Environmental Biotechnology
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Lecture –02
Introduction of Environmental Biotechnology, Scope and Applications of the Subject (Contd.,)

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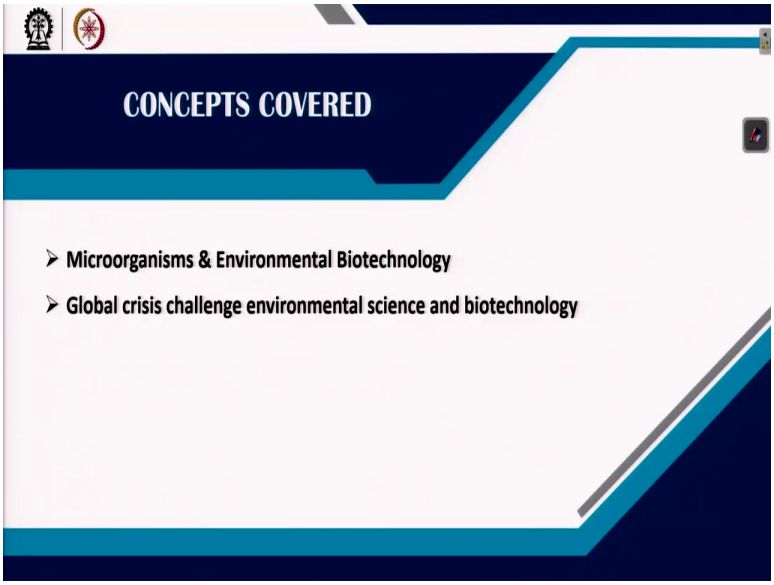

So, welcome to the second introductory lecture on the environmental biotechnology. In this lecture we are going to discuss or highlight rather the involvement of microorganisms in environmental biotechnology, importance of microorganisms in environmental biotechnology. And also we will emphasize some components of the global crisis challenges with respect to environmental science and biotechnology.

And identify the major contributions of environmental biotechnology in providing solutions towards the global crisis management.

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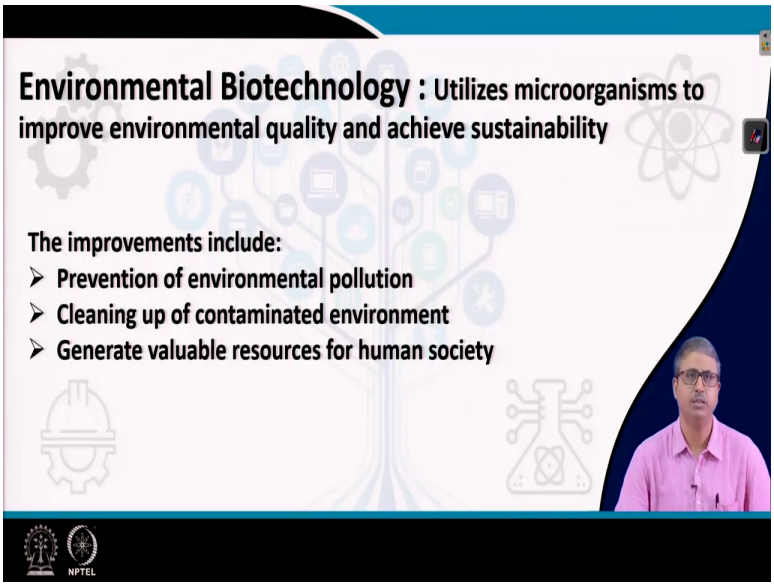

Now as we have already discussed in the first lecture that the environmental biotechnology is basically relying on the catalytic abilities of microorganisms. So, it utilizes the microorganisms to improve the environmental quality and achieve sustainability. So, during this entire through these 12 weeks lecture schedule we are going to have different aspects where we will see that how microorganisms natural microorganisms which are present in environmental environment are going to help us to to achieve the goals of environmental biotechnology.

Now the the microorganisms are used to improve the environmental quality and achieve sustainability. Now what are these improvements? These improvements include the the prevention of environmental pollution which is actually as I mentioned in my the first lecture that it is one of the first and major goal of environmental biotechnology is the remediation of the contaminants or contamination.

So, to prevent the pollutants from causing the damage to the environment cleaning up of the contaminated environment and generate the value valuable resources; for human society. So, as you can see that between these two points there is a distinct difference between these two first and second points the first point is the prevention of environmental pollution. So, any upcoming pollution will be or targeted to be reduced.

And the second point deals with the cleaning up of the contaminated environment that is the existing contaminants or existing contaminations will be handled by by different technologies. And the third one is the generation of different resources which is partly connected to the bio prospecting aspect and the different type of information different type of materials which are obtained from biological systems in order to achieve the sustainability and the environment friendly technology development.

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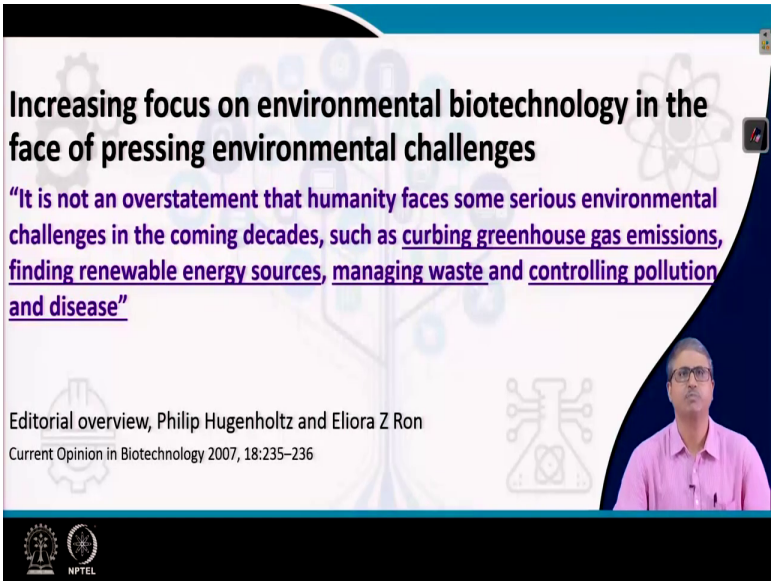

Now with respect to this environmental biotechnology we found that there has been a very consistent trend with respect to increasing the focus of this particular subject of environmental biotechnology, in achieving or in obtaining solutions of different environmental challenges. Now in one of the issues of the journal current opinion in biotechnology the editorial comment was observed.

Which; says that it is not an overstatement that humanity faces some serious environmental challenges in the coming decades. Such as carving the greenhouse gas emissions finding renewable energy sources managing waste and controlling the pollution and diseases. Interestingly; as you can see that this issue of this journal was published in 2007. So, if we try to look into the basic concept behind this environmental biotechnology which was primarily the waste water treatment technology.

From wastewater treatment technology there is a very sharp change in its focus that is the point I want to highlight that the point is it is not only the waste water treatment technology or technologies which are targeted towards only the remediation of the contaminants or the abutment of the pollution which was the principally the major focus of the environmental biotechnology has remained as the major goal of environmental biotechnology.

But in in last around two decades we have learned that in order to solve the major environmental challenges the upcoming challenges the current challenges both we need to understand the importance towards carving the greenhouse gas emissions. So, environmental biotechnology has shifted slightly its focus from only wastewater treatment or pollution abutment towards developing technologies which will help us to reduce the greenhouse gas emission or curbing the greenhouse gas emissions, number one.

Number two: To find the renewable energy sources. So, how can it be possible that environmental biotechnology is capable of capable of providing new avenues new technologies by which we can actually offer an alternative towards alternative for the petroleum or the fuel or the fossil fuel based energy resources. Of course the management of waste and pollution control will remain as the as the central focus but the focus the central focus needs to be expanded because that is ultimately going to be more sustainable more holistic will allow us to provide us the technologies to combat the challenges which are prevailing and which are which are yet to dominate in the the later part.

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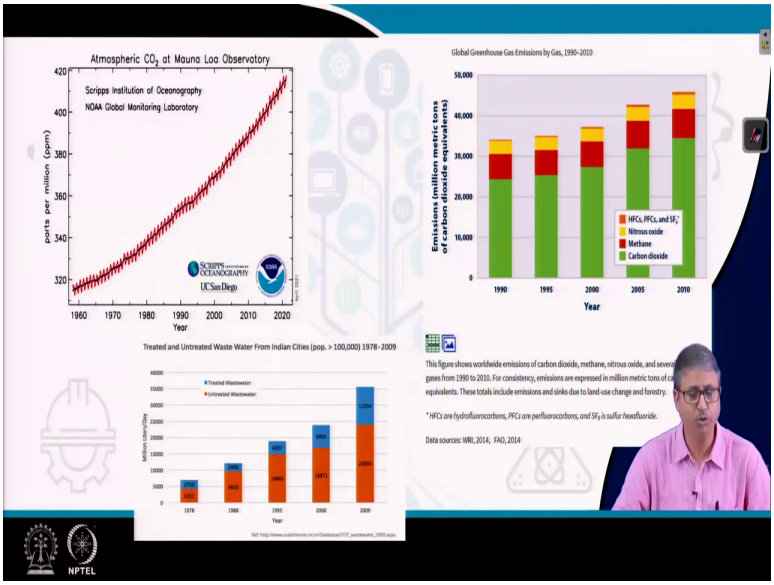

Now if we look at the pollution scenario if I look at the carbon dioxide level. If we look at the the other the global greenhouse gas emissions or if we in the world scale or even if we look at the treated and untreated waste water discharged from different Indian cities. The situations are diverse are very very scary I will say because the rise in co2 the rise in the treated and untreated waste.

And as you can see the with the with the change in time the untreated waste which are released in India particularly is increasing very sharply which of course indicates that there is a there is an in this increasing demand for technologies which can be useful for effective treatment of the different type of waste water for example with respect to the India if we consider. But if we consider the rise in the greenhouse gas emissions rise in carbon dioxide in particular there are also very severe rise in the level in carbon dioxide.

Because the effect of these are catastrophic the effect of this the climate change effect the greenhouse gas level the effect of this the water pollutants things are devastating are going to cause huge on the our planetary processes in general.

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Now if I want to highlight some of the very important issues related to the global crisis and how environmental biotechnology is going to help us to address these global crisis challenges. I think that would must that would set the stage for the subject environmental biotechnology very well. So, before we go into the details of the topics that are going to discuss in the subsequent lectures I would like to introduce you to some of the basic what I say the drivers for this new science and technology for environmental biotechnology.

Now if we look at the human population the growth of human population you can see that from 1960 to 2040 the population is likely to be increasing the following trend. So, from 3 billion in 1960 to 9 billion in which is expected in 2040. Now considering the earth's systems capacity to supply humanity with indispensable resources and to generate and absorb the waste we are generating. What is the bearing capacity of our planet?

So, bearing capacity means how many what is what is the human population entire human population on this planet that human that earth can actually um sustain in or and sustain in the sense that it can actually allow us to obtain all the indispensable resources like the food water and shelter and also to have processes by which the waste materials that we are going to generate eventually will be absorbed.

So, what is that bearing capacity of our planet. So, is it 200 million people or is it 650 million people or if we have some kind of calculations or some kind of projection the scientists have able to do that and it shows that it is to some extent connected to 1.3 planets. So, one earth may not be sufficient to accommodate all these rising human population while providing all the human populations with the required resources indispensable resources and humanity.

So, we possibly need more than one planet considering the resources that we need or believe that we need and considering the waste that we emit.

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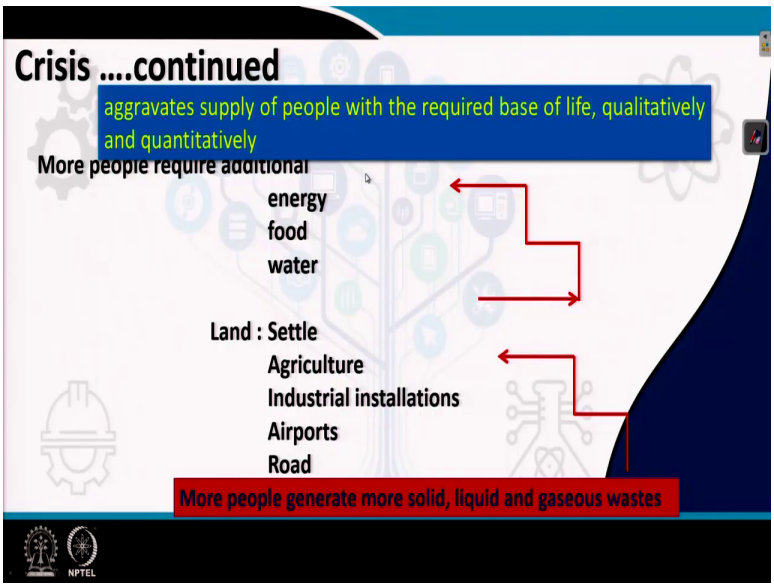

But as everybody knows that we have only one planet at our disposal and what is the problem how it is actually connected this population growth and waste material generation. Because as we have more number of people more number of people of course would require more amount of energy more amount of food and more amount of water. So you generate lots of energy. So, that means you burn more fossil fuels you produce food and in order to produce more food you possibly adopt some of the agricultural practices which are not very not very sustainable or not very not in not in synergy with natural biogeochemical cycles.

That means you use certain chemicals which are actually toxic to natural microorganisms or you use certain other chemicals also. Water you withdraw large amount of the ground water at the

same time you actually shift focus from ground water to different other surface water. And the water cycle is ultimately affected very severely. Similarly with more people we need more land to settle down to do the agricultural activities.

For industrial installations to build airports roads and other infrastructures to essentially more people generate more solid liquid and gaseous waste. So, one aspect is that when we have more people we need more resources. Energy resources, food resources, water resources we need land resources but at the end of the day we consume the resources and also we produce huge amount of waste material which are all kind of waste solid, gas, liquid type of waste.

And as we generate more amount of waste we exploit our resources. So, essentially these generation of waste actually put a burden on the on the natural resources ultimately our agricultural fields are getting contaminated, our groundwater bodies are getting contaminated and essentially that affects the supply of these essential resources to the people and that aggravates the supply of the people with required base of life if we do not get the water which is portable which is which is ready for drinking you need to we do not need then a treatment technology for those water.

But unfortunately if our ground water or our surface water like the rivers or lakes are contaminated then we need to have problems with the treatment of the water. So, for the treatment of water we need to spend more energy for that. So, essentially then these processes are all interconnected.

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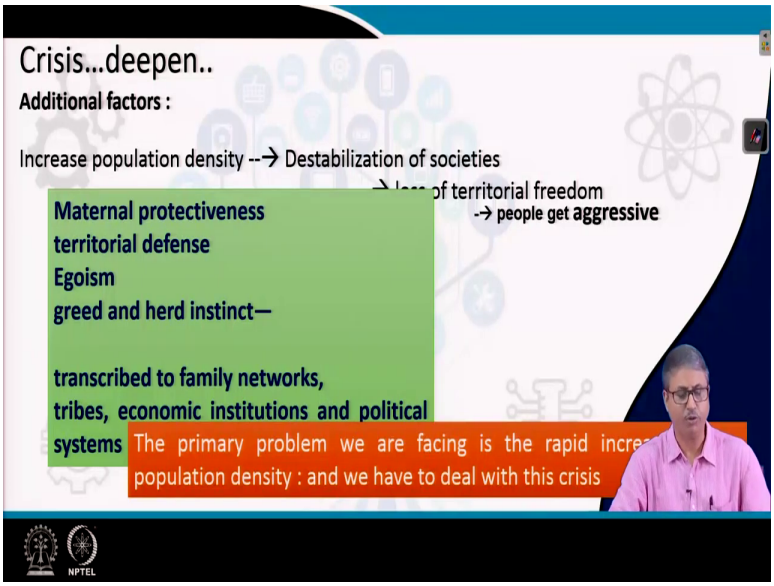

And in addition to that the crisis is further depend because of some additional factors with the increasing population density destabilization of societies occur, loss of territorial freedom and people are getting more aggressive and it continues like maternal protectiveness territorial defense egoism and this transcribe to family networks tribes economic institutions and political systems ultimately. So, overall we found that the primary problem that we are facing is the rapid increase in the population density and we have to deal with this crisis immediately.

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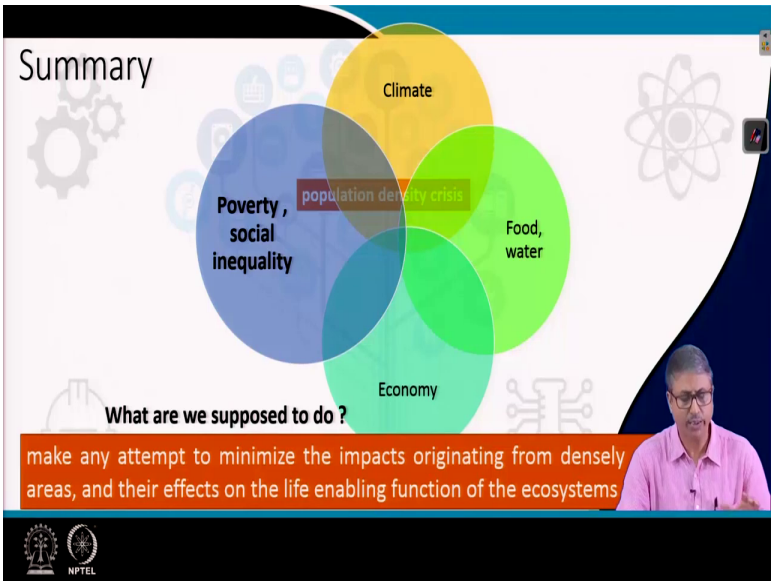

Now this population density crisis which is intrinsically connected to climate change, food and

water quality and the resources available for that, economy and ultimately the poverty and social inequality. Now what are we supposed to do we are supposed to make attempts to minimize the impacts originating from the densely populated areas and their effects on the life enabling function of the ecosystems.

So, from a kind of overall problem which is which is there because of the huge population density or we call it is a population density related crisis. We need to work towards developing technologies developing understanding which will ultimately provide us some solutions and that will rely on the function of the ecosystem.

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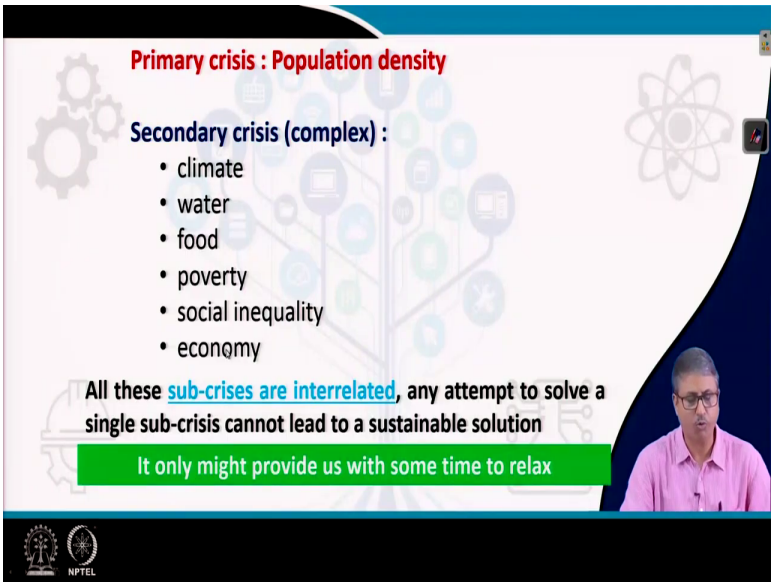

Now some more information about this: The population density and the global crisis. So while we find that the population density is one of the primary crises there are certain secondary crisis. These secondary crises are more complex these include the climate change related crisis the water, food, poverty, social inequality and economical crisis. Now all these sub crises if we look carefully are interrelated.

Any attempt to solve a single sub crisis cannot lead to a sustainable solution. Like we cannot address the water problem that all our ground water must be clean just the water to be cleaned. We cannot do that without addressing the issues related to climate and food because maybe our

water bodies our ground water, surface water bodies may be cleaned by some technology. But if we do not take a particular technology which is more holistic our soil may not be clean.

So if our soils are not clean then the food that will grow the agricultural crops those will be grown on those contaminated soils will be contaminated with some kind of chemicals. And that is going to be sustainable and effective only when which will which will actually be connected to the removal of the poverty and it will actually allow us to reduce our burden on social inequality and ultimately it should be economical.

So, it would have it should have a kind of economical side whatever technology we are planning to develop. Now it only might provide us with some time to relax that is if we target if any particular secondary crisis or climate, water, food etcetera. These are these are not advisable that you at address a party any particular crisis because any particular crisis if it is addressed individually that might provide us with some time to relax or maybe some time to prepare ourselves.

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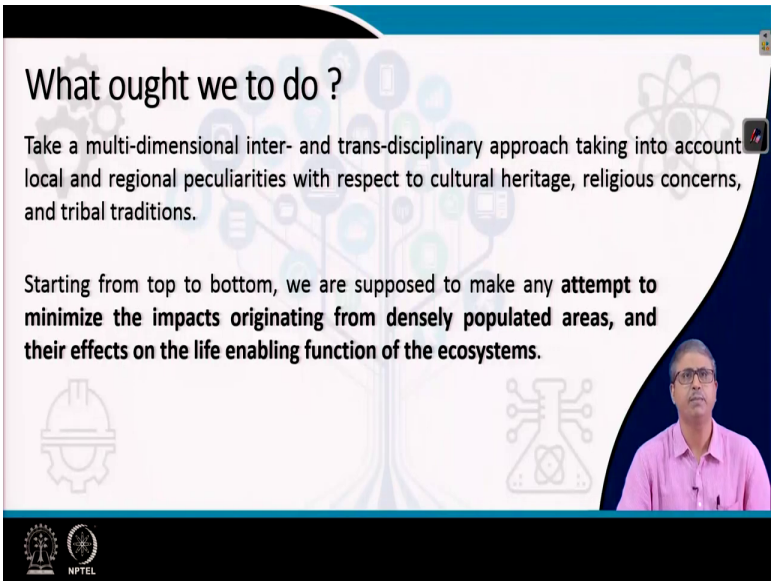

But any kind of technology that we actually want to develop should be holistic and should be a multi-dimensional inter and transdisciplinary approach. Taking into account the local and regional peculiarities and with respect to cultural heritage, religious concerns and tribal

traditions. And it is also important that if we start from top to bottom we are supposed to make any attempt to minimize the impact originating from the densely populated areas and their effects on the life enabling function of the ecosystem.

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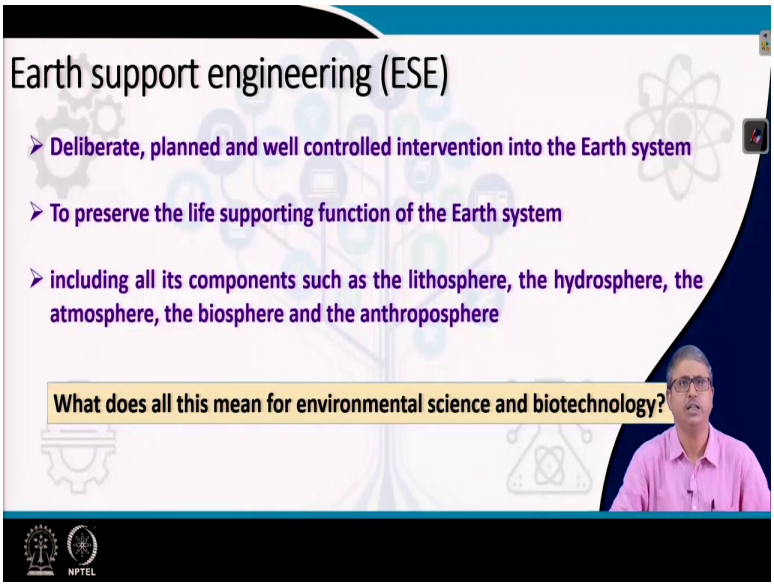

So, ultimately the concept of art support engineering is developed within this environmental science and biotechnology which addresses the deliberate plant and well controlled interventions into the earth system. So, we consider the entire biosphere to preserve the life supporting functions of the system and including all its components such as the lithosphere the hydrosphere and atmosphere the biosphere and the anthroposphere. So, all aspects of the planet need to be considered.

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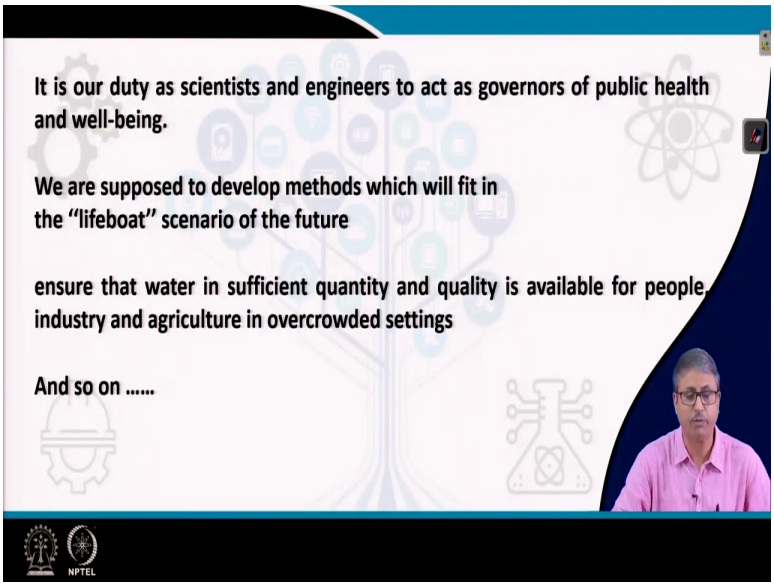

Now what does all this mean for environmental science and biotechnology it is our duty as scientists and engineers to act as governors of public health and wellbeing and we are supposed to develop methods technologies which will fit into the lifeboat scenario in the future. So, we are aware of the our aware of the devastations which are just waiting. So, we know in order in a kind of an meaningful sense that we are ready to have technology.

We are ready to develop technologies which will which will help us to mitigate these challenges. These catastrophic events eventually if we do not take adequate measures if we do not understand the reparkation or the do not understand the consequences of this the contamination of our environment, contamination of our resources the reduced volume of the groundwater surface water land which are not contaminated with then we are going to enter into a very, very bad situation.

So, in order to have, we need to develop these methods and we also need to ensure that there are water insufficient quantity and quality which are available to the people industry and agriculture. We need to have soils which are clean which are we need to have a atmosphere which is having a reduced amount of the greenhouse gases and so, on.

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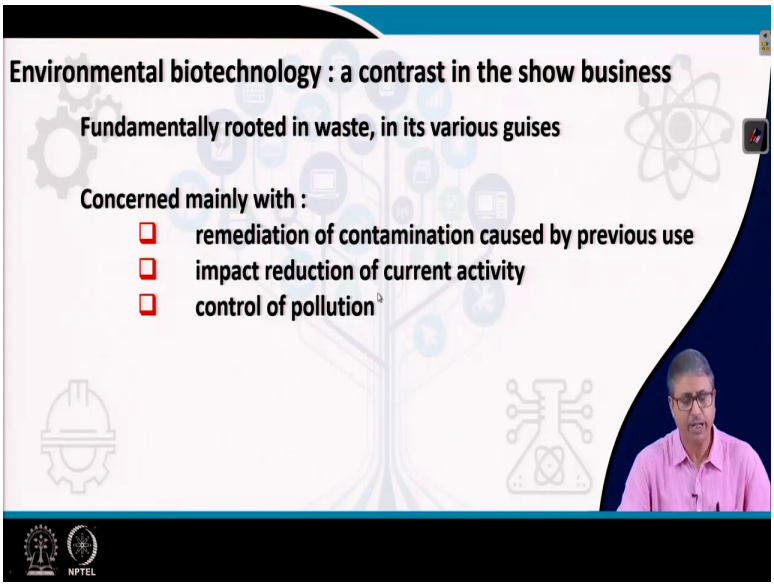

So, environmental biotechnology is developed to address these major challenges which are originally routed into the population density and which is to some extent un manageable in this current sense but we can actually develop technologies to address the secondary crisis. Now in contrast to this show business because in contrast to the other different aspects of biotechnology.

It is fundamentally rooted in waste in its various form as I mentioned that environmental biotechnology is fundamentally focused on or principally focused on the concept of pollution abutment by bioremediation and all such technologies but it has been understood that it it should expand its focus into the developing technologies for mitigating the challenges imposed by the greenhouse gas emissions.

Switching to the renewable energy resources and protecting our ground water resources and many other things. So, when we talk the fundamental concept of the environmental biotechnology which was the pollution abutment technology which was basically focused on the remediation of the contamination caused by previous use that is the existing contaminants. Impact reduction by current activity that is the improvement or development or innovations through research which; will provide us new technology that will reduce the impact maybe the greenhouse gas emission.

The use of different types of chemicals, dyes, pesticides and many other things and of course the control of the pollution.

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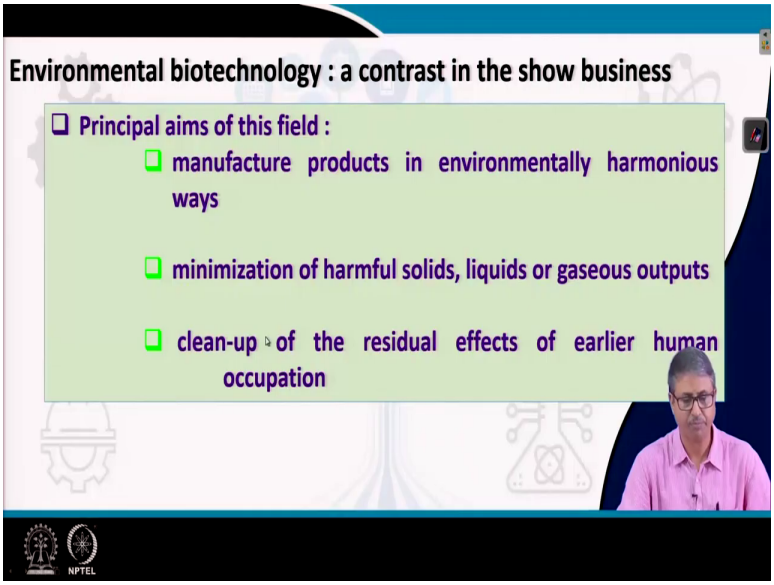

And the principal aims of these fields are therefore to manufacture products in environmentally harmonious ways. To minimize the effects of the harmful solid liquid or gaseous output wherever possible and cleanup of the residual effect of earlier human occupation.

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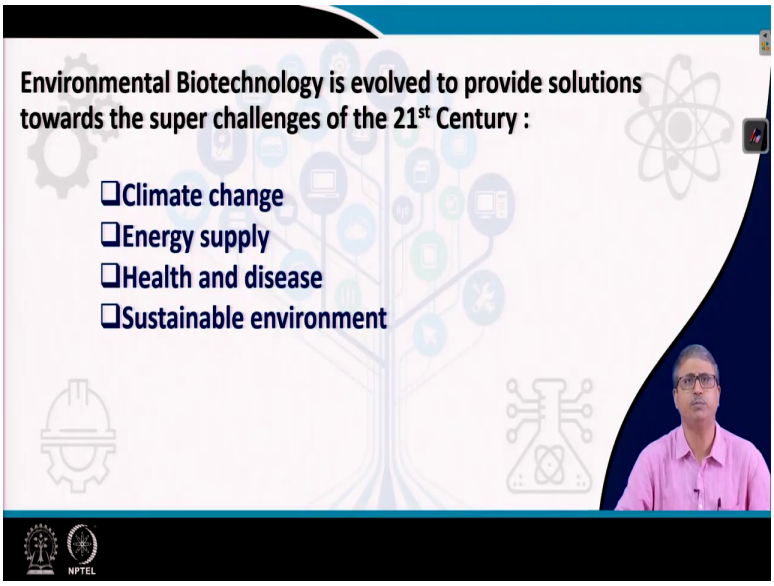

Now the means by which this may be achieved the least that I showed is achieved is to enhance

or optimize the conditions of the existing biological systems to make their activities happen faster or more efficient. In order to treat the waste in order to develop the process which will which will help us to generate technology or innovate technology which will which will be useful for um changing an existing chemical or physical process with a biological process or to control the pollution in general.

We need to actually enhance or optimize the conditions for the biological systems. Resort to some form of alteration to bring about the desired outcome. And if we now look into this the challenges of the 21st century I think the concept that I am discussing will be more clear that the super challenges of the 21st centuries are climate change, energy supply, health and decision and sustainable environment. Now these are all interrelated as you can understand and partly these are all connected to the the crisis one that is the the major primary crisis and then then the secondary crisis are all connected here.

So, the global crisis have actually global crisis has actually culminated into this the super challenges of this 21st century.

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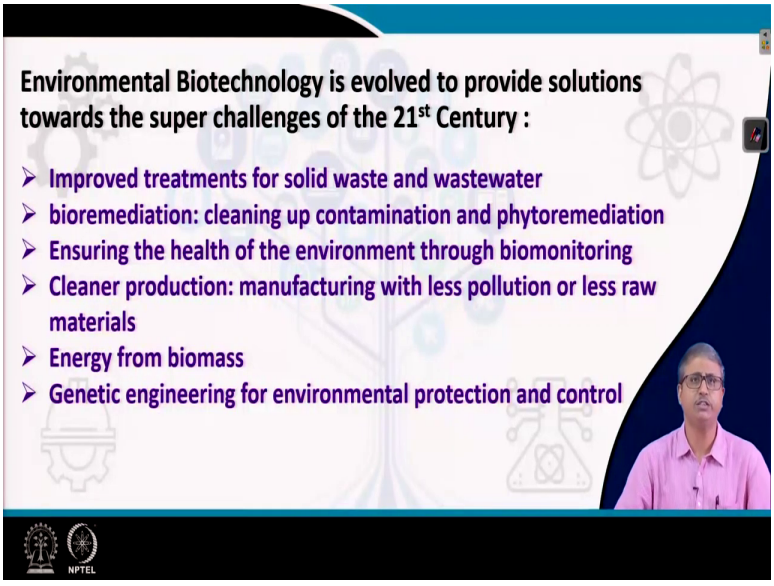

Now these challenges can be addressed or technologies can be developed to mitigate these challenges through environmental biotechnology. If we can develop technologies to improve the

treatment of the waste generation because the amount of waste water or waste solid waste which are what are being generated and the way we are treating them are not sufficient. So, we need to have improved more efficient treatment processes.

But technologies bioremediation technologies that is the cleaning up of contamination and the phytoremediation processes can be developed ensuring the health of the environment through bio monitoring. So improved methods for monitoring the pollutants or the monitoring the the biological activities which naturally are able to degrade or convert the pollutants into non toxic forms, cleaner production that is manufacturing with less pollution or less raw materials, energy from different biomass and genetic engineering for environmental protection and control.

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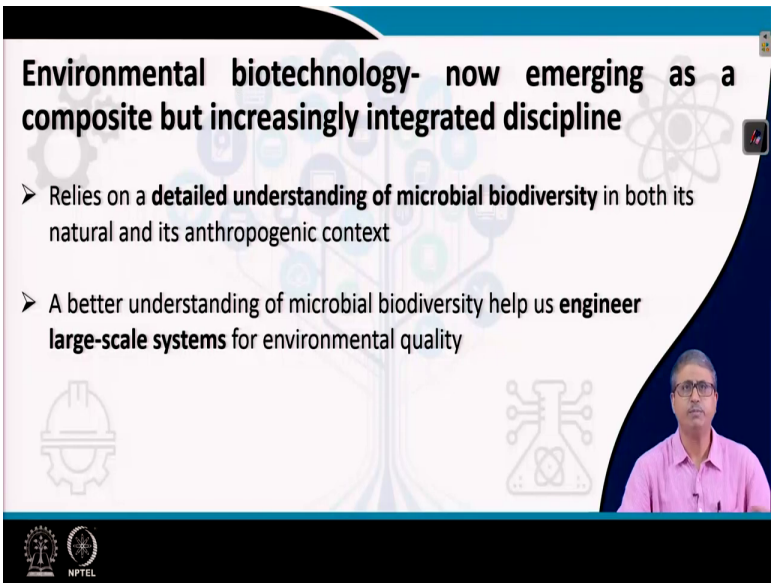

So, environmental biotechnology is eventually. Now as as I also mentioned in in my earlier is as emerging is; now emerging as a composite but increasingly integrated discipline. It relies on a detailed understanding of microbial biodiversity in both its natural and its anthropogenic content. Now; so, detail understanding of microbial biodiversity I will discuss in detail that why we suddenly focus more on microbial by diversity because microbial processes are the major catalysts within these environmental processes.

So, all kind of processes which are connected to water resources the food, the climate change,

the energy are intrinsically connected or dependent on microbial biotransformation abilities and a better understanding of this microbial diversity actually help us to engineer the large scale systems for environmental quality.

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And finally to introduce the innovation and prosperity in human society: In all the areas affected by microbial life from global elemental cycles influencing our climate to the quality and abundance of our food to the health of our gut.

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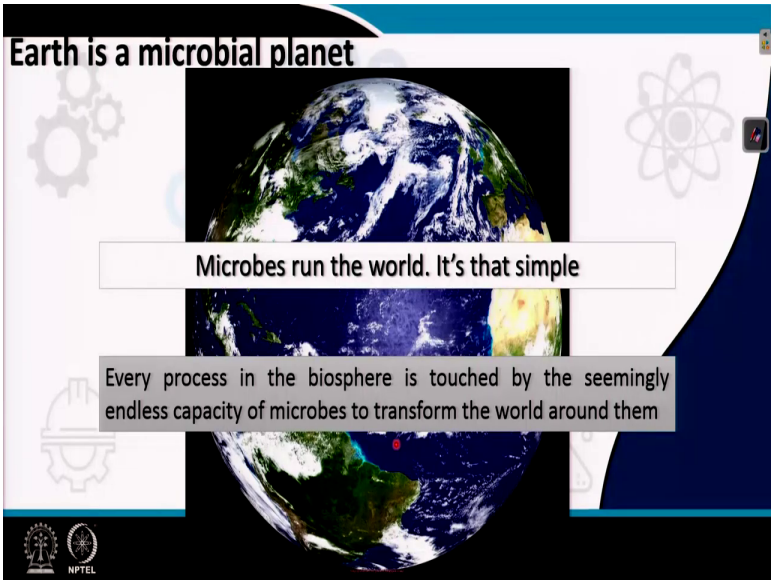

Now why systems of microbial origin? Now earth is a microbial planet, microbes run the world that is it is that simple. Now why it is said? So, that the microbes run the world, it is because that every processes in our biosphere is touched by the seemingly endless capacity of microbes to transform the world around them.

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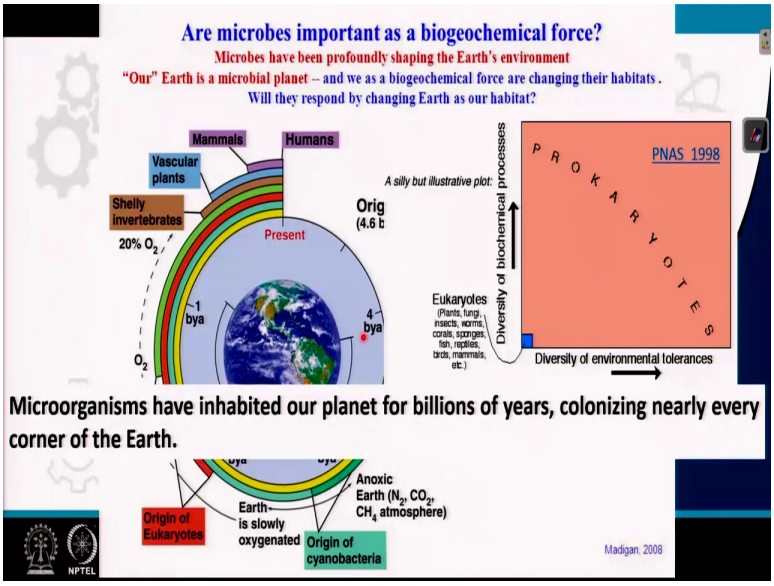

Now if we look into the evolutionary aspect of these microorganisms the microorganisms particularly the bacteria have evolved around 3.8 billion years ago in this planet. And these microorganisms ever since that bacterium for examples ever since they are evolved in on our planet they are colonizing each and every corner of the earth no matter whether human were able to reach to those habitats those locations those environment within the earth.

But microbes have reached those or colonize those habitats even those habitats which are considered to be very extreme conditions. So, it is said that as long as the basic thresholds basic requirements of life the temperature limit, the pressure limit and the availability of water these limits are satisfied the microbes are going to occupy all environments within these planets. And it is also found that with their diversity of biochemical and biochemical processes the prokaryotic microbes like the bacteria and archaea they supersede the eukaryotic organisms very, very significantly.

As you can see in this graphs and which is which is considered to be a silly graph but it is very illustrative plot that the compared to the eukaryotic diversity of biochemical processes the prokaryotic diversity of processes are huge and the diversity of environmental tolerance are also very significant.

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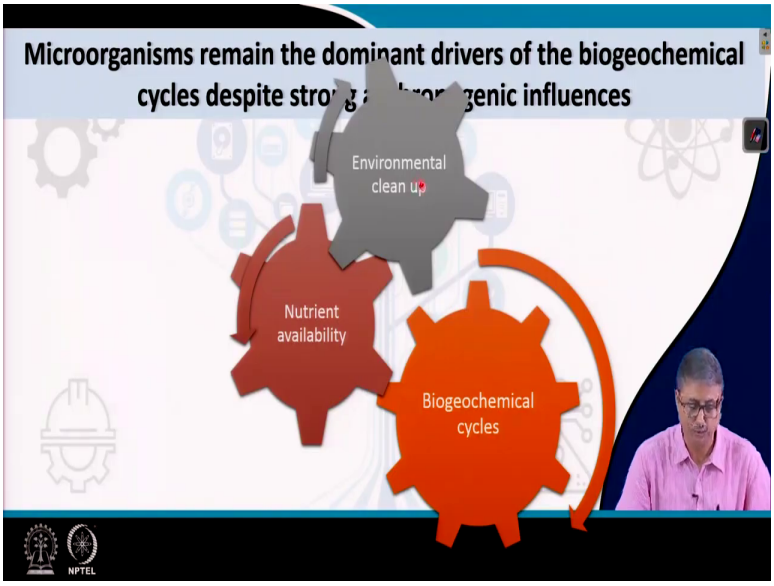

Now it is not that evolutionarily they are superior they are occupying almost all corners of this planet for last 3.8 billion years or so. They are biochemically they are more diverse and all these things. But they also remain the dominant driver of biogeochemical processes and despite the strong anthropogenic influences. Because in last 200, 300 years since the industrial revolution we see that lot of changes happen in our climate.

Particularly the rising climate, the greenhouse gases, the contaminate contamination of our water and soil environments. Even after that the microorganism remain the dominant driver of the bio geochemical cycles and we will during this course we are going to discuss in detail about these processes and particularly highlighting their importance in maintaining the processes and also the homeostasis and also to identify the processes which will be useful for their application.

Particularly this bio geochemicals processes which are catalyzed by microorganisms in diverse environments are useful for environmental cleanup. Of course that is one of the primary goal of

the environmental biotechnology. The second is the nutrient availability and biogeochemical processes. So, the biogeochemical cycle which is the core and the natural process the microorganisms are doing it for their own survival and metabolism.

However these bio geochemical transformation reactions are helping the contaminants which are anthropogenic contaminants are to be converted into non toxic forms or forms which are insoluble in water or having less toxic impact and also making more nutrients available to our plants and then to human and other organisms.

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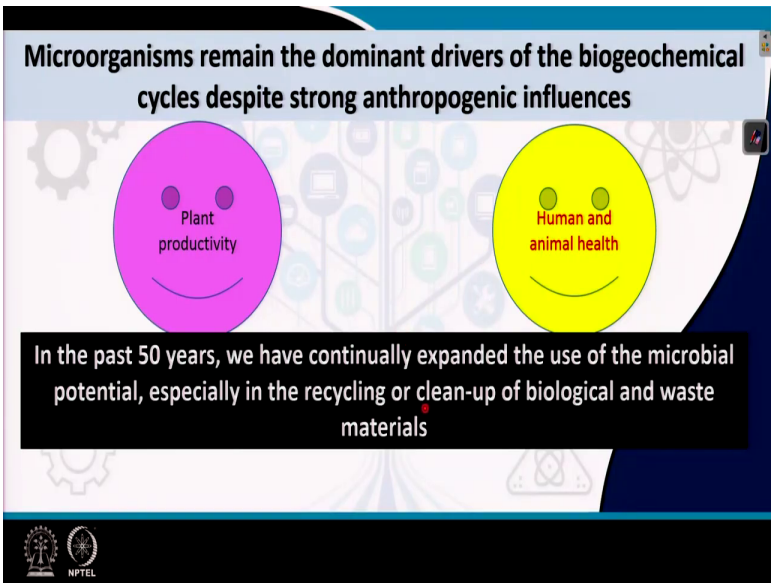

So, essentially that is helping the plant productivity this bio geochemical cycling. The natural bio geochemical cycling is help providing more nutrients because the nutrients are also cycled. And also trying to maintain or improve the human and animal health it is not that they are all they are providing different antibiotics etcetera but also they are providing us numerous clues that how to combat different diseases.

For example many of you are possibly aware about the discovery of crisper gas system. So, all these kind of systems are developed or obtained only because of the our exploration into the microbial world that how microbes basically um defend themselves from invading pathogens invading viruses particularly. So, the knowledge that we gain from different environmental

microbes only help us to improve our plant productivity our the health for both human and animal health of course.

So, basically it helps us to addresses the issues related to the crisis that is the secondary crisis that we highlighted earlier. So, in the past 50 years or so, what we have seen that we have continually expanded the use of microbial potential their bio catalyst, bio catalytic abilities especially in recycling or cleanup of biological and waste materials.

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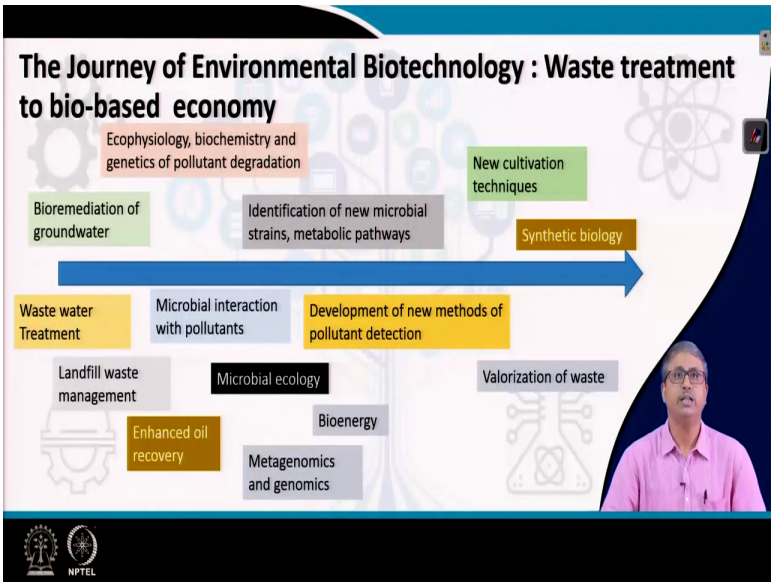

The journey of environmental biotechnology is very interesting. As I have already introduced the topic to you through these introductory lectures and I have identified or I have discussed that the waste treatment technology remained as part of the central focus of this subject in its various forms. But essentially if we look into the journey that is the time scale from early days like when we may be a century ago or more than that when it was basically the waste water treatment technology to the current time.

So, in this particular slide I would like to emphasize that what are the topics and development. Some of the major aspects it is not all inclusive but it is some of the some of the major things are only presented here. So, as I mentioned that wastewater treatment technology or biotechnology for wastewater treatment, biotechnology for landfill wastes management. These were the initial

the application or initial topics covered in the environmental biotechnology.

May be centuries ago we see that there are technologies or there are processes used to treat wastewater and gradually we learned how to treat the landfill waste. So, in environmental biotechnology these were the subject of much interest in early 70's or so, 1970 or so. And gradually then came the bioremediation of groundwater with the help of the United States department of energy where large scale research and development were carried out to treat the ground water contamination across the different sites within united states.

So, huge research was conducted and during this research and research going on in other parts of the world with different contaminated waste materials three things was considered if we look very carefully. So, one was the microbial interaction with the pollutants. So, with this wastewater treatment initially although we were not very sure exactly what was the pollutant because it was considered to be the gross the chemical oxygen demand or the biological oxygen demands which were essentially the primary targets to reduce the BOD or COD levels.

But eventually with the help of the advanced analytical techniques we were more careful about the particular type of the pollutant which needs to be degraded. So, within the wastewater within the solid waste the scientists or the environmental biotechnologists were more focused on how the microbes are involved with the pollutants. What are the different type of microbe pollutant interactions.

During this bioremediation of groundwater program as I mentioned in the earlier that the US DOE based bioremediation of groundwater essentially. These interaction level studies were highlighted and it included the different type of eco physiological biochemical and the genetic studies of the pollutant degradation. And that eventually also lead to the identification of new microbial strains, new metabolic pathways and essentially huge development in the microbial ecology has come.

The concept of microbial ecology and environmental biotechnology was established as early as maybe 2005, 2007. We see that there is a huge interest among the microbial ecologists that how the knowledge of microbial ecosystems in environmental biotechnology can be can be applied. In the meanwhile enhanced microbial oil recovery and development of new methods for pollutant detection, for the detection of the microbes microbial processes microbial biocatalytic events were considered.

The topics; related to bioenergy was also identified as one of the major areas of environmental biotechnology as we will also talk about that. The microbial ecology and its developments the concepts helped us to understand the role of meta genomics and genomics into the environmental biotechnology. And one of the main factors is the outcome of the knowledge that most of the microorganisms particularly the bacteria present in the environmental systems are non-cultivable or that means that we cannot cultivate them we cannot grow them under the laboratory conditions.

So, meta genomics and genomic based technologies allow us to characterize those microorganisms to understand the entirety of the process. The interactions between the different species, the interactions between the genes and all these things and from there also new cultivation techniques were also developed because we realized that many of the almost more than 90% of the natural microorganisms are not cultivable under laboratory condition and so, new cultivation techniques were targeted or emphasized in order to isolate more bacteria in the laboratory condition and so that these bacterial strains can be deployed for different environmental biotechnology research.

The developments in synthetic biology the development in systems biology developments in other aspects of metabolic engineering etcetera also contributed immensely in the current stage of environmental biotechnology. And the concept of valorization of waste that is also very important. So, as we will discuss as you will learn through this course of environmental biotechnology that the waste should not be considered as only waste that may not be very

sustainable, handling or treatment of those waste.

The waste when it is considered as wealth the entire sustainability and entire the process efficiency goes in a different scale. So, in case of environmental biotechnology one of the very important outcomes is the fact that the waste different type of waste materials and their treatment is considered to be is kind of an interesting challenge at the same time and also is a scope of huge innovation for the scientist working on environmental biotechnology because thereby we are able to convert the waste material as some kind of resource material to achieve sustainability.

So, during this course we are also going to highlight the topics that how this valorization of waste or the chemical transformation or the degradation processes or the bioremediation events can be used or can be targeted towards addressing the issues of the climate change or bioenergy or making them in general more sustainable.

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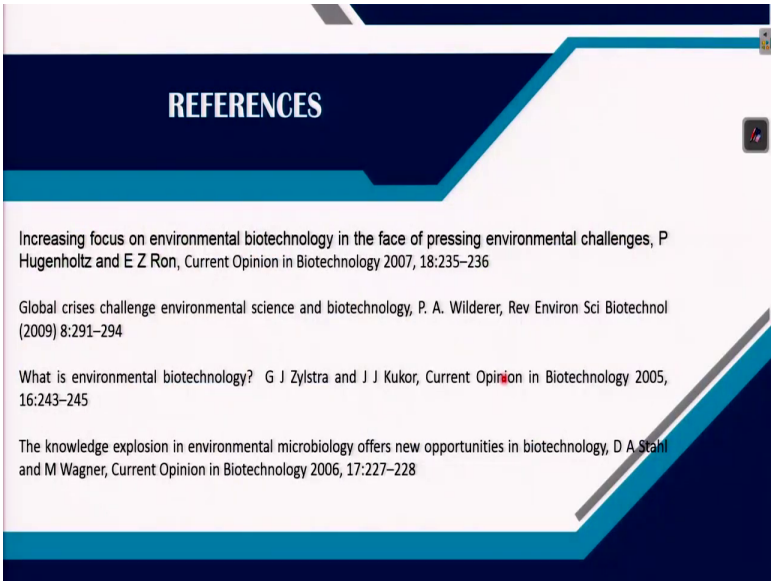

For this part of my lecture the following references can be used.

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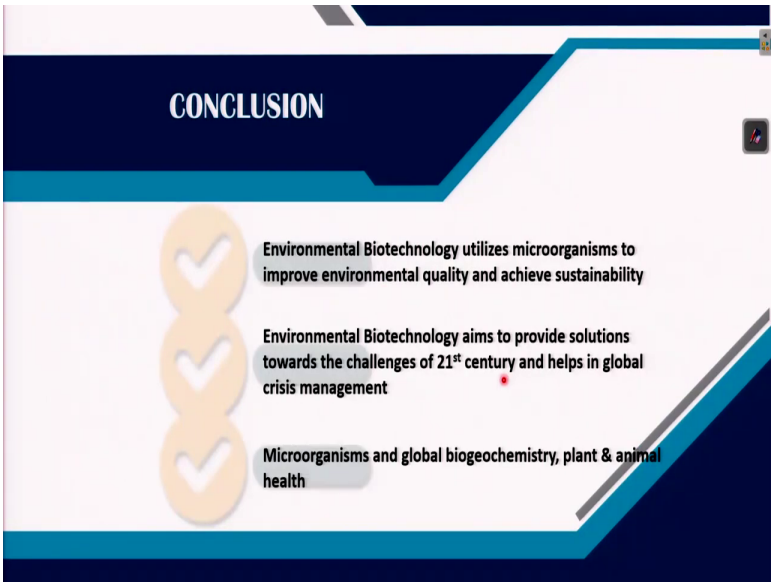

And in conclusion the environmental biotechnology utilizes the microorganisms to improve the environmental quality and achieve sustainability. Environmental biotechnology aims to provide solutions towards the challenges of 21st century and helps in global crisis management and microorganisms and global biogeochemistry their role in plant and animal health etcetera are also emphasized, thank you.