Water and Wastewater Engineering
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Lecture-16

In the last lecture we were discussing the philosophy of enhancement of quality of water and wastewater. Just to review what we have discussed earlier I would like to say that primarily the river water is the source of water supplying and also a sink for the disposal of wastewater. That means we take water from the river and also discharge treated effluents sometime treated sometime not treated into the rivers. So it is the source as well as the sink for the water.

In the last lecture we discussed about the water quality and enhancement with respect to drinking water. Just to have a review; the philosophy of water treatment is to produce potable water which has the turbidity of less than or equal to 5 ntu, I have to produce the water with turbidity less than or equal to 5 ntu, this is required because I have to satisfy the pleasing nature of the people the water should be pleasant and also the water should not have any fecal coliform fecal coliform content should be equal to zero organism per hundred ml of water and total coliform should be of the order of three to five organism per hundred ml. these are the basic requirements of potable water.

What we try to do is that we have a treatment plant, a treatment plant has number of units, these treatment units try to produce water which is free of turbidity or turbidity less than five ntu and also produce water which does not have any coliforms. Really speaking the coliform indicates the presence of pathogens so presence of pathogens is indicated by coliforms.

Now if you look at the various units, water treatment plants if I take water treatment diagram and see the units that are present in the water treatment plant so the following are the units. Number one; the raw water or river water is coming in here, I get the river water and to this river water I add certain amount of chemicals like alum and lime, they are added and then this goes into what is called a unit coagulation and flocculation, this is the unit which tries to remove the turbidity or the suspended particles present in water. So we have got the unit, coagulation flocculation followed by what is called as sedimentation tank.

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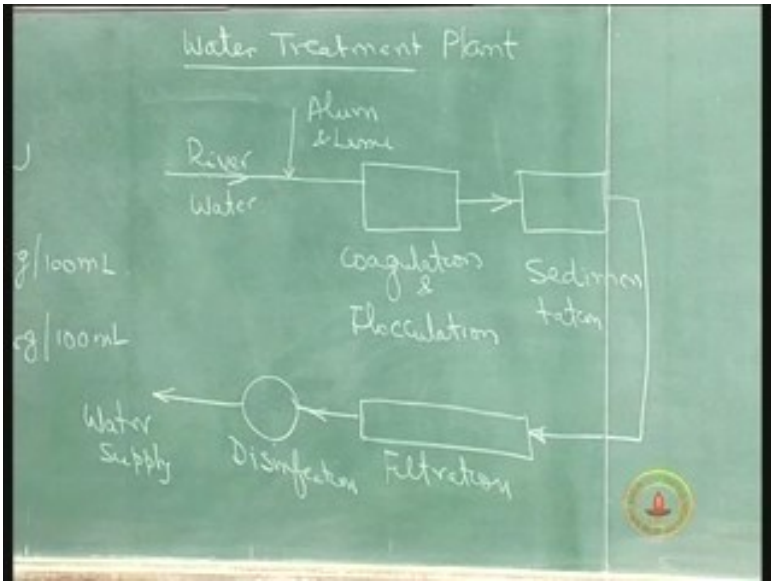

Thus, we have coagulation and flocculation followed by sedimentation and sedimentation is followed by what is called filtration unit and after the filtration unit water moves to a unit called disinfection that is I am trying to kill the microorganisms present in water so this goes to (Refer Slide Time: 5:39) the water supply, this is for water supply.

Now let us see here these are the units and these units have a specific objective. For example, addition of alum makes the small particle into bigger particles the mechanism of which you will study when you take the water treatment and in coagulation and flocculation the growth of flocs will take place particularly in flocculation followed by sedimentation. These units primarily remove up to the filtration. For example, these units; coagulation, flocculation, sedimentation and filtration removes the suspended particles and produces water, the suspended solids are removed and these produces water with turbidity less than 5 NTU, the suspended particle removal will take place here.

In fact up to sedimentation we call it as pretreatment. That is, whatever treatment we are giving here is called a pretreatment to water and the filtration itself is called as treatment and disinfection is called post treatment. These are the three things; pretreatment treatment, treatment and post treatment (Refer Slide Time: 7:40). These are the three subsections we can say pretreatment and post treatment. So up to the treatment we are trying to remove the turbidity after that in the post treatment that is disinfection the purpose is to kill microorganism, to kill pathogens and pathogens are represented by fetal coliforms that is what I said, the presence of pathogens are represented by fecal coliforms that is what we have seen as far as the water treatment plant is concerned.

Now let us turn our attention towards the wastewater treatment. If you look at the wastewater treatment suppose if you have here in the wastewater treatment the purpose of wastewater treatment is to remove the suspended particles number one, in the water treatment plant also we tried to remove the suspended particles and in wastewater also we

remove the suspended particles. In addition to that in wastewater treatment we need to remove biodegradable organic matter. That means we want to remove the biodegradable organic matter as written here.

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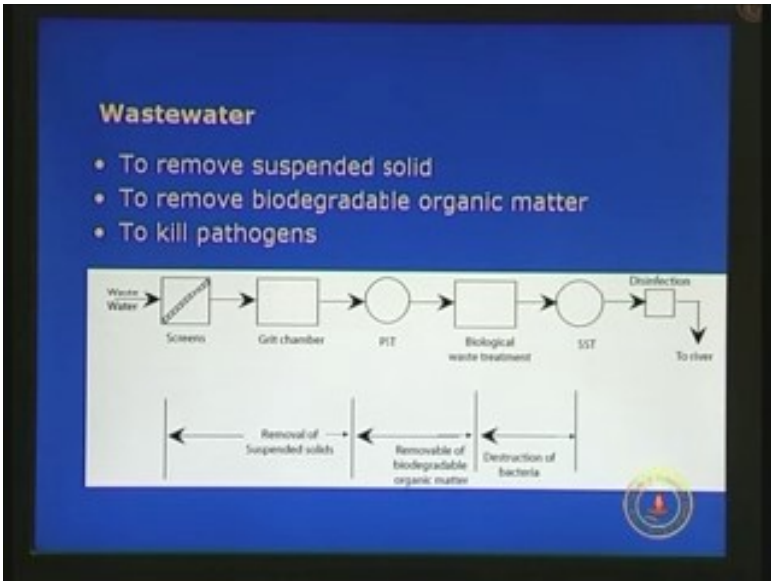

The third one is; the wastewater contains the microorganisms, the pathogens, we have to kill the microorganisms, destruction of microorganisms. For that we again have a treatment system and the treatment system here is called the wastewater treatment system. The wastewater treatment system has several units, there are a number of units in wastewater treatment system.

Looking at slide number one we have the wastewater coming in W.W that is taken into the wastewater treatment plant most of the times by gravity, mostly by gravity it comes into the treatment plant. It comes into the treatment plant mostly by gravity. Sometimes it comes into the sump well and then from the sump well you have to pump into the wastewater treatment plant. That means collect the wastewater in a sump and pump it and this pumping is just for sometime and not always; all these depend upon the topography of the place.

The first thing that will happen is that the wastewater will go into what is called a screen, first unit is the screen, that is what you can see here in the film., wastewater goes into the screen. What is the objective of the screen? The objective of the screen is to remove the floatable matter and to remove the big objects that are present in wastewater. As the floatable matter sometimes racks are there, sometimes linen, hence lots of floatable material will come into the wastewater so the screen is going to remove that particular thing, removal of floatable and large objects.

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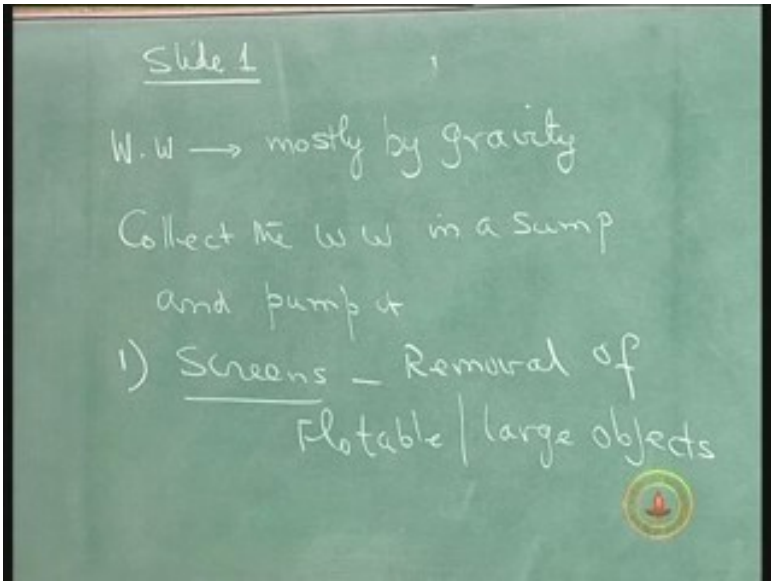

We will discuss very soon about the design aspect of the screens. Now I will tell you what are the different units that are present in this. After screens we have the grit chamber. The wastewater flows from the screens to grit chamber. The purpose of grit chamber is to remove the grit, to remove inorganic solids. So these inorganic solids are called grits. Again grit chamber; the purpose of grit chamber is to remove grit and this is inorganic solids. Inorganic solids means the source of inorganic solids is coming from the street washings hence we are going to get this lot of grits and normally the specific gravity of this particular grit is of the order of 2.65 the density is 2650 kilogram per cubic meter that is the grit.

We design the grit chamber in such a way that, design criteria of grit chamber is such that we do not want to remove any organic suspended solids so no removal of organic suspended solids is there. In other words suspended solids could be organic, suspended solids could be inorganic; both fractions are there, organic suspended solids, inorganic suspended solids. So the grit chamber is designed to remove inorganic suspended solids but it is not designed to remove the organic suspended solids. Because the specific gravity of organic suspended solids is much much less than 2.65 that is the reason why the organic suspended solids are not removed in grit chamber and I am not designing the grit chamber for removal of organic suspended solids.

After that we have got what is called PST primary sedimentation tank. Again going to the slide you have to see the slide so it is the primary sedimentation tank. Primary sedimentation tank is pst. The objective of the primary sedimentation tank is again to remove the suspended solids. And these suspended solids are of two types; organics and inorganic suspended solids. These inorganic suspended solids in this particular case will be very smaller in size hence they are not removed in the grit chamber.

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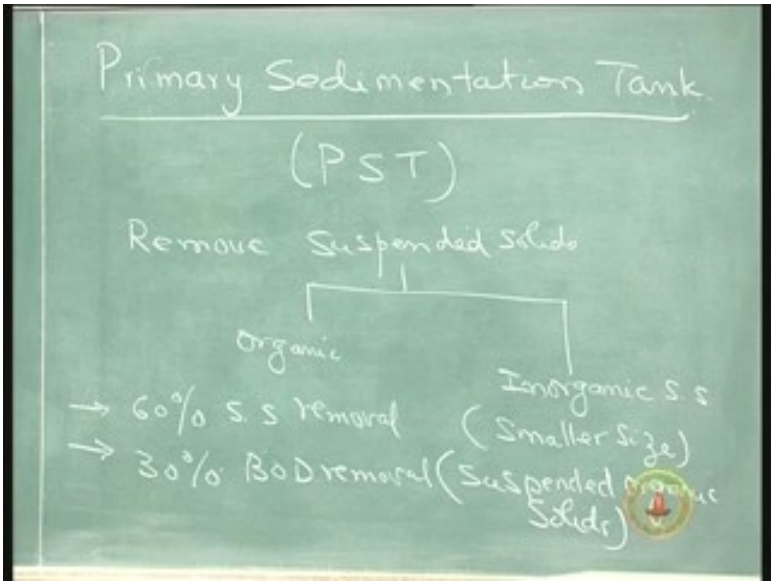

The primary sedimentation tank is nothing but the sedimentation tank where the suspended particles settle down because of the gravity I am not using any other force it is only gravitational force for the settling of suspended particles, these suspended particles gets removed in the sedimentation tank. So the extent of removal of suspended particles in primary sedimentation tank is about 60%; the removal of suspended solids is extended of 60% in primary sedimentation tank and to the extent of 30% BOD removal takes place. The BOD is the biochemical oxidation demand and for these biochemical oxidation demand thirty percent of removal of BOD is there means this BOD is because of the suspended organic solids. Here we are able to remove 30% of BOD. So if you are having a sedimentation tank it removes sixty percent of solids and also removes 30% of BOD.

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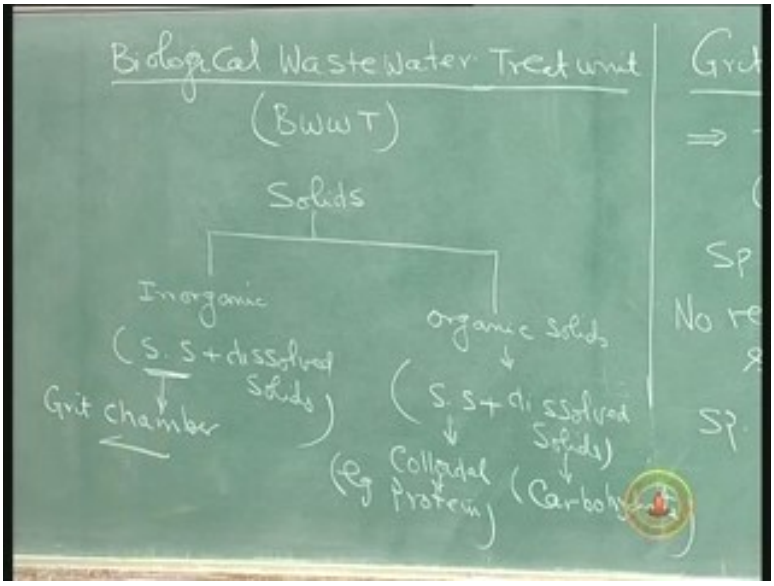

After the sedimentation tank by units that is present is what is called a biological wastewater treatment unit BWWT. This is the next unit that we have in the slide. What takes place here? We have primarily said that we have got the solids which are present in the wastewater, these solids can be divided into two parts; one is the inorganic solids, another is organic solids the solids of organic nature, so inorganic solids could be both suspended plus dissolved solids and similarly organic solids could be suspended plus I have got dissolved solids also in the organic fraction, the suspended solids could be in the form of even colloidal solids. Colloidal solids means the size of the colloidal particle is very very small. An example of the colloidal particles present in the wastewater is a protein.

Dissolved solids that are organic nature could be sort of a carbohydrate present in water carbohydrate present in water. So, in other words what we have is in the wastewater organic solids and inorganic solids. Organic solids could be of suspended form and dissolved form. Dissolved solids are like carbohydrates and suspended solids are colloidal in nature which could be proteins.

For example, the grit chamber removes suspended inorganic solids and primary sedimentation tank is able to remove again inorganic suspended solids and also organic suspended solids that is what I said here. Organic suspended solids inorganic suspended solids are removed by the primary sedimentation tank. Now, what I am left with is some amount of colloidal solids and also the dissolved solids. Colloids plus organics dissolved solids are the two things what we have in the wastewater after grit chamber and primary sedimentation tank.

So, in the biological wastewater treatment what we try to do is we attack we try to remove the colloidal and dissolved organic matter. That means biological wastewater treatment is aiming at removal of dissolved organic matter and removal of colloidal

organic matter. These are the two things which we try to remove; colloidal organic matter, I will write (O.M) here for organic matter.

Now I can write an equation like this that is I have got the organic matter (O.M) is the organic matter plus I have dissolved oxygen to the bacteria, oxygen I am giving plus microorganisms, organic matter is present in the wastewater, microorganisms are also present in the wastewater and I am supplying oxygen using aerators, I supply oxygen by churning the water, by mixing the water I supply the oxygen. So when I have this particular reaction that is organic matter is present, microorganisms are present in the wastewater and I am supplying the oxygen so now what will happen is that the microorganisms utilize the organic matter in the presence of oxygen and produce end products like carbon dioxide and water. Carbon dioxide and water are the end products plus more cells which mean more bacterial cells and the cells which are produced are of different types, they are flocculating bacteria or flocculating biomass. It flocculates, flocculating biomass is produced when this reaction takes place.

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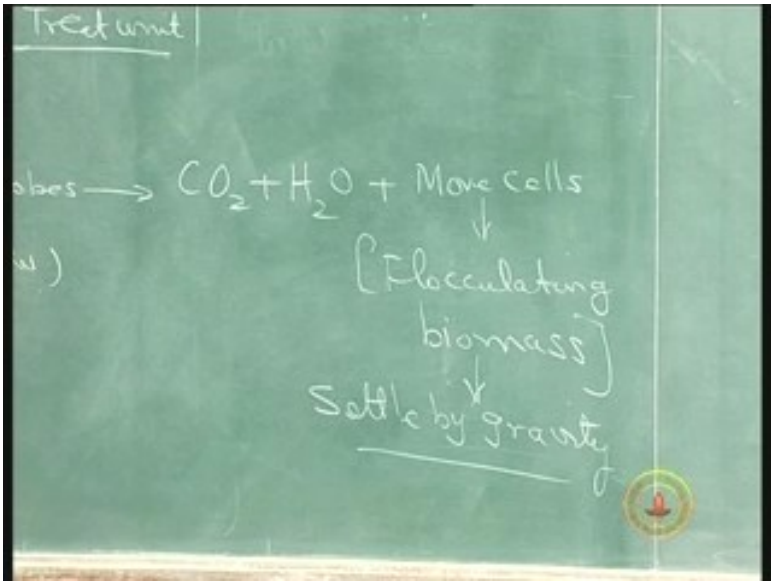

Now this flocculating biomass is produced should be removed. This flocculating biomass which is produced has a specific nature. What is the specific nature? It can settle down by gravity. This will settle by gravity. What I am doing here is I am converting the dissolved organic matter into carbon dioxide and water and also more cells, cells are produced cells are nothing but again organic matter. I can consider cells to be organic matter. So now what all I am doing is that the dissolved organic matter is converted into suspended organic matter again and that suspended organic matter can be settled by gravity in a SED tank that is sedimentation tank.

Suppose if I take an aerobic microbial system, aerobic microbial system means I am putting dissolved oxygen that means presence of (D.O) which means aerators are present. What will happen is that if I give organic matter in aerobic system 50% of this organic

matter will get converted into carbon dioxide and water and the remaining 50% of organic matter goes for the biosynthesis. Biosynthesis means synthesis of new cells. That is what I have written here more cells. Biosynthesis or this is the biomass increase.

Now I would like to ask you a question; if I give one kilo gram of BOD as wastewater that is organic matter is one kilogram in terms of BOD then how much biomass you can expect, how much carbon dioxide and water you can expect. That means the amount of the b o d that goes into carbon dioxide and water which means this is energy production (Refer Slide Time: 27:00) the amount of biomass that goes into energy production is 50% that is 0.5 kg of BOD. So 0.5% of BOD is utilized for the production of energy and energy production is manifested by the production of carbon dioxide and water. The cells are utilizing to produce energy.

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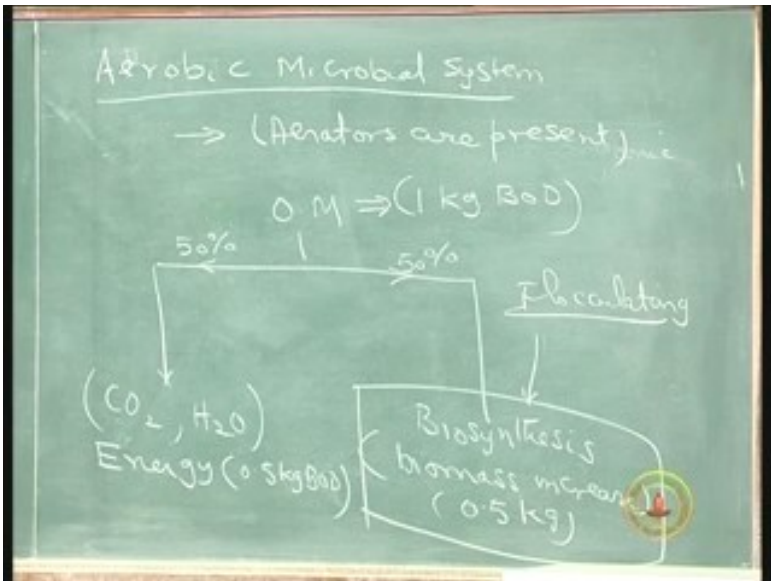

The remaining 50% of BOD that is point five percent of BOD goes into the biomass synthesis. I will get a biomass weight equivalent to 0.5 kg of BOD that is what you are going to get here. So this particular biomass which I am saying here is flocculating in nature. This is flocculating that means it can settle down that is why I have given a secondary sedimentation tank there. You can see a secondary sedimentation tank comes into the picture.

The objective of second sedimentation tank is to remove the suspended biomass. SST is secondary sedimentation tank; the objective is to remove the flocculating biomass by gravity. By gravity I should remove this biomass. There is no other force I am using, no energy is used, it is just by gravity I am trying to settle the biomass that is produced. After the secondary sedimentation tank the biomass is removed after that what I have is the liquid effluent. The liquid effluent in the treated wastewater which does not have inorganic suspended solids, organic suspended solids and organic dissolved solids will be going out into the system. So this particular effluent has no organic and inorganic

suspended solids, no organic dissolved solids. This liquid effluent is finally disinfected. I will disinfected it, add chlorine to it or ultraviolet radiation to it so that I will ultraviolet the effluent so that the microorganisms are killed. That means the final step, the terminal treatment is disinfection. The purpose of disinfection is to kill pathogens before water is allowed to get into the river so I finally discharge the treated effluent into the rivers. So what we do is, now we will go into the next slide and see the treatment system more closely.

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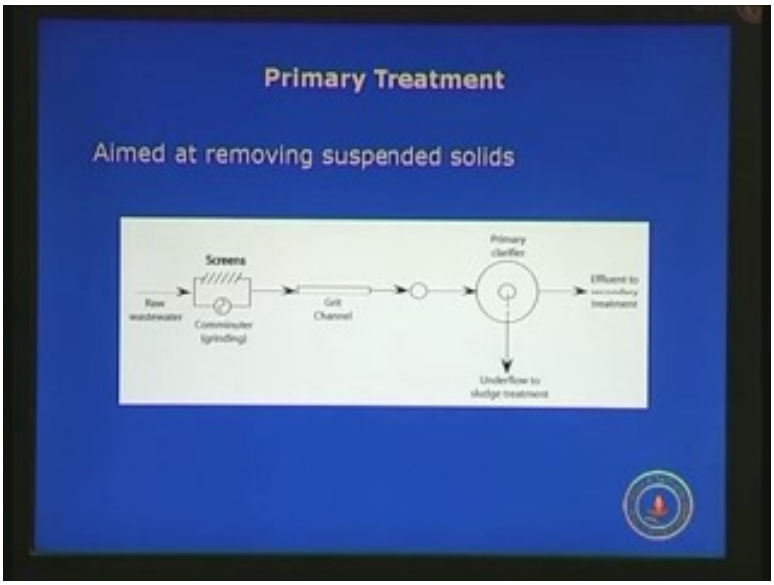

So what I can do is I can divide the wastewater treatment systems into various categories. First one is called primary treatment. I am driving the wastewater treatment system for the convenience of understanding into three segments. One is called the primary treatment. Primary treatment constitutes the following units:

We have screens, then the second thing is communitors, these are also called grinders, the purpose of the grinder is that they grind the large objects into smaller pieces so that they can be removed in the grit chamber so that is what its purpose is. And afterwards we have got the grit chamber for which we will discuss about the design aspects very shortly then we have the flow measurement device. I will install a flow measurement device after grit chamber because I should have an inventory of the wastewater that is going into the treatment plant. If I do not have it is very difficult for me to find out the efficiency of treatment systems. That is why flow measuring device is a must. Unfortunately the most of treatment plant do not have it or if they have it also the flow meters do not work. So it is all the more essential that we should ensure that these flow measurement devices are in place in the treatment plant. After this I have got the PST primary sedimentation tank.

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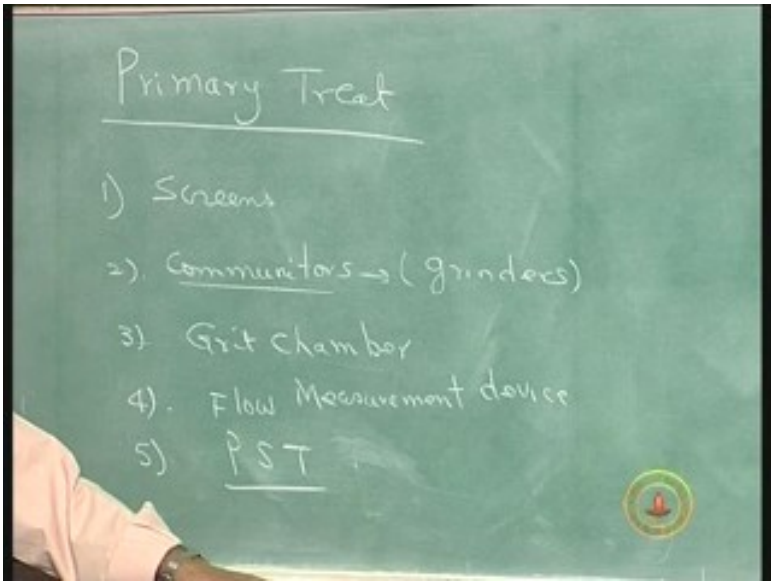

Thus, in the primary sedimentation tank you can see from the figure, there is what is called overflow and underflow. What are these things overflow and underflow?
Overflow is the liquid that is going out of the treatment unit and underflow is the concentrated solids which are removed from the bottom of the sedimentation tank. In the overflow the liquid goes to the secondary treatment system. So from primary the liquid flows through these units to remove the suspended solids to some extent organic solids also then the liquid flows through the secondary treatment system and then underflow goes for what is called solids handling system.

Overflow goes to the next unit and underflow to some other unit. Hence, we will see what would happen for the secondary treatment. If you see the secondary treatment in the secondary treatment the wastewater coming from the primary treatment and it goes to the aerator. The aerator is the one which supplies oxygen to the microorganisms that is what we discussed earlier. And there in the aerators flocculating organisms are produced.

Now let us discuss more about this secondary treatment system with the help of some additional diagrams. Hence, the effluent from the primary is coming into the aerator, these aerators are normally the mechanical aerators, mechanical things and from this aerator the liquid flows into what is called a secondary sedimentation tank or I can put it as SST secondary sedimentation tank. The hatched lines you see here (Refer Slide Time: 36:40) are the settled biomass and this thing is the secondary sedimentation tank here. Now, a part of this settled biomass is pumped this is called recycle pump so using a recycle pump a part of the biomass is put back into the aerators and another goes into the sludge or solids or the sludge treatment system.

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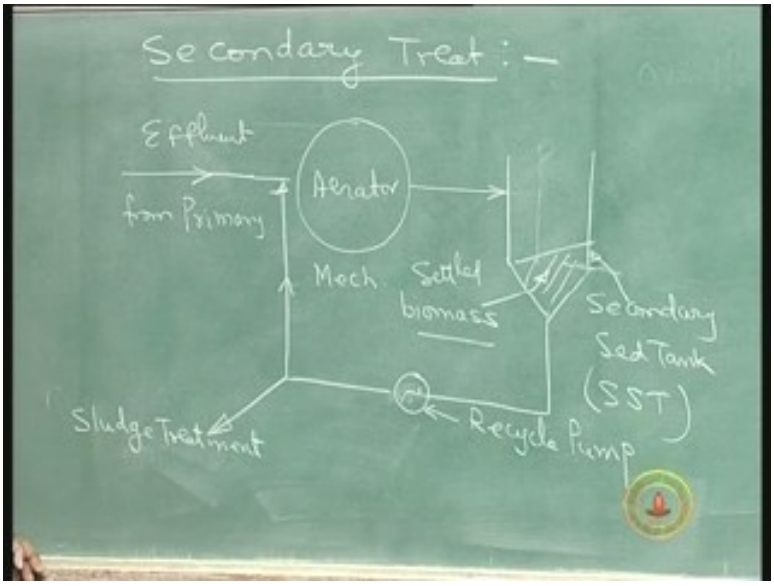

This entails one of the secondary treatment systems. The secondary treatment system which I have drawn on the board or in the slide is what is called activated sludge plant. That means the secondary treatment system constitutes number one is what is called suspended growth system; the growth is suspended that is in the aerator, this is a completely mixed reactor, organisms are growing on the organic matter present in the wastewater because of the oxygen that you are supplying that is called a completely mixed system hence this is a completely mixed reactor what we have in the suspended growth system.

The example is activated sludge process or it is called ASP. It is one type of a system what we have which is suspended growth system which is very very popular. Most of the treatment plants are based on the particular thing. So in these there are some variations or some other groups of activated sludge like extended aeration, another example is extended aeration but extended aeration is also suspended growth system.

Another system could be contact stabilization. So I can have what is called contact stabilization and extended aeration. These are the only two examples I am giving you. Hence, this is one type of secondary treatment system. The second type of secondary treatment system I could have is attached growth systems. Attached growth systems are also called as immobilized growth systems. Therefore, in immobilized growth system what I am trying to do is that I do not have aeration, it is not a completely mixed unit but what I have is I have a solid media in the reactor and I encourage the microorganisms to grow on the solid media; growth of microbes on solid media would take place.

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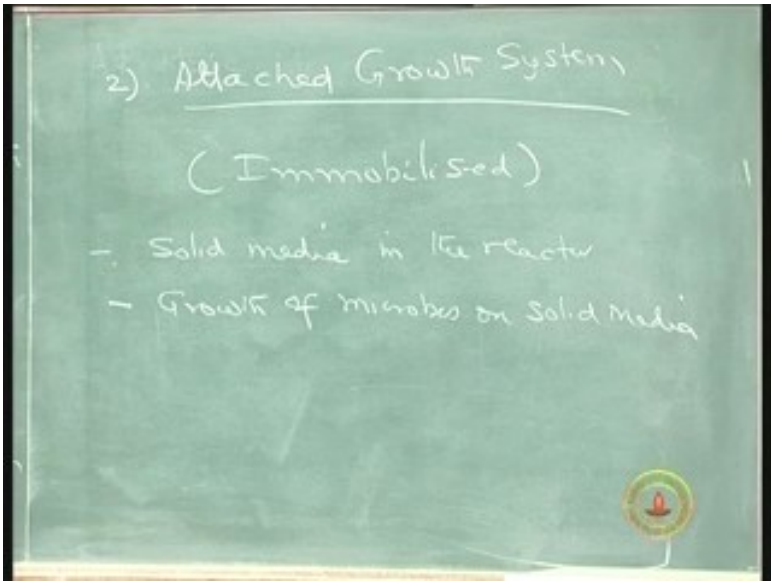

Now let us compare these two things. These are the two basically available wastewater treatment systems what we have. One is the suspended and another is attached growth system. So the suspended growth system is what I have written here. So what we do is that we are aerating the wastewater. When I am aerating the wastewater the reaction that is taking place is organic matter present in the wastewater plus the bacteria present in the wastewater plus dissolved aeration results in carbon dioxide, water and more cells. These more cells are flocculating so these will settle down in secondary sedimentation tank. That is what is happening here (Refer Slide Time: 41:51). Thus, organisms are growing; growth of organism is taking place in the aeration tank.

In the secondary sedimentation tank there is no growth taking place but only settling of the microorganisms are taking place so only settlement of the organisms will take place here and when you take out the liquid from this aeration tank the organisms are also coming out those organisms are settling here and in order to maintain a desired amount of microorganisms in the aeration tank what I have to do is I have to recycle. So this recycling is done to maintain desired concentration of biomass in the aerator or in the aeration tank.

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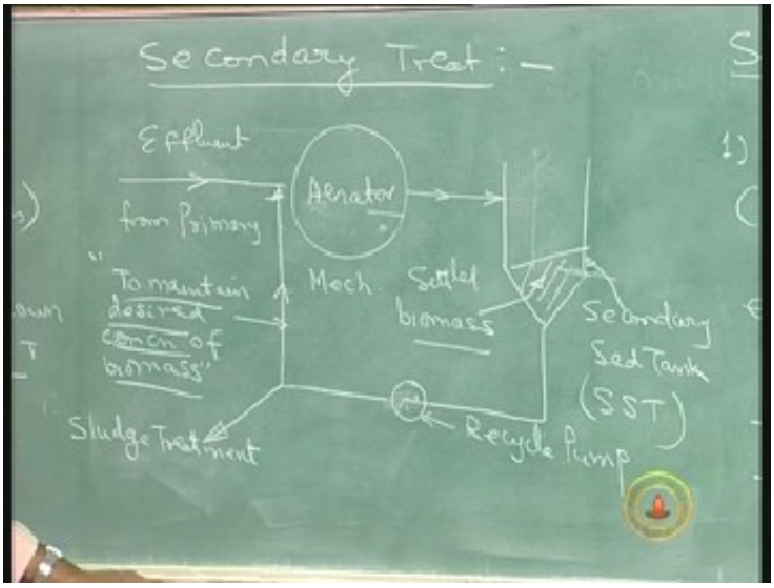

Hence, in the aerator or aeration tank I am putting back some organisms. The organisms which are settled down here, I am putting back some organisms into these through this particular pump and the remaining percent is removed. Normally 30% of Q is recycled and 70% of Q goes as the sludge treatment, only 30% or 0.3 times the flow rate is going into the aeration tank and the remaining goes out that is what is the activated sludge process. So this is an important treatment system because we have only this treatment system that is very popularly used.

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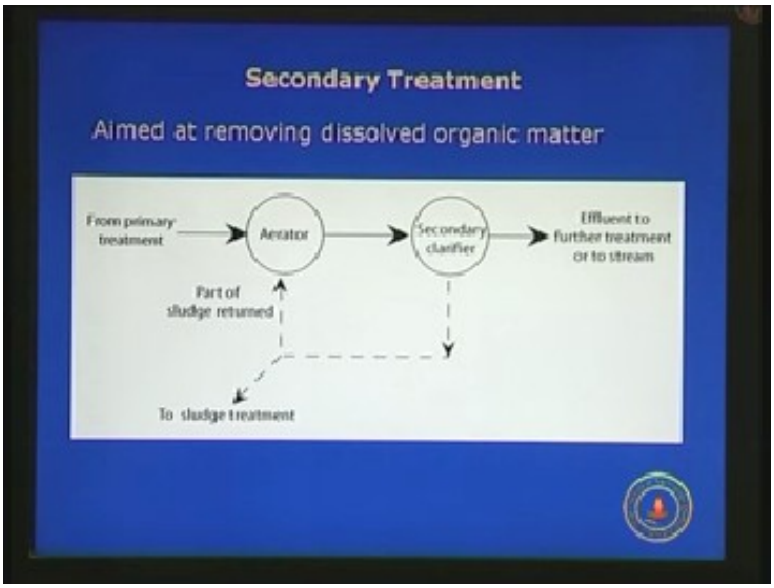

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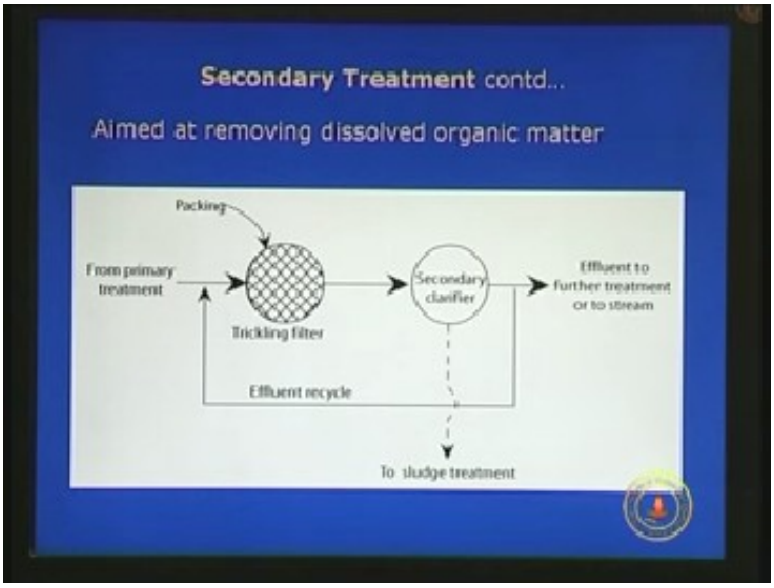

The second treatment system is attached growth systems. The example of attached growth system is trickling filter. Number one is the trickling filter; number two is the rotating biological contractors. These are the very popularly used secondary treatment system for attached growth. So, in the trickling filter what normally we do is, again we will go back to this particular thing and try to draw a flow diagram for that; secondary treatment based on trickling filter TF; so again the effluent is coming from the primary and this will flow into a trickling filter, so trickling filter will have a rotating distributing arm as shown here which distributes the wastewater on the media so this is the plan view anyhow (Refer Slide Time: 45:28); this is the media so the wastewater is distributed, this is the dotted line, these are the nozzles and the distributor rotates in this direction and when it is moving it also sprinkles the water or sprinkles the wastewater on the solid media that is what it does.

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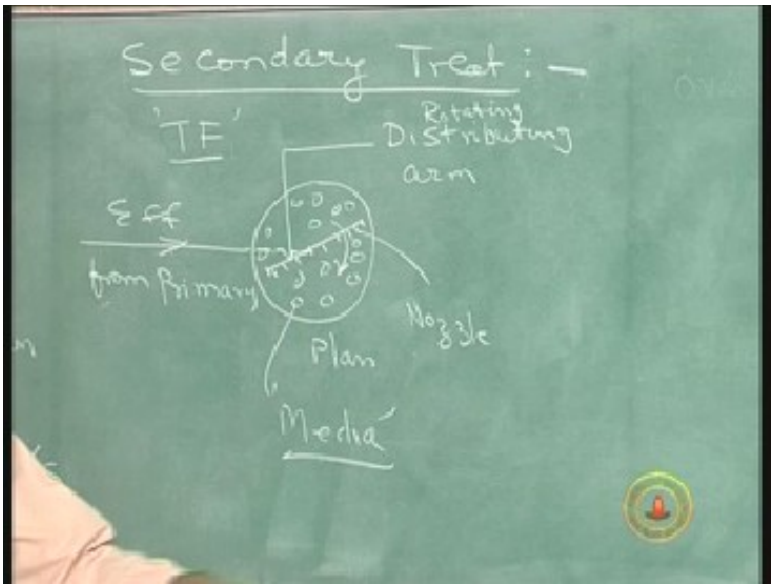

We will discuss more details when we take up the design of these particular trickling filters. At this time I would like to describe this particular process only. So, after that I have a secondary sedimentation tank SST as usual and then this particular thing goes for the sludge treatment, and the treated effluent is going out for disinfection. Now what I will do is recirculate a part of the treated effluent that means this is the recycled pump and treated effluent recycle. This is not recycling of the solids, recycle of biomass is not there here but recycle of effluent is there.

Let us understand what is happening here. The organic matter flows onto the media, on the media there is growth of microorganisms and that growth of microorganisms will remove the organic matter and after that the liquid flows out into the secondary sedimentation tank. When it goes out to the secondary sedimentation tank there are some solids so those solids will settle down and these solids are treated in the sludge treatment unit.

Now, since the biomass is immobilized in the reactor there is no need of supplying the biomass into the system. I do not have to supply the biomass like in the activated sludge. in the activated sludge there is a recycle of biomass; in the tickling filter there is no recycle of biomass, there is a recycle of the liquid effluent.

Why the recycling of liquid effluent is required is this recycle is (Refer Slide Time: 48:50) to rotate the distributing arm, the purpose is to rotate the distribution arm during the periods of low flow, when the wastewater production is less then we are going to sort of rotate the distributing arm by using this effluent, we supply this effluent for distributing this particular thing. So this is the second type of system the attached growth system we have. Now you can see one thing; I have all the time in the activated sludge as well as in the tickling filter as what is called the sludge treatment unit, the sludge has to be treated. So, that sludge has to be treated using another biological system like this the third biological system.

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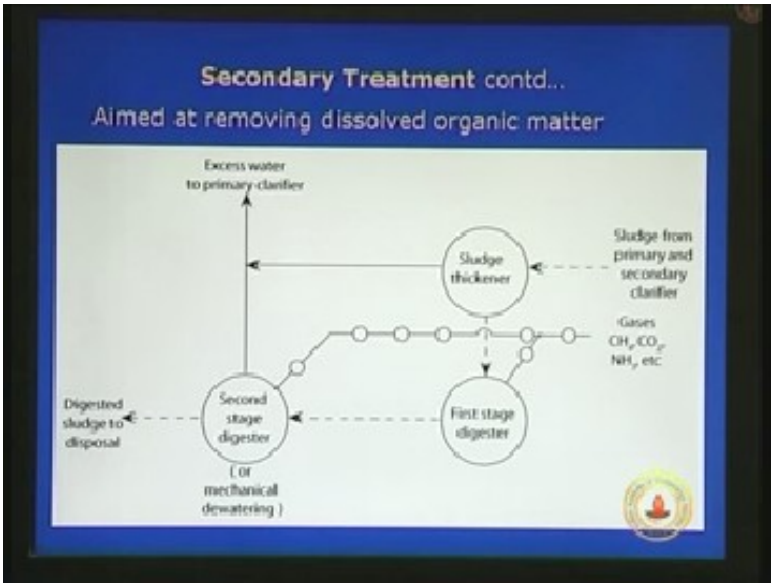

Let us go here, that means this is the sludge coming from primary and secondary classifier. Please recap that in the primary sedimentation tank also some organic solids have settled down. Those organics solids have to be treated further and if I do not treat those organic solids if I do not treat this sludge from the trickling filter if I do not treat this sludge from the activated sludge then what is going to happen is they are going to produce some odour; they produce some obnoxious smell. So in order to eliminate that particular thing we have to treat.

For treating that particular thing I will go back to this slide (Refer Slide Time: 50:32) I will take the sludge from the primary and secondary clarifier and then take it to a sludge thickener. What is the purpose of sludge thickener? The purpose sludge thickener is to remove the moisture so as to have a compact volume of the sludge. Therefore, that sludge from sludge thickener or the sludge will come to what is called first stage digester which is shown in dotted lines on the slide here. therefore, this is the first stage digester and in the first stage digester what happens is that the organic matter……, now the organic matter is nothing but the sludge from the primary and secondary clarifiers that is organic matter has settled down in the primary sedimentation tank and the biomass has settled down in the activated sludge or in trickling filter and that becomes the food for microorganisms. I have to write one equation here and that equation is the following:

I will write it as; organic suspended solids from primary sedimentation tank PST plus biomass from secondary sedimentation tank SST I will put it here; this is the secondary treatment, the first one is the primary treatment. One is the suspended solid or organic; another is biomass, biomass is also organic suspended solids both of them are taken into sort of a reactor and impress on them that is microorganisms; I will give some microorganisms and provide anaerobic conditions, anaerobic condition means no oxygen.

I am not providing any oxygen. When I do not provide oxygen the microorganisms are termed as anaerobic microorganisms. These anaerobic microorganisms convert organic matter into what is called acids. The acids are acetic acid; mostly it is an acetic acid that is produced let us say here. This acid is acted upon by what is called a methane forming bacteria so there are bacteria which are methane forming, which are anaerobic and these methane producing bacteria converts this acid into methane carbon dioxide sometimes ammonia will be there and sometimes H_2S. Hence, these are in traces. So the major components are methane gas and carbon dioxide; ammonia and H_2S are in traces so these are produced.

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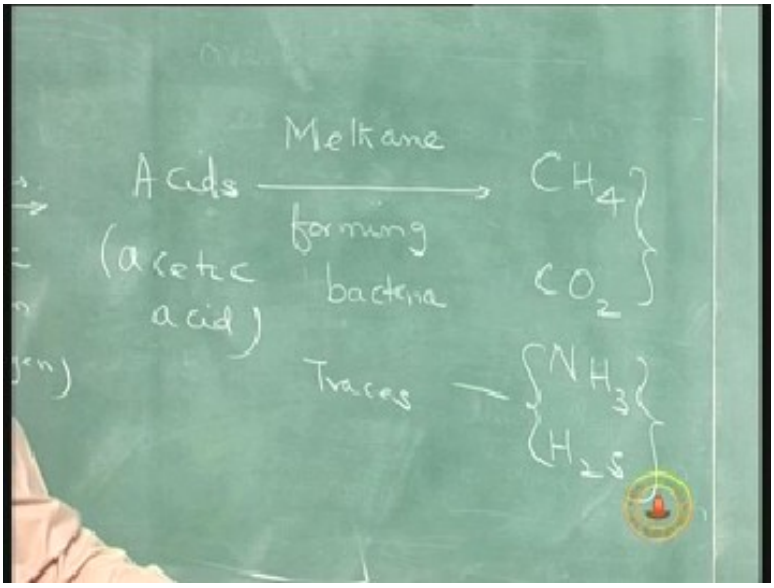

Therefore what is done is that the sludge that is the organic matter or for that matter the biomass is converted into acid and acid into the gas and this gas has got a fuel value, it can be used as a fuel; methane can be used as fuel; as you know this burn this methane gas and get energy out of it. This is what exactly we are doing in the secondary treatment. Again this is also a secondary treatment but this secondary treatment is a lot different from the normal secondary treatment. This employs what is called anaerobic digestion.

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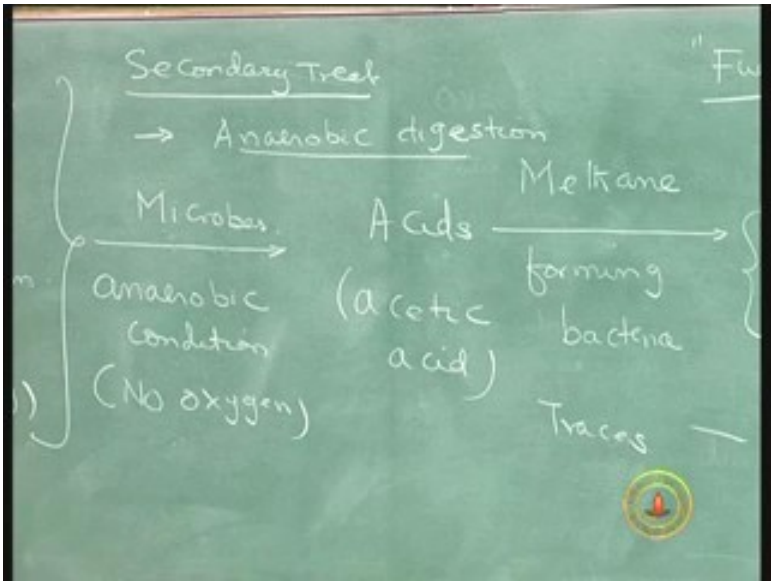

By employing anaerobic digestion I can convert the organic matter as well as the biomass from the secondary sedimentation tank using what is called microorganisms to acids and using methane forming bacteria those acids are converted into methane. So these bacteria are called as, the one which produces acids are called acid producing bacteria; acid formers, this is the specific name we can give. We can come back to the slide (Refer Slide Time: 55:26) that is exactly the first stage digester where all these reactions takes place. And after the first stage digester I have got second stage digester also in order to extract more energy out of it whatever energy that is available.

So in the second stage digester whatever gases that are produced namely methane, carbon dioxide, ammonia etc constitutes some trace concentrations of H_2S also. Then what would happen is that the liquid excess water from the second stage digester will go to the primary clarifier, again it has to the primary treatment and then the digested sludge goes for disposal.

In fact in India and some other countries we use this digestive sludge for growing some of the crops that can be a soil conditioner. We use that particular thing as soil conditioner and that particular digester sludge we can use for the treatment of soil. Now I would like to summarize what all I have done here. Today we discussed about enhancement of wastewater quality by treatment; the treatment constitutes of primary treatment, secondary treatment and tertiary treatment. In the next class we will take up the tertiary treatment.