Wastewater Treatment and Recycling
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Lecture – 35
Anaerobic Degradation: Characteristics and Applications

Hello friends. So, we have been discussing about the Anaerobic Degradation this week. And, in this particular lecture we will talk about the various characteristic, what are the various factors that affect the anaerobic degradation? The characteristic of anaerobic degradation steps and processes and some of it is application ok.

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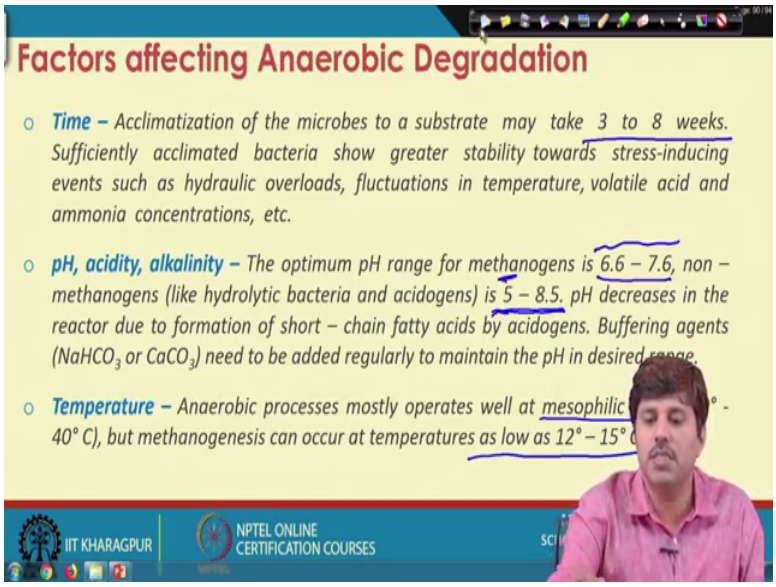

To begin with there are various factors that affect anaerobic degradation, the time it is one of the important factors.

So, as we were discussing earlier also the acclimatization of the microbes with the substrate present in the system may take significant amount of time. At times even it takes in fact, more than 2 3 months as well, but generally it may likely to take 3 to 8 weeks. If, we start with the acclimatized back acclimatized group of microorganisms to begin with we can reduce this time ok.

So, that is again advantage to starting with the acclimatized sludge or acclimatize bacteria which so, greater stability towards the stress, which come at the start of phase

particularly like in the form of hydraulic loads, in the form of fluctuations, in temperature, the level of various volatile acids the pH changes the ammonia concentration those kind of thing.

Then, there is effect of pH as well in the form of like the optimum pH range for methanogenesis 6.6 to 7.6 and non-methanogens like hydrolytic bacteria and acidogens is 5 to 8.5. So, methanogens has more narrow range and more susceptive to pH and alkalinity changes. The, what happens that pH decreases in the reactor due to formation of short chain fatty acid compounds by acidogens, acidogens have relatively higher range of working pH. So, they can work at pH 5.

Now, what happens that if acidogens are action and they are producing lot of acid? So, what happens that pH may fall and the methanogens may get inhibited in that sense. So, there is requirement of buffering agent in the form of weather sodium bicarbonate or calcium carbonate that can be added regularly and so, that we can maintain the pH at desired level, because if we go too low in the pH, the acidogenesis may get greatly affected.

Then of course, there is a effect of temperature. So, anaerobic process mostly operates well at the mesophilic range that is the optimum range 30 to 40 degree is the best temperature range kind of for the anaerobic processes. The methanogenesis can occur at temperatures even at low as 12 to 15 degree Celsius, but for more this thing it is more effective if the temperature is maintained in the good mesophilic range that way.

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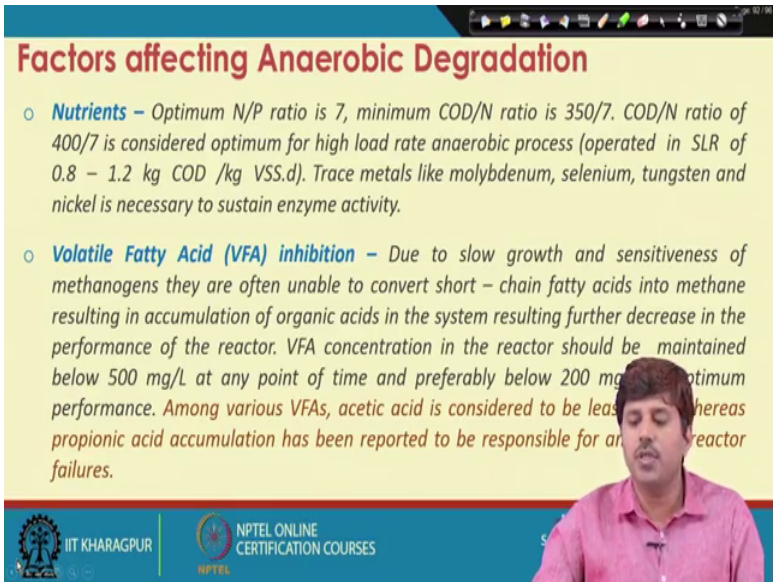

The other things that affect actually are the nutrients. So, how many like the, what is the level of nutrients? The optimum nitrogen to phosphorus ratio is 7, the minimum COD to nitrogen ratio is 350 to 7 ok. So, that way 350 to 7 is to 1 is the kind of ratio, which should be maintained this COD to nitrogen ratio of 400 to 7 is considered optimum for high load means the anaerobic process, which are high rate ok. So, that operated in and the range of say 0.8 to 1.2 kg COD per kg VSS per day.

There are various trace metals like molybdenum selenium tungsten nickel is also necessary to sustain the enzymatic activities in the system. So, that is the effect of nutrient a higher level of nutrient present in the system will not get removed because nutrient uptake is very low. So, there is some requirement of nutrient, which is fairly low as opposed to the aerobic system, but if there are more nutrients are present, we actually it cannot take up all the nutrients. So, the removal of nutrient will not be there, but the advantage is that because requirement is low. So, if there is need to be added nutrient will have to add very little nutrient.

Then there could be inhibition, because of various things the volatile fatty acids can lead to inhibition. So, due to the slow growth of selectiveness of the methanogens there often unable to convert short chain fatty acid into the methane ok and, that results in the accumulation of these organic acids again as we are discussing the accumulation of these

organic acid may reduce the pH. So, this can actually decrease the further performance of the reactor.

The VFA concentrations in reactor should ideally be maintained below 500 milligram per liter at any point of time and preferably below 200 milligram per liter or that range. So, the among various volatile fatty acids the acetic acid is considered to be the least toxic, it is not too like too much of it is not to highly toxic and it can easily convert it to the methane also relatively whereas, propionic acid accumulation has been reported to be responsible for the failure of various anaerobic systems and anaerobic reactors.

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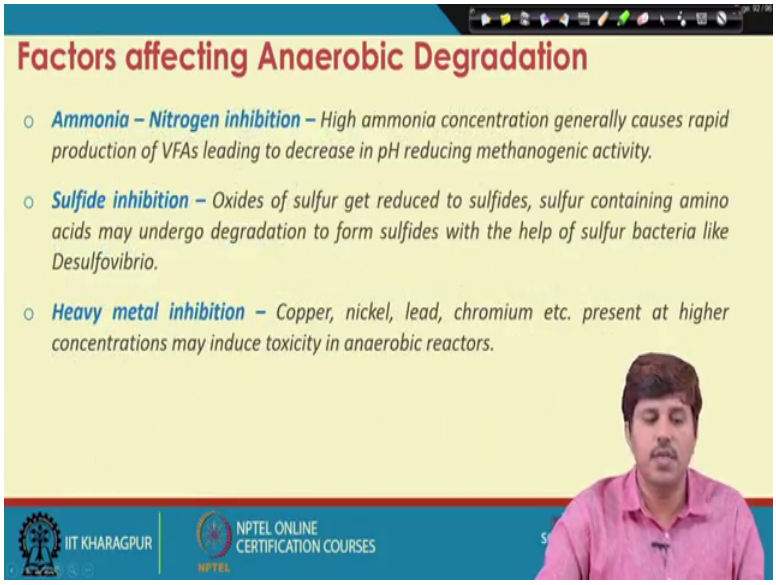

There is inhibition from the ammonia or nitrogen. So, high ammonia concentrations generally causes rapid production of the volatile fatty acids, again which leads to the decrease in pH and reduce the methanogenic activity there is inhibition from the sulfide concentrations. So, oxides of sulfur get reduced to the sulfides and sulfur containing amino acids may undergo degradation from the sulfide with the help of sulfur bacteria ok.

So, that again hampers there is a competition between the sulfate reducing bacteria and methanogens for that purpose and there is a possibility of heavy metal inhibition. So, various heavy metals like copper nickel lead chromium etcetera. If there present in significant concentrations, if there present in a little higher concentration they may induce toxicity to anaerobic reactor.

So, these are the susceptible points for the anaerobic reactor, which actually affects and controls the performance of anaerobic digesters or anaerobic systems.

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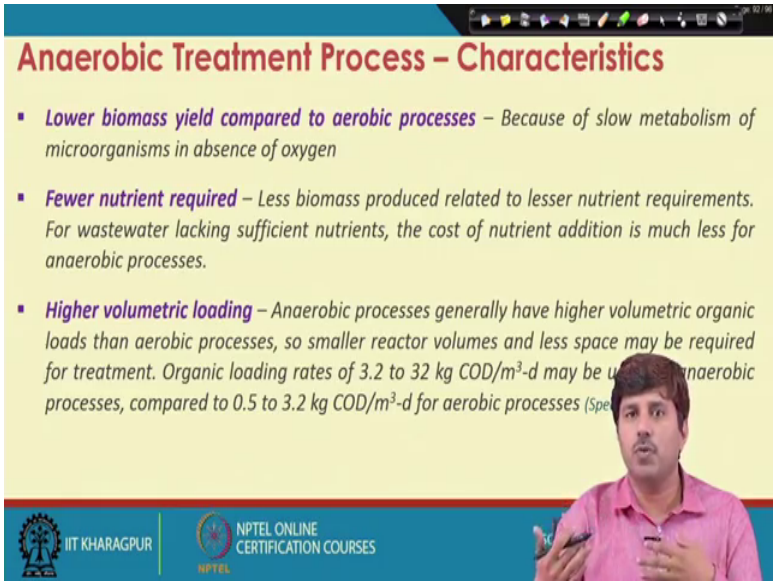

Now, if we see the characteristic of these processes. So, the lower biomass as the biomass yield is lower as compared to the aerobic processes so, because of slow metabolism of microorganisms. So, microorganisms in the absence of oxygen the metabolic rate of the microorganisms is slow and as a result they conversion of the substrate to the cell mass is very low and that results lower biomass yield roughly of the order of 5 percent as opposed to the aerobic process, which is 40 to 50 percent or even higher at times.

Then, fewer nutrient requirement as we were discussing that because the biomass produced is less the less biomass is being produced so; obviously, there will be lesser requirement of the nutrients ok. So, for wastewater where the there is not sufficient amount of nutrient present in the wastewater, and the extra nutrient is to be added. So, the cost of nutrient addition is much less for anaerobic process as opposed to aerobic process because the requirement of nutrient for in aerobic system is far higher as opposed to the anaerobic systems.

But, at the same time if there is already nutrient present in the system so, aerobic process can remove some of the nutrient, because they assimilate them into the cell mass, but in anaerobic system the nutrient removal is not too much, because of the less biomass

produced at the first place. Then, there are higher volumetric loading ok. So, anaerobic processes generally have higher volumetric organic loads, then aerobic process.

So, that in is in at terms advantageous because there smaller reactor volume and installed in a lesser space may be required for treatment it can handle the good load. So, organic loading rate generally 3.2 to 32 kg COD per meter cube per day is used for anaerobic processes. Whereas, just 0.5 to 3.2 kg COD per meter cube per day is used for the aerobic processes.

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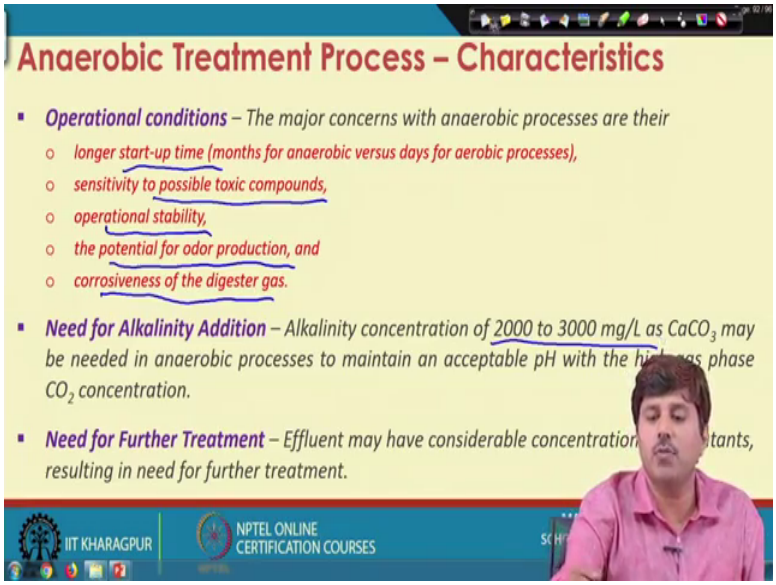

Now, if we look at the operational conditions so, we talk about various positive aspect there are negative aspects as well in terms of operational conditions. So, the major concerns with the anaerobic processes are there longer startup period as we discussed, it may actually go for months ok. For anaerobic process as opposed to few days in the aerobic processes there is sensitivity to the possible toxic compounds, there is operational stability issues are there the there could be potential of odor problems and there because it is generating CO 2 and methane. So, these gases could be corrosive. So, there could be impact on those as well.

And, there is a need for alkalinity addition in order to control the pH. So, 2000 to 3000 milligram per liter calcium carbonate needs to be kind of maintained for an acceptable pH with the high gas phase CO 2 concentrations. And, another thing as we discussed earlier as well that there might be need for the further treatment, because effluent which

is coming out of this thing may not have considerable removal of the pollutant. It could be considerable removal, but it may not actually bring it down to the desired level.

So, if let us say your COD limit is thirty and if you are starting with a waste which is having as influence COD of 2000 milligram per liter. So, it may bring 2000 to say like down to 300 400 200 in that range, but it may not bring it down to 30 ok so, that why there might be requirement of further treatment, in case of the anaerobic treatment processes, if it is not meeting the desired criteria.

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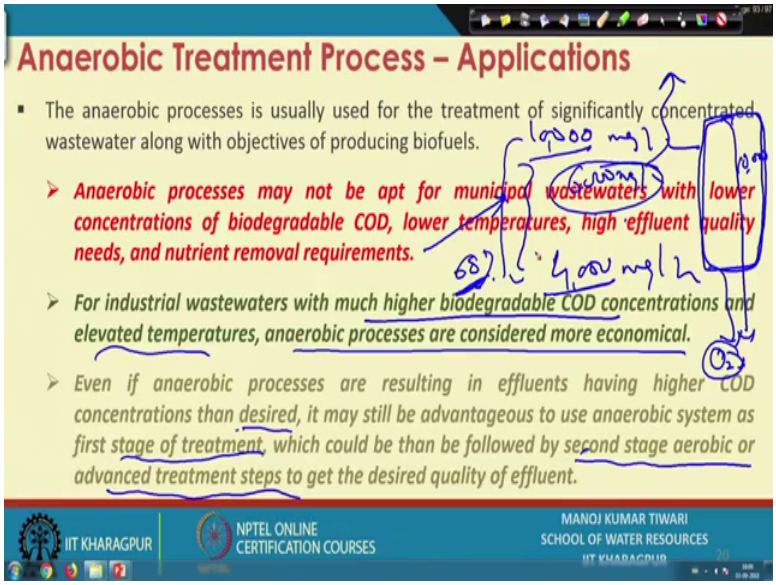

So, even after these limitations and as we discussed in the earlier week that number of installations of anaerobic reactors are increasing kind of exponentially. So, what and we discussed what makes it attractive as well? So, if we look at the application in the sectors in which this anaerobic treatment could be used. So, anaerobic processes is usually used for the treatment of significantly concentrated wastewater ok. And, why it is done there are several reasons. The first and foremost thing is that because the biomass growth is very low 5 percent. So, if you are starting with the low substrate concentration the biomass growth is going to be even low so, all most no biomass growth ok.

And, if you do not have biomass growing in the system and there might be like if we come up with a very good pretty good system it may work, but there might be possibility of biomass washout from the system. So, what happens that? This is one of the very

common problem, when the UASB is applied to the domestic sewage, that because of the low concentration of the substrate or low concentration of COD.

The amount of biomass produced is not significant and rather what we see that there is biomass washout takes place, because these when with low COD the biomass which is even though the biomass, which is produced is not of good quality or is not of high density. So, the retention of this biomass is difficult and as a result we may see that biomass getting washed out with the effluent.

So, we end up losing biomass instead of producing biomass and that becomes a problem, because if the reactor cannot sustain significant or sufficient amount of biomass, it cannot actually give you the good treatment ok. So, that is one problem and further the with the low amount of influence COD. The potential of generating methane is also very low and if you go on trapping that methane or putting a purification system. So, that makes is a very very costly process and the collection of methane even though methane is being produced even though methane is being generated, but the collection of methane at first place becomes a very challenging task in terms of like the financial sustainability, whether it may or may not be financially sustainable it has to be seen.

So, those are certain issues the kind of biomass washout the low biomass production the not feasible collection of methane and then if you allow methane to go away. So, it has far more higher greenhouse gas potential as opposed to the carbon dioxide and can actually be add to global warming and those kind of thing. Though, that is the reason that anaerobic processes may not be considered apt for municipal wastewater with lower concentrations of biodegradable COD.

It is still it is not as such that it cannot be used there are anaerobic processes or anaerobic reactors working for the treatment of sewage as well, but if you see the number wise it is the anaerobic system, which kind of dominate grossly. And, they are generally aerobic systems are generally preferred over an aerobic system for the treatment of municipal sewage, because of the low concentration of biodegradable COD, lower temperature and high effluent quality needs.

So, and again you may need nutrient removal as well, which is not possible in the anaerobic system, but for industrial wastewaters if we see the industrial wastewater generally has generally have significantly high amount of biomass sorry significantly

high amount of substrate concentration. So, then with much higher biodegradable COD concentrations, it becomes very good to go for anaerobic system.

There temperature might also be evaluate like elevated the volume is less. So, that way we can go for a high rate anaerobic treatment process and we can get even if like even if we do not treat it to the desired level. Even, if your anaerobic system is not treating it to the fullest to the sufficient level a partial treatment is also welcome, because it is not taking too much of energy, if you go into the aerobic system the energy requirement would be quite high ok. So, that is why.

So, anaerobic processes are generally considered much more economical for industrial wastewater and even if these are not resulting in the effluent having higher COD concentration then desired. Then, also it is advantageous to use anaerobic system as a first stage of treatment or as a pretreatment and which could then be followed by the second stage of the aerobic or advanced treatment steps to get the desired quality of effluent.

Because, let us say you are starting with a COD of 10, 000 milligram per liter ok. And, your anaerobic system is just giving you say 60 percent removal. So, it is bringing this 10, 000 down to say 4000 milligram per liter. And, then you are going for let us say aerobic process or oxidation process. So, your oxygen requirement now or the requirement of aeration would correspond to just 4000 substrate concentration, but if you directly use this thing your oxygen requirement is too high because that will correspond to 10000 milligram per liter substrate requirement.

So, the amount of oxygen or amount of aeration you save here is worth adding a anaerobic step over here in terms of this thing, because you are not providing any energy to this one and you are getting removal of 6000 milligram per liter. Even at very moderate efficiency, without too much of investment and rather this if let us say of the 6000 milligram per liter significant part can be converted in the form of gas so, in the form of biogas.

So, it may actually end up sort of generating energy or making this process self-sustainable. And, that is why it is advisable even at lower effluent even at like even if they effluent concentration or the outlet in the effluent which is being produced is not

meeting the criteria then also we can use at a first stage of treatment ok. And, that is how it is being used in the industry?

So, many of industries are using UASB to begin with or anaerobic process to begin with and then go on to the aerobic or advanced process for producing effluent of the desired quality ok. But, again that way also this is again always helpful to work in that range.

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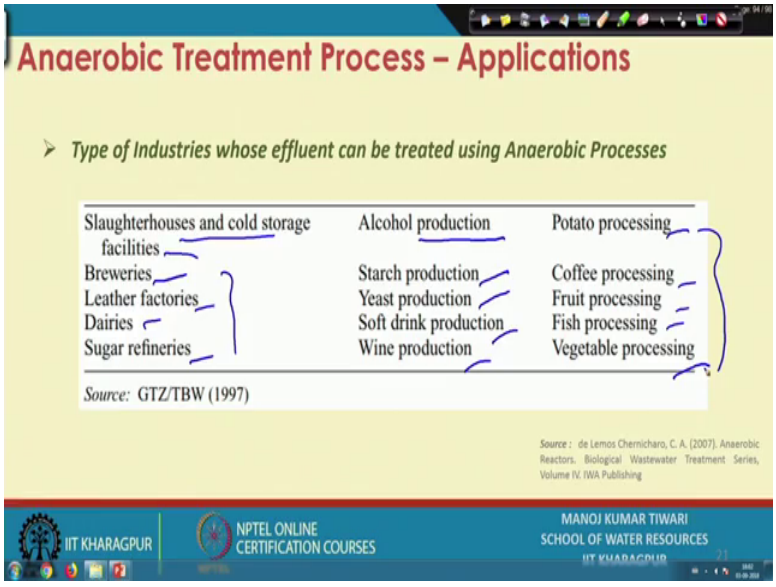

Now, if we see the various types of industries whose effluent can be treated using anaerobic processes? So, there are like slaughterhouse and cold storage. So, all such effluent switch have with which have relatively less recalcitrant compound and more of the biodegradable organic matter. So, very high COD with biodegradable products like alcohol production ok.

So, there is lot of a in the alcohol production industry release lot of COD 20,000 30,000 40,000 even at times higher than that ok. And, that can actually be degraded or decomposed pretty nicely even if with the significant. Then breweries industry may have COD in or leather factories may have dairies sugar refineries these may have COD at times in the lacks ok. So, refineries can actually come up with a COD of say 2 lakh.

Now, imagine the kind of irrigation requirement would be there if you want to degrade 2 lakh COD with activated sludge process ok. So, that is going to be a huge costly intensive process and if with that thing even anaerobic system which is 60 percent 70

percent efficient can remove 70, 000 of COD without much of the cost it is always a well come step. So, that is how these are used in this, then starch production, yeast production, soft drink production, wine production.

So, these are all the industries which leads to the effluent with high COD value potato processing, coffee processing, fruit processing, fish processing, vegetable processing. So, these are the variety of industries, which actually can be kind of we can go for using anaerobic processes as may be first step or there are many times that multi stage anaerobic treatment is also provided.

So, you just provide us anaerobic treatment and then let us say with 60 percent efficiency. So, if your influence COD is say 1 lakh with 60 percent efficiency you reduce down to 40,000 provide another anaerobic system which can bring that 40,000 to say let us further bring down to say 10000 or 8000 6000 and then one can go for the other processes. So, a sequential step can also be chosen.

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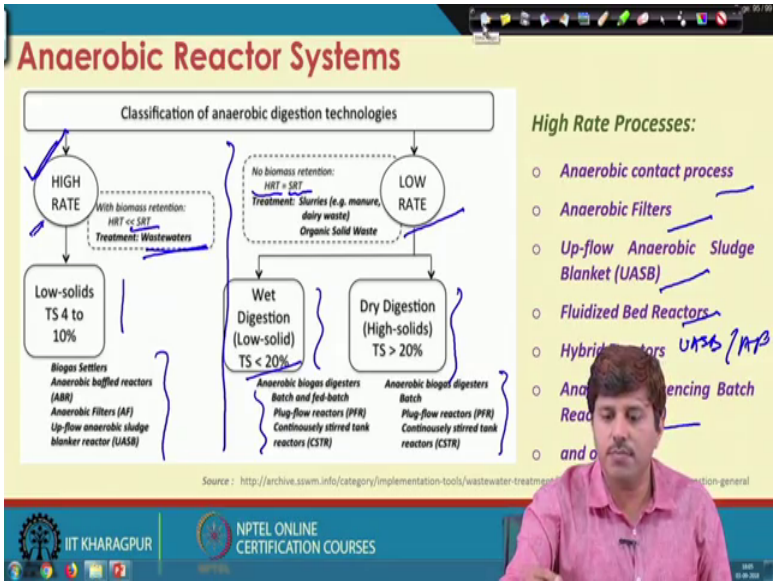

Now, if we see the various reactor systems in the anaerobic this thing. So, there are low rate reactors and there are high rate reactors, these low rate reactors there are like primarily work good for wet digestion or dry digestion. So, for mostly suited for the digestion of solids ok, when you have low solid content less than 20 percent you can go for wet digestion. When you have high solid concentration we can go for dry digestion, but these are for solid we are more interested in the this zone, which is high rate

anaerobic processes, which is good for the wastewater where the solids typically total solids are 4 to 10 percent only ok.

So, with biomass retention the hydraulic retention time is far less than sludge retention time ok, because in low rate process no biomass is retained. So, the time the amount water or the amount your material spends in the reactor same is the amount of sludge, then it is discarded whereas, in high rate processes the hydraulic retention time is much much less than the sludge solid retention time or sludge retention time.

So, the sludge which is produced is retained into the system and the water has much lower retention time. So, that is why these process are high rate this works well and there are quite a few high rate processes, there are anaerobic contact processes anaerobic filters, there are UASB reactors of which is called as up flow anaerobic sludge blanket. There are fluidized bed reactors and then there are hybrid reactors means we can have a hybrid of say UASB and anaerobic filter or UASB and anaerobic contact process that kind of thing. Then, there is sequencing batch reactor anaerobic sequencing batch reactor which is known as ASBR and few more other configurations are coming in the industry.

So, that way the different configurations are being used in such system. So, these are the some of the basic like reactor types.

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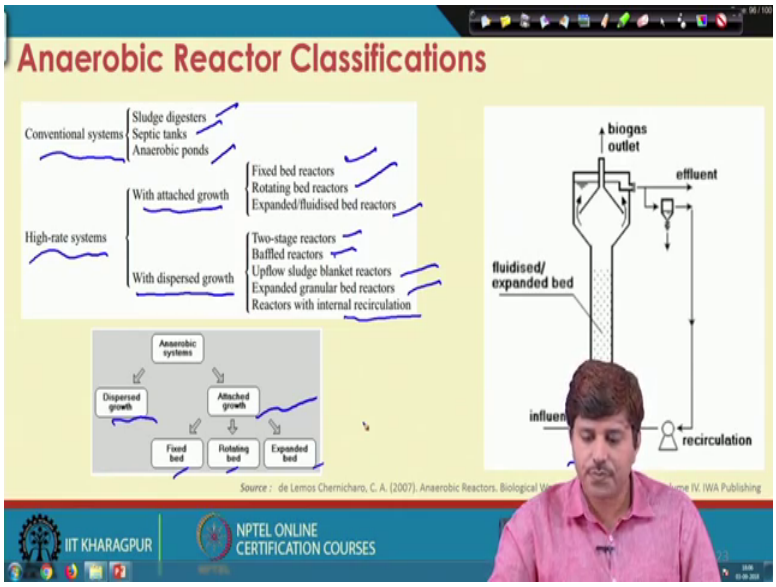

If you see the classification of these reactors. So, there are conventional systems which are like sludge digester septic tanks or anaerobic pond which has been used since as and there are high rate systems for wastewater purpose. So, these high rate systems are with dispersed growth or with attached growth. So, in attached growth we can have fixed bed reactors or rotating bed reactors or fluidized bed and expanded bed reactors.

And, then in the dispersed growth again we can have 2 stage reactor or upflow anaerobic sludge blanket kind of Baffel reactors, we can have we can have expanded granular bed reactor ok, which is kind of a fluidized system ok, which keeps in the suspension and then there is a possibility of reactor with internal circulation ok. So, we can recycle some of these things or like this an example of fluidized bed reactor.

The systems can also be classified based on whether they are dispersed growth or attached growth system. So, dispersed growth system as we discussed this and attached growth system will have fixed bed rotating bed or expanded bed system. And, there is a quite a few classification of the dispersed growth system.

So, these are some of the common configuration and we will take up a few in the next class we will start with upflow anaerobic sludge blanket and then as the time permits will take few other configuration if possible. So, see in the next class.

Thank you.