Water Quality Management Practices

Prof. Gourav Dhar Bhowmick

Agricultural and Food Engineering Department

Indian Institute of Technology Kharagpur

Week-06

Lecture - 27

Lecture: 27 - Factors Affecting Bacterial Growth and Wastewater Treatment Using Bacteria

Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Dhar Bhowmick from the Department of Agriculture and Food Engineering of Indian Institute of Technology Kharagpur. In this particular module as we were discussing about the fundamentals and principles of biological wastewater treatment, today we will be discussing majorly on the factors which affects the bacterial growth and the wastewater treatment using bacteria. As a content we will be more majorly focusing on the factors affecting the bacterial growth and the wastewater treatment using the bacteria. To start with what are the different factors which affect the bacterial growth in our wastewater treatment plant. So, as you have remembered we are now focusing on the second stage of the treatment the secondary treatment systems ok.

In the secondary treatment systems the biological treatment is the one of the major part. In this biological treatment we normally use different kind of microbes which actually consume the pollutant present in the wastewater and by this way they are reducing the pollutant level ok. So, this is how the treatment is being taken place in the biological treatment system. So, as you have clearly understood that in case of biological treatment systems our major goal is to make the microorganisms survive in the system in its optimal way isn't it.

So, for that it definitely response to some factors some environmental factors for sure. So, we will discuss about those factors in which this microbial growth and their kinetics will be involved will be completely depending on ok. So, the first one is the temperature. We can discuss about the temperature, but first let us let us discuss about the what are the different factors temperature, pH, oxygen, salinity, water or moisture content, the light, H plus ion concentration, osmotic pressure and the mechanical stress and all. So, one by one we will discuss in detail about each of this governing parameters.

The first one is the temperature. So, as we know that in general in the wastewater treatment scenario we try to make the temperature of the treatment system in mesophilic in mesophilic range means like somewhere around 20 to 40 degree Celsius or 25 to 40 degree Celsius. So, in this particular range most of the beneficiary microorganisms can easily survive there. In and because of that the wastewater treatment system also we try to design it in this range only like you know try to at least maintain the temperature even if your system you are designing a system for the temperate region. Suppose in Europe somewhere in Europe or USA or Canada still you would the target for the whenever the engineer they would design this kind of systems they try to maintain the temperature of this biological treatment units whether well in between this mesophilic range at least 20 degree Celsius for sure.

So, that this beneficially microorganisms can easily survive and they can easily thrive in this environment ok. There are some microorganisms which are called the thermophilic bacteria like the Geobacillus species. So, some Geobacillus species they grow based in the relatively high temperature ranging between 55 to 80 degree Celsius. There are some very few examples and the very few plants where it is where they sometimes they use this kind of thermophilic microorganisms to perform in a particular type of you know like target a particular type of pollutant. But in general our target is to maintain the temperature of the wastewater well within this mesophilic temperature mesophilic.

So, the mesophilic bacteria can easily survive in this temperature. In some cases there are studies where people even use a cyclophilic microorganisms as well like who can survive in a much colder regime, but it is very scarce ok. Next is the pH. The pH in general the most of the neutrophilic bacteria who can survive at the range of in the in a pH range pH of 7 and they can easily grow they can easily grow in this neutral pH and also they can survive much more easily and they are one of the most commonly used microorganisms which are present in the wastewater treatment systems. Other than that we have the acetophilic bacteria which grows which grow better in the acidic medium like the lactobacillus species and the basophilic bacteria is also there.

From the name itself you can understand this it grows it normally grows in a basic pH medium and all like vivrio, cholerae and all. So, these are the main three different types of microorganisms and, but in case of if you ask me about the wastewater treatments point of view about water treatment point of view the best case scenario we normally use the neutrophilic microorganisms only. Then there comes the oxygen it is one of the major determining factor. Most of the bacterial species like forget about most like all the bacterial species they are very much sensitive to the presence or the absence of oxygen. And they have a varying oxygen requirement based on their growth and their respiration criteria's and all.

So, based on the what oxygen requirement the microorganisms can be classified as obligate anaerobes obligate the microaerophilic, facultative, aero tolerant and obligate anaerobes also. If you remember in last in last lecture also we discussed about it in details and I here also will follow the discussion so that it will be much more easier for you to understand the different types of micro bacteria based on their oxygen requirement. To first start with we have the obligate anaerobic aerobic bacteria which can grow only in the presence of oxygen they like the micrococosletos or the pseudomonas aeruginosa and all. We have a micro aerophilic bacteria that can grow only in a very low oxygen concentration level like an almost like the anoxic concentration and all. So, these are called the campylobacter like one example is the campylobacter and all ok.

There is the facultative bacteria which can grow in the presence or in the absence of oxygen most of the staphylococcus or equalized species and all. We have the aero tolerant anaerobes like the bacterial species that can grow in the presence of oxygen, but do not use the oxygen for their growth. They are tolerant to the presence of oxygen, but they majorly go for the anaerobic respiration process like the lactobacillus process. Even if the oxygen is present still they can perform the anaerobic respiration process. So, that is that is why they are called aero tolerant anaerobes ok.

So, then there comes the obligate anaerobes. From the name itself you can identify that obligate anaerobes means they are different they are very sensitive to oxygen and they cannot grow in the presence of oxygen and they can only perform their regular respiration process in absence of oxygen like the clostridium species and all ok. So, these are the different types of bacteria based on the availability of the oxygen ok. Then there comes the anaerobic battery if we discuss more in details this anaerobic bacteria what they use as a terminal electron acceptor definitely the oxygen that is why it is called the aerobic bacteria right. In case of aerobic respiration energy and carbon source is completely oxidized to carbon dioxide H_2O and the energy in the form of ATP or adenosine triphosphate.

Sometimes this oxidative phosphorylation happens and the conversion of adenosine diphosphate to ATP adenosine triphosphate takes place in the aerobic respiration. And this actually gives the or the energy requirement and all this actually responsible for the all the energy generation in the liberation process happening inside the cellular level ok. So, that is why for aerobic bacteria this oxygen is very much important and which acts as a final electron acceptor. However, in case of anaerobic microorganism in case of aerobic oxygen is playing as a terminal electron acceptor or final electron acceptor, but in case of anaerobic bacteria instead of oxygen they utilize the compounds like nitrate or

sulfate as the final electron acceptor in their respiration process ok. So, they use this inorganic substances for their respiration process.

Just try to remember this is the basic difference between like you know this aerobic and anaerobic bacteria and they where they get their where actually they are contributing their electron excess electrons and all ok. Then there comes the fermentation process. It is also a kind of anaerobic metabolism only anaerobic respiration process only, but in which the complex organic compounds are broken down into the simpler ones ok. Products like the organic acids or alcohol as well as in the gas like carbon dioxide, methane, hydrogen etcetera by enzymatic action without the use of oxygen. So, this is called the fermentation process ok.

So, in case of fermentation process there are different kind of fermentative bacteria those are already those are available and all. So, next important factor is the water or moisture. So, water requirement it generally varies from species to species ok. Bacteria in general they grow best in the ideal osmotic pressure. What is ideal osmotic pressure here? Suppose what happen if you see if you have a certain salt concentration inside your body certain osmotic pressure inside your body right.

I mean like you when you put your hand when you in a high salt solution or say like in a hypertonic solutions or hypotonic solutions like high salt concentration or the very low salt concentration what happen in case of higher salt concentration then the then any living organisms what will happen your bodily liquid will get out of your cell membrane and it will come in contact with the external medium because of the hypertonic solution. Because of that you that living body will squeeze and at certain moment of time it will devour of all the essential medium and it may die. At the same time when it is a hypotonic solutions means the external environment have a very little amount of salt or very little amount of like the salt available. So, what happen in that case? The from external source the water will the water will enter to the living body and because of that what will happen it will start in swelling and at certain moment of time it will burst or it will rapture and it will kill the living organisms. So, that is why they it is always optimal to have a salt concentration of microbial cytoplasm is equal to the external environment.

In that condition only bacteria can grow in its optimal way. So, this osmotic pressure has to be maintained to be as a to be optimal. As I was saying that sudden transfer of bacterial culture to a hypertonic environment can cause the plasmolysis. This plasmolysis as I was mentioning the osmotic removal of water from the cytoplasm to the external environment and leading to the shrinkage of the cell and death. But in case of hypotonic solutions where the salt concentration of the external environment is less than the cytoplasm the osmotic gradient will result in the transfer of water from the into the

cytoplasm from the external environment.

Because of that the micro this micro is not started swelling and eventually it will burst ok. There are some type of halophiles. Halophiles are like a kind of a one type of extremophiles one type of extremophiles or the microbes which can survive in extreme conditions. So, this halophiles they are tolerant to high salt concentration as well ok. You can find it in some like you know high saline water bodies and all.

You will see these are and also it is very commonly found in the material lakes and all the and there are in India also in Maharashtra there are there is a famous lake where actually it is very much famous for actually people come there to just to research on the halophiles and all ok. Anyway so, other factor which affects the bacterial growth is the light the majorly the phototropic battery as you know they require the optimal light for their growth, but if it is a phototropic. If it is not a phototropic in general most of the bacteria they love to survive in absence of light only ok. However, the radiation from the UV ray can drastically reduce the bacterial growth because it presence of UV ray what happens whenever there is a UV ray or is present there it may create some amount of reactive oxygen species in the in the water solution and all or the in the water body. So, this reactive oxygen species it can actually disrupt the cellular functionalities and all and because of that the bacterial growth can be succumbed.

And so, that is why the radiation from the UV rays has to be I mean like it can cause drastic problem to the bacterial growth and all. So, in general what we understood that phototropic bacteria they need light, but if it is not phototropic most of the bacteria they performs well and then normally survives well in absence of light. In general these are the factors that we already discussed. Now, let us come to the fact that how the wastewater treatment is benefited by the presence of this bacteria and all ok. So, broadly speaking the biological methods in the wastewater treatment systems can be classified as aerobic anaerobic and anoxic ok.

In case of aerobic treatment it is suitable for wastewater with the low BOD and COD around 1000 milligram per liter is the best. If it if it goes above that it is better to go for the anaerobic treatment process. It is a standard thumb rule practice ok. So, around 1000 milligram per liter till then the aerobic treatment processes can somehow perform better, but if it goes beyond that it is better not to better to go ahead with the anaerobic treatment first and then you use the aerobic treatment as a further polishing treatment procedure. So, in general anaerobic treatment is preferred when the organic matter concentration is very high and in some cases the combination of anoxic aerobic and anaerobic processes are used to reduce the sludge yield in the system.

So, what are the factors that determine the biological treatment method to be applied? First is the nature of wastewater as I was mentioning when the wastewater has a very high pollutant load you have to make sure that it is a it goes through anaerobic first then aerobic or anoxic ok. So, that means, the nature of wastewater has a quite a good amount of say about the which type of treatment has to be employed based on its pollutant load. Second is the energy demand. In some cases if you have a shortages of energy demand what you can do because in aerobic treatment systems you have to supply aeration you have to supply air dissolved oxygen right because in order to supply this dissolved oxygen you have to operate the aerator 24 7. So, that is why instead of aerobic treatment processes anaerobic treatment processes are actually less energy consuming and rather this anaerobic treatment processes generate a huge amount of biogas then biogas can be utilized for further energy recovery is not it.

So, that is the reason that sometimes based on the energy demand or the availability of energy in the surrounding vicinity you can choose either the aerobic or the anaerobic treatment processes ok. The concentration of the organic matter as I was already discussed I already discussed about it like an amount of organic matter obviously, determine the aerobic and anaerobic systems. The treatment time required the treatment time based on the if you if you remember in the last lecture also I discussed key anaerobic treatment processes needs a high startup time very long startup time ok. So, because it is a this methanogenic microorganisms needs some more amount of time to acclimatize or to the scenario to the system. So, that is why it takes a high long startup time.

So, if you have a certain if you want to start if you need to start your reactor in a faster rate you know you have to you need to start say like in next 10 days you should go ahead with the aerobic treatment processes because it needs less amount less startup time. However, in some cases the anaerobic treatment process is much more efficient than the aerobic one. So, in that case maybe even though the startup time is higher it may actually more beneficial for you to go ahead with the anaerobic treatment processes than the aerobic ones. So, it all depends on the different other parameters also. So, based on that your treatment time requirement and all and based on other parameters you have to choose whether you want to go for aerobic anaerobic or anoxic processes ok.

Then there come the microbial concentration obviously, the microbial concentration will also differ in case of aerobic to anaerobic treatment systems. In aerobic it is like cell biomass is it produces in a much higher rate and in case of anaerobic it much less and because of that actually it may sometimes cause additional problem out cell like nuisance to the system because this sludge that because of the excess amount of biomass that it creates in anaerobic systems this excess amount of biomass is actually converted into

sludge itself. So, you have to deal with a huge amount of sludge daily basis in case of aerobic treatment systems whereas, in anaerobic it takes good amount of time the sludge retention time is quite high ok. And the desired effluent quality based on your desired effluent quality also you may sometimes play with the sequence of treatment procedure in your biological treatment systems. You can go ahead with anaerobic then again aerobic treatment process for further polishing to reduce the effluent pollutant load.

So, this way you normally play with it ok. Once you become expertise so, you normally play with the different type of systems like this and to ensure that your final effluent has a certain quality of output ok. Based on the rules and regulations the norms given by the your local regulatory bodies like in Indian case the central pollution control board national green tribunal they are the one who gives us the verdict about what should be the final effluent quality of the water which is coming out of your municipal wastewater treatment systems or suppose the industrial wastewater treatment systems like the industrial effluent treatment systems and all ok. So, this ETP and STPs the final effluent what should be the values and all it is already given by the regulatory bodies central regulatory bodies of your own country. So, there based on that only you have to sometimes play with the type of treatment that you need to install or need to construct in your treatment plant. So, in general if you see the we can go ahead with the anaerobic anoxic or anaerobic processes it can be further differentiated in like you know 3 different types the suspended growth, attached growth and the hybrid reactor.

So, what is a suspended growth process? If you remember we discussed about in a last module also. So, in the suspended growth process from the name itself we can identify it is in suspension that means, the microorganisms are in the suspension in the column in the column of the reactor ok. So, that is why it is called the suspended growth reactor like the activated sludge process, sequencing batch reactor, anaerobic sequencing batch reactor, off-flow anaerobic sludge blanket reactor, membrane biological reactors. So, we will discuss about all these things in the coming lectures and you will be able to understand this different type of suspended growth process in more in details and you will be able to even design it by yourself at the end of this lecture series.

Then there comes the attached growth process. In the attached growth process what does that mean? That means, it needs some media over which it will or it will try to find some place to stuck on the surface of those media. Normally we call this as a bio media. We provide this bio media it may be made up of ceramic, plastic whatever it is ok. So, on will our target is to provide this bio media with a maximum specific surface area ok. So, if we provide them with the maximum specific surface area, so it will suppose it will get that the bacteria will get maximum amount of surface to actually you know to stay itself to and actually keep on reproducing there itself.

So, we need to provide with the bio media with the maximum specific surface rate. Now in this bio media what happened those bacteria will start growing on the top of it and slowly they will grow on top of it. And then what will happen then after a while when it is it grows enough and on the the some of the microorganisms start dying which is in contact with the surface of this bio media they will automatically remove from the systems. This is called the slogging of phenomena. This it is automatically removed from the bio media because it is thick enough now which on the top of this bio filter and on the very inner part of it started dying.

So, when it started dying it reduces the capacity to stick onto the surface of this bio media and then it will automatically come off as a small carpet ok. So, because of that this phenomena is called the slogging of phenomena. And it is so this kind of system is called the attached growth process or the there are different type of attached growth process like the trickling filter and the aerobic filters anaerobic filters and all. So, we will discuss about this as well like in a coming lectures where you will be able to design the trickling filter and the aerobic filter as well and you get to know about the basic fundamentals about those different type of reactors ok. Then there comes the hybrid reactors there are moving bed biotrheme reactor, rotating biological contactor or the submerged aerobic filters.

What happen in this kind of systems? We in case of moving bed biotrheme reactor it can be hybrid, it can be aerobic as well as it can be suspended as well as attached growth process. In general in moving bed biotrheme reactor we considered as a attached growth process only because there we provide some bio media in those bio media only the bacteria actually start growing on the surface of it. But there are very few there are very few amount of microservices which also stays there in suspension. So, that is why it is sometimes it is sometimes referred to as hybrid reactor ok. The same for the rotating biological reactor and as well as the submerged aerobic reactors and all.

We will discuss about these things in detail. So, it will be much more like you know accustomed you will be able to understand it more in details when we will be designing this individual systems. In case of aerobic treatment systems it is a biological process where normally it break down the organic and pollutant into such as nitrogen and phosphorus in the presence of oxygen right. So, how we provide the oxygen in the system? We normally provide the use the mechanical aeration devices like the air blower, paddle wheel aerators etcetera or we sometimes introduce the compressed air through the diffuser and sometimes we use both the mechanical as well as the diffused air aeration systems as well. In general the organic matter oxidized by the microsomes is often measured in terms of BOD and COD that is like the standard practice as we

already know what is BOD and CODs. The aerobic process it is normally suitable for the low strength wastewater as I was discussing its COD should be less than 1000 milligram per liter when where it actually performs the best.

It normally we go for the anaerobic treatment process and then aerobic for high strength wastewater and depending upon the concentration of organic matter the aerobic treatment can be used as standalone or as a polishing treatment ok. The aerobic treatment also produces odor free sludge that needs to be stabilized further and dried to be used as a fertilizers, but it is the quantity is very high. The most widely used aerobic processes are the activated sludge process trickling filter and some modification like sequencing batch reactor, moving bed biot is a very high level. So, in that level in order to tackle with this high strength wastewater you have to employ the anaerobic treatment systems first ok. How and also another advantage of anaerobic treatment process is like it produces a very little amount of excess sludge that is why the cost of sludge handling is also much less and plus it also eliminate the energy cost for the aeration as required in the aerobic processes that is why it is also much cheaper.

Like aerobic treatment systems anaerobic also exhibit two type of growth attached growth and the suspended growth and based on the growth of the microbes the reactor used in this kind of wastewater treatment can be classified as attached growth and the suspended growth as I was mentioning in the last slide also in last like couple of slides back. So, the popularly used the anaerobic reactors for the wastewater treatment systems are anaerobic filter, off low anaerobic sludge blanket reactor. Please remember this one UASB Afro Anaerobic Sludge Blanket Reactor. This is a very famous one and it is normally been used all over the world and it is because of its functionality and because of its easy to install I would say it takes some start up time good amount of start up time, but once it is installed one it is it works start working perfectly it can be very much beneficial for the treatment of high strength medium to high strength wastewater this Afro Anaerobic Sludge Blanket Reactor UASB ok. Anoxic treatment it refers to the environment lacking molecular oxygen, but containing bound oxygen molecules like nitride or nitrate.

So, it is the microbes is adapt to the respiration metabolic pathway based on the dominant electrode acceptor in the environment. Initially using oxygen and shifting to bound oxygen when the oxygen is depleted like nitrate and nitrite ok. So, this shift in respiration is termed as the anoxic respiration defining as anoxic environment. In anoxic environment wastewater treatment systems most commonly employed for removing the nitrate from the aerobically treated wastewater and denitrification reactor. So, what does that mean? So, suppose it is most famous in the aquaculture treatment systems also what they do in aquaculture treatment we first have a the wastewater the aquaculture

wastewater it does contain a huge amount of say ammonia ok.

So, this ammonia needs to be removed. So, what generally people employ they employ one aerobic treatment system first ok. In this aerobic treatment system this ammonia is converted into nitrate by means of nitrification process because nitrification process demands oxygen ok. So, in this process what happened the ammonia is converted into nitrate. Now, then nitrate is again converted into dinitrogen or nitrogen gas when the anoxic wastewater treatment is employed. I mean like in this anoxic environment this nitrate is denitrification process starts occurring and nitrate is converted into nitrogen by this way we can completely remove the nitrogen from the wastewater ok because it converts completely to the gas state ok.

So, this is how the anoxic wastewater treatment works. So, in this kind of anoxic conditions various anaerobic bacteria such as Pseudomonas aeruginus or Clostridium species or phototrophic bacteria like the Rhodocydomonas species etcetera along with the denitrifying heterotrophic facultative bacteria can thrive and remove the nitrogen and ammonia in the reactor like Aflo-Anamox sludge bed or other anaerobic Aflo reactors as well. So, this Anamox type of battery is also it is revolutionary now all over the world there are people who are working on this Anamox type of microorganisms. So, you I would also suggest I do not have because of the time limitations I cannot go ahead with much of a discussion about this Anamox, but I would request you to search for this a keyword in Google and you will be able to understand the how it functions and all ok, Anamox this one. So, good so, we understood the different parameters and in which the growth of the microbial community of wastewater treatment system depends on and how they are they are applied in the different type of aerobic anaerobic or anoxic type of wastewater treatment systems and all. So, in general the bacterial growth we discussed that it influenced by different environmental and the physicochemical factors.

The key parameters like nutrient, temperature, pH, oxygen, salinity, moisture, H plus and concentration, osmotic pressure, light and mechanical strength. The pH level categorize the battery into neutrophilic, acidophilic and basophilic. Oxygen requirement wise also it classified in following categories. Aerobic and anaerobic they processes they normally involves the diverse electron acceptors some of them needs oxygen some of them needs the nitrate or sulphates. In fermentation it allows the oxygen bacteria to metabolize organic compound without oxygen producing the various end products and other factors like moisture or osmotic pressure and the light conditions also impact the bacterial growth.

Waste water treatment methods like aerobic, anaerobic or anoxic processes are chosen based on the factors like the wastewater composition, organic matter concentration,

desired effluent quality etcetera. And aerobic treatment process is suitable for lower strength wastewater and anaerobic is preferred for higher strength or medium to higher strength wastewater with eliminating the generating the biogas as a additional renewable energy source and minimizing the excess sludge. In case of anoxic it involves an environment without molecular oxygen utilizing different bacteria for denitrification and demonstrating economic and efficient advantages in biological secondary treatment processes compared to the traditional aerobic methods and all. So, I hope you have a very good idea about the systems and this understanding on this on the today's discussion.

This is the references I would like to like you to go through it. Thank you so much, we will meet you in the next lecture. Thank you.