Water and Wastewater Engineering
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Activated Sludge Process Modification
Lecture - 22

Last class we were discussing about activated sludge process that is a secondary treatment process so in activated sludge process we have seen what is happening. The wastewater is coming to the aeration tank, there we are supplying enough air nutrients and other requirements for the microorganisms are already present along with the wastewater so when we supply enough oxygen microorganisms will be oxidizing the organic matter into carbon dioxide and water and as a result new cells will be generated.

In the aeration tank the organic matter which is in dissolved form is getting converted into microorganisms or in the colloidal form. So we have to separate this microorganism that is why secondary sedimentation tank is an essential part of activated sludge process. We also discussed about the kinetics of activated sludge process. So how can we find out the microbial concentration in the aeration tank, how we can find out the substrate concentration or the BOD whatever is coming out of the secondary sedimentation tank.

We have also seen about how we can find out an expression for the recirculation ratio. These are the important parameters whenever we talk about the design of an activated sludge process. Most of the time we design the activated sludge process based upon the biokinetic parameters. We also discussed about two other different terms; one is hydraulic retention time and another one is biological sludge retention time.

Whenever we talk about any biological systems the BSRT or the biological sludge retention time is very very important. This is nothing but the time at which the microorganisms are staying in the system. And if they stay more time in the system naturally the amount of microorganisms in the system will be more depending upon the supply of substrate. These are the important parameters. Then we were discussing about sludge volume index. This is a number which shows the settling characteristic of the sludge in the secondary sedimentation tank and sludge volume index is very very important as far as the performance of the activated sludge process is concerned. We will see why it is so important.

We have seen that if the sludge volume index that means the volume occupied by unit mass of sludge is less than hundred it is a good sludge and if it is 100 it is desirable and if it is 150 or above it is a bulking sludge and if it is above 200 it is not at all desirable or we have to change the system.

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Why it is so important or how it is controlling the performance of the activated sludge process. What is happening is we are re-circulating the sludge to the aeration tank. The purpose of this recirculation is nothing but improving the concentration of microorganisms present in the aeration tank. If your sludge is bulking then what will happen, we are controlling recirculation based upon the volume so if the concentration of the sludge or the volume occupied by the sludge for a unit mass is high then what will happen is though we are keeping recirculation ratio as a constant the amount of microorganisms whatever is going to the aeration tank will be getting reduced.

As the microbial concentration gets reduced in the aeration tank definitely the performance of the system will be decreasing because here in activated sludge process or in any biological system the workers are the microorganisms. So if you reduce the number of workers definitely the amount of work done by them there will be getting reduced. That is the reason why high SVI is not preferred in activated sludge process.

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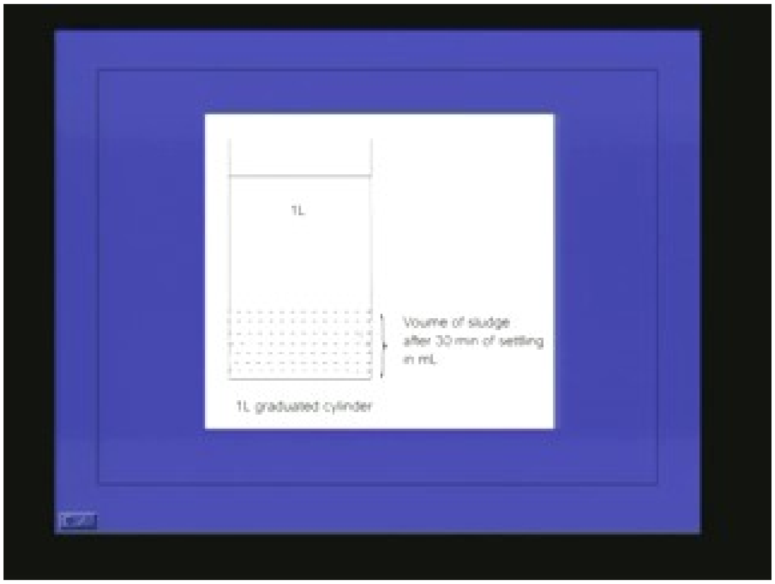

I have already explained how to find out the sludge volume index. We usually use one liter graduated cylinder and we have to take well mix one liter of mixed liquid suspended solids and allow them to settle for thirty minutes and find out what is the volume occupied by the sludge in the graduated cylinder. This will be obtained in terms of ml. Then what we have to do is find out the concentration of the MLSS by filtering and taking **trivate** so we will be knowing what is the volume occupied and what is the rate of the MLSS so from that we can find out what is the volume occupied by unit mass of sludge.

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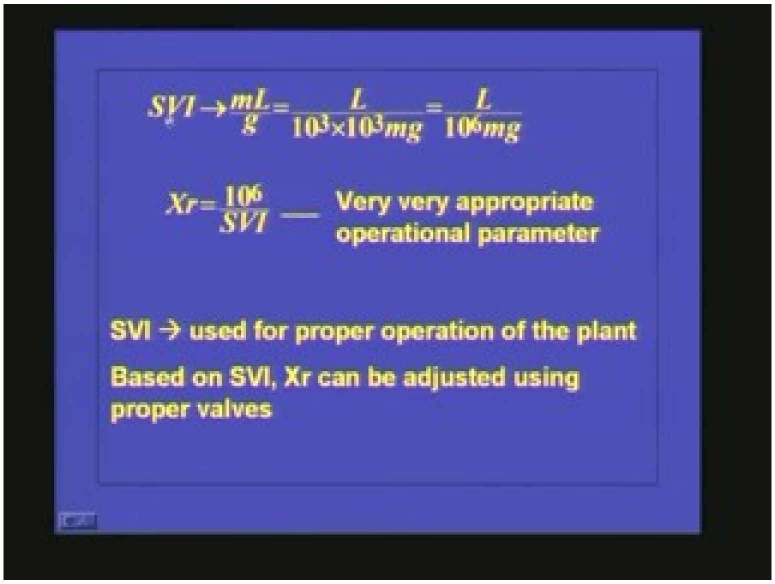

This is SVI. The unit is in milliliters per gram that means liters by 10 raised to 6 milligrams and Xr where Xr is nothing but the concentration of biomass present in the re-circulated sludge that is nothing but 10 raised to 6 by SVI because SVI unit is liters per milligram and Xr unit is milligrams per liter. This is very very important and this Xr is the one which decides the effectiveness of the aeration unit because as we re-circulate if the Xr value is small and if you fix up your recirculation ratio say 0.25 then what will happen is in that 0.25 so much of biomass will be present so the total biomass concentration in the aeration tank will be increasing.

So in most of the cases this SVI is used for proper operation of the plant based upon the SVI we can calculate Xr and this Xr and the biomass concentration in the aeration tank can be adjusted using the proper valves so this SVI is very very important.

We have seen how to find out the concentration of the biomass in the activated sludge. We got some expression in terms of the biokinetic parameter and we have seen what is se value we can get in terms of the biokinetic parameters like Y_T kd $theta_C$ etc and we have also seen some expression for recirculation ratio based upon the biokinetic parameters. These expressions are available so how can we design an activated sludge process. There are three different design problems one can face.

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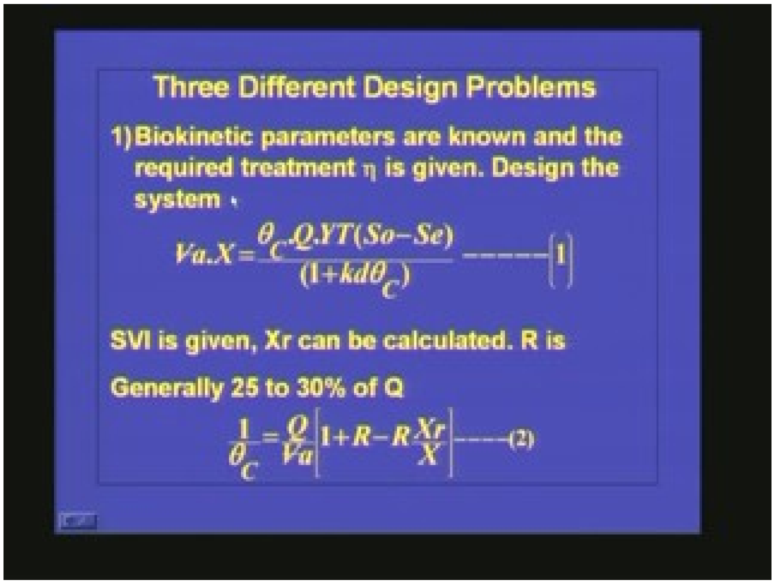

One is the biokinetic parameters are known and the required treatment efficiency is given. We have already found out the biokinetic parameters of the system and efficiency because you know this is the effluent discharge standard we can find out what is the efficiency required. That means you know initial BOD and you know what should be the final BOD so you know what is the treatment efficiency required and how to design the system.

This expression we have already seen; theta_C is equal to this expression or the expression we can change in the other way Va that means volume of the aeration tank into concentration of the biomass is equal to theta_C this is biological sludge retention time into flow rate into yield coefficient into initial BOD minus final BOD divided by one plus this is the decay constant (Refer Slide Time: 8:45) and this is the BSRT again. SVI is given, the equation is there and the other expression we have is 1 by theta_C is equal to Q by Va into 1 plus R minus R into Xr by X and these equations are what we have derived in the last class. Therefore, from equation one and two what we can do is we can find out X and Va.

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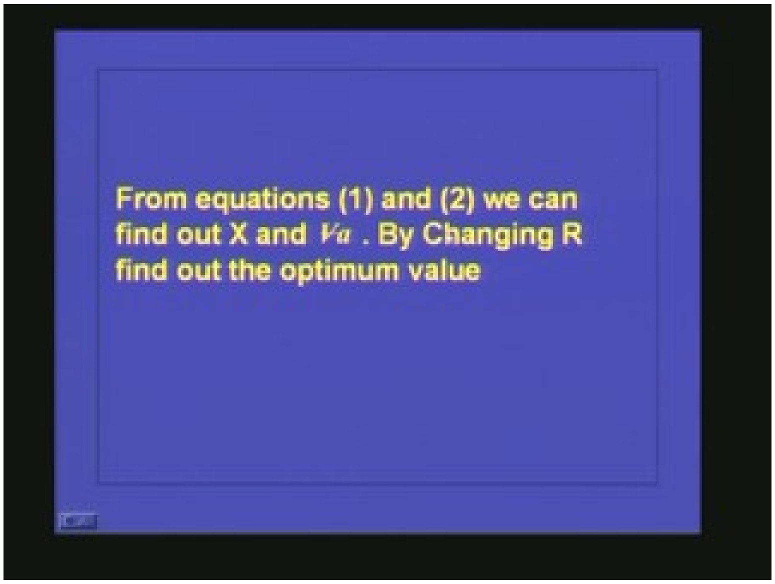

Here we will be knowing theta$_C$, we know Q, we know Y_T we know kd we know So we know Se the only unknown is Va and X. And here also we know Q theta$_C$ and r we know it is in between 0.25 and 0.3 ratio and Xr we can find out from the SVI because SVI we will know so the only two unknowns are Va and X and we have two equations so we can find out what is the Xa and Va value.

But we know that the recirculation ratio can be changed from twenty five thirty percentage. Thus, by putting different R value we will be getting a series of curves so from that one we can find out what is the optimum value. This is one way of designing the activated sludge process. We will see what the second type of problem is.

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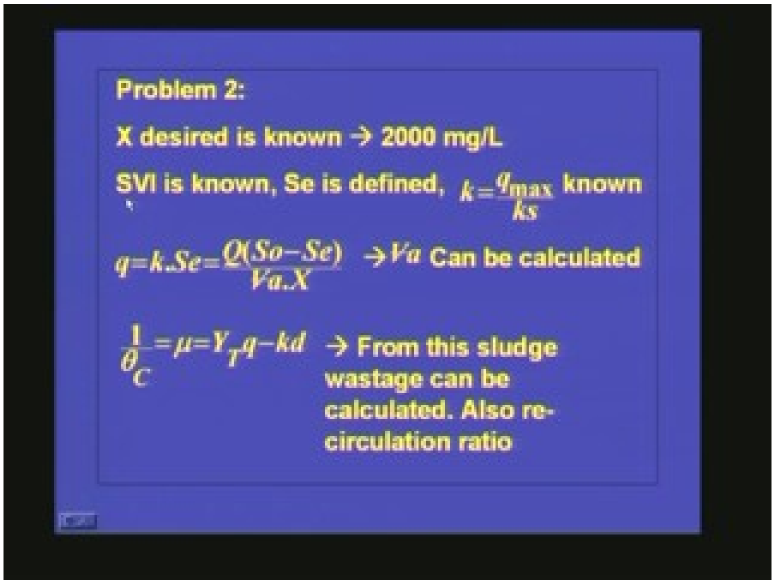

Here X is desired is known so it is given that this much of biomass is present in the system and SVI is known sludge volume index is known and Se is defined because that is the effluent discharge standard. So we can find out what is this k. The k is nothing but q_{max}; this is maximum specific substrate utilization rate divided by ks this is the half saturation constant. So k is known and you know q the specific substrate utilization rate is nothing but k into se and that is equal to x into So minus Se this is the total substrate coming to the system (Refer Slide Time: 10:45) and this is the total biomass present in the system so this equation is known so Va can be calculated, what is the volume of the aeration tank required.

This is the design we have to calculate so we will be able to get this one. We have another equation 1 by theta_C that is the minimum biological sludge retention time whatever we have to provide that is equal to mu which is equal to Y_Tq minus, we have already seen how to get this expression so if you know this one and we know what is theta_C that but how much time the sludge is remaining in the aeration tank it is nothing but the total sludge or total biomass present in the aeration tank divided by how the sludge is getting removed from the system. From that expression we can calculate the sludge wastage required. If the sludge wastage is known and SVI is known we can find out what is the recirculation ratio that is required.

Here X is given so we are calculating Va and we are calculating again Qw the sludge wastage and we are also calculating R based upon the three equations whatever we have derived earlier. Now we will see the third problem.

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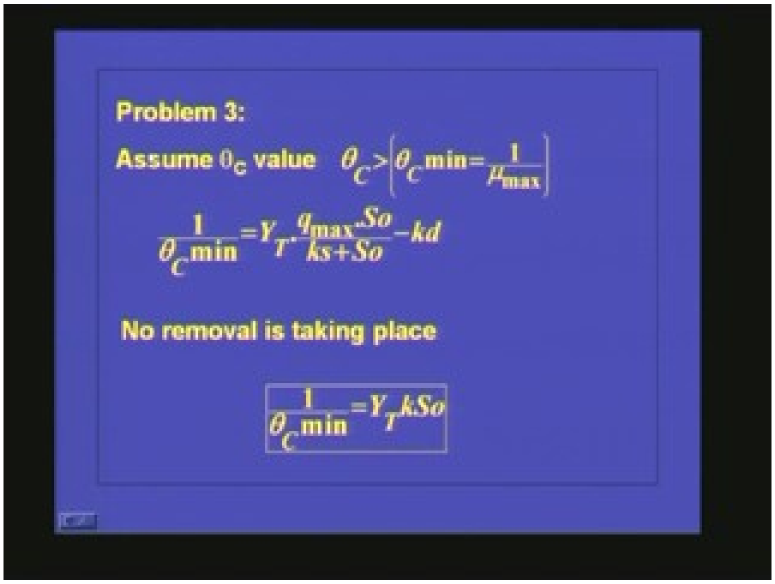

Third problem is theta$_C$ is not known. So we have the biokinetic parameters. We know that what this theta$_C$ which is nothing but 1 by mu or 1 by specific growth rate. The mu value is changing for a system but the mu max maximum substrate utilization rate is the constant. If you take one by mu max we will be getting the theta$_C$ which is required at minimum because as the mu max increases theta$_C$ value will be decreasing.

Since we know the mu max value we can find out the theta$_C$ minimum we have to provide. So assume a theta$_C$ value which is greater than this theta$_C$ minimum which is equal to 1 by mu max. Then we can use this expression; 1 by theta$_C$ minimum is equal to YT Qmax So by ks plus So minus kd. Here what is happening is when theta$_C$ is equal to theta$_C$ minimum up to that stage no substrate removal is taking place and once the theta$_C$ is greater than theta$_C$ minimum then only the substrate removal will be taking place. That is why we are putting So here instead of Sc.

Therefore, we can find out what is this theta$_C$ minimum it is nothing but Y_T K into So. These are the three different problems or three different ways on how we can design and activated sludge process. Till now we were discussing about the conventional activated sludge process. But the conventional activated sludge process is having some problems. So there are various process modifications based upon the requirements and depending upon the nature of the wastewater and the quantity of wastewater coming to the treatment unit. So, based upon that one we can modify the conventional activated sludge process.

We will see what all are the modifications of the conventional activated sludge process.

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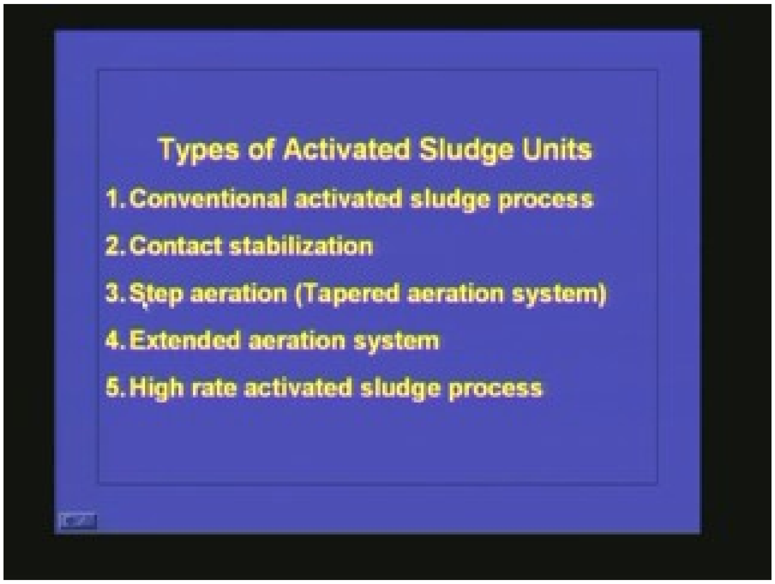

One is contact stabilization, another one is step aeration or tapered aeration system, fourth one is extended aeration system and fifth one is high rate activated sludge process. There is another one which is sludge reaeration. It is not a process modification. to improve the efficiency in earlier days what people used to do is take the sludge reaerate it before putting it back to the system so that oxygen efficiency will be less in the system. That is again another modification or another type of activated sludge process.

Now we will see one by one in detail. When we have to go for this modification or what type of wastewater we can go for with conventional activated sludge process and what type of wastewater or what quantity we can select from one of these modifications is what we will see in detail.

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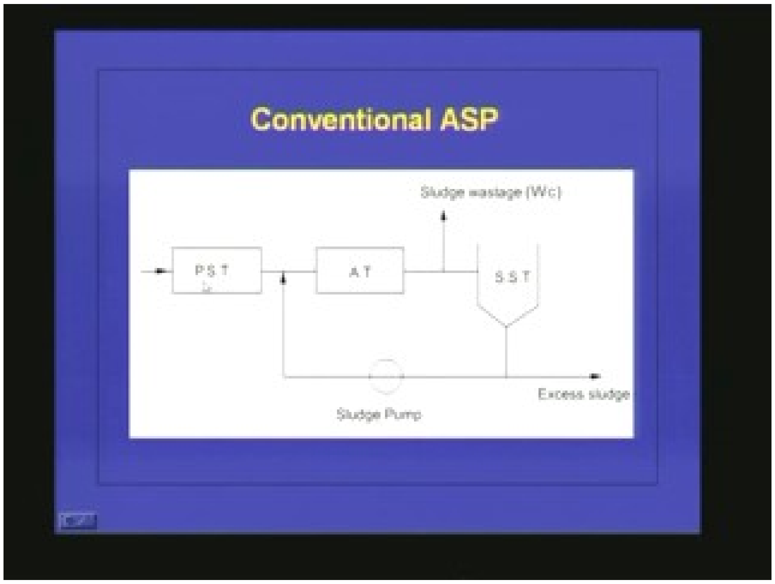

This is the conventional activated sludge process. Primary sedimentation tank, then aeration tank, here we are having the sludge wastage Wc and this is the secondary sedimentation tank and some extra sludge will be there that will be going to the digester and this is the recirculation system and it is coming to the aeration tank.

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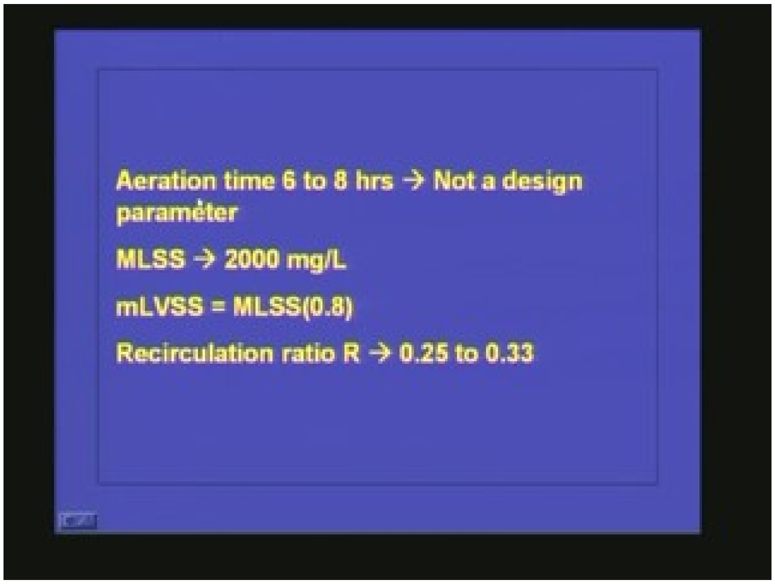

In conventional activated sludge process in aeration tank we give 6 to 8 hours of aeration. And please remember this is not a design parameter. Design parameter is $theta_C$ and X and Xe we have seen that one on recirculation ratio. But usually this is the time we usually in the aeration tank. In conventional process and MLSS concentration 2000 to

3000 milligram per liter is always maintained. And another term used in activated sludge process is mLVSS. MLSS is the total suspended solids present in the system.

We know that along with the wastewater some inorganic solids also will come. So in MLSS mixed liquid suspended solids organic as well as inorganic solids will be coming. But we are interested only the microbial concentration. Whenever we talk about the sludge we are interested only the microbial concentration because those are the things which is affecting the performance. So how can we find out this one? For this we usually use another term that is known as mLVSS that means mixed liquid volatile suspended solids, if it is volatile that means it is organic in nature.

In the mixed liquid suspended solids whatever is organic in nature or whatever we can volatilize that is mainly the sludge or the biomass. Therefore, many experiments were conducted in the lab and in the field and it is found that if you take a ratio of 80% or 0.8 then we can get the mLVSS or otherwise mLVSS is nothing but 0.89 times MLSS. And recirculation ratio in conventional process varies from 0.25 to 0.33 and sometimes it go up to 0.5 also.

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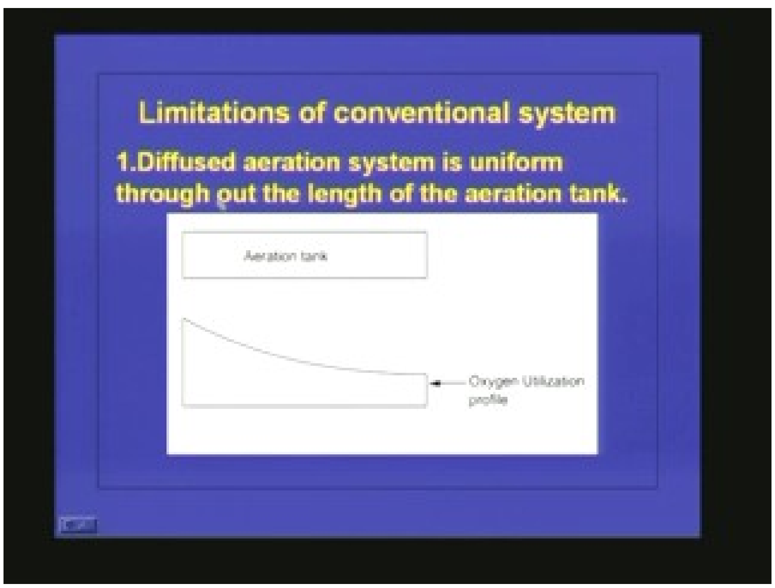

Now we will see what is the limitation of this conventional system. Usually we give diffuse aeration system of surface aeration system. In conventional activated sludge process the oxygen supply is uniform throughout the aeration tank that means from the inlet to outlet the oxygen supply is uniform. But if you see the oxygen requirements the oxygen requirement will be more in the inlet because the wastewater with high BOD is coming into the inlet and the recirculated sludge also will be coming to the inlet so definitely in the inlet the oxygen requirement will be more. and as we pass through the aeration tank we are assuming that that is the plug flow reactor so there is no longitudinal mixing so it is moving with respect to time. As it moves towards the outlet what will happen is the BOD will be gradually decreasing so naturally the oxygen requirement of the system will be decreasing.

Thus, if you take the oxygen requirements or oxygen utilization profile in an activated sludge process it will be coming as something like this (Refer Slide Time: 18:42). So, in conventional system here oxygen deficiency will be experienced and here excess oxygen will be available. But if you can provide oxygen in this way the system will be having more efficiency.

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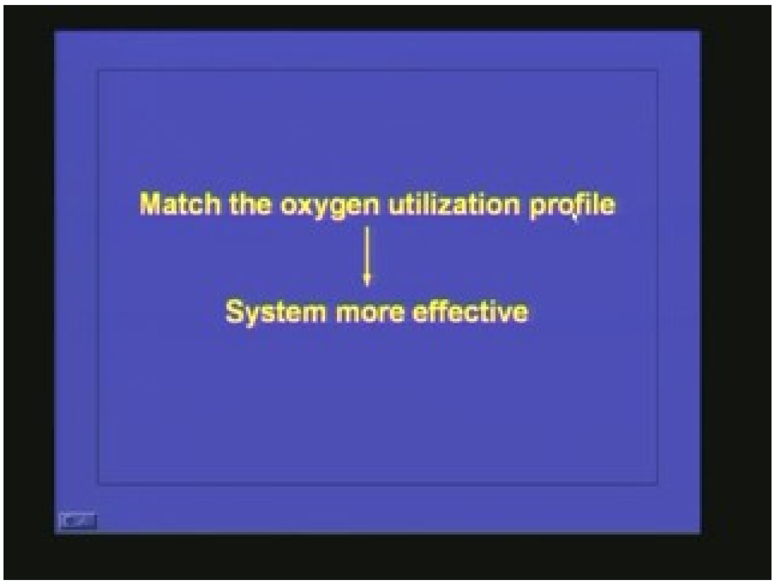

That is what is shown here; match the oxygen utilization profile then the system will be more effective. That is what is done in step feed system or tapered aeration system. That is one modification of conventional activated sludge process. In tapered aeration system or stepped system what happens is the wastewater whatever is to be treated in the aeration tank or the activated sludge process will not be entering in the same part, the wastewater will be distributed throughout length of the activated sludge process.

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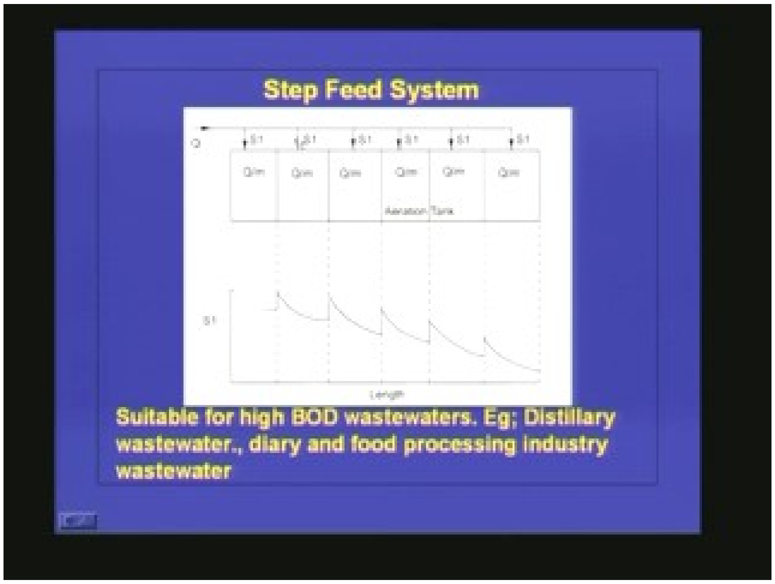

Here we can see it clearly; q is coming and q is divided into m and each q by m is entering in different compartments. This is the aeration tank (Refer Slide Time: 19:46) we are assuming that it is having m compartments. There will not be any division like this but we are assuming that this is divided into M different compartments so Q by M is coming with BOD of S1 Q by M is coming to the second compartment also there and even in the Mth compartment. Hence, if you see the BOD profile along with the length of the reactor what will happen is here you will be having S1 and as it moves up to here the degradation will be taking place and this will be reducing.

Then again we are adding fresh sewage here in the second compartment so it will be slightly increasing and again decreasing. This point is lower than this point and this will keep on happening. Why it is coming down drastically is because the degradation will be taking place and along with that one the **illusion** also will be taking place because this liquid will be coming to this place so dilution also will be taking place so finally you will be getting the BOD of this much concentration (Refer Slide Time: 20:50).

Therefore, if you go for conventional aeration tank or conventional activated sludge process you will not be able to achieve this much of BOD reduction. This type of system is suitable for high BOD wastewaters. For example; distillery wastewater, diary and food processing industry wastewater the oxygen requirements will be so high so whatever aerators we are providing they will not be able to supply that much of oxygen whatever is required in the entrance of the system of the influent chamber of the system. Hence, if you can divide the wastewater into different compartments what will happen is high oxygen requirements will be equally distributed along the length of the aeration tank so the efficiency will be much more.

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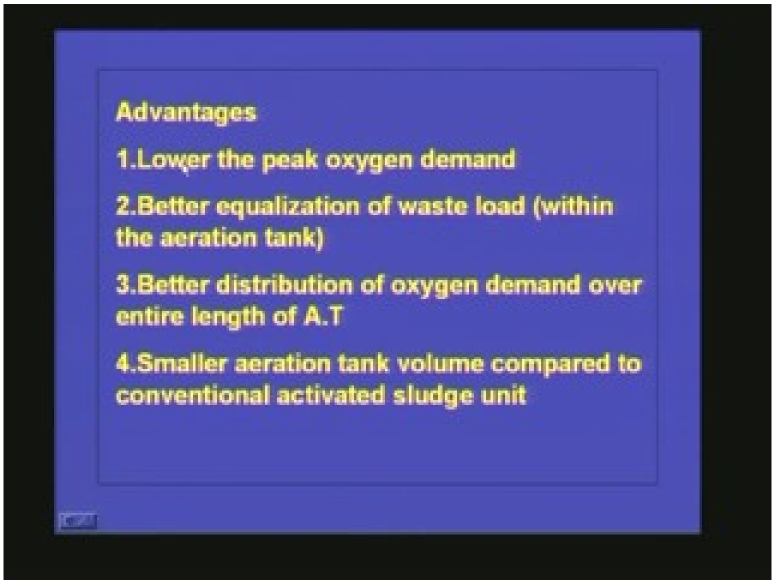

The advantages of this tapered aeration system of stepped system is;

Lower the peak oxygen demand because we are distributing the flow better equalization of wastewater within the aeration tank better distribution of oxygen demand over the entire length of aeration tank and smaller aeration tank volume compared to the conventional activated sludge unit.

Here we have seen biodegradation as well as dilution will be taking place and the concentration available will be high then it will be reducing then again it will be increasing and reducing so you will be getting high and low concentration gradient which will be increasing the degradation efficiency and moreover the volume of the waste present in the tank will be effective in the dilution. Because of these reasons the volume required in tapered aeration system is less than the conventional aeration system. Now we will see what is modification extended aeration system.

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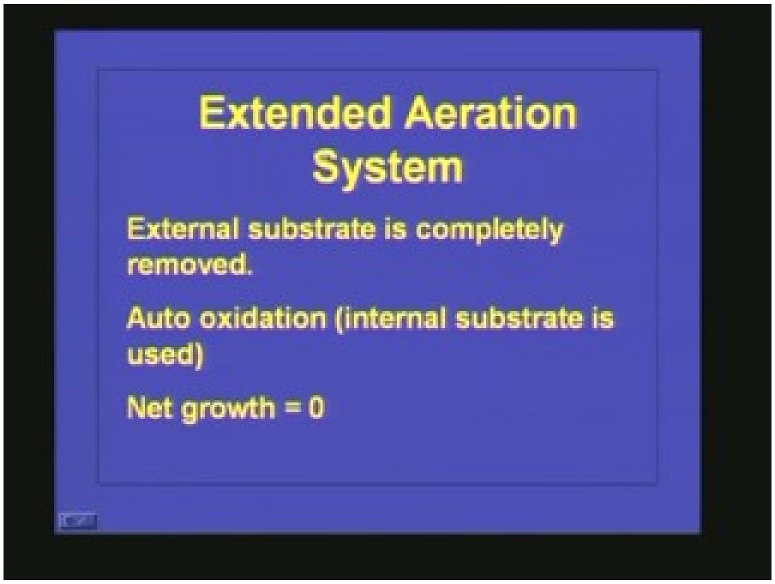

We have seen that in activated sludge process the biomass is present and the wastewater is coming with high organic matter and we are providing the aeration. So, during the aeration the organic matter is getting converted to carbon dioxide water and fresh cells. But in extended aeration system what happens is the food supply will be limited and the aeration time will be comparatively larger so what will happen is whatever the food is available first it will be getting converted to biomass and afterwards there will not be any food available in the system so whatever biomass is present in the system it will be undergoing auto oxidation or endogenous respiration.

Are you remembering the growth curve of microorganisms?
We have a lag phase then a low growth phase then stationary phase and endogenous respiration phase. In the endogenous respiration phase what will happen is some cells will be utilized by other microorganisms as food and energy sources that is endogenous respiration. In extended aeration system this endogenous respiration will be taking place or external substrate is completely removed and auto oxidation or internal substrate is being used so net growth system will be equal to zero there will not be any excessive biomass production in the system.

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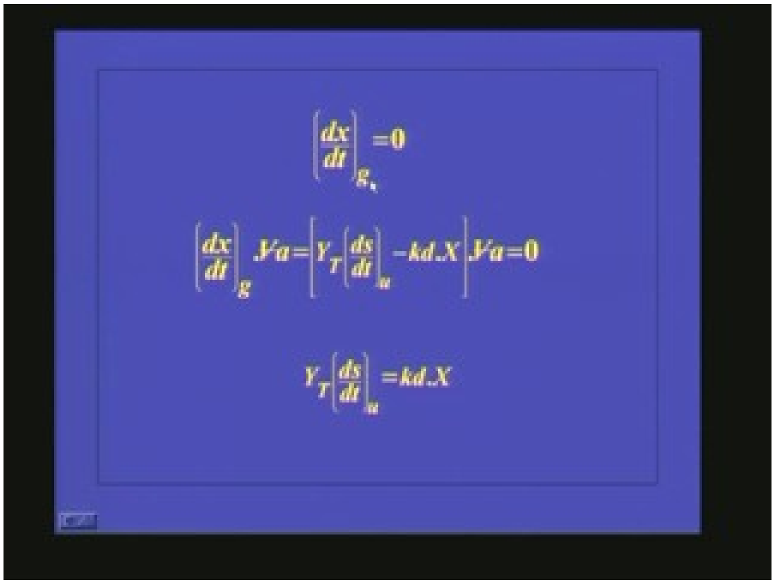

Or we can write like this; dx by dt growth, the biomass growth is equal to zero or if you write down mass balance equation dx by dt growth into Va this is the total change in microbial concentration in the aeration tank that is equal to Y_Tq minus kd into X into total volume. And we have seen that the growth is equal to zero or from this equation we can write like this; Y_T into ds by dt is equal to kd into X. So this is the expression for extended aeration system or we can write q is nothing but q_{max} Xe by ks plus Se that is equal to kd into X or Q is equal to kd by YT so this is the expression for extended aeration system and q is nothing but q into s not minus Se by Va. And in conventional activated sludge process or in extended aeration system if you see Q will be coming around 0.1. And in conventional activated sludge process Q is equal to k into Se that is equal to around 3.

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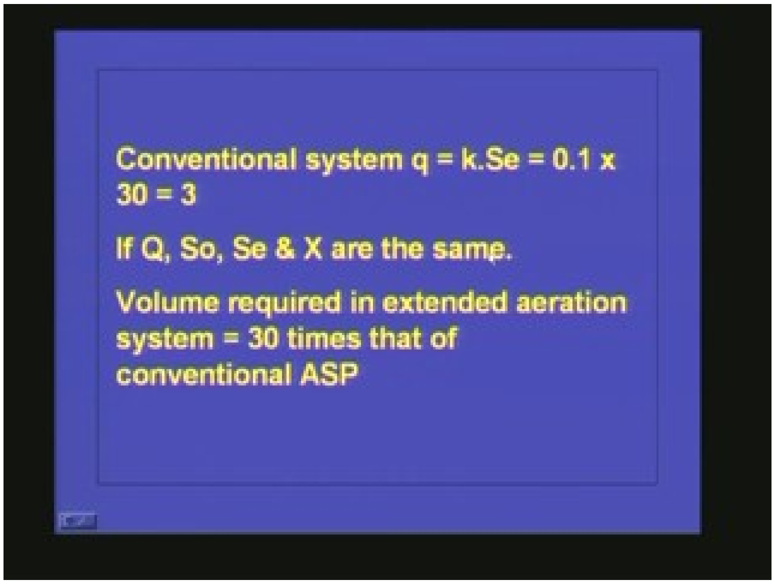

And if Q, So, Se and X are the same in conventional activated sludge process and extended aeration system the volume required in extended aeration system is thirty times that of conventional activated sludge process because here we have to give much more time for the auto oxidation of the cell because in conventional activated process we will be keeping the system in the stationary growth phase. But in the extended aeration system we are aerating it for such a long time that the entire external carbon source is completely utilized and internal carbon source will be utilized afterwards.

The advantages of the system is sludge production is minimal. Usually the sludge will be producing but whatever sludge is produced everything will be undergoing auto oxidation so the net sludge production will be very very minimal and moreover whatever sludge is available or whatever sludge is present in the extended aeration system will be completely stabilized so we can just discharge it and put it into the sludge drying beds or we do not have to go for any sludge digesters. Then the sludge handling in the extended aeration system will be much much easier. Those are the advantages of the system.

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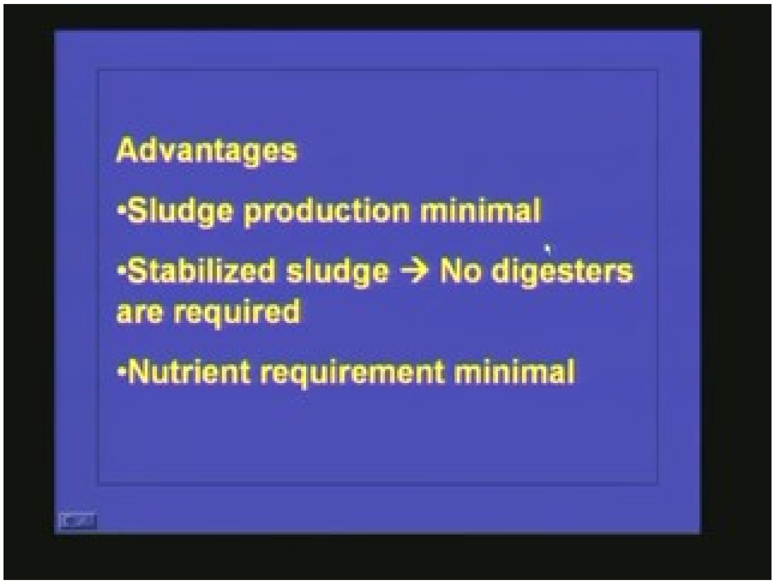

The sludge production is minimal and the sludge is stabilized no digesters are required and nutrient requirement is minimal. Why it is happening? It is because biomass will be produced and there will be auto oxidized so as a result carbon dioxide and water will be formed and the nutrients nitrogen, phosphorus, etc will be still remaining in the system so whenever the new biomass is produced that will be utilized and again the same thing will be coming back to the system. So the nutrient requirement of extended aeration system is much lower compared to conventional activated sludge process. Obviously there are certain disadvantages of this system.

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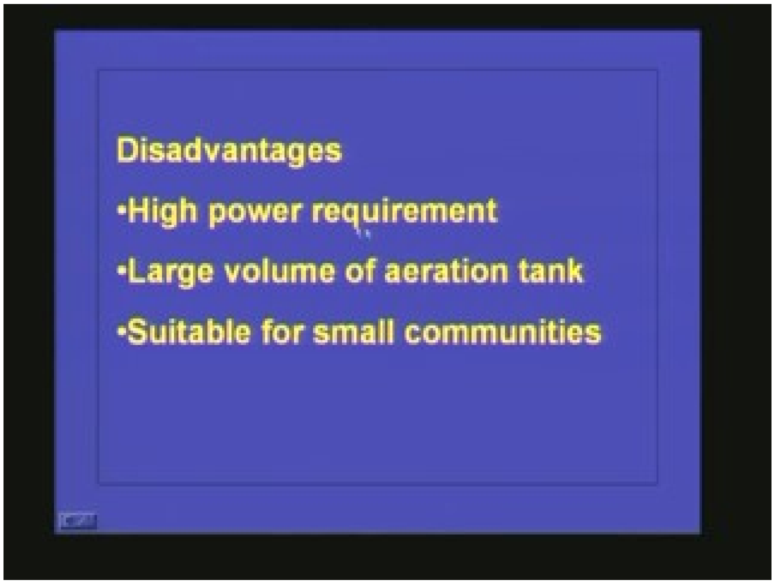

One is high power requirement. Since we have to go for aeration for such a long time definitely the power requirement is high and there is a large volume of aeration tank. Since we have to keep the wastewater for such a long time and aerate it the volume of the aeration tank will become very high. This extended aeration system is usually practiced for small communities where the wastewater quantity is less and if they do not want to go for sludge digesters etc this is the best treatment option. We can get up to 90 to 95% of BOD removal efficiency in this system.

Now we will see the biological sludge retention time in the extended aeration system. Theoretically speaking the BSRT is infinity because we are not wasting any sludge from the system.

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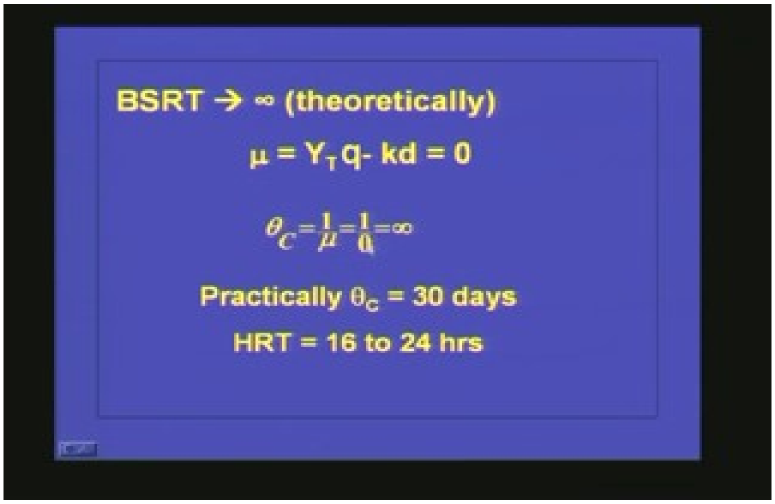

In conventional activated sludge process we are wasting the sludge so we can find out the BSRT which is nothing but the total sludge divided by whatever is the sludge wastage daily. so this is the equation we have; mu the specific growth rate is equal to Y_Tq minus kd and you know that mu is equal to 0 or theta$_C$ that is BSRT and theta$_C$ is nothing but 1 by mu so it will come 1 by 0 and 1 by 0 is infinity. But practically we cannot provide infinity time in the aeration tank so usually we give a theta$_C$ value of 30 days and hydraulic retention time of sixteen to twenty four hours. So that is the extended aeration system.

The oxidation ditch or Pasveer ditch is one type of activated sludge process which is working on extended aeration system.

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Here there will not be any sludge production or the sludge production is minimal and whatever the sludge is coming it is completely stabilized so we can discharge them into the sludge drying beds. This shows the photograph of an oxidation ditch.

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This is a type of brush aerator**.** It is a surface aerator so it will be aerating the system and it will be giving the horizontal velocity for the flow.

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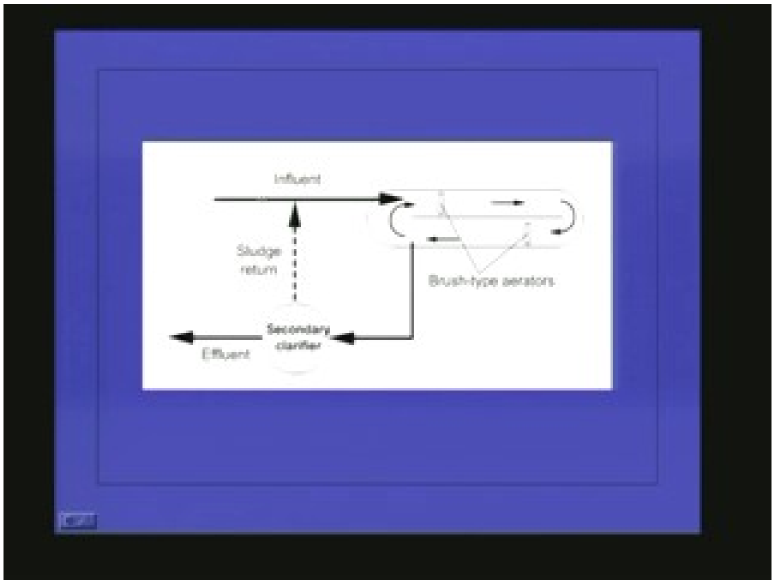

This is the schematic of oxidation ditch. Here we have the **brush aerator** and the influent will be coming like this and it will be going around the ditch. This is the long narrow ditch so definitely the flow region will be plug flow and it is going like this (Refer Slide Time: 30:34) and whatever sludge is there everything will be getting re-circulated and we can collect from here the treated water and definitely we will be giving a secondary clarifier. So whatever biomass is coming out can be settled here and the entire sludge will be re-circulated in the system.

The working principle of this oxidation ditch is nothing but extended aeration system and it is a compact unit. Sedimentation, aeration and sludge stabilization are taking place in one unit.

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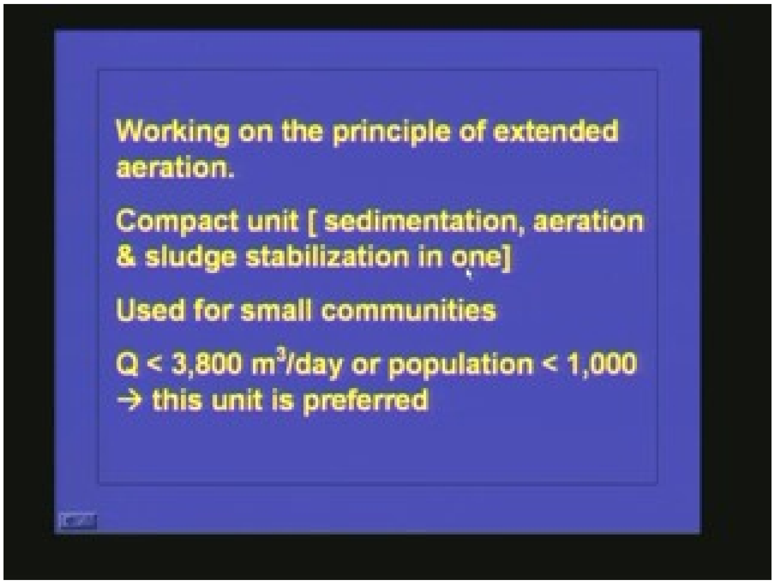

We do not have to provide a primary sedimentation tank or a sludge digester, everything will be taking place in the same system and it is very good for small communities. If Q is less than 3800 meter cube per day or population is less than thousand this unit is preferred. If the Q is more than what will happen is the area required for the system will be very very high so at the time this oxidation ditch is not recommended. Do not get confused with oxidation ditch and oxidation pond. The oxidation pond is entirely different from oxidation ditch we will be discussing about oxidation pond later. Oxidation pond is not an activated sludge process whereas oxidation ditch is modified version conventional activated sludge process.

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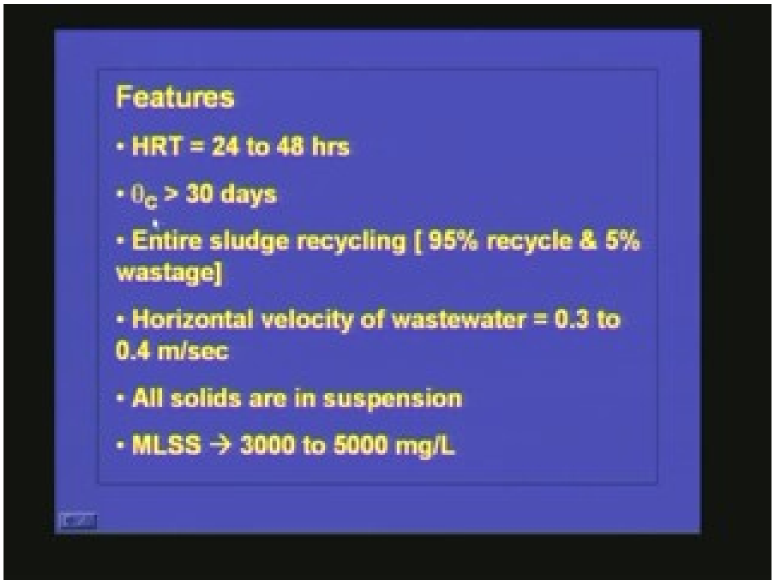

The features of this oxidation ditch are; HRT varies from 24 to 48 hours and theta$_C$. The biological sludge retention time is more than 30 days and entire sludge is recycling. Usually what happens around 95% of the sludge is recycled and 5% is wasted. This will take care of the accumulation of inorganic substance in the system and horizontal velocity of the wastewater varies from 0.3 to 0.4 meter per second and it is controlled by the fresh aerators. And all the solids are in suspension. The aerators are placed in such a way that all the solids are in suspension and MLSS concentration varies from 3000 to 5000 milligram per liter.

Now we will see the other modification of activated sludge process that is contact stabilization process. In conventional system we have an aeration tank and a secondary sedimentation tank. But in contact stabilization tank we will be having a contact tank initially then secondary sedimentation tank then the stabilization tank that is why this is known as contact stabilization.

This process is used or useful for wastewater which contains lot of colloidal particles. for example, the waste is coming from the diary industry it will be having lot colloidal particle so, if colloidal particles are presented it will be very difficult for treatment. The reason is, we have seen the mechanism by which the microorganisms are utilized in the organic matter. The first step is the organic matter has to go and get attached to the microbial cell then it has to penetrate to the cell wall then only the microorganism can metabolize it and produce carbon dioxide and water and other products. But if the particle size is very high for example colloidal particles the particle size will be much higher compared to the cell so those particles will not be able to penetrate through the cell so how can the cell utilize the organic matter it will be very very difficult. Before utilizing that one the microorganisms have to hydrolyze the colloidal particle or split that one into very small pieces so that it can penetrate through the cell wall. How it is possible?

Or if you want to go for this hydrolyses, you know that in conventional activated sludge process the aeration time is only six to eight hours so this time may not be sufficient for hydrolyses and the penetration through the cell and the metabolism. So, if you want to treat the colloidal particles really in a conventional activated sludge process the time required in the aeration tank will be very very high that will become uneconomical because that much time we have to aerate it and volume of the tank will become very huge. So to avoid that one this modification has come up. That is what I have written here.

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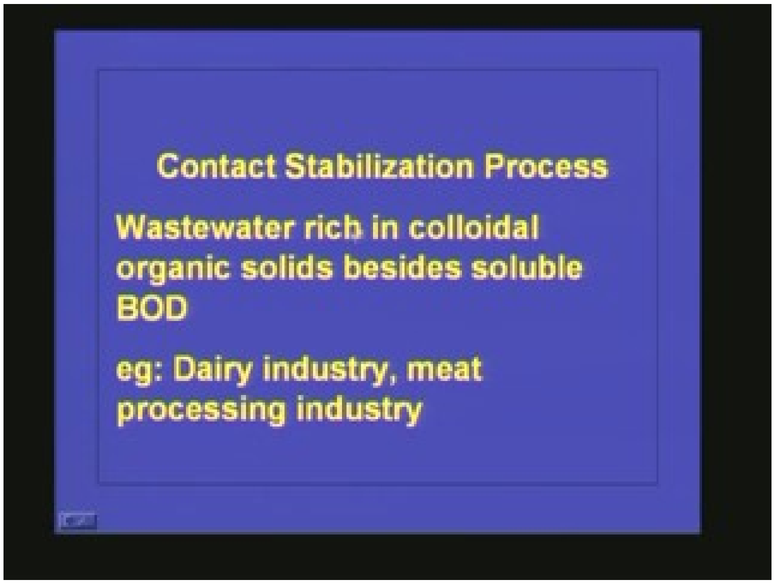

- Wastewater rich in colloidal organics solids besides soluble BOD

This process is suitable. Example is; dairy industry and meat processing industry. So, if you see the filtrate BOD in such cases we can see this trend.

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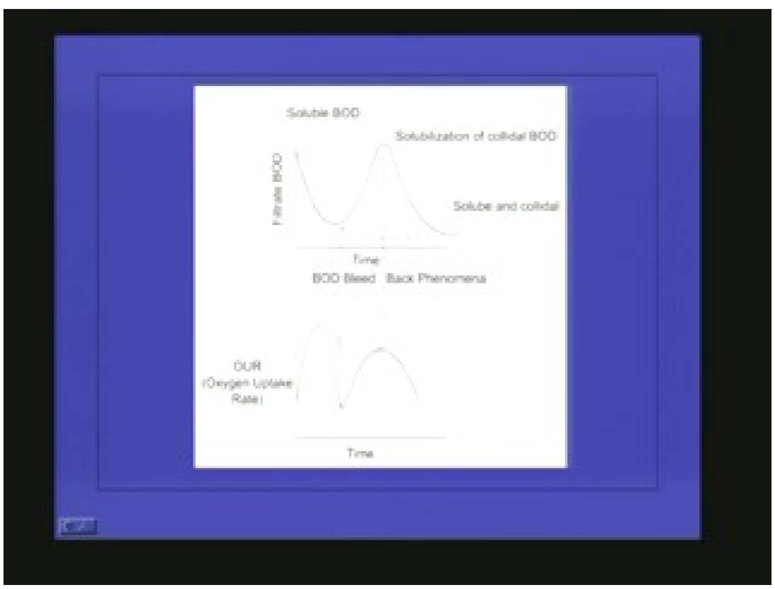

This is the filtrate BOD with respect to time. Initially the filtrate BOD will be very high and the microorganism will start utilizing it so it will be reducing. Only the soluble BOD is there and this will be having a strand like this, it will be going like this (Refer Slide Time: 36:00). But if colloidal particles are there then it will be going like this and mean while the microorganisms will be hydrolyzing the colloidal particles and making them in the soluble form so again the soluble BOD will be increasing like this then again it will be decreasing. This is the pattern of filtrate BOD or the soluble BOD. This process is known as BOD bleed back phenomena because initially the BOD is coming down again it is shooting up and again it is coming down so this is known as BOD bleed back phenomena.

The BOD profile is like this; it shows how oxygen utilization takes place or it shows the oxygen uptake rate in the system. Initially the oxygen uptake rate will be zero then it will be suddenly increasing. We can see that as the BOD decrease that much of oxygen will be consumed by the microorganism so the oxygen uptake rate will be increasing then as it comes down this also will be coming down. Again here is the peak for the BOD so again the oxygen uptake rate will be increasing and it will be coming down. So, if you want to go for a conventional aeration tank or conventional activated sludge process we have to provide this much of time for the complete treatment of the waste and we will be aerating it continuously. So here the oxygen will be utilized and here whatever oxygen we are supplying will not be utilized because the oxygen requirement is very very low and again here (Refer Slide time: 37:40) we are utilizing the oxygen.

Therefore in this contact stabilization process what is happening is the first tank will be taking care of this portion and the second tank will be taking care of this portion. We will see in detail.

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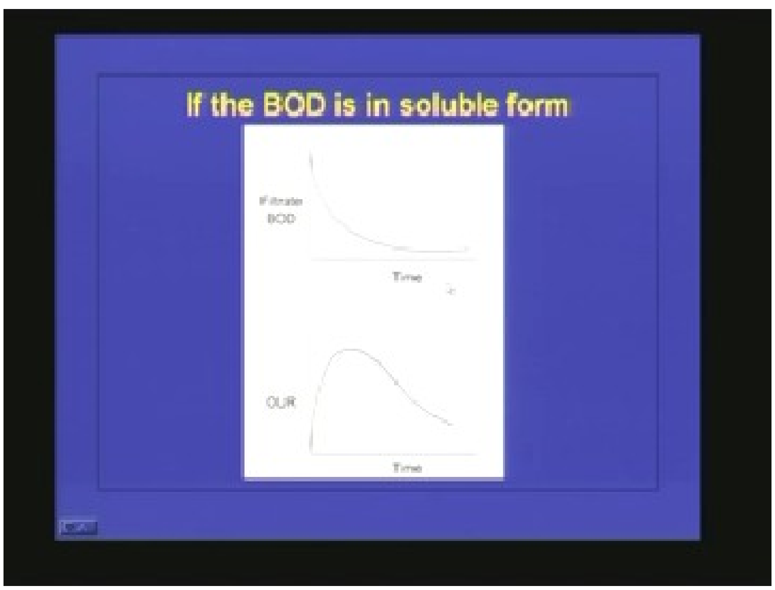

This is the profile. If the BOD is completely soluble the filtrated BOD will be going on decreasing. So if you see the oxygen uptake ratio or oxygen uptake rate initially it will be increasing then it will be decreasing there will not be any further increase.

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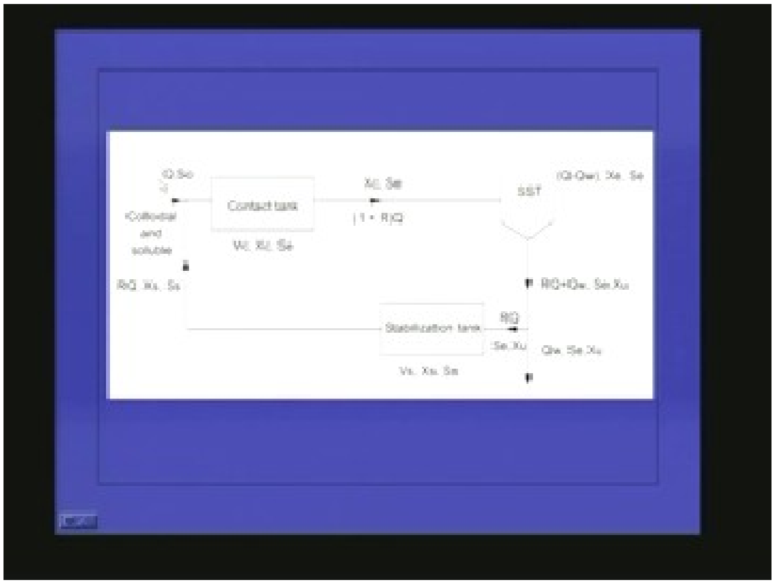

This is the schematic of a contact stabilization tank. The wastewater is coming with a flow rate of Q and a BOD of So and it contains both colloidal and soluble matter and this is the contact tank with a volume of Vc (Refer Slide Time: 38:30) and biomass concentration of Se and BOD of Se. Here the soluble BOD is changing from So to Se then this is coming, this is the secondary sedimentation tank so if we waste the sludge from here or here the effluent flow rate is Q minus Qw and biomass concentration is Xe and BOD is Se. And here what we do is a portion of the sludge will be going out and remaining will be coming to the stabilization tank, the flow rate is Rq and soluble BOD is se and biomass concentration is Xu and this is the volume of the stabilization tank Vs Xs and Ss.

Here this is Xu, in the contact tank we give the detention time very less may be thirty minutes so what will happen is whatever is the soluble BOD which is highly degradable that will be getting degraded and some biomass increase will be taking place and whatever is the colloidal particle we give enough time here so that the colloidal particles will be getting attached to the microbial cells so we will be having biomass which is having the colloidal particle attached to them and that one will be coming to the secondary sedimentation tank. Here the biomass is getting settled and along with that one the colloidal particles are also getting settled but we are giving sufficient time here. We are giving 1.5 to 2 hours in the secondary sedimentation time so meanwhile the microorganisms will be secreting extra cellular enzymes which can hydrolyzes the colloidal particle. So along with the biomass the colloidal particles also will be coming to the stabilization tank by the time it will be almost hydrolyzed or it must have become the soluble form.

Here we are again aerating the stabilization tank so whatever is the BOD available in the soluble form along with the microorganisms so it will utilized by the microorganisms and more and more cells will be getting generated and only biomass will be coming to the contact tank. We will see the volume of contact tank aeration tank and we will compare the contact stabilization tank and conventional tank.

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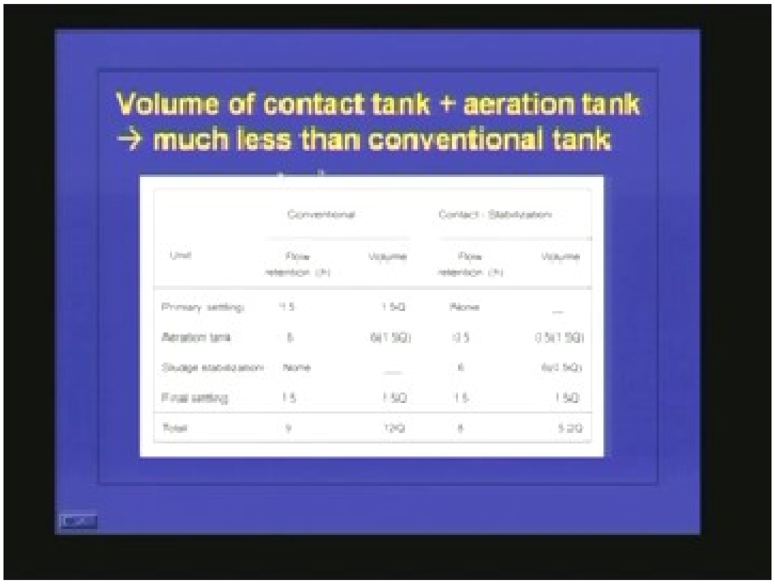

When we talk about this one; in conventional system we need a primary settling. usually the detention time we give is 1.5 hours but naturally the volume required is one point five times Q. In contact stabilization tank we do not want to remove any suspended organic matter because the stabilization tank and the contact tank will be taking care of that one so flow detention is zero and volume of the tank required is zero.

And for aeration tank usually the detention time of 6 to 8 hours is provided so volume required is 6 into 1.5 Q and here only 30 minutes is given in the contact tank so the volume required is 0.5 into 1.5 Q. Here we get 1.5 Q because we are assuming a recirculation of 50% and sludge stabilization or stabilization tank is not present in conventional system whereas in contact stabilization the stabilization tank is present and we usually give an aeration time of 6 to 8 hours so the volume required is 6 into 0.5 Q.

As we can see here the re-circulated thing only is coming to the stabilization tank so the flow coming is only 0.5 Q and that is why the volume is 6 into 0.5 Q and final settling 1.5 Q is there so the volume required is 1.5 Q.

Here also (Refer Slide Time: 42:40) secondary sedimentation tank is there 1.5 and the volume required is 1.5 Q. So if you sum up the volume in conventional tank and contact stabilization in terms of q we can see that conventional aeration conventional activated sludge process require a volume of 12 Q whereas contact stabilization requires a volume of 5.2 Q. That means the volume requirements in contact stabilization process is only 50% of that in conventional activated sludge process. How we can design the contact tank?

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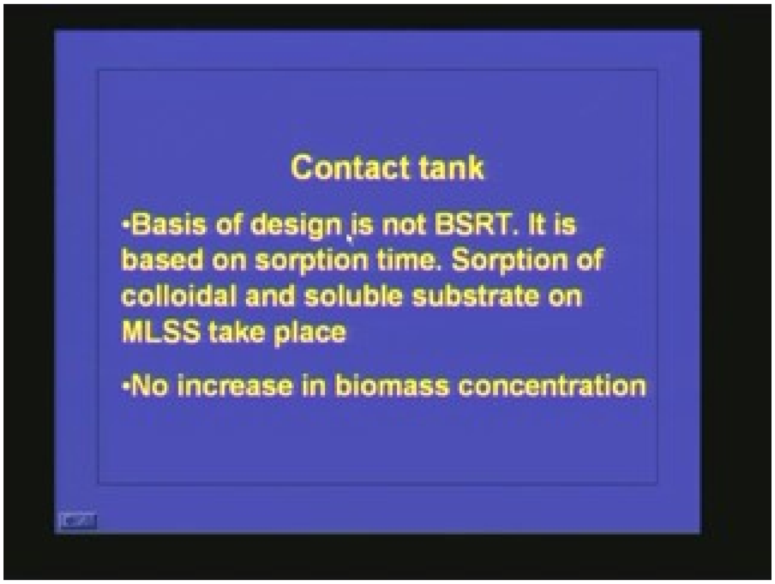

The contact tank design is based not on the BSRT because we are not converting all the organic matter present in the system; it is based on sorption time. Whatever colloidal particle is present in the system we want them to get attached to the microbial cells so the adsorption process is more important in contact tank than the biodegradation. So we have to design the system for that purpose. We know that adsorption is the very fast process so the time required for adsorption is very less that is why we give a contact time of only thirty minutes.

Sorption of colloidal and soluble MLSS take place, we are assuming that though there is slight increase in the biomass concentration because soluble BOD is present and we are giving an aeration time of thirty minutes but we are assuming that no increase in biomass concentration take place in contact tank.

In stabilization tank the stabilization of colloidal and soluble BOD by microorganisms are taking place so naturally there is an increase in biomass concentration and stabilization tank of contact stabilization process is designed in the same way as the aeration tank of conventional activated sludge process that means the design is based on BSRT. The detention time is stabilization tank is three to four hours and sometimes it goes up to eight hours. Now we will come to the next process modification that is sludge re-aeration.

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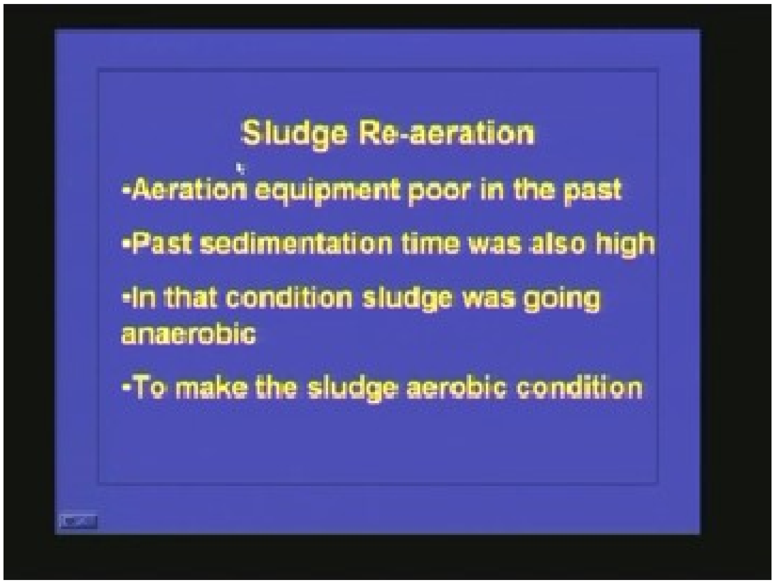

In the earlier stages aeration equipment was having a very poor capacity so they were not able to provide the oxygen requirements whatever was required in the aeration tank. So, to reduce the oxygen requirement in the initial stages where the oxygen requirement was very very high the secondary sedimentation tank whatever is re-circulated to the aeration tank was aerated so that the microorganisms will be in a highly active stage and there will not be any oxygen deficiency experienced by the sludge. So, because of this oxygen requirement the inlet of the aeration tank could be considerably reduced. Hence, in that condition the sludge was going anaerobic. So, to make the sludge aerobic the re-aeration tank was provided. The system look similar to contact stabilization but the process is entirely different.

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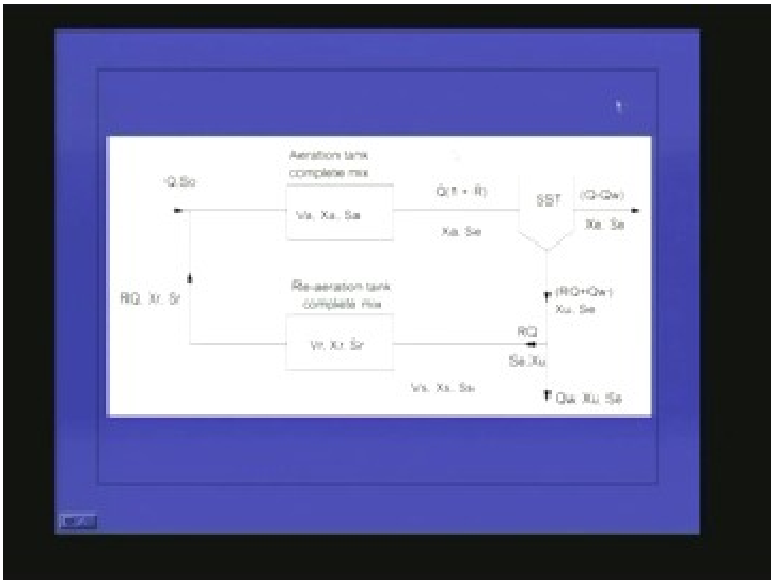

Here all the biodegradation taking place in the aeration tank and this aeration is just to make the system aerobic that was the only purpose of re-aeration. Here there is no biomass increase or degradation of organic matter was taking place. In aeration tank all the treatment is taking place but in contact stabilization process it is entirely different.

Till now we have discussed about various process modifications. We have discussed about tapered aeration system, step aeration system, we have seen extended aeration system and we also discussed about oxidation ditch which is working on the principle of extended aeration system, we have discussed about contact stabilization tank which is useful for the treatment of wastewater which is having high colloidal particles and we also seen what is this sludge re-aeration system.

There is another system which is known as high rate activated sludge process. There what we do is we keep the microbial concentration low and aerated for a short period so what will happen is the mu the specific growth rate will be very very high or the entire system will be working in log growth phase so the sludge generation will be very very high and the treatment efficiency also will be less.

This is because the microorganisms in the low growth phase may not be secreting or producing the extra cellular polymers which are responsible for the flocculation. So high rate activated sludge process this flocculation of the particle will not be taking place, hence so much of biomass will be coming out along with the treated effluent. The efficiency usually is in the order of 70 to 75% so depending upon the purpose if you want to generate more cells we can go for high rate activated sludge process.

We have seen the different process modifications. Now we will see the design considerations for activated sludge process. This is the treatment process that is most commonly used for the domestic wastewater. The first one is loading criteria.

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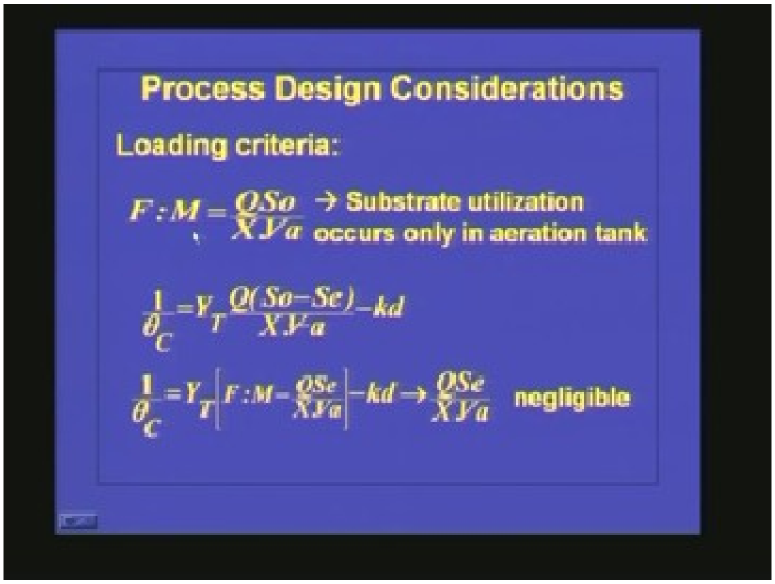

Therefore, we can express the loading criteria in terms of food is to microorganisms because the organic matter whatever is coming along with the wastewater is nothing but food for the microorganisms and the treatment is based upon the workers that is nothing but microorganisms. So the loading criteria can be expressed in terms of food is to microorganism that is nothing but Q into So this is the total food coming to the system and the total microorganism present in the system is X into Va where X is the MLSS concentration in the aeration tank and Va is the volume of the aeration tank. Why we are considering only this system is because the substrate utilization occurs only in the aeration tank.

We also have seen that 1 by theta$_C$ is equal to Y_Tq into So minus Se divided by X into Va minus kd or we can write like this; 1 by theta$_C$ is equal to Y_T into F is to M minus Q into Se by X into Va minus kd. So Q into So minus Va is F is to M and this term will be coming and towards the end of the time we know that this Se very very negligible compared to So, so this term we can neglect. Hence, if you neglect that term we will be getting like this; 1 by theta$_C$ is equal to Y_T into F is to M minus kd.

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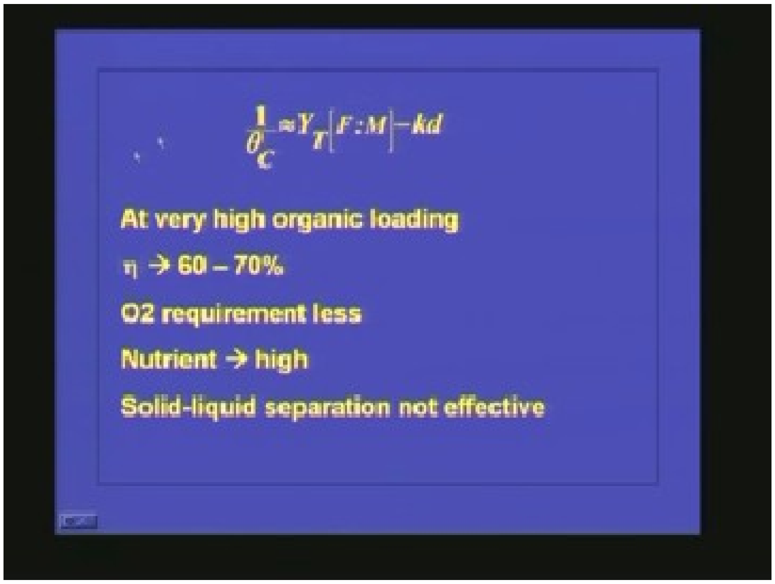

So if you design based upon the biokinetic parameters theta_C it is having a definite relationship between food is to microorganism ratio. So the loading is based upon this F is to M and we can find out the efficiency of the system. And at very high organic loading that means very high F is to M ratio the efficiency will be decreasing the efficiency will be only 60 to 70% and if you go for high F is to M ratio oxygen requirement is less. The reason is the process will be working on high rate activated sludge process. That means the entire system will be in the low growth phase and in the low growth phase the oxygen requirement is less and the sludge production will be maximum. So after knowing what you need or what is the final thing you need, then depending upon that one we can change the F is to M ratio.

In extended aeration system we keep this F is to M ratio very low but in high rate activated sludge process this F is to M ratio will be very high. And if F is to M ratio is high naturally oxygen requirement is less, more biomass will be generated so nutrient requirement will be very high and all the microorganisms will be in the low growth phase so solid liquid separation will not be effective, the reason is flocculation will not be happening properly. The next design criteria is excess sludge production.

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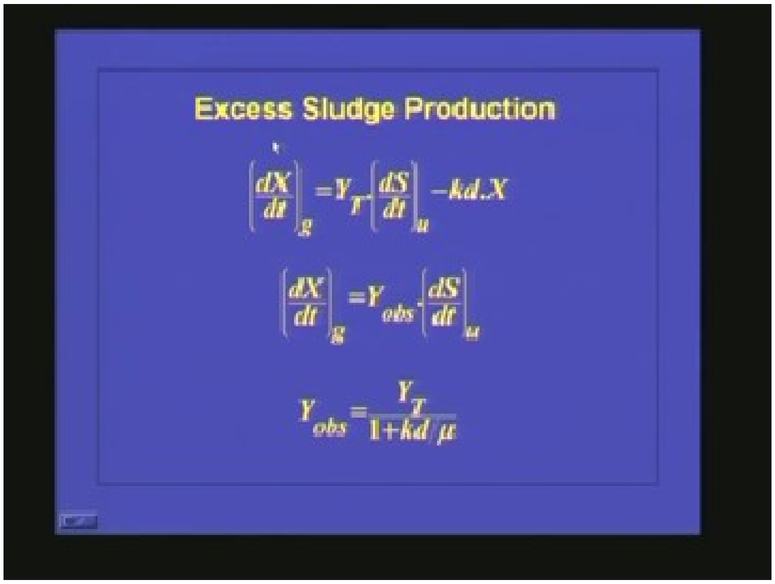

Whenever we talk about the activated sludge process more and more sludge will be generated so we have to handle the sludge. If the process is generating more sludge the post treatment requirement is more. Se has to go for sludge digesters and sludge handling itself problem. So how can we calculate the sludge production? We can this formula (Refer Slide Time: 51:45) for calculating the sludge production. We know dX by dt the rate of change of biomass in the system is equal to Y_T the yield coefficient into q dS by dt the rate of change of substrate in the system minus kd into X this is the decay constant into biomass concentration. We also know that dX by dt growth is equal to y **absorbed** into dS by dt that means **observed** yield into the rate of change of substrate concentration or Y_{obs} we can write like this Y_T divided by 1 plus kd by mu.

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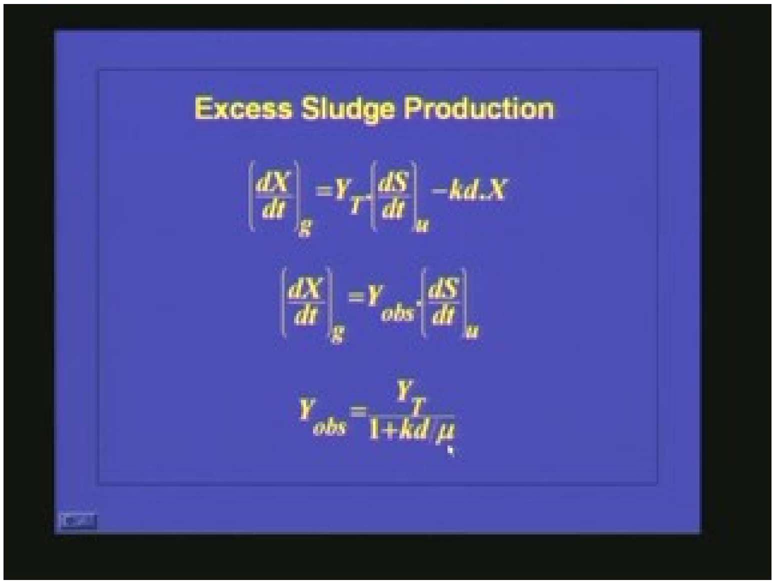

Now, what is the biomass produced, that is nothing but delta X is equal to Y_{obs} into delta X. So if you know the observed yield then we can find out what is the biomass production or biomass production we can calculate like this; delta x is equal to Y_{obs} and delta s is nothing but q into s not minus Se this is the substrate utilized in the system So is the initial BOD coming to the system and Se is the BOD going out of the system.

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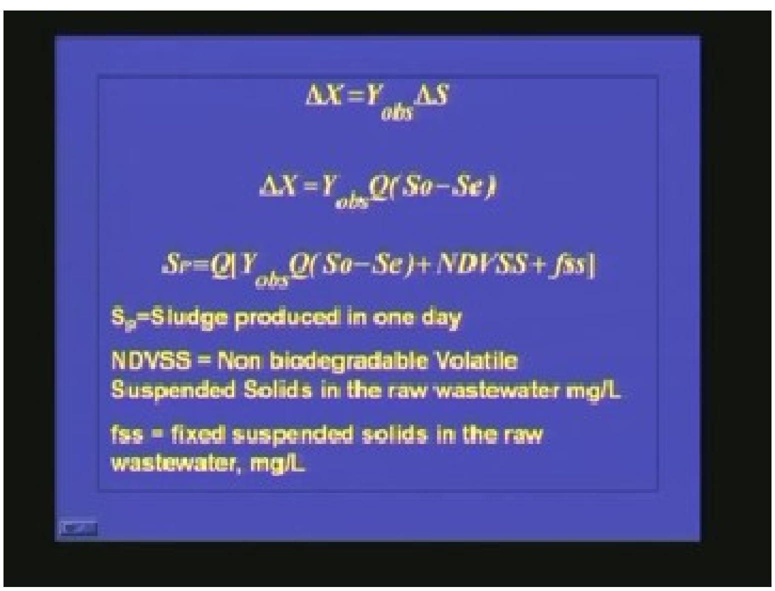

And we know what is the y observed which we can calculate using this formula. We know Y_T from the biokinetic parameter estimation and kd we know and mu we will be knowing so from that one we will be knowing y observe. This is the total biomass production. But in activated sludge process apart from the biomass there will be other solids also whatever is non biodegradable and the solids which is of nitrogenous origin. So if you want to find out what is the total sludge produced in the system we can use this formula; Q this is the flow rate into y observed into So minus Se plus NDVSS plus f into SS where Sp is the sludge produced in one day and NDVSS non biodegradable volatile suspended solids in the raw wastewater because all the organic matter whatever is present in the system may not be biodegradable so there will be non biodegradable volatile organic matter present in the system and fss is the fixed suspended solids in the raw wastewater. So the total sludge produced will be available because this is essential for the design of the sludge digester.

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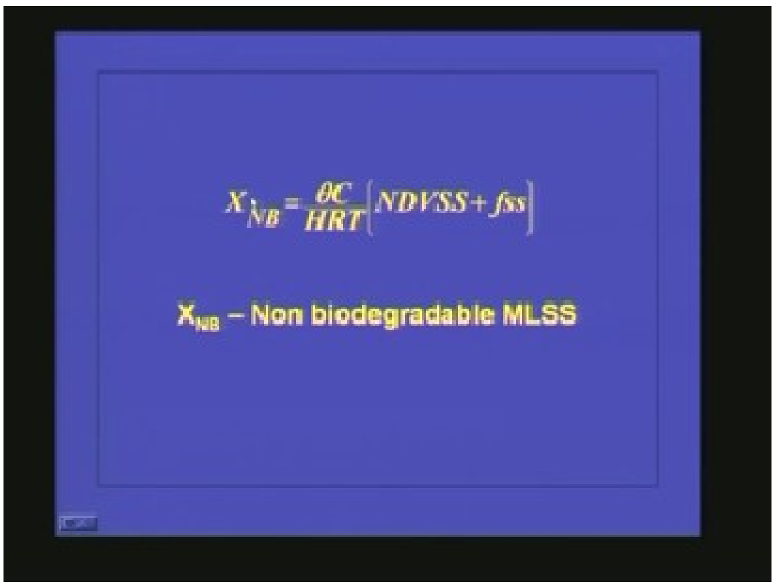

Now we can calculate what is the non biodegradable MLSS in the system by using this formula. This is nothing but X_{NB} where X_{NB} is the non biodegradable liquid suspended solids that is equal to theta$_C$ this is the BSRT so BSRT by HRT into NDVSS plus fss. If we know the non biodegradable volatile suspended solids present in the system and what is the concentration of fixed suspended solids present in the system we can find out what is the non biodegradable MLSS concentration in the system.

Now we will see what are the things we discussed today. We have seen the different ways we can design the activated sludge process. We have seen three different ways. In one system we know all the biokinetic parameters. So using the expression whatever we have derived for the biomass concentration in the activated sludge process and substrate concentration coming out of the system and the recirculation ratio we can find out what is the volume of reactor required and the biomass concentration required.

The second system is where we assume the sludge concentration in the system and we know the SVI so we can find out what is the volume of the aeration tank required and what is the recirculation ratio required. In the third case we do not know any of these things so what we do is we find out the theta$_C$ value we assume that theta$_C$ value BSRT is based upon the minimum theta$_C$ value. The minimum theta$_C$ value is nothing but the reciprocal of maximum specific growth rate.

So if you provide a theta$_C$ less than that one no treatment will be taking place. Then we have also seen the different modifications of activated sludge process. Those are step aeration system, contact stabilization process, extended aeration system, sludge aeration and high rate system. We have also discussed about what is the loading rate we can adapt. It is the food microorganisms ratio.

So, by varying the food organism ratio what we are going to get is also what we have seen here and we also discussed what is the amount of sludge that is generated in the system both in terms of microorganisms and we have also seen what is the non biodegradable sludge production in the system if we know what is the non biodegradable organic matter concentration and the fixed suspended solid concentration. In the next lecture we will discuss about the oxygen requirement and associated things.