Urban Services Planning
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Lecture 36
Waste to Energy Part I: Biomethanation

Welcome back in in module 8, we will talk about adoption of advanced waste treatment technologies and lecture 36 is waste to energy part 1 where we will talk about biomethanation.

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The different concepts that we will cover is on what is waste to energy, then we will talk about biomethanation, biomethanation benefits and considerations biomethanation process. Then we will talk about the Nisargruna biotechnology, biogas technology system that has been developed by BARC. Typical design of biogas plants, we will discuss about that, Bio gas application and finally, we will talk about a case study of a biomethanation plant at Koyambedu wholesale market by the Chennai metropolitan development authority.

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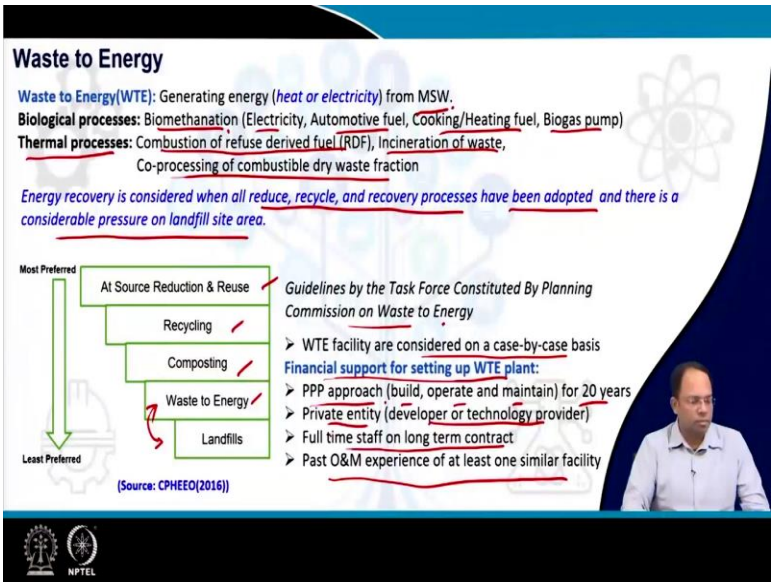

So, we have already learned about waste to energy in our in previous lectures. So, waste to energy is refers to generation of energy either heat or electricity from municipal solid waste and usually this could be done via both biological as well as thermal processes. So, biological processes include bio methanation. Again we have learned the basics about biomethanation earlier.

Through by biomethanation we can produce electricity, automotive fuel, cooking or heating fuel or we can run biogas pumps. The thermal processes of waste to energy is either by via combustion of refuse derived fuel. First we have to produce refuse derived fuel and then we can burn it to generate energy. Direct burning of waste incineration of waste, and then there are different techniques for that, then co-processing of combustible dry waste fraction.

So, these are the different ways we can generate energy from waste. Now, energy recovery is considered we have already learned about the integrated waste management system where we first want to reduce or the total generation of waste and then we have to consider recycling of waste one recycling is done, then, along with recycling, we have to also do composting.

And then once recycling and composting is complete whatever remains then we can think about converting those waste into waste to energy. So, sometimes waste to energy and landfill is considered parallelly, why? Because landfill requires area if I do not have area then I can go look into energy production, but energy production also leads to emission.

So, it is not always a positive thing. So, if I have other sources of renewable energy sources, I will probably not use waste as energy. So, we have to take a call on should we put the waste to landfill or we should produce energy. So, energy recovery is considered when all reduce recycle and recovery processes have been adopted and there is considerable pressure on landfill site area.

Now, waste recovery, waste to energy facilities are primarily these are mechanized plants or these are larger plants where energy is produced. So, there could be different scalar plants of course, but when we talk about electricity generation usually these are larger plants. But if I just talk about these smaller facilities like biogas plants and all then it could be done at a smaller size as well. But if it is the insinuation facilities, usually these are large plants.

So, the taskforce constituted by the planning commission on waste to energy has given certain guidelines and they have said that waste to energy facilities has to be considered on a case to case basis that means each case is different, each context is different, we have to take a call based on that. Then financial support could be given for setting up waste to energy plants, whatever kind of plant it may be.

And usually, we should adopt a PPP approach because the private entity or the should be a developer or technology provider for this kind of a system. So, this private entity should actually provide the technology and they should be also responsible for building operating and maintaining the plant for at least 20 years, because current will be you always do not have this expertise, then this entity should have full time staff on long term contract requirements.

So, we cannot design the initiate the system for few years without and then we find that okay the system cannot be run because the neither the quantity nor the quality of waste is good enough. So, we have to really do those kind of planning or analysis beforehand before we set up the plan.

So, when we set up the plan, we should take staff long term contract and of course, if the processes are not viable, then the private entity will never start this kind of operation. So, that is why PPP approach helps in these particular cases and post past operation maintenance experience or at least one similar facility has to be there for this private entity. So that it will be given this kind of job.

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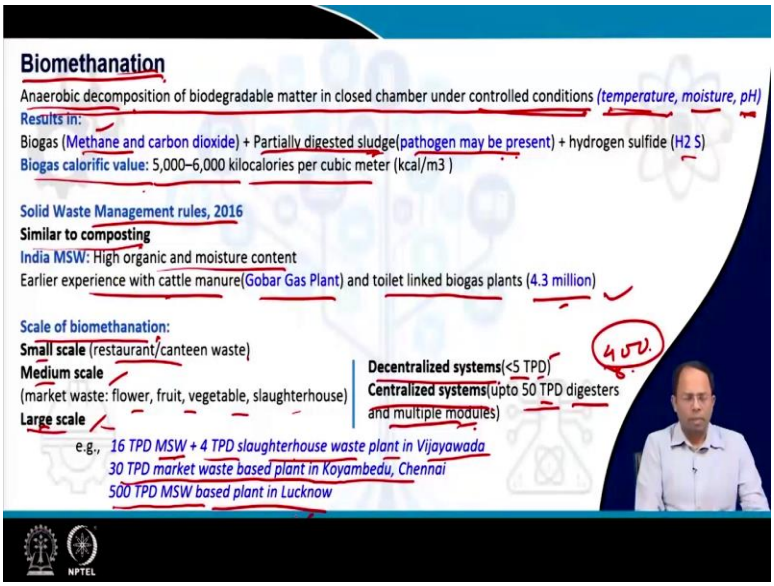

Now, we will discuss biomethanation in this particular lecture out of all the different waste to energy processes, we will discuss biomethanation and we will subsequently in the subsequent lectures will discuss about incineration and other processes. So, biomethanation is the anaerobic decomposition of biodegradable matter in closed chamber under controlled conditions. So, this sounds similar to in vessel composting.

So, but instead of aerobic decomposition which we are targeting in composting, this is anaerobic decomposition, and because it is in anaerobic decomposition, it generates a lot of methane gas and this methane gas is used for energy methane and Co2 gas of course, but methane is the one which has got high calorific value, which comes to around 5000 to 6000 kilocalories per cubic meter. That is why methane is a good has potential to be a fuel.

So, that is why biogas the which is mostly methane, of course, mixed with carbon dioxide, some amount of H2 S and all but still we were try to clean that gas and generate as much methane as possible and that could be used for generation of electricity generation of heat generation of this cooking gas and so on.

So, usually, because it is a control, we can we have to control the operation and here temperature, moisture and pH plays a large role. So, we have to maintain a certain bands of temperature, because at those temperature, the processes are more effective, you have to

maintain a certain amount of moisture and we have to maintain certain pH levels of the operation.

So, not only biogas is being produced at the same point of time similar to composting, we also have got partially digested sludge, which is the in composting also it we gradually decompose the matter and then it becomes composed. So, here because we are instead of sending dry material, we are sending a slurry, which is like big sub organic and organic material and water, we end up with a sludge and this sludge is mostly digested, but it still some amount of graduation remains at the end of this biomethanation process.

And because this temperature is not sometimes as high as that of normal composting pathogens maybe remaining. So, usually what we do is when we do biomethanation the sludge which is generated we take it out, we dry it and then we can allow it some amount of time for composting like aerobic composting and that will kill all the pathogens by raising the temperature.

So, this is basically the biomethanation process. So, solid waste management rule 2016 whatever it says about composting which we have discussed earlier, the same in every stage where composting could be considered or be considered transporting a waste for composting. The same could be considered for bio methanation as well that means all societies all complexes all large institutions greater than 5000 square meter, they should either do composting or do biomethanation any one of them has to be adopted.

So, in India, we have got very high organic and moisture content in a waste so, of course it is suitable for biomethanation. And we India already has got some earlier experience with cattle manure where a lot of Gobar gas plants and lot of toilet linked biogas plants have been constructed in India earlier around 4.3 million households have this kind of biogas plants in their houses. So, this experience is there in India already.

So, we can continue it further. And we can now instead of just generating this kind of toilet or manual based biogas plants, we can also have solid waste-based biogas plants as well. The scale of biomethanation could be small, medium or even large. Now, small is where we have got some institutional canteens, restaurants from there the waste could be generated and they could be treated locally.

Medium scale is market waste like flour, fruit vegetables slaughterhouse this could be treated in the vicinity in nearby areas. So, as per the (())(10:01) we can set up biomethanation plant. Large scale is where the entire city's waste comes sorted and then actually we can have different digesters or a series of digesters which could be used for creating biogas via biomethanation.

So, there are decentralized systems usually for a medium scale, we have decentralized system less than 5 tons per day with the amount of waste is less than 5 times per day or we have got centralized system at a city scale where from different areas waste can come here and we can have 50 tons per day digesters.

So, if the waste is 400 tons, obviously, I will have 8 digesters. So, this is more or less the optimum size of a digester 50 tons per day beyond which there will be other complications. So, we can have multiple modules or multiple digesters in series in the same area and we can have a larger biomethanation plant.

Some examples are 60 tons per day MSW and 4 tons per day slaughterhouse waste plant has been set up in Vijaywada. So, both slaughterhouse waste and normal municipal waste is being put inside this digester. 30 tons per day market waste-based plant in Koyambedu in Chennai, this we will discuss in detail later and then 500 tons per day municipal solid waste based plant has been set up in Lucknow.

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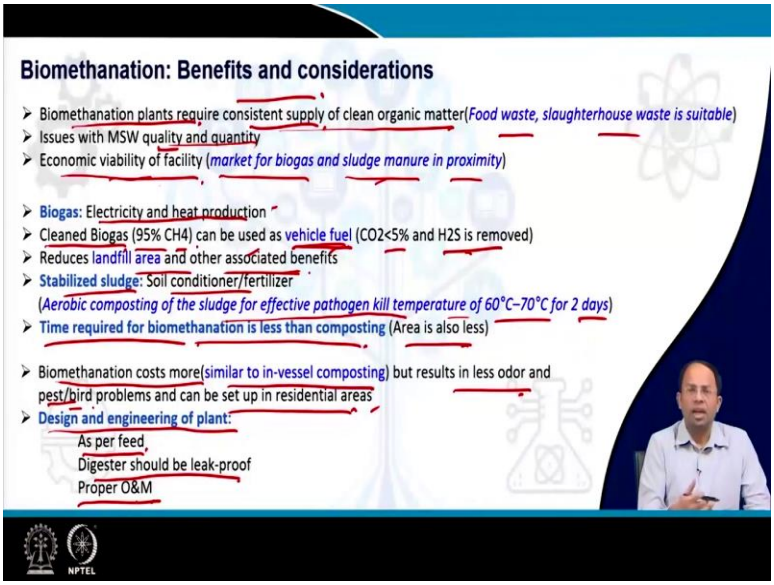

So, what are the different benefits and considerations for setting up a biomethanation plant? Now, biomethanation plant means a plant where biogas is produced and of course, there is a end use of this particular biogas that means, either use it for lighting or for cooking gas and so on. So, the supply has to be consistent, we cannot have biogas one day another day there would be no gas.

So, to ensure that there has to be a consistent supply of clean organic matter. So, food waste slaughterhouse waste, these are suitable of course, but if we do not have consistent supply, then there is a problem. So, when we are setting up a plan, we should make sure that there has to be consistent supply of the waste.

So, always there is quality and quantity issues, is adequate quantity available because very small quantities are not feasible. So, at least some amount is required to run a particular digester and also the quality of the rest. If the quality is very poor, then we require pure organic waste. So, if it contains a lot of material, then we have to do sorting and all which will increase the cost of the process and make the entire process unfeasible.

So, minor sorting fine, but very extensive sorting should not cannot be done over here. So, economic viability of facility also needs to be checked like is there is a market for the biogas or a market for the sludge in close proximity because otherwise you cannot transport the gas over long distances.

And even transporting sludge manure can also result in large costs transportation costs, which would not be effective. So, economic viability has to be also checked. Now, the biogas could be used for electricity or heat production. So, you can produce heat and use the heat directly or using the heat you can boil water and using that boil water you can again generate steam and run turbines and generate electricity and so on.

Then, clean biogas that means the biogas that comes out is not that clean, it includes both Ch4 Co2 and so on, but if I clean the biogas and I remove the Co2, so that eventually only 5 percent Co2 remains and the rest 95 percent is CH4 and similarly H2S is removed significantly then only we can use this biogas as automotive fuel that means vehicle fuel. Otherwise, it cannot be used as vehicle fuel.

So, that means additional cost is involved to convert this to vehicle fuel. But definitely this is much much better than standard gasoline that we use a standard diesel or petrol that we use. So definitely this is a much more sustainable option. But of course, it requires certain beyond biomethanation it requests that in other this thing.

So biomethanation reduces landfill area and others and because it reduces landfill area it can and also this organic matter is not going to the landfill area. So definitely it will have a lot of other benefits less (())(14:34) production, more landfill life and all these other less gas production and so on over there.

Then stabilized sludge could be used as a soil conditioner or fertilizer and but we have to do aerobic composting of the sludge for reaching the effective kill temperature for pathogens which is 60 to 70 degree for 2 days we have learned this in composting that how we can reach this kind of temperature. Time required for biomethanation is less than composting.

So definitely when time is less, the total area required for a, this bio methanation plant is less than a composting plant. So, because we have to store waste for a lesser amount of days. So, these are the different benefits of bio methanation and some of these benefits are even better some biomethanation is even better than composting in certain ways. But biomethanation cost more than composting. Standard aerobic composting using minerals biomethanation costs more than that, but it is similar to in vehicle composting, in vessel composting sorry.

And the but the benefits of biomethanation is it results in lesser order. And because it is cover process, it is happens in a chamber it pest bird problems these are not there. And this can be set up in residential areas and it does not pollute. So that is the benefit of biomethanation. So it is a bit costly, but at the same point of time, we can have it in a more decentralized fashion.

So, design and engineering of this particular biomethanation plant this has to be as per the feed of that particular area, what kind of material I am getting, digester should be leakproof there should not be the leached and out or leaking out of the digesters, and there has to be proper operation maintenance of these digesters. Otherwise that means this requires continuous monitoring and all.

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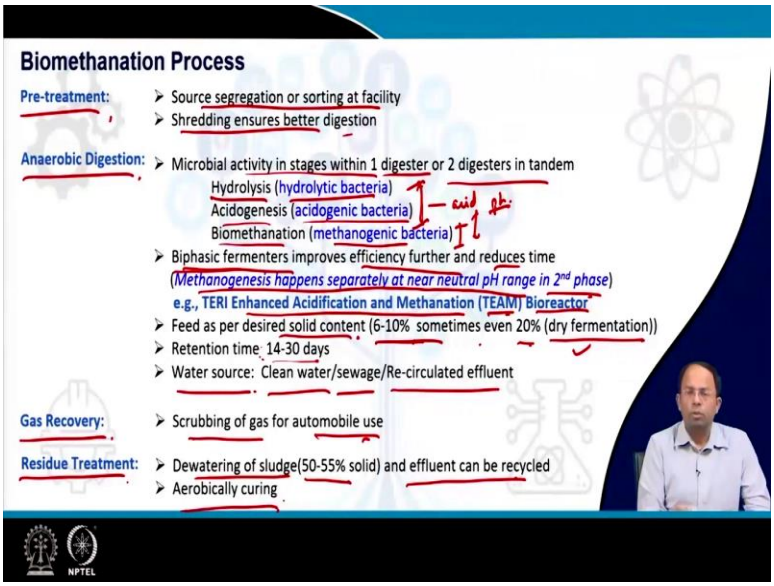

So, coming to the overall process, first there is pretreatment, before we take waste into the digester. First, we source segregation at sorting facility or sorting could be done little bit and then the waste is shredded. So, this helps in the digestion we make the waste into smaller particles, of course, we then mix it with water and then we put it into the digester and in the digester anaerobic digestion takes place this is not aerobic again this is anaerobic digestion, microbial activity happens in two stages.

It could happen inside one digestive one after another the stages will happen or it could happen in two digesters in tandem as well. So, what are the different kinds of bacteria like earlier we have learned about different kinds of bacteria, which act as per different temperature ranges, here also the similar concepts apply hydrolysis is hydrolytic bacteria acidogenesis by acidogenic bacteria and finally, by methanation via methanogenic bacteria.

So, these two processes happen before it creates the acids and all these things, and in the biomethanation process. So, in these processes, acid is created and the pH goes down, but bio methane, this methanogenic bacteria cannot act when pH level is high, it acts when the pH level is neutral. So, this happens in two stages.

So, if I can separate these two stages, then if the process would have been more effective. So, for that, people have designed biphasic fermenters and this improves the efficiency and reduces the overall time. So, that means here methanogenesis happens separately at near neutral pH range, in

the second case. So, it is a biphasic one. So, in the first phase, we do acidogenesis and hydrolysis in the second phase, we do bio methanation in two separate chambers.

So, TERI designed a TERI enhanced acidification and retention bioreactor, which you now have this biphasic design. The feed that is given into this digester is as part the desired solid content depending on what process you are adopting, what patented technology you are adopting, you decide on this, usually it is 6 to 10 percent. Sometimes it is a little bit more like 20 percent, where dry and this is known as dry fermentation.

So, this is another technology of biomethanation. So, most likely it is going to be 6 to 10 percent solid organic content the rest is water. The retention time is around 14 to 30 days again this varies as per what methods we are applying. The water source that is mixed with organic waste should be clean water or it could be sewage or it could be even recirculated effluent coming out of the system as well of the from the digester as well.

Once the gas is prepared, the gas is cleaned or scrubbing of gas, if you want to go for automobile use, you have to clean the gas you have to remove Co2 H2S and so on. And the residue this has to be de watered similar to dewatering in sewage treatment and all we use cruise to press on the waste and then eventually it becomes 50 to 55 by present solid and the effluent can be recycled. And this could be this aerobically cured open in open to atmosphere and then it could be used as fertilizer.

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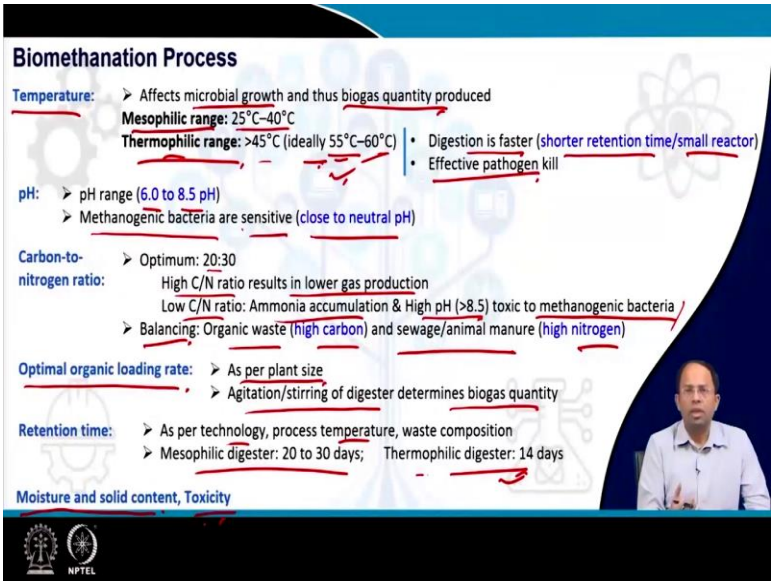

So, coming to the processes little bit more details. The temperature ranges in which biomethanation operate, as you know that temperature effects microbial growth and depending on microbial growth, the biogas quantity that will be produced is also dependent. We have those two same temperature ranges that we discussed in composting that is mesophilic range and thermophilic range. Mesophilic range is 25 to 40 degree whereas thermophilic is more than 45 and in this particular stage we achieve this 55 to 60 degrees centigrade which is required for killing of pathogens in the waste.

So, in that case, the need for aerobic treatment further may not be there. And in thermophilic range if I can operate my digested in this particular temperature range then the digestion is faster it required shorter it will have shorter retention time and we will require a smaller reactor. Because we are having a shorter retention time. If it is a larger retention time of course, everyday waste comes in we have to have a larger reactor.

So, and we have effective pathogen kill, because we are running this operation at a higher temperature. The pH range also ranges from 6 to 8.5, the methanogenic bacteria or the second phase, if I have a biphasic system, then these are sensitive to this pH and they operate at close to neutral pH, so, that has to be checked.

Carbon to nitrogen ratio could be either 20 or 20 is to 30 if the CN ratio is high, then it results in lower gas production, if the CN ratio is low then ammonia will accumulate or the pH will be higher and this will be toxic to methanogenic bacteria and if methanogenic bacteria do not work the gas will not be produced or lesser amount of gas will be produced. So, we have to balance the incoming waste. So, we have to balance the carbon and the nitrogen content.

So, either it is we can mix organic waste which is high in carbon or we can make sewage or animal manual which is high nitrogen as per the requirement. The optimal organic loading rate of this particular reactor or digester this would be as per the plant size and but we have to keep on agitating or stirring this particular reactor because the more we stir more amount of biogas will be generated.

The retention time is again as per the processes or as per the technology or the temperature if it is mesophilic, then we require less the thermophilic digesters takes around 14 days whereas mesophilic digesters takes around 20 to 30 days. So, that means thermophilic is higher

temperatures, so, we require less amount of time. Then in addition to all this, we also need to check about moisture in the solid content of the initial feed and also the toxicity of the waste if it is toxic, then of course, the process will be hampered.

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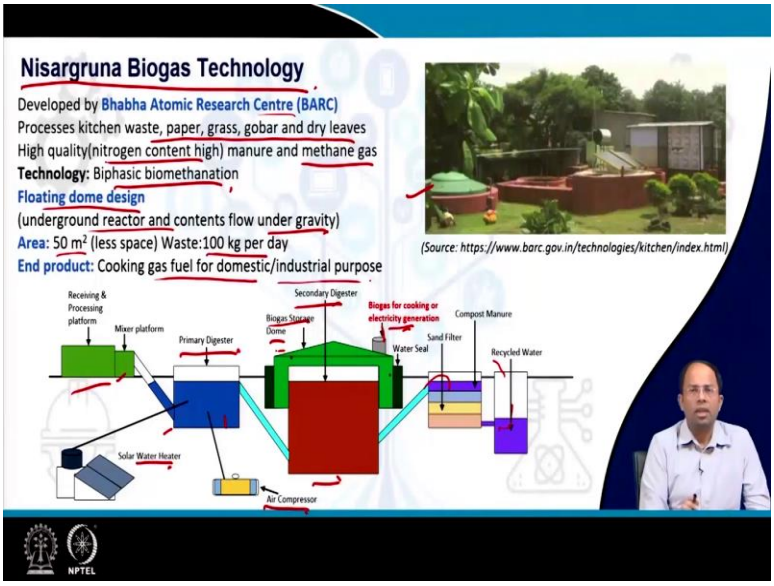

Then, we talk about this Nisargruna biogas technology which has been developed by BARC as you can see over here. So, here we have got this receiving platform then the mixing platform where the waste is mixed with water, then solar water heater this heats up this particular chamber, so, that at high temperature the operation happens, we have also air compression we send aid through this, this is the primary digester the first one and then we have the secondary digester this is a two-phase digester.

Then over here is the biogas storage dome the gas is stored at the top from where we can take the biogas for cooking or electricity generation. There is a water seal from here we can take out the compost or that sludge, then we take it through a sand filter the effluent and after the effluent is recycled, we can again use it back into this particular digester. So, this is developed by Bhabha Atomic Research Center, kitchen waste paper glass gobar and dry leaves are taken up by this particular reactor, this has got very high nitrogen content.

So, the manure that is generated is very high qualities and methane gas is also clean, it uses biphasic biomethanation and floating dome designed for the gas collector and the reactor is underground and all flows from one chamber to another happens via gravity, there is no pumps

involved and total area required is 50 square meter, which is very less total waste its receives around 100 kilograms per day. The final end product is cooking gas fuel for domestic or industrial purposes.

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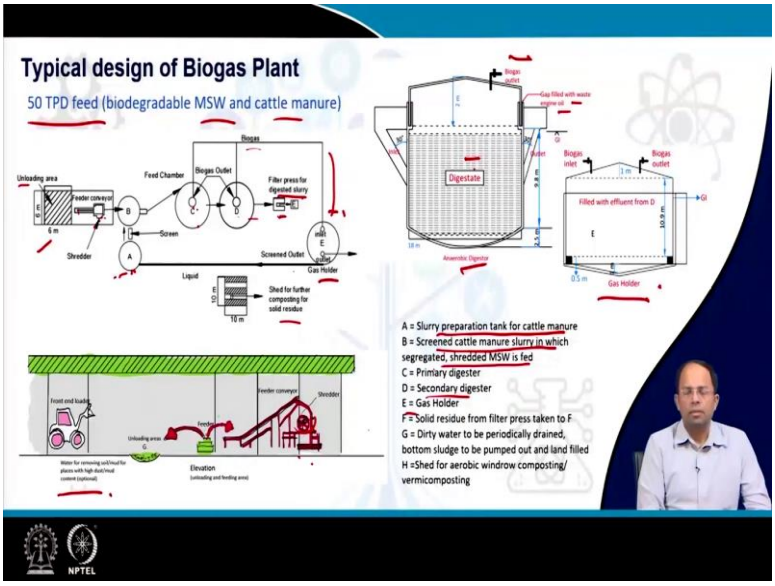

So, this is the typical design of a biogas plant of 50 tons per day capacity. So, both MSW and cattlemen manure is being utilized. So, you can see this is the loading unloading area for the waste. This is the feeder to the conveyor belt and the heat this is where the waste gets shredded. Once the waste gets shredded, it goes into this particular two chambers. This is slurry preparation tank for cattle manure A and B is the screen cattle manure slurry in which segregated shredded MSW spread. So, first water and this manure cattle manure is taken in and then it is mixed with shredded waste and then finally it goes into the digester.

So, we have got two digesters in sequence C and D, primary digester and secondary digester it is a biphasic one of course, and in both stages biogas is generated which is then taken to this gas holder. So, E is the gas holder and the slurry is taken, the digester slurry is taken from over here and from then it from there it could be actually further taken to a composting site for solid the solid residue could be taken to a composting this one and some amount of effluent can again go back into this particular tank.

So, this is the design of anaerobic digester. As you can see that, this is the digestate, this is the biogas outlet from the top and this gap is filled with waste what engine oil and then we have got

the design of the gas holder. So, this is some typical designs. And over here you can see the loading unloading area and then from here we have the feeder where it is put into a conveyor there finally, it goes into a shredder and finally, it is shredded and mixed with the manure slurry and then it goes into the digesters.

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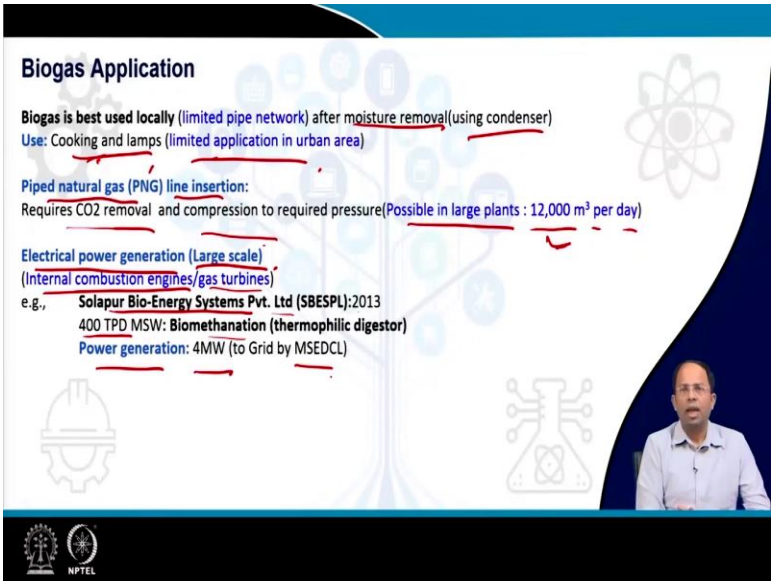

So, one problem with biogas is its application that means we can produce biogas, but who will apply it. Usually, it is best if you can use it locally. So, because you cannot otherwise, we have to have a long pipe network which is costly and unfeasible to send little quantity of gas and so, we have to remove moisture using a condenser from the gas and then we can use it for cooking and for burning of lamps.

So, this kind of uses are okay for rural areas, but in urban areas, there is only limited application for either using biogas for cooking or for burning of lamps. So, cooking gas is usually LPG compressed natural gas and so on or natural gas. So, one thing that could be done is in urban areas, that we can insert this bio gas directly into the pipe natural gas PNG line.

So, that means if we have a pipe network for gas supply in the urban area, we can directly put in our gas inside that particular line, but this request Co2 removal and certain amount of compression of the gas is to be done so that we convert it into liquid gas and this is possible in only larger plants and where the production is around 12,000-meter cube per day. So that means it is a very very large plant.

Again, electric power generation could be also done from this kind of plants, but again, this can be only done at a very large scale. And this gas is used to run internal combustion engines or gas turbines. One example is the Solapur Bioenergy Systems Private Limited plant which was set up in 2013. It takes 400 tons per day of municipal solid waste and using thermophilic digested and biomethanation, of course, it converts generates biogas which is usually which is ultimately used for power generation using this gas turbines. And 4 megawatts of power is sent to the electricity grid of MSEDCL. So that is how we can apply biogas.

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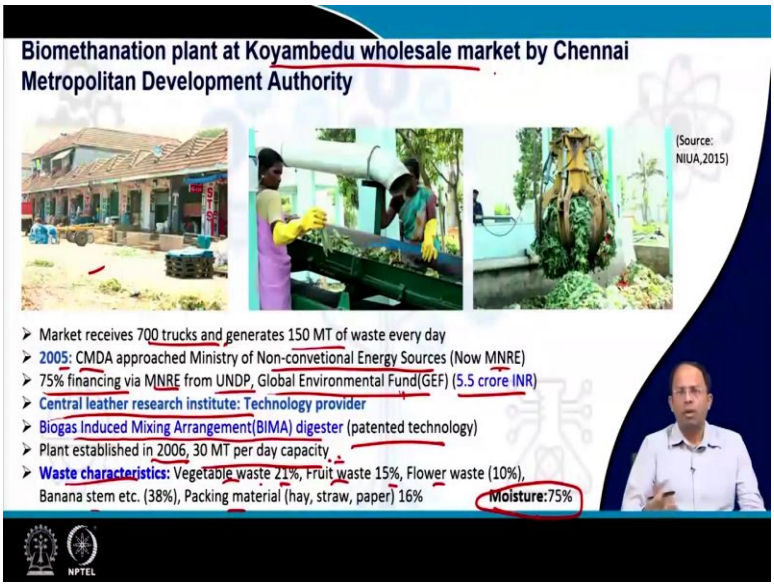

So finally, we will come to a case study of biomethanation plant at Koyambedu wholesale market. And it was developed by the Chennai Municipal Development Authority. So, when we talk about planning, it is not only about the technology, it is also about how do you conceive the entire process, how do you set up how do you arrange funds and so on. So that is why this case study is important.

So, this was done at Koyambedu wholesale market deals with food waste, flower waste, vegetable waste, Banana steam packing material, this is a very large market around 700 trucks comes over here, and it generates around 150 metric tons of waste every day. Initially waste used to go to landfill site but they later on this CMDA Chennai metropolitan development authority in 2005. They approached the ministry of non conventional energy sources now its ministry for new and renewable energy sources for money to set up a waste to energy plant.

So MNRE ministry agreed to finance 75 percent of the money which came to around 5.5 crores and the money was obtained from the United Nations Development Programmed from the global environment fund. So, this has to be done via the ministry. That is why this was money was obtain but the source was a bilateral agency this multilateral agency in this particular case.

The technology provided for this setting up this particular plant was provided by the central labor research institute. And they had a patented technology which is known as biogas induced mixing arrangement digester, Bhima Digester. So, this was set up, the plant was established in 2006, the capacity of the plant was 30 metric tons.

The rest of the plant the rest of the waste again was sent to other facilities but only 30 metric tons of waste of segregated properly cleaned organic waste was taken for this particular plant. Right now, they are also willing to expand it to 50 or 60 metric tons. The waste characteristics as you can see mostly vegetable waste 21 percent, food waste, 15 percent and so on. So, this kind of waste is being taken the overall moisture content of the waste was 75 percent. So the total moisture so that is actually good, because biomethanation require the waste to be have adequate moisture content.

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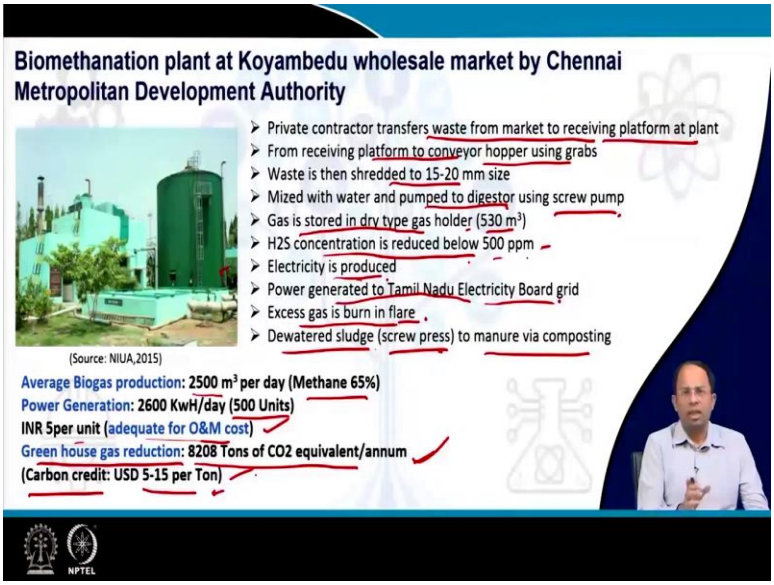

So, the private collector transfers waste from market to the receiving platform at the plant from the receiving platform, a hopper using grabs lift the waste and put it into the conveyor and the conveyor takes the west to the shredder where the waste is shredded to 15-to-20-millimeter size

mixed with it is mixed with water and pumped and then pumped to the digester using screw pumps.

So, this is the pumping mechanism is used here. It is not via gravity, but via pump. The gas that is generated is stored in a dry type gas holder of 530-meter cube you can see it over here. Electricity is produced sorry H2S concentration is reduced to below 500 ppm. And once that is done then we can produce electricity using this particular gas, the power generated is taken to the Tamil Nadu electricity board grid.

Now, H2S is to be removed but Co2 can remain because we are just burning the gas for power generation. Sometimes if we cannot run the turbines for some reason or something the excess gas or sometimes excess gas is produced, we cannot store it in that case the excess gas is burnt in flares. Similar to this landfill gas then the dewatered sludge whatever remains. So, we have to using screws press it is dewatered then it is converted into manure via composting aerobic composting process.

The average biogas production for this plant is around 2500-meter cube per day, this methane content around 65 percent power generation is around 2600 kilowatt hours per day which is comes to over 500 units and they are selling it at a rate of rupees 5 per unit. So, you can understand the money that they generate and which is adequate for their own operation and maintenance cost and for salary of the operators and so on. The total greenhouse gas reduction is around 8208 tons of Co2 equivalent per annum.

So, this is very very important because earlier we or even we can get carbon credit for this amount of gas foreign countries and all they buy these carbon credits because they have to meet some target reduction for greenhouse gas target reduction. So, they used to buy carbon credits from other countries. So, this you can sell this carbon credit at 5 to 15 dollars per ton, which is quite a bit.

So, you may not generate enough money by electricity, but via carbon credit, you can generate a lot of money. But now this carbon credit operations are not there, but earlier it used to happen like that. So, this is more or less the study of biomethanation plant. And this is you can see it is how it is operated, how the entire process is set up, you require land area for that you require

different operators you require agency which will develop the technology and you have to apply all this. So, this has to be planned properly and according that then you can generate energy.