Environmental Biotechnology
Prof. Pinaki Sar
Department of Biotechnology
Indian Institute of Technology, Kharagpur

Lecture – 11
Microbial Ecology and Environmental Biotechnology - Part B (Contd.,)

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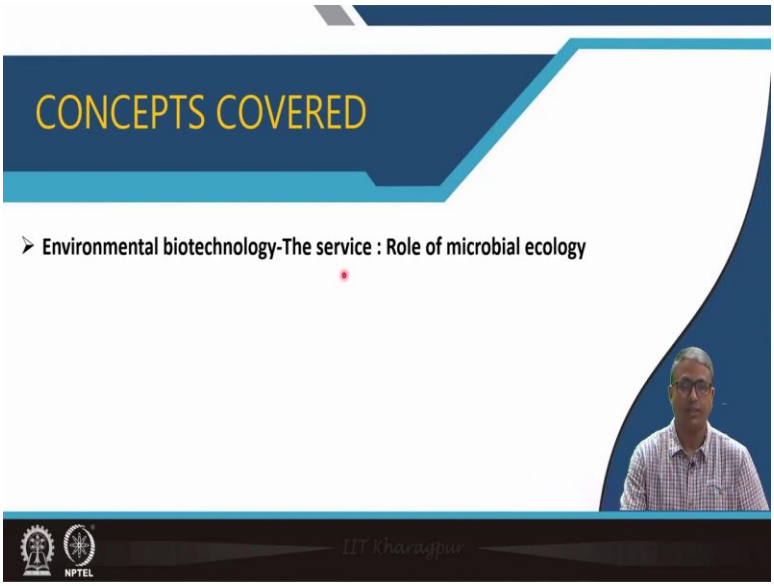

In today's lecture we are going to talk further on Microbial Ecology and Environmental Biotechnology. In this particular lecture we are going to discuss more about the role of microbial ecology in environmental biotechnology particularly when we consider the various services which are expected and provided by environmental biotechnology.

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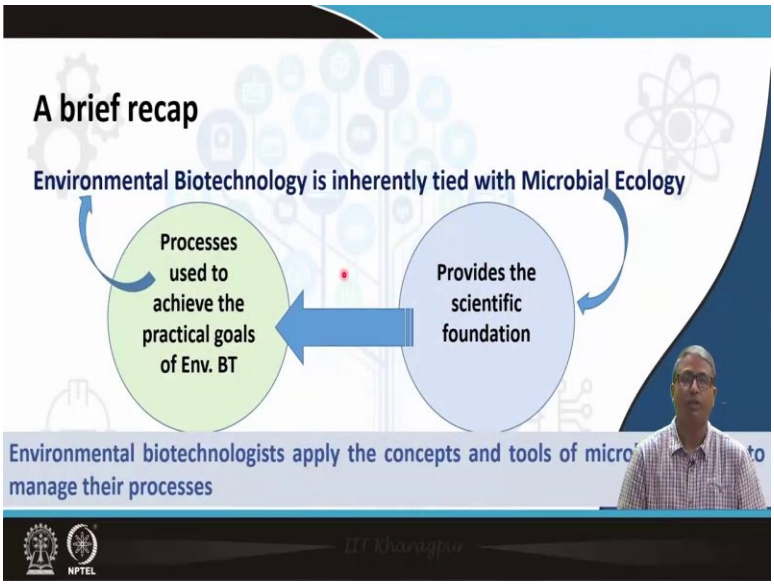

Now before we enter into the different services that is expected and environmental biotechnology is aimed to provide the services environmental biotechnology is inherently tied with microbial ecology. Now as we have already discussed in some other lecture microbial ecology is the scientific foundation which provides the basic concept of microbial functions. And these scientific understanding gained from the microbial ecology is utilized towards developing the processes which are relevant for environmental biotechnology.

And in particular when we aim to achieve the practical goals of the environmental biotechnology with very specific domains for example with respect to treatment of a particular type of wastewater or harnessing energy from a particular type of waste material or for the treatment of nutrient pollution or may be for the treatment of the plastic and other emerging pollutant containing waste materials etcetera.

Now environmental biotechnologists they appear they apply the concepts and tools of microbial ecology to manage their processes. So, basically environmental biotechnologists they to some extent depends on the scientific basis scientific foundation which is obtained through the understanding of microbial ecological concepts and microbial ecology processes with respect to any given environment.

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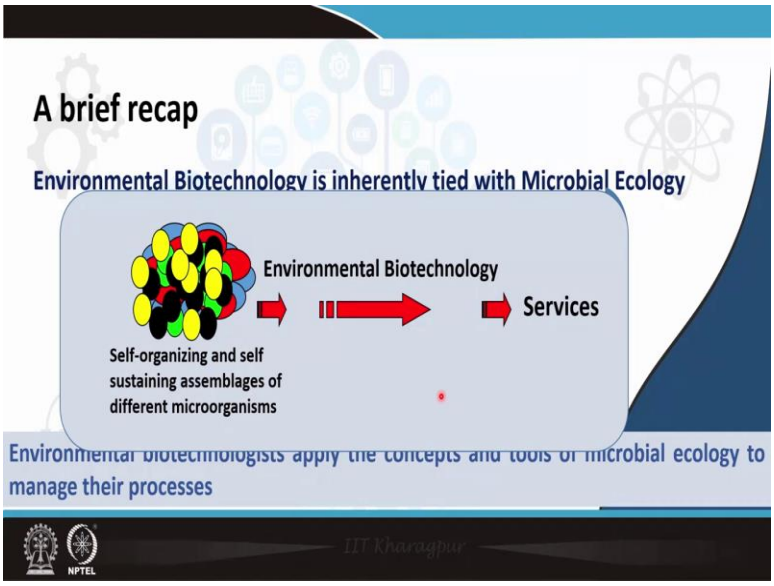

Now for example as we have already discussed the microbial communities are basically self organizing and self sustaining assemblage of numerous species particularly the prokaryotic bacteria and a number of archaea. So, these are self organizing and self sustaining assemblage of microorganisms which represent any kind of microbial community are investigated are utilized are explored to achieve the different goals of environmental biotechnology which is considered as the services which are obtained from the functionalities of the microbial communities.

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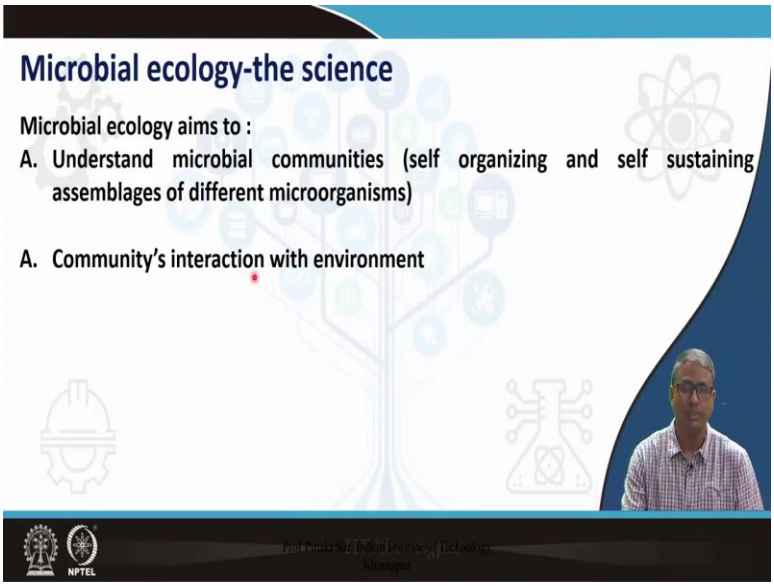

Now microbial ecology is the is the scientific foundation of the core concept which aims to understand the microbial communities which are self organizing and self sustaining assemblage of numerous microorganisms and it also aims to understand or explains the community's

interaction among different species members and also with the different other components of the environment.

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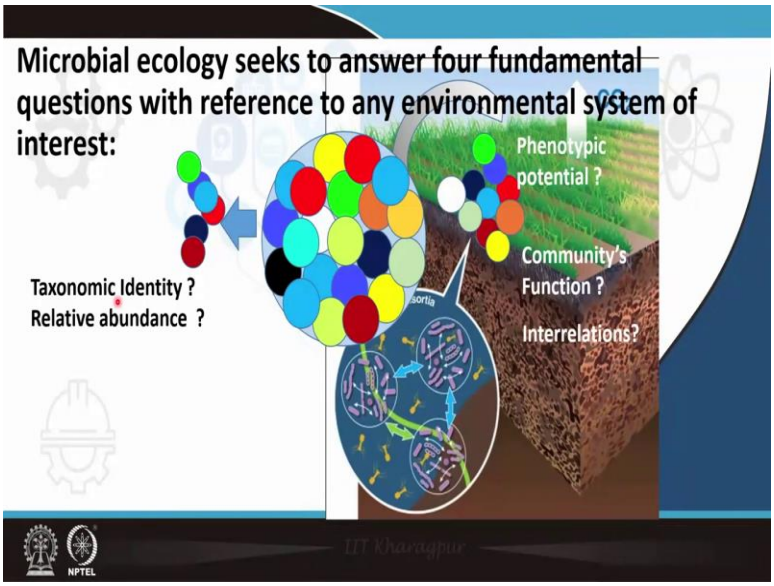

Now while we try to look into the microbial ecology concept of microbial ecology concept within any environmental system we generally try to get answer of these four fundamental questions. And these fundamental answer to these fundamental questions are actually key to the exploitation of any particular community for its environmental application. And the questions are as follows. So, the first question that we ask is the basically what is the composition of the community or what are the microorganisms which are present within the community.

That is basically connected towards the taxonomic identity and relative abundance of the microorganisms. The second question that we ask is on the phenotypic potential of the organism. This is followed by the communities function that what function the community members are actually capable of doing of and then finally how the community members interact among themselves and with other parts or other components within the environment.

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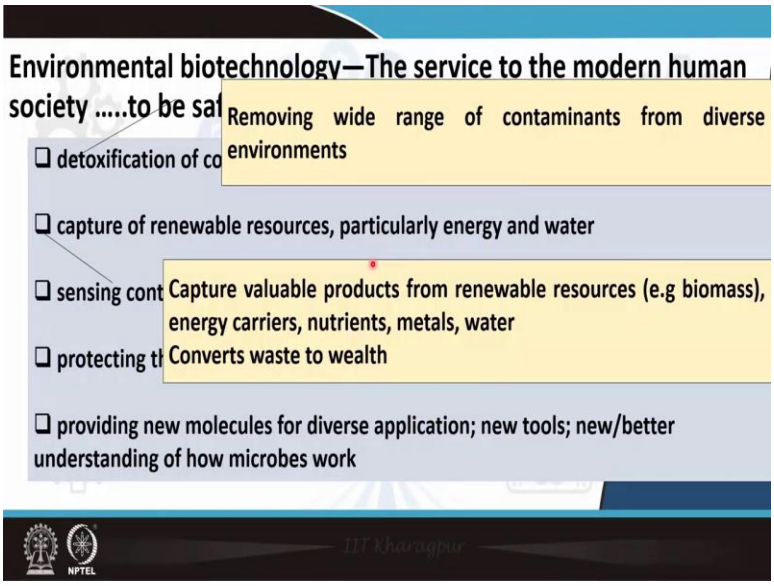

Now environmental biotechnology aims to provide the services. Now when we talk about providing services with environmental biotechnology it is inevitably the application of microbial ecology. Why? Because it is when properly managed in an environmental biotechnology context it is the microbial ecology or microbial community rather which provides a wide range of services very reliably, continuously and also economically.

Now, environmental biotechnology the services to the modern human society to be more safe sustainable and secure. Now the major areas or the services which are expected or are obtained from the environmental biotechnology are first the detoxification of contaminated water waste water sludge sediment or soil. So, any kind of contamination is supposed to be cleaned or detoxified. The second one is the capture of renewable resources particularly energy and water.

Sensing different contaminants or pathogens in the environment is the next priority area and that is also connected to the fourth one which is basically protecting the public health from dangerous exposure to the pathogens. And finally providing new molecules for diverse applications, new tools, new methods and better understanding about how microorganisms work. Now with respect to the detoxification of the contaminants present in different environment it is basically the removal of a wide range of contaminants from diverse environments.

These diverse environments truly include all kind of environments wherever pollution can be

there. And these removal of pollutants using different microorganisms remains one of the priority areas of environmental biotechnology for a long period of time. So, be it a century old wastewater treatment technology or more recent advancement made with respect to bioremediation and application of genomics and meta genomics into advanced bioremediation etcetera.

Now with respect to the detoxification of the contaminants there is another component which is also the kind of the sensing the presence of the contaminants. So, here we are not going to sense the organisms or the pathogens here with respect to when we work on detoxification of the contaminants there have been numerous processes which have been developed under environmental biotechnology to achieve detection of different type of contaminants chemical contaminants we are referring to through the specific interaction of different microbes or specific interactions of different microbial products like the enzymes or genes using bioreporter concept etcetera that may be discussed and some other point of time.

The next one is the capture of renewable resources. Now in this regard capturing the valuable products from renewable resources for example the biomass which can be an energy carrier different type of nutrients different pressures and otherwise useful metals like heavy metals and radionuclides and also water. Because recovering the usable form of water from the waste water is a huge challenge.

And environmental biotechnology is continuously working towards improved method towards not only capturing the valuable energy forms in terms of biomass or in terms of energy carriers but also recovering the water that can be actually utilized within the industrial system as much as possible if not in domestic sector.

And it also allows the capturing the renewable resources this process also allows the conversion of waste to wealth. That is when we try to implement the concept of environmental biotechnology to capture these resources. We actually facilitate towards the circular economy or what you called consider conversion of the waste material to wealth material and in addition to that as I already mentioned protecting the public from dangerous pathogens and other hazardous

microorganisms and providing the new molecules for example the diverse of for diverse applications including the which is basically covered as the bio prospecting of new molecules.

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So, essentially when the microbial communities they are managed properly they provide these services the services those are listed and the services which are not listed but could be easily be accommodated within any kind of environmental biotechnology research. So, it is it is the microbial community function which will allow us to gain the instruments towards the towards achieving the goals of the environmental biotechnology.

But the major point over here is that the microbial communities need to be properly managed as we are able to manage the microbial communities within different systems properly we will be able to gain this or get the services reliably continuously and economically without creating any other hazards.

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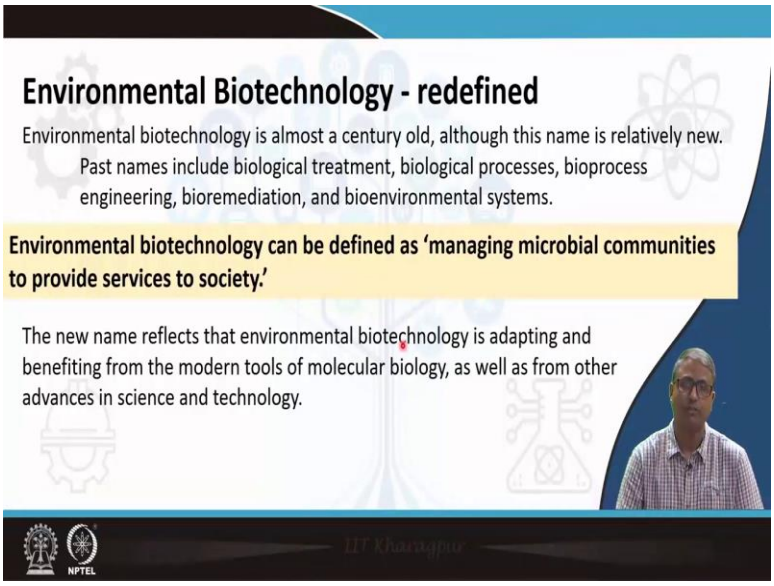

So, now we will move on to the how this amalgamation of microbial ecology into environmental biotechnology has enabled redefining environmental biotechnology because environmental biotechnology is not as such a very new subject it is almost a century old although the term environmental biotechnology may be recent may be relatively new. So, what is important over here that environmental biotechnology though it is a very old rather we can consider is a century old concept the name has been modified over the period of time and the past names include the for example the biological treatment biological processes bio process engineering bioremediation and bio environmental systems.

Now this environmental biotechnology can now be defined as managing microbial communities to provide services to society. And the extent of the services could be could be very, very elaborate that we will come very soon. So, it is basically can be redefined as managing microbial community to provide the services to the society and this new name which accommodates the the role of microbial communities and their management to towards gaining the services out of the entire process reflects that environmental biotechnology is adapting and benefiting from the modern tools of molecular biology.

And advent of the genomics and other omics; approaches as well as from other advances in science and technology that that I am going to discuss shortly.

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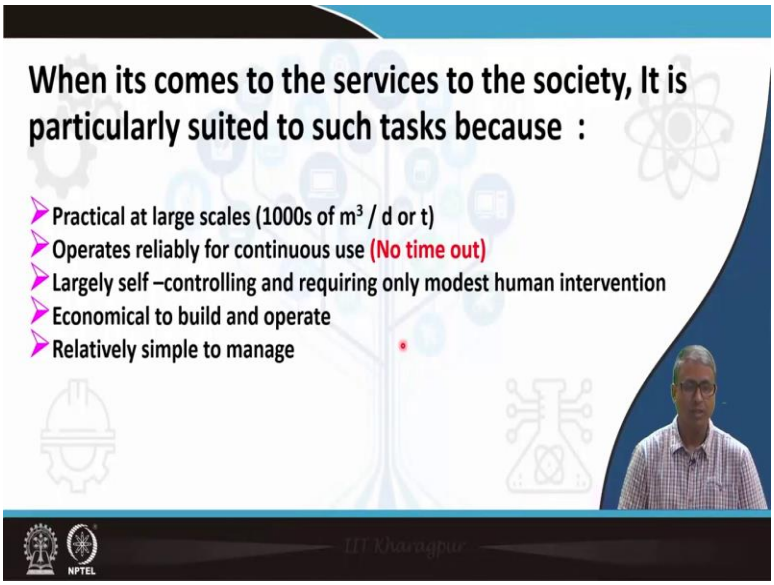

Now when it comes to the services to the society the services may be of detoxification of the waste water detoxification of a contaminated soil or it could be capturing the energy from a waste material or it could be sensing the pollutants or sensing the pathogenic organisms. So, we have we have found that this type of technologies which are actually accommodated with the environmental biotechnology are particularly suited because of the following reasons which include that these technologies are practical at large scale.

They operate reliably for continuous use that is almost like no time out no resting time because most of the cases these are microorganisms based and accept some minimum minimal maintenance of the equipment or something these processes actually can run continuously. Largely self controlling and requiring only modest human interventions; because microorganisms when they are provided with their nutrients and including the electron donors carbon sources electron acceptors and other resources.

They will be functioning of their own. Next is the economical these processes are economical to build and operate compared to the uh the physico chemical or other processes which are applied in the same domain like detoxification of water or treatment of the water. These environmental bio technology processes are much more economical and economical also for the building the infrastructure and also from the operational point of view and also these are relatively simple to manage.

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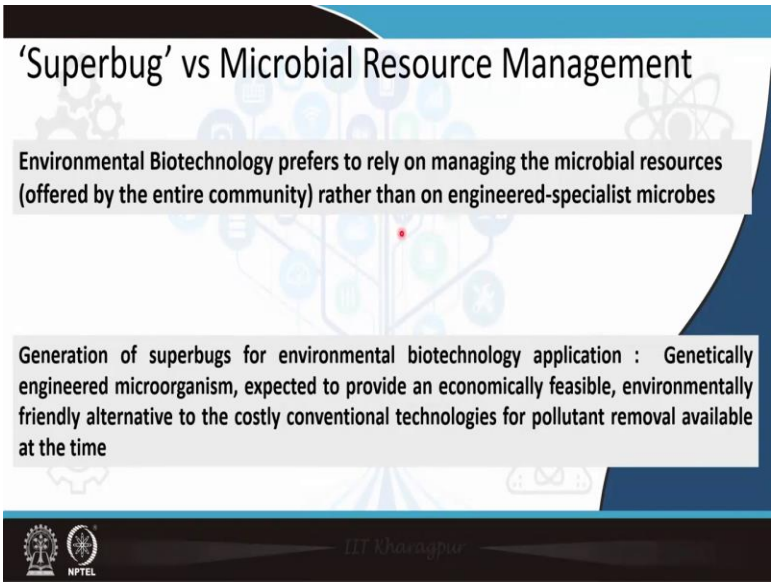

Now here is a concept of application of superbug in environmental biotechnology application versus the microbial resource management. Now environmental biotechnology prefers to rely on managing the microbial resources that is offered by the entire microbial community of a given environment rather than on an engineered and specialist microbe.

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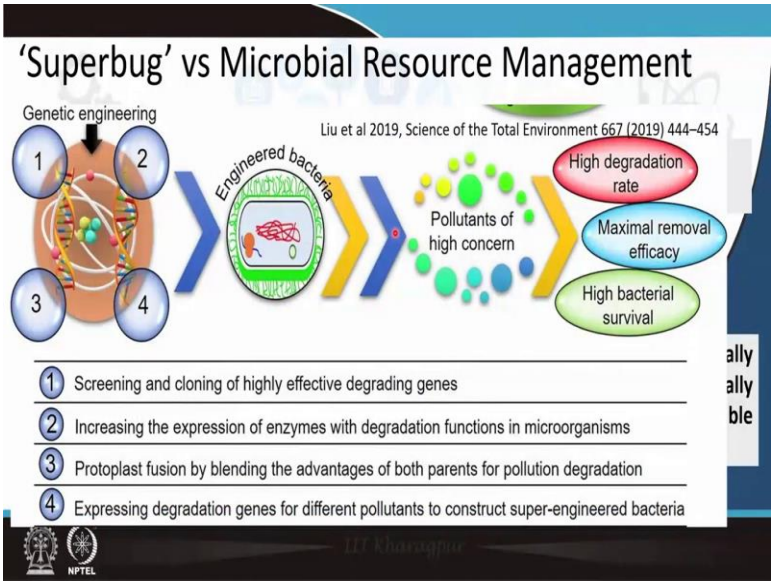

Now these specialist microorganisms which we conventionally called as superbugs the superbug name refers to a kind of an invention where we were able to engineered bacterial species for degradation of a wide range of hydrocarbon compounds in early 80's. Or so, it is basically relying on the genetic engineering and utilizing different plasmids.

So, that we can actually accommodate highly effective degrading genes that is genes involved in biodegradation of multiple contaminants and also we try to enhance the expression of these genes with the with the degradation function within the microorganisms and then the microorganisms are made so, robust that they are they are capable of degrading the pollutants with a very high rate and maximal removal efficiency and the bacterial survivals are also very high.

However in spite of developments in superbug creation a couple of decades ago this kind of approaches were not found to be very sustainable and viable. So, some other in during some other classes we may discuss about that that why superbug technology was not so, successful with respect to environmental biotechnology. Because one of the fundamental reason it we could we can understand that that the environmental biotechnology processes rely on microbial communities.

So, it is it is not a very, very simplistic process or very simple process where the involvement of only one microorganism could be expected only one micro organism could play an important role. But that type of process could be more sensitive more vulnerable to variation in environmental conditions and they may face competition and other events which often occur within an open setup.

So, so this kind of generation of superbugs which basically offered the genetically engineered microbes they expected to provide economically feasible environmentally friendly alternative to the costly conventional technologies for pollutant removal available at that time was found to be not a very sustainable way of or a very effective way of utilizing microbial resources. So, rather the resources offered by the microbial communities that is called MRM or Microbial Resource Management.

The point is the microbial communities are having enormous functional potential within themselves. Now how well we understand that and how well we are able to manage and exploit that for our goals for achieving the environmental biotechnology goals that is a big challenge or

that is a that is an issue of major concern.

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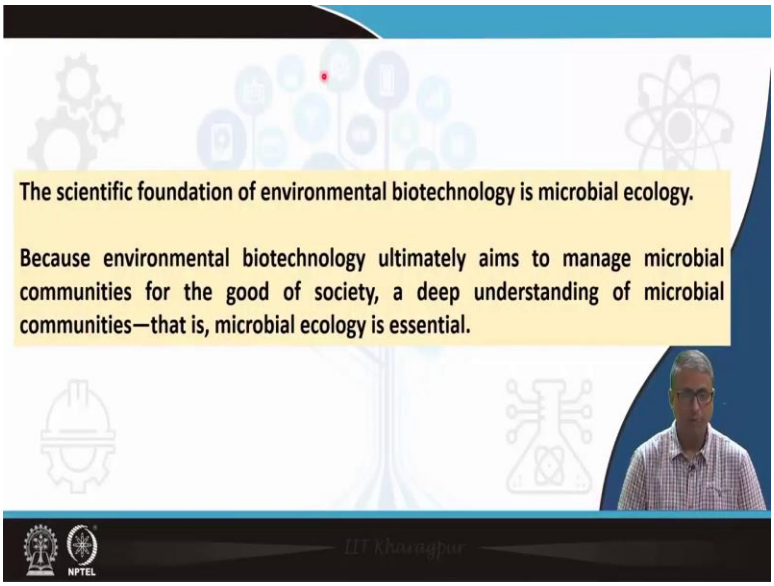

Now the scientific foundation of environmental biotechnology it therefore is the microbial ecology and because environmental biotechnology ultimately aims to manage microbial communities for the good of the society. A deep understanding of microbial communities that is the microbial ecology is essential. So, now the word that is the deep understanding of microbial communities is essentially is a very comprehensive understanding is required. Because there are as we mentioned there are few thousand different microbial species they live and then they work together.

Now how do they interact with themselves? How do they utilize the available electron donor electron accept or other nutrients and then function together as a kind of a macro organism. Understanding that or those processes are a kind of a key component towards applying the microbial ecology concepts into the environmental biotechnology.

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Now processes relying on microbial communities with respect to environmental biotechnologies have been have been around for nearly a century and two long standing processes are the activated sludge treatment of wastewater and the second is the anaerobic digestion of the sludge. These all came into widespread and successful use long before their microbiological bases were understood.

So, without knowing the much knowing the much details about the microbiological processes the activated sludge treatment of wastewater in particular and followed by the anaerobic digestion of the sludge remain in practice in the large part of Europe and subsequently in US and other advanced western countries. We found that these kinds of waste water treatment technologies were practiced and these activated sludge which is basically refers to a flocculant culture of microorganisms 95% or so, by aerobic bacteria developed in aeration tanks.

Basically by continuously aerating vigorously the waste water these cultures are able to metabolize aerobically the most of the organic pollutants over there under a control condition and they are activated because we have some kind of an particulate aggregation of the materials which have developed within this the waste water gradually. and the And as we as we see that the culture is able to metabolize these the organic components organic pollutants present in the wastewater they grow and they settle down.

And those settled cultures can be again inoculated used as inoculum for growing for their growth in a new setup where again they can be utilized for degradation of the contaminants the organic contaminants within the wastewater. So, these concept of activated sludge based waste water treatment remain a very popular till that as I said that it is a century old technology. So, it is being utilized. So, but the details of these micro organisms this 95% or so, we say that aerobic bacteria.

But only in a last couple of years or last decade use of the molecular techniques or molecular microbial ecology techniques where were; able to decipher the composition of activated sludge microbial communities and also allowed scientists to actually achieve the better efficacy out of them. Similarly the once the cells are settle down they produce the sludge and those large materials produced by the wastewater treatment processes are subjected to anaerobic digestion.

That is the anaerobic metabolism of those biomass and biomass mixed with residual contaminants lead to the production of biogas like methane. So, that allows the digestion of the sludge.

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So, here you can see that we have a picture of a traditional biological process used in full scale wastewater treatment and but three particular setups were marked as you can see by the marking a which is basically the battery of aeration basins where aeration that is the use of the activated

sludge inoculum is used to aerobically degrade the organic pollutants and then the b where are basically the settling tanks.

So, most of the dead materials or the heavy particular materials are going to be settled there. And those settled sludge will be finally transported or transferred to these tanks which basically anaerobic digestions are will be going on over there. Now during this aeration or aerobic processes mostly oxygen will act as a terminal electron acceptor and aerobic microorganisms will act on the organic pollutants organic matter and they will metabolize them very quickly because thermodynamically those processes are very fast.

However the sludge which is deposited and taken into the anaerobic digester where anaerobic metabolism particularly it begins with the kind of a fermentation and fermentation will produce kind of different type of small organic molecule and then eventually they will be all converted to the gases like the methane and these methane is is a kind of a valuable product valuable energy product.

So, converting a waste material to a resource material that is methane this particular concept we remember that this kind of this kind of setups become became available around the globe for many, many years but the actual details of the all the processes and how can we can achieve more efficiency out of the processes where recently only the implemented.

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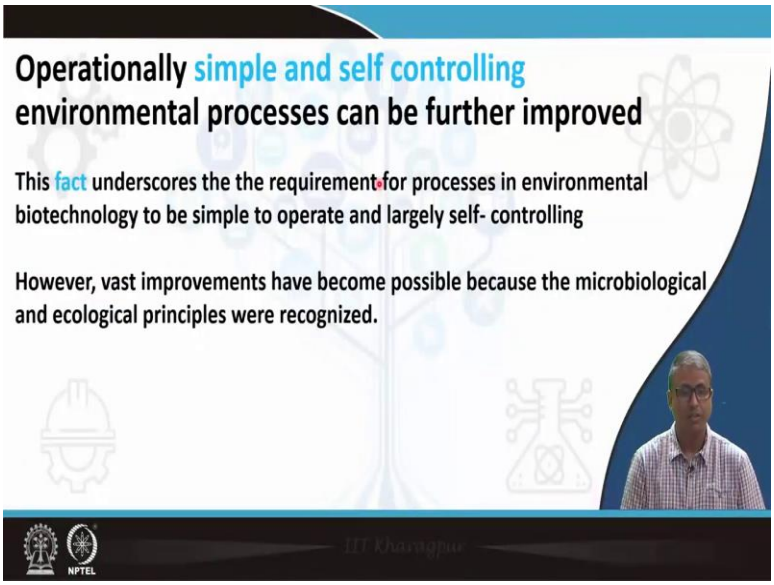

Now these operationally simple and self-controlling processes can be further improved. Now these operationally simple and self-controlling processes this fact basically underscores the requirements for processes in environmental biotechnology to be simple to operate and largely self controlling. So, these are because these are very simple process it is not a very complicated and sophisticated very sophisticated instrumentation and etcetera may not be required.

And they are mostly relying on the self controlling or self controlling phenomena because these microorganisms once they are inoculated within the waste water they will be growing there and they are growth. Now we need to remember there are 100s of or 1000s of different species. Now how do they adjust themselves the growth of one species will be more or the growth of other species will be more or the growth of the all the species will be more these are all self controlled.

So, that is the beauty of the process that though it is actually a very complex process it appears very simple because these microorganisms together they work like a single entity. However in the recent decades we can see that vast improvements have been possible because the microbiological and ecological principles were recognized and were are improved. Now improvements done after recognizing the microbiological and ecological principles with that respect we would like to discuss or emphasize briefly about one particular process.

Because earlier we were mentioning that during this activated sludge based wastewater treatment

we were not aware of much of the basic understanding or the detail understanding about the microbial processes. But as soon as the scientists were trying to look into the microbial processes they tried to make huge improvements one of such improvements is here which is called biological nutrient removal or BNR.

So, this is considered to be a wonderful example because in this case both aerobic and anaerobic cultures are used and in a kind of a cyclic manner the waste water is circulated through tanks which are aerobic and anaerobic. So, basically cycling the microbial community through a series of aerobic anoxic and anaerobic stages enable the complete removal of nitrogen and phosphorus from the waste water.

Because the otherwise the nitrogen and phosphorous compounds remain non bio degradable compared to the carbon component of the waste water because carbon components can be metabolized as a source of their electron and source of their energy. So, microorganisms the heterotrophic microorganism they generally degrade them very quickly but with higher nutrients available in the waste water.

These kind of technologies were required and the environmental biotechnologist were able to come up with some such excellent ideas that if we can if we can circulate the com the water or the waste water through a series of aerobic anoxic and anaerobic system then that that might allow natural enrichment of this organism. So, although we act we add some kind of inoculum but essentially the organisms get enriched there.

Now the different stages are used to select for three distinct groups of bacteria that are able to oxidize ammonia to ammonia nitrogen to nitrate nitrogen and then reduce nitrate nitrogen to nitrogen gas. So, nitrogen gas basically leaves the system and the while the bacteria they do this conversion that is ammonia nitrogen to nitrate and nitrate to nitrogen they store extra phosphate which is which is there in the wastewater.

As a pollutant as a very important polyphosphate bodies and those polyphosphate producing bacteria they accumulate huge amount of polyphosphate bodies. And it has been found further

that by doing this many of these bacteria they also produce huge amount of lipids within themselves. They accumulate they degrade the carbon component also they accumulate lipids within them. So, these lipids and polyphosphates remain any in any wonderful resource for further application.

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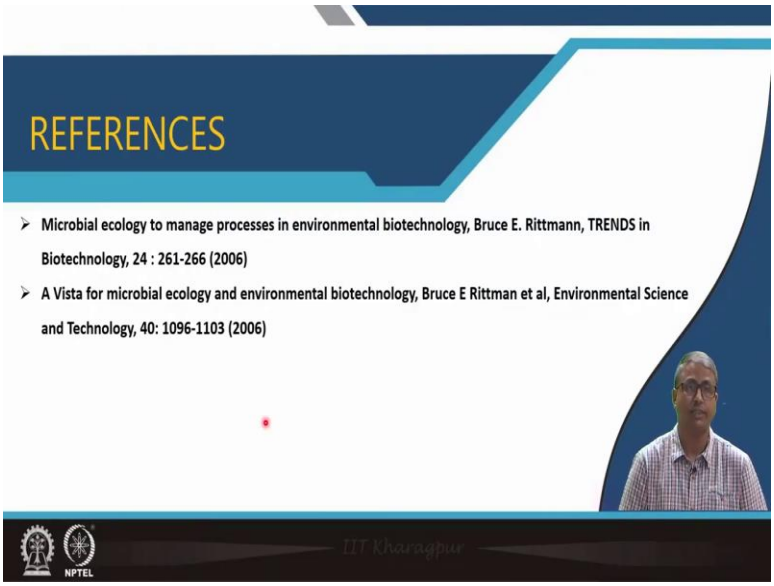

So, with this particular section this follow these two to review articles are used or can be used as a reference material.

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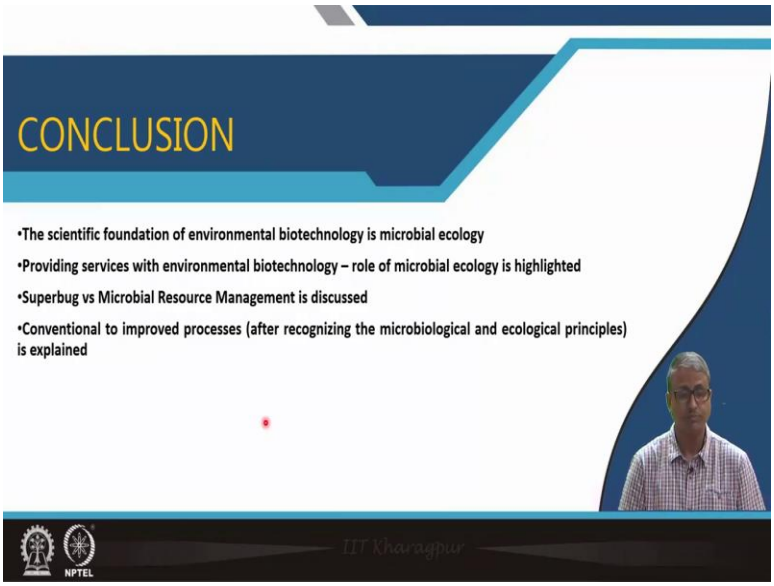

And in conclusion in this particular part of the lecture the scientific foundation of environmental biotechnology in is microbial ecology which is emphasized. Providing services with

environmental biotechnology and the role of microbial ecology in that is highlighted. We also talked about the superbug versus microbial resource management where we discuss that superbugs are not suitable for environmental biotechnology in sustainable application.

Rather it is the microbial resource management or applying the entire community is or is always better. And the conventional to improved processes like we have a parallel the con conventional waste water treatment and anaerobic digestion of the sludge but also we are continuously improving water treatment and other waste treatment processes based on or recognize after recognizing the microbiological and microbial ecological principles, thank you.