Wastewater Treatment and Recycling
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Lecture - 37
Anaerobic Treatment of Wastewater: Other High Rate Anaerobic Processes & Biogas Production

Hello friends. So, we are in the last lecture for this week 7, and in the previous class we were discussing about the one of the most commonly used anaerobic treatment process which is USB reactor, and there are other [noise] high rate anaerobic treatment process which are used mostly by various industries though. So, we will talk about some of those processes in this lecture, and then conclude this week with there little deliberation on the biogas production aspect with the Anaerobic Treatment of Wastewater.

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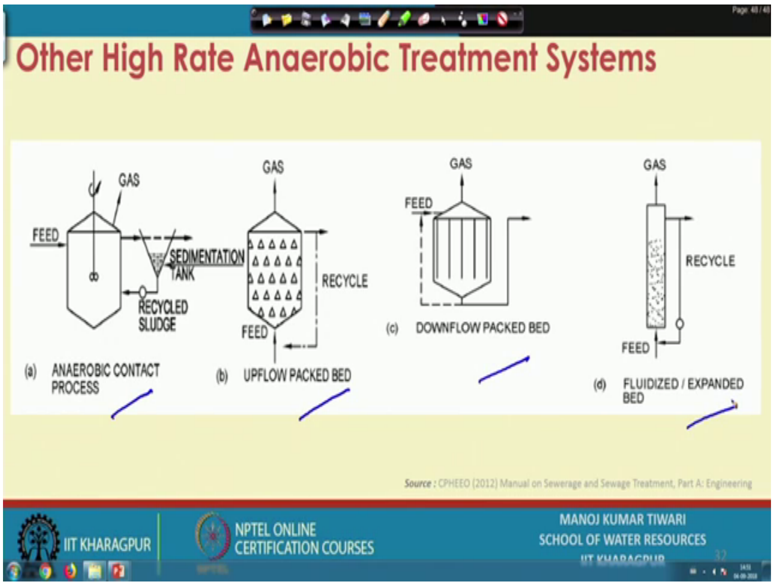

So, to began with, there are various other high rate anaerobic treatment systems there are anaerobic contact processes. So, we had a brief list when we were talking about the classification of the anaerobic treatment systems. So, we did saw there are suspended growth systems, pad growth systems and then based on those kind of things. So, up flow aerobic sludge blanket or USB reactor we discussed in the previous lecture, but the other common processes that are times people use mostly industries are anaerobic contact process, then up flow pad bed process, the down flow pad bed process and the fluidized or kind of expanded bed processes. So, these are the one which are which are some of the other processes which use which are used in the industries or even some for municipal treatment as well.

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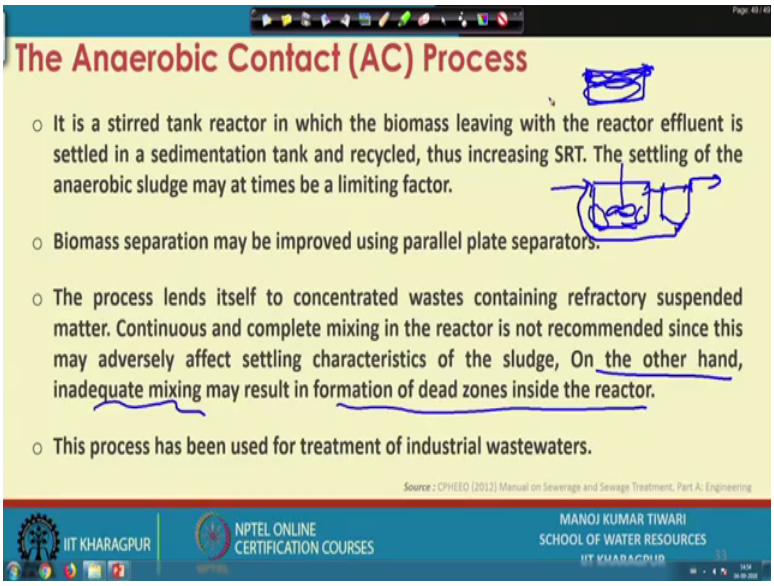

So, if we see the anaerobic contact process is essentially a kind of stirred tank reactor, where there is a mixing is ensured for contact of the biomass with the substrate that way. So, in this the biomass which is leaving the reactor effluent is settled in a sedimentation tank and recycled back. So, that way the sludge retention time is increased.

The settling of the anaerobic sludge may at time be like limiting factor in this case. So, how fast it settled, because whether this is the growth rate is slower as opposed to the aerobic system, many times we see that the settlement is not that good as the typical secondary settling system in activated sludge process, which we discussed in the last week.

So, if we see it is kind of the, this is kind of your similar system, activated search process kind of system, but in a closed this thing. So, in the absence of oxygen you will have a reactor with the steering system, closed from the top and then the that goes to the another settling a system and then sludge is recycled over here. So, that way the sludge retention time is increased and the effluent is taken out of.

The biomass separation may be improved using parallel plate separators though case. So, instead of just like secondary simple secondary settling, if we go for the plate settling or using parallel plate or those kind of thing as we discussed during the sedimentation time. So, even that can be used here for the enhanced settling of the biomass.

This process lends itself to the concentrated waste containing a kind of refractory suspended matter. There are continuous and complete mixing in the reactor like when we although it is a stirred tank reactor, but at times even this continuous and complete mixing is not recommended, since it may adversely affect the settling characteristic of this large.

So, how nicely like because we do not want sludge particles to be disintegrate we want at least them the flogs or the granules are formed. So, that the better settling is obtain. So, if we the mixing is very critical in such systems in anaerobic contact processes, that is primarily because if we mix at two rigorous speed to higher speed, we may see that there is a disintegration of the sludge and it settling characteristic may get adversely affected and the that may the sludge retention will suffer.

While on the other hand, if we do not properly mix if we go with inadequate mixing. So, there may be formation of dead zones inside the reactor. Because you are getting the flow so, if there is no proper mixing you may see find some dead zones over here, in the corners or those kind of places.

So, the flow recirculation may be a problem in case of improper mixing, we may see the short circuiting here. So, short circuiting essentially means that your flow is directly like a packet or plume flow is directly find its way or let us say coming in this way not spending adequate or enough time in the reactor. So, that may also be a problem in this case. So, this process has been used for treatment of industrial wastewater though anaerobic contact processes, where the biomass is kept in the contact with the help of a steering system.

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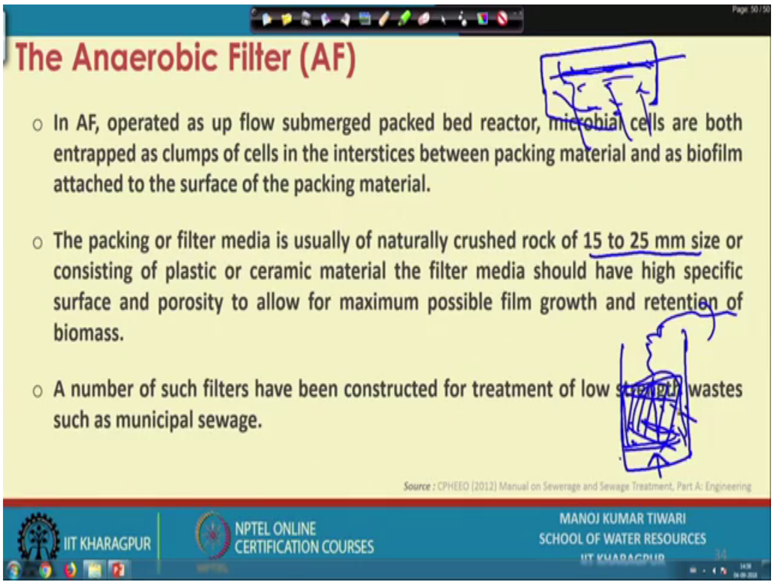

Then the other treatment system is anaerobic filters. So, in anaerobic filters these are operated as up flows submerged packed bed reactor kind of systems. So, there are microbial cells they are both entrapped and clumps of cells in the kind of like interstices between the packing material and as a bio film attached to the surface of the packing material. So, this is essentially kind of you know attached growth system as opposed to the anaerobic systems, we have as a suspended as opposed to the USB we discussed in the previous class as a suspended growth system

So, in these anaerobic filters what happens that, there will be a packing material. So, the packing material allows the microbes to grow on the microbial cells to grow and form biofilm onto the surface of the packing material what is ever is used, and then the water is basically like filtered through this. So, this packing or filter media is usually kind of naturally crust rock. So, of around 15 to 25 mm dia, this is the typical size of the typical size of the particles. So, they consist plastic or ceramic material in the filter media can also be there instead of rock.

Now what we have that the like high specific surface and porosity is needed so, that the biofilm so, that like microbes get sufficient space to grow and the maximum possible film growth and retention of biomass is possible. So, that way we need to ensure this significant amount of surface area as well as significant amount of porosity in the system. The number of such filters have been constructed for the treatment of low strength wastewater such as municipal sewage and many places.

Now, so, the anaerobic filter is essentially kind of trickling filter, where you have a packing material and the water is trickle from the top and passes through this. There trickling ensures this significant supply of oxygen here because of its anaerobic filters it is done in a closed system. So, in a closed system the basically water is passed. This filter can operate in both way we can have a up flow filter or down flow filter.

So, we may have let us say down flow filter, where you provide this and then it goes through a packing media packing material and then water as is passes through this it actually like the biofilm grown here over the packing material or the biomass grown here in this system, will eventually degrade and decompose the organic matter and from the top will get. So, as we are discussing up flow anaerobic sludge blanket USB reactor. So, there this thing was in suspension and the biomass retention was because of its hydraulic characteristic of the reactor, where here the biomass retention is because of its attached growth to the packing media. Biomass is retained because of this attached growth and this attached growth allows biomass to be retained in the system.

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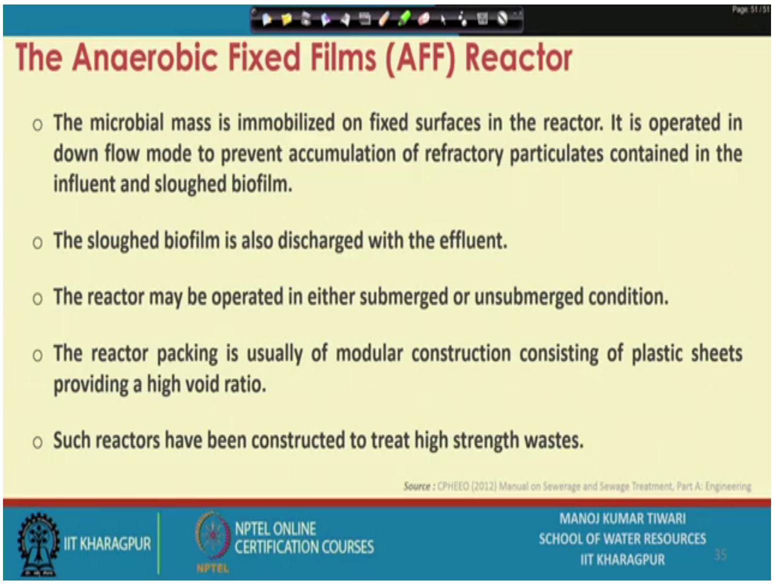

So, that is another this thing there is anaerobic fixed film reactors. So, these are the like microbial mass is immobilized on fixed surfaces in the reactor, it operates in down flow mode usually to prevent accumulation of the kind of refractory particulates that contains the influent and can basically sloughed biofilm.

So, this biofilm is also discharged with the effluent in this case in this down flow. So, up flow reactor the anaerobic filter which is typically up flow, could be could be down flow also, but most of the time it is an up flow filter those kind of thing.

Now, these reactors, the AFF reactors may be operated in either submerged or unsubmerged conditions, and the reactor packing is usually of kind of modular construction consisting of plastic seats providing a high wide ratio. So, these kind of reactors are typically used to treat high strength wastewater.

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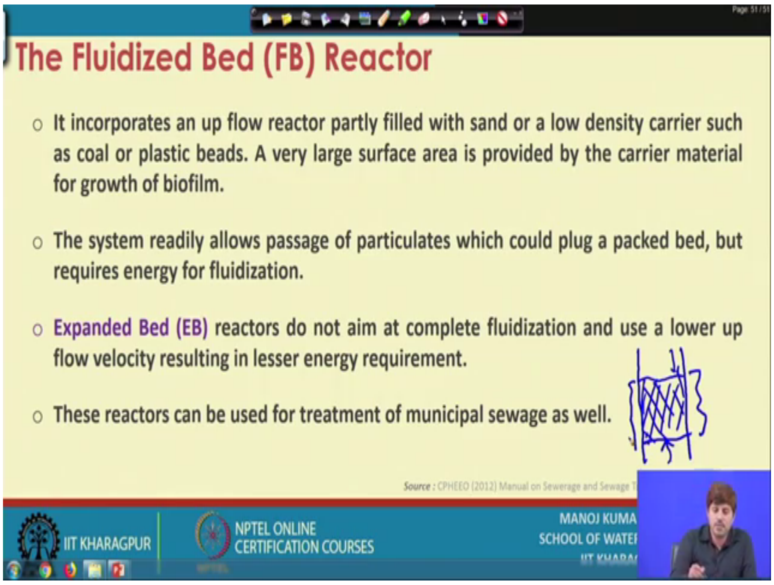

Then we have the fluidized bed reactor. Now this fluidized bed reactor essentially incorporates an up flow reactor partly filled with the sand or very low density carrier. So, the basic difference between a pad flow and fluidized bed reactor is that, in packed flow in packing in kind of filter or whenever we have a packed media. So, we packed this media inside the reactor, and then allow the flow either from top or from bottom depending on the characteristic. And that way the flow passes through this and the biomass and media remains in here.

But in fluidized bed reactors what happens is that the, reactor is partly filled with some material, some media material which could be sand or could be low density carriers such as coal or plastic beads, now these are low density carriers. So, they actually and we do not make them fix in the system.

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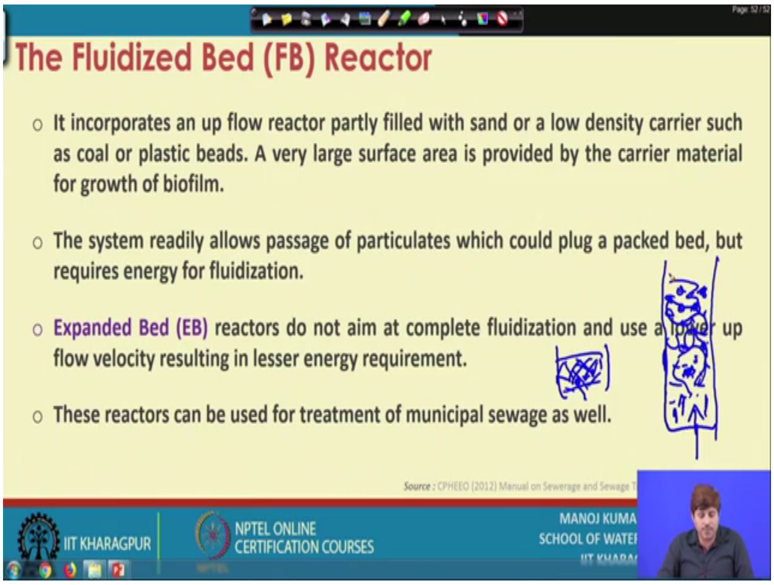

So, when and the flow is up flow. So, there is there will be a kind of when water is flowing in up flow direction. So, water keeps these media particles in the fluidized state. So, it is not fixed as in its not these media particles are not fixed with anything, these are low density material and the flow of the water itself ensures that they are also in the suspension.

Even the media on which the biomass is growing remains in the suspension. So, biomass grows an attached system because that will get plenty of surface to attach with. So, there is a very large surface area would be provided by these carrier materials for the growth of biofilm. So, biomass eventually grows on this surface. So, there is attached growth on the surface of the media which is in the fluidized state, but the media itself in the suspended state. So, that is why we call it a fluidized bed system kind of thing.

So, this system readily allows the passage of particulate which could plug a packed bed reactor, because in a in a packed bed reactor if we have let us say packing media is and this things are fixed. So, anything going in here may get trapped and can actually block the pore spaces, you can caused significant amount of head losses whereas, in the fluidized bed system because these things are already in suspension. So, nothing gets trapped over here that will find some way here or there, but it will eventually escape the system.

So, if there are like particulate or those kind of things are coming, they again like we will get, but they of course, required energy for fluidization; the expanded bed reactors which is again a standardized or specific case of fluidized bed reactor kind of thing. So, do not aim at complete fuel like fluidization, but use a lower up flow velocity resulting in lesser energy requirement. So, that just bed is expanded here in fluidized bed system the entire material is kept in the fluidized state, whereas, in expanded bed systems this energy requirement is lesser, but rest of functioning more or less is of the similar nature.

So, these reactors can be used for the treatment of municipal sewage as well as industrial sewage, both type of treatment can be like both type of wastewater can be subjected to treatment with the fluidized bed reactor although the installation with the municipal sewage is very limited. So, these are some of the other configurations of the high rate reactor processes high rate flows.

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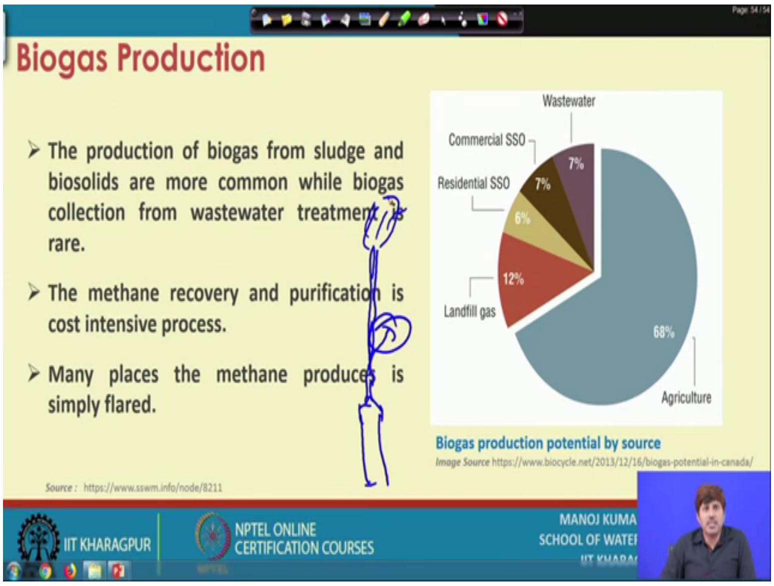

Now, if we see the aspect of biogas production, because we have been saying that the one of the most attractive advantage of anaerobic treatment of wastewater is the generation of potential generation of energy. And we do not need to supply too much of energy in the form of variation so, saving of energy in the application front and generation of energy in the form of biogas and methane.

So, but biogas production when we see is actually like the production of biogas from the sludge either the even the asp sludge, activated sludge process sludge which comes that is also kind of decomposed anaerobically. So, digested anaerobically or any form of sludge, which is being produced any form of bio sludge or bio solids which is being produced. So, they are subjected to kind of anaerobic decomposition and the biogas production and biogas production collection and processing from that way.

But, methane recovery and purification from the wastewater treatment; wastewater treatment means come when we are exactly treating wastewater not this sludge of wastewater. So, for the wastewater treatment is really rare, you know why it is rare? Because the recovery and purification is a cost intensive process. So, the methane which is produced we need to trap that methane. So, we need to have to have a collection mechanism, because whatever system you saw. So, if you are basically making let us say reactor.

So, you will make a reactor like this even if it is a then the gas is being collect being coming out of a pipe over here from that system, but what after that? How to collect this, how to store this how to transport this if you need to transport it or if you need to purify it, because this gas is not just methane there is a lot of carbon dioxide also in this one. So, how to basically get rid of the carbon dioxide present in the gas and eventually how to basically then you may need to go for a purification process and then what are reuse application what are the applications, where this gas can be used.

So, all in all if you see this is a quite cost intensive process and we need to kind of look for a financially sustainable process to utilize this gas. Because if we are investing huge amount of money much more than the; much more than the basically in alternate renewable energy source can be obtained if with the same investment or with the lesser investment, if we can go for if we can find some alternate energy source. So, why one would want to spend so, much amount in just collecting purifying treating this.

And as a result of this even though the anaerobic treatment systems have been installed at quite a few places particularly with low strength wastewater, the many places the methane which is produced is simply flare is not even collected at all. So, we will have normally people have a flaring systems or the gas which is coming out of here because it has a lot of greenhouse gas potential. So, they do not let it go in the atmosphere it is because the greenhouse gas potential of methane is far more higher as opposed to the carbon dioxide. So, what they do, they just put it to the flame.

So, that the gas is burned in the atmosphere for know practically fruitful uses. So, that is one of the challenges in terms of the biogas utilization here. Now what happens that, with the sludge or with the solid waste with the concentrated waste, the amount of organic matter present is too much and corresponding production of methane is sustainable means there is a significantly high quantity of methane that can be produced. And then it makes some sense to install certain kind of systems to collect purify if needed tree transport the gas.

But in the wastewater the volume are large, but typically organic loading is less or particularly with the sewage. So, with very low COD when we have these COD values, very low of the order of say 200 300 400 milligram per liter. So, how much potentially methane can be generated out of that and whether it is like viable financially viable to go for make this much amount of investment make huge amount of investment, for the collection and management of that waste.

The potential is there though if you see these the like biogas production potential across the different sources or significant part around 7 percent can come from the wastewater, but this includes sludge also, but majority coming from the agricultural waste. So, that way there is a significant potential for the generation of biogas from the wastewater as well. But this like financial viability of such systems is to be should be investigated properly.

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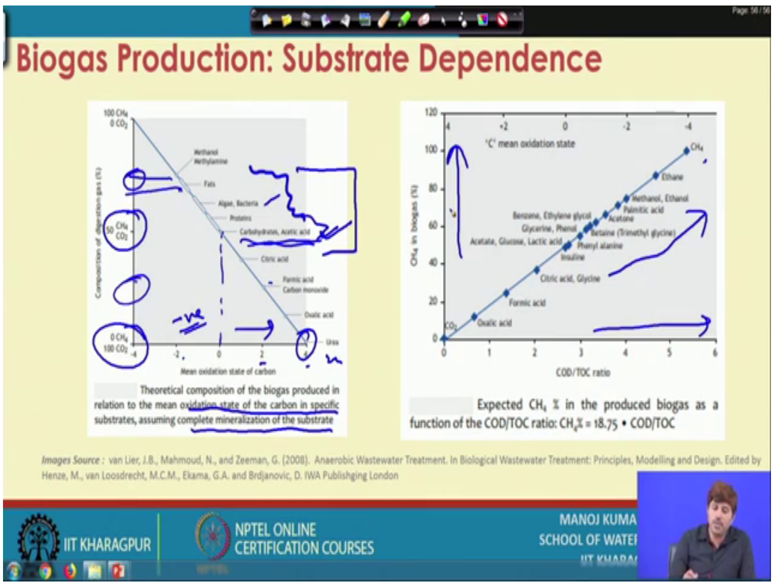

Now, this biogas production again largely depends on the type of substrate, what type of substrate is there which is being used for the production of biogas. Now, if we see the like depending on the kind of substrate or depending on the theoretical sort of if we see, the mean oxidation state of the carbon in that substrate in that specific substrate and if we assume the complete mineralization of the substrate. So, that will give us an idea of what would be the composition of biogas in terms of the kind of percentage of methane to percentage of COD.

So, something which is at around say neutral or zero oxidation state like carbohydrates acetic acid or those kind of thing. So, the typical fraction of methane in such scenarios in such with such substrate or with such organic matter is likely to be 50 50 percent so, 50 percent methane and 50 percent carbon dioxide. I we are working with the substrate which are of higher oxidation state. So, if the mean oxidation state of the carbon is high. So, let us say plus 2 plus 4 those kind of thing so, like citric acid formic acid oxalic acids or urea those kind of thing.

So, that in that case we may see actually lesser fraction coming as a methane and more going as a carbon dioxide. So, like for urea if you see theoretically. So, urea will not produce any methane, but will produce 100 percent carbon dioxide only. Similarly, the formic acid or carbon mono oxide will eventually like the kind of produce just 25 percent methane and close to 75 percent of the carbon dioxide. But, if we go with other side where the oxidation state of carbon is negative. So, for oxidation state of say minus 2 where, there is like a methanol or these things or various fats in these kind of things. So, if we see them, they produce more of the methane and less of the carbon dioxide.

The bio like algae bacteria also from somewhere here so, they produce some 60 percent methane or 60 to 65, 70 percent methane and then remaining as a carbon dioxide. The fats also produces around 70 percent methane and lesser of this thing. So, our typical food waste which contains these fats proteins carbohydrates. So, they are kind of if you see they produce more of the methane and less of the carbon dioxide, and that gives an attractive advantage or potential to basically explore that how much methane can be generated and whether it is possible to trap that or not sustainably in a financially sustainable way.

Now, if you see there again kind of like percentage of methane produced as a function of COD to TOC ratio. So, as these COD to TOC ratio sort of increases. So, that means, if the total organic carbon COD is high and total organic carbon that way is low. So, what we see is the like more and more of the biogas potential production will come as.

So, for various substrates for various matters which are having high COD two TOC ratio will lead into high methane fraction in the biogas whereas, for substrate with COD to TOC ratio very low. We will probably see the lesser methane production or lesser composition of the methane in the total biogas which is being produced.

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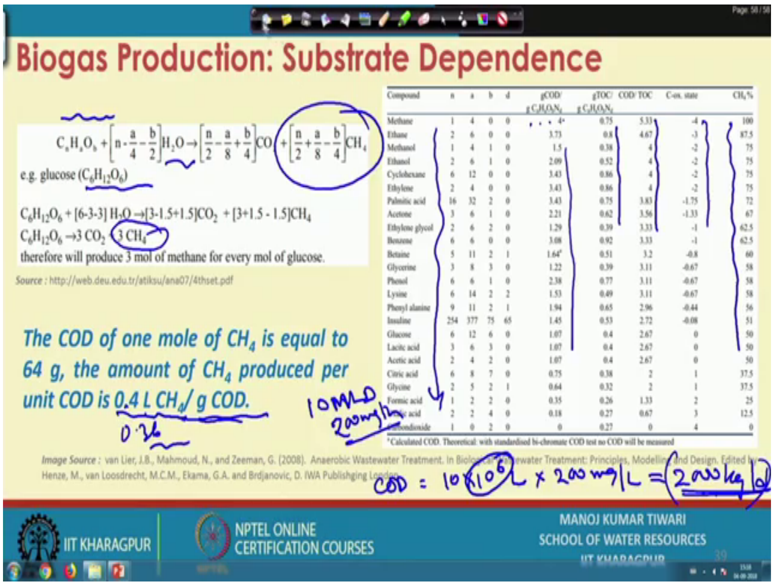

Now, as we have been discussing in that it depends on the substrate eventually. So, if you see the various substrate like methane ethane methanol. So, a variety of substrate there composition actually is this way if it is C a H a C and H a O b and a nitrogen d. So, that way it will be the basically like methane will have 1 c and 4 H CH 4 no oxygen and no nitrogen. So, that way we can get this formula.

Now, if we see the gram of COD of this various particular compounds is like this. So, one gram of this how much gram of COD will generate. So, like one gram of methane will produce 4 gram of COD that is a typically rough estimate.

Then gram of TOC per gram of the compound this is your COD to TOC ratio, this is the kind of oxidation state of carbon and based on this oxidation state of carbon we can see what is the percentage of methane that is expected in the bio gas in the total bio gas.

So, here the COD is basically theoretical. Now if we see the COD of one mole of methane is typically equal to 64 grams with and the amount of COD produced per unit COD consume that way is 0.4 liter of methane per gram of COD. So, this is kind of thumb rule 0.4 or many differences is taken a 0.36 or something.

So, that is kind of a thumb rule which is taken for the potential biogas generation or potential methane generation and from where does it come from? It basically comes from this that if you have a compound like this, it will need this much mole of reaction and it eventually will produce this much of a methane. So, far say for the case of glucose if you see. So, glucose will produce 3 moles 1 mole of glucose is going to produce three mole of methane and so, that way three moles of methane for every mole of glucose will be produced. And, if we kind of taking all these averages and convert it over the COD. So, this is what typically we get 0.32 or 0.4 liter or means depending on how we are expressing. So, it comes eventually 0.4 liter of methane per gram of COD removed from the system.

So, if you are having let us say; let us take an hypothetical case if let us say your treating a 10MLD sewage plant with a COD value of 200 milligram per liter. So, 200 milligram per liter and 10 MLD so, in 1 day you are getting 10 MLD that means, 10 to the 10 into 10 to the power 6 liters and the concentration of COD is 200 milligram per liter. So, the total COD if you see in the weight form here will be we can convert milligram to say kg by removing this 10 to the power 6. So, that will become 2000 kg per day is the total COD which is coming into the system.

Or let us say if it is having 250 in flow and it is removing 200 milligram per liter. So, this 200 kg per day is this COD of the COD which is actually being removed from the system. So, we can correspondingly this we can calculate how many liters of methane will be generated. So, that way like for 0.4 liter of methane per gram COD. So, for 200 kg COD how many liters of methane will be generated what will be the storage requirement for that what will be the partial pressure that this methane can generate, and then eventually what could be the potential uses of that can be estimated.

So that way, the estimation of methane or biogas can be done for a given set up or if we know the characteristic of the system. So, with this we conclude the discussions for this week, we will upload some practice problems, in the as a supplementary material of course, and then next week we will discuss about the sludge management.

Thank you.