Applied Environmental Microbiology
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Lecture - 37
Wastewater Microbiology II

Dear students, in today's lecture we will continue from our previous lecture. We started talking about the importance of wastewater treatment plant for any community and for a city, and we will dive into the microbiology of wastewater treatment plant. So, when we talk about microbiology, we have three options. First, we can go ahead and we can get an overview picture of how many different kinds of microbes are present, and who is eating whom, how are they interacting and what jobs they are doing. So, we might be interested in enumerating different groups of organisms and we can do it in two formats. We can divide the groups into like all bacteria as one group, all viruses as one group, all protozoa as one group, all algae and other higher orders of life as one group.

So, this is one way we can do. So, we are doing it by broad phylogenetic or classification or the taxonomy classification. The other approach, that we can have in via classifying them into groups is instead of looking into these broad classifications, we might look at some function, For example, we might be interested in microbes that are heterotrophic, microbes that are autotrophic, microbes that are eating other microbes, microbes that are eating BOD, COD.

So, we might divide them according to the groups - microbes that are removing, that are nitrifying or de nitrifying, microbes that are accommodating phosphate, phosphorus and all microbes that are releasing phosphorus. So, we can classify them according to functions that we are interested in, when we talk about wastewater treatment, right? The next approach that we have and we talk about microbiology or wastewater treatment plant is, we can look at them in a very mathematical way and understand the kinetics of microbiology in wastewater treatment plant.

So, we want to know how fast the microbes grow, how fast they eat and how much aeration is required, how much food is required, how much biomass can be allowed, how much of the biomass can be recycled, how much should be thrown away. So, we are looking from a very practical and operational perspective. So, in this there are certain

kinetics models that we have come up with. Growth model, substrate utilization model, and then doing a mass balance of how much food is coming in, how much food is getting eaten up and how much is being released, we can get equation that will help us answer these questions. The third approach that we can do when we are talking about microbiology or face water is, we can profile the entire microbial community and learn up the names and the functions of each of the microbes.

This is very tedious and it is not as informative or as targeted as the other two approaches. The first approach gives us a very good understanding of who are the main players and even if we do not know for example, if I select nitrifying bacteria, I might not know all the names of the nitrifying bacteria. all morphologies all kinds of nitrifying bacteria, but I have a big general idea of what they need, what environment is good for them and what their biomass is and what will be toxic for them, what would be not toxic for them and I know how much time they require. So, I know the general characteristics of nitrifying bacteria. There is no need for me to know the microbes and I know how and when to promote nitrification, how I can promote nitrification and how I can control it when I want to control it.

So, this is a very functional understanding of microbiology, which I think is more applied and useful especially in context of environmental science. The second approach which talks about the kinetics is very important, when you are actually operating a wastewater treatment plant. The third approach is tedious and I do not see it very relevant as for this course and for the question that this course is trying to answer.

So, this lecture and the lecture afterwards, I will be talking only about the broad classification of microbes in wastewater and in wastewater treatment and then we will be talking about the kinetics. How fast microbes grow how fast they eat and what are the different phases of growth they undergo, what are the typical problems we come across and why how do we solve them. So, that is what we will be talking about in this lecture. So, let us get started. So, last class we talked about why do we need wastewater treatment and these are the things that we want to get rid of in a wastewater treatment plant.

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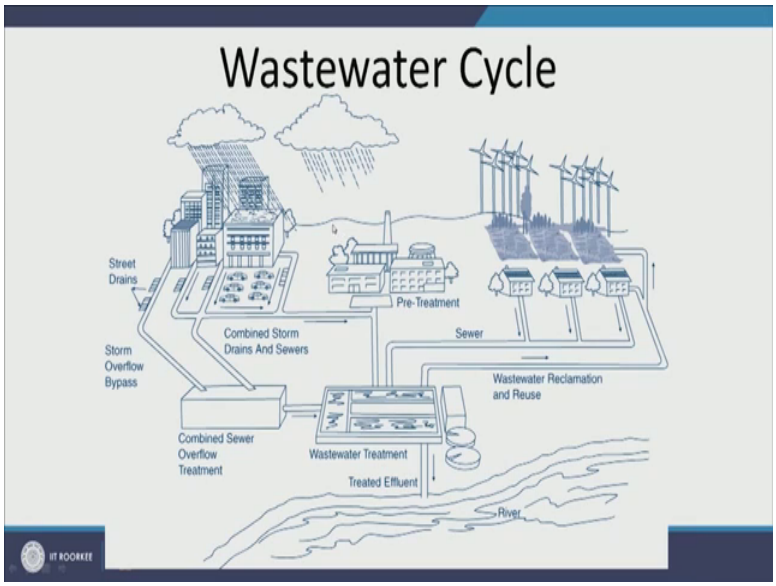

So, this is a typical wastewater cycle. Here, we have establishments. So, we have houses and industries or shops commercial areas and then each house each commercial area is producing wastewater. At times we also collect the sewage, not only sewage but also kitchen waste and also the storm water. So, storm water is the water that falls from the precipitation rain and it is a runoff; surface runoff.

So, at times both of them are collected. There are street drains that collect their precipitation, there are pipes that collect waste from each of the houses and they all lead to a combined sewer overflow treatment plant. So, here we are combining the storm water and the wastewater. Now, when this is combined in a combined severe overflow treatment plant, it directs it to wastewater treatment process, it treats it and then the treated effluent is released in the river. A part of the wastewater can be reclaimed.

So, this reclaimed water have been treated to good enough standard for it to go to houses for cleaning, irrigating the grass agriculture. So, some of the parts of the water can go back and then the sewage produced can again be connected. Already in some places like India, we do not have direct collection of wastewater; instead what we have is the pre treatment in house pre treatment. So, in house pre treatment, each house or each residential location would have a septic tank. The septic tank will collect the wastewater from the community or from the house and then it undergoes anaerobic degradation.

So, right here, we reduce the volume of the wastewater that will go to the wastewater treatment plant and ideally and routinely it should send the wastewater in the wastewater treatment plant, but this is advantageous, because it reduces the burden on the wastewater treatment plant and the disadvantage of this in a country like India is that these septic tanks require periodic cleaning, and because of the taboo in India associated with a faecal matter and cleaning very septic tanks, this is a big social problem. People do not want to clean their septic tank.

So, they are mostly making big septic tanks and then, because of the unequal society that we live in, there are certain segments of our society - the underprivileged sections that are exploited by the more powerful sections and they are forced against their wishes to clean this manually. It is a manual scavenging, it is a big- big issue and one of the recommendations that I am giving in this week's homework is actually to watch a recent documentary, 'Kokush'. It is not in English and not in my native language definitely, but thankfully it has subscripts.

So, I encourage you to watch it and understand the problems of manual scavenging. It is not only a social problem; it is definitely an environmental problem. So, even after we move from open defecation to toilet usage in India, we rely a lot on septic tanks. There is no one to maintain septic tanks and the ones that are being forced to maintain septic tanks either socially, economically or by force they are being exploited. So, it is a big issue and until we solve this issue, we cannot solve our wastewater treatment and our public health problem and environmental health problem also. So, this is pre treatment for you and there will be homework for you to watch a documentary on YouTube and answer some questions. Ideally, the septic tank here, provide its effluent to wastewater treatment plant, where it will be treated; treated differently and will be thrown in the river and part of it can be reclaimed.

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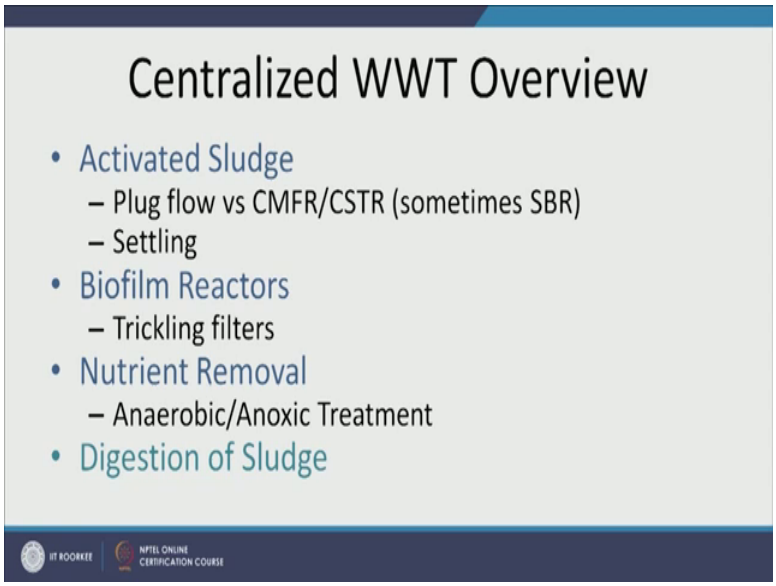

Now, in centralized wastewater treatment, there are a few very important sections. The places in the base water treatment, where biologically waste is removed, can either be an activated sludge process tank, it can be a bio film, or we can talk about nutrient removal. These are the three places where microbial processes are used. Let us talk about activated sludge. So, if you remember in the previous class, I talked about primary treatment, secondary treatment disinfection and disposal.

In secondary treatment, we use aerobic oxidation by microbes to degrade waste. So, this can we have two types. As I have mentioned, either our microbes can be freely floating in the waste water or they can be attached to some filter or bio film and they can make filter on bio film filters. So, the attached microbes will come in this category - bio film reactor and the ones in which they keep moving, they will come under activated sludge.

Now, here we have two options. We can either have plug flow reactor or we can have a CSTR, sometimes referred to as SBR and I remember, in the beginning of previous class, I talked about activated sludge process and SBR process. This is your activated sludge process and this is your SBR process. So, what is the difference between ASP and SBR, we will be talking about ASP very soon, but let me very briefly revisit PFR and CSTR, so that you know what the difference is. I have talked about it in previous lectures, but just in case, I hope this review will be helpful for you. So, let us start with the PFR. In PFR, we have a batch reactor.

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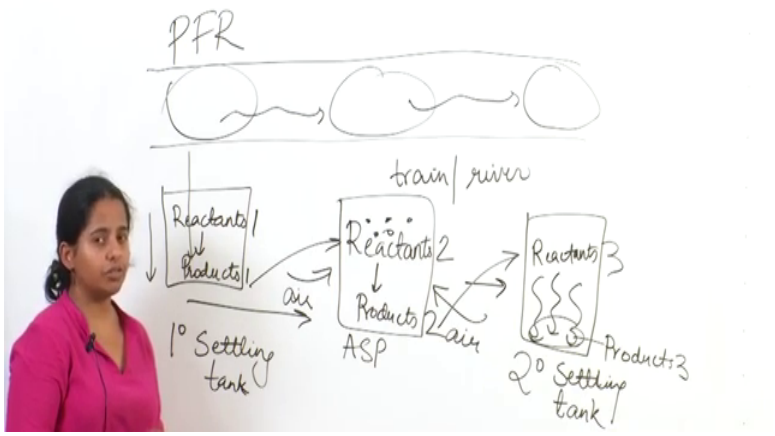

So, everything that all the reactants and the products are forming, are present together in a batch and this batch moves from one portion to another and as it moves from one portion to another, it undergoes certain changes. So, when it is in the settling tank, even the primary settling tank. So, this is the first settling tank. Whatever needs to settle will settle, whatever can settle physically in the given time they will settle and then this entire batch will move to the activated sludge process tank ASP. Now, in a ASP process, this entire reactants will be converting into products.

So, reactants here are your waste. Your oxygen and all other nutrients that are present will be eaten up by microbes and they will make products. So, you have not added anything, you have not removed anything, though in ASP we evade. So, we add here, because microbes will very quickly run out of oxygen. So, lot of investment is made in ASP and then this batch again travels to the next step, which is the secondary settling tank. Whatever can settle from here will settle, and this will be your settled, which you can refer to as product settled solids.

So, notice here. This is your PFR based plug flow reactor based water treatment plant. Here, the batch of your material travels from one step to another; it physically travels. So, this will be another tank, this will be another tank and the third one will be another tank and then, there will be more tanks. I had to disinfect the water and depth tanks before it. So, the key point is that, this entire batch reacts. The products of this batch

would be reactant of this batch; reactor and products of this batch would be reactant of this batch and so on and so forth. So, basically it becomes reactant one; product one. Now, this becomes your reactant and this becomes your product and so on. So, this is a plug flow reactor and I think I had talked about plug flow reactor in the past and given you example of a river.

So, in a river or in a train, the coach does not mix with coaches before it or coaches after it, the river does not mix in the direction of the flow, but the entire cross section of river travels together. So, the entire compartment of coach in the train travels together. So, whatever material is present in the primary settling tank, will not mix with the ASP material. ASP material will not mix with the secondary settling tank material, but they will travel together. So, basically it is like a river or like a train and they are flowing together. So, when the reactant and product reach here, they undergo primary settling. When they travel forward and they reach here, they undergo activated sludge process. When they reach here they undergo settling tank. So, by the time they are done with this strain of wastewater treatment plan, you will have good quality treated effluent. So, this is your PFR base system.

Now, let us go ahead and look at your CSTR base system. I must say that in India, initially most of our public water treatment plants were ASP based, but in past the few years and past decade, we have seen a surge of SBR or CSTR based water treatment plants for the reason that, operation and maintenance is really good and the quality of treated effluent that it bears and it produces is very nice, also they require less space and why would they require less space, let us look into it.

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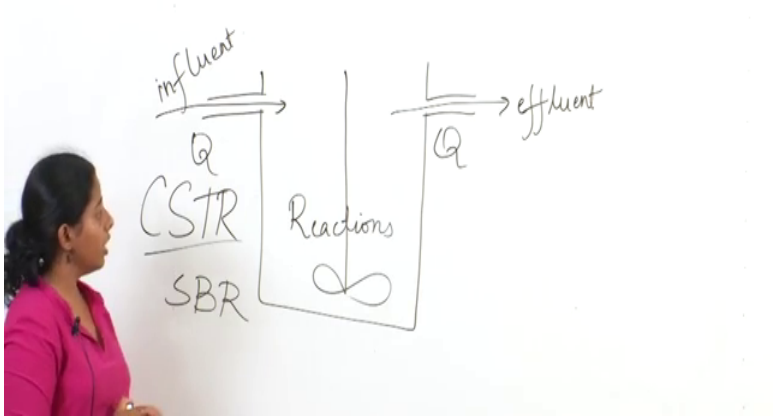

Now, let us look at what is a CSTR and what is a SBR. This is your second type of wastewater treatment plant. The definition of CSTR is continuously stirred tank reactors in which the tank is a reactor and it is continuously stirred. So, there is a stirrer that continuously stirs it. Now, in CSTR, there is a continuous input of influent and there is a continuous outflow of effluent. So, the influent is continuously coming in, the effluent is continuously growing going out; obviously, because the volume is constant, the rate the flow rate is same for both and the reaction is happening here.

So, this is your typical CSTR, continuously stirred tank reactor. This is different from PFR, because the reaction happens in the tank. In PFR the reaction also happens here, and only in the train, not in the tank. In PFR based ASP it happens; obviously here, but the entire product moves from one tank to another tank and until the reaction is not complete it would not move ahead, but in a CSTR, even partially complete reactants would move. Even as the reaction is going, there is a continuous outflow of effluent and continuous inflow of influent. Now, let us see what a SBR is. A SBR is more like a CSTR and let us see why.

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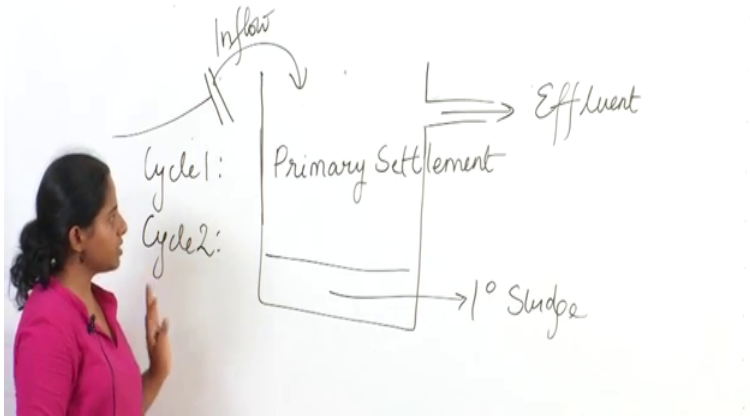

So, your SBR, our sequencing batch reactor will look like this. It is a singular tank. So, unlike PFR, when you have multiple tanks for different steps and the entire batch moves from one time to another, much like a train the compartments of a train. In a sequencing batch reactor, everything happens in a single tank.

Now, remember the first step of treating wastewater is screening. So, the influent comes and it gets mechanically screened and then is influed into the tank. Once, it reaches the tank, the next step is primary settlement. So, this is the cycle one. So, for cycle one, we will have primary settlement. So, for certain minutes, the influent will be allowed to undergo primary settlement and then the primary sludge collected here will be removed. Now, once this has been done, begins the cycle two. Now, in the same time cycle two will be carried out. If you remember, cycle two is activated sludge process.

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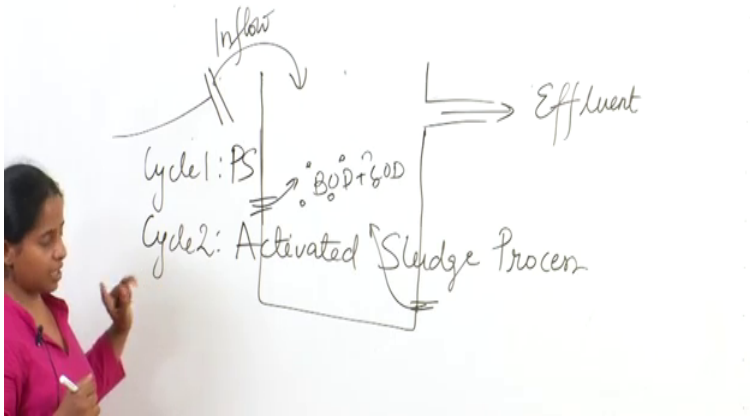

So, the second cycle will begin after the end of cycle one, which is primary settlement and second cycle is activated sludge process. So here, there are aerators and the aerators will blast oxygen into the air of the supernatant of primary settling tank. Primary settlement process and then the microbes will eat the entire waste BOD and COD will be consumed; how much of our microbes can eat in their cycle. So, for certain amount of time the activated sludge process would be allowed. Once the time is up for cycle 2, it will come to cycle 3 or step 3.

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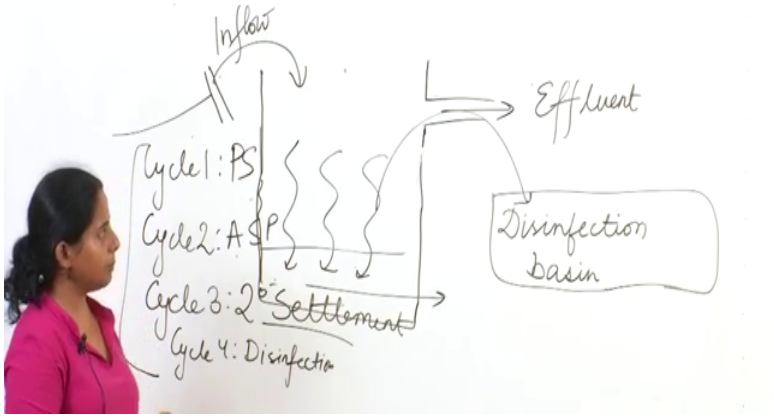

In step 3, we will have secondary settlement.

So, in cycle 1 we did primary settlement, in the same tank and then when the time's was up for primary settlement, we will allow ASP for certain amount of time and when ASP process has been done then, we will allow secondary settlement and then the biomass will settle and the secondary sludge will settle, and after this settlement has happened, this sludge would be removed. Alright?.

And what is the next step after secondary settlement? Let us say it is disinfection. So, the cycle 4 will be disinfection. Now, disinfection can happen either in the same tank, but we do not like disinfection to happen at the same time, because if there is residual disinfectant, it will kill the microbes in the next. When these cycles are repeated in the second run, they will kill the microbes.

So, the efficiency will drop. So, typically after secondary settlement, the supernatant is removed and then there is a disinfection basin here and the disinfection is done separately. So, the key difference between SBR and the PFR based ASP process is that in SBR, all the processes happen in a singular tank. This is very important for a country like India where land is a precious resource, because we are running out of the land and we are going before setting up expansive ASP process, but our population continues to grow.

It is very - very important for us to consider such less land occupying SBR based water treatment systems. Now, the problem with SPR based water treatment system is that, they require more rigorous maintenance over time. So, they are more susceptible to breaking, because everything is happening in the same system and usually these cycles are very small; however, the advantage is that right now in India, they are being operated and maintained really well, usually under a public - private partnership and the quality of effluent that we are getting is really good; in fact, the best in the country. Now, that I hope you are clear about and you should be clear about SBR versus plug flow based activated sludge, and then the second part is definitely settling, either case settling is important after degradation aerobic oxidation by microbes.

Now, the next kind of wastewater treatment plants are bio film reactors. Now, in bio film reactors, the biomass is attached to a filter or a material where the degradation happens and the typical among them are 'trickling filters'. I will show you a picture crippling -trickling filter split, either in this lecture or the next and this is the secondary treatment.

After the secondary treatment has happened, sometimes we add a tertiary treatment to remove nutrients. When we talk about nutrients, you a talked more nitrogen and phosphorus and we do not want them going out in the environment and in a country like India, where fertilizer use is rampant and sometimes quite excessive it is very important to get rid of the nutrients in a wastewater treatment plant.

So, after primary physical treatment, secondary biochemical treatment, we can have a tertiary treatment and the typical way of removing nitrogen, phosphorus is to alternate anaerobic (Refer Time: 21:31) treatment and though very important part is digestion of sludge. So, twice we have removed the sludge 1 first from the primary settling tank and second from the secondary settling tank. Now, this is a normal and enormous amount of waste and you know this amount of biomass. So, it is this carbon rich microbe rich sludge and what do we do with this. So, it is very important for us to digest the sludge, water it and then either incinerate it or use it as a fertilizer. So, this is a typical activated sludge process.

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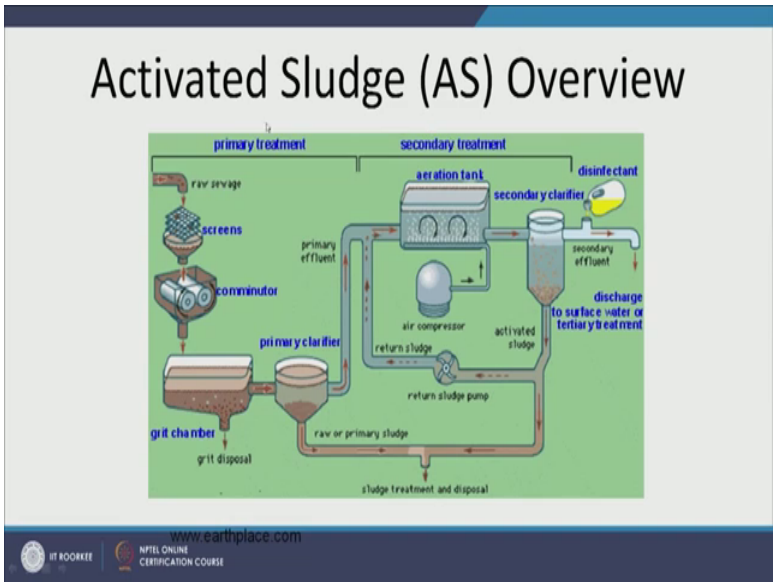

This is a PFR based process and we will quickly go through this. The primary treatment would include receiving the Rossi ways and then screening it to get rid of the big particles and particles that can destroy your wastewater treatment plants such as, aluminium forus and you have a communater, which breaks them into small pieces and then you have a grit chamber, this is where the grit is allowed to remove.

So, I did not talk about it, when I talked about the basic functioning, but always for real implants, ASP base will have a grit chamber, to get rid of sand and other inert particles which will reduce the efficiency of rest of the wastewater treatment plant. Then supernatant goes to the primary settlement tank of the primary clarifier. This is your raw sludge or your primary sludge and just taken away for sludge treatment. The supernatant then goes for aeration and now, this aeration tank is where your activated sludge process happens, look, its connected to an air compressor.

So, the air compressor will aerate this aeration tank. Here microbial processes happen, biomass grows very rapidly and since this is where you have the highest microbial population, we have so many microbes and they are hungry, so, they eat up all the faecal matter,, they eat up all the organics here; as much they can eat BOD and COD and then the supernatant, after clarifying and this will go to secondary clarifier and then the biomass settles.

A part of it is thrown and rejected and taken for sludge treatment and disposal, but because this is so rich in biomass, usually the flocks and what settles in the secondary treatment plant is biomass. Some part of it is returned back to aeration tank, to maintain a good amount of microbes here. Initial amount of microbes, the supernatant is very clean and ideally it looks very clear, it is not turbid at all and looks as clear as drinking water or nearly so and then the disinfectant is added to remove the microbes and then this is discharged to this surface water.

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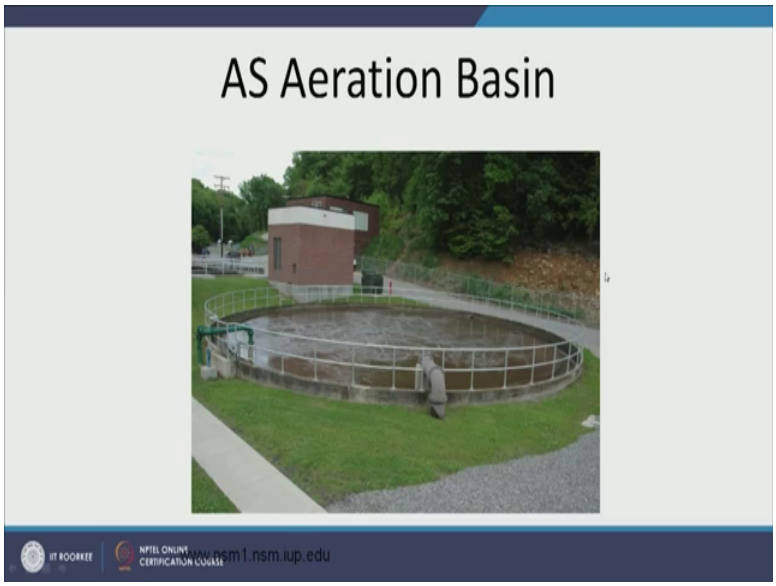

This is your typical aeration tank.

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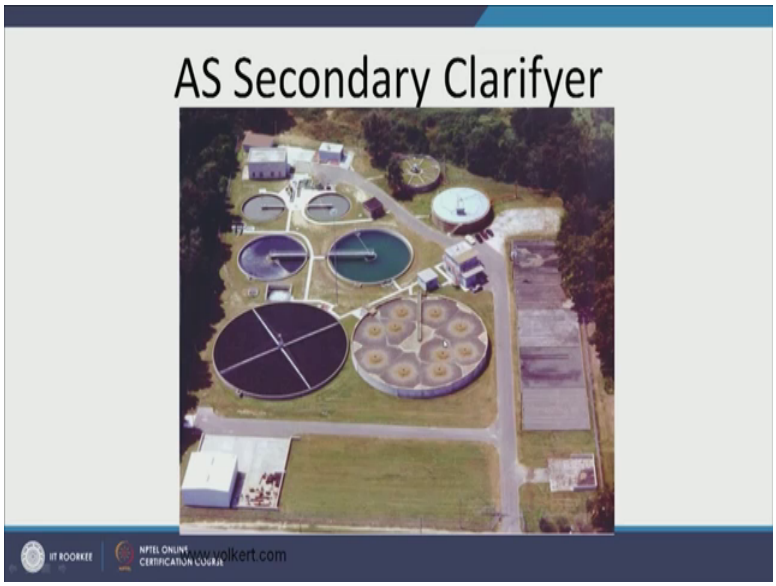

And these are secondary clarifier.

So, this is an aeration tank circular, this is where variation is happening and then this is transported to secondary settlers.

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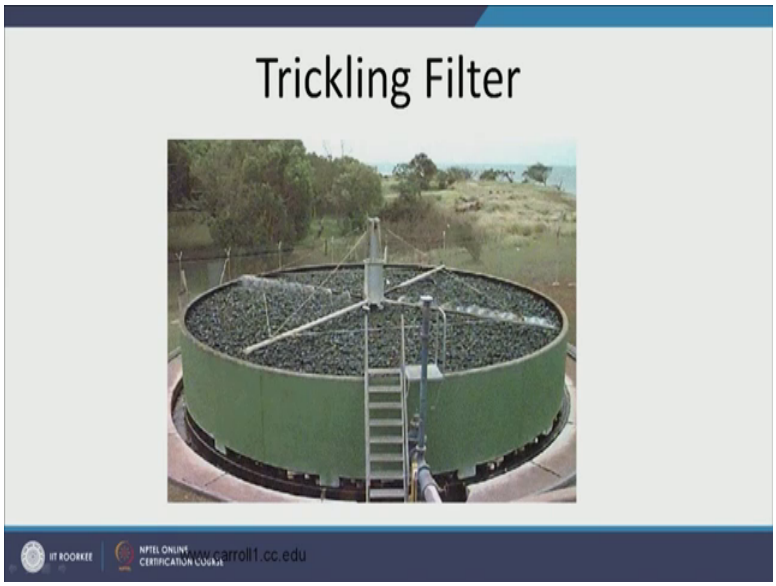

This is a trickling filter. So, in trickling filter, you have these pipes. These two pipes, if you can see carefully is your trickling filter and this bed is you filter, and these pipes are throwing the supernatant from primary clarifier. So, this is your waste water that has already undergone screening, grit removal and primary settlement and then this is thrown on this filter and this means that my bio films are going in this filter and what trickles out here is your treated water.

So, this then can be taken for disinfection. Trickling filter's major disadvantage is the amount of the rate of treatment of water flow that this can accept, the loading that this can accept; the other problem is cracking. If the water is very dirty, then the filter would get clogged and the trickling will be inhibited.

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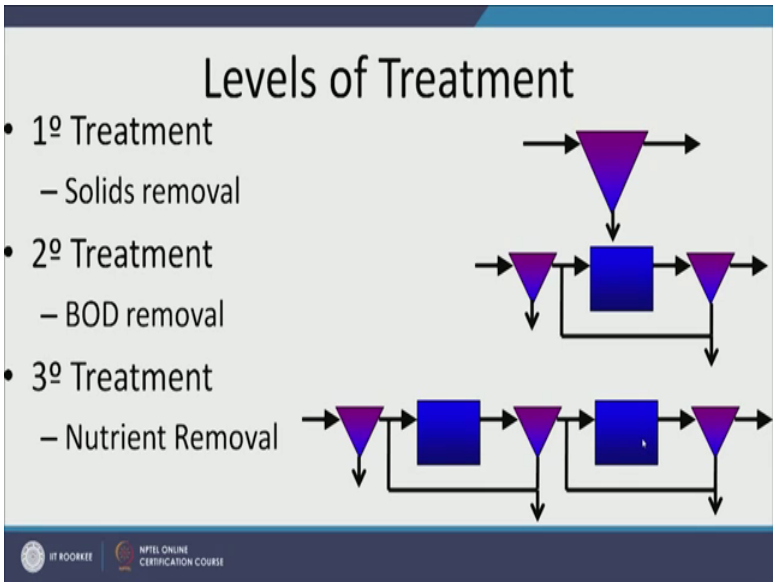

Now, let us look at the levels of treatment. Primary treatment, physical process we remove solid, then we can add to primary treatment, we can add secondary treatment, where we are trying to remove biodegradable organics or BOD and then you can add third degree treatment. So, this is primary, this is secondary. BY third degree, we are trying to remove nutrients from the wastewater already.

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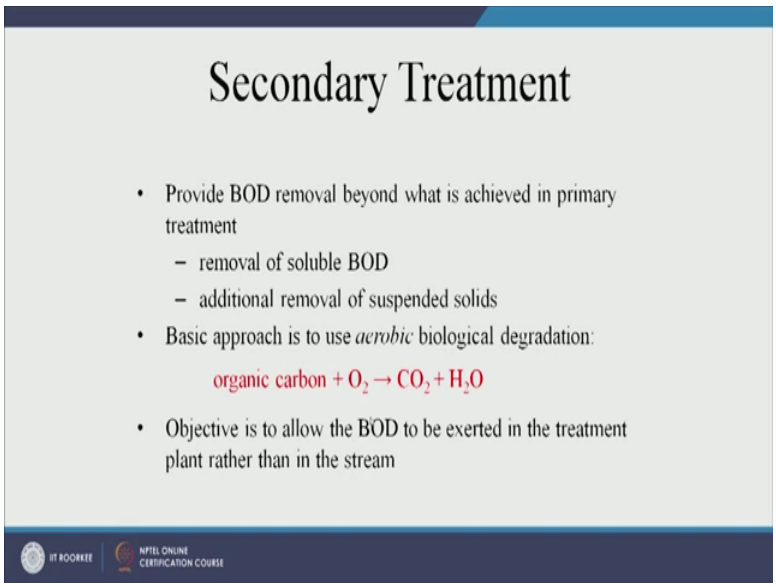

So in secondary treatment, we are trying to remove BOD, beyond what be removed in the primary treatment. So, in primary treatment, whatever could settle, the habit

particulate matter - BOD has been removed, but the soluble BOD remains. So, this needs to be removed and then it also removes the suspended solids in the water. The basic approach in secondary treatment, that I have mentioned before is, aerobic oxidation of biological aerobic oxidation.

So, we have a lot of carbon material waste, which is organic carbon for food. It can serve as an electron donor and carbon source is aerobically degraded, mineralized the objective is that whatever oxygen the microbes require to degrade, the waste should be made available in secondary treatment process, so the microbes can consume the waste as much as possible, in the secondary treatment and not in the stream. So, the reason why not in the stream is because if this organic carbon is thrown in the stream, the microbes there will try to degrade this organic carbon by using oxygen and then they will deplete the oxygen in the stream. So, the stream will become anoxic on even anaerobic which is very bad for aquatic life and environmental health too. So, we want the entire BOD to be exerted in wastewater during the secondary treatment.

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How is this accomplished? We completely create a very complex and rich microbial community which have amoeba. We have different kinds of microbes including bacteria, bacteria furze and diatoms and all kind of rich communities of microbes.

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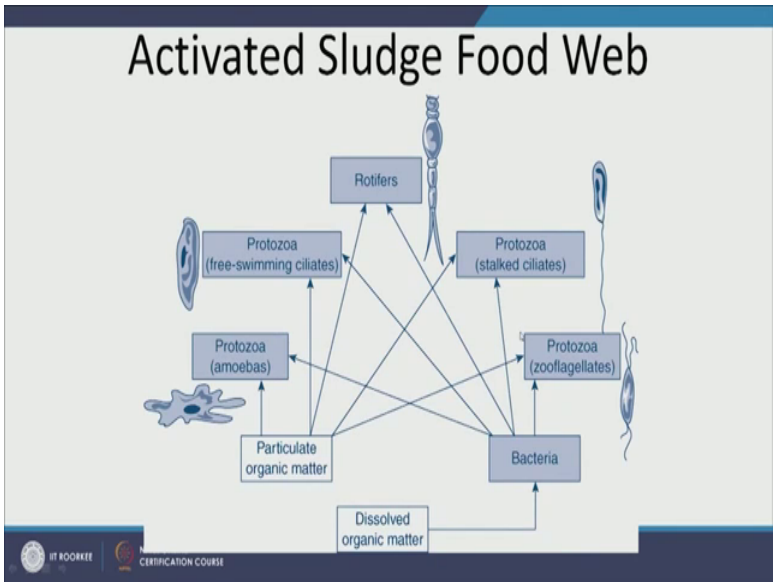

And this is the last slide for this lecture, and let us look here, we have dissolved organic matter, we have particulate organic matter, that was not removed in primary settlement in secondary process. The dissolved organic matter will be consumed by bacteria, because bacteria love to eat these small pieces of organic matter. The bacteria, in turn are consumed by protozoa which are (Refer Time: 27:25) or amoebas, which are again protozoa or all free swimming ciliates. So, all rotifers, all protozoa - that are different kinds of protozoa. So, bacteria do not survive very well as they are eaten up by different kinds of bacteria, protozoa. Now, the particulate organic matter is taken up by higher order of life, the eukaryotic protozoa and eventually what we have is a very good protozoan strength in the wastewater.

So, if you look under wastewater treatment plant, you will see a very beautiful community of very diverse waste protozoa and these are different kinds of protozoa that are present. Now, if there is any misbalance in this microbial community - if the bacteria decrease or increase or decrease rather, let us say there is bacteria forge, which kill the bacteria or there are toxins that kill the bacteria, then the protozoa would starve and the microbial community in the activated sludge process, may not be able to do its job. If protozoa increase too much, and bacteria are not there then, the BOD might not get dissolved and removed very well.

So, very fine balance of this is required to be maintained in it, because it is a wastewater treatment plant. So, dear students, this is all for today. We talked about general treatment in wastewater treatment plant and the microbial community. In the next class, we will be talking about the kinetics of wastewater treatment plant, how microbes grow and how they die,

Thank you very much.