**Wastewater Treatment and Recycling**
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**Lecture – 28**
**Biological Treatment of Wastewater**

Hello friends and welcome to week 6. So, earlier week we had discussions over the primary treatment of wastewater where, we did talk about the basics of screening, then grit removal and primary sedimentation and some of the other process like equalization. This week we will have the discussion on to the secondary treatment of wastewater which is primarily achieved through the Biological Treatment procedures.

So, our discussion towards the week will be centered to the different types of biological treatment process that are adopted for the treatment of wastewater which is secondary treatment steps and often employed after the primary treatment or primary sedimentation. This class we are going to discuss the basics of biological treatment of wastewater.

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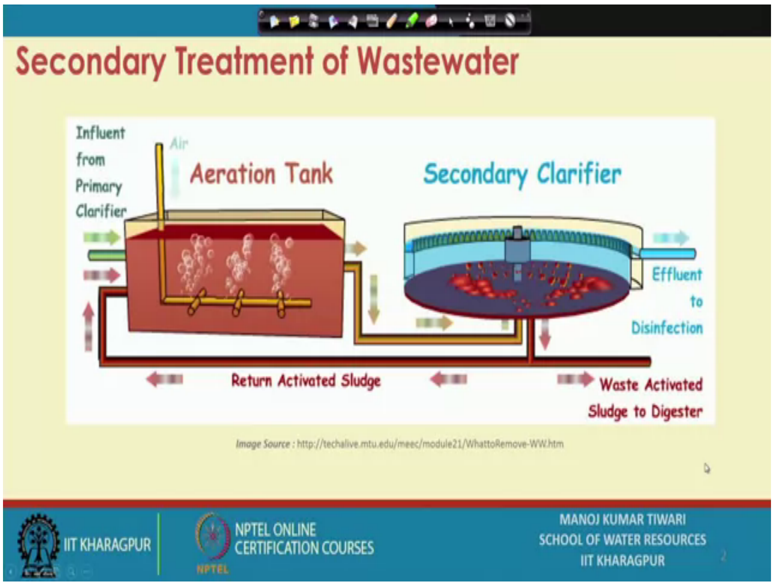


And in then subsequent classes we will be taking one by one the some of the treatment units which are used for the purpose of biological treatment of wastewater. So, the idea, basic idea of the secondary treatment is that we get influent from the primary treatment or primary clarifier. And then we process in a way in for the purpose of removal of the organic matter. There are, do not go by this figure only, there are various setups, various types of treatment system, secondary treatment system, what you are seeing is actually activated sludge process which is one of the most common biological treatment system, but there are very various other designs or other schemes are also available.

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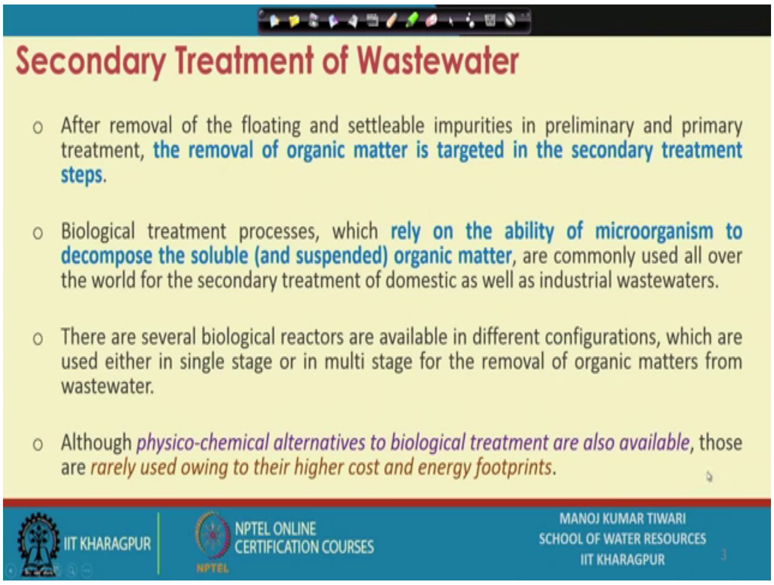


Now, if we see the basic idea of the secondary treatment of wastewater. So, by the preliminary and primary treatment, we have removed the major floating materials and settleable impurities from the wastewater. Then after removing these floating and settleable impurities our next target becomes the removal of organic matter primarily. So, the secondary treatment is basically focused on the removal of organic matter which is typically in the soluble form; however, could be even in the suspended form also at times. So, these biological treatment process basically rely on this ability of microorganisms or ability of bacteria to decompose the soluble and suspended organic matter.

Now, these are commonly used all over the world, these biological treatment processes, for secondary treatment of domestic as well as industrial wastewater. Although there are other alternatives available, there are physical chemical processes available which can actually remove the organic matter, but those alternatives are very rarely used particularly in the industrial processes some places it is used for, but for domestic, if wastewater treatment or municipal sewage treatment, they are very - very rarely used, ok. And the treatment is primarily achieved from the biological processes, ok.

The physical chemical processes in fact, could be more effective in terms of the removal of organic matter because of the higher control on the processes, but they are rarely used because their cost is very high and their energy footprint is quite high. So, because of this cost and energy footprints these process are generally avoided. There are several biological reactors that are available. There are various configurations of such reactors which are available, ok. They are used either in a single stage or in a multi stage for the removal of organic matter from the wastewater.

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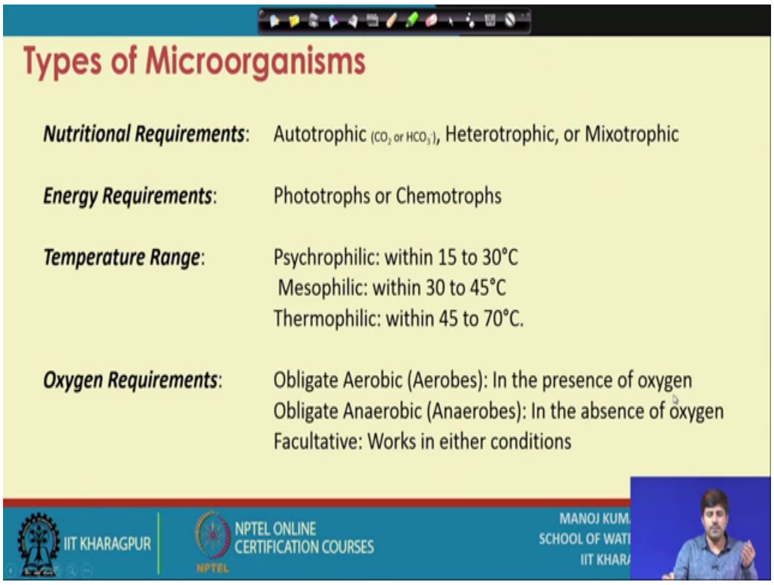


Now, once we are talking about the biological treatment of wastewater, and we are saying that it is typically achieved through the microorganism. So, it is very important to first understand, what kind of microorganisms are there? And then subsequently we will talk how they act on for the removal of the organic matter from the water.

There are variety of microorganisms, if you go by species, I do not know the exact number, but maybe 1000 and 100000 of species have been identified. If we see, if we try to classify these microorganisms there are different ways through which we can classify. We can classify based on their nutritional requirement; so, from where they are getting their nutrition's or getting their carbon source.

So, there are autotrophic microorganisms which actually derive the which derived the nutrition and nutrition and carbon from the CO 2. So, they basically synthesize mass using the atmospheric carbon dioxide available, or from the bicarbonate. So, from the inorganic carbon sources they synthesize the organic carbon, ok. So, they are autotrophic, then similarly heterotopic which basically derived based on the chemical reactions, synthesize based on them. And there are mixer tropic which can be both ways based on the energy requirement. Those who get their energy from the solar system or sunlight are called phototrophs. So, these are the one who basically do photosynthesis and based on that photosynthesis they derive energy and then synthesize mass.

Then there are chemotrophs, who basically derives energy from the chemical reactions, like there are again a series of microorganisms who derive energy from the chemical reactions based on that and they are typically called chemotrophs. Then we can classify them based on the different temperature ranges they work, there are psychrophilic bacteria which works well within the range of 15 to 30 degree Celsius. There are mesophilic which works well within the range of 30 to 45 degree Celsius and there are thermophilic whose optimum range of working are higher than 45. So, they work well between arounds 50 to 60 degree Celsius, can go up to as high as 70 degree Celsius.

These are not the only classes, we can have bacteria which can actually survive our work well within at even lower temperatures less than 15 or we have certain species which can survive or can operate beyond 70 degree or even close to 100 degree as well ok; however, most of these species cannot. So, that way there are exceptions, but these are the major classes and for the purpose of treatment or for the purpose of uses if the mesophilic are the one which are preferred because they work well in the typical temperature range of the arid climates. Then we can classify the bacteria or microorganisms particularly based on their oxygen requirement. So, there are aerobic bacteria which is also called aerobes, who works in the presence of oxygen.

So, they basically do the oxidation on respiration activities in the presence of oxygen and oxygen becomes the electron acceptor for them, ok. There are an anaerobics or anaerobic bacteria or we call them anaerobes who works in the absence of oxygen. So, they, they do not need oxygen for their metabolic processes and instead it is the sulfate or nitrate or those kind of things which who basically works an electron acceptor for them. So, the process more or less remains same, but the electron acceptor changes and they cannot work in the typically they prefer to work in the absence of oxygen.

Now, when we put obligate in as a prefix, so, like obligate aerobic or obligate anaerobic. So, obligate aerobic means the one who can only work in the presence of oxygen, if you remove the oxygen they cannot survive. Similarly there is obligate anaerobes who can work or can sustain only in the absence of oxygen as oxygen becomes sort of kind of toxic to them.

So, if you expose them to oxygen, they cannot survive. The obligate anaerobe need a complete anoxic conditions has to be completely devoid of presence of the oxygen for them to work and survive. Then there is a group facultative organisms, or facultative bacteria who can work in either conditions. So, they can basically work in even if there is absence of oxygen or presence of oxygen. In the presence of oxygen they may use oxygen as an electron acceptor, in the absence of oxygen they may use the sulfate or those kind of thing as a electron acceptor in their metabolic process.

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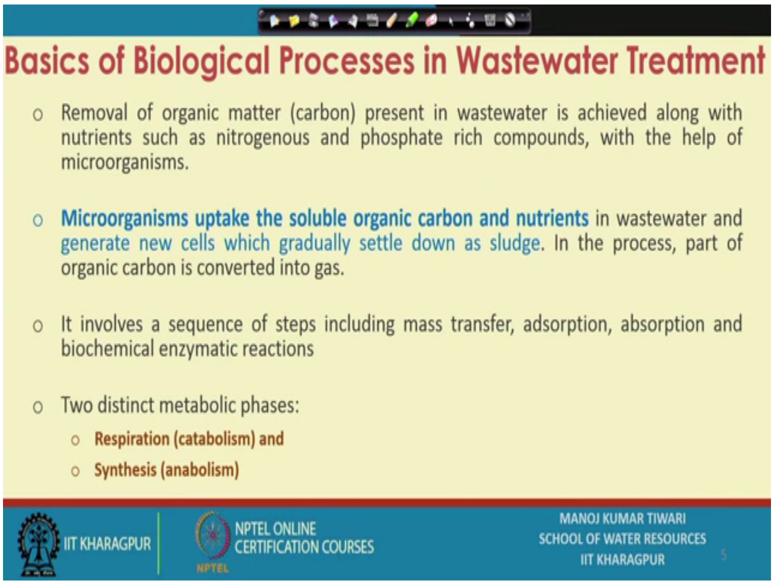


Now, if we see the basics of biological processes in the wastewater treatment. So, the removal of organic matter which is essentially organic carbon present in the wastewater is typically achieved with the help of microorganisms. And it is not only the removal of organic carbon that is achieved, actually we can get the removal of nutrients also various nitrogenous and phosphate rich come from phosphate rich compounds. Some of the nitrogen and phosphorus removal can also be achieved based on these biological processes. The microorganisms uptake the soluble organic carbon and nutrients present in the wastewater and generate new cells which gradually settle down as sludge.

So, that is the basic process, ok. The bacteria are typically micro organisms so, they uptake these organic carbon and nutrient and they synthesize them into the new cells or which basically becomes more and more biomass. So, biomass increases in the system and they settle down at the sludge, in the process part of organic carbon is converted into gas. Now, what kind of gas? Will again depend on the what kind of organisms or what kind of the system involved in. Now this involves a sequence of steps that includes the mass transfer.

So, the mass or the soluble say organic carbon which is present in the water has to be transferred to the within the cell wall of the bacteria where they can synthesize the newer cell mass or those kind of things. So, this in, this will involve mass transfer, this will involve adsorption, this will involve absorption, this will involve a variety of biochemical and genetic reactions. So, there are various enzymes that are secreted which actually make this process smooth, they catalyze these processes and then the production of the subsequent biomass or the biogas rate of that depends on the kind of enzyme kinetics which is being followed. There are 2 distinct metabolic processes one is respiration which is catabolism kind of and then there is a synthesis which is anabolism.

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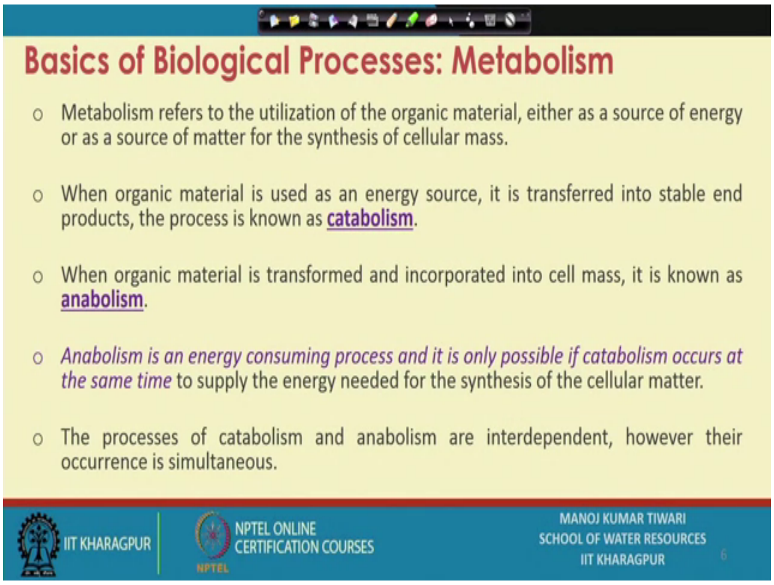

Now, if we see the metabolism, so, metabolism typically refers to the utilization of the organic matter either as a source of energy or as a source of matter for the synthesis of cellular mass. So, it is actually utilized in 2 different form, it can be utilized either as a source of energy or as a source of matter, a source of matter is used for the synthesizing new cellular masses.

Now, when organic matter is utilized as a energy source ok, it is transferred into the stable end products and this process is typically known as catabolism. Whereas, when the organic matter is transferred and incorporated into the cell mass it is known as anabolism. The anabolism is an energy consuming process because in order to synthesizing the mass, cell mass, we need energy or microorganisms need energy, bacteria need energy. So, that way anabolism becomes energy consuming process whereas, catabolism when it is transferred into stable, so, let us say complex organic molecule you can let us say take a complex organic molecule for say and let us say this is being broken up.

So, when you there is certain bond energy associated with these bonds and when these bonds are broken up in order to convert this to more stable or end products or smaller end products. So, when these bonds gets broken up, energy is released, that is why the process of catabolism actually produces energy, ok while, the process of anabolism consumes energy. So, anabolism been a energy consuming process will only be taking place, if there is a source of energy present in the system. And catabolism is such a process which can provide that energy. So, that way catabolism and anabolism typically occur at the same time, where the catabolism supply the energy needed for the synthesis of cellular mass, in the form of anabolism the process are interdependent because then, then anabolism will be synthesizing new cells.

So, that new cells will further or new biomass or new bacteria will further actually act upon the organic carbon in order to break down to a smaller product. So, that will generate more energy and that energy consuming that energy, more new cells will be synthesized. So, catabolism and anabolism become an interdependent process and their occurrence has to be they, they typically occur in a simultaneous fashion.

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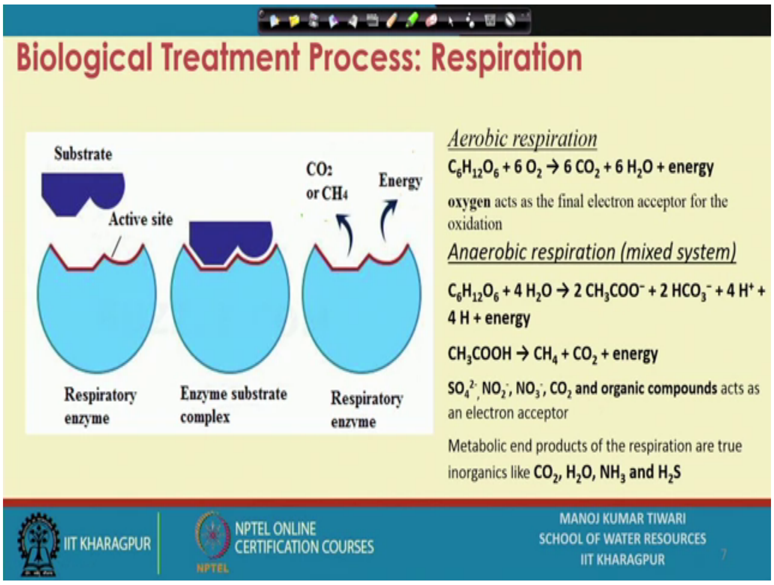


If you see the respiration process, where then typically what happens that there, there has, there is has to be a respiratory enzyme, there is typically a respiratory enzyme which is having an active site and then there is a substrate which comes on this active site and forms an enzyme substrate complex. And then at this active site, at this surface this product is broken down energy is released and smaller compounds like C O 2 or C H 4 will release depending on the kind of process, and your respiratory enzyme again becomes free.

So, there is, if you see the aerobic respiration where the oxygen is the electron acceptor in the presence of oxygen. So, let us say you have a source of carbon which is reacting with the oxygen. So, it will produce the gas and energy, ok. So, oxygen acts here as a final electron acceptor for the oxidation process in a aerobic respiration. However, if you see the anaerobic respiration so, then the same product will actually be let us say being hydrolyzed, being converted to this way and energy is released then the product which is produced may further break down into C H 4 and C O 2 releasing the energy.

Now, the ions such as sulfate nitrate, nitrite and various other organic compounds could become an electron acceptor in this case, ok. So, electron acceptor in this case is not oxygen, as in the case of aerobic respiration it is, it becomes the other process other elements present in there and there the energy is released and then we also get the C H 4 and C O 2 or those kind of thing. The metabolic end products of these respirations are true in organics like C O 2 H 2 O ammonia H 2 S those kind of systems are finally, formed through these metabolic processes.

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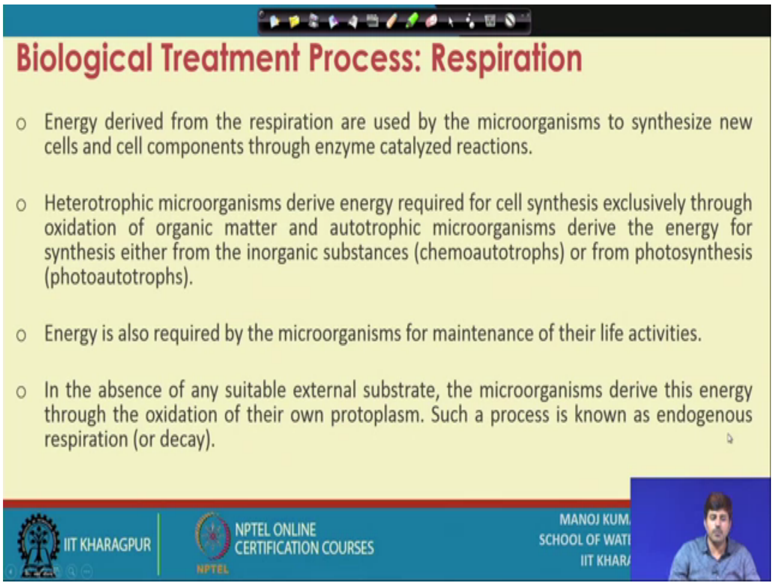


Now, if we see the respiration process the energy derived from respiration are used by the microorganisms to synthesize the new cells and cell component through the enzyme catalyzed reactions. There is heterotrophic group of microorganisms, that derive energy required for cell synthesis, exclusively through the oxidation of organic matter and autotrophic microorganisms derive the energy for synthesis either from the inorganic substances which is of the form of chemoautotrophs or from the photosynthesis which are from the photoautotrophs.

So, it is basically autotrophs who can synthesize these things. So, if they are deriving energy from the solar systems they becomes the photoautotrophs, if they are deriving energy from the chemical process they become the chemoautotrophs. Energy is also required by the microorganisms for maintenance of their life activities. So, one like the normal life activities need certain energy for every living entities including the microorganisms. So, that energy requirement is also needs to be fulfilled and comes from the respiration primarily.

Now, in the absence of any suitable external substrate, if there is no external substrate available: means there is no source of organic carbon available then micro organisms derive this energy through the oxidation of their own protoplasm. So, they kind of their own cell mass that they have been developing, they try to oxidize that they try to break down they their own protoplasm and actually derive energy out of that and such processes then because if their protoplasm is oxidized and broken down.

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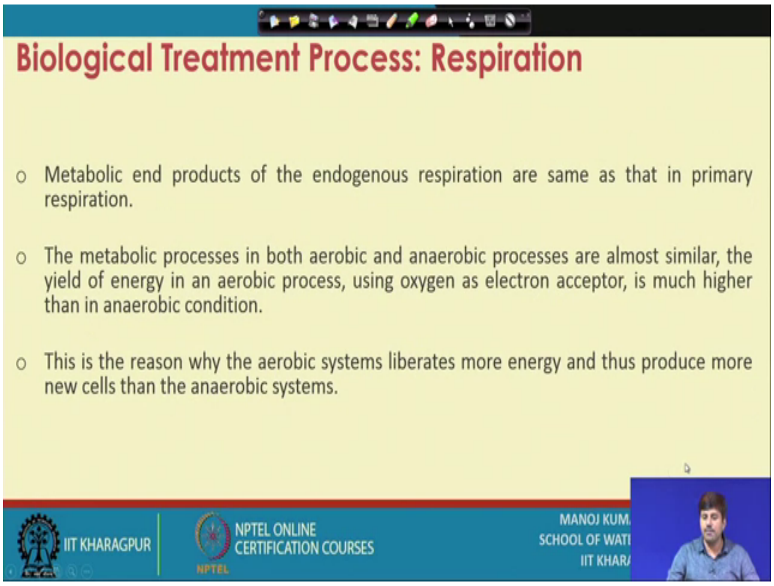


So, the bacteria or microorganisms will be killed in a way and that is why this process is known as endogenous respiration or what we call typically decay of microorganisms, ok, kind of leading to negative growth because there is no substrate available. So, for survival of microorganisms some of them can actually attack on their own like the micro, the protoplasm of these species which are present in there and that leads to the decay of the species.

If we see further the metabolic end products of your endogenous respirations are same as the primary respiration. So, the end products whether it is using our external substrate or using its own protocol for the respiration purpose the end products are going to remain more or less similar. The metabolic processes in both aerobic and anaerobic processes are almost similar, ok. The yield of energy in anaerobic processes using oxygen as a electron acceptor though is actually much higher as opposed to the anaerobic condition.

So, the aerobic conditions when oxygen becomes electron acceptor yields much more energy as opposed to the anaerobic systems and that is the primary reason, that is one of the basic reason that your anaerobic systems, the synthesis of the cell mass is very low. Because of the low energy yields the lot of like cell mass is not synthesized and the growth rate of the anaerobic system or the rate at which the new cells are being formed, in the anaerobic system is far typically far lesser than that of aerobic system which liberate much more energy.

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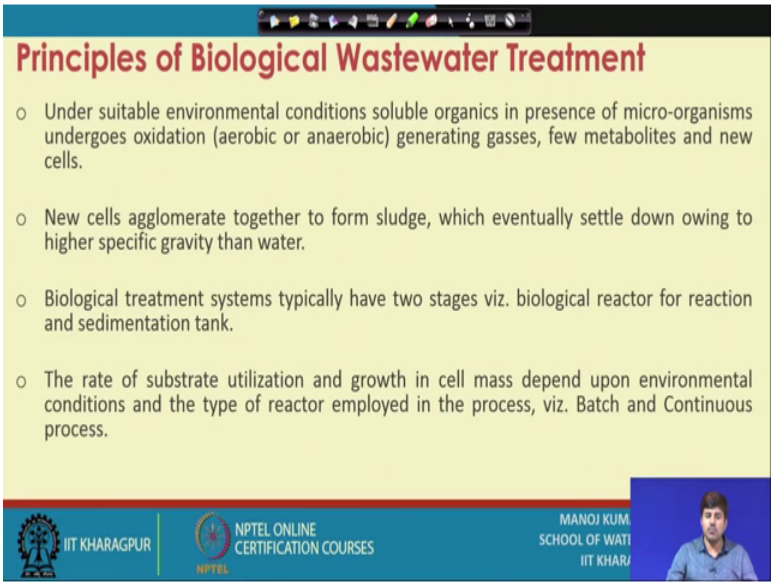


So, that is why we typically see the anaerobic growers are slow as opposed to the aerobic microorganisms. Now, under suitable environmental conditions the soluble organics in the presence of microorganisms undergo oxidation, this could be aerobic or anaerobic and generate gases few metabolites and the new cells. So, this is typically what happens in the wastewater treatment system, biological wastewater treatment systems we provide the organic matter typically the soluble organic matter and then there are microorganisms present. So, they undergo like this organic matter undergo oxidation microbial oxidation that form of the aerobic system or anaerobic system, but then it undergoes oxidation and through the process, it creates few metabolites it creates new cell mass or sludge, what we refer as and it creates some gases.

Now, these new cells which are created they agglomerate together to form sludge which eventually settle down owing to higher specific gravity than the water because microorganisms and particularly this sludge which are cumulative or combined, flocks of microorganisms they have higher specific gravity and that is why they can settle down in the water. But they need a static condition typically or very low flow condition to settle down as we were discussing in the previous week in the case of sedimentation or grit removal the velocity, horizontal velocity, horizontal flow velocities to be reduced in the order of settling and that is why that becomes an important step of the biological treatment system.

So, if we see the biological treatment systems typically have two distinct stages, one is the biological reactor where the reaction takes place, the different reactions takes place in these biological reactor, different reactions means this including oxidation, the formation of the new cellular mass, formation of the gasses the metabolic metabolism of the organic matter leading to the, leading to various end products or byproducts, ok. So, all these reactions takes place in a biological reactor for reaction. And we have another stage of sedimentation where this mass which is produced gets settle down, ok.

So, we can have these 2 in a 2 distinct reactors or 2 distinct units or we can have them amalgamated or we can design a reactor or a system where these 2 can takes place in a single unit, ok. So, that will depend on the configuration of reactor, but typically these 2 stages are there. The rate of substrate utilization and growth in the cell mass will eventually depend on the various environmental conditions, what type of reactor employed in the process? Whether it is a batch reactor or a continuous reactor because the growth of bacteria how it is taking place, what is the configuration of reactor? There is possibility of reactor being packed with something or reactor being like the, the growth could be actually in the aqueous phase only.

So, that there is no medium on which the bacteria can attach and they grow in the suspension which is typically called the suspended growth system. And there are systems where bacteria can attach to a media present in the reactor which is called attached growth system. So, what type of growth system is this, what type of inflow is this? Whether it is a batch system or a continuous systems we discussed earlier the batch and continuous system the batch systems where the inflow comes in the batches and remains there in the reactor for quite some for some time whereas, in continuous the inflow and outflow simultaneously keeps on happening.

And based on the design of reactor, we can adjust we can set up a retention time for which an average time the fluid particles spend in that reactor. So, depending on all these conditions, the rate of biological reactions or rate of the cell synthesis or late of the metabolism or substrate utilization will eventually depend on this; will eventually depend on the kind of procedure. Particularly from microbial growth prospective in a batch system the amount of organic matter certain organic substrate has come into the reactor and then it is up to the micro organisms to utilize that because that is the fixed source, if it is a batch system no further source is no further addition of the organic substrate or organic matter is being done in the reactor.

So, bacteria has to utilize that survive on that only and once it is completed the batch might be taken out. In a continuous flow there is a continuous supply of these, there is a continuous supply of the substrate. So, the kind of kinetic of the bacterial growth processes and this thing changes because you have a continuous supply of the food, ok. That happens and then a as we were discussing based on the type of system whether it is attached growth system or fixed growth system there are various attributes to these two there are like in attached growth system the growth rate might be higher, but in suspended growth system, the substrate utilization rate might be higher.

So, we will discuss the subsequent thing in the next class. We will break this lecture here only and in the next class we will have the further elaborated discussions onto these, and then we will eventually see what are the different reactor regimes or type of reactors that are available for the treatment of wastewater.

Thank you.