG, it will be 1000 KG so multiplied by the 0.75, this 0.75 has been arrived from the moisture content determination.

So we have 25 percent moisture in the municipal solid waste. So we will if we just see here the moisture content of the organics fraction of municipal solid waste is 25 percent, so 100 minus 25 percent is the 75 percent which is the dry fraction, dry matter or content, dry matter so that multiplied by 0.93. The 0.93 is the volatile solids content and multiplied by point 60 which is the BVS fraction, so total it will be 418.5 KG.

So next we have to determine the expected BVS conversion factor, so the expected BVS converts fraction is the actual biological volatile solids that what we are going to get in our study. So here we are given the expected BVS conversion efficiency is 95 percent.

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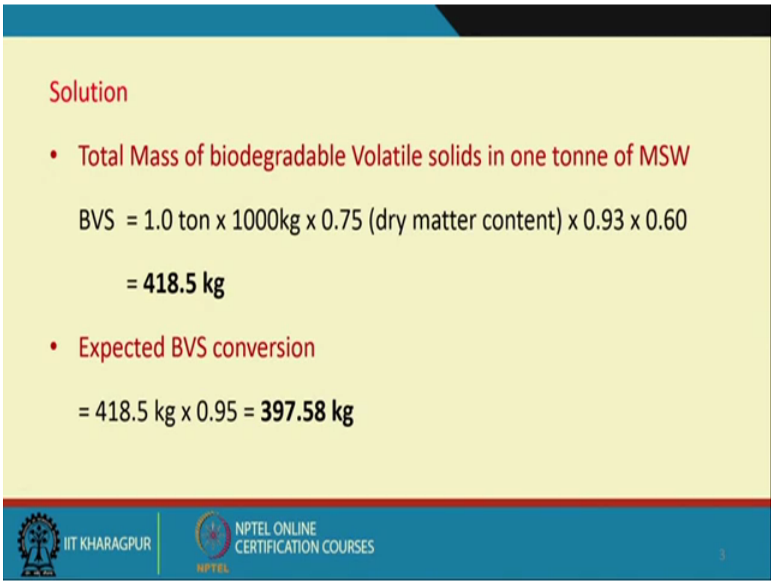

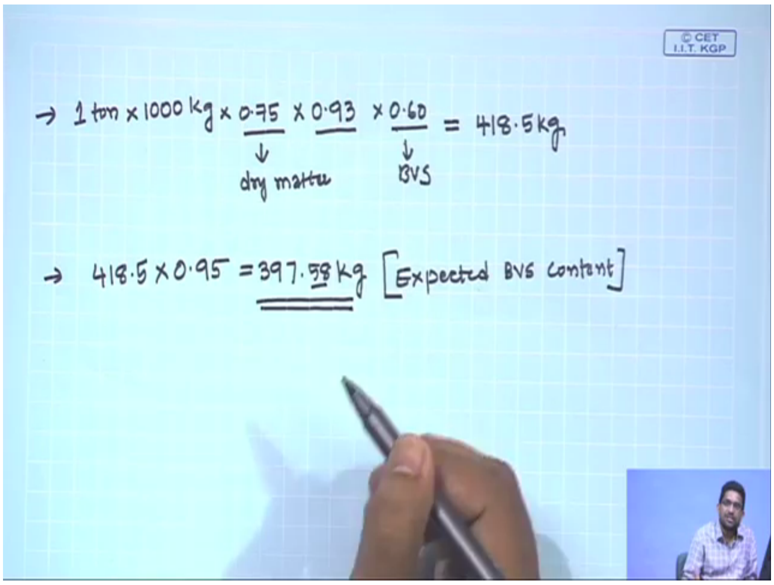

So now take the 418.5 KG the total mass of biodegradable volatile solids multiplied by 0.95 we will get the actual content that is 418.5 into 0.95 which is giving is to 397.58 KG which is the expected BVS content, so we will be using this value in our calculations. So in the examinations we request all the students to go for the 2 decimals percussions.

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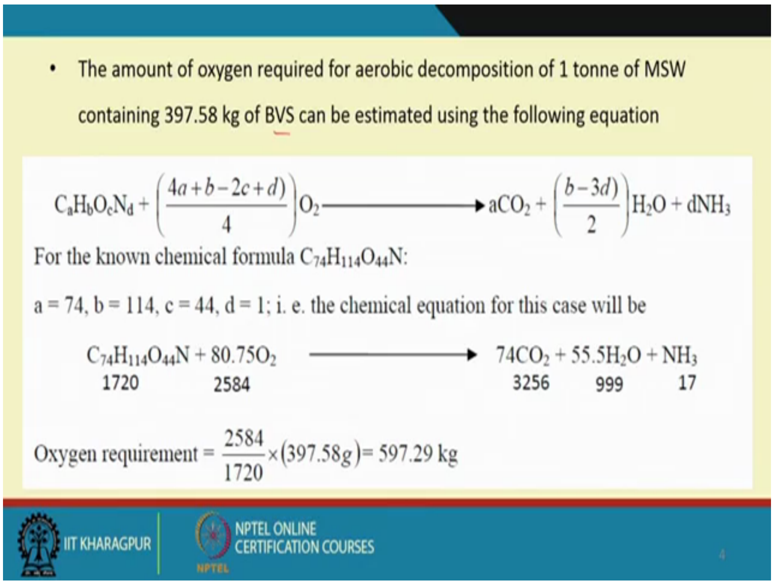

Now we will be calculating the oxygen required, so the amount of oxygen required for an anaerobic decomposition of 1 ton of municipal solid waste container 397.58 KG of BVS can be estimated using the following equation. So in the PowerPoint presentation we can just see the equation which has been developed over here and it has been taken from the standard literature and textbooks.

So in this already the Ca Hb Oc Nd is the chemical formula and we have been already provided with the chemical formal C 74 H 114 O 4 and N, so where the a will become 74, and b is equal to 114, and c is equal to 44, and d is equal to 1. So the chemical equation for the case will be written in the format where we will the molecular weight of the given chemical is 1720 and for the oxygen we calculated 4 a plus b minus 2 c plus d divided by 4 we will get the molecular weight of oxygen 80.75 molecules is 2584.

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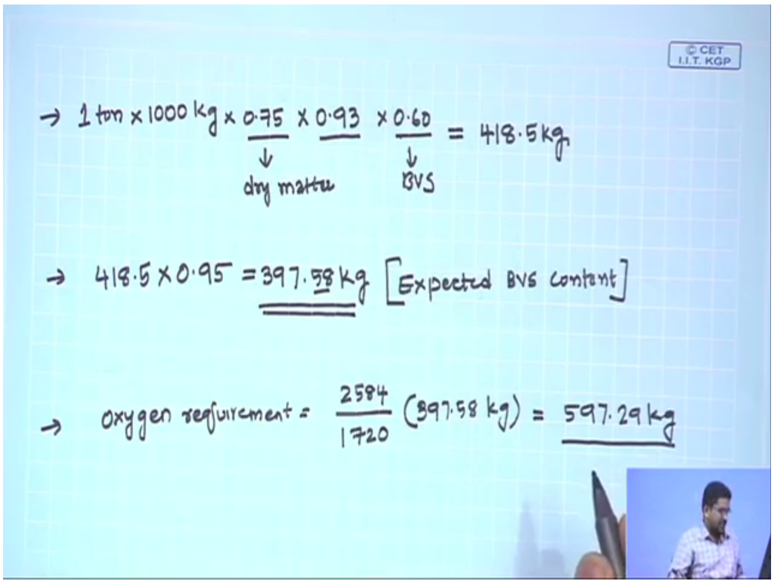

Now the oxygen requirement is oxygen requirement is equal to 2584 divided by 1720 into 397.58 KG, which is equal to 597.29 KG, so we required 597.29 KG of oxygen. And now we have to calculate the amount of oxygen, after calculating the total amount of oxygen will calculate the total amount of air required for 1 ton on the municipal solid waste.

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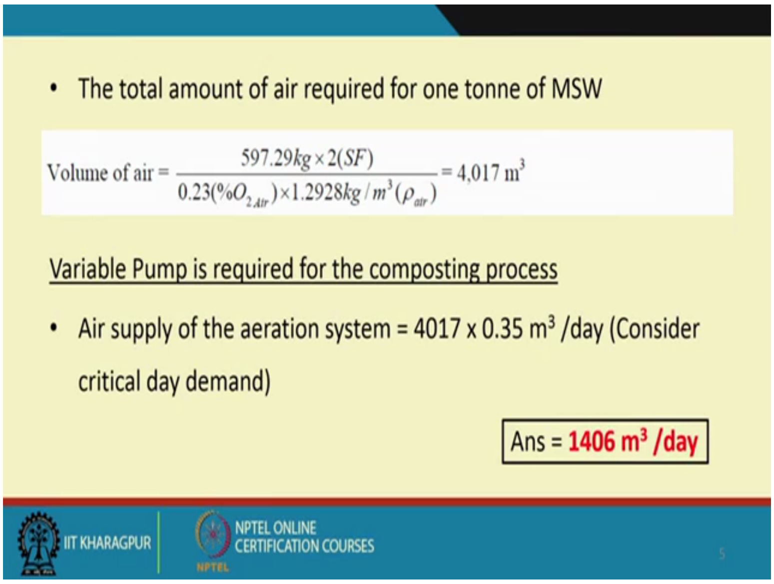

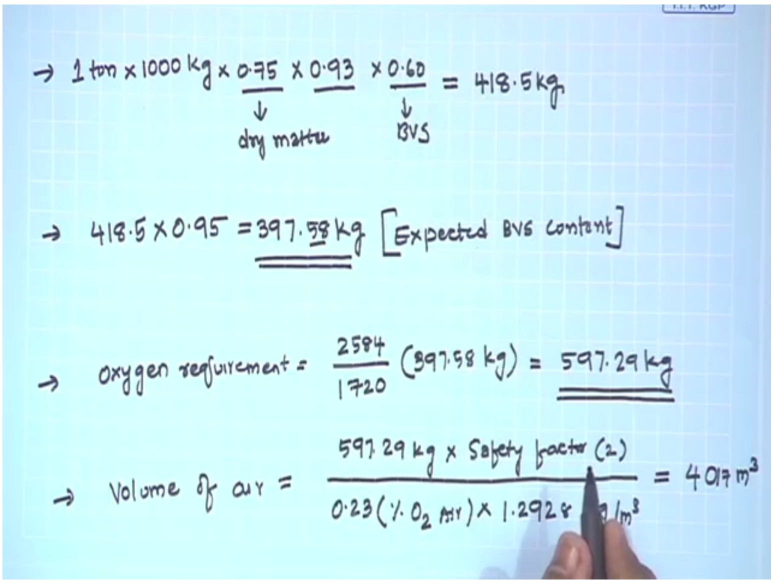

So in the PowerPoint we can see the volume of air calculation over here. So in the volume of air calculation. So we will first take the total oxygen that is there 597.29 KG, so multiplied by safety factor so in the question already it has been given that the safety factor is equivalent to 2 and the total divided by the percentage of oxygen in the air which is 23 percent that is 0.23 that is the percentage of oxygen in air multiplied by the specific weight of the oxygen specific weight which is 1.2928 KG per metre cube which is the specific weight. So we will be getting 4017 metres cube that is 4017 metres cube volume of the air.

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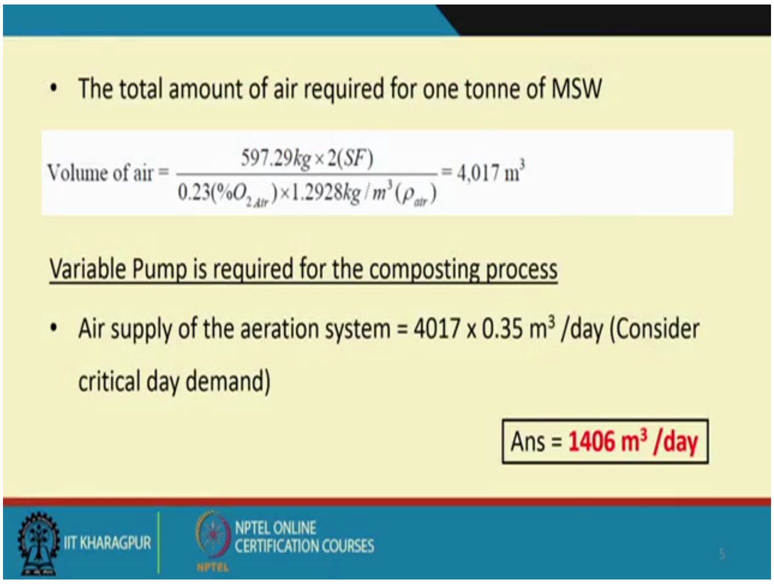

And we have been given that the air supply of the aeration system for 0.53 that is where we are taking the day 2, so here the day 2 has been considered to be the critical. So that percentage will be 35 percent, so we will multiply the air supply of the aeration required for the critical demand.

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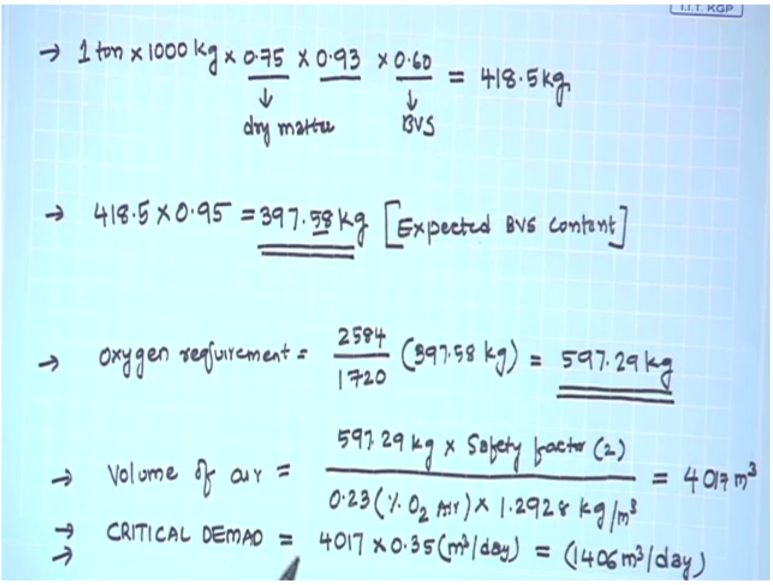

So the critical demand the air required is equal to 4017 multiplied by 0.35 meter cube per day, which is arriving to 1406 meter cube per day. And now we will just look in to the next numerical, that is anaerobic digester is to be designed for a dairy farm; the dairy farm has 12 cows. Assume each cow producing 10 KG of dung daily, the Cow dung from all the cows.

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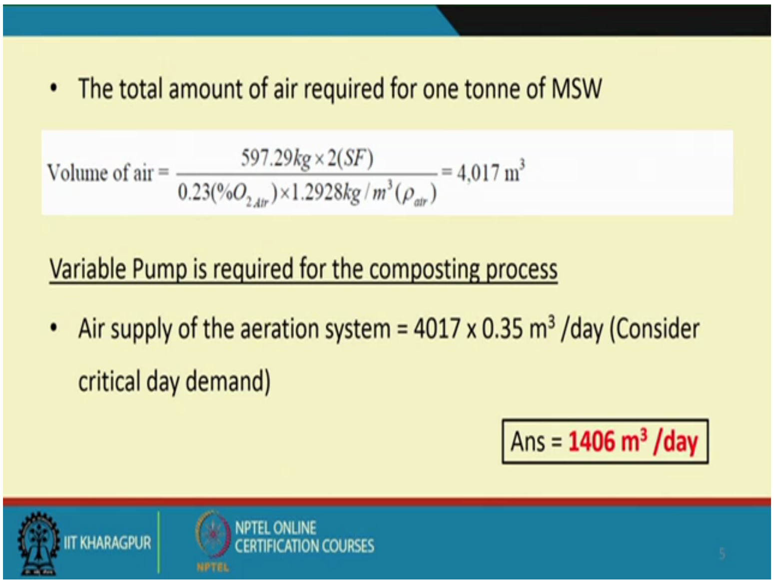

Now we will design an anaerobic digester, an anaerobic digester is to be designed for a dairy farm, the dairy farm has 12 cows. Assume each cow producing 10 KG of dung daily. The cow dung from all the cows is available to the feedstock this is the assumption. Assume the temperature is 30 centigrade, and the solid content of the cow dung is 15 percent and hydraulic retention time HRT is 45 days for the anaerobic digester.

And Determine the total volume of the digester for the present case and then the diameter of the digester, the height of the digester. It is the wall here we are use the formula V3 that is the volume of cylindrical portion V3 of the digester can be computed by this formula. In the examination we will be providing this formula.

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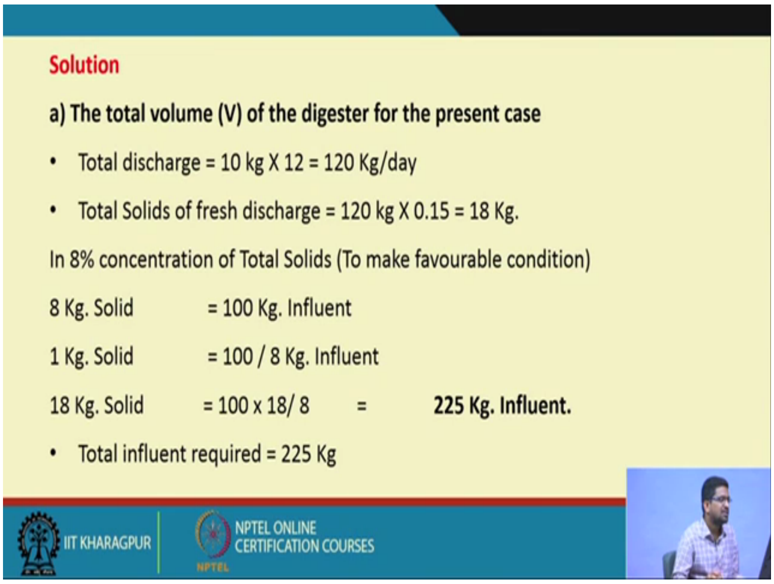

Now we will be calculating the total volume of the V of the digester for the present. Here the total discharge is 10 KG of the cow dung that is arriving from the 12 cows which is 120 KG per day. And the total solids of fresh discharge be 0.15 percent that is 120 KG into 0.15 which is equal to 18 KG. And to have the favourable condition we will have 8 percent concentration of the total solids. So now in the 8 KG of solids is equal to 100 KG influent, so 1 KG will be 100 divided by 8 KG of the influent and for the 18 KG's, it will be 100 into 18 by 8 which is equivalent to 225 KG of the influent. So the total influent that is required is 225 KG.

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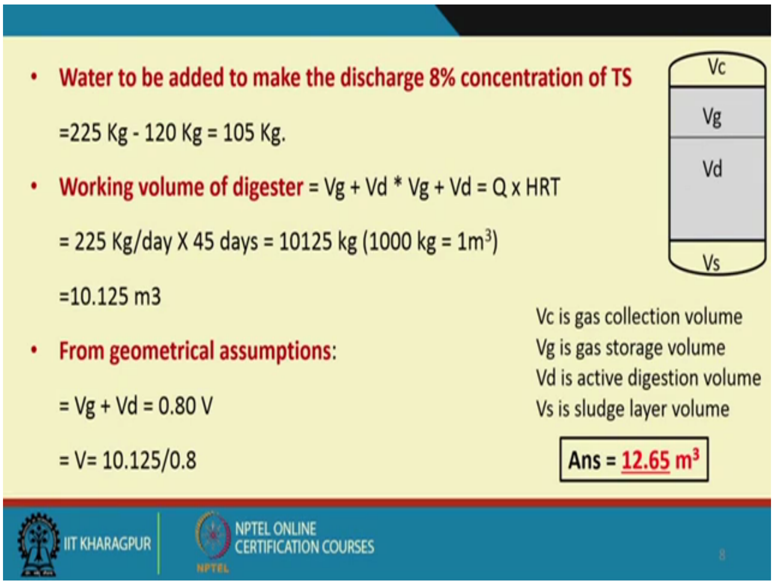

So now the water to be added to make the discharge 8 percent concentration of the total solids we have to check out. It is 225 KG minus the 120 KG so which is equivalent to 105 KG, so this is the total amount of water to be added to make the discharge of 8 percent concentration of total solids.

Now to determine the working volume of the digester, so in the diagram you can see the different portion of the digester, where Vc is the gas collection volume. So in after the digestion process once the gas is been generated it will be collected in the Vc, and Vg is the gas storage volume and Vd is the active digestion volume and Vs is the sludge layer volume.

So in the anaerobic digestion process once the active digression volume, the municipal solid waste will undergo the degradation process like hydrogenises, acitogeenesis and methenogenisis and we will get the gas and the sludge. The sludge will be stored in the sludge layer volume and the gas will be stored in the gas storage volume and it will be collected from the collection volume area.

Now we are interested in calculating the working volume which is equivalent to the volume of the active digestion volume Vd plus Vg that is the gas storage volume, so which is equivalent to the flow into the hydraulic retention time. So the flow Q is equal to 225 KG per day and the hydraulic retention time is provided to be the 45 days, so multiplying this will get 10,125 KG and when we are converting it to metre cube, 1000 KG is equal to 1 meter cube, which is equivalent to 10.125 meter cube.

And for the geometrical we are taking Vg plus Vd is equal to 0.8 of the total volume. We can see from the diagram even the Vg and Vd will be covering 80 percent of the anaerobic digester. So the geometrical assumption that means the construction process we have to take that portion geometrical assumption which is equivalent to 0.8 of the total volume. So the V is equal to 10.125 divided by 0.8 which is coming to 12.65 meter cube. So this is the volume of the anaerobic digester.

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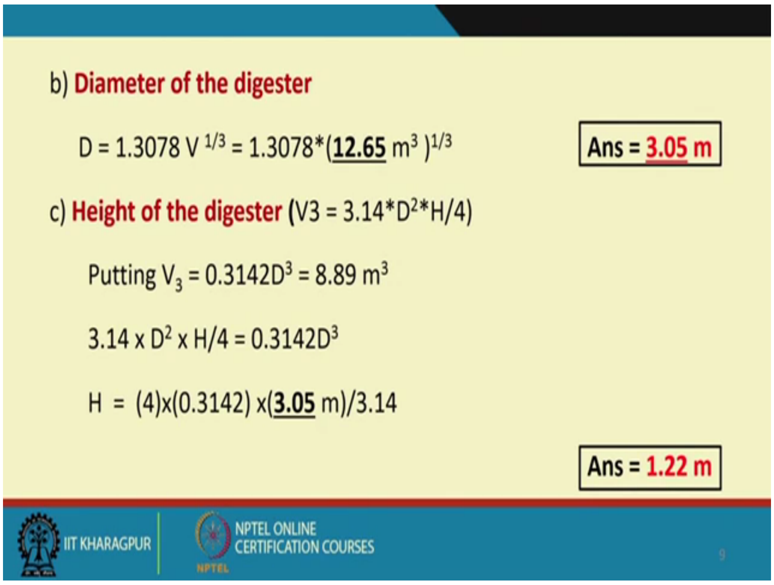

Now we will calculate diameter of the digester, so the diameter of the digester can be directly collected from the formula 1.3078 V raise to the volume raise to the power of 1 by 3. So the volume has already been calculated from the previous slide that is 12.65 m cube, so simply substituting this into the given formula, 1.3078 multiplied by 12.65 metre cube raise to the power of 1 by 3, we will get the diameter which is equivalent to 3.05 meter.

Now we will calculate the height of the digester, so for calculating the height of the digester we have V3 is equal to 3.14 into D square into H divided by 4 that is height divided by 4. So putting the V3 value which has been given as 0.3142 D cube is equivalent to 8.89 meter cube. We will calculate the substituting this we will get the height of the digester as 1.22 meter.

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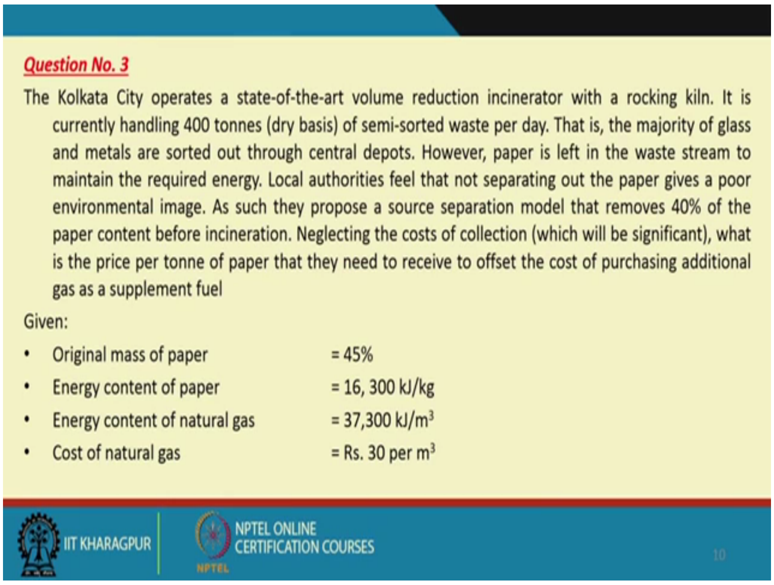

Now we will just calculate the numerical on the incineration. So the Kolkata city operates a state of the art volume reducing incinerator with a working kiln. It is currently handling 400 tons on dry basis of semi-sorted waste per day. And this is the majority of class and metals are sorted out through the central depots. However, paper is left in the waste stream to maintain the required energy. The local authorities feel that not separating out paper gives a poor environmental image. As such they propose a source segregation model that removes 40 percent of the paper content before incineration.

So neglecting the cost of collection which will be significant and what is the price per tonne of paper that they need to receive to offset the cost of purchasing additional gas as a supplement fuel. So in the given data, we have the original mass of paper as 45 percent, energy content of paper is 16300 kilo joule per KG, the energy content of natural gas is 37300 KG per metre cube and the cost of natural gas is rupees 30 per metre cube.

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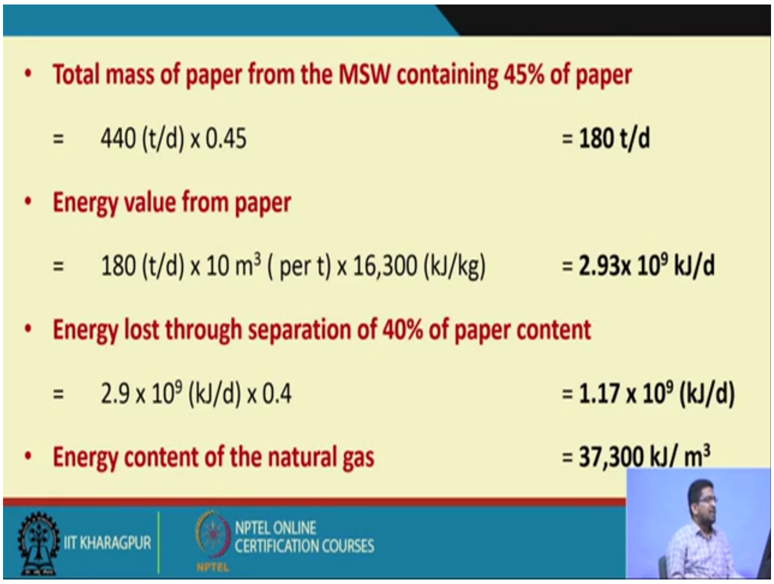

Now initially we have to calculate the total mass of the paper from municipal solid waste containing 45 percent of the paper. So we are generating 440 tons per day out of which 0.45, 45 percent that is 0.45 will be the total mass of the paper. So 440 tons per day multiplied by 0.45 we have 180 tons per day.

So the energy value from the paper is 180 tons per day into10 meter cube per ton to 16300 kilo joule per KG, so which is equal to 2.93 into 10 to the power of 9 KG per day. The total energy value of the paper is 2.93 into 10 to the power of 9 KG per day. The energy lost through separation of 40 percent of the content, since we are segregating the paper, so we have to remove that energy loss.

So it is 2.9 into 10 to the power of 9 kilo joule per day into 0.4, so which is coming to 1.17 into 10 to the power of 9 kilo joule per day. So if we not taking this 10 power 9 in the assignments most of the students are solved with the full-length calculation just like 117346 the value is coming, so we request all the students to take this 2 decimal precision. So it is 1.17 to 10 to the power of 9 or 2.93 for the calculations.

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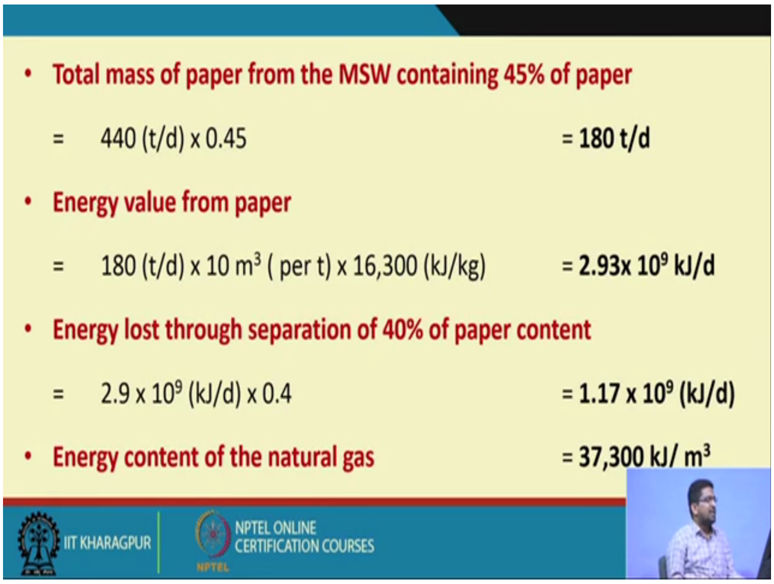

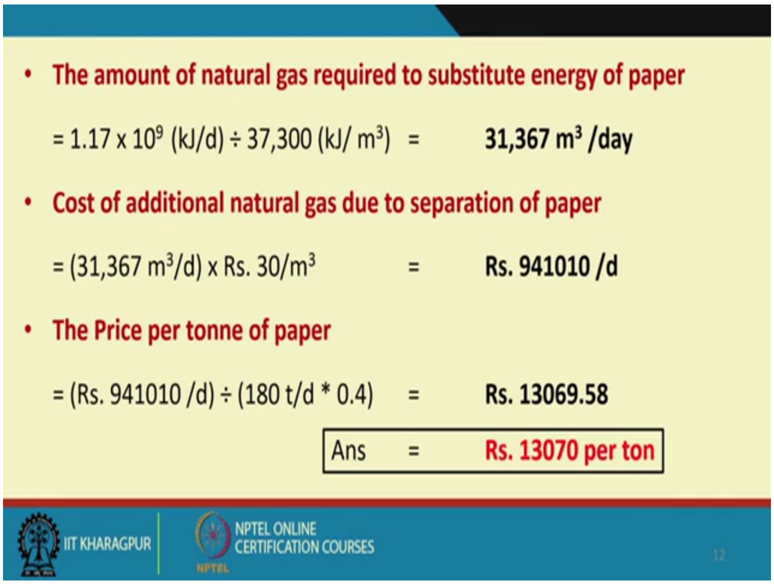

The energy content of the natural gas from that equation will be you have to calculate, so the total amount of natural gas required to substitute the energy of paper. So the energy of paper is 1.17 into 10 to the power of 9 divided by the energy content of the natural gas, so which is equivalent to 31367 meter cube per day.

Now we have to calculate the cost of additional natural gas due to separation of the paper. So for the amount of natural gas required to substitute the energy of paper that is 31367 into the 30 will be the additional cost of the natural gas, so which is equivalent to 941010 rupees per day. So the price per tonne of paper we have to calculate, so the overall ton as 180 tons we are receiving in the paper form, so for the each ton we have to divide this 941010 rupees per day divided by 180 into 0.4, that is the total paperweight which is arriving to 13069.58, so rounding it off will get 13070 per tonne.

So in the assignment we have been like there are a few calculation mistakes their precision errors have done from our side and your side. We are calculated 2 decimal precision and the total number has been calculated by the students over there, so which is led to different answers. So what we suggest the student is to use the 2 decimal precision. So to arrive this sort of answers even in your examination there are questions of this model, so you just take the 2 decimal precision and calculate to reach the required answers. So all the best for your examinations, thank you.