**Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems**
Prof. Vaibhav V. Goud and Dr. R. Anandalakshmi
Department of Chemical Engineering
Indian Institute of Technology – Guwahati

Lecture - 23
Practice Problems

Good morning everyone. Welcome to Part 1 of Lecture 3 under Module 7. If we just recollect our discussion in the previous lecture, so, we discussed about the classification of biogas plants. Then, after that we discussed about the different parameters which affect the biogas production in the digester, followed by the raw materials availability, and the biogas yield from the specific raw materials.

So, all those things we will discussed in the previous lecture. So, in this lecture, we will focused on some practice examples. So, based on the previous discussion, we will try to solve some examples in this particular lecture. Before that, some specific points which are required to practice some examples based on the bio digestion process. So, if you see here, as I said earlier, we discussed about the classification of biogas plants.

(Refer Slide Time: 01:20)
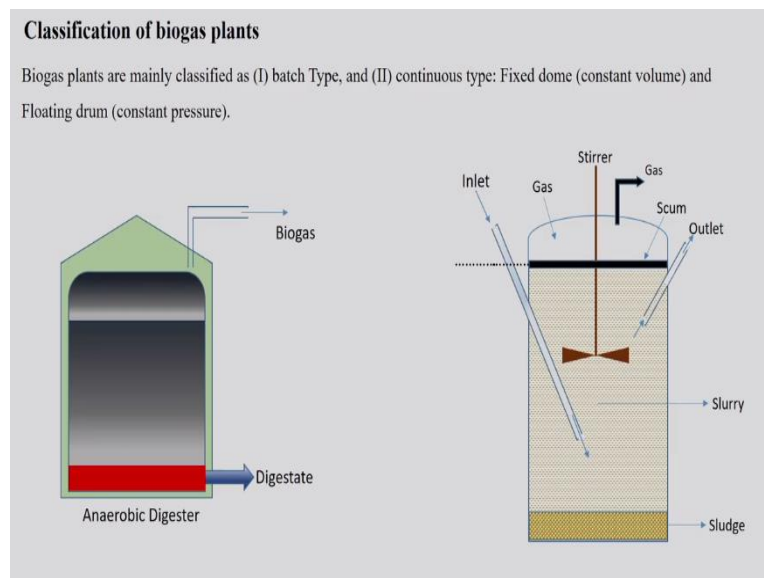
So, in that, we discussed about the batch type of biogas plant and then the continuous type biogas plant. So, in the continuous type, it is further sub classified as a floating drum and then the fixed dome type biogas plant.

(Refer Slide Time: 01:40)

Raw material availability and gas yield

Most of the organic matters containing proteins, fats, and carbohydrates can be microbiologically transformed into biogas. These are mainly (i) animal-waste based resources, (ii) land based resources and (iii) water based resources.

The availability and gas yield of from some of these resources is given here

SN	Raw material	Production rate	Gas yield (m³ per kg of dry matter)
1.	Cow dung	10 – 15 kg/day/head	0.34
2.	Poultry manure	0.06 kg/day/head	0.46 – 0.56
3.	Sheep manure	0.75 kg/day/head	0.37 – 0.61
4.	Rice husk	1 – 1.3 tons/ha/year	5.67
5.	Algae	40 tons/ha/year	0.32
6.	Water hyacinth	60 tons/ha/year	0.42

* Courtesy: Non-conventional energy resources, by Twidell and Weir, 3ʳᵈ reprint edition, 2010, T&F

So, followed by that raw material and the availability and biogas yield. So, this is very important point which need to be considered before starting the designing of a digester or you can say a sizing of the digester as well. Because, the specific gas yield it varies from feedstock to feedstock. So, as a result, if you see the particular slide, there we have tabulated certain different kinds of feedstock and their specific biogas yield.

So, there are mainly 3 types of feedstock which are generally being used for the bio digestion purpose. So, first is animal waste based resources followed by the land based resources and then the water based resources. So, here water based resources means here it mainly talks about the sewage sludge which comes from the wastewater treatment plants. So, those types of sewage sludge can also be used for the bio digestion purpose.

So, for a specific reason, the most widely used feedstock for the bio digestion purpose are also shown here in the table. So, if we just see the least among the least the first one is talks about the cow dung that is nothing but called as a cow manure also or the cow waste, which is normally being used for the bio digestion purpose and it is called as a gobar gas also.

So, if you see the production rate as well as the gas yield that is nothing but the biogas yield from this particular source is around this much. And this talks about in terms of meter cube per kg of dry matter. Similarly, if you talk about the second, third example also these all waste coming from the animal waste category. So, fourth one it mainly talks about the rice husk which is nothing but agricultural residue.

These are also being used nowadays for the bio digestion purpose along with some cow waste to balance the C by N ratio as well and followed by algae and then the water hyacinth. But then if you see the range of gas production from this particular material, it varies. So, it is mainly depends on the feedstock which is used for the bio digestion purpose.

(Refer Slide Time: 03:52)

So, now, based on this, we just try to estimate the volume of digester for a biogas production. So, there are certain facts which need to be considered before we start estimating the volume of the particular digester. So, what are those particular facts? Let us see those particular facts one by one. So, in case if the feedstock is a cow waste, so as I said, if the feedstock is changing, accordingly, the assumption will also change.

There may not be a huge variation, but there will be a slight variation in the assumption as well. So, in this case, we were mainly discussing about the cow waste as a feedstock for the bio digestion purpose. So, in this model also as well as in the examples, our main focus will be only on the animal waste, which can be used for the bio digestion purpose and to produce a significant amount of biogas.

So, in practice, around 70% of this particular waste can be collected. However, 30% is lost into the field due to grazing. And then the amount of dry solid if you see in this particular waste, it is around 18%. And remaining is nothing but the moisture content in the waste. So, normally 1 kg of wet waste, it is mixed with the 1 kg of water to get the slurry. Because by doing so, we can maintain the solid content in the range of say like for 9 to 10%.

So, to do that, we need to add equal amount of water in this particular dry solid so that it can convert it into 9 to 10% of the solid content in the slurry. Similarly, as mentioned here previous table also, so, 1 kg of dry waste it gives around 0.3 meter cube of gas per kg of dry solid. So, here our main focus as I mentioned it is on the cow waste. That is why we have considered this particular amount here.

And if the gas requirement and the duration of batch are known, so then in that case, the amount of water and the waste needed can also be calculated very easily to just find out the sizing of the digestion chamber. And the volume of the digester is just equivalent to the volume of the slurry which is required for the biogas production. Therefore, to store the gas, a gas space of around like 10% of this volume could be provided in the digester.

Of this volume means the volume of digested slurry or the volume of the digester. So, 10% of the volume of the digester or 10% of the volume of the slurry is to be provided to store the gas inside the digester itself. And hence, the total volume of the digester it can be 1.1 times the volume of the slurry or the volume of the digester. So, these are certain facts, which need to be considered before you start sizing the digester.

Now, before we touch upon the real designing of the particular digester, we need to consider into the 2 particular aspect of the process.

(Refer Slide Time: 07:05)

Wet and dry fermentation:

Parameters	Wet fermentation	Dry fermentation
Optimum total solid concentration	7 to 9 %	25 to 30%
Solid content	To maintain 7-9% solid content, based on input materials optimum solid to moisture ratio should be adjusted (normally equal amount water is added to maintain the solid concentration)	Water amount is kept to its minimum value for active fermentation
Scum formation and flotation	Problem of scum formation and flotation on the surface of slurry	Problem of scum formation and flotation may not arise
Acid accumulation and entrapment of gas	Less Likely to occur	Likely to occur
The problem of pH regulation, movement of material and non-uniform culture	No	Yes

That means, as I mentioned, this particular process is carried out using 2 different practices like wet fermentation and the dry fermentation. If you just try to see the difference between

these 2 processes, that is wet fermentation and dry fermentation as well as the parameter which affect this particular process. So, while analyzing this process itself one can make sure that how to design a particular digester based on this particular process parameter itself.

So, now, if you see here the parameter which are required for the specific process or which differentiate between these 2 particular process are nothing but total solid concentration. So, as I mentioned earlier also, the wet fermentation process, it requires around 7 to 9 or 9 to 10% of the solid content into the digester for its easy operation. Whereas, in case of dry fermentation, if you see here, the solid content can go up to even like 25 to 30%.

Because that is why is called as a dry fermentation technique. Here the wet fermentation to maintain this particular solid concentration, certain amount of water, it need to be added into the digester. So, for that reason, what we do is like normally, equal amount of water is added so that we can bring down the solid content to around this particular range, whereas, here the amount of water is kept to its minimum value just for the active fermentation, because this is a dry fermentation technique.

Similarly, the scum formation and the flotation, yes, the problem of scum formation as well as the flotation on the surface of slurry will occur in this particular process that is called as a wet fermentation. Because here the material is in the slurry form, but, that particular problem may not be encountered in the dry fermentation because it is mostly a dry solid. So, as a result, there is no formation of any scum or on the surface of the slurry as well, because there is no slurry at all in this particular process.

So, the acid accumulation and the entrapment of the gas less likely to occur in this particular process, because as this is a slurry, so the acid accumulation will not happen in this particular case. Moreover, the entrapment of the gas also will not occur here. But in this case, it is most likely to occur, because as this is a solid fermentation. So, the acid which are being formed in the specific zone will remain there only.

It will not get distributed in the entire digester. Similarly, you can say the entrapment of the gas, yes, it is more likely to occur, because, wherever the fermentation is happening, the gas will get trapped here. And as there are certain solid particles are there above that particular zone, so it will not allow the gas to release very easily from the digestion chamber.

Apart from that, the problem of pH regulation, movement of material and non uniform culture that problem will not be their in the wet fermentation, because it is mostly a slurry. So, this particular moment of substrate will happen easily in this particular process. pH regulation will be very effective in this particular case and non uniform culture also will not happen.

Whereas, in this particular case, those problem may be encountered in the dry fermentation technique, because, as was the solids are getting deposited there, so the acid formation will takes place and the acid will accumulate in the specific zone only. As a result, certain bacteria will be active in the specific zone, whereas, in the other part of the digester the activity will not be that much. So, those kind of irregularities will be happening in the dry fermentation.

So, that is the reason the wet fermentation technique is the most widely used technique for the bio digestion of the waste by designing a specific size of the digester.

(Refer Slide Time: 10:42)

So, now, based on all these understanding, we just try to find out the sizing of the digester. So, how to do that? So, before we start the designing of a digester, so, we need to follow certain approximate rules for sizing a biogas plant or you can say for estimating their performance. So, what are those particular rules?

See, for example, if the energy available from a specific digester if you need to calculate, it can be calculated in terms of like this efficiency of the combustion process or maybe the

efficiency of the burning process also. Then, heat of combustion of a volume of a gas and then V b is the volume of a biogas which is being used. If you just multiply this quantity. So, you can easily get the energy which is available from the biogas digester.

That means the specifically biogas which is coming out from the digester. So, this is in terms of the biogas means, here, we are not talking about the exact composition which is there in the biogas. Whatever the biogas which is coming out from the digester which is directly being used for the combustion purposes or for burning purposes and based on that the energy available from the particular gas has been calculated.

But now, what happened in this case is since biogas is mainly consist of the methane and the CO 2. So, due to this what happens is like, some amount of heat of combustion of the methane, it goes waste in the heating of CO 2 in the biogas. So, as a result, what happens is like, that amount of energy is not available or in the other sense, if I would say, the net effect of the energy it is getting decreased, because of the some amount of loss of energy in the heating of CO 2 only.

So, on those particular aspect, if you just try to find out the net energy from the specific gas, then it can be calculated in terms of again, it is the efficiency of the combustion process, then the this Q m it indicates the heat of combustion of only the methane. Because here if you see this is heat of combustion of the biogas, that is why we have specified it as a Q b, but when Q suffix m it is mentioned, then it is nothing but the heat of combustion of the methane.

And then this factor represent here the fraction of methane in the biogas. Because as the fraction of methane it may vary from feedstock to the feedstock, so accordingly this particular fraction will also vary in the calculation, and then followed by the volume of a biogas. So, this is also the same amount, which is represented in the previous equation also. But, this 3 terms, out of this, the efficiency also is going to remain the same.

Only these 2 terms are nothing but talks about the methane and its combustion and the presence of methane in the specific composition of the biogas. So, with the help of that, we can calculate the net energy which is available from the combustion of the specific gas.

(Refer Slide Time: 13:46)

Where,

Q_m : heat of combustion of methane ($\sim$ 27-29 MJ m^{-3}) and

f_m : fraction of methane in the biogas (50 to 70%)

The volume of biogas is given by: $V_b = c\,m_o$ -------- (iii)

Where, c is the biogas yield per unit dry mass of whole input (0.2-0.4 m^3 kg^{-1}) and

m_o is the mass of dry input.

The volume of fluid in the digester is given by : $V_f = m_o / \rho_m$ -------- (iv)

Where, ρ_m density of dry matter in the fluid ($\sim$50 kg m^{-3}).

The volume of the digester is given by : $V_d = \dot{V}_f\,t_r$ ---------- (v)

Where, t_r is the retention time in the digester ($\sim$20-40 days) and $\dot{V}_f$ is the flow rate of the digester fluid

density slurry = 1090 Kg/m^3

*Courtesy: Non-conventional energy resources, by Twidell and Weir, 3rd reprint edition, 2010, T&F

So, once we have this particular that is why I mentioned like Q m is the heat of combustion of the methane, which is normally in the range of these you may find certain other values also in the literature, maybe up to like a 32 or something like that. So, there are certain representation changes it is all depends on the combustion of methane with CO 2 or without CO 2. So, this is the value which is we have referred in this particular designing purposes.

And the f m is nothing but the fraction of methane in the biogas, it is also varying between 50 to 70% as I mentioned. So, once this will vary, accordingly the above value will also vary in the combustion process. So, 50 to 70 we have considered this as a range. So, when you are will be solving any specific example. There will specifically mention the f m value. So, accordingly you can calculate the energy content in a specific gas.

So, the volume of the biogas can be calculated in the very simple way using this particular equation, where this c is the biogas yield per unit dry mass of a whole input. So, it is in this particular range. So, we will be considering this particular value also for the designing purpose. And m naught, it represents the mass of the dry input.

So, this also can be calculated on the per day basis, once you know the total volume of the slurry or the mass which is input to the digester. So, based on that, we can calculate also on per day basis, how much feedstock has been entered into the digester. And then the volume of the fluid in the digester can be calculated very easily by using the mass divided by the density of that particular dry matter in the fluid.

So, this value is 50 kg per meter cube, but then just try to see this particular term here very carefully, this is the density of the dry matter in the fluid and this is not the density of the slurry. Whereas, when you are it is mentioned that density of the dry matter and the density of the slurry, accordingly you need to calculate the specific answer.

Because the density of slurry is 1090 kg per meter cube, because that will be mostly discussing about the wet fermentation process. But here as the design has been done, mostly considering the dry matter in the fluid. So, the density of the dry matter is 50 kg per meter cube. So, accordingly the volume of the fluid also will change and then according to that the size also will change for the digester.

And then once you know this V f, then it is very easy to calculate the volume of the digester because then it is nothing but the V f is nothing but the volume of the fluid which is entering into the digester or you can say the total input of the volume of the fluid into the digester. And if you just multiply by the retention time to (()) (16:41) that is nothing but the t suffice r is nothing but the retention time.

So, this particular value also will change based on the feedstock. So, it is in the range of say for example, 20 to 40 days. So, accordingly this value will also change and then based on that the volume of the digester also will change. For example, if I consider here, the retention time is 20 days. So, accordingly this volume will change. But if I make it 30 days, so obviously, there will be a slight variation in the biodigester sizing.

And V f it is the flow rate of digester fluid as I mentioned. So, how much amount of fluid is entering inside the digester per day or the total fluid which has entered into the digester, based on that you can calculate the volume of the digester as well. So, once we know this particular thing, we can easily calculate the digester size.

But, as I mentioned, there are certain facts which need to be known before you start sizing the digester in terms of like some specific quantity which are required. And I already mentioned those values here in the slides. Similarly, we will also try to specify this specific value in the practice example as well. So, based on those example and the values mentioned in that example only you have to solve the problem not like considering these particular values.

Because, this is we have considered mostly based on the cow manure. So, if I change suppose example from cow manure to sheep manure or maybe you can say the piggery manure, accordingly, there will be a slight variation in this particular value will happen.

(Refer Slide Time: 18:13)

So, if we just try to solve one simple example in today's lecture about the sizing of a biogas plant, so, this is the first example, and you can see here the statement of the example is also mentioned. So, in this case, this is a family size biogas plant. This need to be constructed and it is suitable for dry input of mass of 10 kg per day.

That means, the dry input value is specified in this particular example that this much amount of dry material is fed inside the digester per day. And the retention time is mentioned as 30 days. The temperature of the digester is 30 degrees C and the biogas yield in this case is 0.34 meter cube per kg. So, again in this case, the example is considered as a cow waste, the burner efficiency is 60%.

That means, if you remember the formula, so, the efficiency of the burning is considered as a 60%. The fraction of methane f m is 0.7. So, here we are not given any range, it is a specific value which we have mentioned. Because, if it is a cow manure, we have mentioned that okay 70% of the biogas will come out from the particular digester if the cow waste is being used as a raw material.

And in the heat of combustion of methane, we are given a specific value here. So, this particular value only you have to use for the calculation purpose. And density of dry matter is

50 kg per meter cube. So, now, based on this given data, we have to estimate the volume of biogas plant and the power available from the plant. So, now with the help of this given data, just try to see the equations which I have discussed in the previous lecture.

Using those equations and this value, we can easily find out the volume of the digester. So, to do that, if you remember, first we need to find out the volume of fluid by using a specific equation. Why? Because already the dry matter input value is given here. So, based on that you can easily calculate the volume of a fluid in a digester because m naught which represents the dry mass input into the digester.

And here this particular value it represents the density of the dry matter. So, as I mentioned here the density of dry matter is already given. So, if we just divide 10 by this 50 (()) (20:47) V f in terms of 0.2 meter cube per day. So, this is very simple. So, V f is the amount of fluid is entering in the digester on daily basis. So, once we know the V f value, with the help of V f, we can also calculate the volume of digester.

(Refer Slide Time: 21:04)

For the volume of any digester we have following eqn.

$$\text{Vol}^m = \boxed{V_f \times t_r}$$
$$V_d$$
$$= 0.2 \text{ m}^3/\text{day} \times 30 \text{ days} = \boxed{6 \text{ m}^3}$$

Similarly, volume of the biogas is calculated from following eqn.

$$V_b = c \times m_0$$
$$= 0.34 \text{ m}^3/\text{kg} \times 10 \text{ kg/day}$$
$$= 3.4 \text{ m}^3/\text{day}$$

So, it is represented as V suffix d. So, how to get this value? As we know the volume of fluid per day injected inside the digester is this much and the retention time is also known. So, if you just multiply these 2 quantities, you will get this much amount of size of the digester that is 6 meter cube is nothing but the volume of the digester we can say or the size of the digester.

So, once we know the size, then with the help of size, now, we can calculate the amount of biogas which is getting generated inside this particular digester. That is V suffix b that is nothing but the volume of a biogas. So, it is c into m naught. So, c is nothing but 0.3 kg per meter cube and m naught is already known.

So, if you multiply this, so, because this is the gas which is generated from per kg of dry matter which is fed inside the digester and we are feeding around 10 kg per day. So, that means, this much amount of gas is getting generated per day inside this particular digester. Now, once we know the volume of the biogas as well as the volume of digester.

(Refer Slide Time: 22:27)

The power available from the digester is

$$E = \eta \cdot Q_m \cdot f_m \cdot V_b$$

$$= 0.6 \times 29 \text{ MJ/m}^3 \times 0.7 \times 3.4 \text{ m}^3/\text{day}$$

$$= 41.41 \text{ MJ/day}$$

$$= 11.59 \text{ kWh/day (since, 1 MJ = 0.28 kWh)}$$

$$= 11.59 \text{ kWh/24 hrs}$$

$$= 482.391 \text{ W (continuous thermal power)}$$

$$=\sim 482.4 \text{ W (continuous thermal power)}$$

Then we can easily calculate the power available from that particular digester. As I mentioned in the previous slide as well that the energy available or the power available can be calculated very easily. Because we know the combustion or the burning efficiency of the gas, then the methane its calorific value and the combustion value is also given. The fractional composition of methane in the biogas is also given followed by the volume of the biogas.

So, as this particular value is 0.6. This is 29 and its fraction is 70%. And then, this is the amount of biogas which is generating per day. So, we just multiply this value, you get this much amount of heat of combustion of the specific gas in the process. So, this is the amount of heat which is getting generated. Now, if you just convert this value in terms of watt or kilowatt, there are slight just conversion we need to do.

Because, 1 megajoule is nothing but equal to 0.28 kilowatt hour, so that is why we have just converted this value here in terms of kilowatt hour per day. And then, if you again convert this into a watt, so, simply we just divide this per day basis value to a hour basis value, and we will get the value in terms of 482.4 watt. This is the continuous thermal power which will be available from this particular digester.

So, this is how the energy or you can say the power available from the specific digester also can be calculated. So, this is very simple example, where we are just doing certain calculation using the some specific value for the specific feedstock. So, based on this feedstock, now, suppose if I change this particular feedstock from cow manure to a piggery manure, so in that case, maybe this particular value of volume of the biogas it may change based on the gas yield from that specific feedstock.

So, those slight variation will be there in some examples. So, this kind of examples will be given to you in the assignment as well, so which you can easily do. So, based on that only we will design the assignment problem as well, so, this is how is about the sizing of the digester.

(Refer Slide Time: 24:47)

Now, if I just take a another example, which is just opposite to the one which you had discussed earlier. Why? Because the earlier example in that case, we mostly discussed about the density of the dry matter which is input to the digester. So, here we will just try to have slight deviation in the specific example.

So, the statement of the problem here if you see it is a community type biogas plant which is to be designed for the cooking and the lighting need of a village which is consistent around like 50 families. And the quantity of waste which is fed to the digester, it is also given here it is now 850 kg. So, this is the quantity which is again the example if you see here it is the cow waste which you have consider and then the retention time here is 35 days.

Now, the density of the slurry is mentioned here instead of the density of the dry matter. So, in this case, now, the process is carried out in terms of the wet fermentation technique and the calculation need to be done to find out the minimum working volume of a digester. And also calculate the actual volume of digester which should be 10% more to provide certain headspace to store the gas inside the digester as we already discussed before.

And considering this actual volume calculate the height and diameter of the digester. This is very easy example. Here also the most of the data is given. So, based on the data only, we need to calculate the volume of the digester and also the actual volume of the digester. And based on the actual volume only calculate the height and diameter of the digester. So, now, if you see in this case, the amount of dry solid content in the waste as this is a cow manure, it is 18%.

So, now, we need to reduce this 18% to suppose 9%. So, what need to be done in that case is like? We need to add equal amount of water to this particular waste so that the 18% solid content will get converted into a 9% solid content. So, what is to be done in that case is the quantity of waste which is fed to the digester each day it is given here. It is nothing but 850 kilogram.

So, now, as this is a quantity of waste which is fed inside the digester, so in this 850, there is a 18% of the solid content or you can say the dry solid content is 18%. So, to bring down this 18% to a 9% value, so, what need to be done in that case is like so this will be mixed with equal quantity of water to make the slurry.

(Refer Slide Time: 28:39)

The volume of daily charge to the digester $= \dfrac{\text{Weight of (Waste + Water)}}{\text{density of slurry}}$

$= \dfrac{(850 + 850)\ Kg/day}{1090\ Kg/m^3}$

$= 1.55\ m^3/day$

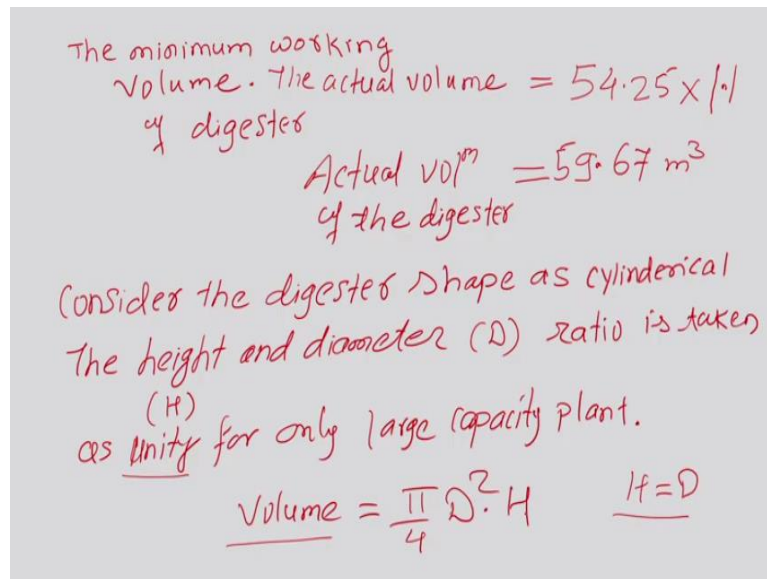Digester volume $= 1.55 \times 35\ days$

$-\|- = 54.25\ m^3$

So, if you just add equal amount of water to it, so what will happen in that case is for example, the volume of daily charge to the digester is weight of waste plus water divided by density of the slurry. So, now, once you know these 2 quantity, so, as we know the weight of the waste is around 850 and if you add equal amount of water that is around 850 again, if you just divide it by the density of the slurry that is 1090.

So, what happened in that case is like suppose if you divide it, now, in this case here, it is the density of slurry and it is not the density of the dry matter content that need to be understood very carefully. If you try to solve this equation here, so we will get the value in the form of 1.55, because this is in the kg per meter cube, whereas this is kg per day. So, if we just try to solve this, you will get the value in the form of 1.55 meter cube per day.

So, this is the amount of slurry which is fed inside the digester on daily basis. So, now, if we just try to find out the digester, so, volume, so, this is the amount of slurry which is fed inside the digester on daily basis and here, the retention time is given as 35 days. So, if you just multiply this, you will get the value in the form of. So, this is nothing but the digester volume for the specific slurry, because here the values are changing.

Because, based on the feedstock and the density of the material which is being considered for the designing purpose. So, here as the density of the slurry is considered and its value is 1090, so based on that, the value is coming like this.

(Refer Slide Time: 31:47)

The minimum working
Volume. The actual volume $= 54.25 \times 1.1$
of digester

Actual vol^m $= 59.67 \, m^3$
of the digester

Consider the digester shape as cylindrical
The height and diameter (D) ratio is taken
(H)
as unity for only large capacity plant.

$$Volume = \frac{\pi}{4} D^2 \cdot H \qquad \underline{H = D}$$

So, now, once we know the volume of the digester, then based on the volume of the digester, we can easily calculate the minimum working volume and the actual volume of digester. So, as the minimum working volume that we already calculated in the previous slide, that is 54.25. So, now, the actual volume is nothing but what it will be just 10% of this minimum volume.

So, that is considered as a minimum volume and to accumulate the 10% of the volume of the gas. So, that is the reason we are considering it is like 1.1 times the volume of the digester. So, it is 1.1 times the minimum working volume of the digester. So, if we just calculate this value, it comes around 59.67 meter cube. So, this is what is the actual volume now, actual volume of the digester.

So, now, based on this particular volume, if we just try to find out the height and diameter of the digestion chamber that can be also carried out very easily, so now, consider the digester shape as cylindrical, so, based on this the height and diameter ratio, so, this is we can represent as D and here we can represent height as H. So, this particular ratio is taken as unity for only large capacity plant.

So, as this is unity, so here you can say that H is equal to D. So, now, once we know the actual volume of the digester, so volume equal to, so if you are considering this as a cylindrical shape, so, the height and diameter ratio is considered as a unity in that case. When the large capacity plant has to be designed, so in that case, if H is equal to D as we know the

volume of the digester, so simply we can calculate it based on the pi by 4, this is area into height of the digester.

$$H^3 = \frac{Volume}{\pi/4}$$

$$-\,''\,- = \frac{59.67}{0.785}$$

$$\underline{H = 4.23\,m}$$

$$\therefore \underline{D} = 4.23\,m$$

So, now, once we know the volume, because the volume is known, so D is equal to H. So, H cube equal to pi by 4, because D is equal to H in that particular case. So, that is why H D is equal to H square. H square into H is equal to H cube and then volume upon pi by 4. So, we know the volume it is 59.67 divided by here is if you calculate this value, it is 0.785. So, now, if we just try to get this value here, so the H value is equal to 4.23 meter.

Similarly, as H is equal to D. So, the D is also equal to 4.23 meter. So, accordingly, we can calculate the H and D also for the specific kind of a digestion chamber. Because, as I mentioned, this is mainly considered for the large capacity size biogas plant, where H is considered equal to the D and then you can calculate very easily the H and D also.

So, this kind of examples will be given in the assignment based on the different feedstock to you to solve. So, I guess these are very simple examples to follow.

(Overview of next lecture)

Module	08 (Bioconversion of Substrates)
Lecture	01
Content	Bioconversion of Substrates into Alcohols, Thermo Chemical Conversion of Biomass, Conversion to Solid, Liquid and Gaseous Fuels, Pyrolysis, Gasification, Combustion.

Thank you

For queries, feel free to contact at : vvgoud@iitg.ac.in

So, that is all about this today's lecture. So, in the next lecture, we will also try to solve some more examples. And then after that, we will start the module that is Module 8, which is the last module of this particular course. And in that module, we will discuss about the bioconversion of substrate into alcohols, thermochemical processes as well as the conversion of solid to liquid and gaseous fuel.

And then, we will discuss about pyrolysis, combustion and the gasification process in more detail. And in this particular module, we will try to solve some practice example. So, about this particular lecture, if you have any queries, you just feel free to contact me at the email ID which is shown here in the specific slide. Thank you.