Environmental Biotechnology
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Lecture – 17
Microbiology of Environmental Engineering System

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Welcome to this lecture on microbiology of environmental engineering system in this lecture, the following concepts will be covered. The practical goals of microbiology of environmental engineering system will be discussed, groups of microorganisms relevant to environmental engineering and by technology will be highlighted energy sources for the growth of pro carriers and other psychological factors, relation to oxygen and use of alternate electron acceptors by the microorganisms in the environmental engineering system will also be discussed.

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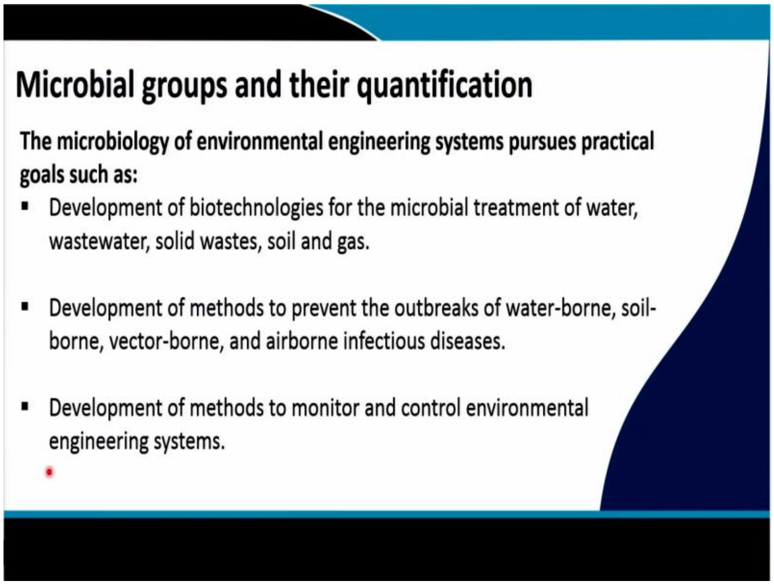

Today's lecture we are going to cover some important aspects on microbial groups they are quantification including some of the fundamental aspects regarding their carbon energy metabolism and also, the use of oxygen and alternate electron acceptors. So, to begin to it the microbiology of environmental engineering systems pursue practical goals, such as the development of biotechnologies for the microbial treatment of water, waste water, solid rest oil and gas.

And in recent times this has been extended two advanced application of microbial conversion, conversion of atmospheric gases like carbon dioxide or conversion of methane to useful molecules or useful products. The next goal is defined as the development of methods to prevent the outbreaks of waterborne, soil borne, vector borne and airborne infectious diseases because in most of the cases microorganisms that prevail in contaminated sites they pose a huge health risk as many of them are identified to be of pathogenic initiative.

Therefore, detection these organisms and methods to prevent their spread, their growth, is considered to be a very important aspect next is the development of methods to monitor and control the environmental engineering systems. Because for continuous and efficient performance of any environmental engineering system; wherein microorganisms incorporated, or playing a very important catalytic role, it is of immense importance to follow proper methods to monitor the growth and the activities of the microorganisms.

And also control the activities of the mind to organism, particularly with respect to the long term performance of such environmental systems and also, taking into consideration of the dynamic nature of many of the influence and other input substances.

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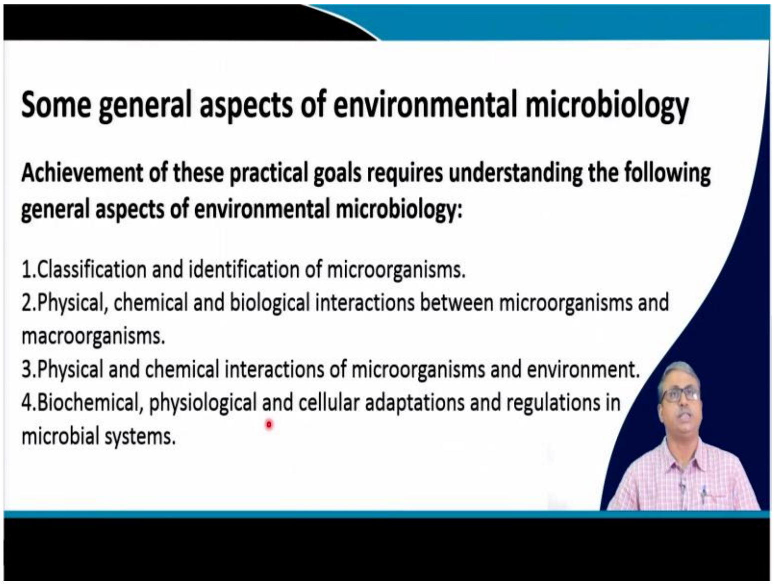

Some general aspects of environmental microbiology are the achievement of these practical goals? The practical goals that were identified in the previous slide these require understanding of following general aspects of environmental microbiology. Number one is the classification and identification of microorganisms, physical, chemical and biological interactions between microorganisms and microorganisms physical chemical interactio; of microorganisms and their environment and biochemical, physiological and cellular adaptations and regulations in microbial systems.

Now to elaborate on these points, briefly the classification and identification of microorganisms remarked as a very advanced and very important aspect in environmental engineering system and as we will learn in the later classes that in recent past there has been very significant advancement with respect to using molecular approaches, molecular tools to identify the microorganisms, particularly the microorganisms prokaryotic microorganisms, like bacteria and archaea, which remain uncultivable, or unhealthy bible organism, under the laboratory conditions.

The interaction between the physical, chemical, biological components and between the microorganism and microorganisms, these aspects have also been advanced considerably, with respect to the advanced analytical tools, as well as incorporation of different methods into the microbial ecological concepts. Physical and chemical interactions of microorganisms and the environment is similarly enriched.

And finally, the mechanism of biochemical, physiological and cellular adaptation by the microbial systems, which are relevant for environmental engineering and environmental biotechnology processes and regulations are also advanced in the recent time. We will learn about all these methods, all these approaches in detail, in our later classes.

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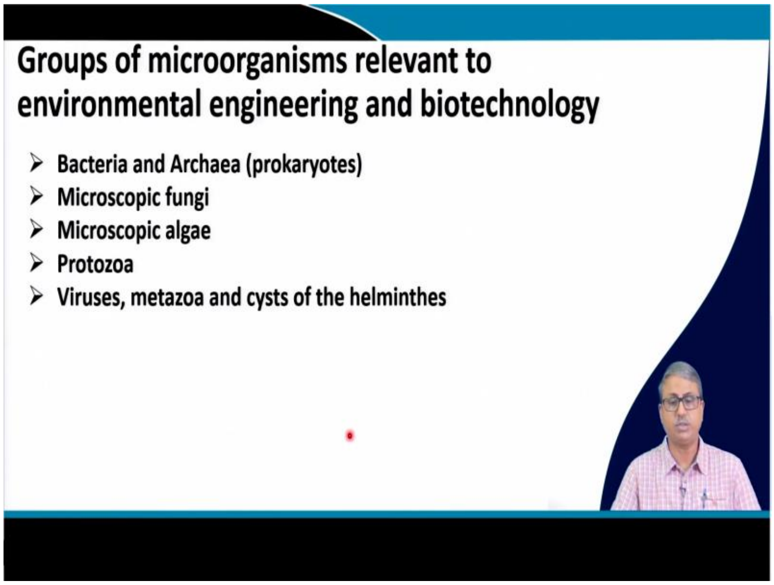

Groups of microorganisms relevant to environmental engineering and biotechnology are the following bacteria and archaea which represent the prokaryotic organisms, microscopic fungi, microscopic algae different type of protozoa, viruses, metazoa and cysts of the helminthes are all identified to be very relevant for environmental engineering and biotechnology processes.

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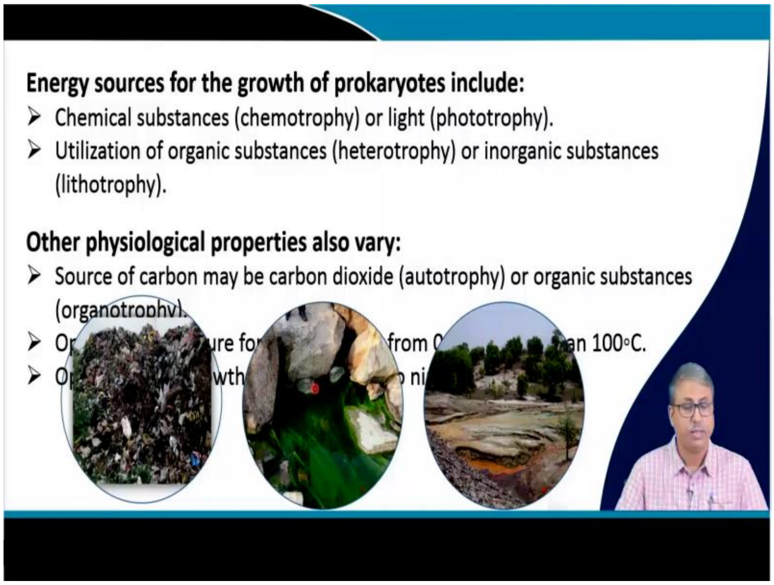

Now, the energy sources for the growth of the prokaryotic include both the chemical substances as well as the light because many microorganisms can rely on or utilize light as the source of their energy. Whereas other microorganisms, they can utilize only the chemical energy or chemical bond energy, to drive their metabolic. And based on that principle that whether they are using light or whether they are using chemical energy, the prokaryotic organisms are classified or categorized broadly as chemotropic or phototrophic organism. And this kind of metabolism is referred as chemotropic, or phototrophic.

Similarly, the utilization of organic substances or inorganic substances as the source of the chemical energy, because we have learned that there are organisms which rely on chemical energy or chemical substances, which are basically relying on chemotropic or we call them camouflage microorganisms. They can utilize either the organic chemical substances or inorganic chemical substances as their source of energy.

Now, when they use organic substances as their source of energy, they oxidize, the organic substances, because most of these organic substances, which are used as their source of energy are reduced. And these can be oxidized by microbial metabolic activity and these organisms are called heterotrope and this process is required heterotrophy. On the other hand, the organisms which are relying on inorganic substances as their source of chemical energy are called lithotrope and this process is called lithtrophy.

Among the other physiological properties which are important, and that play significant role in controlling the activities of these microorganisms and catalytic processes within environmental engineering or environmental biotechnology process. Are the source of carbon which may be carbon dioxide, or inorganic carbon that basically, allow the growth of the autotrophy type of microorganisms or the organic substances that is the organotropic microorganisms are allowed to grow and function.

So, depending upon the source of carbon available in the environment or in the system in which these particular organisms are performing the autotrophy, or the organotropic processes, or the organotropic microorganisms function. In case there are both carbon dioxide, or bi carbonate or similar inorganic carbons are available and organic substances are also available we can find out organisms which are of both nature, like mix of tropic in nature or organisms, simultaneously performing some organisms autotrophy some organisms performing heterotrophic.

In case of such influence or such inflow, waste materials. Optimal temperature for growth is a very important parameter among the physical chemical factors. Temperature and pH are the two most important parameters, along with the redox potential, moisture content and many other factors that we will discuss at some other point of time. But the optimal temperature for growth of microorganisms in environmental engineering system varies from zero degree to close to 100 degree centigrade.

Whereas the optimal pH for growth varies from pH 2 around pH 9 or also there could be some systems where we find that highly alkalic organisms are growing at around pH 11 or so, are highly acidific, or extremely acidific organisms are growing at pH 1 or less than 1 so particularly in systems like acid mine drainage or similar waste effluent. So, here are the some examples some pictures of the waste.

You can see that the first one over here in the left side is basically a landfill waste and within the landfill waste, we can expect that the carbons, which are available in this system, would be abroad or different types. So, you can expect a number of organic carbon, as well as some kind of inorganic carbon, which may be released by some kind of carbonate minerals, or other things, or the carbon dioxide, which are produced because of the metabolism of the microbes could actually play important role within this kind of system.

So, any kind of environmental systems or environmental particle of the process microorganisms are involved, are going to be involved, surely the types of carbons play a significant role. And this type of waste material so, both organic and inorganic carbons can be there, so, they control the type of organisms prevailing there and their activities are. However, if you look at the sum of the stream of water coming out from waste rock piles so, we can see significant amount of algal growth.

So, phototropic processes must be prevailed in this system, along with some lethotropic or other type of organisms, or metabolism can be simultaneously operating because lot of inorganic ions are often released from this kind of rock drainage system. On the right most side we have the acid mine acidific environment, where you can see that highly acidic effluence are released from the tailing spots.

And particular diseases from a copper mine and this kind of acidic waste streams, or acid mine drainage harvest most of the time, the lethotropic and lethotropic organisms, because there is not much of organic carbon present in this kind of waste stream. So, they are mostly dominated by autotropic litho autotropic organism. So, they are using inorganic carbon, which is from the atmosphere, atmosphere they are able to fix the atmospheric carbon dioxide.

And also, they are using the inorganic chemical energy derived from inorganic substances to derive their metabolism.

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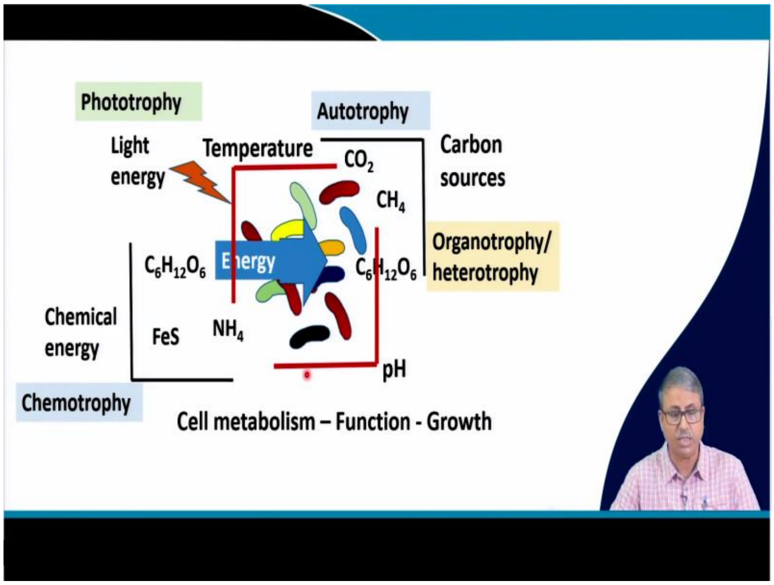

So, now we are going to learn some details of these processes. So, looking at the different microorganisms, which are generally prevailing in a kind of an environment, or in a kind of a common environmental engineering system, we can have organisms which are capable of using light energy. On the other hand, we can have organisms which are kept using chemical energy, which we have already discussed, that chemical energy could be obtained from either the complex or reduced organic compounds, like represented, represented as the glucose like molecules.

Just a representation, or the FeS, or ammonia this could be oxidized to produce the necessary energy, particularly if we look at the systems like the acid mine drainage or similar environment other waste effluence, a lot of ammonia, are there. So, ammonia could be acting as a source of energy, and they could actually drive a lot of microbial growth, ammonia, oxidizing microbes. So, these ammonia oxidizing microbes, or the sulfur oxidizing microbes, could derive energy from these inorganic substances whereas the organic carbon, utilizing heterotrope, organotropic microorganism can actually metabolize these organic sources and gain energy out of it.

So, eventually we will be able to delineate or identify phototrophic microorganisms, or photo trophy as a metabolism and chemotropy or chemotrophic microorganisms operating in the environment. Now because to be understood that in a kind of an open environment where some kind of waste is being dumped, or a landfill or a waste stream is flowing through, if we look at those kind of environment want to implement some kind of environmental engineering processes into that.

So, those kind of waste, since they are exposed to light. So, there could be opportunity for the light harvesting organisms, or the phototropic organisms, to operate, to gain the energy out of the light and fix the atmospheric carbon. Or they can also use the organic carbon whereas the presence of the organic carbon, like glucose, or the reduced nitrogen or iron sulfur compounds, could actually help the organisms to oxidize them.

And then the abundance of those lithotropic or litho autotropic organisms will prevent. So, this could be actually governed by what types of energy sources are available. So, eventually the energy will be opted. So, the essence of the entire deliberation is the micro organisms which are prevailing in the system, will gain energy out of the substance. So, no matter whether they are getting energy from the light, or getting energy from organic or inorganic residues they are gaining energy.

And this energy will allow them to function, to carry out their necessary a metabolic activities to grow and to proliferate under this under the given environmental condition. On the other hand we can have a range of carbon substrates which will again vary between the inorganic carbon, carbon dioxide, or carbonate, or methane or the complex organic carbon, like the glucose molecules there could be hydrocarbons and similar other reduced compound, which can be easily metabolized by different microorganisms who posses the relevant capabilities.

So, in general, you we can see that autotropic microorganisms, or autotropic metabolism, as well as the organotropic or heterotrophic metabolism will prevail or will play a significant role depending upon the abundance of this molecule in the environment. Now we should also remember that in many environments, which are apparently reached in glucose or organic residues will also have carbon dioxide.

Because the following the metabolism or oxidation of the complex organic compound the blue carbon dioxide will be released because the oxidation of complex organic compounds leads to the formation of carbon dioxide. And this carbon dioxide will be then available to the organisms, any organism who is capable of fixing carbon dioxide will possibly try to fix carbon dioxide. Similarly, if the condition is anaerobic, some carbon dioxide will be reduced to methane.

Maybe in some micro environment, or within a micro niche, will find that the submitted is also produced if the condition is anaerobic and strictly anaerobic and then eventually that methane will be subjected to utilization by different microorganisms. It is also absorbed with high throughput DNA sequencing molecular approaches, or molecular investigation, that in natural environment or in controlled environment often , it kind of mixture of different microorganisms, who are capable of doing or performing autotrophy, heterotrophy both are prevalent.

With respect to the abundance of the carbon substrate the particular type of organisms or a particular type of carbon fixation, metabolism, or carbon metabolism might trigger. But in general, we may expect that the kind of assemblage of organisms with broad abilities, either very specific ability of autotrophy or a kind of a dual ability of both autotrophy and heterotrophy could we expect.

Now, along with this carbon energy substances, as I mentioned earlier, the temperature and pH are the two important factors which might control or which you into control the microbial activities within the system. And it is not only actually temperature and pH there would be other physical, chemical factors that we will learn later but temperature and pH are considered to be the most important, along with the redox and moisture content, and the presence of different ions, etcetera.

Overall, these carbon substrates, the flow of energy and the favourable temperature and pH, etcetera will control the cell metabolism. The cell will try to metabolize these substrates, , use the electron toners, electron acceptors etcetera. They will function according to their genomic or metabolic potential and they will, grow and essentially as the function, they will control the environment, which is a very important aspect of the entire environmental engineering and environmental biotechnology aspect.

Because they are function with respect to the environmental process, is the most demanding topic or demanding aspect of the entire discussion.

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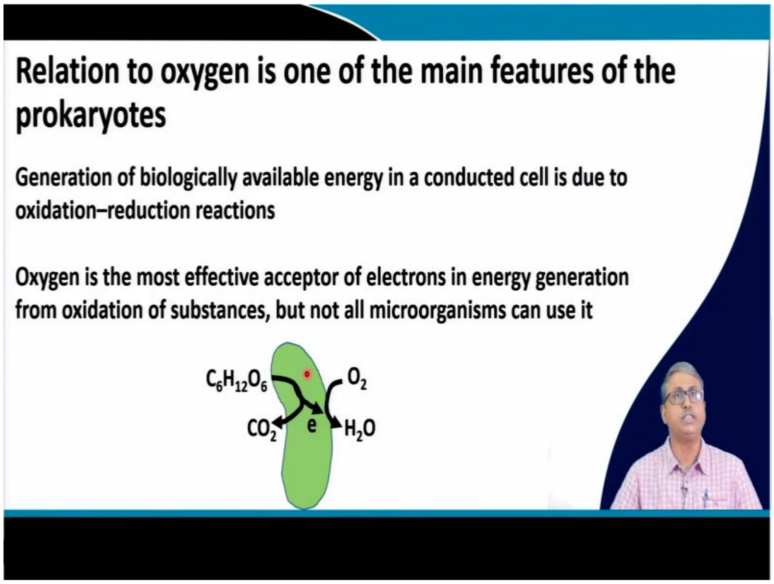

Now relation to oxygen is one of the main features of the prokaryotes. Generation of biologically available energy in conducted cell is due to oxidation reduction reaction. As we have seen earlier that the complex carbohydrates or complex are reduced carbon monitors, as represented by the glucose molecule, it is a simple example, is that glucose. Glucose is to be, is oxidized, oxidized to simpler compounds, like pyruvic acid, or acetic acid, or acidic, or other intermediates.

And eventually the energy and the electrons are released from the glucose molecule or the reduced organic compound. Now, these electrons, and these energy we have their definite function or definite role within the microbial metabolism, or microbial system. Where the energy can be easily be utilized in different function, including the anabolism like processes or biosynthesis of different molecules or for the movement of the cell or for the other function energy is required.

The energy will be utilized the electrons, which are derived out of this oxidation reaction, will be given to some substrate, which received the electrons and will be reduced. So, these are called electron carriers, which are readily available within the cellular system, like nicotinamide allene di methtyl or nicotinamide allene trimethyl phosphate commonly known as NAD or NADP.

These are electron carriers, and these electron carriers will eventually facilitate the flow of electrons from the organic compounds of the organic substance, which is getting oxidized.

And these electron carriers are going to be reduced. Once these electron carriers are reduced, they will further transfer the electrons to the suitable electron carriers which are considered to be the terminal electron acceptors like oxygen. So, now we will see that oxygen is the most effective electronic sector of the electrons in the energy generation from oxidation of substances like glucose substrates.

So, any environmental system or environmental engineering system where complex carbon or reduced carbon, like glucose or similar compounds, are present and if oxygen is there the metabolism, as well as the oxidation of the glucose, is strongly controlled or regulated by this oxidation and the transfer of these electrons to the oxygen. Now all microorganisms may not be able to use it some microorganisms are capable of using.

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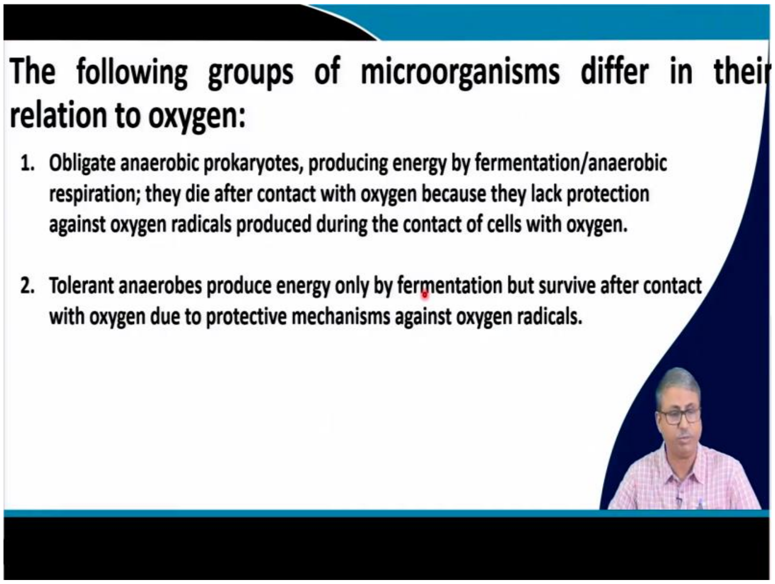

Now we can see that there are some groups of microorganisms based on their relation to oxygen. So, for example, we start with the obligate anaerobic process producing energy by fermentation or anaerobic respiration they die after the contact with oxygen because they are highly sensitive to oxygen, and they lack protection against oxygen radicals produced during the contact of cells with oxygen they are typically very, very sensitive to oxygen and they are the obligate anaerobic procedures are the most of the bacteria and archaea.

The next is the tolerant anaerobes to produce energy, only by fermentation but survive after contact with oxygen. So, they are not going to be killed in presence of oxygen due to protective mechanisms against oxygen radical. So, they have some protective mechanism to withstand the oxygen toxicity and they are not going to die in presence of oxygen. We will learn about their mechanism of function in which respect to the oxidation of substances like fragmentation and anaerobic respiration in our next lecture.

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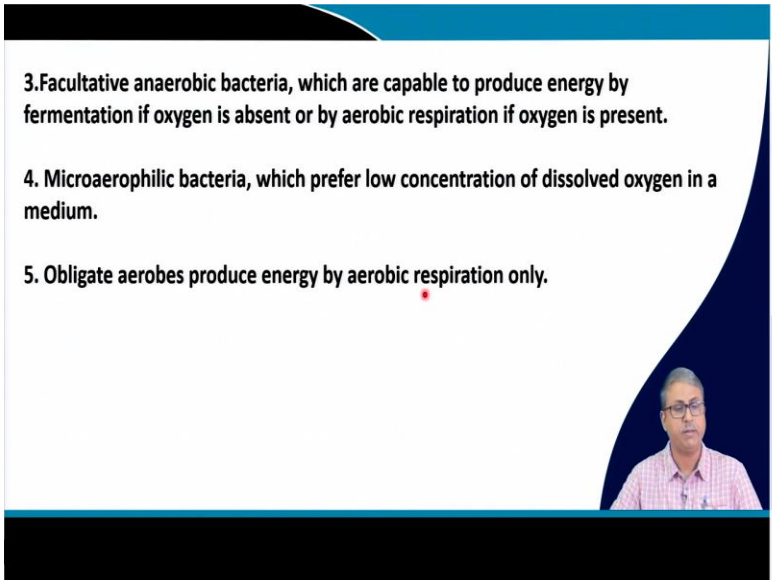

The third category is a faculty of anaerobic bacteria, which are capable to produce energy by fermentation if oxygen is absent or by aerobic respiration if oxygen is present. So, these organisms are more versatile in nature because if oxygen is absent, they will perform the anaerobic respiration or the fermentation. And if oxygen is present, they will perform the anaerobic respiration. Now here also mention that these three processes fermentation and anaerobic respiration and aerobic respiration are three distinct events.

In case of aerobic respiration, where oxygen is used as the electron acceptor, the metabolism of oxidation of carbohydrate, or the complex sugar, is facilitated by using oxygen as the terminal electron acceptor. Whereas in case of anaerobic respiration, which we saw that in earlier case we had the anaerobic respiration, anaerobic electron acceptors other than oxygen. And these electron acceptors or electron acceptors, which are obtained from outside environment we call them exogenous electron acceptors like nitrate sulfate iron carbon dioxide or maybe manganese.

Or other inorganic electron carrier electron acceptors they will be used during the anaerobic respiration. Whereas, in case of fermentation it is the endogens electron acceptor, which are mostly organic substances, and often the metabolic product of the oxidation of the complex ontrole itself, like, for example, the fiber we can they will act as the electron acceptor and will facilitate the oxidation of the substrate.

So, eventually we will have less amount of energy, and we will learn about this fermentation and anaerobic respiration, anaerobic respiration, a little more detail, as I mentioned in our subsequent classes. The next group of organism is the microaerophilic organism or microaeraophillic bacteria, for example, which prefer low concentration of dissolved oxygen in the medium. So, they are not capable, or they are not happy with high concentration of oxygen but they are able to function very well with a relatively lower concentration of dissolved oxygen.

And finally, the obligate aerobes that produce energy by aerobic respiration only so, they are the organisms who grow happily in that kind of oxygen, oxygen saturated zone, or the top layer of the soil or water bodies, where the oxygen level is maximum. So, what we see, basically, with respect these 5 types of microorganisms that, with respect to oxygen gradient, there could be possibility that if you want to see that how microorganisms are distributed.

We will be able to see that there are actually the 5 types of microorganisms which are, at least from their ability to utilize oxygen assurely present there any kind of open system like a kind of a open tank reactor, or a kind of open lake, or a river or even a soil system also. We can see that obligate aerobes followed by the Macroaerophillic bacteria then the obligate anerobes and then we had these oxygen tolerant anecdotes, and then the obligate anaerobic prokaryotes or the bacteria and archaea.

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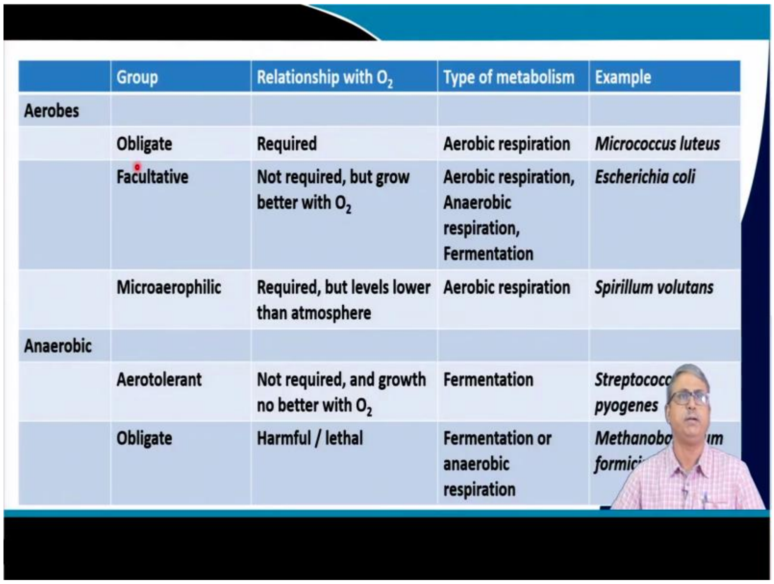

	Group	Relationship with O_2	Type of metabolism	Example
Aerobes				
	Obligate	Required	Aerobic respiration	*Micrococcus luteus*
	Facultative	Not required, but grow better with O_2	Aerobic respiration, Anaerobic respiration, Fermentation	*Escherichia coli*
	Microaerophilic	Required, but levels lower than atmosphere	Aerobic respiration	*Spirillum volutans*
Anaerobic				
	Aerotolerant	Not required, and growth no better with O_2	Fermentation	*Streptococ… pyogenes*
	Obligate	Harmful / lethal	Fermentation or anaerobic respiration	*Methanobo…um formic…*

So, based on these oxygen presences of their ability to make up, use oxygen and so. So we can see that there are, these are the organisms and some of the examples are also highlighted here.

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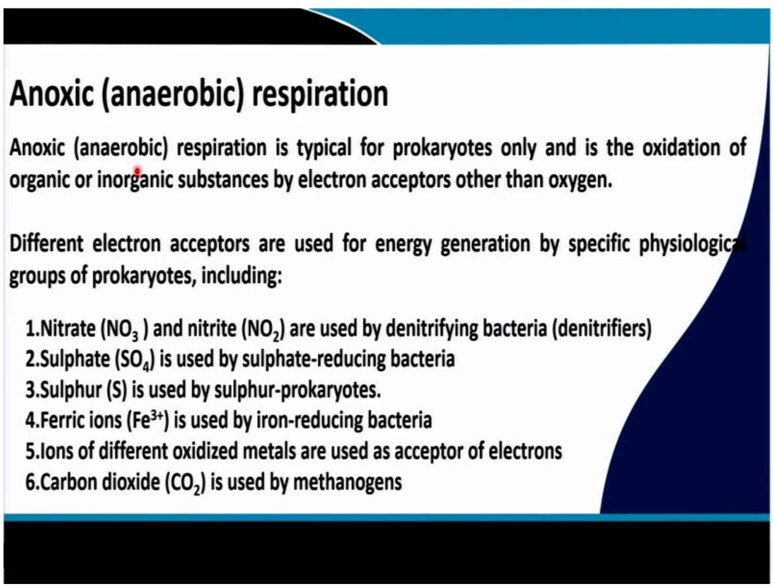

Now, with respect to the anoxic or anaerobic respiration this anaerobic or anoxic respiration is a typical event for prokaryotes only because we do not know whether any eukaryotes are there who can perform such an aerobic respiration in general in an environmental engineering contest particularly. And is the oxidation of organic and inorganic substances by electron acceptor other than oxygen. So, these organisms are capable of using alternate electron acceptor that I was referring to archaea.

So, these are called anaerobic respiration conducting organisms. So, these organisms are relying on alternate electron acceptors, but not on oxygen so to metabolize or to oxidize, the substrate, the organic carbon substrate. Now, different electron acceptors are used for energy generation by specific physiological groups of prokaryotes. So, we have a range of electron acceptor utilizing organisms in environment.

And that includes the nitrate and nitrite utilizing bacteria sulfate reducing bacteria, sulphur reducing bacteria, ferric iron reducing bacteria, ions of different oxidized metals are used at selenium, arsenic, etcetera, are, of course, used by different microorganism. And finally, the carbon dioxide of utilizing bacteria, which are basically archae sorry is not a bacteria. So, carbon dioxide reducing archaea like betamethanes.

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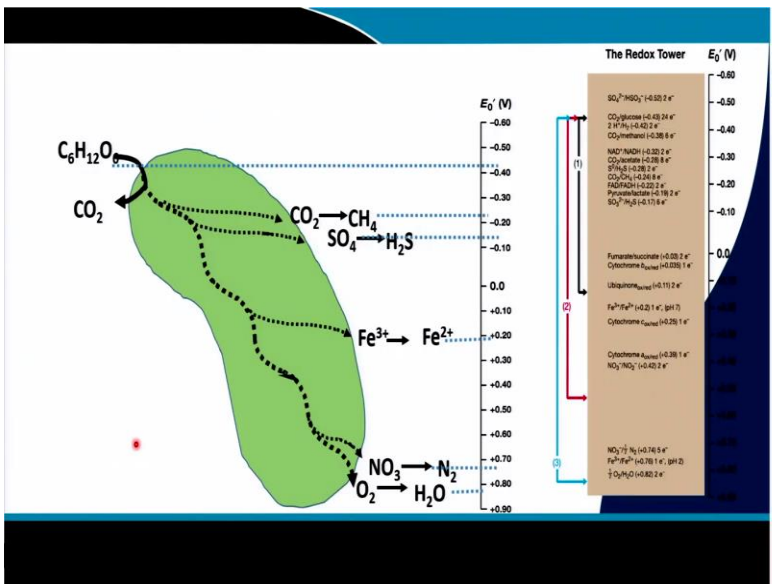

Now if we look at this diagram, we will be able to see that that the oxidation of the glucose to carbon dioxide, , which is a main reaction and it is being followed by a number of electron carriers, which will be taking the electrons and most preferably, reaction would be that the transfer of the electron to the oxygen. Now, if we look at the electron volt of this reaction from the oxidation of the glucose like molecule, which is minus 0.43.

So the transfer of the electrons to the oxygen, which is plus 0.82, so, it is the maximum potential differences obtained. So, as a result, maximum amount of energy can be gained if the organisms are capable of transferring the electrons to oxygen. So, that means the aerobic metabolism or so, aerobic, despairing organisms would be capable of producing maximum energy out of this entire process. This is followed by the utilization of nitrate as the electron acceptor.

However, when nitrogen is used as electron acceptor and nitrate is reduced to nitrogen, the potential difference is slightly low as this particular electron volt is 0.74, around 0.74. So, compared to oxygen, this is slightly low. Followed by iron Fe 3+ to Fe 2+, and this Fe 3+, Fe 2+ is +2, so, it is much lesser than nitrate, followed by sulfate to sulfide, which is again further low and finally, we have the carbon dioxide which is quite low, is minus 0.2.

So, if we now compare that the redox or the electron volt, of these glucose oxidation to carbon dioxide to carbon dioxide, sulfate, iron, nitrate or oxygen, we can surely identify that the carbon dioxide is the least preferred in terms of the energy that we obtain, because the potential difference is the minimum. Now organisms growing under strict anaerobic conditions where there is no other electron acceptor, except sulfate or carbon dioxide.

They need to rely on such reduction process, where only the sulfate can be reduced, or carbon dioxide can be reduced. Now this is also interesting to note that where the sulfate, iron, nitrate, even oxygen are obtained from the environment. Environment means the west influenced itself, or the waste itself or the atmosphere around them itself. Carbon dioxide is produced from the microbial activities and other metabolic activities of other organisms present in the system.

So, at least the carbon dioxide is available as electronic acceptor. So, if the condition is favourable, like this strict anonymous condition, there will be some microbial activities going on by utilizing at least carbon dioxide. However, the presence of sulfate, nitrate, iron, they are also expected because in most of the environment, we see their present as natural nationally abundant in most of the waste, water or the contaminated soil or landfill environment.

So, there will be eventually a sequence of events based on the electron acceptors those are available. And eventually it is not only sequence of events with respect to electron acceptors, which are being used but also set of organisms prevailing in that environment. That means in an environment we expect aerobes and strictly aerobic bacteria, then microaerophilic or nitrate, reducing bacteria.

Then moderately or oxygen tolerant iodine reducer, these are anaerobic bacteria but some of them can be oxygen tolerant, because they can be strictly anaerobe also or sulfate and carbon dioxide reducing bacteria and archaea are strictly anaerobe. So, we can expect that, along with the metabolic arranged metaphor groups of processes that are also microorganisms, which are present, which are having a distinct ability to utilize the electron acceptors.

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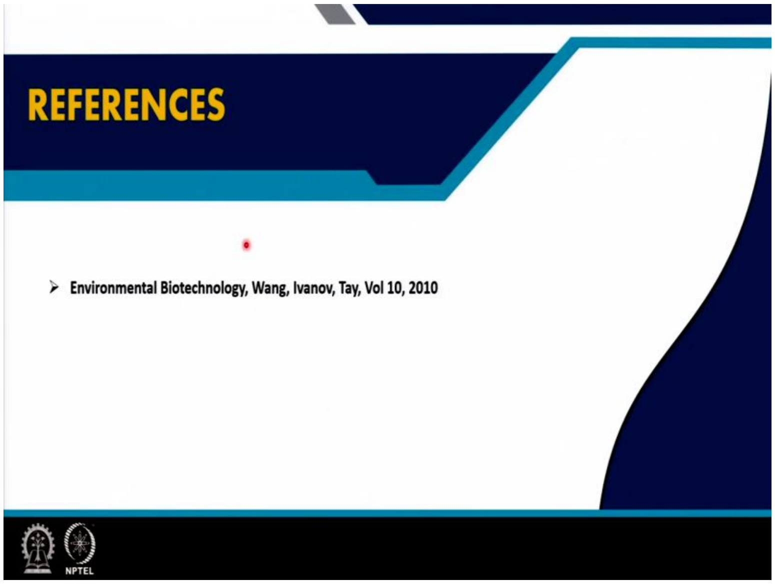

Now, this part of the lecture is basically taught from the environmental biotechnology, the book, edited by Wang et al.

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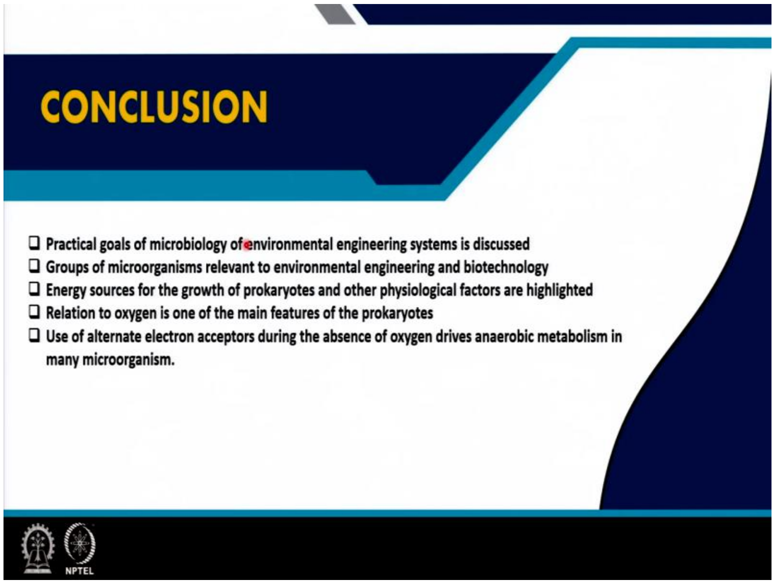

So, in conclusion, the practical goals of microbiology of environmental engineering system is discussed, groups of microorganisms relevant to environmental engineering and technology highlighted. Energy sources for the growth of prokaryotes and other physiological factors are also discussed. Relation to oxygen is one of the main features of the prokaryotes, use of alternative electron acceptors during the absence of oxygen that drives the anaerobic metabolism in many metabolism is discussed, thank you.