Wastewater Treatment and Recycling
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Lecture – 33
Secondary Treatment Processes:
Introduction to Anaerobic Treatment of Wastewater

Hello friends, and welcome to in this week 7 of the course Wastewater Treatment and Recycling. We have started discussing about the various treatment aspects of wastewater and we have discussed the preliminary treatment in the week 5 and then last week, we took up the secondary treatment where we discussed the aerobic treatment systems. This week we are going to focus our discussions onto the anaerobic treatment of wastewater and in this particular lecture we will start having an introduction towards the anaerobic treatment what anaerobic treatment means and how it is implied or how it is used for the purpose of treatment of wastewater.

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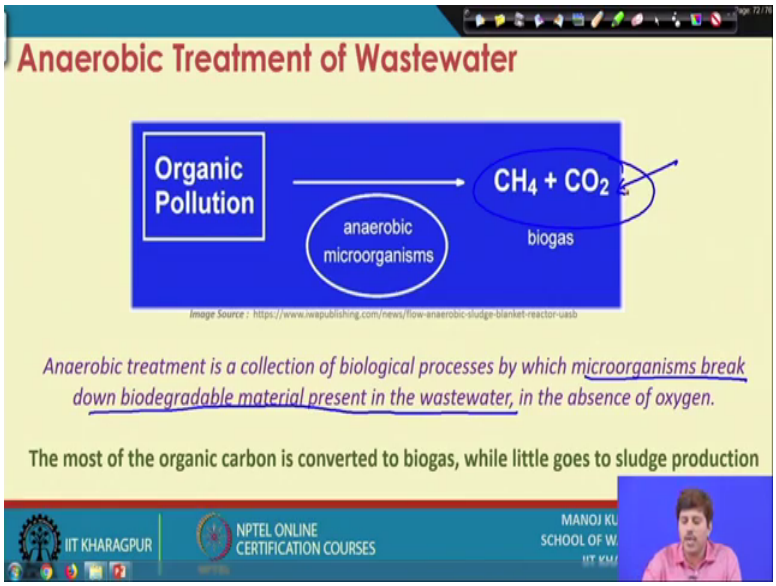

So, to begin with anaerobic treatment essentially means as we discussed that the while discussing the different type of microorganisms, we did talk there are aerobic anaerobic and facultative microorganisms. So, anaerobic microorganisms are those who work in the absence of oxygen. So, when they take part in any of the bio oxidation reduction reactions, so it is not the oxygen but other elements like sulfate, nitrates or those kinds of

things they become the electron acceptor. So, anaerobic microorganisms primarily work in the absence of oxygen.

Now, if we see the basic process of anaerobic digestion, so we have organic matter in the wastewater which we account as BOD or COD. So, when we are having this organic compound or organic matter in the wastewater, the anaerobic microorganisms degrade and decompose this in absence of oxygen and the ultimate or the major bio product becomes the methane and carbon dioxide which collectively is referred as biogas.

So, essentially the anaerobic treatment is a sort of various collections of various steps or various processes by which these microorganisms or anaerobic microorganisms break down the biodegradable material present in the waste water. Now they break down in what? They break down in biogas, they break down in primarily biogas of course there is some cell formation of course, there is some part will go in the effluent, but the major end product remains the biogas. So, the most of organic carbon is converted to biogas while only little goes to the sludge production, so that is what is the basic of anaerobic bio degradation.

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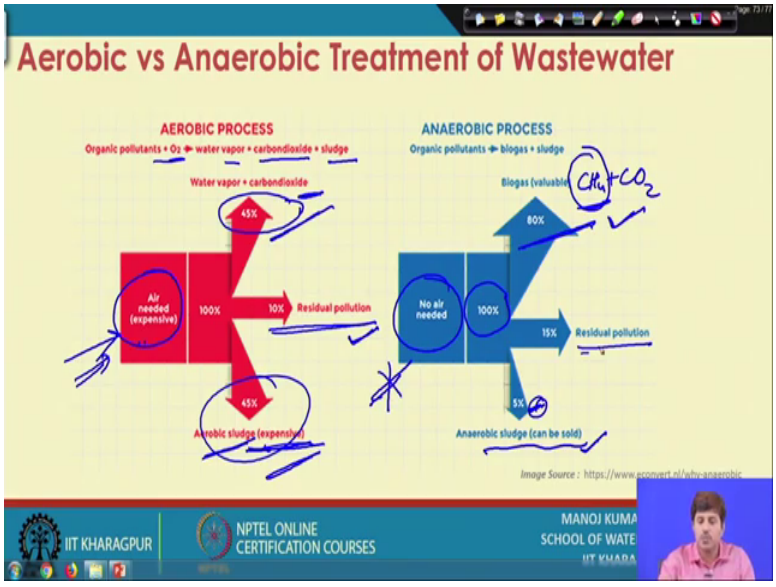

Now, before we go into the detail let us have a look how they are different with the aerobic systems, why we are saying anaerobic microorganisms are like a end product is different so how it works? In aerobic processes we typically have the organic pollutant

and oxygen converting to the water vapour carbon dioxide and sludge ok. So, a significant mass about 45 percent all of these number varies though.

But a significant portion goes to the sludge formation in aerobic systems ok, there is some organic matter or some BOD goes with the residual pollution. So, still like if you have say for say 100 milligram per liter BOD coming in you probably will be able to remove ninety and 10 will go to the affluent. So, this is the residual pollution which is going along with the effluent and then what is removed is basically distributed in the water vapour and carbon dioxide.

So, on the name of gas carbon dioxide is produced which again has it is own environmental footprints because it is a greenhouse gas. So, the carbon dioxide gas is produced and the significant almost half of that goes to the sludge. Further there is requirement of air because the aeration needs. So, as we were discussing in the earlier week for the purpose of aerobic system we need to supply air in some form of other and that typically needs aeration which again is the energy intensive process and expensive. So, we are actually supplying energy and then as a result we are generating certain amount of biomass and certain amount of gas in the form of primarily carbon dioxide.

Now what happens in the anaerobic system is because it is works in the absence of oxygen so there is no air needed. So, the requirement of air is gone. So the one which is a basically energy and cost intensive process in the aerobic system is not there in anaerobic system that is one part and then the amount of the organic matter which comes into the system into the anaerobic system part of that is converted to the sludge anaerobic sludge which is very less in quantity.

So, you see here in aerobic system it was almost half of the one which is getting removed 40 to 50 percent is converted into sludge here sludge conversion is just 5 percent. So, conversion to solid biomass is very little, the majority of the majority of the organic which is coming into the system is converted to biogas. And as we were discussing biogas is basically CH 4 plus CO 2, out of which 60 percent is CH 4 and which is a useful fuel ok.

So, in which is a form of energy in fact, if we can trap that. So here we are supplying energy we are supplying energy and producing the carbon dioxide and biomass. Here we are not supplying energy no energy supply is needed, but we are producing energy and

the biomass or solid waste produced is very low that there is higher degree of residual pollution though ok. So, this is what is the basic difference between aerobic and anaerobic system and this difference if you see, again these numbers varies from source to source and if you see into the more detailed one.

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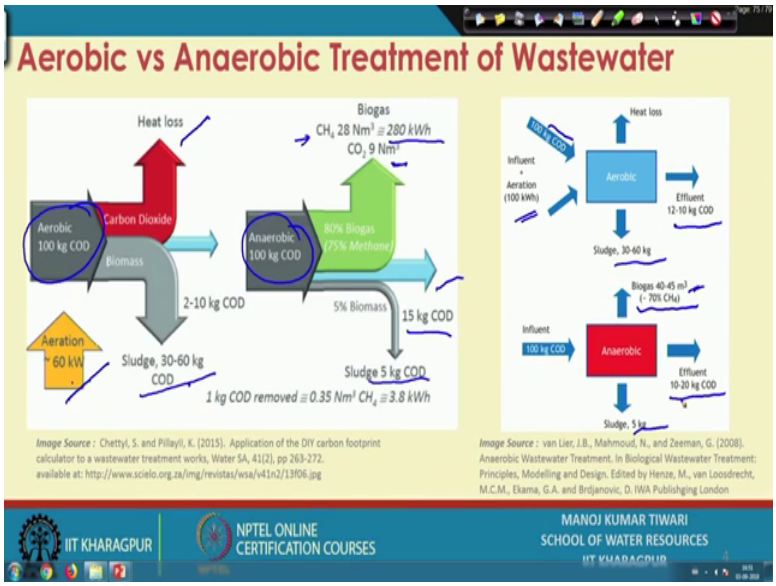

So, like these are the couple of references from different sources ok; so, here you see that almost for a 100 kg of COD, the 60 kilowatt is the requirement of variation ok. Then the significant amount goes to the heat loss and around 30 to 60 kg of the COD is converted to biomass ok. So, that way in anaerobic system if you again feed 100 kg of COD same amount of COD just around 5 percent of, that means 15 per around 5 kg of COD goes here, around 15 kg goes with the effluent and there is a biogas generation carbon; there is some carbon dioxide is generated also.

But the significant amount of methane is also generated which has a potential of around 280 kilowatt hour. So giving 60 kilowatt, generating 280 kilowatt ok, here that is the basic difference. Though these numbers vary, so like here if you have a 100 kg COD in flow you the oxygen requirement was estimated to be around the power requirement was estimated to be around 100 kilowatt hour, then heat loss and affluent 10 to 12 kg this sludge 30 to 60 kg whereas in case of anaerobic 70 percent 60 70 percent is methane.

So, the biogas form is 40 to 45 meter cube and 10 to 20 goes to the affluent and 5 goes to the sludge. So, if we see, if we compare aerobic versus anaerobic treatment option

options, so the 2 things are crystal clear; aerobic system needs significant amount of energy to for the treatment itself in the form of variation and generate significant amount of solid waste in the form of sludge, if you consider that as a waste. And significant amount of carbon dioxide is generated which is a form of greenhouse gas pollution.

But if you compare that with anaerobic system, so here what you get that the very little of sludge is generated the majority portion almost 80 percent of the total COD goes to the biogas and of that 80 percent 60 to 75, 60 to 70 percent of even at times higher goes to the methane production. So, we are actually producing energy instead of consuming energy. So obviously from energy perspective the anaerobic systems are far more attractive as opposed to the aerobic system ok. Because aerobic system requires energy, anaerobic system generates energy. So that is the kind of difference ok.

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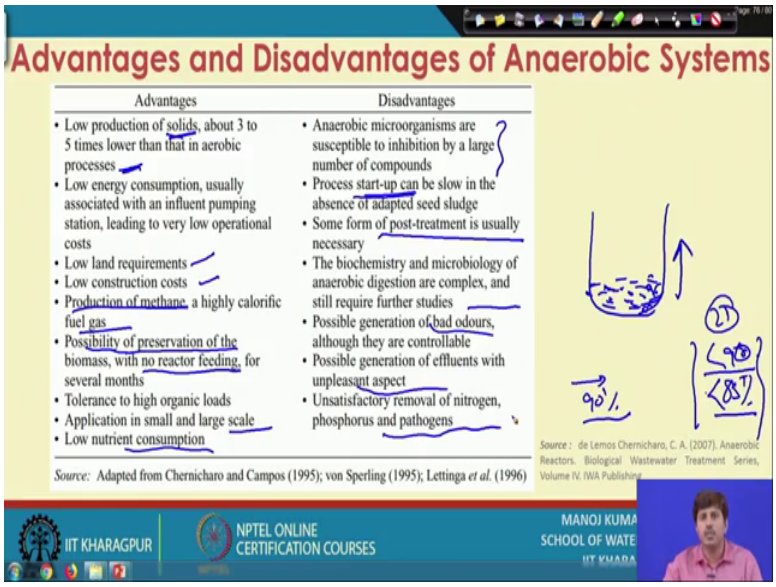

Now, if we see the advantages and disadvantages of anaerobic system specifically. So, anaerobic system: if you look at the advantages first in the anaerobic system, there is low production of solids ok, almost 3 to 5 times lower than the aerobic processes aerobic process generate lot of sludge. Now we need to basically handle the sludge because then you have to have handles sludge handling facilities, drying beds or the dewatering mechanisms then make that of sludge cake. If you are able to reuse it is fine, otherwise you go to the find some landfill for where you can dump this sludge.

So, there is lot of energy and environmental footprint of such sludge production as well, whereas which is very high in aerobic systems, but very low in anaerobic system just 3 to 5 like very around 5 percent is converted to biomass and rest goes to the form of bioenergy or that way. Anaerobic system has low energy consumption usually because as we were discussing the requirement of energy is very low. We do not need to aerate anything, so the only the pumping cost is there and apart from that there is no as such energy cost.

So, the energy consumption is low usually associated with the influent pumping station only which leads to very low operational cost as well. So, your operation and maintenance cost is also going to be low, the land requirement is low it is a simple tank kind of thing and can be basically a there are high rate anaerobic processes. So, they can in a compact fashion, they can work at a high rates and the land requirement would be low.

Construction cost would be low we do not need a mechanical equipments or aerator or diffuser kind of thing and then ensure oxygen supply, So those things get away, then the ultimate advantage is production of methane which is a having very high calorific fuel gas. So, that is one of the very distinct advantage which makes the anaerobic processes quite attractive. Then possibility of preservation of biomass with no reactor feeding for several months because, the amount of biomass produced is very low so that much this thing can be retained inside the reactor and anaerobic systems are slow growers generally that is why their growth is very slow.

So, anaerobic species are slow growers and at the same time their decay is also slow. So even if like reactor feeding is stopped for a few days for even for at times month, so they do not need they do not need oxygen to survive. So, that oxygen criteria is anyway not there and even if some feed or the carbon source is stopped carbon supply is a stopped, still they can survive for several months that gives a possibility of preservation of the biomass. So, biomass is still remains active and still remains workable.

There is a tolerance to high organic load. it can actually sustain even high organic load there is application to small and large scales. So whatever is scale we want we can apply it and the nutrient consumption is relatively low. So, that is another advantage of this. Then if we look at the disadvantages part we will discuss though the some of these points

in detail later on. But quickly to disadvantages part the in anaerobic microorganisms are susceptible to inhibition by a large number of compounds. So, some of the metals or toxic elements or those kind of things it present they can inhibit the anaerobic microorganisms and process failure or risk of process failure are quite high.

Then processes start up can be slow in the absence of adopted sludge see. Because, of the low growth or because of the low accept susceptibility of these microorganisms what happens that if we start a anaerobic system where we have a seasoned sludge or the microorganisms that we put in our pre acclimatize are of the good granulation form. So then this can be like this can take up quickly. So, startup period could be low for this one but if we start with the sludge which is not adopted which is not acclimatized to the system, then this acclimatization phase may go very long and at times even 2 to 3 to 4 months at times even 6 months. It could take to basically your the reactor could take this much of time in getting stabilized at first hand.

So, there is a possibility of high startup time, if it is not being started up with acclimatized sludge. But this of course can be dealt with if we can bring in acclimatized sludge or if we can start with the sludge which is already adapted to such conditions or to such waste. So, then they start a process could be quite rapid and we can actually achieve that within a few days span at times depending on the quality of affluent needed many times some post treatment becomes necessary ok.

So, as we are just discussing when the in the previous slide the aerobic versus anaerobic treatment system, the effluent from aerobic treatment system have generally like of the order of 90 percent or higher removal. But in anaerobic system the removal efficiency is generally less than 80 85 percent or so or definitely around less than 90 percent or so for most of the cases ok.

Infield of course, in laboratories we can get a good removal efficiency with anaerobic system as well, but infield this kind of problem may arises. So, what happens when we are working with a waste which is having high COD or high BOD and we are not getting adequate degree of removal, so then the post treatment becomes necessary. The biochemistry and microbiology of this digestion process is complex and basically needs too much of control and those kind of thing at times even like leakage or those kind of thing oxygen entering to the system can become toxic to the bacteria, so they are

susceptible to so many things ok. So, many matters oxygen those kind of thing and they need to be further investigation to carried out how we can reduce the risk of the failure of anaerobic system.

There is possibility of generation of bad order. So the false smell can also be generated at anaerobic sites although they are controllable it is not that high. So, that is possible to basically deal with that and then possible generation of affluent with unpleasant aspects. So, many times those because it is coming from a system which is devoid of oxygen. So there might be some unpleasant aspects associated with such effluents in form of order in form of some of the insects coming in or those kind of thing might be there and the removal of nitrogen phosphorus or pathogens is not achieved from anaerobic system.

So, that is another demerit of the anaerobic system ok, why it is not achieved because of the nutrition and because since the growth is slow, so the nutritional requirement is slow. So, nutrient uptake is also slow. So the enough nutrient is not up taken by the anaerobic systems and that leads to the that leads to somewhat the not significant or not satisfactory removal of the these nutrients ok.

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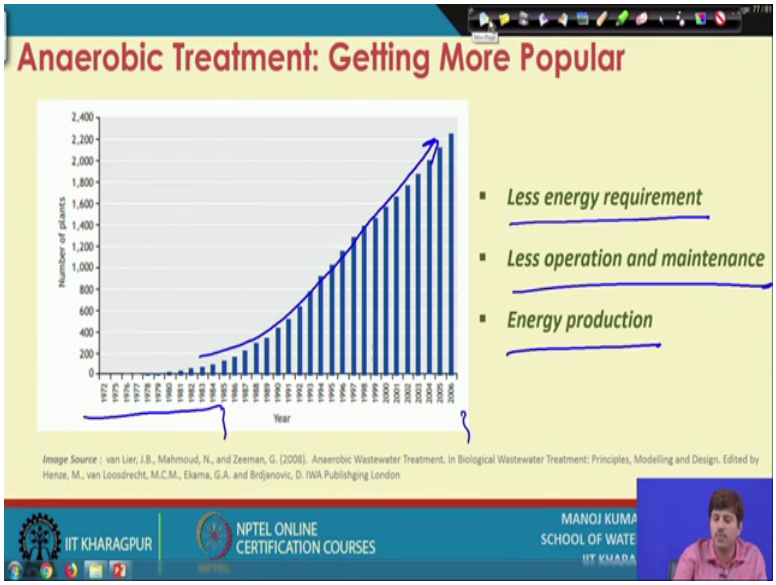

So, now if we see the anaerobic treatment systems, so we discussed about some of the advantages there are some disadvantages also, but still what is observed that anaerobic treatment systems are getting more popular ok. So, this is kind of number of installations number of anaerobic plants across the year. So, we see that these numbers were more or

less negligible till 1980 or so and then once we had a energy crisis and focus shifted more towards the renewable energy and reducing the energy. So, there has been a substantial rate of increase in the installation of anaerobic systems ok.

So, there is a huge number of anaerobic reactors came into the installation post say 1990 or so and this number is still growing on. The major reason for this popularity is the less energy requirement less operation and maintenance cost and energy production chances of energy production making it the process self sustainable, still it is not used or it is not applied to everywhere the civic sector has very limited anaerobic installations. Whereas, the industrial effluent treatment or the wastewater coming from the industry the anaerobic process are far more attractive for industrial systems and there has been quite a few number of installation in the different industry of the anaerobic processes of these anaerobic units.

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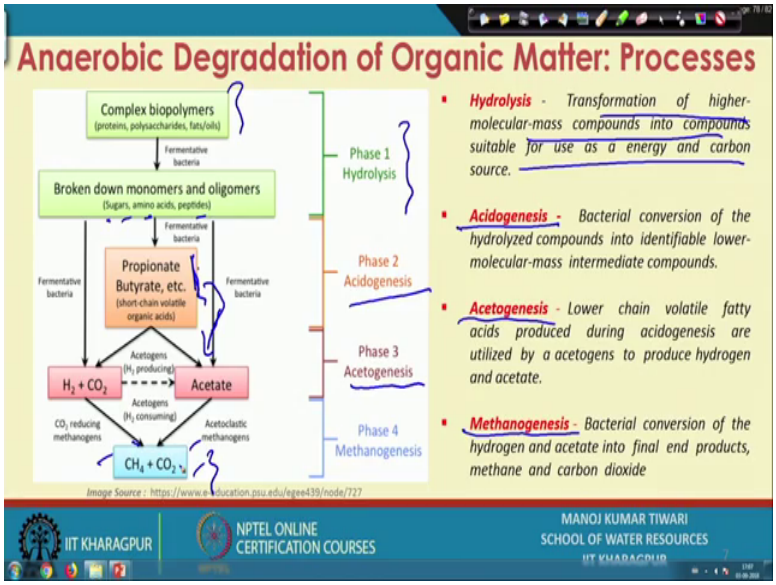

Now, if we see the process of anaerobic degradation of organic matter what happens how this gas is generated ok. So, then the typical degradation of anaerobic typical degradation by anaerobic bacteria would actually follow 4 different steps. So, there are 4 different steps and that leads to the different type of microorganisms involved in that. So, these 4 different steps eventually like is responsible for degradation or decomposition of the organic matter and converting them to the final end product ok

So, what are these 4 different steps or 4 different processes? So the first step or first phase of anaerobic degradation is the hydrolysis ok. So, what typically happens that the complex by polymers of complex polymer or those kind of things. So there is protein polysaccharides fats oils lipids ok. So, these things are first hydrolyzed ok, so it was hydrolyzed and there are fermentative group of bacteria involved in this hydrolyzed hydrolysis process which is essentially the transformation of your higher molecular mass compounds into the compound suitable for used as a energy and carbon source. So that is the major objective of hydrolysis ok.

This happens so that becomes the first step first phase and then what happens that these hydrolyzed products which then broke down to the monomers and oligomers. So, sugar amino acid peptides these kind of things are formed ok, then these are converted to the lower molecular mass intermediate compounds through the process of acidogenesis. So, that becomes the first phase second phase or second step the acidogenesis where this sugar long chain sugar amino acid and those kind of things are converted to propionate butyrate those kind of fatty acids ok.

So, that is the process of acidogenesis and then the third step or third phase is acitogenesis, so acitogenesis where the lower chain volatile fatty acids produced like these lower these volatile fatty acids um. The this long chain volatile fatty acids are then further converted longer intermediate chain fat volatile fatty acids are then, basically converted to the acetate or those kind of thing ok.

So, acetate or hydrogen are kind of produced from these volatile fatty acids and that reaction is known as acetogenesis or that step or that phase is known and as acetogenesis and then there is the last one which is methanogenesis. The last phase of the typical anaerobic degradation process where this acetate or hydrogen are converted into the final end products which is methane and carbon dioxide ok. So, that way the complex biopolymers are converted to the final end product methane and carbon dioxide through a series of steps which involves hydrolysis as a first step or first phase acetogenesis as a second step then acetogenesis and methanogenesis ok.

It is not this way like these some of these sugar amino acid could directly be converted to acid acetate and this thing. So, we may not see acidogenesis step over there and it could directly form the acetate. So, there are different group of bacteria also act upon there are

fermentative bacterias which are responsible for hydrolysis or acidogenesis there are acetogens which are responsible for acetogenesis. So, they convert kind of this and hydrogen can also be converted to acetate hydrogen and carbon dioxide and then there are primarily 2 different groups of methanogens with which all which leads to the methanogenesis and these are the acetoclastic methanogens and hydrogenotrophic methanogens.

So, hydrogenotrophic methanogens are the one which reduce hydrogen carbon dioxide into methane and acetoclastic methanogens are the one which convert acetate into methane. So, that way the methane production is that way the methane production is achieved from the complex biopolymers ok. So, the anaerobic process simply because this entire thing is done in the absence of oxygen and the rate of the different processes could be different ok.

So, whichever among all these steps or all these processes whichever turned to be the lowest or the slowest process would eventually become rate limiting step ok. So, that is how the different steps in combination convert the soluble COD or at times even the particulate COD because, through hydrolysis we can convert the insoluble or particulate form of the COD or particulate form of the organic matter into the soluble organic matter that is what hydrolysis primarily aims for.

So, whatsoever the COD present in the system can then be converted into the in through these substantial steps to the final end product. So, these are the process we will discuss the detail of all these steps all these processes in the next class.

Thank you.