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

Lecture – 13
Microbial Ecology and Environmental Biotechnology - Part C

Welcome to this lecture on microbial ecology and environmental biotechnology part C. And in this particular lecture we are going to discuss on the Principle of Good Management with reference to the application of the knowledge and understanding of microbial communities in various fields of environmental biotechnology.

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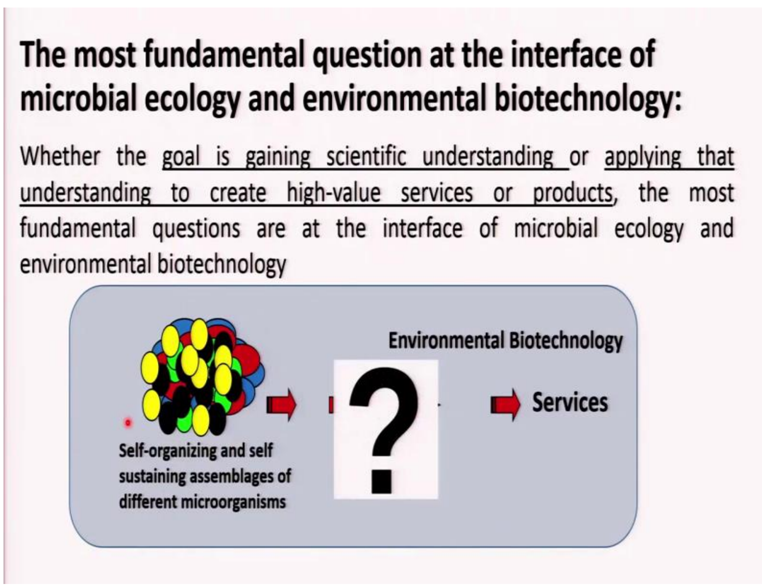

Now the most fundamental question at the interface of microbial ecology and environmental biotechnology is discussed and this particular question is very, very prominent and the question is how do microbial communities self assemble to achieve and maintain a function. Because whether the goal of utilizing this particular concept of microbial ecology into environmental biotechnology is basically gaining scientific understanding or applying that understanding where microorganisms are functioning.

And functioning towards production of certain compounds or cleaning up certain waste materials or certain other purposes. So, applying that understanding and sometimes to create a high value services or products. In both the cases we need to have an answer to this question that how do these communities which occupy or work in a particular environment on a particular system where these environmental biotechnology related processes are going on. They self assemble and the function.

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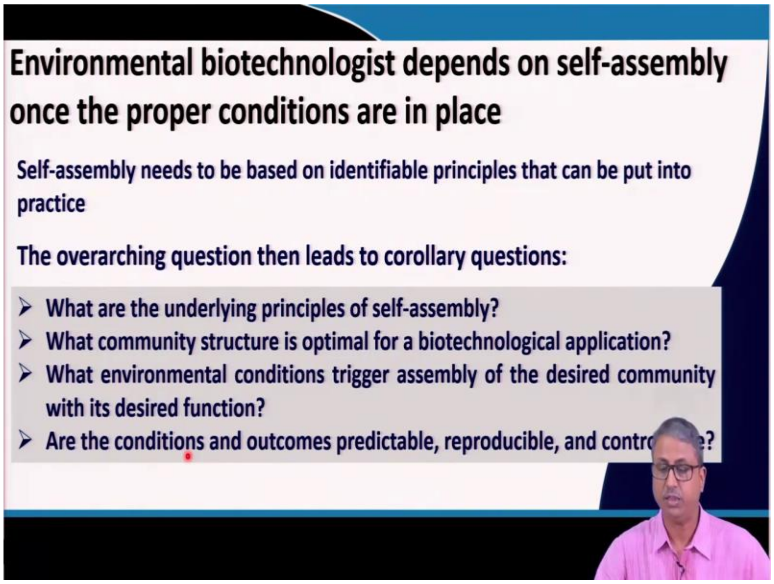

Now environmental biotechnologist depends on self assembly. Self assembly in the sense the self assembly of different species once the proper conditions are in place. And self assembly of these organisms need to be based on identifiable principles that can be put into practice. And the overarching question then leads to certain corollary questions that what are the underlying principles of self assembly?

Because the assembly must be guided by certain factors certain processes. So, who are those? What are those factors? How the microbial species are actually involved in a synergistic or in a kind of antagonistic assembly because often in a community which are which is basically used for any particular process we find that there are numerous species which are which are forming different type of clusters those clusters are basically the assembled species members.

So, these assembled species member forming the clusters could be positively correlated that means they must be having some synergistic relationship or the they could they could also be having some kind of negative interaction between themselves and basically developing antagonistic or portraying the antagonistic relationship among themselves. So, taking into account all these synergistic as well as antagonistic reactions we can very well understand the process of self assembly.

But we need to before that before we understand the self assembly we need to first define what are the principles of self assembly? The second question would be that what community structure is optimal for a biotechnological application? So, whatever may be the applications it may be the production of biofuel, it may be production of methane, it may be decontamination of certain waste material.

So, whatever it is. So, we need to actually understand that what community structure is optimal for biotechnological applications. The next question is what environmental conditions trigger assembly of the desired community with its desired function. This particular question is very relevant because we know that in a particular community there could be several 100's or even 1000 or more than 1000's microbial species.

And these species are expected to form different kind of self assembly or clusters and these clusters as I said could be synergistic cluster could be antagonistic clusters. So, some of these organisms within the clusters or some of the clusters in fact they might be useful for the desired community function. Now what environmental conditions will trigger the appropriate assembly formation that is the particular assembly or particular cluster which is required or optimal for a particular community function would certainly be dependent on certain certain environmental factors.

So, what are those are environmental factors which triggers the or trigger the assembly of the desired community function that that has to be delineated. And the next and the last question in this case is are the conditions and outcome are predictable reproducible and controllable. So, the conditions which actually guide this assembly particularly the assembly which which allows the desired community function.

Are these conditions which actually favour the formation of those kind of clusters or those kind of interactions are predictable and we can we can reproduce them and we can control them. And it is not only the conditions and also the outcome because the desirable condition will only lead to the appropriate outcome. So, once we are able to control the desirable conditions it is expected that the outcomes are also going to be controlled.

So, the one of the major questions in this case is basically these conditions and outcome which basically are defining the desired community for formation community assembly with respect to a particular environmental function. Are they predictable, reproducible and controllable.

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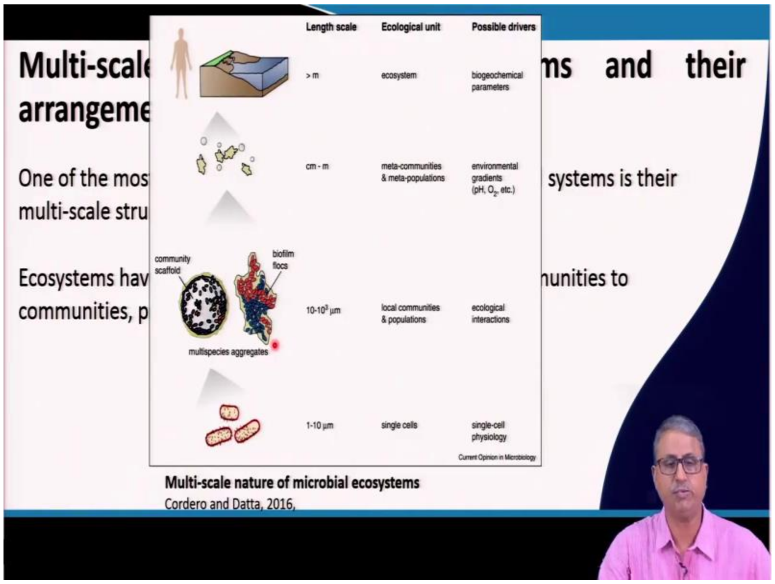

So, in most environments microbial interactions take place within micro scale cell aggregates as I mentioned there are synergistic interactions and there are antagonistic interactions. So, often we found that these interactions are taking place in a micro scale cell aggregates. Now at the scale of these aggregate that is around 100 micrometer interactions are likely to be dominant driver in population structure and dynamics.

And in a microbial ecology study with respect to its application in environmental biotechnology or for basic understanding of microbial ecology function. Understanding these interactions are one of the of the priority areas. Now in particular organisms that exploit inter specific interactions to increase ecological performance often co-aggregate. So, these are basically the synergistic interaction.

So, there are as I said there are many species out of many species some species would be engaging with interactions between themselves which will be helping them to perform better to utilize the resources there and also might be useful for producing or functioning to the extent that is desirable to us, us means the environmental biotechnologist. So some organisms will be exploiting the intra specific interactions which are synergistic and which will allow them to co-aggregate that is they will form distinct clusters.

Conversely there would be some organisms which who are not involved in the previous cluster and rather they might have some antagonistic role with respect to each other or with respect to other cluster and they will tend to form separate clusters often or they may remain isolated as a discrete members often they may very often they form different clusters and that might create distinct sub communities or sub clusters and increase diversity at larger length scale.

So, if we look at those communities at a higher scale we will be find out that there are actually more diversity than number of species present. So, multiscale structure of the system and their arrangements are very important. So, one of the fundamental properties of complex system are the multiscale structure and ecosystems have a hierarchical arrangement which might go from the meta communities to communities populations individual pathways and genes.

For example if you look at this different communities which may be expected in different environment. We will find out that the in a length scale the drivers are entirely different. So, in a in a scale of like centimeter to meter we may have environmental gradients which are controlling some meta communities or meta populations whereas at the scale of 10 to 10 to the power 3 micron or so we can have local communities or populations will have like a biofilm frocs or a kind of cell different cells are growing within a community scaffold.

These are all multi species aggregates but when we come down to micron level or micrometer level resolution we will be able to find out the single cell physiology and will be able to find out that there are actually discrete sub clusters or some aggregates are there. So, those are basically synergy reflecting the synergistic and antagonistic interactions among the members. So, self assembly which basically enables us; or provides us information about all these micro details about how the community members are structured within a particular system and what factors control them.

Particularly a particular cluster a particular assembly might be very critical for a particular function. So, knowing that defining that and predicting their behaviour is a very important task with respect to translating the knowledge of microbial community into environmental biotechnology.

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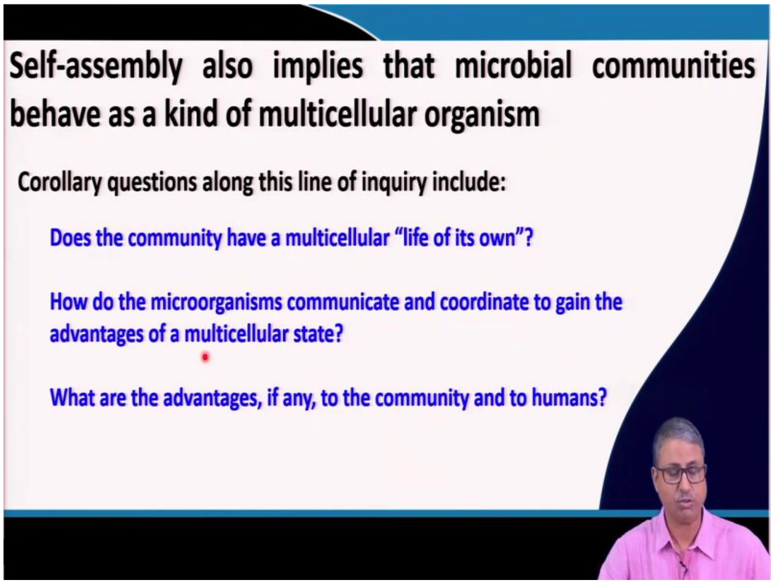

Now self assembly also implies that microbial communities behave as a kind of multi cellular organisms. Because all these micro clusters or clusters they are all tied together. The synergistic cluster the antagonistic clusters all these clusters are basically components of a particular community. There would be some connections which are already existing there and these in a totality they behave like a multicellular organism.

Now as we understand that some more questions along this line of inquiry include does the community have a multicellular life of its own? And how do the microorganism in communicate and coordinate to gain the advantages of a multicellular state. Why do they like to achieve this multicellular state with numerous or several clusters or interactive assembly or sub assemblies they form this kind of multi cellular structure it is actually a entire structure like a biofilm.

So, how they communicate and coordinated with the coordinate with themselves that is a big question and what are the advantages if any to the community and the and to the human. So, to the community in in particular and to the human where we are actually trying to explore or exploit the benefit out of these. So, what are the advantages of this kind of interactions between themselves.

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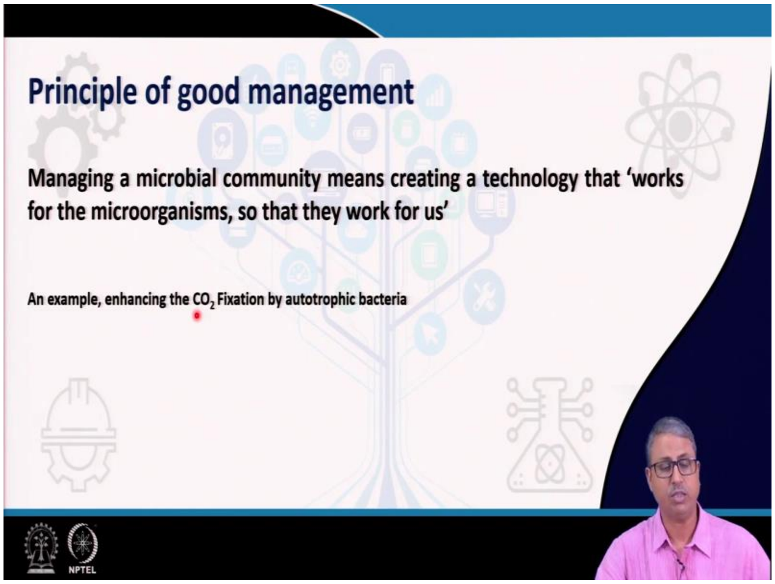

Now the next point that we are going to discuss here is managing the microbial community. Because essentially this particular aspect managing the community will enable us to gain the outcome from the community or the microbial members because when we target that a particular community or a particular microbial system would be delivering some function. So, be it a treatment of wastewater be it a production of certain com compounds or increasing the certain other activities.

In all the cases it is basically managing the microbial community and it has been said that it is actually a win-win situation. So, here we discuss this particular point of this win-win situation why we are saying it is a win-win situation? Through certain concept of principles of good management, now managing a microbial community means creating a technology that works for the microorganisms.

So, that they work for us. Just assume that we want to use an activated culture activated sludge for waste water treatment. So if we understand how the organisms present within the activated sludge actually work with respect to degrading the degradable pollutants which are present in the wastewater we would able to exploit them apply them and get the benefit out of them in the best way that is why it is said that works for the microorganism.

So, that works for us. Now here I would like to take one particular example other than the waste water treatment that is activated sludge that I just mentioned that enhancing the carbon dioxide fixation by autotrophic bacteria because lot of interest is being paid on this particular aspect owing to the rising concern over the atmospheric carbon dioxide level and its impact on the climate.

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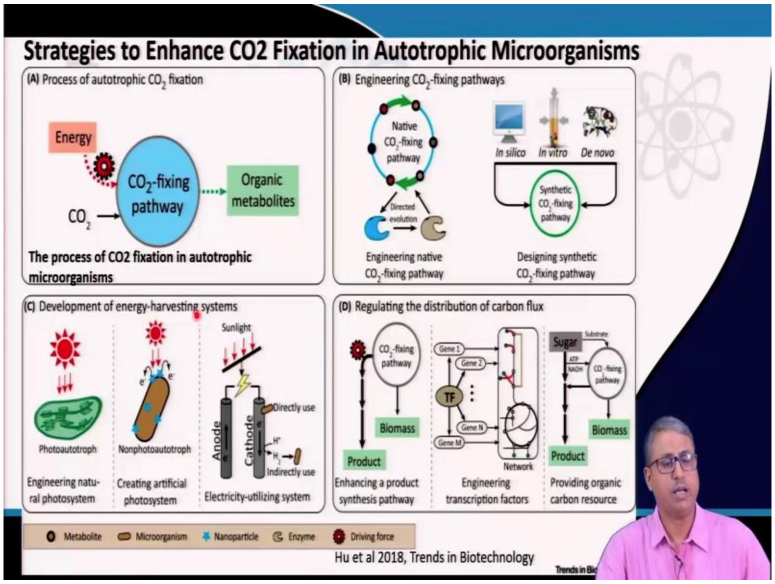

So, there are defined strategies to enhance the CO 2 fixation by autotrophic microorganisms.

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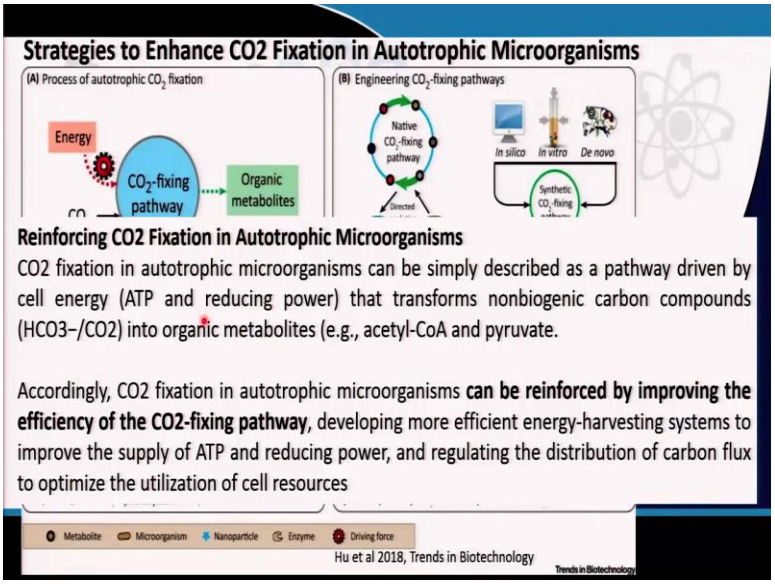

So, basically what is autotrophic carbon dioxide fixation it is basically a pathway like here it is depicted that is a pathway which is driven by these autotrophic microorganisms and it allows the cells to transform the inorganic carbon like HCO 3 or CO 2 into organic metabolites like acetyl-coa and phytophene. So, autotrophic organisms are already existing they are there in the environment.

Now the CO 2 fixation by these autotrophic microorganisms can be reinforced by improving the efficacy or efficiency of the CO 2 fixes in pathway by developing more energy harvesting system to improve the supply of atp and reducing power etcetera. So, let us see what are the ways to do that? Now it can be done number one by engineering the CO 2 fixation pathway. So, once we have certain good organisms which are candidate organisms.

We aim to engineer the CO 2 fixation pathway and the efficiency of the native CO 2 fixes in pathway can be increased by over expressing its key enzyme like putting them into a plasmid vector and then over expressing them or sometime replacing them with a better enzyme that is a part of the metabolic engineering I will say. More efficient synthetic CO 2 fixing pathway can be also designed using synthetic biology and other omics data.

So, these are all open ended research areas where people are working on that. Similarly the next option could be development of energy harvesting systems like efficiency can be improved also by optimizing the natural photo systems in natural autotrophic microorganisms. Creating artificial photo systems for non autotrophic microorganism or developing some electricity utilizing system.

So, where non photo autotrophic organisms can be made to do carbon fixation and essentially we can allow them to convert carbon dioxide to produce some something like electricity utilizing system or something like that the last one could be regulating the distribution of carbon flux. Now the distribution of cellular carbon flux can be regulated through enhancing the product synthesis pathway because flocs is basically the flow of rate of flow of metabolites.

So, as inorganic carbon will flow through that engineering the transcription factors and providing the organic carbon resources etcetera would be immensely beneficial we have found that. Now for all these things for all these carbon fixation in autotrophic microorganism based system which is one of the best areas or one of the most important areas of environmental biotechnology. We need to know how these actually autotrophic microorganisms which are present so in so abundantly in the natural environment they actually function.

They actually function in terms of their interaction with a species member their interaction with the physical and chemical materials that they use as a resources or they could be affecting the microorganisms and essentially also how their genes and how their metabolic functions are coordinated through these self assembly processes.

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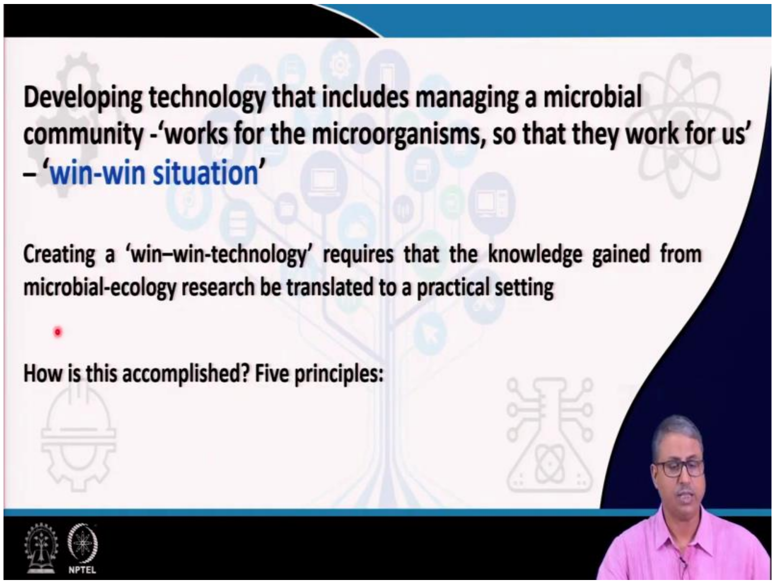

Now therefore developing this technology that includes managing a microbial community works for the; microorganisms. So, that they work for us is a win-win technology win-win situation because we need to know the microbes their interaction their function how they work for a particular process very well then only will be able to deploy them or apply them for our purpose.

So, whether they will be useful for our purposes or not that means whether they will work for us or not it depends on whether that itself work for the microorganism. Now creating that win-win technology requires that the knowledge gained from microbial ecology research we translated to a practical setting and how it is accomplished?

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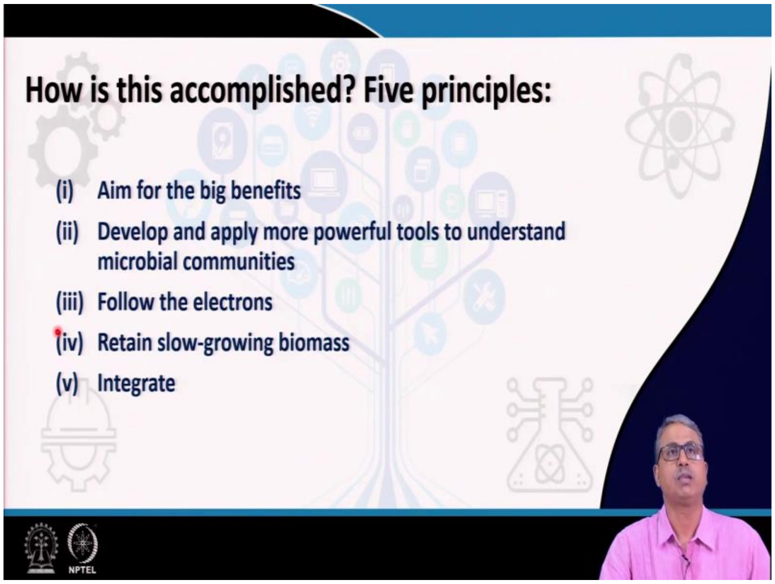

These there are five principles. These five principles are aim for the big benefits, develop and apply more powerful tools to understand the microbial communities, follow the electrons, retain the slow growing biomass and integrate all the concepts all the knowledge that we derive from these our studies on microbial community function microbial community structure their interaction with respect to any given environmental setup.

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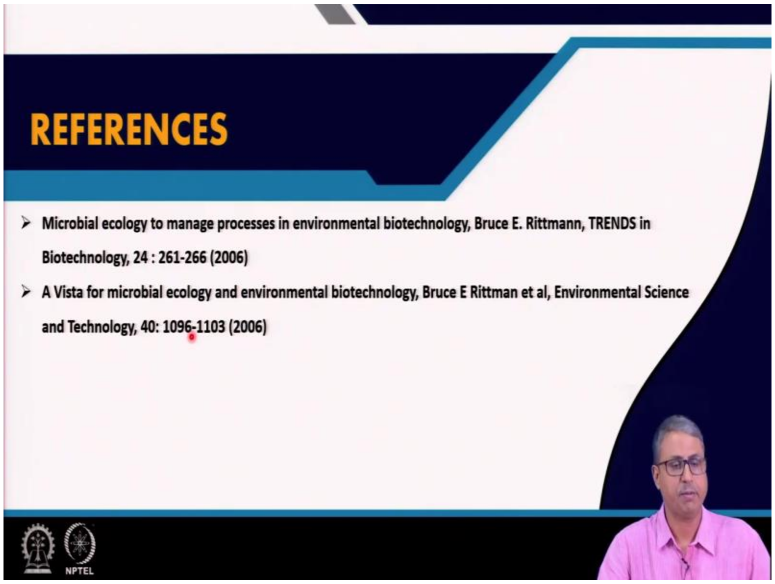

So, with this topic is ended here and for this particular portion I would recommend these two following articles that is the Microbial Ecology to Manage Processes in Environmental Biotechnology by Bruce Rickman and A Vista For Microbial Ecology and Environmental Biotechnology by Rittman et al published in environmental science and technology in 2006.

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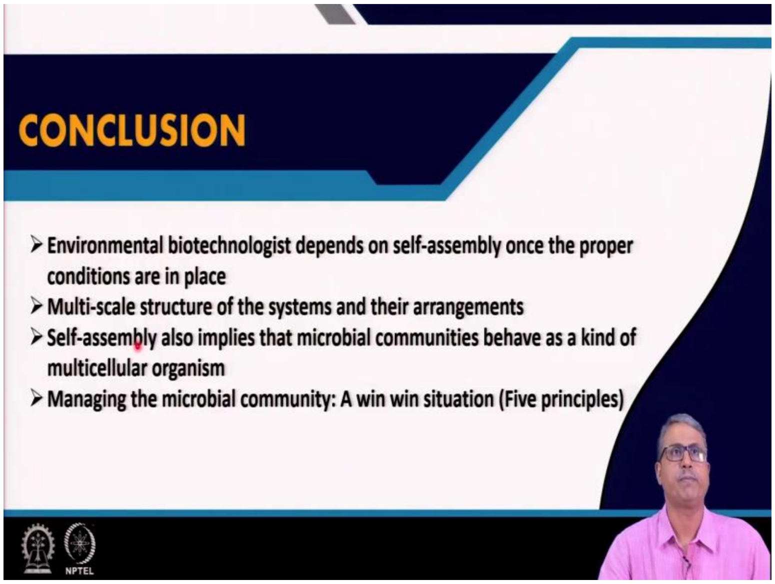

So, in conclusion environmental biotechnologies depend on self assembly once the proper conditions are placed. And the multiscale structure of the system and their arrangements are very important. Self assembly is also very important to understand for understanding the community function and it also implies that microbial communities behave as a kind of multicellular organism. Managing the microbial community essentially is a win-win situation and we have 5 principles towards that, thank you.