Municipal Solid Waste Management
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Lecture - 32
Types of Biogas Digester

Hello students, so we are at the last lecture on anaerobic digestion transformation or biological transformation. So in this lecture, we will talk about types of biogas digesters. So, in the previous lecture, I talked about different stages of anaerobic digestion process, different factors affecting anaerobic digestion process. In the previous lecture, I talked about how beneficial the pretreatment process is for various types of lignocellulose biomass.

And also I talked about co-digestion or co-digestion of different by mixing different substrates together to maintain the proper carbon to nitrogen ratio. Now, once you understand the proper substrate mix hydrolysis process. Now, we will come to that acid phase and methane phases on the last stages and these last stages will be inside the one particular reactor called biogas reactor. So, here in this lecture we will talk about the different types of biogas reactors and what are the different benefits of having the different biogas reactors.

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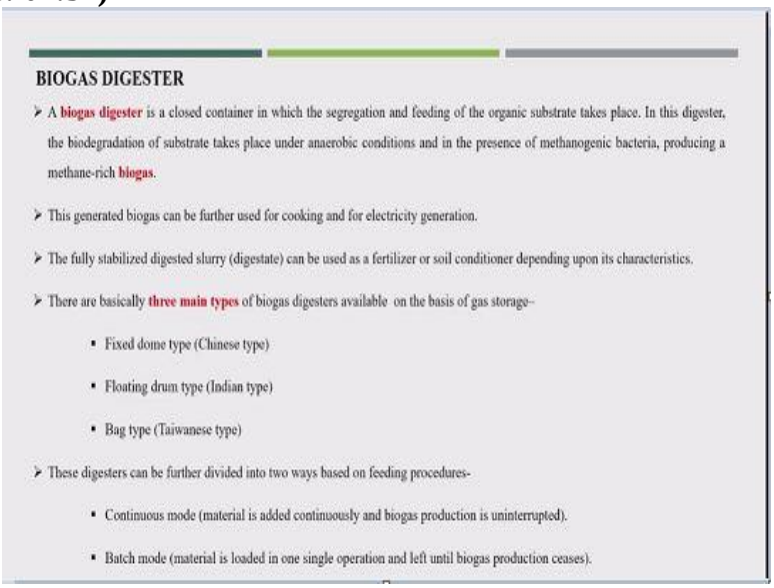

So, what is a biogas reactor? The biogas digester is a closed container in which segregation and feeding of the organic substances take place are majorly the acidogenesis, acetogenesis and methanogenesis will be inside these biogas reactors. So, in these digesters the biodegradation of

substrate takes place under the anaerobic condition, and in the presence of methanogenic bacteria producing methane-rich biogas the generated biogas can be further used for cooking and electricity generation that is obviously that is the benefit of biogas production.

The fully stabilized digested slurry or digestate can be used as a fertilizer or soil conditioner depending upon this characteristic. So, that is also the benefit, what waste product we are getting from the biogas reactors. So, there are basically 3 types of biogas digesters are available fixed dome, that normally we call is a Chinese type of reactor, floating drum type reactor that is Indian type and the bag type of biogas reactor that is Taiwanese type, I will show you the different photographs also where these kinds of reactors are installed.

And already in the working conditions under these digesters can be further divided again I think these the different type of biogas reactor and further divided into the either in the continuous mode the material is added continuously and biogas production is uninterrupted. So, here you can say is a continuous mode or you can say fed-batch process. Continuous means, continuously or 24 hours the substrate is adding into the biogas reactor.

It is also possible like our country, the waste collection once a day, in morning we are collecting the waste and every morning every day, we are feeding the reactor continuously. So, I think you can say is a continuous reactor or we can say paid batch reactor means every day we are feeding the reactor. Another is a batch mode a material is loaded once in single operation and left until biogas production ceased.

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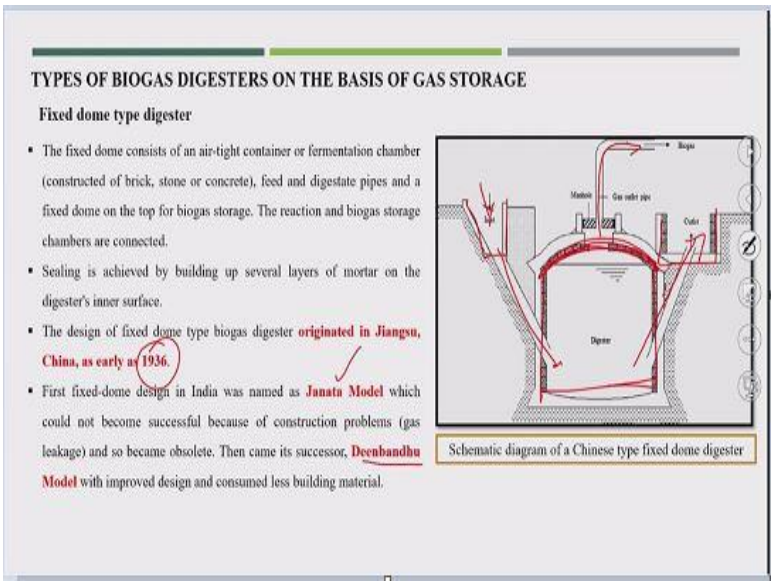

So, the first type of reactor is a fixed dome type of reactor. So this is the dome the top area, so the first type of reactor is a fixed dome type of reactor. So this is the dome, dome is fixed and this is the reactor. So dome is fixed here. So the fixed dome consists of an airtight container or fermentation chamber. This could be constructed by brick, stone or concrete so, this is the inlet. So, by inlet and this is the outlet.

So, onto the top you will find this time and this is the outlet tank and this is the fixed one dome and from the top one pipe will be inserted into the digestate to get the biogas the ceiling is achieved by building up several types of motor on the digested inner surface. The design of fixed dome type of biogas digester originated in China in 1936 is one of the oldest techniques you can see you can say that, for biogas production and first fixed dome design in India was named as Janata model which could not become successful because of construction problem.

The major problem was gas leakage because this ceiling should be there properly onto the dome and that become obsolete and then came its successor like this is the very popular model Deenbandhu model with improved design and consumed less building material. So, you remember this 2 point the first model was Janata model was similar to the fixed dome and modified one is Deenbandhu model and typical feedstock for these digesters is animal manure, night soil and agriculture base.

So, mostly I think these kinds of reactor had been started long before especially for the animal manure like cow dung in India normally the Deenbandhu model we used to talk over gas plant, so, over gas go over him you called the cow dung the cow dung based or sometimes we will add night soil that was also very popular by or otherwise that was a mixing of night soil with cow dung that was not some agriculture waste.

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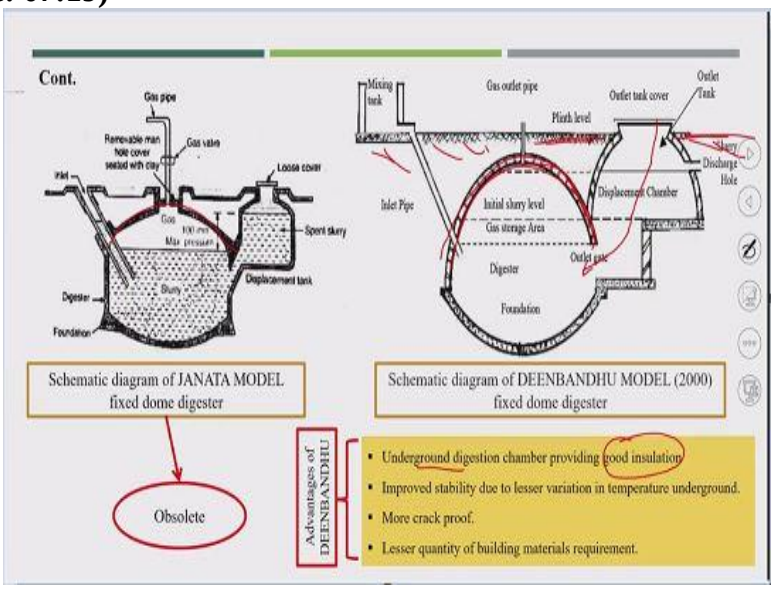

So, is a schematic diagram of Janata model? So, these Janata model you see that is same to same of Chinese model, fixed dome model and now, here is the Dennbandhu model, this is the Deenbandhu model. So, only the changes was the construction was easy under here you can see that here the outlet is different. Now here you see the outlet chamber. So, now suppose some kind of problem in the reactor suppose somewhere leakages there suppose in this dome.

If you find someday some leakage of gas in this case, if suppose some leakage is there, you cannot do anything. Now, once a leakage problem will start is very difficult to reduce that leakage in the Janata model. But in the case of Deenbandhu model, here, even one particular person can enter so, that outlet is so big. So big so, that any person also can go inside and can take the leakage and if some leakage is fine, they can remove that particular leakage that was the benefit of the Deenbandhu model.

So, now, that is why because Janta model has become obsolete, now nowhere you will find and Deenbandhu model because the other advantages of that underground dilution chamber

providing good insulation. So, you see here this entire area now, this is the outlet plinth level you see here see the entire construction is underground. So, because of that, it becomes good insulation, because normally it is believed that these anaerobic digestion processes are highly affected by the local conditions.

And like India kind of country where not only the temperature but the different climatic conditions you will find in the entire year as I talked about in the composting process also is getting affected by the different climatic conditions. So similarly, this anaerobic digestion is also highly affected compared to the aerobic degradation process like composting. So there is the entire unit will be underground.

So that we do not have to create any problem for the local conditions improves stability due to lesser variation of temperature underground more crack-proof and lesser quantity of building material requirement that was the benefit of Deenbandhu model.

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So, you can see here the same one, so, this could be inlet, this is the dome. So, one pipe is coming out for the gas and this is the outlet tank now, this is the one other one in Kenya. So, many developing countries they adopted this model and installed in the various location but, mostly these kinds of digester has been installed in the rural areas and substrate was majorly the animal manures or animal waste along with that some agriculture residues.

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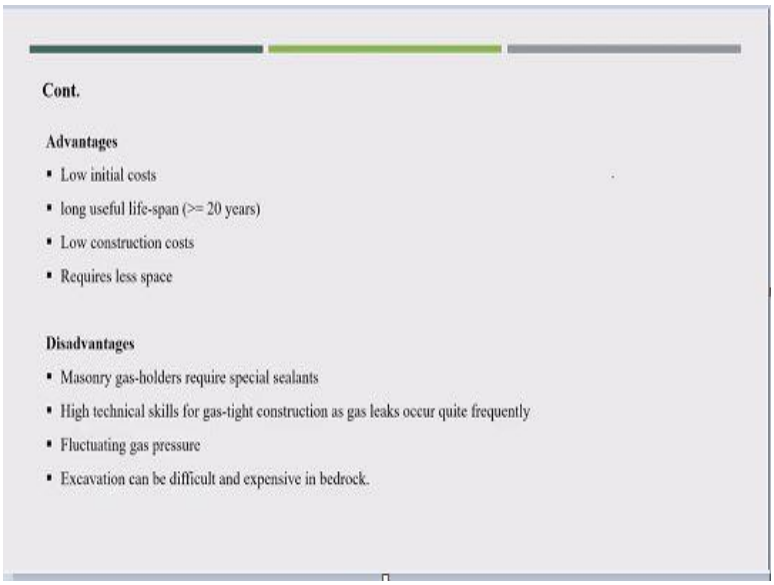

So, what are the advantages of that low initial cost, long useful life span? This is also very important, it can work for more than 20 years low construction costs and required less space if you talk about 1-meter cube or biogas reactor, which can handle 5 kg or 10 kg of waste even 5 kg of waste in a day will be required maybe 5000 rupees was enough for the construction purpose and even the operation also is not that difficult any farmer was not knowing the proper operation, but the operation was simply just fed it.

Whatever outlet is coming that you put it into for the in the agriculture area and whatever gas is coming that used for the cooking purpose. But only there are some disadvantages that masonry gasholder required special sealants, because see, along with the biogas production, there will be some water vapors also are getting produced. So, when you are putting the pipe, so, in the pipe the moisture also will come out and because of that, the blockage of gases could be possible.

So, high technical skills for gas tight construction gas leaks occur quite frequently. I think this gas leakage mostly is because of what I said it that because moisture is coming out because there would not be any operation because it is inside the pipe. So, that somewhere the water will accumulate in one particular location, because of that the flow of gas will be reduced and because of that, a lot of gas rather than coming to the gas pipe, it will come out into the outlet.

So, you will see that a lot of air bubbles you can find in the outlet tank fluctuating gas pressure acceleration can be difficult and expensive in the bedrocks so, because is an entire reactor is

underground one. So, you will be required acceleration and if there is a bedrock in those cases the acceleration is not easy.

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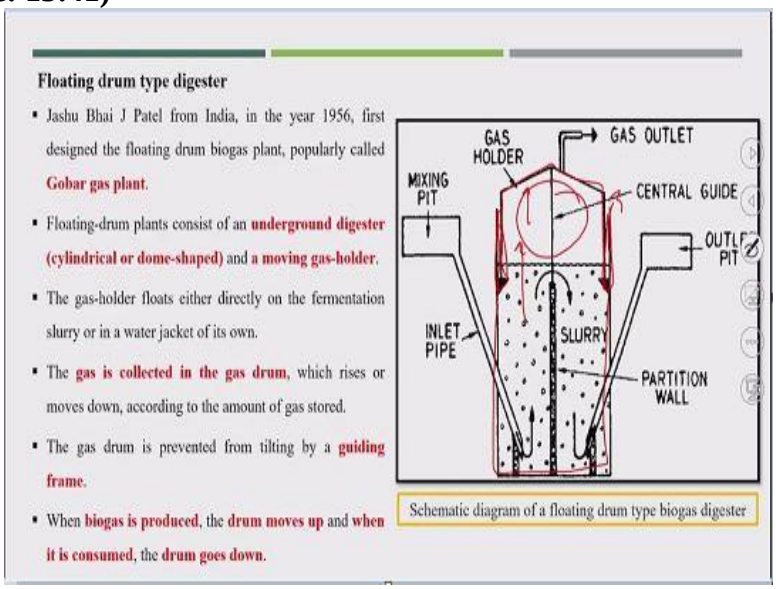

Now, the next reactor is a protein drum type of reactor or Indian kind of reactor. So, in India the first time Jashu Bhai Patel I think you need to remember that, but it is a long back this person in the year 1956 first designed the protein drum biogas plant and that popularly called a gobar gas plant that was floating type and you remember that in the 1950s if that person had thought about because the when I was reading about something about that particular person.

Because in both the cases like whether you take the Janata model Deenbandhu model was installed in the large number, but the problem was leakage was always in both the cases because, in the floating drum biogas reactor, the gas has to become out wherever it will, find the space. So and because the entire dome was fixed, and what this person had thought of why not? We would not do not put these, dome as in fix and if you float this dome. So, obviously, the gas will come out from only one location.

So, likewise rather than leakage you need not to have make these domes with the unique civil construction material, because it has to be a float. So, you can go of metal of construction of these kinds of dome or we can make some plastic also we can put it so, that we can reduce the leakage of the gas. So, floating drum type consists of in the underground digester maybe cylindrical or dome-shaped and moving gas holder.

So, that was his idea this is the fixed one and this dome is a gas holder and once the gas production will be there, this gas will stored into the gas holder. And if the gas concentration will increase, this dome will go upward. The gas holder floats either directly on the fermentation slurry or in a water jacket on its own, because in this one, there will be water so that there would not be any leakage. So, there could be a water jacket or directly into the waist.

It can enter the gases collected in the gas drum which rises or move down according to the amount of gas stored and the gas drum is prevented from tilting by a guiding frame because there will be some guiding frame will be required. So that it will be a rise in affording properly. When the biogas is produced, the drum moves up and when it is consumed, that drum goes down.

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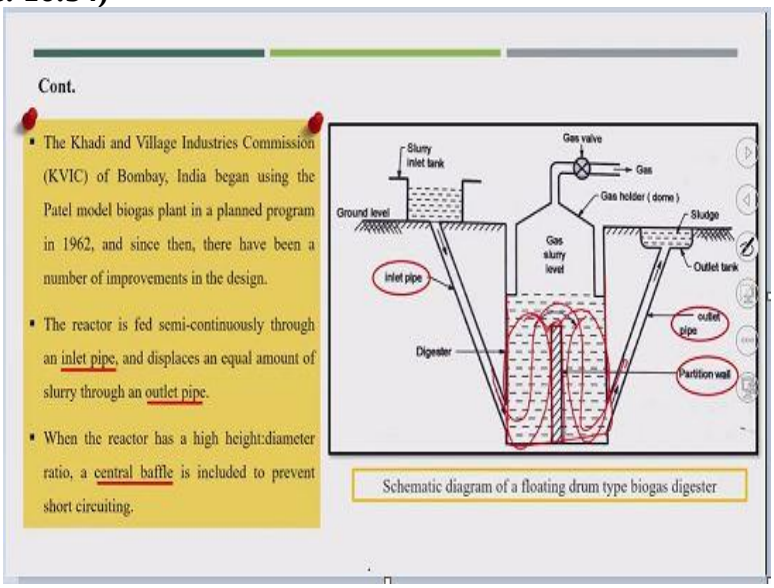

So, in 1962, the Khadi and village industry like KVIC, Bombay, India began using the Patel model, the same Patel model biogas plant in the plant program in 1962. And since then, there have been a number of improvements in the design, the reactor fades semi-continuously through an inlet pipe and displays an equal amount of slurry through an outlet pipe. So, when the reactor is in a high height to diameter ratio a central baffle is induced to prevent the short-circuiting.

So, that was one very important improvement that has been done in the reactor that Patel model. So, earlier the Patel model was only the one particular unit, but the improvement was there was one baffle central baffle has been added. So, now how the flow of waste slurry will be like this.

And the idea was that half of the area will be for the exit phase and the other half will be for the methane phase that was the thought but it is not completely separated one.

But the idea was that entire material will be inside the reactor or the residence time could be increased and so that more methane production could be possible. So, there will be there was the inlet pipe, the same reactor outlet pipe and one partition wall or central baffle were added.

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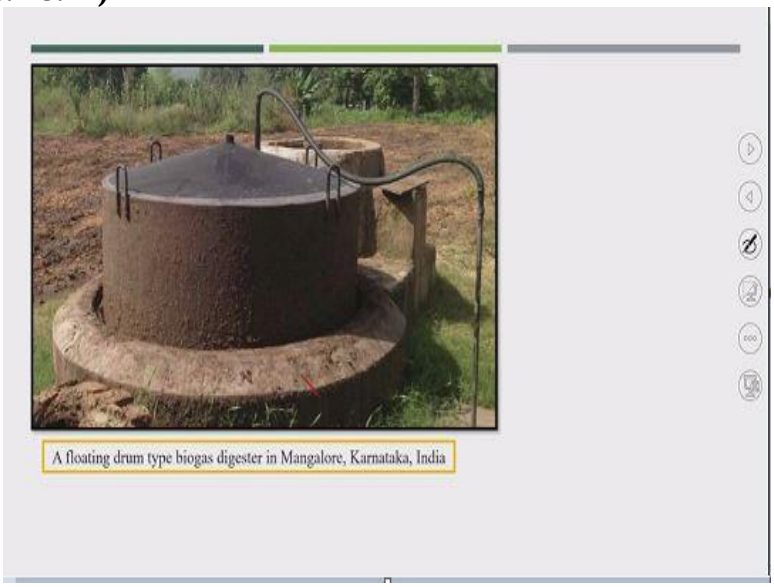

So, this was the one protein drum type. So, you see here these are metal constructed. So, this is the civil construction material for the lower side of the reactor and this protein drum of metal and the gas collection pipe.

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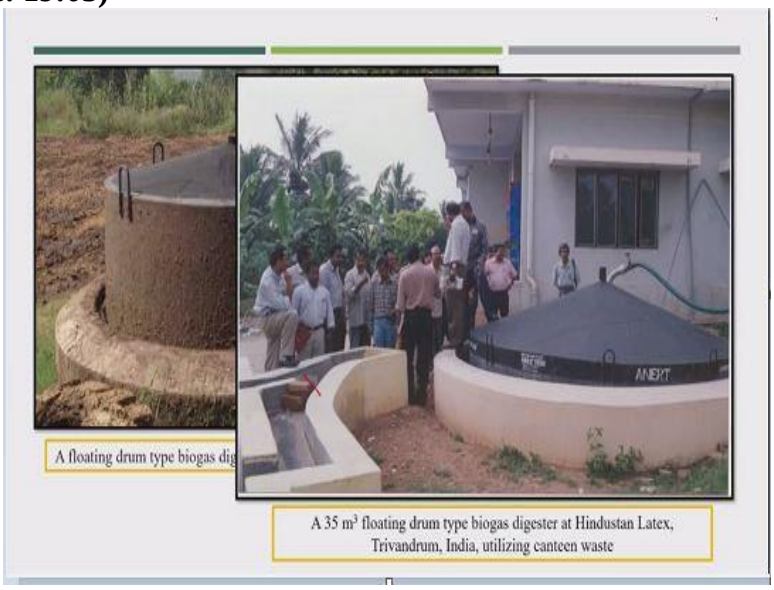

So, this is one of the units like 35-meter protein drum type of reactor you can see this is also metal unit.

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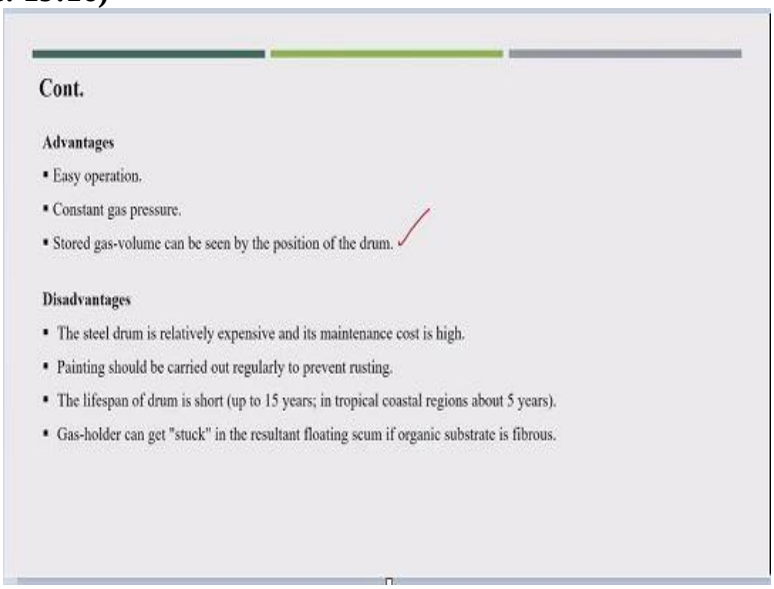

Now, what are the advantages, easy operation, constant gas pressure and stored gas volume can be seen by position of the drum. This is one very important benefit, like in the fixed dome. We are not able to see how much gas has been stored in the reactor. But in the protein drum, we know that by seeing that how much is gas has been produced. So based on the availability gas we can use for the cooking purpose or energy production of that. So every day we can see easily how much gas has been stored in that protein dome.

Under the disadvantage that steel drum is relatively expensive and his maintenance cost is high, obviously, we need to use steel drum or otherwise, if you use other metal the corrosion will be the major problem and painting should be carried out on regularly to prevent rusting and even for the steel in where required time to time painting and lifespan of the drum is shot up to 15 years in tropical coastal about 5 years gas holder can get stuck in the resulting proteins come if the organic substrate is fibrous.

But again is depends upon the special type of substrate if you maintain the proper substrate, this kind of disadvantage can be possible.

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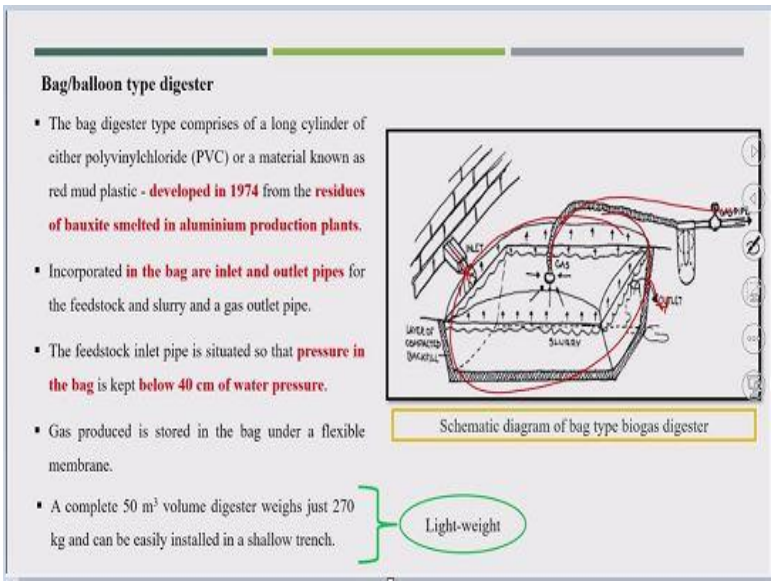

So, next is the bag or balloon type of digester. So, the bag digester type comprises of a long cylinder of either PVC or polyvinyl chloride or a material known as red mud plastic that is developed in 1974 from the residue of oxides melted in the aluminum production plant, that was one particular industry, they started these kinds of the digester. The idea was that this is the balloon. So, here the waste will enter into the balloon and degradation will be followed inside the balloon and the gas will produce and there will be one outlet.

From that time to time the outlet will get collect also, there is only a simple digester. To incorporate in the bag or inlet and outlet pipes for the feedstock and slurry and gas outlet pipe, the feedstock inlet pipe is situated. So that pressure in the bag is kept below 40 centimeters of water pressure. So, that is important for inlet pipe gas-producing stored in the bag under a flexible membrane, complete 50-meter cube volume digester with just 270 kg and can be installed in a shallow trench is a lightweight material and we can change the location also time to time very easily.

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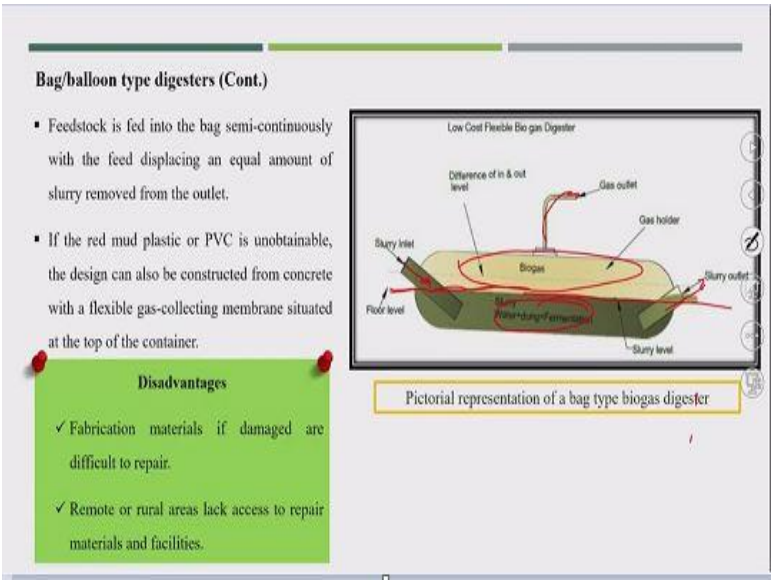

So, this is what you can see here. So slurry lead. So, this is the floor level, this the floor level. So, this is the slurry inlet and this is a slurry outline. Now, this is the degradation process. So, this much area is available is half of the balloon for the storage of biogas, which we can easily collect from the gas outlet. The feedstock is fed into a bag semi-continuously with the feed displacing an equal amount of slurry removed from the outlet.

If the red mud plastic or PVC is unobtainable, the design can also be constructed from concrete with a flexible gas collecting membrane situated at the top of the container, but that is also difficult. So, disadvantages of that, like fabrication materially damaged are difficult to repair, remote or ruler area lack access to repair material facility.

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So, you can see the balloons. So half is underground, that is for the fermentation process and half is on to the top of the surface. So these are the inlet pipes inlet, and the outlet is directly going to the field. So you can see that and these kinds of balloon digester can be easily we can change the location. So the transport bags are attached to the system and filled with gas. These are 4 kg filled pillows with biogas. So it is 4 kg so anyone can easily transport it.

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You can also see here, these are the gas bags. These pillows are stored in the houses in this way. You can see here the 4 kg pillows can provide it to 4 hours of continuous operation of a gas burner for heating or cooking. So, the production is somewhere else, but the same bags so, you can take it out and get it to the different houses for cooking purpose.

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This is one balloon-type biogas digester in Ahmedabad, Gujarat, but these majorly are the cattle manure. This is in Costa Rica.

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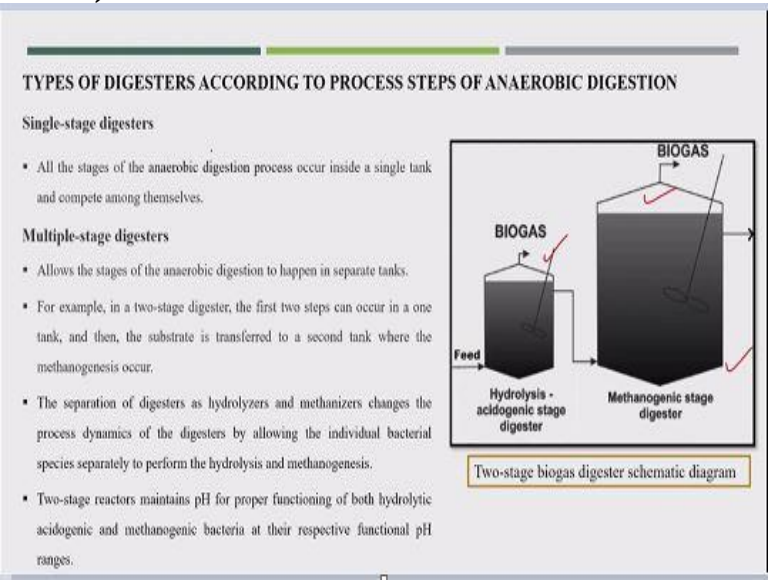

Type of digesters according to process steps of anaerobic digestion. So, there could be a single-stage digester. So, all the stages of the anaerobic digestion process are currently inside a single tank or complete among themselves. So, only one reactor for hydrolysis acid phase and methane phase all the 3 or 4 stages in a single reactor could be multiple stages digester, like all of the stages of anaerobic digestion to happen in separate tanks, like in an example of 2 stage reactor.

So, the first 2 steps can occur in 1 tank, then the substrate is transferred to the second tank, where the methanogenesis is occurring. So, there is a possibility that there will be 2 tanks one tank for

the hydrolysis and acid phase and the other in the same outlet is reaching another tank for the methane phase or methanogenesis stages. So, here, this hydrolyzes like the same, there will be 2 tanks, the first tank hydrolysis and acidogenesis stage could be possible and the next stage the methanogenesis stage could be possible.

The separation of the digester is hydrolyzers and methanizers changes the process dynamics of the digester by allowing the individual bacterial species separately and to perform the hydrolyzes and methanogenesis 2 stage reactor maintenance pH for the proper functioning of hydrolytic, acetogenic and methanogenic bacteria at their respective functional pH range. So, you know that in this acidogenesis stage the pH will be always in the acidic condition and for mythologized will be required a neutral pH.

So, in that case, you know to spatially maintain the particular pH for the particular stage that could possible and here in the hydrolysis process if the entire material in the acidic condition also your hydrolysis will be faster could be possible.

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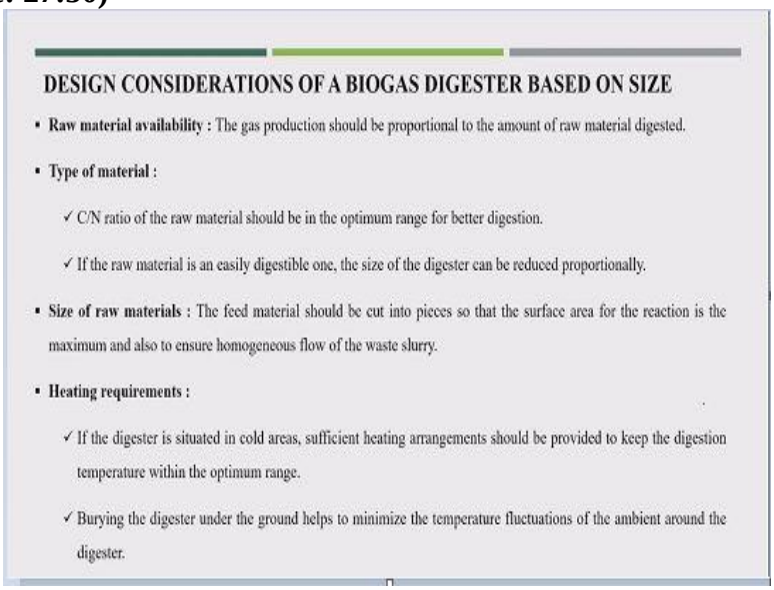

Now, next is the raw material availability, the gas production should be proportional to the amount of gas material available, like the type of material, like C/N ratio of raw material should be in the optimum range for the better digestion, if the raw material is easily digestible one and size of the digester can be reduced proportionally. So, based on that we can design means the

biodegradity of raw material, based on that we can design the volume of the digester also size of raw material the fed material should be cut into pieces.

So that the surface area for the reaction is the maximum and also to ensure a homogeneous flow of the waste slurry. This is also important and heating requirement. If the digester is situated in the cold areas sufficient heating arrangement should be provided to keep the digestion temperature within the optimum range and burying the digester under the ground helps to minimize the temperature fluctuations of the ambient around the digester.

So, I think specially in India like, where the temperature is around 4 degrees-10 degrees in December-January months, so that condition is good, if you muddy the digester underground, we can reduce the disadvantages of the temperature.

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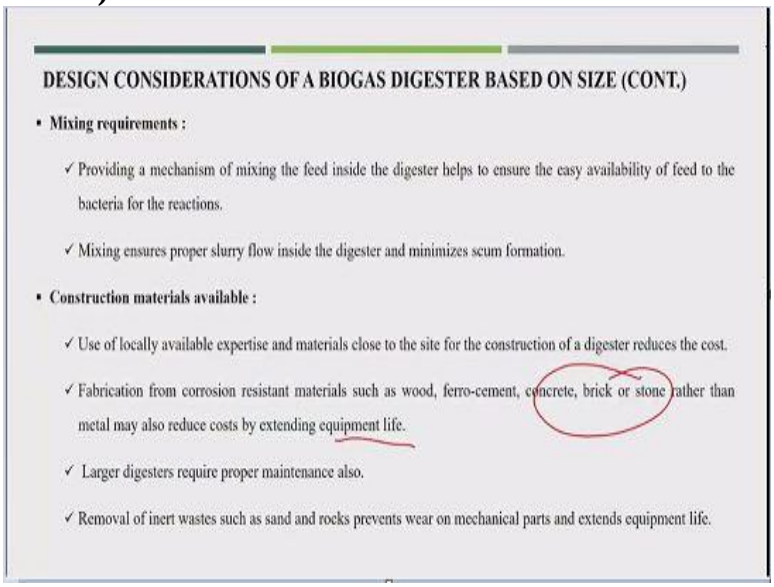

In the reactor like mixing requirements, so providing a mechanism mixing the field inside the diaster helps to ensure the easily available availability of feed to the bacteria for the reaction. So mixing ensures have proper slurry flow inside the digester and minimizes scum formation. So I would not say that is required for all kinds of reactors the mixing but if you make having some mixing unit inside the reactor that obviously that will be more beneficial for flow also and also the availability of biomatter to the particular bacteria that for that also is highly beneficial.

Now, new construction material available the use of locally available expertise and materials close to the site for the construction of biogas reduce the cost fabrication from corrosion waste and materials such as wood, ferro-cement, concrete big Stone rather than metal may also be reduced caused by extending equipment life. That is why in most of the rural areas in India, now, this biogas reactor has been constructed by concrete and bricks or stone or to increase the equipment life or the life of the entire reactor can go up to 20 years, 25 years.

And maintenance also could be easy. And even the cost of these kinds of civil materials or construction materials is not very high compared to the metal reactor. So, a larger digester required proper maintenance also basically and removal of inert material such as sand rocks prevents wear on mechanical parts and extends equipment life. So, these again depend upon what kind of feed we are feeding into the reactor or what kind of substrate so, the substrate has to be cleaned or should not be how the inert material in the substrate otherwise it will also create problem inside the reactor.

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Now, there are some successful trials of various waste materials at the solid waste laboratory of IIT Guwahati by the waste management research group. Similar way I explained in one of the lectures of composting of different materials has been done. Similarly, the different successful trials had been done in IIT Guwahati, like for food waste, for water hyacinth, *hydrilla*

verticillata. These kinds of material highly lignocellulose material, very difficult to degrade so easily like Pulp and paper mill. This is the industrial sludge.

It is a crop residue like rice straw, these are the terrestrial weed especially *parthenium hysterophorus*. It is very difficult and these kinds of weeds also are toxic weeds difficult to utilize for biogas production.

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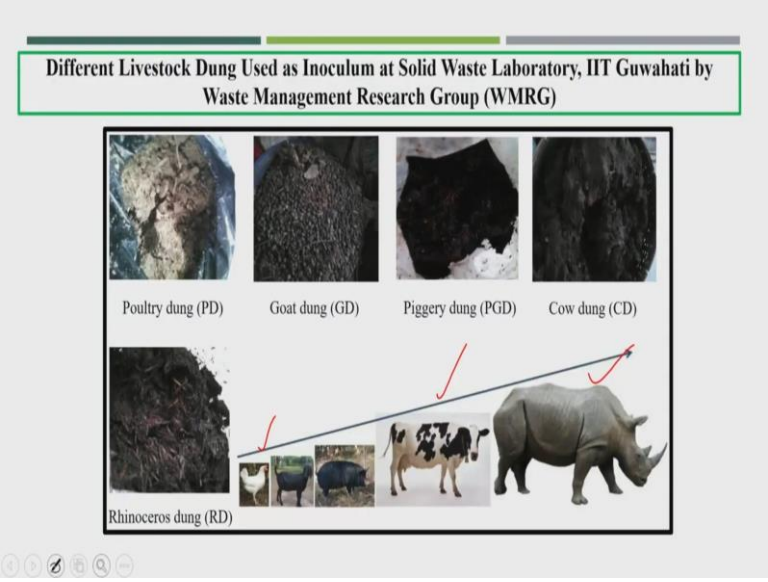

And also some research has been done on different kinds of cattle dung, also compared that the smaller cattle to the bigger cattle. So, based on that how their dungs are beneficial for the biogas production also compared and found that cow dung is the best cow dung what found for the degradation process.

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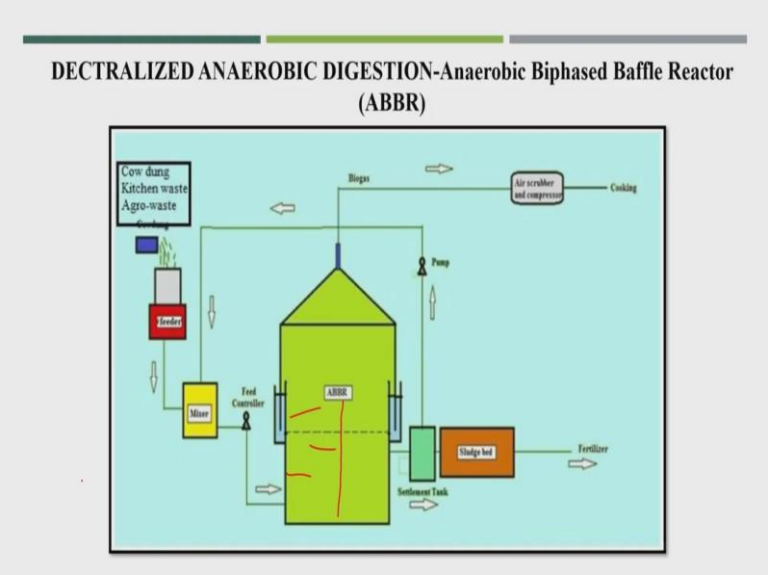

And also the one design has come out from the IIT, Guwahati. They named is in ABBR anaerobic biphased baffle reactor. So, I think just to explain that, because this was the one patented technology. So, I think you see in the Deenabandhu model, there was one partition was given, but here in this case, different baffles have been added into the first phase of the reactor and there are some changes that has been done by addition of different baffles in the reactor.

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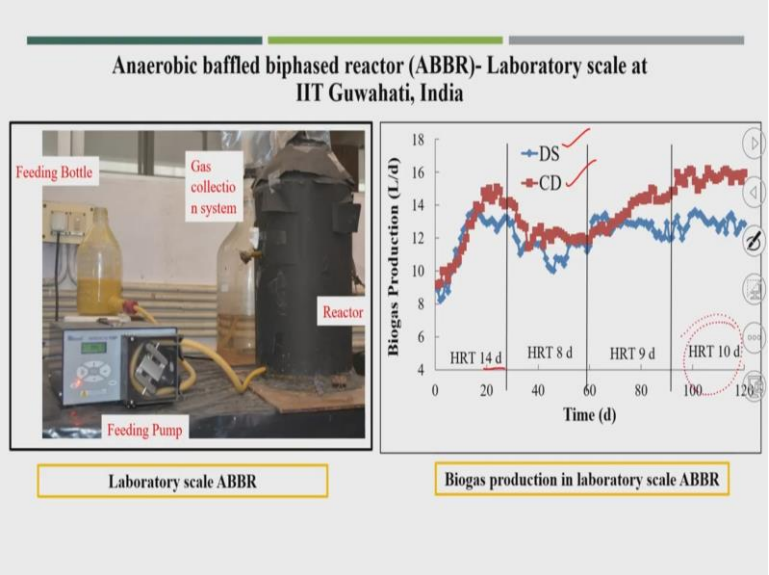

So, this is one laboratory studies has been done on 20 litres of the reactor and you see here these are the different inoculum addition like digested sludge and cow dung has been compared and found that cow dung is more beneficial than the digested sludge as inoculum into the reactor. So, and had started from 14 days HRT and found that 10 days HRT is more beneficial for this reactor.

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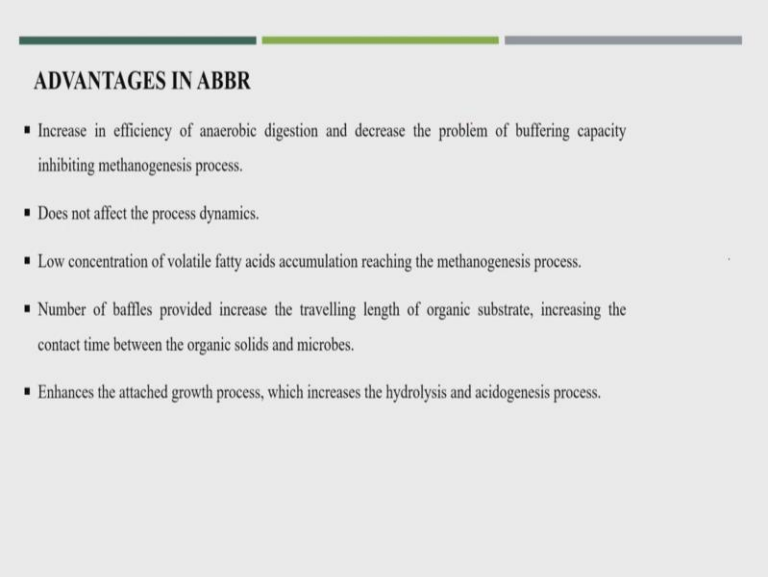

So, what are the advantages of ABBR like increase in efficiency of anaerobic digestion and decrease the problem of buffering capacity, inhibiting the methanogenic process. Does not affect the process dynamics. Low concentration of volatile fatty acids accumulation, reaching the methanogenesis process, and number of baffles provided increase the traveling length of organic substrate, increasing the contact time between the organic solids and microbes. And enhanced the attached growth process, which increases the hydrolysis and acidogenesis process.

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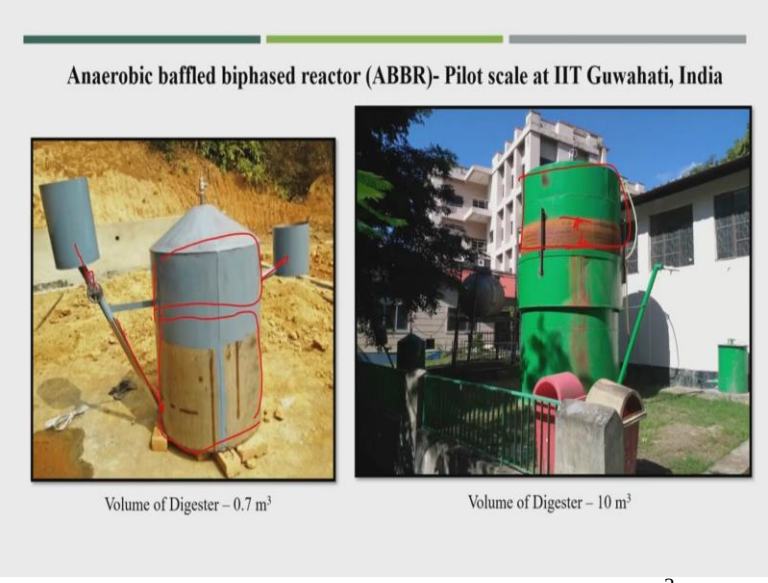

So, they also studied the pilot scale. So, this is a 700 litres or 0.7 m^3 reactor. So here, the 500 litres was for the degradation process and the remaining 300 litres was for gas storage. So, it is a fixed dome reactor and this is the inlet. So, inlet was added from the bottom and the outlet from

the top area. So, only the slurry will come out and this is the very big reactor. So, this was the fixed one and this was the floating drum reactor.

So, this is the floating drum, you will see here this is this much has been raised they found. So, feeding was around 200 to 300 kg per day into 10 m^3 reactor. Now, when I talk about the substrate addition, so, in the 0.7 m^3, they will be able to feed around 20 to 25 kg of food waste in the reactor. So, that is the major benefit why because the HRT is very high and degradation is very fast and even the methane production also was around more than 70%.

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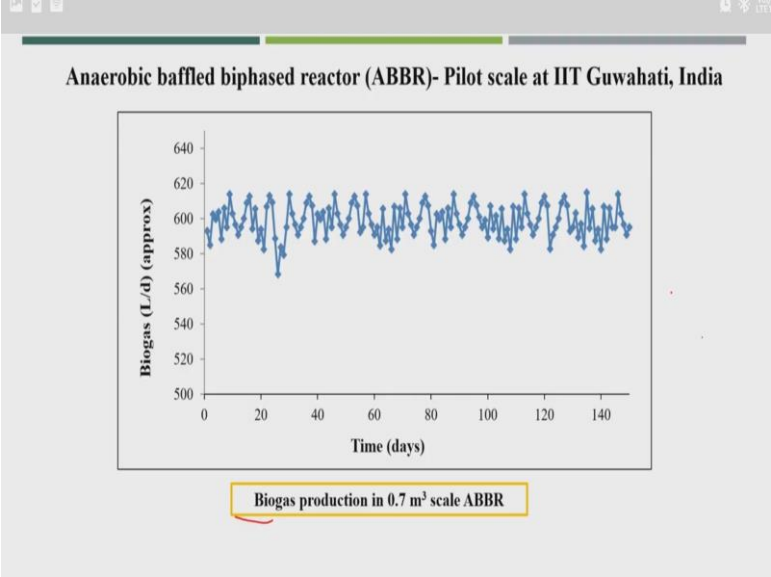

So, you see here biogas production was good and ran up to more than 140 days.

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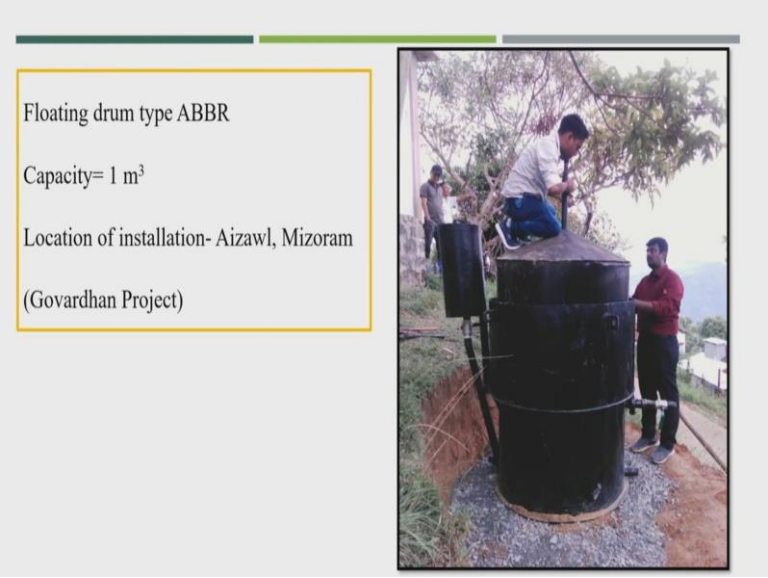

And also this floating type of ABBR of capacity 1 m^3 has been installed under the Govardhan project in Aizawl, Mizoram. So, the small unit and this was especially for the piggery waste and you know in the northeast India the major cattles are pig. So, and here we get more amount of piggery waste compared to cow waste or cow dung. So, and this was one successful unit that has been installed.

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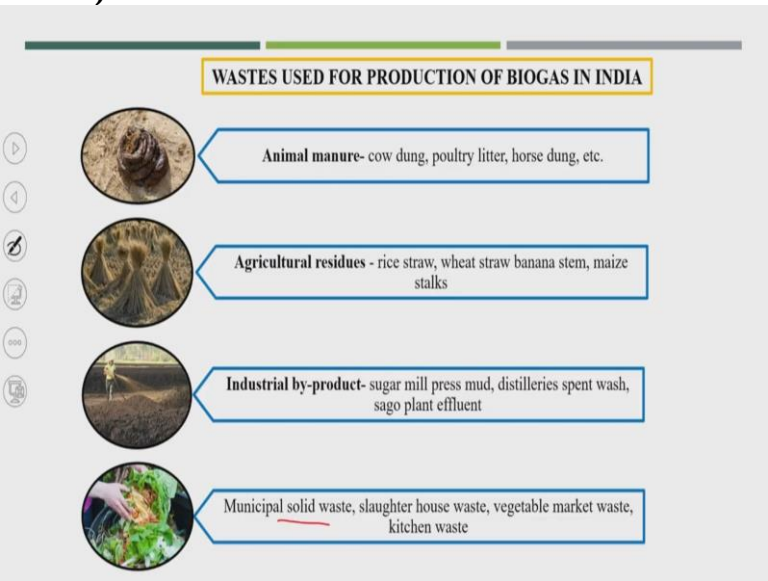

Now, for Indian scenario, there are different kinds of waste and different reactors. So, there are different kinds of waste means animal manure like cow dung, poultry litter, or even I was talking about piggery waste northeast, agriculture residue and various type of agriculture residue,

industrial by-products, MSW especially food waste or vegetable waste possible to utilize for the biogas production.

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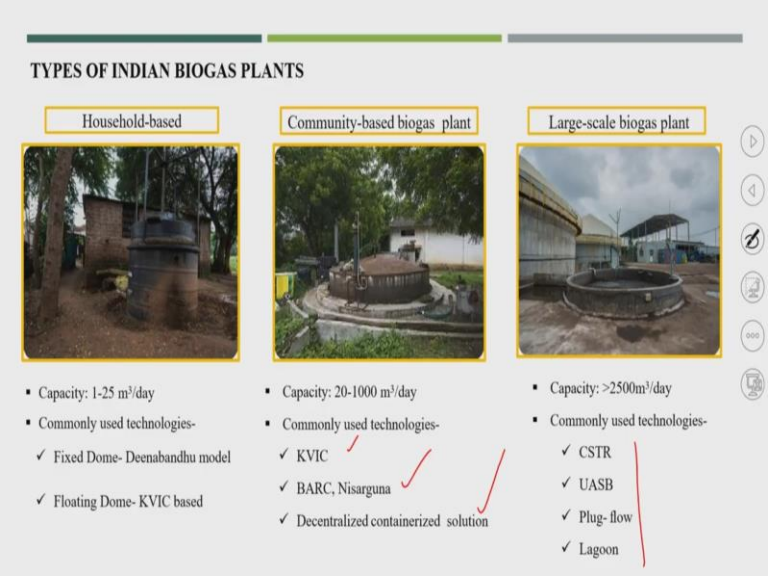

And types of biogas plants like this is household biogas plant this is the Deenabandhu model, same KVIC based floating dome. This is community-based biogas plant capacity of 20 to 1000 m^3 per day and commonly used technology could be based on KVIC also and even BARC also they come up with one technology called Nisarguna where they are maintaining the higher thermophilic temperature operation of the reactor is able to produce more methane gas.

And I was talking about decentralized Composting as more beneficial compared to the centralized composting facility and in that case also the Rotterdam Composting is more beneficial. If you talk about a decentralized composting facility. Similar way these kinds of community-based biogas plants are very important for the decentralized containerized solution could be possible.

If you are not going for composting, we can go for biogas production. This is the large-scale biogas plant of capacity more than 2500 m^3 per day. It is a very large unit and other technologies could be CSTR, UASB. These are all technology for sewage treatment also is available. This is very popular. And if you want to read, you read more onto CSTR, UASB. So these are the different technologies are available.

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And few commercial digesters are available in India, where the HRT goes to 25 to 30 days. This is the one very well-known company in especially in Kerala in South India, where these are biotech limited. They come up with this biotech reactor. It is a flexi balloon biogas plant, you can see the one person name and this is the Sintex reactor. This is also very popular in India. This is Arti biogas and this is also FERT reactor and this is biogreen solution. So, these are all kinds of reactors. If you see the biotech to Arti to biogreen and Sintex is almost similar kind of reactor.

So, although and almost all the reactors are floating dome reactor and almost size 1 m^3 of all the reactors but the only problem is that HRT is 25 to 30 days, but if you compare that reactor of designed by IIT Guwahati that ABBR where HRT is only 10 days means, the same kind of reactor of Sintex or biotech in a 1 m^3 of reactor you will be able to feed only 2 kg or 5 kg of waste material in a day. But in ABBR you will be able to feed 20 kg or 25 kg of waste material. So, for community biogas units, the ABBR is more acceptable and these kinds of reactors be able to install it the household level only.

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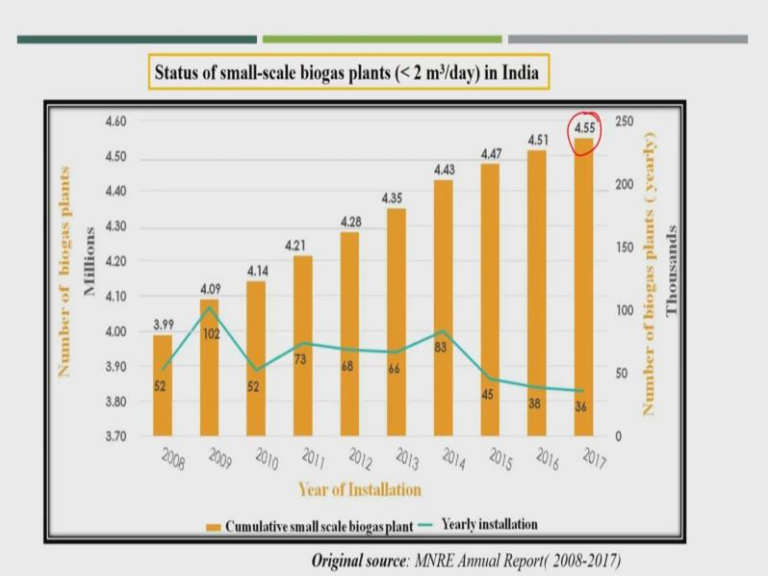

And if you see the status of small scale biogas plants, small scale means the size less than 2 m^3 per day in India and along with that the yearly installation so, you see the numbers in millions, this is the cumulative numbers of 4.55 millions of biogas plants and yearly installation you see that the now it has been reduced, earlier was a large number. Now, in 2017, only 36, I think is again depends upon how much data are available or how much data is documented. This was we got it from Indian biogas association these data.

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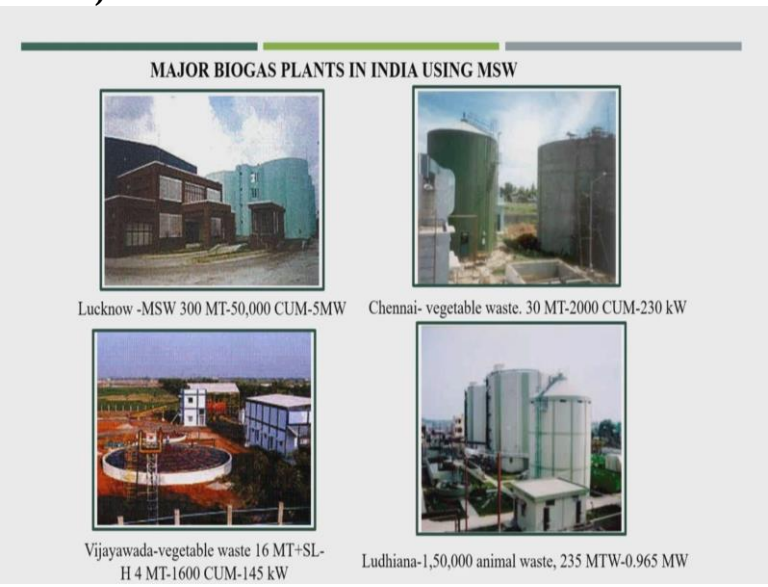

And for major biogas plants in India like in Lucknow, for MSW 300 metric tons and producing 5 megawatt energy is Chennai vegetable waste 30 metric tons able to produce 230 kilowatt energy or electricity and this is the Vijayawada vegetable waste 16 metric ton which able to produce 145

kilowatt electricity and Ludhiana, this is specially for the animal waste and produce around 1 megawatt energy. This is the status of grid-connected biogas plants.

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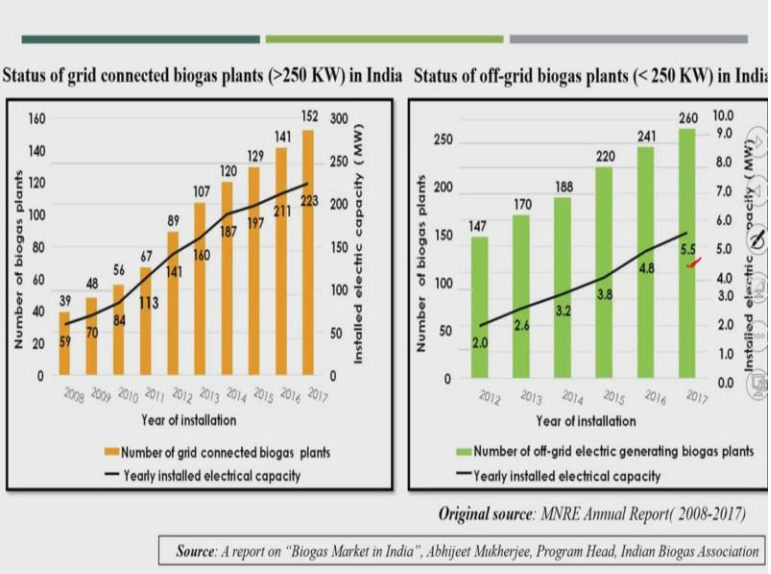

And the size is more than 250 kilowatt in India and the cumulative, see the number of biogas plants are now around 152 and yearly installed in electrical capacity like now, each up to 223 Megawatt energy is connected to the grid. And this is offgrid electric generation means, I think this is not connected with the grid, that number is also very large, like around 260 biogas plants are available size, less than 250 kilowatt and yearly installation also is 5.5 Megawatt electricity production.

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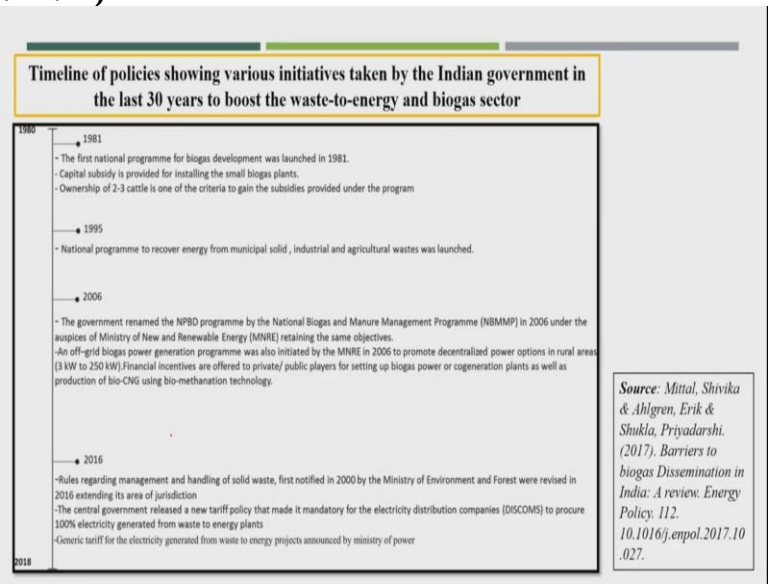

Now, if you see the timeline of policies showing various initiatives taken by the Indian government in the last 30 years to boost the waste-to-energy and biogas reactor. This is also one important point when you talk about waste-to-energy. Please do not only thought about the incineration process. This is also waste to energy production. So, here the waste-to-energy means the same gas could be used for the cooking purpose also, that is one kind of energy and also same gas can be possible to convert in the electricity, the same methane gas.

So, this is also one kind of energy production. So, in 1981, the first national programme for biogas development was launched. And ownership of 2 to 3 cattle is one of the criteria to gain the subsidies provided under the programme. So, even the farmers which were having 2 to 3 cattle with them, they used to get it 5000 rupee subsidy or even I saw in some of the states, I visited few locations in Nagaland state, where the local authority are providing rupees 5000 rupees for construction of one m^3 biogas reactor.

So, that was 1 programme has been come up. In 1995, a National programme to recover energy from municipal solid, industrial, agricultural waste was launched and 2006, an off-grid biogas power generation programme was initiated by the Ministry of Renewable Energy. In 2006, to promote decentralized power stations in the ruler areas like 3 kilowatt to 250 kilowatt energy and financial incentives are offered to private/public players for setting up biogas power or cogeneration plants as well as production of bio-CNG using bio-methanation technology.

So, in that also there are a number of off-grid biogas power generation plants has been installed. Size was small like is less than 250 kilowatt electricity production or power production. So, in 2016, the rules regarding management, handling of solid waste were first notified in 2000 and that has been revised in 2016. And central government released a new tariff policy that made it mandatory for electricity distribution company to procure 100% electricity generated from waste-to-energy plants.

So, this is I think, 1 very important document has been come up now. So, for electricity distribution company, they can procure 100% electricity whatever is generated from waste to energy plants, they can collect it and they can distribute to the local residents.

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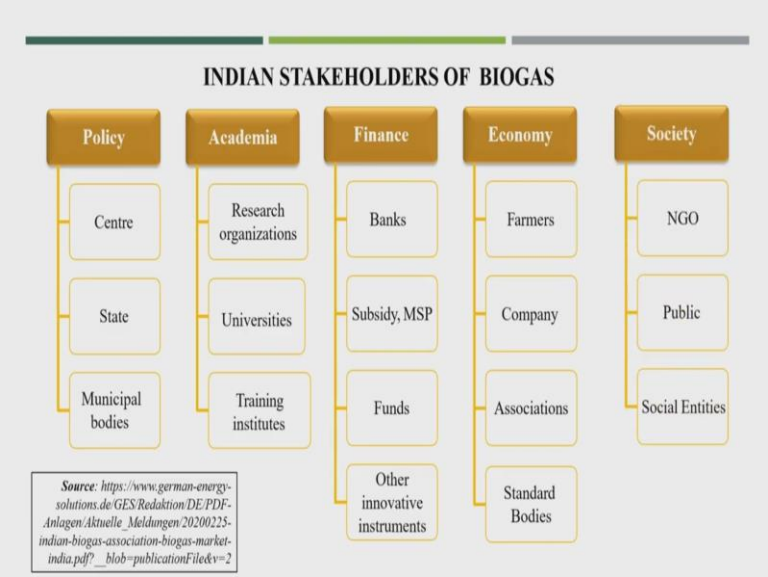

So, now, who are the Indian stakeholders for biogas? So, whatever the policy has been made by centre, especially MRE, Ministry of renewable energy and even some more ministries also they come up with different policies like Ministry of Science and Technology. They also provided some funding for the different projects on biogas production from the state like one example, was Nagaland they also promote some municipal bodies, they come up with different biogas units.

And academics like I was talking about Research Organization like IIT, Guwahati, they have 10 m^3 of reactor, even you see in IIT Delhi, there is a 1 Centre in Rural Development, they also have big biogas units in their campus also and also install in some local areas in some local ruler areas, similarly, in some universities, some training institutes and financing could be from banks, some subsidies, some funds and some other innovative instruments can come up with the financing and economy.

It is beneficial to the farmers, some companies, some associate, and some standard bodies. And finally, who are the beneficiaries? The beneficiaries were NGO, public and social entities are beneficial from biogas projects.

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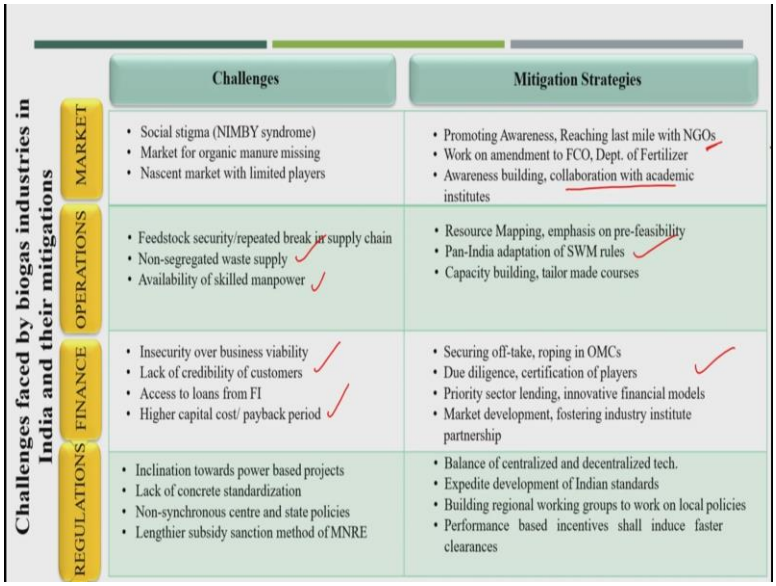

So, challenges faced by biogas industries in India and their mitigations. If you see the challenges, challenge 1 was the social stigma like NIMBY syndrome was in India. This is not only for the biogas one but also for composting and NIMBY means not in my backyard because obviously are these both the technologies like whether it is a composting or biogas techniques are dealt with organic waste.

Organic waste means there will be odor issues, handling issues will be somewhat different than the other ways and the market for organic manure is missing. This is also I think, I talked about composting also I think because already the commercial fertilizers are available. So, why somebody will purchase the compost. Similarly, we have different ways of electricity production.

So, why somebody will try to produce biogas out of that. So, I can think about the ruler areas because maybe if such areas are not available, the cooking gas is not available in the local area or 24-hour electricity is not available, in that case, they can accept, there could be some market is possible, but again the both I can say that I do not say that you will be required proper skill to run those things.

But for an anaerobic digester, you should be well aware of feed and operation conditions, you need to be well aware and some issues will come up also you need to know that, how the maintenance or repairment of the reactor could be possible. Those kinds of skills are required.

And feedstock security, supply chain, availability of skilled manpower. Even waste supply also is not proper non-segregated material, even the higher capital cost, if somebody wants to have the very big units.

So, you will be required large capital costs and in the security of the business and the lack of credibility of customer. This is also one of the risks is include in the biogas units. So, likewise, these are some challenges, but, there are some mitigations also you can find like for NIMBY syndrome or there is no market. So, you need to promote awareness more and why not include some NGOs which can work for local authorities like for municipal board or state.

Even for the centre, these NGOs can work for the awareness process and even they also can work to collaborate with the academic Institutes, because there are a number of academic institutes are working like I was sharing about IIT Guwahati or IIT Delhi are working onto the very the 10 m^3, 20 m^3 of biogas reactor is very difficult in the academic research institute. If such kind of reactor can run the academic Institute.

Obviously, the same experience can be shared into the other part or the other area or into the field in a bigger scale could be possible. So, and these academics also they are the skilled people. They know more operation things can easily share with the local people. And also like waste means, I think if you talked about new MSW rule, 2016 already targeted for segregation of waste.

So, the biological waste or wet waste, segregated material, if you are able to get you can easily change the supply chain and also market industrial market can be created and likewise there are the challenges, see challenges could be for any kind of treatment facilities could be but there will be some mitigations and when you talk about the centralized facility, obviously you have to depend upon the proper policies and for local authority, you will be required a lot of help will be required from them.

But if you talk about the small units or decentralized facility like in the apartment, so apartment you need not to take help from the local authority. So, this is your apartment, where segregation

could be easily possible. There are whatever the residents are available maybe 20 families or 25 families, you will be able to aware them very easily by showing that, how once the, this waste is not segregated, and once you reach into landfill what could be the problem.

So, people will be more aware in the small community and can have the small reactor in that particular apartment and whatever gas is producing that gas could be utilized for the cooking purpose or can be shared to every residence into that particular apartment or for electricity production also could be possible. Only the problem will be the capital cost has to be shared, but see, these kinds of facilities can be run for 20 years. And suppose, capital costs can go up to 5 lakhs rupees also 5 lakhs or 10 lakhs rupees.

So, 20, 25 families easily can put that much amount of fund, can raise that much amount of fund to have such kind of facility. I suppose local authority will give some subsidy to such kind of apartment maybe 50% subsidy also if the local authority or local Corporation will give it to such kind of apartment people, that is highly beneficial and can easily possible to install such reactors into such localities. So, by that way, I think we can promote the biogas units into the residential areas.

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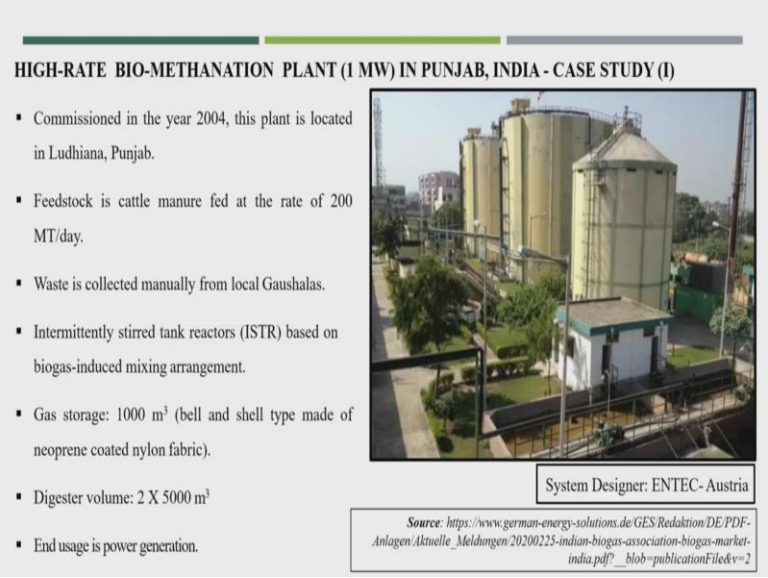

Now, we will see the 1 or 2 case studies in India. So, this is a high rate bio methanation plant. This is a 1 Megawatt electricity production plant in Punjab, India. So, this is a 1 reactor that has been designed by ENTEC-Austria. So, it is commissioned in the year 2004. This plant is located

in Ludhiana, Punjab. Feedstock is a cattle manure fed at the rate of 200 metric tons per day means is a very big unit.

Now, waste is collected manually from the local Gaushalas and fed into the reactor. Intermittently stirred your tank reactor, so it is ISTR based on the biogas induced mixing arrangement. So, intermittently stirred tank reactor means the mixing unit is available in the reactor, but it is intermittent. The gas storage is 1000 m^3 bell and shell-type made of local nylon fabric and digester volume is 2 into 5000 m^3 means 2 units of each of 5000 m^3 and end usage is a power generation.

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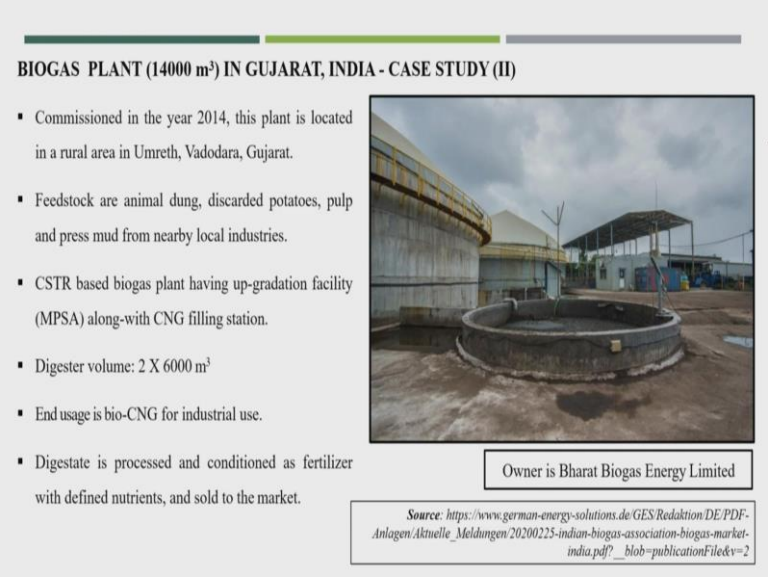

Now, this is another biogas plant or 14,000 m^3 in Gujarat India. So, this is the owner is Bharat biogas energy limited. So it is commissioned in the year 2014. This plant is located in the ruler area in Umreth, Vadodara, Gujarat. Feedstocks are animal dung, discarded potatoes, pulp, and press mud from nearby local industries and CSTR based biogas plant having up-gradation facility along with CNG filling stations, CSTR means continuously stirred tank reactor.

So, continuously the field is steered into the reactor and along with the CNG filling stations. So digester volume is 2 into 6000 m^3 is also 2 units, each of 6000 m^3 and end usage is bio-CNG for industrial use. And digestate is processed and conditioned as fertilizer, with defined nutrients and sold to the market. So, whatever the digester also is coming. So this is the digested 1, from this is both reactor, this is the digester. The outlet is properly dried and selling to the market.

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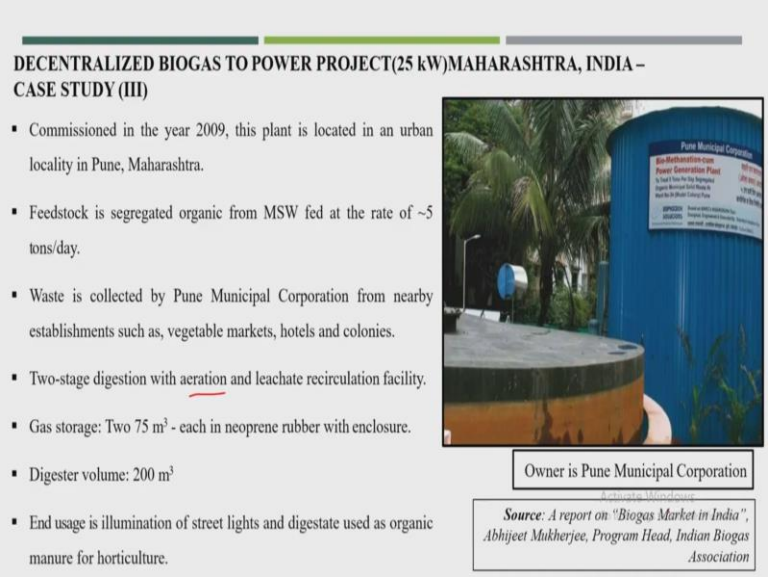

This is another study, it is decentralized biogas to power projects around 25 kilowatts in Maharashtra. So, commissioned in year 2009, this plant is located in the urban locality in Pune, Maharashtra. Feedstock is segregated organic from MSW fed the rate of 5 tons per day and waste is collected by a Pune Municipal Corporation from nearby establishments such as vegetable markets, hotels or colonies and two-stage digestion with aeration and leachate recirculation facility.

So, the 2 process means in the first reactor, the aeration is provided for the hydrolysis process and leachate recirculation facility means whatever the digestate is coming out, that is again replaced into the biogas reactor. The reactors have the gas storage of two 75 m^3 each in neoprene rubber with exposure. The gas storage of two 75 m^3 tanks is available for the gas storage digestate volume is 200 m^3 and end-usage is the illumination of streetlights and digestate used as an organic manual for horticulture purpose. So, this is especially for MSW.

So, now here today, we saw that there are different reactors. We started from 1936, the Chinese reactor and again 1956 of ())(1:01:34) model by Mr. Patel. And now, there are different kinds of reactor different scale of reactors are available, but I am seeing that the HRT is very high in most of the reactor, that HRT goes to 25 to 30 days again I think the substrate, if it is agriculture base reactor, in that case, your HRT is again going for more than 25, 30 days. So, in that case, you will be required large size of the reactor.

Now, still, I think the in India research is required to reduce the HRT means were to again modify the reactor like what reactor has been modified by IIT, Guwahati. So, similarly the there is more research, and not only the research but the operation onto that such kind of scale is important to know that. Because some factors are not possible to resolve at a small scale like the climatic conditions, availability of the substrate, the mixing facilities, grinding facility, pretreatment facility, or the production of digestate.

And again the management of digestate is not possible to walk onto the small scale unit like 1 m^3 or even 10 m^3 facility. You need to have the experience of the larger capacity and also for the production of bio-CNG or electricity production. For that, you need lots of research. So, I believe that the collaboration of local authorities like corporations or states to the academic Institutes could go for these kinds of research or at a higher level and I believe that in India, either composting or biogas is important.

Without that entire solid waste management should not be possible. Whether you installed an incineration facility or design a proper landfill, you need to have proper biological treatment facilities. So I believe that you people now understood completely the biological transformation process, starting from composting to the anaerobic digestion process. Now, the remaining portion is a landfill. So, the waste is not incinerable, not biological treatable will goes to the landfill site. And from the next class, I will talk about landfill design and its operation. Thank you.