Waste to energy conversion
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Lecture – 28
Design of anaerobic digester

Good morning, now we will start discussion on a new module design of anaerobic digester. In this module we will discuss basically on the sizing of anaerobic digester for this purpose we need some background information particularly what type of substrates we have the availability of the substrate, type of substrates and the ambient conditions the location where we have going to setup the anaerobic digester what is the average temperature there. So, all those things are required to decide a particular size to handle certain amount of feed stocks or to produce certain volume of biogas through this anaerobic digestion unit.

So, we will discussion on this in this module on the sizing of the anaerobic digestion unit or the anaerobic digester.

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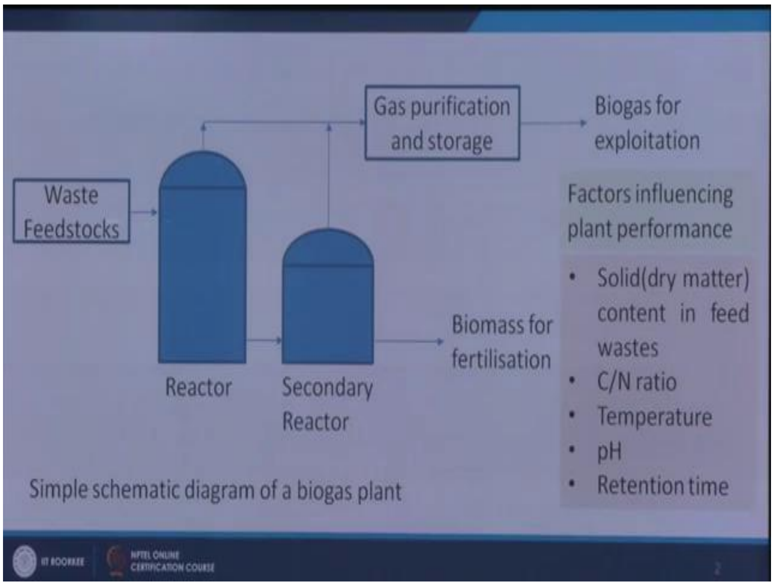

So, now at first we will see the simple schematic diagram of a biogas plant. So, here waste feed stocks its entry into first reactor then second reactor secondary reactor then biomass for fertilizations and biogas for storage and the factors which influence the plant performance are solid content in the feed stock and then C by N ratio temperature pH and retention time. Now we will see the different feed stocks have different solid content different biomass potential, which reactor is designed to handle wheat straws that cannot handle the same amount of dried leaves because their biogas potential is different.

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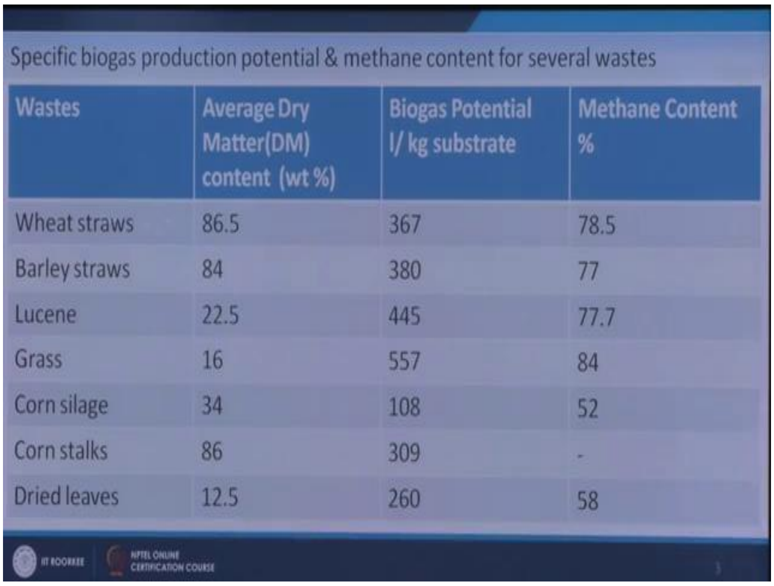

Specific biogas production potential & methane content for several wastes

Wastes	Average Dry Matter(DM) content (wt %)	Biogas Potential l/ kg substrate	Methane Content %
Wheat straws	86.5	367	78.5
Barley straws	84	380	77
Lucene	22.5	445	77.7
Grass	16	557	84
Corn silage	34	108	52
Corn stalks	86	309	-
Dried leaves	12.5	260	58

So, these are some other types of wastes which has having different biogas potential and temperature also play a significant role for the biogas productions higher the temperature more the gas formation here you see different types of waste has been considered different temperatures that 35 25 and 8 degree centigrade has been considered.

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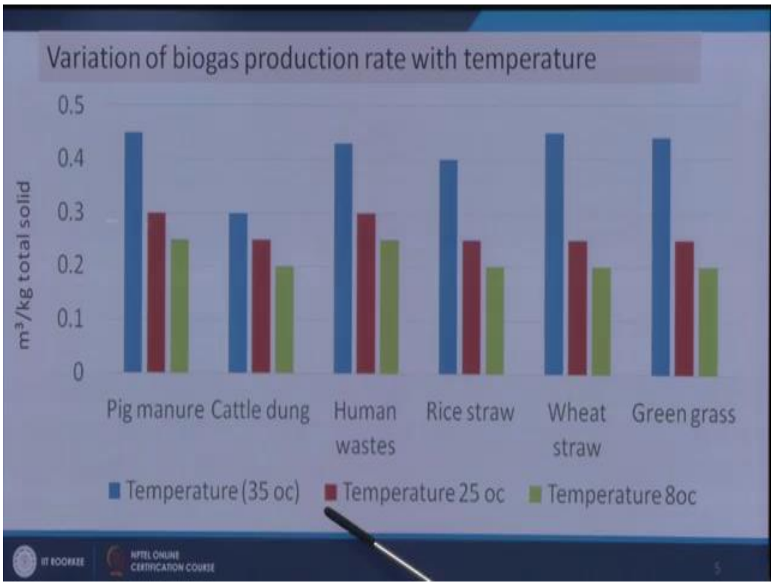

So, we see here in all the cases 35 degree is giving us the higher rate of gas production. So, we will be considering the mesospheric zone there is 35 38 degree centigrade and after considering specific conditions we will find out the sizing of the reactor.

Now, we will see the C by N ratio, C by N ratio is very very important because it provides the nitrogen for the growth of microorganisms if N is very less, we have to supplement nitrogen from some other chemicals like some nutrients.

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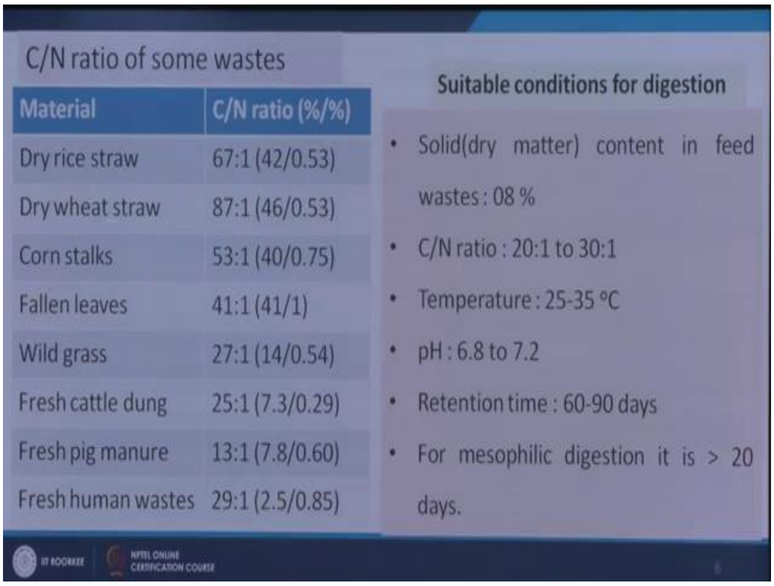

So, here some C by N ratio is provided for different types of feed stocks like say rice straw wheat straw corn stalks fallen leaves wild grass and fresh cattle dung fresh pig manure and fresh human wastes. So, these are this is the actually the carbon and N percentage like percent 42 and 0.50 that is converted in terms of 67 is to 1 similarly for these others.

And on the basis of literature or background information, solid content is around 8 percent this is for conventional practice, C by N ratio 20 to 30 is to 1; 20 is to 1 to 30 is to 1, temperature 25 to 35 and pH 6.8 to 7.2, retention time 60 to 90 days and from mesospheric digestion it is more than 20 days. So, these are the conditions which we have got from the literature or background information. On the basis of background information under a certain conditions to handle certain amount of waste or to be we will be discussing how to get the size of the anaerobic digestion unit.

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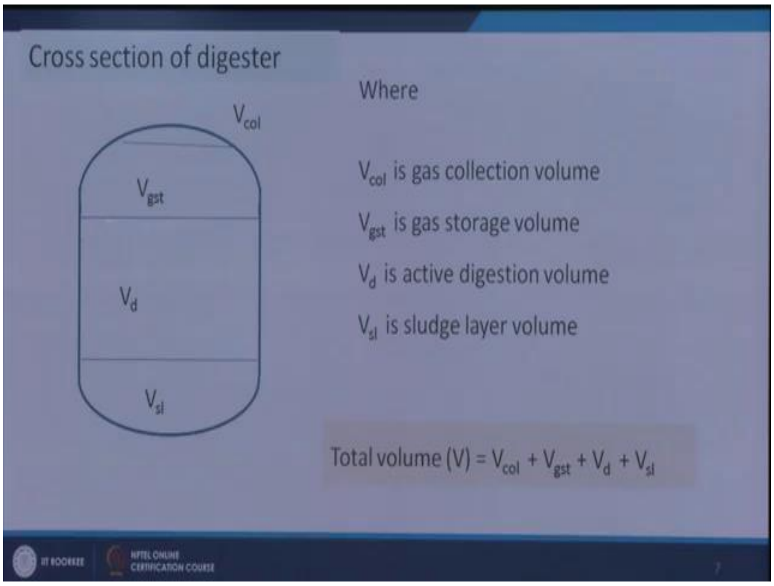

So, for this purpose let us see first the cross sectional of a digester. So, this is the cross section of a digester if we take the cross section of a digester when it is under operation then we will get different zones inside it, so this is s l that is V s l is large layer volume then V d is at active digestion volume and V g s t is your gas storage volume and V c o l is gas collection volume. So, gas collection volume, gas storage volume and active digestion volume and sludge volume these 4 volumes we will be getting in the whole reactors. So, 4 zones we will get. So, what will the total volume? So, total volume is equal to V collection plus V g s t plus V d plus V s l. So, this is when it is under operations in process this type of phenomena we will get inside it or zones will get inside it, but if you think about the reactor dimensions our objective is to get the dimension of the reactor and volume of the reactor. So, in this case this is the say reactor the dimension is we are getting 3 different parts.

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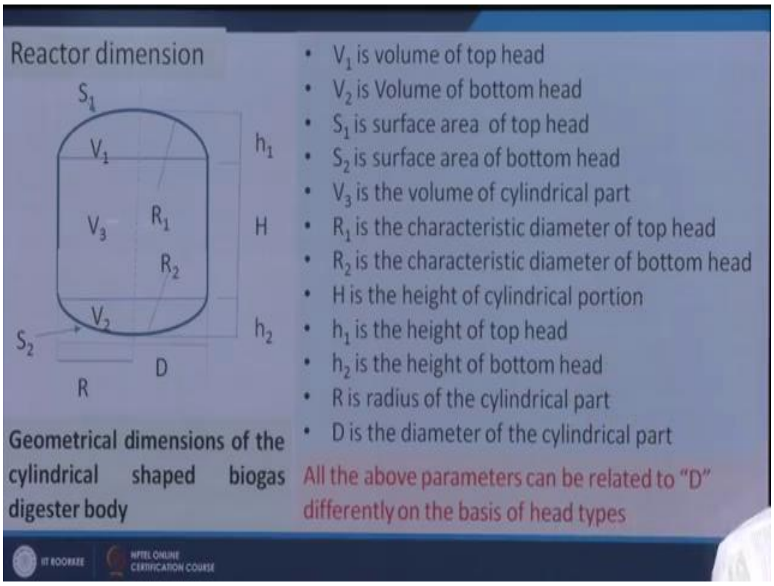

So, this part is having V 3 volume the V 1 is top part V 2 is bottom part and V 3 is the volume of the cylindrical part. So, cylindrical portions top and bottom head these are the total volume of the reactor V 1 plus V 2 plus V 3 and here also there is some h 1, height of the top head height of the bottom head and capital H is the height of the cylindrical portion and this top head and bottom head may be of different types it maybe hemispherical it maybe torispherical or many other forms. So, depending upon or these 2 heads maybe of similar type or maybe of different types also and all the heads will be having some characteristics diameter like say R 1 is the characteristic diameter of the top head and R 2 is the characteristic diameter of the bottom head and R is the radius of this cylindrical portions and D is the diameter of the cylindrical portions h 1 is the surface area of the top head and h 2 is the surface area of the bottom head

So, this is different parameter we can through which we can explain the geometry of this anaerobic digestion unit now all these V 1, V 2, S 1, S 2, V 3, R 1, R 2, h small h 1, small h 2, R D R, etcetera all can be expressed in terms of D, if we know the type of heads present here. So, depending upon the head type the expressions will be different, but we can correlate all those terms with R.

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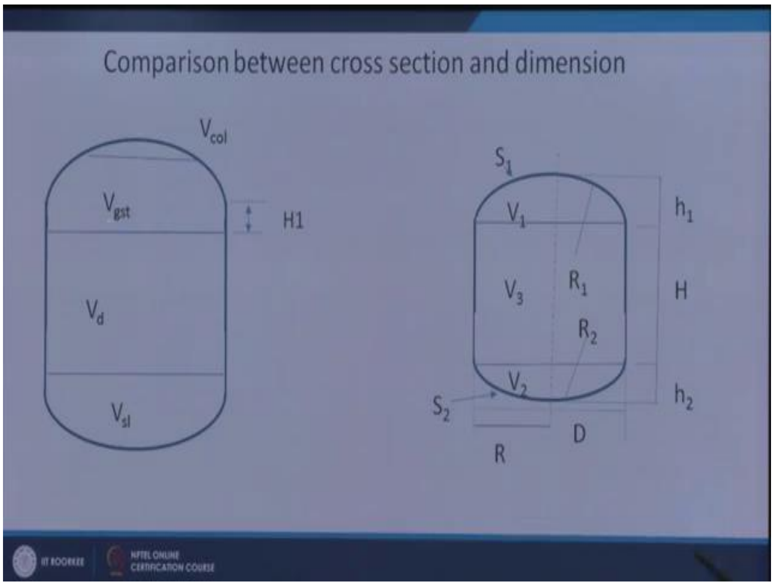

So, here we some example I will show how to correlate these things before that what is the basic difference between the dimension and the cross section if we take the cross section we will get 4 parts gas collection gas storage active digestion sludge.

But here V 1 V 2 V 3, but this is starting from the top of this cylindrical part only this is your V 1, but here V g s t is not from this from the top of the cylindrical part some gas will be always stored and the liquid will be going out from this. So, not from the junction of this that is cylindrical part and top head not from this it will be having some below this part. So, that is called h 1. So, we have to calculate what is the h 1 value? So, now, V b V g s t V collection V d V S l will try to find out and also we will try to find out the V 1 V 2 V 3 h, h 1, S 1 R etcetera, this one example which we have collected from this source that under these conditions the type of head the d the view V d and V is related with this other parameters like V 1 V 2 h 1 h 2 R 1 R 2 all those things S 1S 2 are related with d by different expressions.

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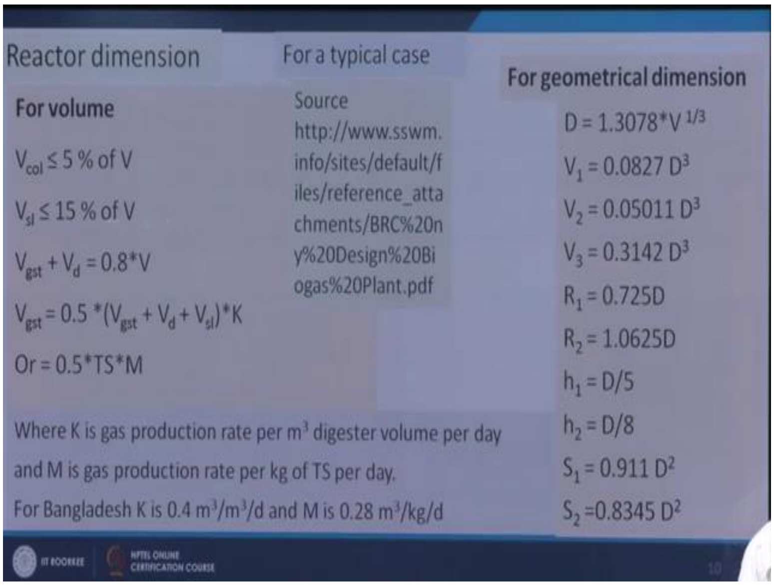

So, these are the different expressions; these expressions are responsible for the head type reported here, but these will be different if the head types are changed and these are some thumb rules, some thumb rules are there that we are considering volume of gas collection is less than equal to 5 percent of the total volume, we are considering volume of sludge that is less than equal to 15 percent of total volume, we are also considering that volume of gas storage plus volume of active digestion zone is 80 percent of the total volume of the reactor and we also assuming that V g s t is equal to 0.5 into V g s t plus V d plus V s l; that means, gas storage volume active digestion volume sludge volume in 2.5 that will be 50 percent of that into K, what is K? K is the gas production rate per meter cube digester volume per day.

So, if we get the production rate meter cube digester volume per day. So, then ma multiply this with this and 0.5, we will get the V g s t one thumb rule another rule is that fifty percent of total solids that is 0.5 into T S into M, what is M? M is the gas production rate per k g of T S per day. So, per day how much T S we are adding and how much gas can be produced per unit gram or kg of T S that is M if we multiply it with and multiply it with 0.5 that will also give us g V g s t there is another way of thinking.

So, these all are our thumb rules or assumptions we can say. So, what will be the value of k and M that will depend upon the substrate type and also the properties of the substrate the parameters or the characteristics of those substrate for Bangladesh this k value is 0.4

meter cube per meter cube per day and M value 0.2 meter cube per k g per day that is basically for a cattle dung or cow dung.

Now we will try to calculate the volume of the digester system or anaerobic digestion systems under these conditions, what is the condition? That you have to determine the volume of the digester chamber and dimension of the chamber for the biogas production from the cow dung of 10 cows having body weight of 200 kg each. Assume the temperature is 30 degree centigrade, the solid content of the cow dung is 16 percent HRT is 40 days; 1 cow produces 10 kg cow dung daily.

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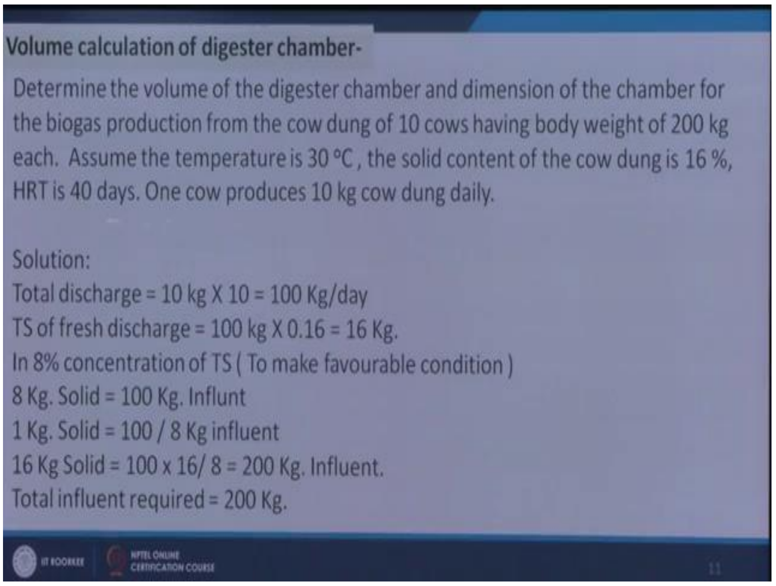

So, this is the conditions under this conditions under this feed stocks availability we have to design the anaerobic digestion unit and the sizing it. So, what is the total discharge, how many we have 10 cows and how many one cows produces 10 kg cow dung daily. So, total discharge or cow dung produced per day is equal to 10 into 10 there is equal to 100 k g per day, then what is the T S of the fresh discharge? That is you are having that 60 percent 16 percent. So, out of this 100 kg we will be having T S is equal to 100 into 0.16 or 16 kg.

Our objective is to we have to make it 8 percent in terms of T S we have to make it 8 percent in terms of TS. So, here 8 kg solid is available in 100 kg influent that is our requirement. Now 1 kg solid will be 100 divided by 8 kg influent. So, 16 kg solids will be available in 2,000 kg influent. So, this 16 kg solid is present in 100 kg of cow dung or discharge. So, we have to make this volume to 200 k g. So, that it will be of 8 percent in terms of T S content. So, what will be the influent that is 200 kg? So, what will be the water addition? That is 200 minus 100 k g, 100 k g is the cow dung. So, 100 will be the water addition.

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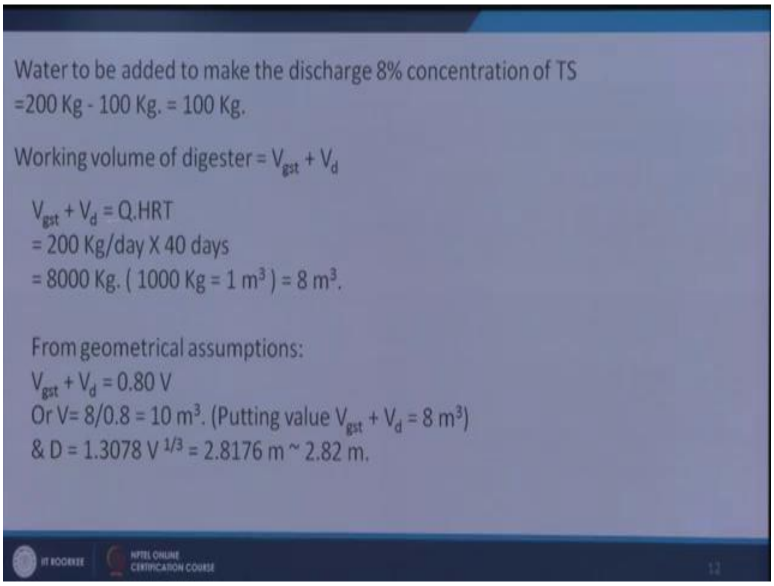

So, working volume of the digester, we will be having working volume is equal to obviously, gas to rate zone plus V d that is active zone. So, V g s t plus V d is equal to Q into HRT.

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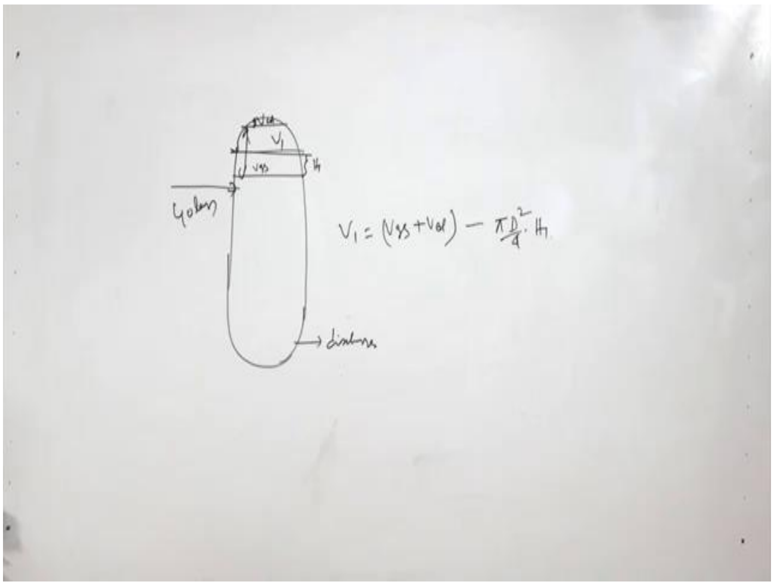

What does it mean? We have that 40 days HRT; that means, hydraulic retention time is 40 days. So, if we have the digester we will be putting the feed stocks for 40 days then only we will get the discharge from it. So, after 40 days we will get the sludge out. So, retention time is this one. So, the material which is coming out that is V g s t plus V d that will be Q into HRT. So, that is equal to, what is this Q? 200 k g per day into 40 day, 40 into 200; 8,000 k g we are getting. So, 8,000 k g in terms of volume it will be 8 meter good if we assume that 1,000 k g is equal to 1 meter good that is our assumption.

So, that will be 8 meter cube, for geometrical assumptions, V g s t plus V d we have assumed V g s t plus V d; we have assumed that this is 0.80 of the total volume 80 percent of the total volume. So, V plus we have getting these 18 meter cube. So, V is equal to 8 divided by 0.8 or 10 meter cube. So, 10 meter cube is the volume of the digestion unit. So, what will be the d then? So, d is equal to we have got here d is equal to 1.3078 into V to the power one-third. So, we will put the value of V here as equal to 10 we will put the value of B equal to 10 here and we will get the value of d that is equal to 2.8176 meter or around to 2.82 meter.

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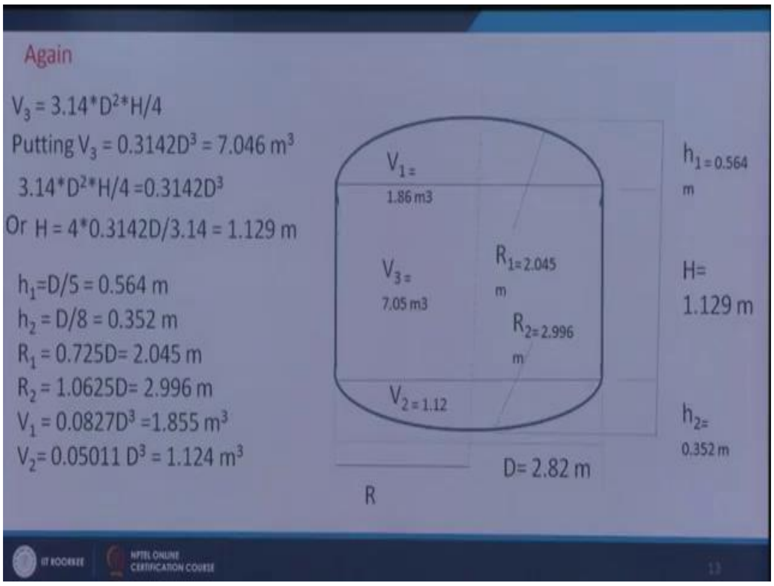

So, next we are having say V 1 V 2 V 3, what is the V 3? This V 3 equal to pi R square H. So, pi into D square by 4 pi into D square by 4. So, this equal 2 and then D equal to how much? We have got D is equal to 2.82 meter. So, if we put the value of D, here D cube when this VV3 is coming 7.046 meter cube and again VV3; we have got from this expressions V 3 is equal to 0.13142 D Q and we are getting V 3 here this 1. So, this and these are equal. So, these and these are equal and if we equalize this then we can get the value of H. So, capital H value we are getting from 1.129. So, this H equal to 1.129 meter.

Now h 1, what will be the h 1? What will be the h 2? Once we have got the value of D, we can get the value of h 1 because h 1 is equal to D by 5 and h 2 is equal to D by 8. So, we are getting the 0.564 meter and h 2 is equal to 0.352 meter and what will be the characteristic radius R 1 and R 2? R 1 is equal 1.0625 D that is equal to 2.996 meter and this is R 2 and R 1 is equal to 0.725 D there is equal to 2.045 meter.

So, then what is V 1 and V 2? V 1 and V 2 we have V 1 and V 2, 0.827 D cube and 0.5011 D cube. So, we have got the value of D. So, we will get the value of V 1, here 1.855 meter cube. So, this 1 and this is equal to V 2 equal to 1.124 meter cube. So, now, all the dimensions we are able to calculate.

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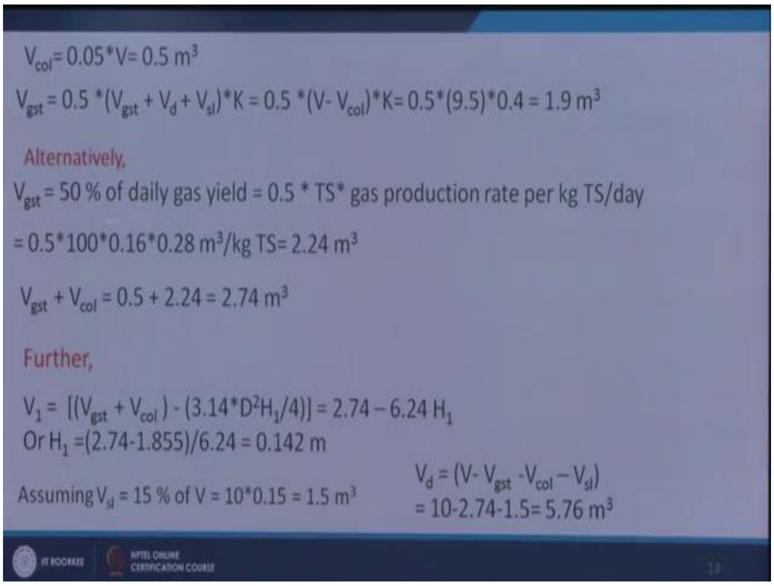

Now, we will say b collection is equal to maximum say 5 percent we are assuming of V. So, 0.05 V equal to 0.5 meter cube and V g s t is equal to 0.5 into V g s t plus V D plus V s l into k that is equal to 0.5 into what is this V g s t? V D and V s l this is equal to total V minus V c o l. So, that is equal to V minus V c o l into k or 0.5 into 10 minus 0.5. So, 9.5; we are getting 0.5 into 9.5 into 0.4; 1.9 meter cube.

So, that is V g s t is equal to 1.9 meter cube we are getting now we are V g s t that is another thumb rule we have we have taken another consideration that V g s t is 50 percent of daily gas yield that is 0.5 into T S into gas production rate per k g T S per day. So, here also we will put the values. So, 0 point into 100 into 0.16; the total solid present in it and then 0.28 is the N values. So, we are getting 2.24 meter cube. So, one assumption is giving us 1.9 meter cube volume requirement another assumption is giving us 2.24 meter cube volume requirement for the digestion unit.

So, to be conservative we will be considering 2.24 meter cube. So, 2.24 meter cubes are V g s t. So, V g s t plus V collection these 2 will give us 0.5 plus 2.24 that is 2.74 meter cube then V 1 is equal to what if we see this one what is this V 1? Here we have V 1, this is our V 1 and this is our V g s t and this is our V collection on the top. So, V 1 is equal to we can write V g s t plus V g s t plus V c o l. So, this is our V g s t and this is V c o l and this is this part is our h 1 this height is to h 1 V g s t plus V c l V c o l minus this cylindrical part.

So, pi D square by 4 into h 1. So, this is the expressions we are getting here. So, this 1, minus pi D square h 1 by 4, we will put this value here that is 2.74 minus 6.24 into h 1; this value we are getting. So, by rearranging h 1 is coming, what is V 1? V 1 is equal to 1.855; V 1 is equal to 1.855. So, if we will put the values there and then h 1 is coming 0.142. So, assuming V s l is equal to 15 percent. So, V equal to this 10, 15 percent of V then 10 into 0.15, there is equal to 1.5 meter cube. So, now, we have got the different dimensions and then what is V D? V D equal to V minus V g s t minus V collection minus V s l. So, we have got the value of V 10 and V g s t is equal to 2.74 V c o l is equal to 1.5 and V s l equal to V s l equal to 1.5 and V c o l equal to 0.5. So, V g s t plus C l both are 2.74.

So, ultimately we are getting V D equal to 5.76 meter cube. So, this way, we are able to calculate all the dimensions all the volumes that is here V D V g s t V equal V collections and VV s l in terms of the dimensions of this anaerobic digestion unit. So, this is all about the sizing of the anaerobic digestion unit we have discussed in this module.

Thank you very much for your patience.