Wastewater Treatment and Recycling
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Lecture - 36
Anaerobic Treatment of Wastewater: UASB and Other High Rate Anaerbic Processes

Hello friends, and welcome to the 36th lecture for this course Wastewater Treatment and Recycling. This week in the week 7 we have been discussing about the anaerobic treatment of wastewater. And in earlier lecture, we discussed the basic concepts of anaerobic treatment, how anaerobic treatment takes place, what are the various aspects related to the anaerobic treatment and then what are the different systems that are there for anaerobic treatment of wastewater.

So, there are systems for generally sludge digestion and those kind of thing, but we are primarily focusing onto the waste management aspect wastewater treatment aspect. So, we will discuss the high rate processes, various high rate processes or various systems anaerobic systems which are used for the treatment of wastewater. So, this is the prime agenda for this lecture. We are going to talk about one of the most common anaerobic treatment systems which is up learn aerobic sludge blanket UASB system and we will briefly talk about some other high rate anaerobic treatment processes in the later part of this lecture.

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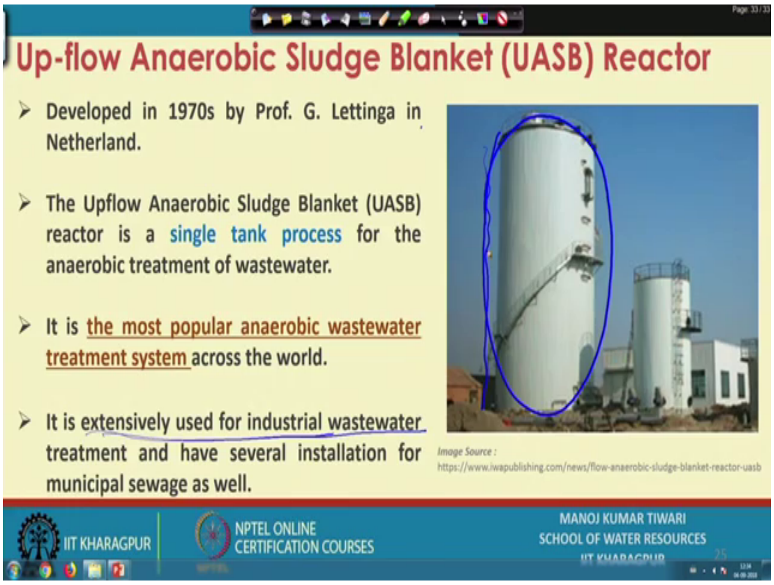

So, we will begin with the UASB reactor. UASB is actually Up-flow Anaerobic Sludge Blanket reactor. So, it is expanded as up-flow anaerobic sludge blanket. It was developed in 1970s by Prof. G. Lettinga in the Netherland. And it is actually have been immensely popular for the treatment of industrial wastewater. Though the treatment of domestic wastewater is also being done with the UASB reactor at quite a few places now; initially it was not that popular, but it is slowly getting popularized in the for the treatment of municipal wastewater as well. But in the industrial sector it is quite extensively used for industrial wastewater treatment.

Overall if we look at all the anaerobic treatment systems the UASB is by far the most popular anaerobic treatment system across the world so that is the most popular anaerobic treatment system. It is actually just single tank process. So, what we have eventually is a single tank like this or and all the treatment processes there are various steps as we were discussing the various steps for anaerobic treatment. So, all those things are actually achieved within this tank itself. So, this tank takes care of all such steps and processes.

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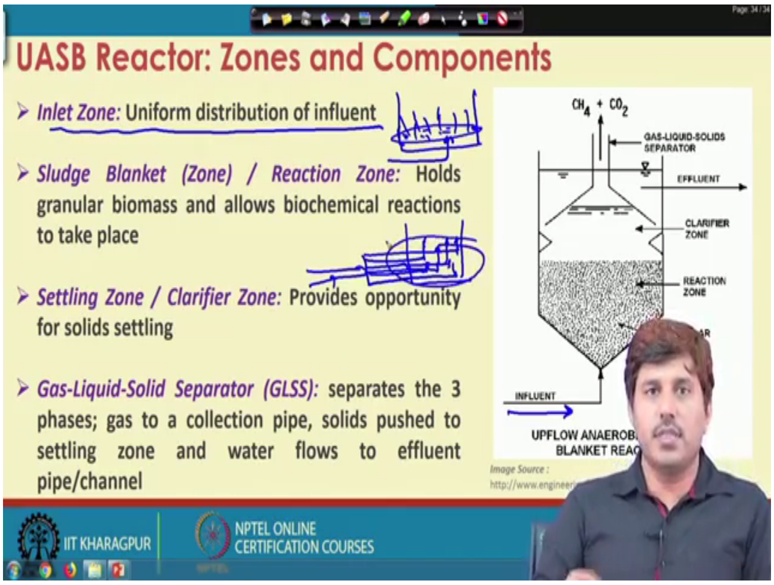

Now, we have already talk about what are the various reactions that takes place in an aerobic system. Same thing happens in the UASB reactor as well. But this reactor is kind of virtually compartmentalized into various zones, there is no as such clear cut separation between the zones. But ideally if we see so there are various zones or various compartments, various components of a UASB reactor. So, the first thing is when the water it is upflow anaerobic reactor. So, flow direction or regime of the flow is up. So, the influent is given from the bottom.

So, there is a there would be in fluent line in the bottom, which eventually will bring the influent. Now, this influent line put the water in the bottom or base of the reactor; and from there we put some mechanism for the uniform distribution of the flow. So, the first zone or first part it may not be called as a zone as such, but it is first part of the reactor where this influent section where the influent is uniformly distributed across the bed.

So, if let us say you have a UASB reactor of this kind and I am putting a influent pipe like this. So, if we do not do anything maybe I can put a plate over here perforated plate which allows, then effluent to walk to move through all these perforations or the alternate is that I have like the influent main influent line is coming. And, then I have several distribution of this infinite line so some leaving influent here some leaving influent here, some leaving influent here some leaving here some other line living influent here.

So, I may have that way various lines various sub channels, which discharge the which put the effluent at the different part of this reactor, and that is how this influent is distributed within the reactor, so that is the inlet zone which is about the which kind of distributes or is attempt to uniformly distribute the influent.

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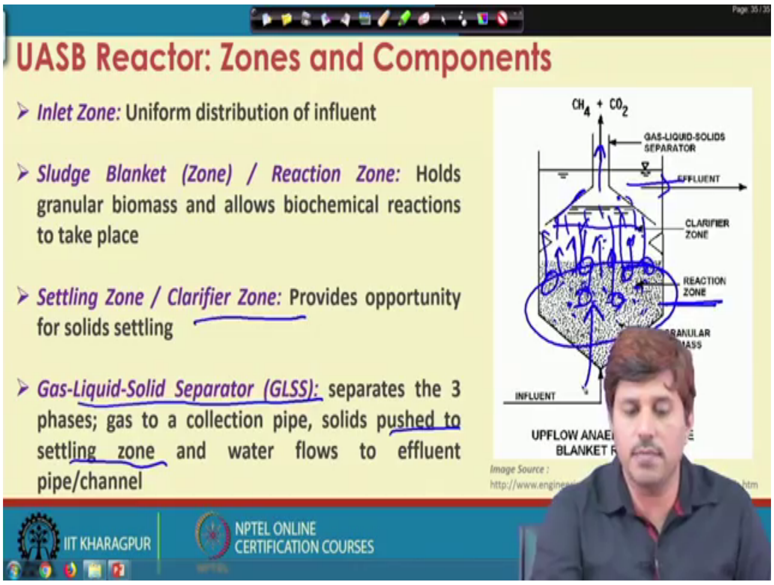

And then the water enters into the next zone, which is called sludge blanket zone or reaction zone, so that is the next zone, where the granular biomass stays. So, it holds this granular biomass, and also it allows biochemical reactions to take place in this, because here is the biomass and your influent is reaching to this zone. So, what happens that your substrate in the influent gets an opportunity to interact with the biomass, and the bacteria or anaerobic bacteria were present in this, degrade and decompose that in that substrate or that organic matter in this zone only.

So, this becomes your reaction zone as well. So, this is called either reaction zone or sludge zone or sludge blanket ok, so that is next part of this. Then we have a settling zone or clarifier zone in the reactor. So, upper part what happens that when the degradation decomposition takes place your water further moves up, now while it is moving up, it can carry some solids along with it. And we discussed in the previous lectures of this week that anaerobic decomposition essentially converts the organic matter into the biogas and very little of sludge is formed.

So, since majority of the portion is getting converted to biogas, so there is a lot of gas bubbles also arises. So, these gas bubbles also lift up because of the nature of the gas, so the gas bubbles go up and the water because it is a upflow. So, there is a hydraulic thrust and that takes the water up in the reactor, so water is moving up, gas is moving up. And along with gas, we may have certain solids attached here, so they may also move up. So, what happens that the solids which are moving up, there is some space provided for them, which actually can make the solids settle. So, there is a kind of settling zone or clarifier zone is provided, which allows the or which kind of provides an opportunity for solids to settle down back to the sludge zone.

And what then the thing which is actually moving from here goes to a GLSS, which is gas-liquid-solid separator, which separates these three phases. The gas liquid and solid phases are separated. The gas goes to a collection pipe or collection channel. The liquid goes to the effluent pipe or effluent drain. And the solids then are basically strike to this wall, and put down the like then pushed back into the settling zone, and from so solids will be pushed back to settling zone. And then from there, they can again settled ok, so that way the three phases are separated.

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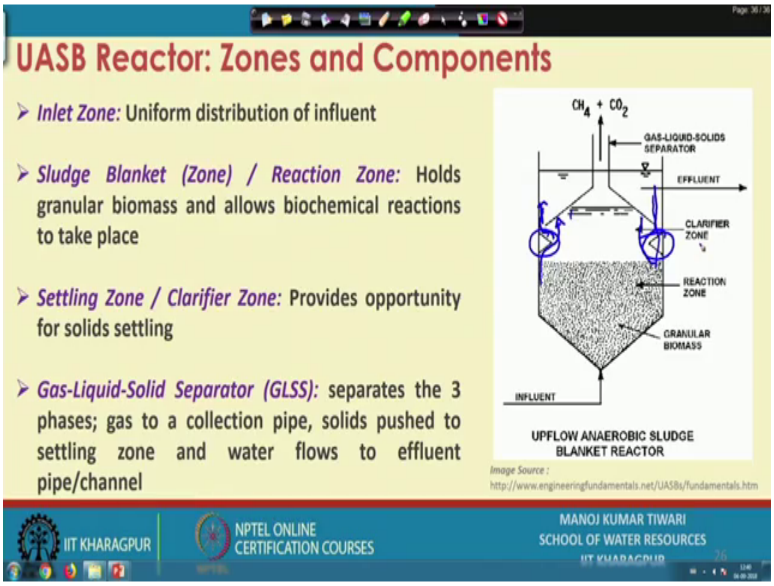

Of course, there are some other components like there would be a what we call is deflector. So, this kind of deflectors would also be there ok, which deflects the flow and does not allow the flow to basically directly pass through the openings across the gas-liquid-solid separator. So, this kind of deflects the flow and then flow regime becomes this. So, solids and this thing and or gas will go through this, while the liquid can again sneak in through this opening, so that is another component, if we can say that way. So, these are the basic zones or components of a UASB reactor.

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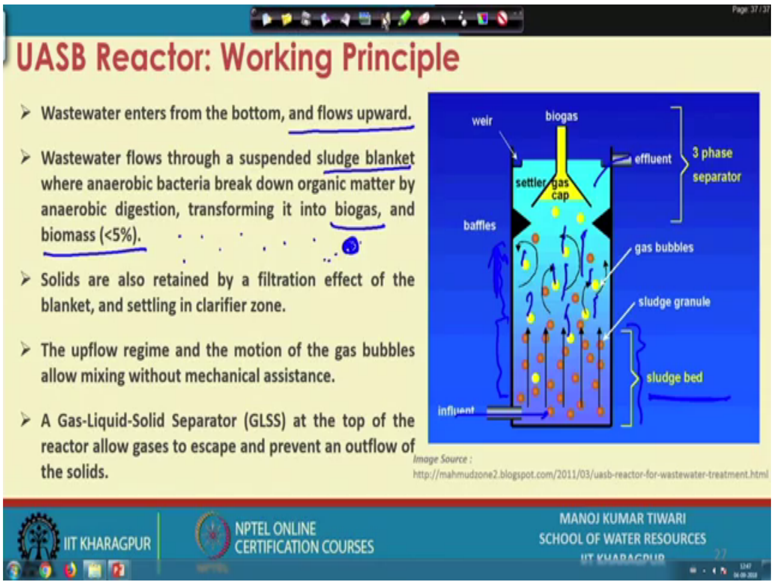

Now, if we see the working principle, what actually happens in the reactor, so it is essentially a anaerobic degradation process anaerobic decomposition process. Now, what happens, that when the wastewater is entering from the bottom that is the first step, as we discussed. So, wastewater enters from the bottom and moves up. So, there is an upflow, the water actually moving in the upward direction, so there is a upflow in the reactor. Water entering from the bottom, again if there might be some distribution mechanism as we say we can put a perforation plates or have the different level or different space ports for the entry into the reactor.

Then the wastewater flows through this sludge zone or a sludge blanket. Now, this sludge blanket consists of anaerobic bacteria or more, so basically the granular biomass (Refer Time: 10:22). What is granule, granule is actually like we have the individual bacteria's say separately individual bacterium separately. Now, since their mass is very little ok, it is very difficult they are of the order of say one micron typical size of the bacteria. So, size is a small, mass is a small, and that is why they have very poor settling characteristic. And particularly in a reactor like upflow reactor, so what happens that your biomass or the sludge if it is independent or if it is individual sludge, so what is possible that this sludge because of its low mass and very small size, it can actually flow through the water and can escape in the effluent. So, the settling characteristic is not good for that sludge.

What is rather preferred in a UASB reactor, and which actually happens also when we have a significant amount of organic loading that these cells are there. So, there is agglomeration of various cells takes place. So, like quite a few cells agglomerate over there due to the growth and splitting on one another and due to the nature of the sludge bed. So, and there is a bio-film formation also takes place although on the sludge mass itself, so that way we get what we call is granules. So, granules are basically agglomerate of biomass. And since, they are bigger in size, so they have very good settling characteristic.

Once the granules are form, the sludge retention improves, because sludge washout will reduce. If there are individual cells or there are ungranulated biomass in the system so because of their low settling characteristic or low mass smaller size, they tend to flow, they tend to basically get washed out along with a water, so that sludge washout is a major problem. Particularly in the when you have low organic content coming into the system, so you do not generate that much of sludge anyway. And the mass of the sludge which is generated or the cells which is being produced are also not that great, so they are not that solid or they are not that compacted, the granule formation does not take place.

But, in a high strength wastewater, when you have significant amount of organic matter available, the bacteria grow in relatively larger number, and they interact, attach, forms granule, and that actually enhances the retention of the sludge in the reactor, which is a important aspect important phenomenon for the treatment of wastewater. So, this sludge retention is ensured within the reactor and that is helpful in a way, because we can retain the sludge, so this is where like the sludge bed that we have typically. So, in sludge bed, what these biomass or granule or anaerobic bacteria or the sludge granules are retained there.

And then when the wastewater flows through that so all the like different processes of the anaerobic decomposition, so your hydrolysis, acetone genesis, acetone genesis, and methanol genesis all will take place in this zone. So, as we were just discussing in the previous slide so; this is your reaction zone and the reaction takes place in this zone itself. So, what happens in this zone or in this sludge blanket, when the water is passing through the sludge wastewater is passing through the sludge blanket, the anaerobic bacteria are there or in anaerobic or the anaerobic granular sludge present in there, they will break down the organic matter by the usual process of anaerobic digestion. And, of those process of digestion as we discussed in the earlier lecture; what is the final end product, the final end product is the biogas and little of biomass ok. So, some part of new cell will also be formed, but the large portion converts to the biogas converts to the carbon dioxide and methane.

Now, so the gas which has been produce, so the yellow are say gas bubbles. So, these gas bubbles also because they have a tendency to go up, so these gas bubbles will lift up ok. And some of the new cells form or from the upper portion or the lighter granules lighter cell mass, will also may also float along with the water, because eventually water is also moving up, there is a up thrust. So, it is a upflow reactor we are pumping water from down, so water will find its path. So, along with the water, the solids also flow, some of the solids may not all large portion actually is retained in the sludge bed, but some portion may also actually float and go to the upper zone.

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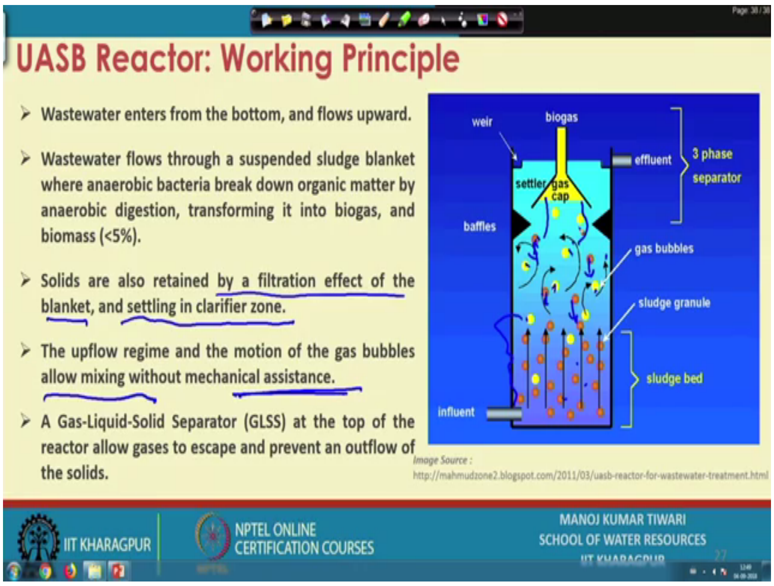

Now, then there is a settling zone, which actually because of course, you are the yellow bubbles or gas bubbles are not going to settle, gas has a tendency to rise. So, they will go up, but the solids or the sludge, which is having they actually can get settle in the settling zone. And so, the solids are retained. First thing is that majority of the solids will be retained in the sludge zone itself, so they are retained by the filtration effect of the blanket. But, those who are actually even going, so they get to a clarifier zone, and there is a possible settling of solids from the clarifier zone also. A still some solid will make it the smaller solid or fine solids will still make it upper, then your settling zone also.

So, what happens that the upflow regime and motion of these gas bubbles also ensures, there is a significant mixing. Because, if you have distributed, and then the flow is upflow and the there is a gas being produced, so that is also moving. So, this ensures kind of reasonable amount of mixing without any mechanical assistance or without providing any mechanical device for the mixing purpose, so that is another advantage that we do not need any such mixing equipment also.

And finally, so what happens that what is coming up, the water that may contain little amount of solids or biomass that will contain lot of gas bubbles in this, and then water is already there. So, there are gas, there are liquids, and there are solids all three things actually are coming into the clarifier zone and moving up. So, now what happens that at the we have a baffle or deflector kind of thing, which deflects the flow does not allow the flow to go directly. And then over and above that, we have a cap or funnel or those kind of things.

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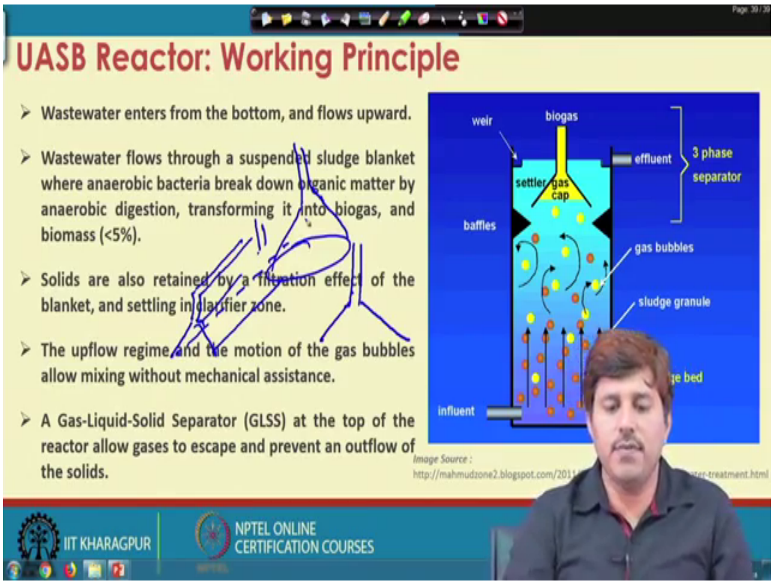

So, depending on the whether it is circular system rectangular system or what whatsoever kind of system, so we will eventually have a deflector device like this or in a circular system it can actually be a like particularly like inverted funnel kind of thing can also be there. So, we can have a basically let say inverted funnel like a device like this or we can have a rectangular channel device like this. So, basically it will be like this in the direction that way ok, so that way we have devices, which are called gas-liquid-solid separator or GLSS.

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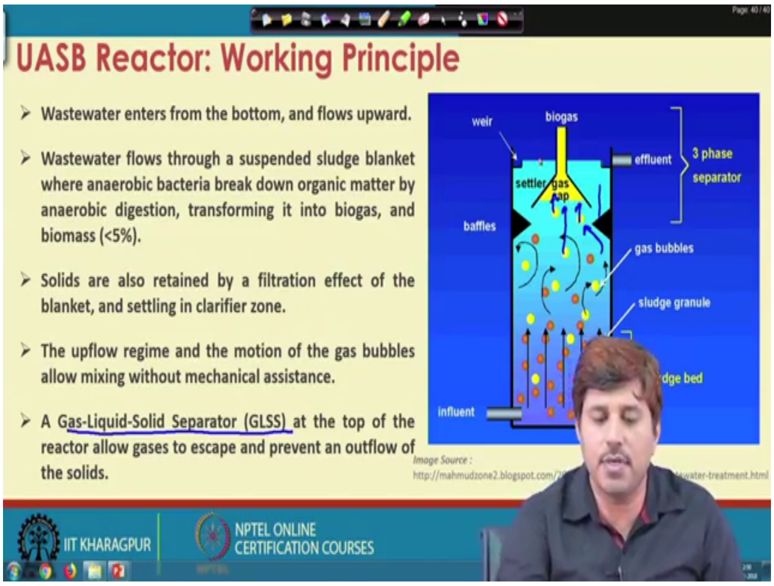

So, as we are discussing the role of GLSS is to separate or to phase out the gas liquid and solids from the reactor from the material or mass which is coming up. So, what happens that this deflector helps the gas bubble not to go directly, but to basically it deflects the gas bubbles and solid particle along with the water to this zone. And then the gas will once it is deflected, it will rise up ok. So, this gas bubbles that way go up, and then there is a gas cap or gas trap.

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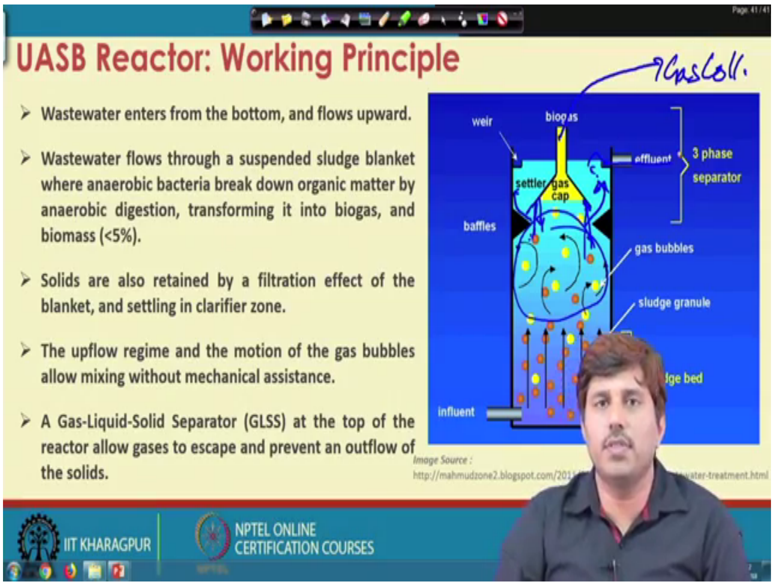

And through this pipe or tube, this gas is collected. So, this goes to gas collection system eventually. So, our gas is separated, it is got collected or it is got basically separated away from the water. Now, what happens to the solid and liquid over here, water here, so solid particles also basically rising up.

So, as they rise up, they strike to the walls of gas-liquid-solid separator GLSS, and this wall does not allow the solids to move up. So, as they strike, this wall will push them back. So, they are pushed back again to settling zone, and they come back to the clarifier or settling zone, and again try to get settle, so that improves the washout of solids as well the GLSS, and able to separate solids that way.

And water will eventually find its path through these openings, and come to the effluent section from where we collect the overflow is collected in a wear, and that eventually goes to the effluent system. So, this is how the UASB reactor works. This is the what is the working principle of a typical UASB reactor.

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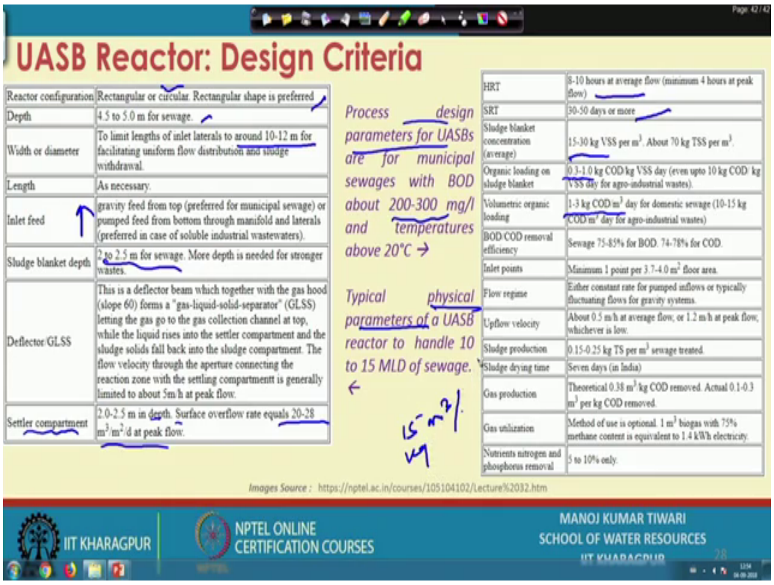

Now, if we see the various design criteria ok, so the design criteria again there is reactor configuration, it can be rectangular or circular. If we see the physical parameters over here, so it can be rectangular or circular ok. Rectangular shape is generally preferred. The depth is 4.5 to 5 meter for sewage treatment. The width to diameter is the inlet length of the literals are around 10 to 12 meter.

Length could be as necessary ok, it is inlet feed is generally gravity feed from the top for municipal sewage for many other this thing, but UASB is generally bottom fed, so because it is an upflow system. The sludge blanket depth is 2 to 2.5 meter. The deflector and GLSS is basically can be kind of gas hood of slope 60 degree, which forms this GLSS. There is a settler compartment, which could be 2 to 2.5 meter depth; the surface over flow rate could be 20 to 28 meter cube per meter square per day at peak flows.

If we see the process design parameters for typical UASBs treating municipal sewage having BOD of the range of 2 to 300, generally this minimum 250 or 200 BODs must for operation of UASB reactor higher is preferred. So, the HRT needs 8 to 10 hour, if the your BOD load is higher, you can go for a lower HRT. The sludge retention time is 30 to 50 days or even more. The sludge blanket concentration is 50 to 30 kg VSS per meter cube.

Then the organic loading rate could be point one to 0.3 to 1 kg COD per kg VSS per day, or 1 to 3 kg per COD per meter cube, the volumetric organic loading rate. Now, the volumetric organic loading rate is this is for kind of sewage for industrial processes. The volumetric loading rate could be as high as 15 meter cube per 15 kg COD per meter cube ok, so that is also possible to have a organic loading rate for of that order ok.

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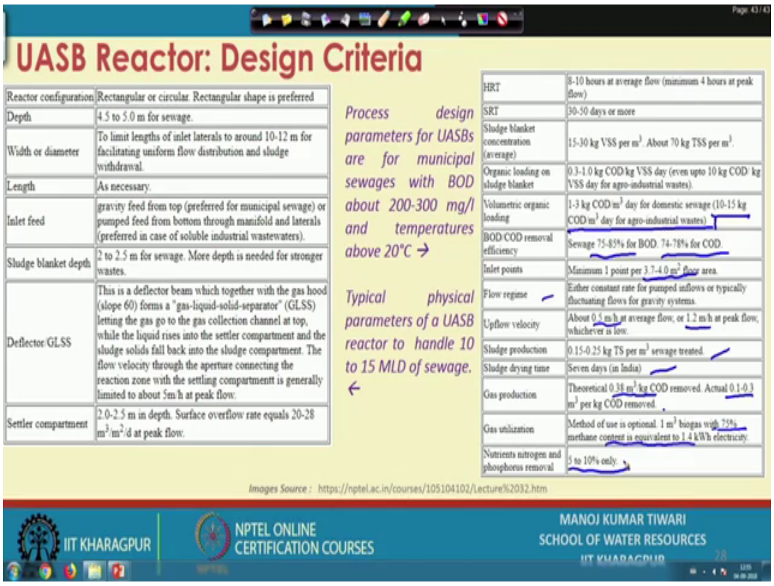

So, this could be up to like as said that agro-industrial wastewater, it could be 10 to 15 kg COD per meter cube; then BOD to COD ratio 75 to 80 percent for BOD ok, 74 to 78 percent for COD. The inlet point minimum 1 point per this much square of floor area, so many inlet point is needed for the even distribution of this. And then that way there is flow regime. The upflow velocity should be 0.5 meter this thing; or at max like peak flow is 1.5 meter per hour.

Then the sludge production is this much; sludge drying time typically 7 days in India. The gas production is 0.38 meter cube per kg, COD removed. This is the theoretical, actual would vary 0.1 to 0.3 meter cube per kg per meter cube per kg, COD removed. The gas utilization this method of use is optional 1 meter cube of biogas with 75 percent methane content is equivalent to around 1.4 kilowatt hour of electricity. And nutrient nitrogen and phosphorus removal is very little. So, these are the other criteria’s.

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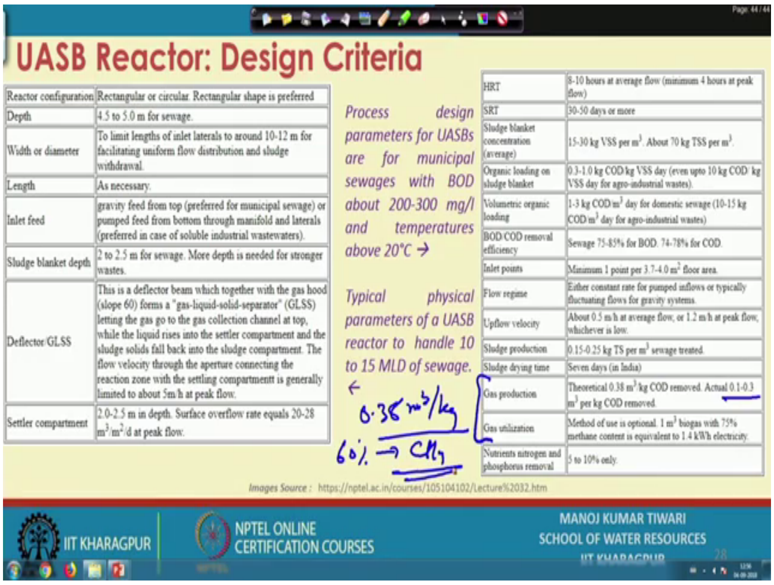

Now, the important point or key points at this place are that the typically, the gas which is produced, and gas where it could be utilized will depend on the processes kind of processes ok. So, generally the 0.38 meter cube per kg of gas is produced theoretically. The actual gas production could be somewhere between 0.1 to 0.3 meter cube per kg of the COD. And majority of this gas which is being produced, so close to 60 percent is in the form of methane, we can take the calorific value of methane, and that way we can see.

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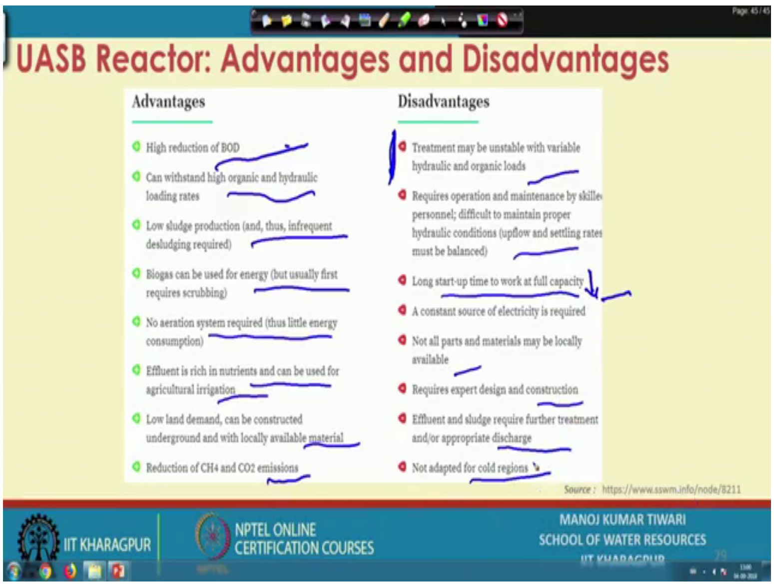

Now, whether we want to use this gas or not that again is a big question, because there is aspect of the treatment and removal of this the purification of this gas may come into the picture, which is a cost intensive process. Now, if we look the various advantages and disadvantages of UASB reactor, of course all the advantages or disadvantages all major advantages and disadvantages associated with anaerobic processes are there for the UASB reactor as well. So, like there is a high reduction of BOD can be observed. Then there is it can withstand high organic and hydraulic loading rates as we discussed. So, quite a few like very high COD even also can be used.

Low sludge production so there is like desludging requirement is pretty infrequent. The biogas can be used for energy. And then no variation system is required, because we do not need those things and mixing is ensured by the hydraulic regime of the system itself. Then effluent is may be rich in nutrients and can be used for agricultural irrigation. So, nutrient removal is not there, so the effluent which is coming may be actually having good amount of nutrients. So, can be directly used for agricultural practices, and that may reduce the fertilizer consumption as well. The land demand is low land requirement is low. Reduction in the CH_4 and CO_2 emission is another advantage.

And then the disadvantages is treatment may be unusable with variable hydraulic and organic loads. So, there if there are heavy shocks coming in terms of hydraulic shocks or organic shocks, so there is possibility of reactor failure. But, that can be taken care with if we go for granular sludge, because the major problem with high hydraulic loading rate or this thing is the sludge washout. So, if you are having a granular sludge that problem can be taken care to some extent.

Then it requires operation and maintenance by skilled personnel; the long start up time to work at full capacity. So, generally as we discussed for use well anaerobic processes, the UASB also has a long start up time. But, if we seed the reactor with good granulated sludge to begin with, we can reduce that start up time as well. So, then there is a possibility of improvement over here. Then a constant source of electricity is required for the pumping. Not all parts and materials may be locally available. Then it may require expert design and this construction.

The effluent and sludge required for the treatment or appropriate discharge, so because the efficiency if not that great, so then it may go for it may require further treatment. And generally, not adopted for cold reason because, as we discussed that it is the mesophilic bacteria which works based in that range. So, if you are working in a colder climate, the mesophilic bacteria may not be that efficient, and may not be that effective in treating and managing that sludge, and the managing that treatment procedure, so that way you may further see the loss in the removal efficiency or loss in the performance of the reactor. So, that is why it is not generally adopted or generally recommended for colder reasons.

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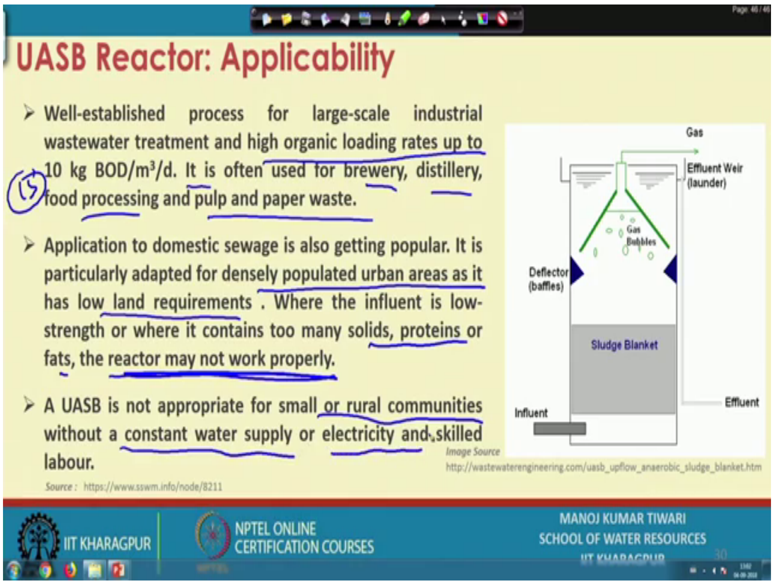

And so, in terms of applicability if we see, so it is a well-established process for large-scale industrial wastewater treatment and high rate organic loading means for industrial wastewater treatment, where there is high organic loading rates up to 10 or even up to 15 actually can be easily used. So, it is often used for brewery, distillery, food processing, pulp and paper waste it is pretty common for these. It actually in the industries, it is very very popular all the industries which produce high strength wastewater, generally go as a to UASB reactor as a first step or maybe other anaerobic process at times.

Then the application to domestic sewage is also getting popular. It is particularly adopted for densely populated urban area as it has low land requirement ok, where the influent is of low strength or where it contains too many solid, proteins or fats, the reactor may not work properly, so that is the problem that when your COD influent COD is too low, there is not sufficient organic matter present in this. To sustain the anaerobic growth or to sustain the anaerobic processes, it may actually not work properly. The too many solids or kind of proteins or fats, the complex organic matter may also give some problem at time.

And it is not appropriate for small or rural communities with a without basically constant water supply or electricity. So, because we need to pump the water continuously into the system, and we need to the kind of for that purpose, we need regular electricity also. The consumption is low, but requirement is there, because we it is a upflow reactor, so we will have to pump it there. And generally, being a continuous function, we cannot operate it in a let say batch systems usually. So, we go for continuous flow operations, and that kind of leads to the requirement of a constant water supply and constant electricity source ok, and of course there might be skilled labour requirement, which is difficult to find any small and rural communities.

So, these are the major application of the UASB reactor. And we will conclude this session here. And in the next lecture, we will talk about some of the other high rate processes, and how their application can how they can be used in the field for the anaerobic treatment of wastewater.

Thank you.