Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems
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Lecture - 21
Conversion mechanism of biomass to biogas and its properties

Good morning, everyone. Welcome to Part 1 of Lecture 2 under Module 7. So in this module, we will discuss about the bioconversion into biogas mechanism or you can say the stages in the anaerobic digestion and the properties of the biogas. So, let us start with the discussion about the what is mean by the biogas.

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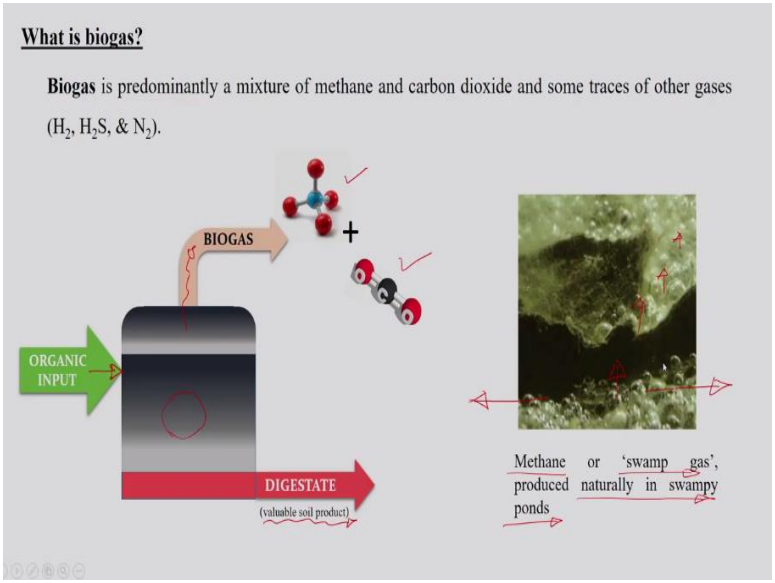

So, biogas is predominantly a mixture of methane and carbon dioxide and some traces of other gases such as H2, H2S and the nitrogen. So, the biogas is produced mainly by decomposition of the organic matter in a digester. So, this particular digestion process is carried out by the action of the microorganism in absence of oxygen. So, the biogas produced during this particular stage may act as a source of renewable energy as well.

So, if you see here in this slide, we have shown here a small biogas digester. So, in this case, the organic matter is fed into the digester. So, it is allowed to carry out the digestion inside this particular digester. And once the digestion process is carried out, it evolves the gas in the form of biogas, which is a mixture of methane and the CO 2.

So, at the end of this particular digestion process to digest a slurry, which comes out from the digester is also one valuable product, which is called as a valuable soil product also. So, this

methane or you can say the swamp gas, this particular production is also happen naturally in the swampy ponds. Why?

Because, if you see here the picture which represents the swampy ponds, so, in this particular swampy ponds, the material which is maintained under the anaerobic condition, because as there is no access to the air under this particular condition. So, it is exposed to the anaerobic condition. So, as a result, the organic matter which is present in this swampy ponds undergoes decomposition reaction.

And once it is get decomposed, it releases the methane gas which is getting evolved in this particular process. So, likewise this kind of process happens naturally in the ecosystem as well.

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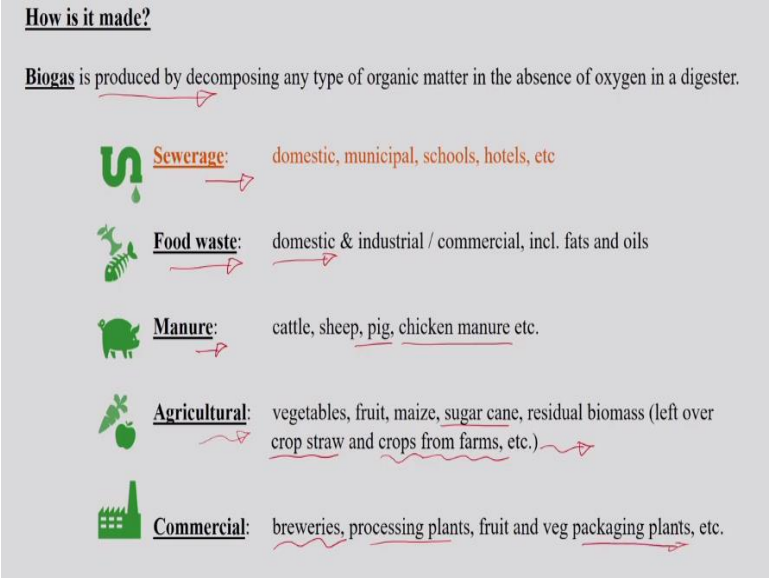

So, how it is made? So, the biogas says it is produced by decomposing any type of organic matter by the action of microorganism in absence of oxygen. So, the organic matter may be it in the form of sewerage. So, if you see here it may be a domestic, municipal, school or hotels. The sewerage of these particular sources which contains some organic materials can be digested to produce the biogas.

Later if you see here, there is a food waste. So, the food waste is one of the most commonly used organic matter for the bio digestion purpose. So, the food waste from the domestic, industrial, commercial, which is inclusive of the fats and oils can also undergo decomposition reactions to produce the biogas. Likewise, if you see here, the cattle manure. So, cattle

manure, maybe in the form of like manures of the sheep, you can say the pig, chicken manure.

This particular resource also can be utilized for the biogas production. And this is one of the most commonly used you can say the organic matter from the decomposition purpose to produce the biogas. Apart from that, the agriculture residues in the form of say vegetables, the waste fruits or you can say the sugarcane residues or the residual agricultural material, which is leftover you can say, crop straw and crops from the farms.

So, these are nothing but the residual materials, which can also be utilized for the production of the biogas. So, now, the more attention is nowadays is given for the utilization of this particular resources for the biogas production. And at the last if you see the commercial outlets that means the breweries, the processing plants, fruits and vegetable packaging plants.

The waste generated from this particular commercial outlets can also be utilized for the biogas production. There are a number of organic wastes which can be utilized efficiently for biogas production. So, these wastes can be co digested or individually can also be digested in the digester to produce the biogas.

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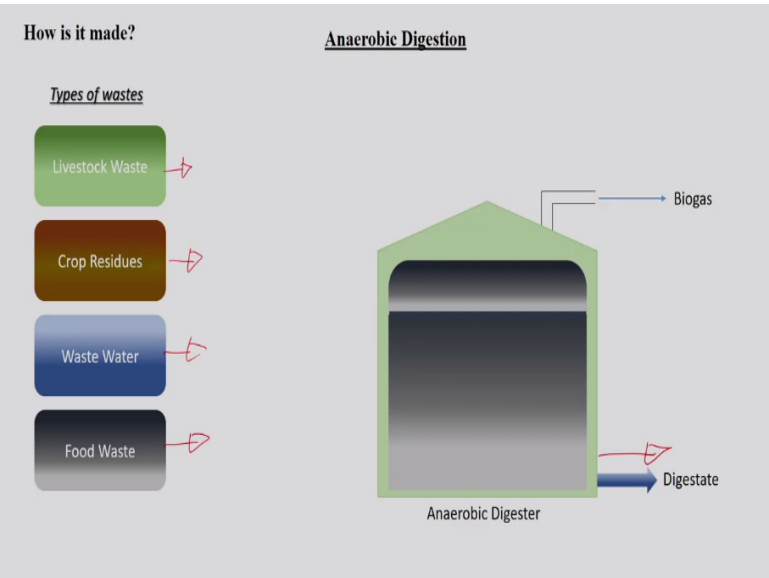

So, the waste once it is collected, either it is in the form of say for example, livestock can be processed in a digester to produce the biogas. If you see here the picture which is running on the slide, which shows the individual waste which can be fed into the digester, so, the

digestate slurry can evolve the gas. And once the digestion process is completed, the digestate slurry can be recovered from the digester from this particular section.

So, this entire process is carried out either using the individual waste or can also be co digested so that there can be a dynamic equilibrium between the acid former as well as the methane former bacterias and which is very much essential in the anaerobic digestion process. So, that the efficiency of the anaerobic digestion can be maintained and the generation of the gas can be carried out in a very efficient manner.

So, likewise, this particular process can be carried out by feeding this kind of waste, as I mentioned earlier, individually or also can be co digested in a specific combination in the digester to have dynamic equilibrium between the acid formers bacteria as well as the methanogens bacteria in the digester.

So, now, as I shown here, the waste which is collected can be processed by using some preprocessing stage, either it can be a size reduction or just by removing the some external material which is present in the organic waste and this particular waste can be fed inside the digester.

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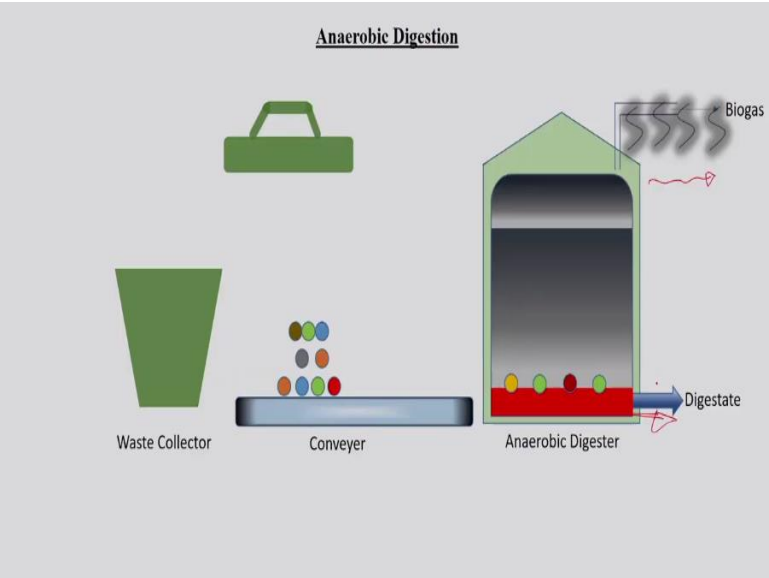

And if you see here, the gas which is evolved, can be collected in a common gas holder, so, that it can be used as and when required basis. Similarly, digestate slurry can be collected from the bottom of the digester once the cycle of the digestion is completed. Cycle of the

digestion means, if it is a batch type operation, then it requires at least 50 to 60 days to complete the single batch of the organic waste.

So, after 60 days, the particular digestate slurry can be collected from the batch type plant. So, that is what is the meaning of the collection of the digestate slurry from the digester. If you are operating as a continuous mode, then, with specific input on the per day basis, that much amount of waste can be rejected from the digester on daily basis, and it can be automatically collected from the digester as well.

So, there is difference between the batch type as well as the continuous plant type digester. So, that will be discussing in our subsequent slides.

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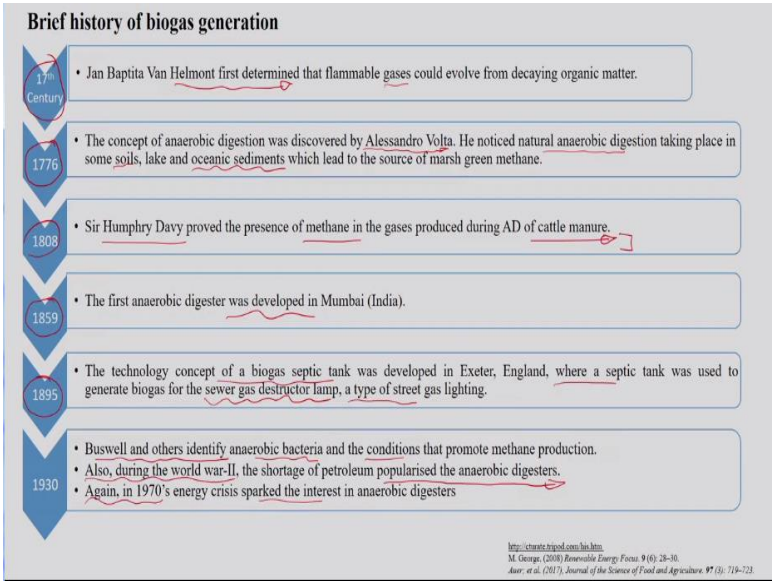

So, before we go in more detail about the discussion on the biogas production or the biogas generation. Let us discuss about the brief history of the biogas generation. So, if you see here, Van Helmont first determine in 17th century that flammable gases could evolve from the decaying material under the anaerobic condition. So, later in 1776 the concept of anaerobic digestion was discovered by Alessandro Volta.

He noticed the natural anaerobic digestion is taking place in some soils, lake and oceanic sediment which leads to the source of marsh green methane. So, why it is happening? Because, these kind of places are exposed to the anaerobic condition. So, once the anaerobic condition prevails in these particular places, so, the organic matter which is present in this particular places undergo decomposition reaction.

And as a result it will evolve the methane as a gas along with the some fraction of the CO 2. Because this particular microorganism, they will utilize the oxygen which is present in the organic matter itself. So, as a result there will be a some fraction of CO 2 may also evolve during this particular process under this condition. Similarly, in 1808, Sir Davy, he proved the presence of methane in the gas produced during the anaerobic digestion of the cattle manure.

So, that is the time when the utilization of the cattle manure is carried out for the anaerobic digestion process as well. So, after that in 1859, if you see, the first anaerobic digester was developed in India in Mumbai. So, this is the first anaerobic digester which was developed in India in Mumbai. And it was like in 1859. Later in 1895, the technology concept of biogas septic tank was developed in Exeter in England.

So, in this case, a septic tank was used to produce a biogas. And this particular produced gas was used as a sewer gas destructor lamp or you can say a type of street gas lighting. Later in 1930 with more (()) (10:26) in this biogas technology, Buswell and others, they identify anaerobic bacteria and the conditions that promote methane production. Later during World War 2 also, the shortage of petroleum product popularized this particular technology.

And it was used in more advanced way for the biogas production and the produced gas was utilized as a source for the energy. And then in 1970s, energy crisis further sparked the interest in the anaerobic digesters. So, likewise, if you see here, how this biogas generation technology was evolved in the science and technology can be visualized from this particular slide.

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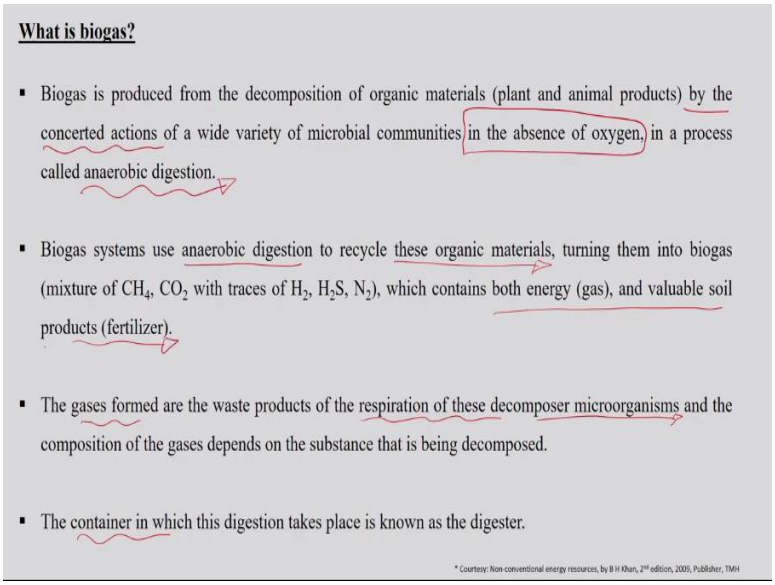

So, the biogas, as I mentioned, it produced from the decomposition of the organic matter by concerted action of wide variety of the microbial communities in absence of oxygen. And this particular process is called as a anaerobic digestion process. So, if you see in this case, the biogas system, it use anaerobic digestions to recycle these organic materials, and turning them into a valuable material in the form of biogas, which can also be act as a source of energy.

And it also produce a valuable soil product, which also act as a fertilizer. So, by using this particular waste, we can produce 2 different kinds of product one in the form of fuel, or you can say the energy and other in the form of fertilizer. The gaseous form are the waste products of the respiration of these decomposer organisms.

So, the composition of this entire biogas is solely depends on the type of waste or the organic matter or the substance, which is getting decomposed in the digester. And the container in which this digestion process is carried out is termed as a digester. So, this is very simple concept.

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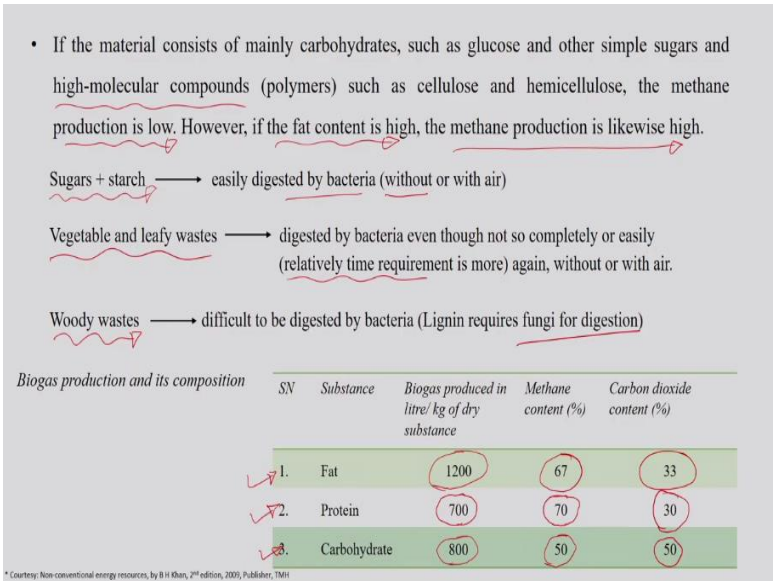

- If the material consists of mainly carbohydrates, such as glucose and other simple sugars and high-molecular compounds (polymers) such as cellulose and hemicellulose, the methane production is low. However, if the fat content is high, the methane production is likewise high.

Sugars + starch ⟶ easily digested by bacteria (without or with air)

Vegetable and leafy wastes ⟶ digested by bacteria even though not so completely or easily (relatively time requirement is more) again, without or with air.

Woody wastes ⟶ difficult to be digested by bacteria (Lignin requires fungi for digestion)

Biogas production and its composition

SN	*Substance*	*Biogas produced in litre/ kg of dry substance*	*Methane content (%)*	*Carbon dioxide content (%)*
1.	Fat	1200	67	33
2.	Protein	700	70	30
3.	Carbohydrate	800	50	50

* Courtesy: Non-conventional energy resources, by B H Khan, 2nd edition, 2009, Publisher, TMH

Now, if you see if the material consists of mainly carbohydrate, such as for example, glucose, or simple sugars, or high molecular wet compound in the form of cellulose and hemicelluloses, then the methane production is low in such cases. However, if the fat content is high in the raw material, the methane production is likewise high.

So, as I mentioned earlier, the composition as well as the production of methane in this particular process is mainly depends on the type of waste as well as the substance which are presenting the specific organic matter. For example, if you see here, if the organic waste mainly contains the starch and the sugar, so, this kind of materials can be easily digested by the bacteria without or with air. What is meant by the without and with air is?

If the decomposition is carried out with air, so, as a result, this kind of decomposition reaction mainly produces CO 2 and ammonia as a gas. And hence, it is not converting into any valuable product. Similarly, if the same decomposition reaction, if it is carried out without air that means in absence of air, then it leads to the production of energy in the form of biogas and its composition is mainly methane and the CO 2 as well as some traces of other gases.

And also along with that, it gives digestate slurry as a product. So, this is the difference between the decomposition of the organic matter in presence of air and in absence of air. Similarly, the vegetables and the leafy waste can also undergo decomposition reaction in the similar manner again in presence of air or in absence of air.

But in this case, if the decomposition is carried out in absence of air, so, relatively time requirement for the decomposition of such material is more compared to the previous case. So, this is what is the difference, because, as I mentioned, it all depends on the substance which are present in the organic matter. Because, starch and the simple sugars are very easy to digest or degrade for the bacterias which are present in the anaerobic digester.

Whereas, if you talk about the vegetables and the leafy waste, so, to act on these particular materials, the bacterias need to spend some more time so that the digestion process can takes place and then it will evolve the gas. But then this is a time consuming process if the material contains the vegetable and the leafy waste whereas if the material is a woody waste then it is very difficult to digest this kind of material by the bacteria.

Because, the lignin content in this kind of materials mainly require for the digestion purpose. So, just to have the comparative analysis of the material or you can say the substance present in organic matter, and how this particular substances can convert into a biogas and what is that particular ratio of biogas can be produced from this kind of substances is summarized in this particular table here.

So, if you see in this particular table, you can see that, if the substance contain mainly of fat, then in that case, it produces around the (()) (16:03) liter of biogas per kg of dry substance. And the methane content in the biogas produced is around 67% and the carbon dioxide content is around 33%. Similarly, if the substance is a protein then in that case, although the gas produced from this kind of substances is relatively less compared to the fat.

But then if you see, the methane in its composition is relatively higher and also the carbon dioxide concentration is relatively low, if the substance is a protein. Similarly, if it is a carbohydrate, then even in this case, the gas production is intermittent between the fat and the protein. But, the methane content is relatively low is only 50%. But, the carbon dioxide production is little high.

So, this is how the decomposition reaction it varies. And it mainly depends on the substance which is available for the decomposition reaction. As a result, these kind of processes can be carried out using a co digestion operation as well so that we can maintain a specific ratio of this particular material in a digester.

And this also helps to maintain proper proportions of the acid forming bacterias and the methane forming bacterias in the digester in a dynamic equilibrium condition. And this particular condition, it also helps to run the digester in an efficient manner. And it also provides effective bio generation of the gas during this particular process.

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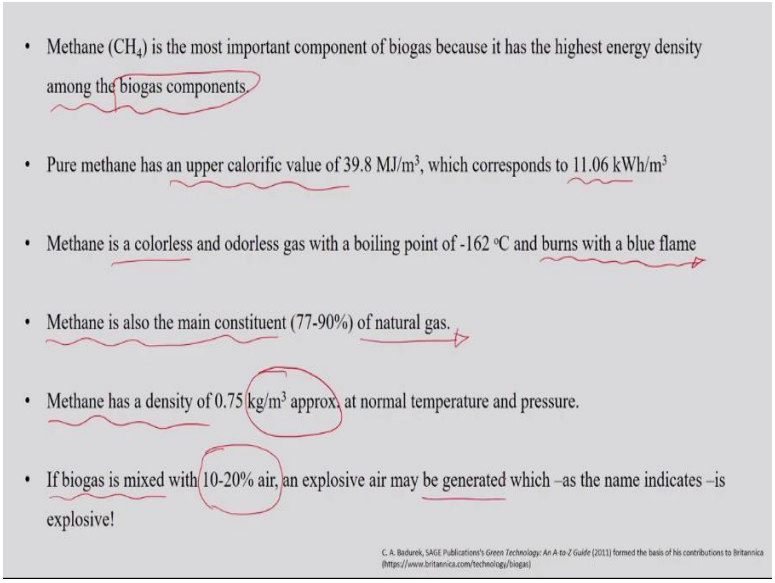

As I mentioned, the methane is the most important component of the biogas because methane is the only gas which has the highest energy density among the other gases present in the biogas. Apart from that, the pure methane has an upper calorific value of around 39.8 megajoule per meter cube. And it corresponds to around 11.06 kilowatt hour per meter cube of a gas.

So, this also shows a significant amount of calorific value of the methane if it is a pure methane. It is a colourless and odourless gas with a boiling point of around minus 162 degrees C and it burns with a blue flame. And the methane is also the main constituents of the natural gas. This is also one of the most important thing. If the gas produced during this anaerobic transition process is further purified, then it can be also utilized as a bio natural gas or you can say bio CNG.

The methane has a density of 0.75 kg per meter cube approximately at a normal temperature and pressure. Similarly, if this particular biogas is mixed with 10 to 20% of air, an explosive air may be generated, which as the name suggest is a explosive. Thus, it is very much essential to utilize this gas in a safe manner for the energy purpose.

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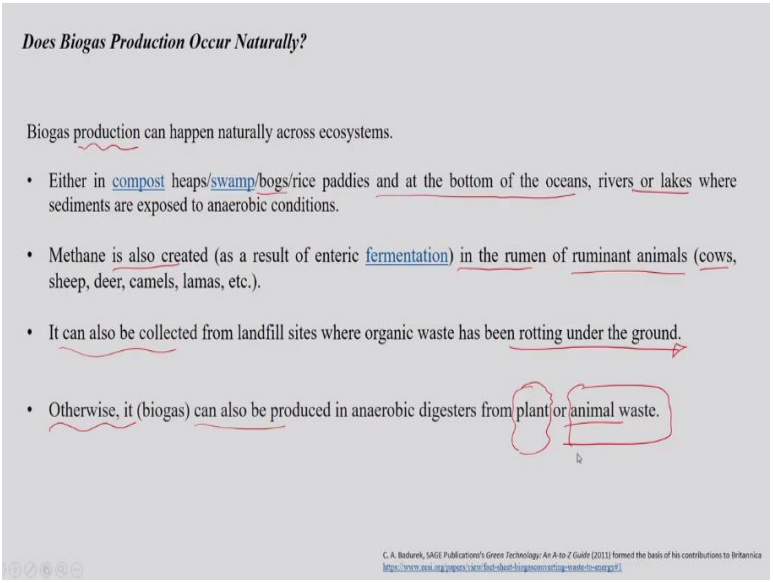

So, now, as I mentioned earlier, does this biogas production happens naturally? Yes, because this particular biogas productions can happen naturally in a natural ecosystem, either in the form of compost heaps, and you can say the swamp, bogs, the rice paddies, and at the bottom of oceans, rivers or you can say the lakes where sediments are exposed to the anaerobic conditions.

So, when this kind of places are exposed to the anaerobic conditions, so this anaerobic digestion process will start. And as a result, the decomposition of the organic matter will takes place and then it will evolve the gas with a slow manner from such kind of places. Methane is also created in the rumen of the ruminant animals. The ruminant animals like cows, sheep, deers, camels and the lambs.

It can also be collected from the landfill sites, where organic waste has been rotten under the ground. So, this is also one of the source from where you can collect the biogas. Otherwise, as I mentioned earlier also it can be produced in anaerobic digester from plant and animal waste. So, this is one of the widely utilized source for the anaerobic digestion purpose is on the timber the plant.

Or, you can say that the waste plant material and also the animal waste, which are widely being utilized for the anaerobic digestions to produce the biogas in the form of renewable energy.

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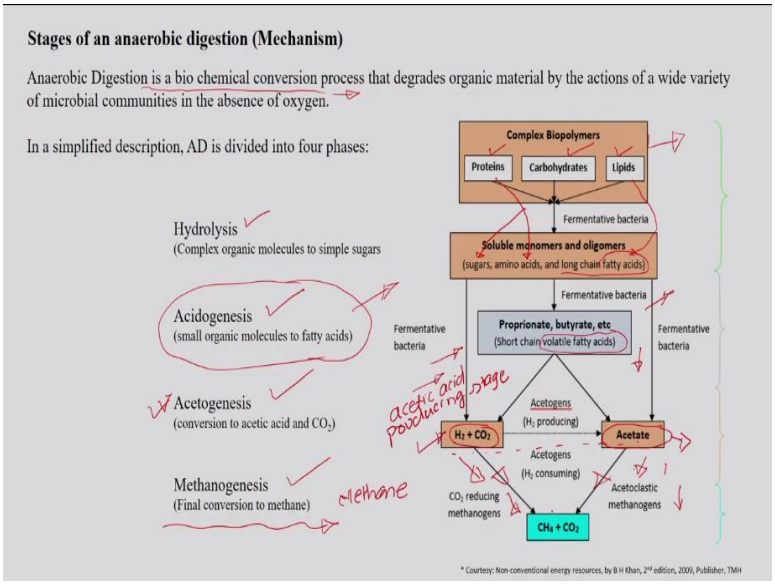

That means the anaerobic digestion is mostly a biochemical conversion process, and that degrades the organic matter in absence of oxygen by the action of wide varieties of the microorganism. So, if you just try to simplify this particular concept, so you can see that this anaerobic digestion process is carried out in 4 different stages. That means first is the hydrolysis stage, then the acidogenesis, acetogenesis and then the methanogenesis.

So, what happened in the first stage in this particular stage here, the insoluble organic compounds in the form of say for example, carbohydrates, proteins and the fats or some other simple carbohydrate molecules. They undergo decomposition by the action of the enzyme or the anaerobic bacteria. So, once these particular microorganisms act upon this particular organic matter.

So, in that case it produces the simple sugar compounds or simple molecule in this particular process, which are soluble compounds. The simple soluble compounds which are produced in this hydrolysis stage are act as a substance for the bacteria in the next stage. So, in this particular hydrolysis stage, the carbohydrates are mainly decompose or you can say broken down into simple sugars.

Similarly, if the protein contents are there in the substance, then those proteins are converted into the are broken down into the amino acid. And if some fatty compounds are present in the mixture, then those fats are converted into a fatty acids during this hydrolysis stage. So, once the simple compounds which are produced in the hydrolysis stage, then these particular

compounds are transformed by the action of enzymes in the acidogenesis stage, which is called as a acid forming stage.

So, in this particular process, these simple compounds are transformed into a volatile acids propionate and butyrate molecules. The H plus ions form in this particular stage may reduce the fermentation process. That is the reason if the concentration of H plus ion in this particular stage is relatively high, then it reduces the production of the acetate in the subsequent stage.

So, that is the reason it is very much essential to maintain the H plus ion concentration in this particular stage as well. The compounds which are formed in this particular stage are act as a substrate for the bacteria in the acetic acid producing stage. So, in this case, the product which are formed in this intermediate stages are nothing but H2 and CO 2 along with the acetate.

So, in this particular stage, what happened mainly that the (()) (24:17) bacteria as well as the methanogenic bacteria, they grow together. So, once these particular compounds are formed, which is called as a acetogenesis stage. So, during this stage, the compound which are formed in the form of hydrogen, CO 2 and the acetates, these particular compounds are act as a substrate for the bacteria in the last stage of the anaerobic digestion which is called as a methanogenesis.

So, during this stage, the methane gas is produced strictly under the anaerobic condition and the reaction in this particular stage is nothing but the exothermic reaction. So, this particular methanogenesis stage is subdivided into a 2 stages. That is nothing but the in the first stage what happened is like this particular compounds are reduced to form the methane. Similarly, in this particular stage the hydrogen and CO 2 are converted into the methane.

So, likewise these 2 operations occur simultaneously in this particular stage, which is called as a methanogenesis stage in the anaerobic digester. So, acetotrophic bacteria which are present in this particular stage which is called as a acetotrophic methanogens. These are mainly responsible for the reduction of the acetate to the methane in the methanogenesis stage.

Similarly, the hydrogenotropic methanogens are responsible for the conversion of H2 and CO 2 into the methane in this particular methanogenesis stage. As a result, the entire compound which are present in the form of hydrogen, CO 2 and the acetate in the particular methanogenesis stage are converted into a methane and small amount of CO 2 as a gas.

So, this is how the anaerobic digestion process takes place in the digester in the stage wise manner. And the reactions which are mainly responsible in the methanogenesis stage are shown here.

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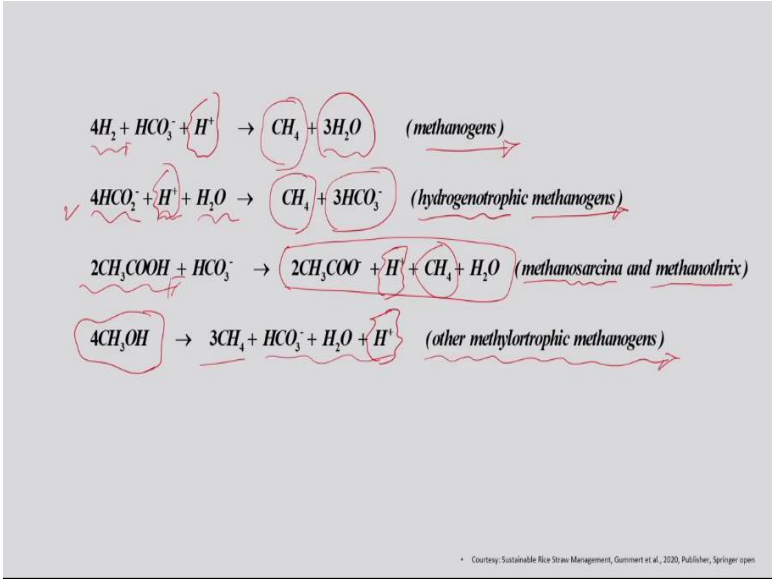

So, if you see in this case, the hydrogen molecule is getting converted into a methane along with the some intermediate product. So, the water which is produced in this particular stage is used to stabilize the slurry as well as to stabilize the pH of the slurry in the digester. Similarly, the second reaction, it shows the intermediates which are produced are getting converted into a methane and also produce some intermediate compound.

And this is mostly carried out by the hydrogenotrophic methanogens. So, this indicates the organisms which are responsible for this kind of reaction. And the acetic acid which is available in the slurry further undergo decomposition reaction and produces methane as a gas along with this intermediate product. But in this case, methanosarcina and the methanothrix are the microorganisms which are responsible for this particular reaction.

And at the end, some alcohol which is also produced during this decomposition reaction converted into a methane and this kind of intermediate products. So, this particular reaction is

mainly carried out in the presence of this microorganism. So, if you see this entire reaction mechanism, it shows how the concentration of H plus ions is getting balanced in this particular reaction so that we can maintain a (()) (28:05) slurry inside the digester.

So, that the pH of the particular slurry can also be maintained in the specific range and it results in the dynamic equilibrium between the acid formers as well as the methanogenic bacteria, which are very much essential for the efficient generation of the biogas.

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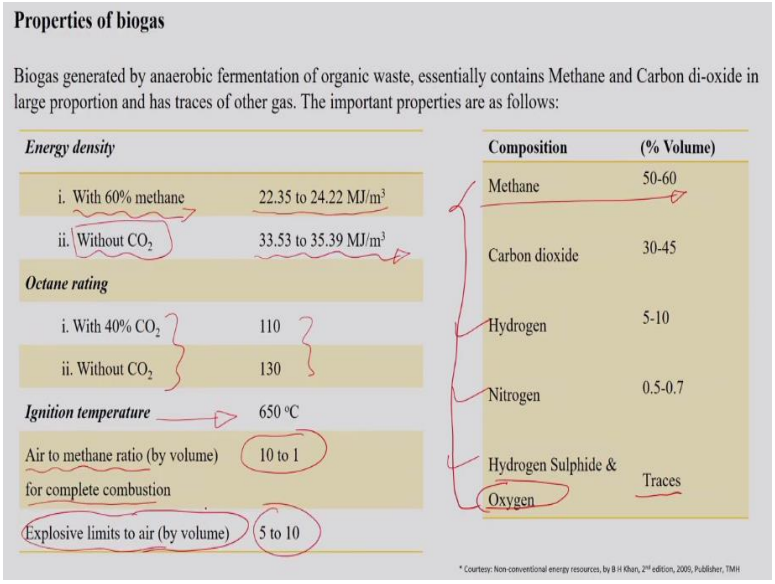

So, if you talk about the biogas, which is produced from the digester, and if you just try to see its properties. So, first from the composition point of view, if you just try to see, the composition of biogas is mainly consist of methane, carbon dioxide, hydrogen, nitrogen, hydrogen sulphide and small traces of the oxygen.

So, now, if you just ask me a question, why there is oxygen in this case, because, as I mentioned earlier, the oxygen which is present in the organic matter itself will be utilized by this particular bacteria. So, obviously, there will be a some fraction of oxygen will be present in the biogas. But this particular gas is present in the very small or you can say in the trace amount. So, the oxygen that is why I have mentioned here in the traces, maybe you can say like 0.5 or 0.4% in the total composition of the biogas.

But methane is the major gas in the composition of biogas followed by the carbon dioxide, hydrogen and then the nitrogen. Now, if we just talk about the properties of this particular gas so the energy density of this gas if you see, with a 60% methane its energy density is in the

range of like 22.35 to 24.22 megajoule per meter cube. Similarly, if we remove the CO 2 from this particular gas, so, its energy density value if you see here it is relatively high.

Similarly, the octane rating with or without CO 2 also is a significant value. And the ignition temperature is around 650 degrees C. But air to methane ratio by volume for the complete combustion, it required in the range of like 10 is to 1. And the explosive limit for this particular gas is 5 to 10% by volume with air. So, this is a very important information which tells about the properties of this kind of gas.

So, now, after learning about this biogas and how the biogas is getting produced, or you can say the number of stages, which are involved in the biogas production. So, let us discuss about the advantages of this anaerobic digestion process. The most important advantage of this anaerobic digestion process is because, it utilizes the discarded material and this discarded material is getting converted into the energy.

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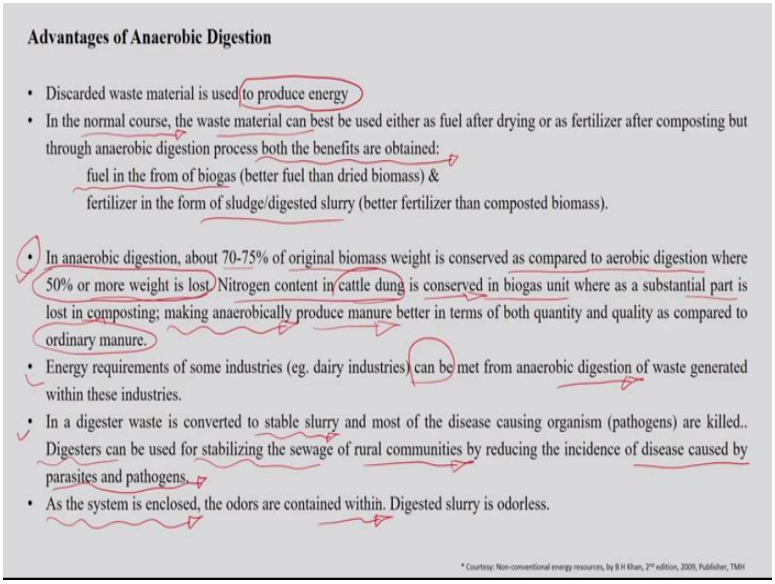

Apart from that, in the normal course, if you see, the waste material can best be used either as a fuel or can be composed to produce the fertilizer. But in case if this particular waste is digested using this anaerobic digestion process, so, then you can see like, both the benefits can be achieved by using this particular process, whereas, the material is the same. So, it can produce fuel in the form of biogas as well as it can also produce the fertilizer in the form of digested slurry.

So, from the same material 2 products can be obtained if the material can be digested using the anaerobic digestion process. Similarly, the another advantage of this particular process in anaerobic digestion about 70 to 75% of the original biomass weight is conserved as compared to the aerobic digestion where around 50% or more of the weight is lost.

The nitrogen content in cattle dung or you can say the cattle manure is conserved in a biogas unit, whereas, substantial amount of this particular nitrogen source is lost in the composting process. So, if we just compare these 2 processes, so, the anaerobically digested material also produce a manure which is better in terms of quality and quantity compared to the ordinary manure. So, this is one of the significant advantage of this particular process.

Similarly, the energy requirement of some of the industries, for example, if some of the industries are producing organic waste just take a example of the dairy industries, so, the waste which is produced from such kind of industries can be digested to produce the energy so that the energy produced from such kind of waste can be utilized in the same industries itself.

The energy requirement of the specific industry can be made from the waste generated by this particular industry itself. For example, is the dairy industry. In a digester, waste is getting converted into a stable slurry and most of the disease causing bacterias or the organisms are getting killed in this confined digester itself. So, this is also one of the advantage of this particular process.

And the digesters can be used for stabilizing the sewage of the rural communities by reducing the incidence of disease caused by parasites and the pathogens. And as the system is the enclosed digester, the odours are also contained within it. And the digester slurry which is recovered at the end of the process is also odourless slurry. And hence it can also act as a soil enhancer or (()) (33:55) soil product.

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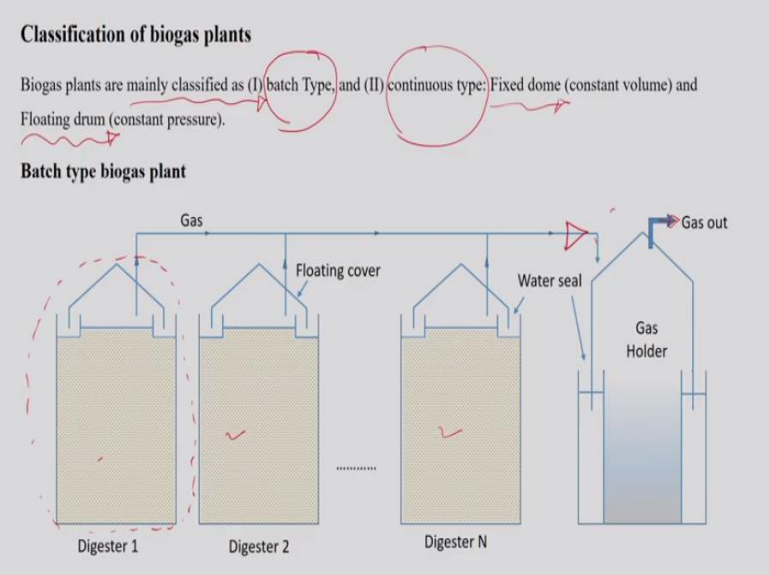

Now, based on these advantages as well as the importance of this particular process, let us discuss about in details, how this particular process carried out or what type of biogas plants are being used for the digestion purpose. The biogas plants are mainly classified as batch type and the continuous type plant. And continuous type plants are further sub classified as fixed dome type plant and the floating drum type plant.

So, the schematic which is shown on this particular slide, it represents the number of batch type plants which are installed in series and the outline of this particular plants is connected to a single gas holder. As a result, the gas from this particular holder can be utilized as on the requirement basis. So, the purpose of utilizing this particular plant in this particular manner is because one can also operate the digester using a single batch type unit or also we can have such kind of units in the series.

And the outlet of all this particular plant can be connected to a single gas holder unit where the entire gas can be accumulated and can be released to the users on the requirement basis. So, the advantage of this kind of units are these kind of batch plants can be operated in a synchronized manner. And it can be (()) (35:36) by one by one or also you can say can be fed alternatively so that it will not affect the gas output.

So, once we are in such kind of number of units in series. So, it is equivalent to a continuous plant.

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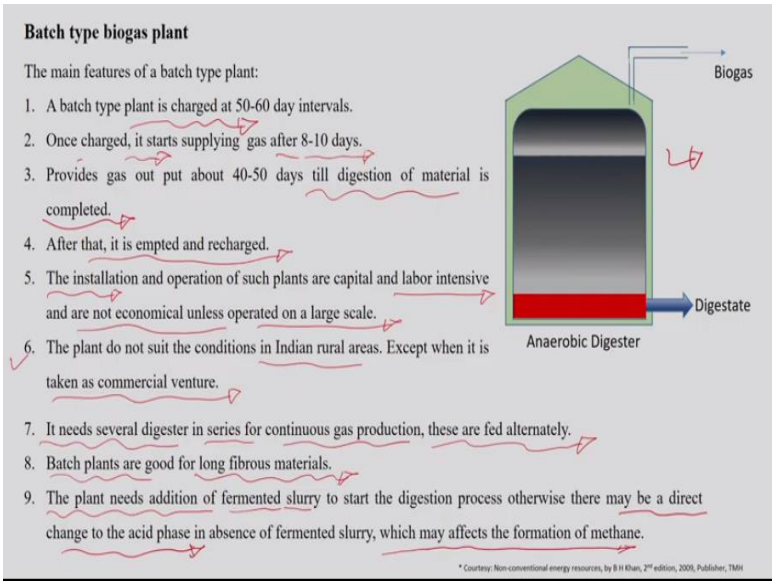

So, let us see some important feature of such kind of unit. So, a batch type of plant is charged at 50 to 60 days intervals. So, if it is a single unit, it is charged at 50 to 60 days interval. And once it is charged, it starts to produce gas after 8 to 10 days. And it continues to produce gas for 40 to 50 days, unless the digestion of the material is completed in the digester. Apart from that, once the digestion process is completed, then this particular plant can be (()) (36:33).

And we can recover the digester slurry from the digester. And then again it can be recharged for the next operation or you can say that next cycle of the operation. The installation and operation of this kind of plants are capital and the labor intensive and are not economical unless operated on a large scale.

And that is the reason if you remember the previous slides, I mentioned that if such kind of plants need to be operated, so, then we need to install such kind of plants in the series so that the operation of the entire plant can be economical. And the plant do not suits the condition in the Indian and the rural areas except when it is taken as a commercial venture. That is what I mentioned in the previous slide as well.

And it needs several digester in series for continuous gas production. And these are fed alternatively. So, once we need to convert this batch operation into a continuous operations, then we need to have several digester in series and outlet of all these digester can be connected to a single gas holder. And the gas on the requirement (()) (37:40) can be released from that particular gas holder as well.

So, the best type of plants are good for the long fibrous materials. One of the important point here, this particular plant, it needs addition of some fermented slurry to start the digestion process, otherwise, what happened in that case is like there may be a direct change to the acid phase in absence of the fermented slurry and then which may affect the formation of methane as well.

So, this kind of plants are always fed with some amount of fermented slurry at the beginning to start the operation as well. So, this is how the best type of biogas plants are being operated. So, now, if you talk about the continuous type of biogas plant, so, in case of continuous type of biogas plant, the plant is fed daily with small or certain amount of biomass on daily basis.

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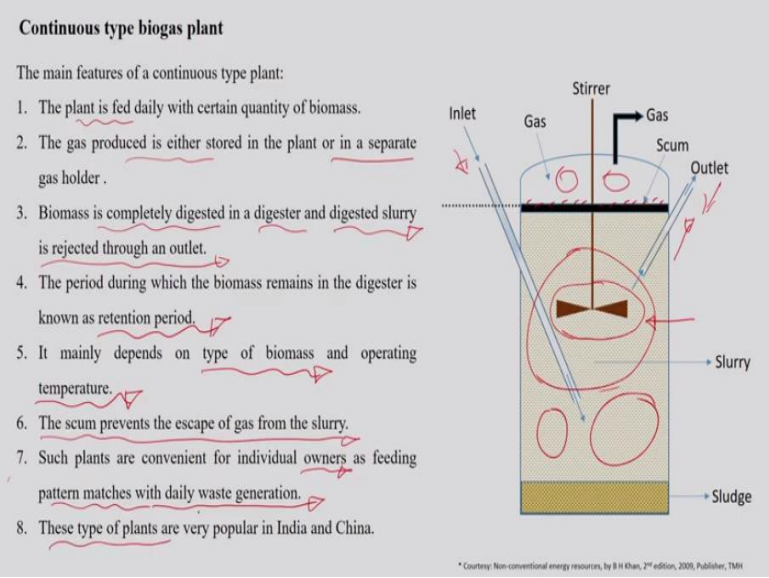

And this is how is the difference between the continuous and the batch type of biogas plant, because in the batch type of plant, as I mentioned, the amount of biomass is fed at a interval. So, first batch if it is fed today, so, once the digestion of this particular batch is over, we cannot fed another batch in between. So, once this particular digestion process is completed, then the best type of plant is emptied to recover the digested slurry.

And then the next batch of operation can be started. Whereas in case of continuous plant, the small amount of biomass need to be fed on a daily basis. And the gas produced is either stored in the plant as shown here the gas holder or can be stored in the separate gas holder. So, either way, we can store the gas in the continuous plant. The biomass is completely digested in a digester and the digester slurry is rejected through an outlet you can see here.

So, as I mentioned, this kind of plants are fed on daily basis. So it also reject or digest a slurry on interval basis. And it can be rejected through this particular outlet. This is what is the advantage of this particular continuous type plant as well. And the period during which this particular biomass remains in the digester, it is called as a retention period.

And the retention period of this particular digester slurry, it mainly depends on the type of biomass and the operating temperature of the digester. The scum which is formed at this particular top layer of the digester, it prevents the escape of the gas from the particular slurry. So, this thin layer of scum which is formed at the top layer of the slurry can be broken by agitating this particular slurry.

This particular agitation operation also helps to maintain the slurry as well as the concentration of slurry inside the reactor. Such plants are convenient for the individual users. As I mentioned here, the pattern which matches with the daily wage generation is best suited for this kind of plant. And this type of plants are very popular in the country like China and the India. So, this is about the classification of the biogas plant.

So, today we will stop here. So, in the next lecture, we will discuss about the classification of the biogas plant as well as the some properties of the biogas plant.

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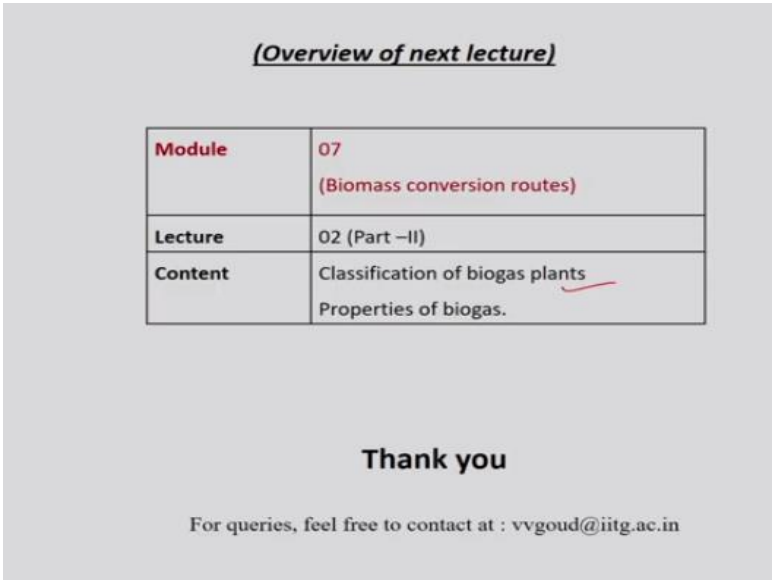

So, if you have any doubt regarding this particular lecture, you just feel free to contact me at vvgoud@iitg.ac.in. Thank you.