Biological Process Design for Wastewater Treatment
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Lecture 26
Up-flow Anaerobic Sludge Blanket (UASB) reactor

Welcome everyone in this NPTEL online certification course on Biological Process Design for Wastewater treatment. Till now, we have studied the aerobic biological treatment systems and within this we studied regarding activated solar system, tickling filter, rotating biological disc reactor, then sequential batch reactors. So, we found that all the treatment systems were aerobic in nature, they may be attached growth and they may be suspended systems also. So, we studied those systems.

Now, we will continue with the anaerobic treatment systems, which do not require oxygen for their treatment. So, will there are only few type of reactor systems among them Up-flow anaerobic sludge blanket reactor is one of the common. So, we are going to study the anaerobic treatment systems now first.

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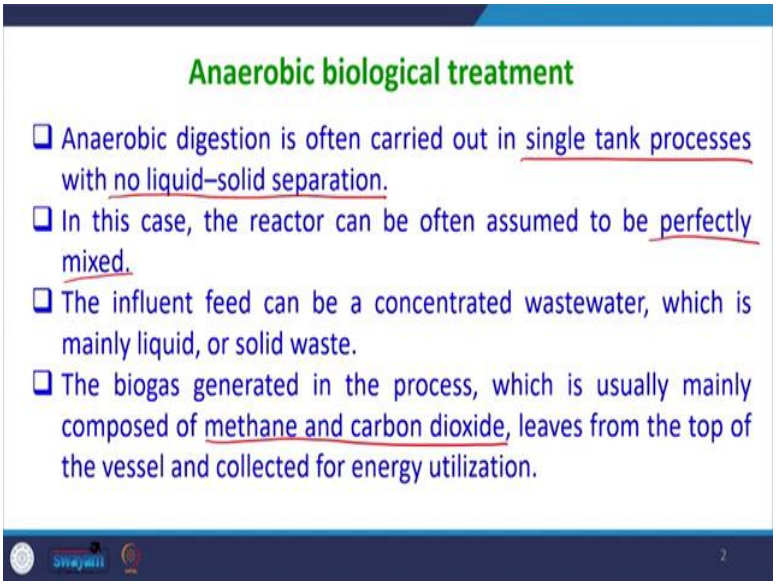

So, anaerobic biological treatment systems, they are often used and they are carried out the most of the treatment systems the treatment is carried out in a single tank process with no liquid-solid separation. So, this is the fundamental difference that there will be generally be carried out in a single tank process, in this case the reactor can often be assumed to be perfectly mixed.

So, we assume to be CSTR type of systems the influent feed can be concentrated wastewater which is may be liquid or solid based combination. In the under aerobic biological treatment systems, we have gases which are generated. So, the biogas which is generated in this process is usually mainly composed of methane and carbon dioxide and leaves from the top of the vessel and is collected for further energy utilization.

So, anaerobic biological treatment systems are nowadays lot of demand is there, because if any wastewater contains very high organic load, so we can convert the organic load into methane and carbon dioxide and then this biogas can be used as such for running vehicles or for other applications.

Similarly, it is possible there are some technologies which have been developed which can be used for separating carbon dioxide out of methane and that bio-methane which should be more than 90 percent concentration, so methane this bio-methane can be used with the usual natural gas mixed together and then they can be used for whatever applications the usual natural gas is used. So, there is lot of demand of bio-methane generation in the country and this area is growing very quickly.

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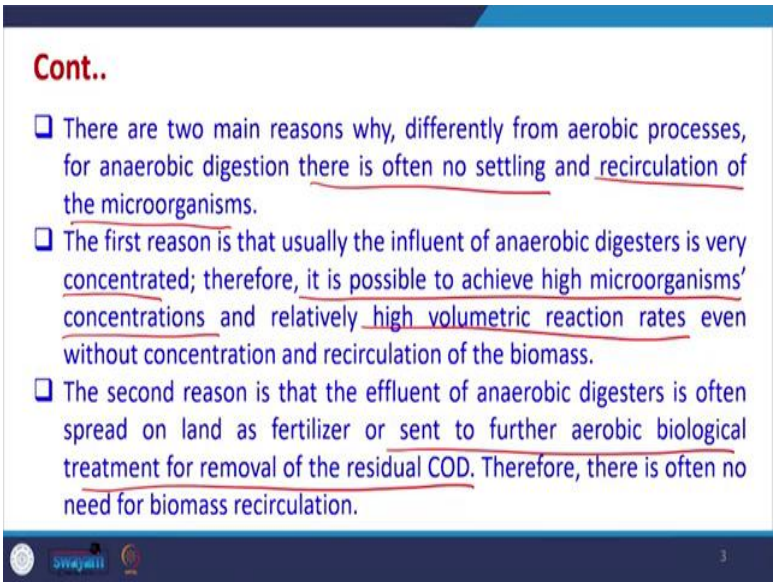

There are two main reasons why differently from aerobic processes the anaerobic digestion there is often no settling and nose recirculation of the microorganism. The first reason is that the influent of anaerobic digester is very concentrated that means we used only those wastewaters which contain very high organic load, so that we can get enough amount of biogas. Since, the influent to the anaerobic digester is highly concentrated, it is possible to

achieve high microorganisms concentration also within the reactor and relatively high volumetric reaction rates even without concentration and recirculation of the biomass. So, this is the one of the reasons.

Then the second reason is that the effluent of anaerobic digesters is often spread on land as fertilizer are sent to further aerobic biological treatment for removal of residual COD. So, therefore there is no need for biomass recirculation, so it is possible that the sludge may be used for as a fertilizer, the wastewater treatment after this also can be used as a fertilizer in different for irrigation etcetera. So, these are the reasons that in the anaerobic treatment systems we have no settling and no recirculation of the microorganism.

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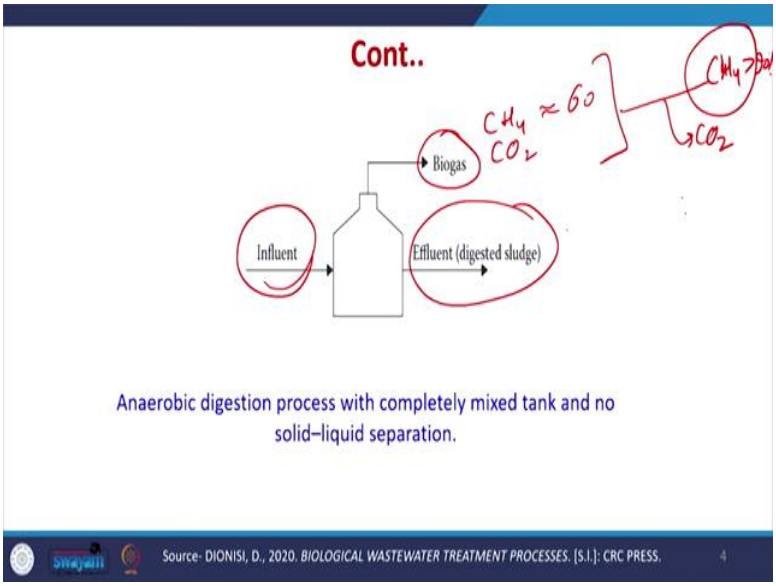

So, we have influent which is coming and effluent which is that the digested sludge going out and we have the biogas which is generated which is used. So, this biogas contains lot of methane usually in the range of 60 percent and then the rest CO_2 and other gases. And there is lot of demand of this biogas, this biogas if possible can we separate the CO_2 and if we can have CH_4 more than 90 percent then this bio-methane can be clubbed together with the usual CNG lines and then we can have more application of this.

So, this technology of anaerobic digestion is lot of demand is there for treatment of wastewater which contain lot concentration of organic loading, also it is being used for treatment of Municipal Solid Waste in particular if the solid waste is already separated and we have biodegradable fraction which is used. So, this is why the anaerobic digestion is coming in a big way.

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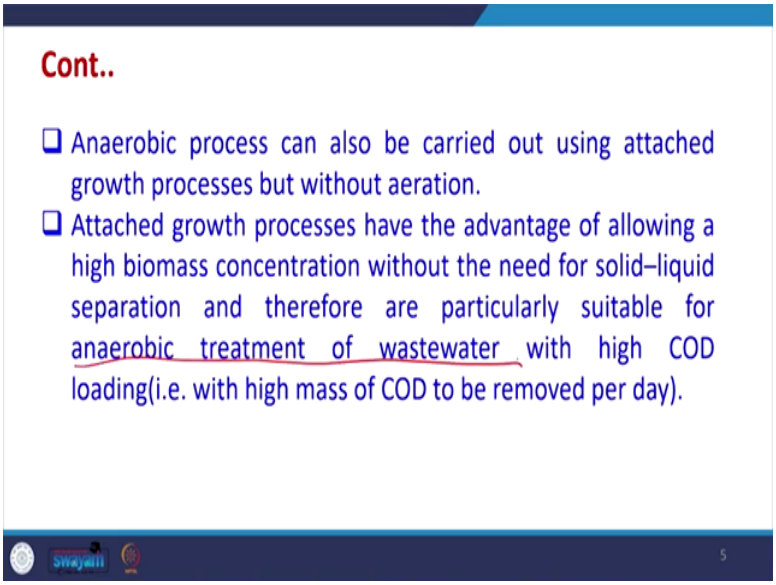

Anaerobic processes can also be carried out using attached growth processes but without aeration, so it is possible to use the attached growth processes without aeration for anaerobic treatment also. Attached growth processes have the advantage of allowing a high biomass concentration without the need of solid liquid separation and therefore are particularly suitable for anaerobic treatment.

So, we can have like bio towers where the attached growth system is there with the high COD loading. So, we can use the attached growth system for anaerobic treatment only difference will be that there will be no aeration or no supply of oxygen.

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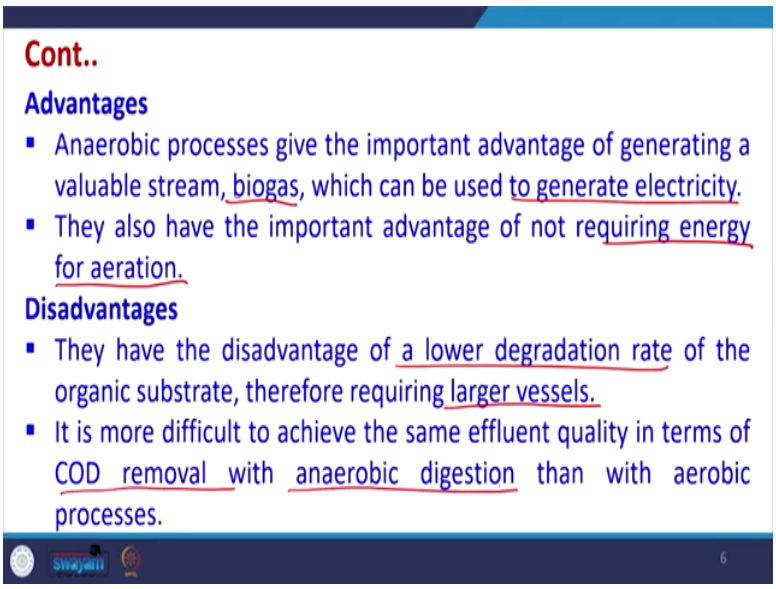

The advantages of anaerobic treatment systems are that, that they give they generate biogas and which can be used to generate electricity. So, this is the four most advantage of anaerobic processes and generally we apply anaerobic process where we can generate large amount of gas, so this is one important parameter.

Now, since we are generating bio guys it is possible to attach some method so that we do not require any energy for outside and also since there is no aeration we do not require energy for aeration also. So, the energy requirements in the anaerobic processes are less and they also generate biogas which can be used to generate electricity.

The disadvantage is that the, they have lower degradation rate of the organic substrate and they therefore require very larger vessels. So, the vessels dimensions may be bigger than the aerobic treatment processes. It is more difficult to achieve the same effluent quality in terms of COD removal with anaerobic digestion, then with the aerobic processes. So, generally aerobic processes will follow the anaerobic process, so that we can achieve the desired effluent quality.

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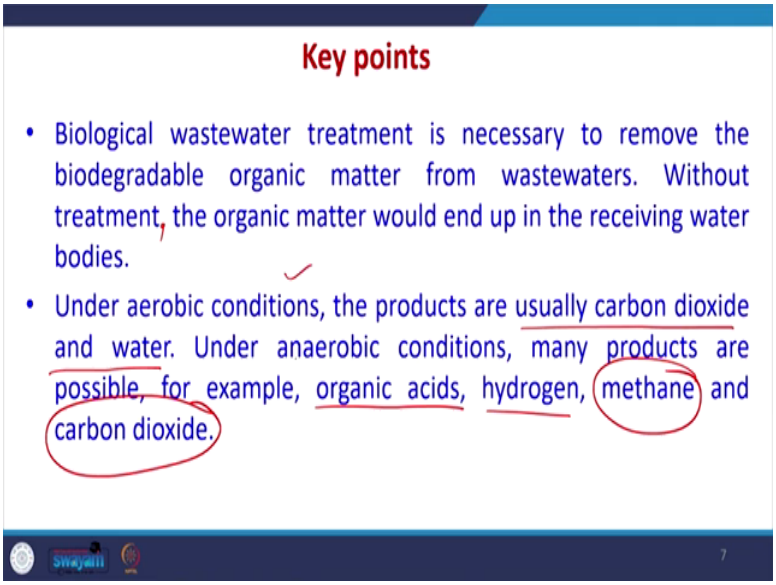

The key points with respect to this is that the biological wastewater treatment is necessary to remove the biodegradable organic compound from wastewater without treatment the organic matter would end up in the receiving water body. So, we have to go for treatment further.

Under anaerobic condition the products are usually carbon dioxide and water, whereas under anaerobic condition we can get organic acids, hydrogen, but methane and carbon dioxide will be predominantly we produce. So, that is why we go for anaerobic treatment for those

wastewater which contain very high organic loading that means they have lot of carbon content or they have more COD, so we can go for treatment of such wastewater, so that we can generate large quantity of methane and carbon dioxide, so this is possible.

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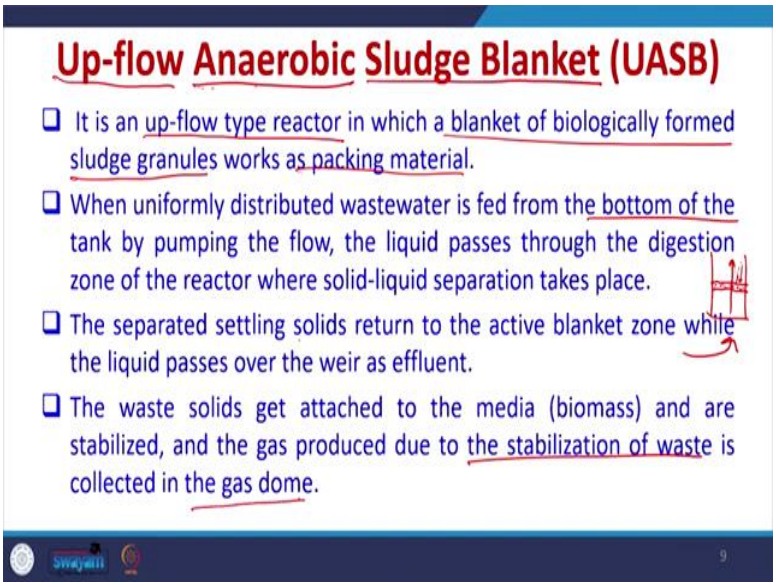

Now, within anaerobic treatment systems up-flow anaerobic sludge blanket reactor is one of the most common reactor and this can be used for the anaerobic treatment of wastewater. So, what is UASB reactor? It is an from the as suggested up-flow that means it is an up-flow type of reactor in which a blanket of biologically formed sludge granules worked as packing material, so this will understand.

So, first thing is sure that in the UASB reactor the flow is from bottom to up, so if this is the reactor, so the flow will go up only, so this is up-flow anaerobic blanket reactor. Also we have a blanket so it is anaerobic we have sludge blanket, so we can divide into three section up-flow, anaerobic, anaerobic means there is no oxygen present inside the system, so we do not supply oxygen it is anaerobic condition, sludge blanket means we have some typical blanket of sludge.

So, in this case in the UASB reactor the mechanism is such that, that we have a portion of the USB reactor which has sludge in the form of blanket that means the density of sludge in that area is very high and when the wastewater is going up through that blanket of sludge the treatment happens. When uniformly distributed wastewater is fed from the bottom of the tank by pumping the flow, the liquid passes through the digestion zone of the reactor where solid liquid separation takes place. And the separated settling solids return to the activated sludge.

So, when at least some amount of solid may be carried but a solid liquid separation unit is there and when this happens this sludge returns back to the blanket, so this is there. The waste solids gets attached to the media biomass and are stabilized and the gas gets produced due to stabilization of the waste and is collected in the gas dome.

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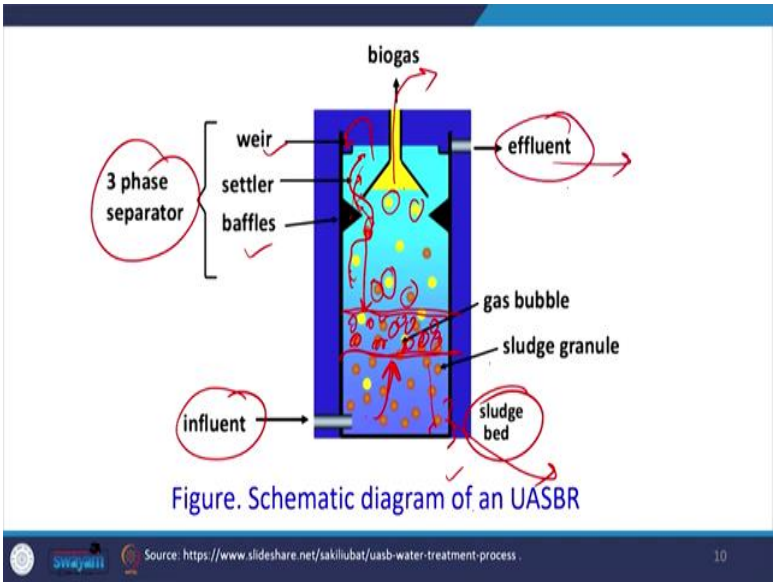

So, we can see the vessel, this is the USB reactor schematic, now here actually in some places the density of sludge will be very high, now the influent is coming influent is going up, we have some sections where the influence flow rate is in such a manner that the sludge which gets formed the microorganial sludge which gets form it is actually within this zone and now when the wastewater is passing through this zone the anaerobic digestion happens.

So, we have some gases which are formed, so we can see the yellow color ones the gases the biogas molecules it may be methane, it may be CO_2, it may be some other gases. Now, this is formed and they are going up, so gases will be going up and they will be collected further.

Now, in addition the because some more solids are formed we have such a system of baffle and weir when the wastewater along with these solids is moving through this settler and baffle system will not allow the solid to pass through only very small amount of solid will pass through and most of the solid will return back to this blanket.

So, this blanket when the molecules within the blanket become very heavy they settle down and ultimately some sludge bed will be formed that has to be removed. Now, that means, so in total we have this is the three phase separator which is having a weir, a settler where the

solid will return back and a baffle system, ultimately the effluent will go back into this weir and effluent will be taken out.

So, if required it may be used for irrigation, it may be used for further treatment, so this is the schematic of UASB reactor the up-flow sludge blanket reactor and the main beneficiation is that we get biogas which can be used further.

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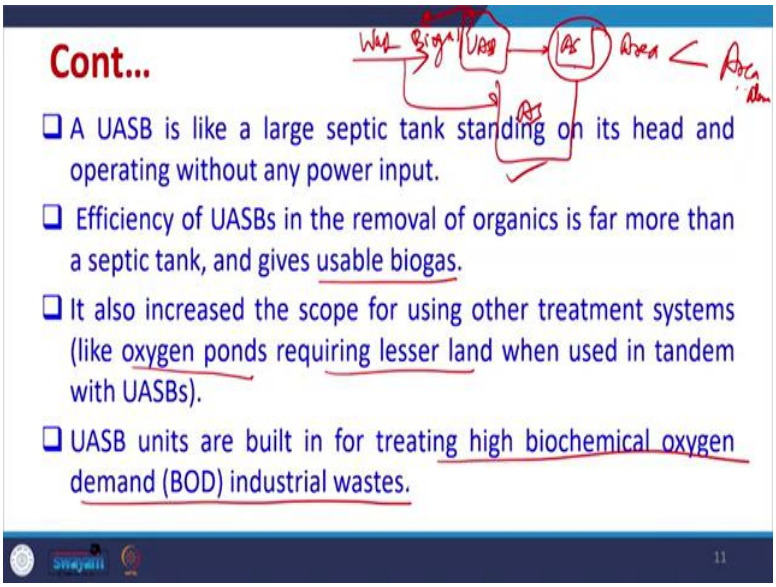

Now, a UASB is like a large septic tank standing on its head and operating without any power input. The efficiency of UASB is in the removal of organics much more than the septic tank and gives a very heavy amount of biogas. It also increases the scope of using other treatment systems, like oxygen pond requiring lesser land when UASB is used first.

So, that means when the wastewater is having certain characteristics and we are using a UASB reactor, first UASB and followed by may be activated sludge system, then the area required for this sludge system will be much lesser than the area required for the this activated system when used alone. So, this is the difference and same ways water if it is going for the activated system alone the area required for this activation system will be very, very large.

So, this is the difference and this is the main benefit and also we are getting lot of biogas, so this is there. So, all those Industries which have very high concentration of organic loading they generally prefer UASB reactor followed by activated sludge system. UASB units are built in for treating High biochemical oxygen demand industrial base. So, they will be used for such systems.

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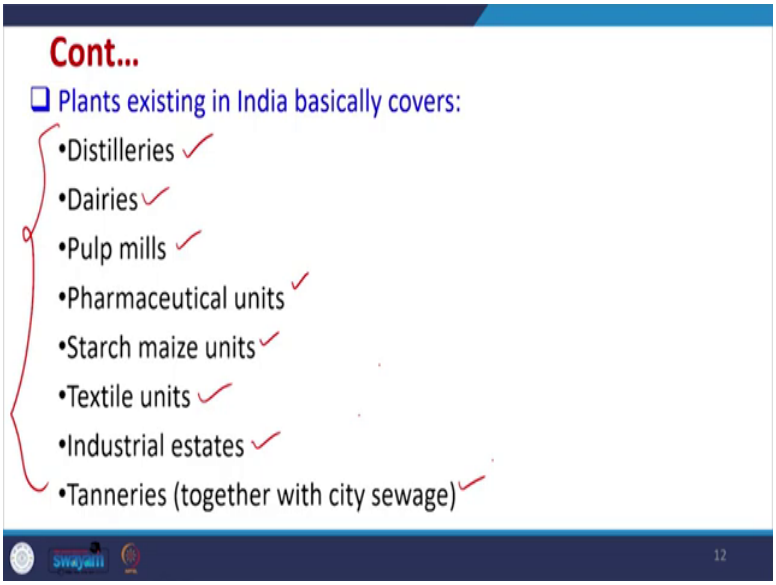

Plant in existing in India basically cover all these industries have UASB reactor systems, like distilleries, all the dairy industries they have a lot of organic loads, so they will go for this UASB reactor, then pulp and paper mills, pharmaceutical units, starch generating units, the maize units, then the textile industries, bigger industrial clusters where CTPs are there, then tanneries together with the city sewage, they can go for UASB reactor. So, these USB reactors are common and they can be used for various treatment of such wastewaters which contain very high organic loading.

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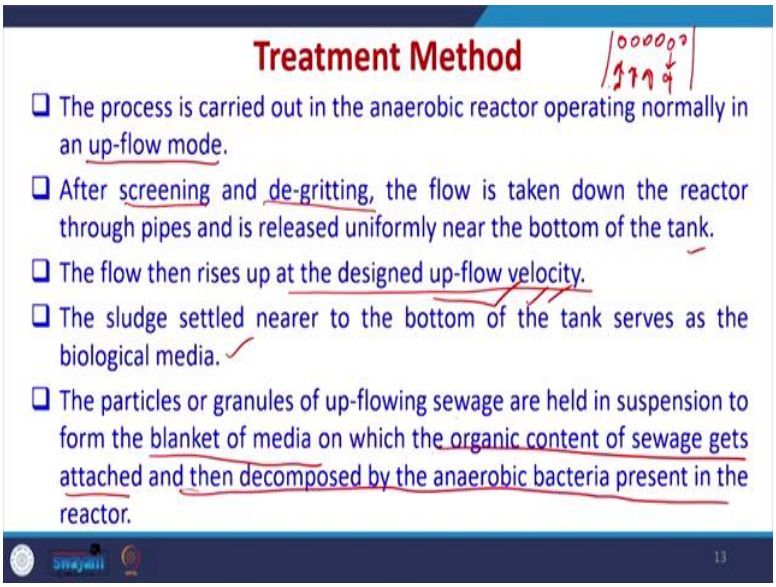

Now, how the treatment method works let us discuss this, the process is carried out in the anaerobic reactor operating normally in an up-flow mode. So, generally it will be up-flow

mode. After screening and de-gritting, so we have some primary treatment which is done, which is like screening and removal of the grits.

The flow is taken down the reactor through pipes and is released uniformly near the bottom of the tank, so this is there. So, that means if this is the UASB reactor, so the distribution of water from the bottom up will be uniform. The flow then rises up the design of flow velocity, so this is the most critical parameter at what flow velocity it should be released, because it should be good enough, so that the sludge of certain size and density are always floated above that size the sludge may settle but whatever targeted size is there that should float.

Now, the sludge settled near to the bottom of the tank serves as biological media, the particle or granules of up-flow in sewage are held in suspension to form the blanket of the media, so we have to this up-flow velocity is very critical parameter for forming this blanket, on this blanket the organic content of the sewage gets attached and then further decomposed by the anaerobic bacteria present in the reactor. So, this is the most important parameter the up-flow velocity.

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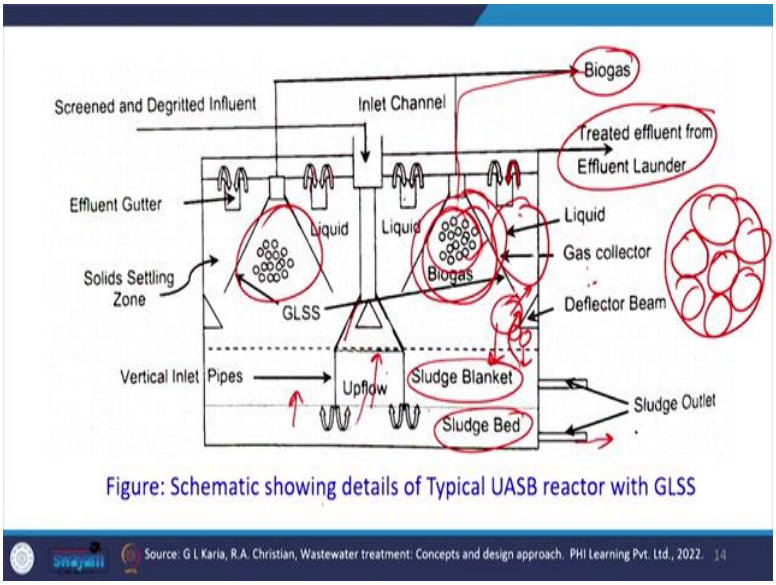

So, this is the schematic showing details of the typical UASB reactor, so we have up-flow reactor, so we can see, so vertical pipes are there, so we have up-flow, now this is the sludge blanket is there and ultimately sludge bed from with the sludge will be taken out water will be distributed here.

So, now the up-flow will go up, here the separation will take place, the separation of the gas as well as the sludge, now the biogas will be separated like this in the system. So, we have the

gas collector which is there, the liquid will be when it is going up the bigger solids will be now the bigger solids cannot pass through the system and they will be collected back in the sludge blanket, the gas will be collected here and this gas can be taken together for biogas.

So, we can have different like we have one chamber here another chamber, so we can have within a bigger reactor, suppose this is the top view, so we have, we can have a gas collection chamber here, here, here, like this we can have different gas collection chambers and from each collection chamber the biogas will be taken out.

Similarly, within below that there will be solid liquid separation unit also which will be in form of deflector beam and the bottom portion of the biogas electric system which will actually separate out. Now, in between this, this area also works as a separation unit a settling chamber in a way, so for the solid, so that it is not carried out, after treatment the water will go into this weir from all the weirs the effluent will be taken.

So, treated effluent from effluent launder will be taken further, so this is the effluent which is going. So, this type of treatment system may be there, some screening or degrading effluent may also be released, so this is possible. So, this is the overall up-flow sludge blanket reactor.

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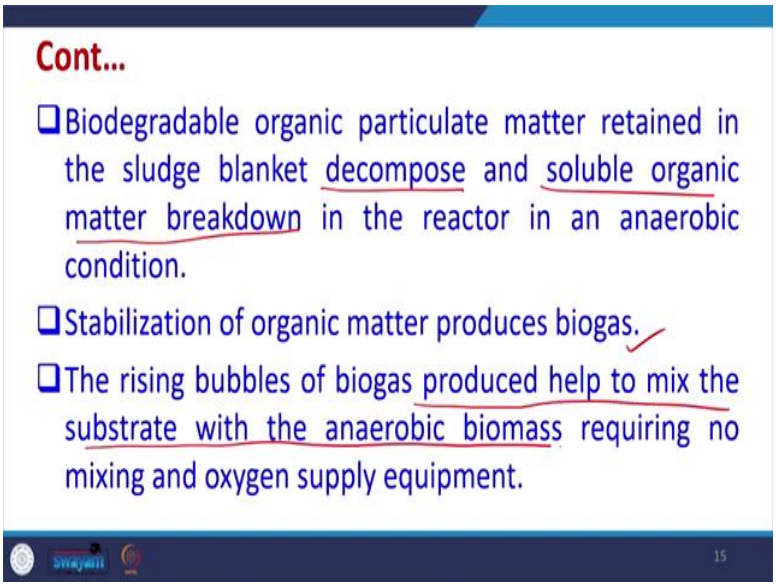

Biodegradable organic particulate matter is retained in the sludge blanket and it decomposes and soluble organic matter breakdown takes place in the reactor in the anaerobic condition. The stabilization of the organic matter produces biogas, the rising bubbles of biogas produce help to mix the substrate with the anaerobic biomass requiring no mixing. So, because the gases are formed these rising bubbles of the gases help in the mixing of substrate with the

anaerobic biomass and thus we do not require any other mixing mechanism. So, this is how the biogas helps.

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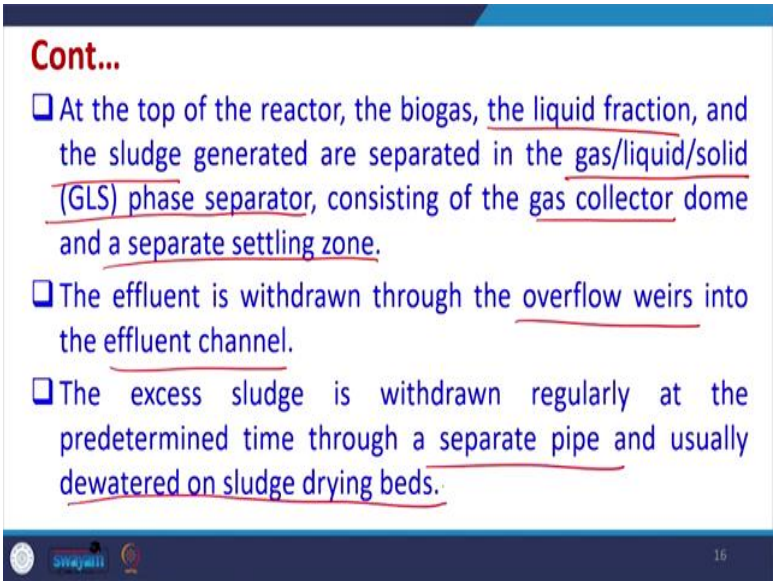

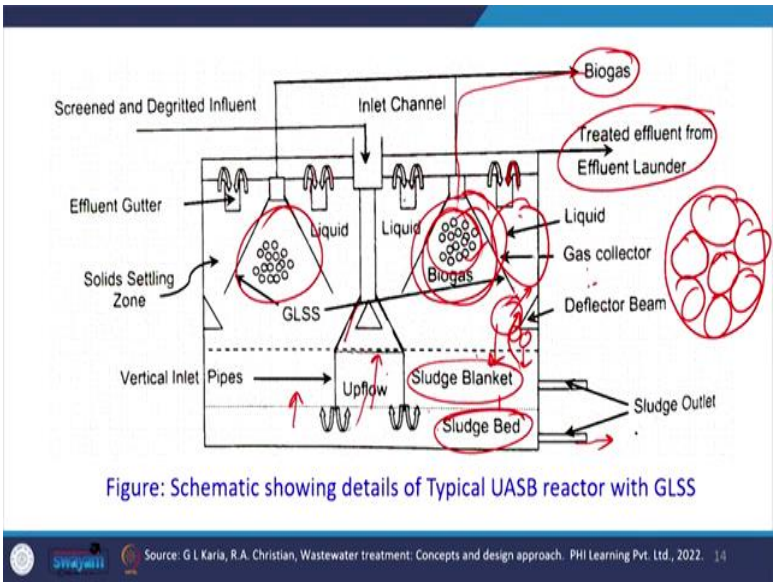

At the top of the reactor the biogas and the liquid fraction and the sludge generated are separated in a gas liquid solid phase separator, consisting of gas collector dome and a separate settling zone. So, we have a system of gas liquid solid separation unit which actually is a gas collector along with some area adjacent to the gas collector which works as a separate settling zone.

The effluent is withdrawn through the overflow weirs into the affluent channel and is further taken for treatment. The excess sludge, the excess sludge which actually it settles down and goes into the sludge bed, the excess sludge is withdrawn regularly at the predetermined time

through a separate pipe and usually dewatered on the sludge drying bed and then this sludge can be further be taken for the treatment etcetera. So, this is done.

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The applications of the UASB reactor, the UASB reactor is implied for the treatment of industrial waste, in particular those waste which contain very high organic load and the treatment for the primary and secondary sludge. So, we use UASB reactor for two purposes, one is for industrial waste water which contains very high organic load, the UASB reactor can also be used for treatment of primary and secondary sludge which is generated, because the primary and secondary sludge will contain very high organic load, so that can be.

Also, it can be used for treatment of municipal wastewater as such, so it can be used. The usually the UASB process is followed by the post treatment by other biological treatment processes such as ponds or lagoons. The UASB process is one of the most important options for sewage treatment in warm countries, because in the warm country the temperatures are good, the biogas formation will be more.

Also, the second this industrial all those the solid waste which is generated from household, if it contains only biodegradable matter that means like kitchen waste, the leftover food etcetera, then the anaerobic treatment is very good and we can use it for generating lot of biogas.

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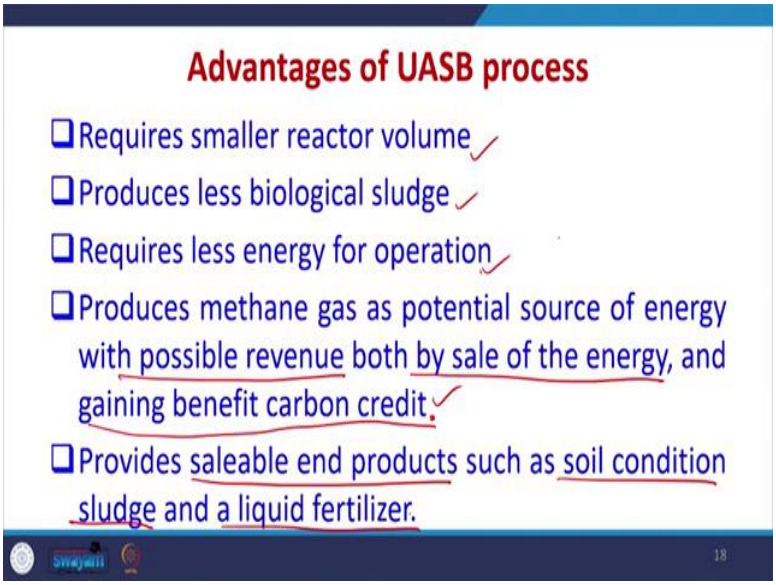

The advantages of it requires smaller reactor volume as compared to anaerobic treatment system, produces lesser amount of biological sludge as compared to anaerobic treatment systems, requires virtually very less energy and in fact we can recycle back some amount of biogas to get whatever energy is required for the operation, produces methane gas as potential source of energy with possible revenue both by sale of the energy and gaining benefit with respect to carbon credit.

So, this area is being targeted by many companies, because we can there are three benefits, we can treat the water or the sludge or the municipal solid waste if it contains very high amount of biological matter. Now, these first benefit is that we are treating something, second benefit is that since we are producing lot of biogas we can sale that biogas and get revenue out of that, also since we are reducing the carbon, so we can get the carbon credit also benefit. So, these three benefits we can give.

This anaerobic treatment system or UASB processes provide saleable end products such as soil condition sludge and a liquid fertilizer. So, also in some of the industries like in sugar industry the treatment after treatment the water can be used for fertilizer, also for irrigation in different types of crops, also it the sludge which can is generated can be used as a soil amendment material, so that the carbon content is retained in the soil. So, this is these are the major benefits of UASB processes, the products.

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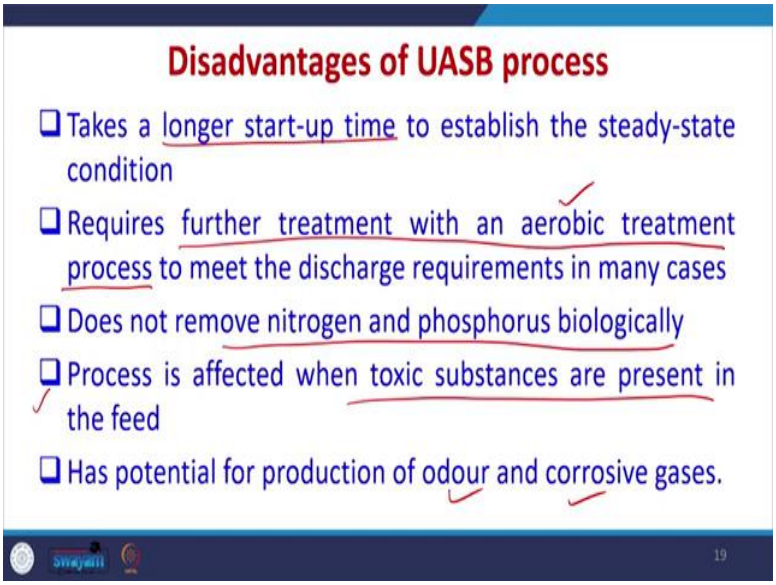

What are the disadvantages of UASB process, it takes a longer startup time that means the startup type is longer to establish the steady state condition, it requires further treatment with an anaerobic treatment process to meet the discharge requirements many in most of the cases UASB reactor alone will not receive achieve the target which is required with respect to COD or BOD. So, we will have to use an aerobic treatment system after the UASB process, so this is.

It does not remove the nitrogen and phosphorus biologically, so it will only remove the carbon, so if the wastewater contains lot of nitrogen and phosphorus we will have to use a separate aerobic treatment unit for removal of nitrogen and phosphorus. The UASB process is highly affected by presence of toxic substances in the feed, so if you have lot of toxic substances they also have to be removed beforehand, otherwise the performance of UASB reactor will go down.

And UASB reactor produces lot of odour and corrosive gas, so in the vicinity of UASB reactor people may feel that some treatment is happening and we have odour and if the UASB reactor is in any residential area then certainly problems may happen because the people who are living in those residential areas will fill the odour.

So, I think will stop with that today and will further discuss the design of UASB reactor and solve some problems in the next class. So, we will continue with the UASB reactor in the next class. Thank you very much.