Advanced Aquaculture Technology
Professor Gourav Dhar Bhowmick
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur
Lecture 40
Bio-Electrochemical System-based Wastewater Treatment (Contd.)

Hello, everyone. Welcome to the fifth lecture material of the module-8, technology of water treatment. Here I will be discussing about the bio-electrochemical system based wastewater treatment, in continuation with last two lectures. My name is Professor Gourav Dhar Bhowmick; I am from the department of agricultural and food engineering of IIT Kharagpur.

(Refer Slide Time: 00:46)

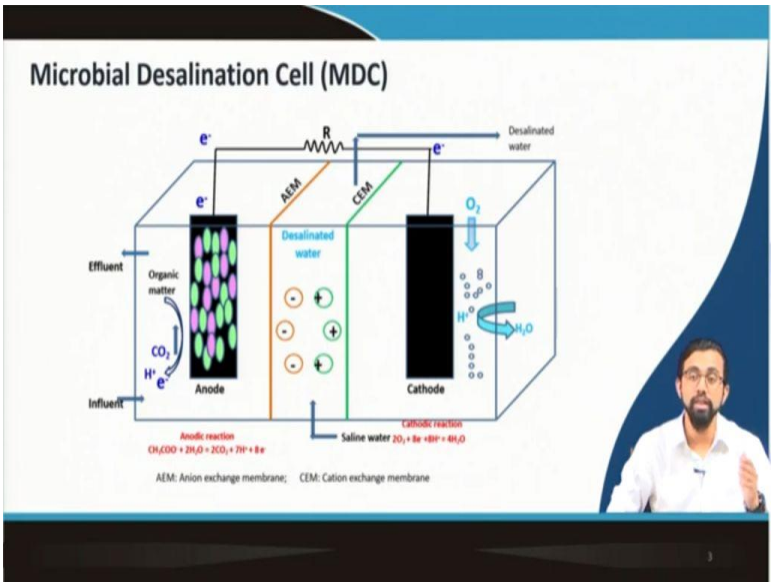
The concepts that I will be covering in this particular lecture material are the different forms of bio-electrochemical systems. In continuation with the discussions that we already have, based on the microbial fuel cell, microbial electrochemical cell, microbial electrolysis cell, and the microbial electrosynthesis cell. Here will be discussing more about MDC, MCC and SMFC. What is MDC? It is a Microbial Desalination Cell. From the name itself, we can understand desalination means it is a work it is a something related to the desalination of the already saline water right.

Second one is the Microbial Carbon Capture Cell, where we are trying to capture the carbon from the atmosphere as much as possible. And it will be, and make it useful for our system to get give more yield in terms of wastewater treatment, as well as bio-electricity production. Third is

the Sediment Microbial Fuel Cell; it is a very recent technology which people are working right now all over the world, who are mainly be using the sediment different zones of sediment to be act like a bio-electrochemical systems.

And it it is named as, it is coined as sediment microbial fuel cell okay; so, will be discussing each one of them in in coming, in this coming in the coming slides.

(Refer Slide Time: 02:01)



To start with microbial desalination cell, what is the purpose of it? First of all, suppose you are utilizing saline water for the product for your farm production and all. But, the saline water levels is some you know, it varies a lot; and sometimes suppose the water levels, see the water level is not up to the mark, and the salinity is very high. So in that case, what you can do? You can introduce some desalination treatment unit. So, there are a lot of processes are already there established conventional processes of desalination.

And one of them is this you may heard of the RO system right, reverse osmosis and all. Some another one is the incineration; simple is simply, we just simply boil it. And it is like you boil the water, you evaporate the clean water, you condense it, and separate it. All these systems, all these conventional systems of desalination are energy of taking huge energy up taking processes okay. So, still there are a lot of research is going on in this field; and people have come out with very advanced RO processes and all; very advanced pretreatment units for RO processes and all.

One of these pretreatment unit to the RO processes can be a technology like microbial desalination cell. One of the technology that, one of the another useful application of this microbial distillation cell is the application for wastewater treatment. What is happening here? In this reactor, in this particular type of in this MDC, which is like the one that is shown here. It is three chambered MDC; it can be five chambered, it can be seven chambered MDC as well as okay. So, in case of three chambered MDC, what is happening? In the middle chamber, in the chamber which is sandwiched between the anode and the cathode chamber, anodic and the catholic chamber, what we are doing?

We are introducing the saline water. Once we are introducing the saline water there, and in the left side if you see in the picture in this figure, we have the anode. In the right side we have the cathode. In the anode, we have introduced the wastewater; it actually acts more like a microbial fuel cell here, from the same concept you can think of it. In the anodic side, we have inoculum, we have keep on provided with the, providing it with wastewater. So, whatever the ingredients there in the wastewater, it will consume this biofilm; and then they will convert it to the electrons and protons and all okay.

So, what is happening in the cathode, the same way the electrons and protons which is come in contact with the oxygen, and it will produce H_2O okay. So, what is happening in between? What is happening in between clearly, clearly if you in the saline water is introduced; and we have this AEM. If you in the left side if you see instead of one protonation membrane in case of microbial fuel cell, we have two membranes here; one anion exchange membrane, one cation exchange member. If you see this orange one, it is like the anion exchange membrane is the green one is the cation exchange membrane that is introduced.

Anion exchange membrane is bifurcating the salination chamber, disalination chamber, and anodic chamber. And the cation exchange membrane bifurcating the; I mean like separating the cathodic chamber and the desalination chamber okay understood. Now, when suppose saline water. Saline water means what? It is a salt; salt normally they are they are connected with anions and cations; they connected to the conduction band bond right. So, these anions and cations because of the, because of their dissemination through the dissemination through this chamber in the desalination chamber; the anions and cations are migrated towards the anodic and the cathodic side.

So in general, what is a normal tent? Definitely, anode is you know they try to attract the anions. So, because of that the anion exchange membrane, through the anion exchange membrane; because anion exchange membrane is it is a selective membrane right. It will only let the anions pass through it. So, that is why what will happen? The it is an initial level of screening is done in an anion exchange membrane; and then this anion comes into the anionic chamber. I mean the anodic chamber and it comes in contact with the anode. The same way, the cations pass through the cation exchange membrane; and it will come in contact with the cathodic side, cathodic chamber and all.

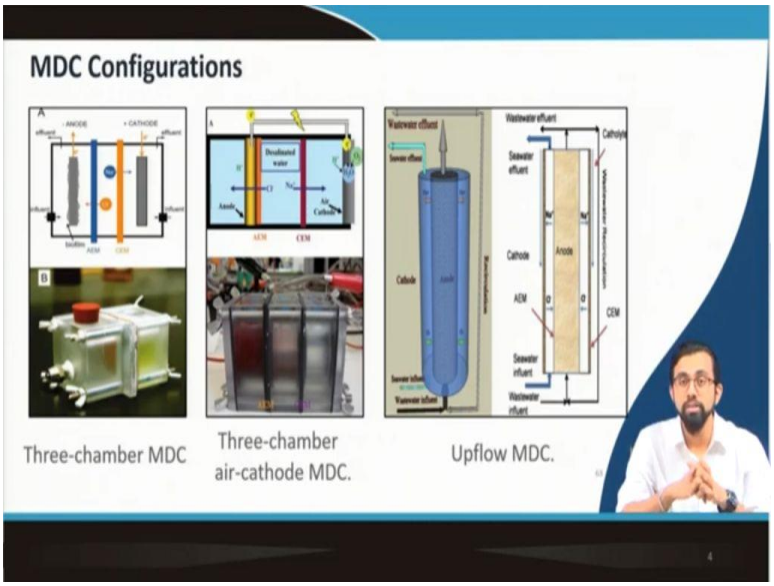
In the cathode, it will get utilized by the terminal electron acceptor to form the H2 and other byproduct. So, what is actually happening here? Because of this migration of different ions in different sites, anion and cation in the different sites; the water which is coming out of this chamber is desalinated. Because, all these salts are dissoluted and they are they migrated towards the other side of the chamber. Because of that, the desalination efficiency is very high in this kind of in this kind of system.

You understand how it works? Saline water is getting desalinated because of the migration of the different ions in either side of the of the chamber, anodic and the cathodic chamber, through anion exchange membrane and the cation exchange membrane. In the anode and cathode, we have the, it is the same working principle. It is connected with the load, and we can get them in a high amount of you know electricity from there, because of the excess amount of ions that is present because of the introduction of the saline water. So, that is how it works okay; this is called microbial desalination cell.

In the microbial desalination cell, we can treat the wastewater; we can decelerate the saline water. We can get the bio-electricity you know, we can get the pure water out of it; so all the things that can be, all these things are possible in a single unit okay. Now, there because of the some limitation in the electrochemistry; still this system is not at each and every household. But, people are working on it; and it will be in the very near near future. It will be a very, how to say like you know converted into a technology which can be well utilizable and well you know profitable for their manufacturer.

And also people anyone can they make by themselves; or they can utilize it in for pilot skill applications okay. So, I will discuss more in details about different configurations.

(Refer Slide Time: 08:18)



The three cell MDC, we have already discussed; you know how three chambered MDC works. The anions are bifurcating into anodic chamber and the catholic chamber; how it looks like you see in the number B in the left bottom. In the middle one, the middle, the picture is it is showing the three chamber air-cathode MDC. What does that mean by air-cathode? The cathode you see the anodic part the yellow one; and the we have this anion exchange and the cation exchange membrane. At the end we have the cathode, which is in connect with the atmosphere okay; which is open to atmosphere; it is one side of it.

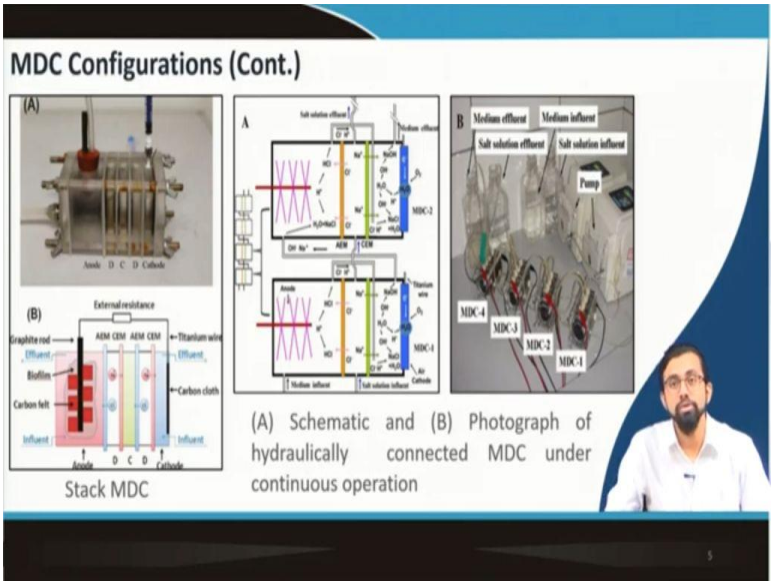
Because of that what is happening? Because its one side of it is open to atmosphere; the more availability because we do not have to provide dissolved oxygen. What is happening with the problem with the three chambered MDC in normal one? Because they are the cathode; you need to supply it with oxygen right; you have to keep on bubbling it with the aerator and all. So, that you will keep on supplying the dissolved oxygen, so that it will get in contact with the electrons and protons coming from the anodic chamber; and it will, it can get reduced to H2 and O2. However, in case of air cathode MFC, the efficiency is much higher; because it can, it is ample amount of oxygen is already available in the atmosphere, and it can get easily in control.

There are a lot of verdict in it also, like whether really air-cathode MFC is much more efficient or not; there are a lot of paper working. There are a lot of paper, a lot of researchers are working on it; so, it is still in the verdict. But, in general, air-cathode MFC is experimented to be much

more efficient than the three chambered MDC, considering the energy efficiency and all. Then, there comes the off low upflow MDC and all. Here also we have this anodic chamber in the middle, and in the desalination chamber, and the outside; and this is like catholyte and the cathode will be there in the outside.

So, here the seawater effluent is coming from its peripheral site; and in the middle we have this wastewater there. And this wastewater effluent is going through the anodic chamber; it can treat, it is like a modular chamber okay. So, it is a much more design efficient this upflow type of MDC.

(Refer Slide Time: 10:28)



Then, there comes the stack MDC. Remember I told you instead of three chamber, we can have five chamber, seven chamber MDC as well. This is one one example of like that you know; example of this kind of five chamber MDC. We have this series of you know AEM, CEM, AEM, CEM like anion exchange, cation exchange, anion exchange, cation exchange. In the C number C chamber if you see in the left side; number C we introduced the saline water. So, what is this D chambers are doing? In the D chambers is actually very interesting. In the D chambers, either of its size based on the its cathodic which side it is.

Like in the cathodic near to the cathodic side or near to the anodic side. We can recover acid and alkaline, alkaline material out of it. How we can do that? It is as simple as that. Suppose, you are introducing NaCl okay, you are introducing NaCl from the chamber C okay. Now the, what is

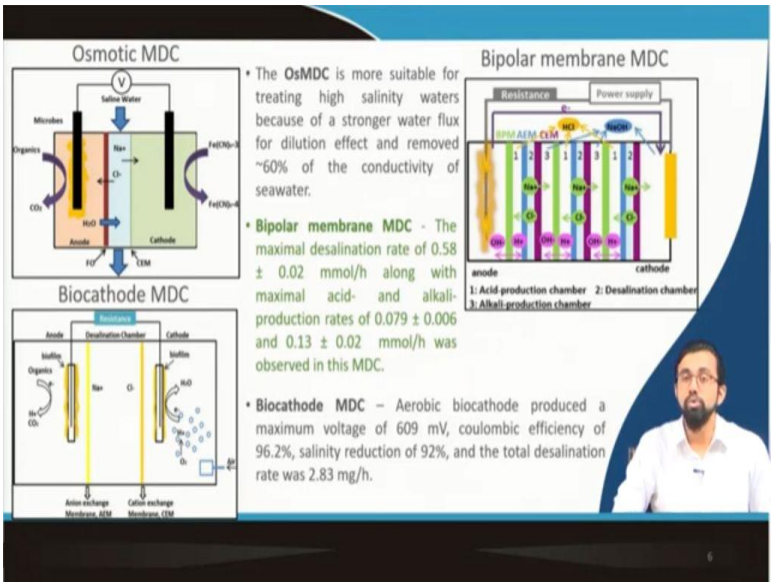
happening the (chlora), the Cl negative and Na positive is there? They will, they will go to its respective side based on the cation exchange membrane and anion exchange membrane that is introduced. It will go to the, say like, the sodium ion will come to the through it will pass through the cation exchange membrane; and it will come to the chamber number D, which is in the left side.

In the same way, suppose because of the anion exchange membrane which is there and all in left side; suppose the anions are some other cations are, and anions are, anions are coming in contact with the this Na. And what will happen because of that, you will get say sodium hydroxide and all. There is a possibility of generation of the sodium hydroxide in that chamber. In the same way if you change the direction, if you do like say if you think about the other way around. Because of the anion exchange membrane, it depends upon you actually okay.

How you place it? How you do your research? How you want to put the anion exchange and cation exchange in the other way? So, anyway, suppose you have anion exchange membrane, the chlorine the chloride ion will pass through it. And suppose from the other side, H plus ion will come in contact with them; so, you will get the HCl. So, that is there is a possibility of acid and alkaline recovery from this kind of MDC; so, that is another advantage. Not only it can treat the wastewater, it can desalinate a saline water; it can even give you the additional help with the you know acid and alkaline recovery from the system.

And fourth, obviously the bio-electricity okay. In the right side pictures, it is like a stack, it is it is like you know see the stack MDC with the hydraulically connected MDC. In the continuous operation, how it looks like?

(Refer Slide Time: 12:56)

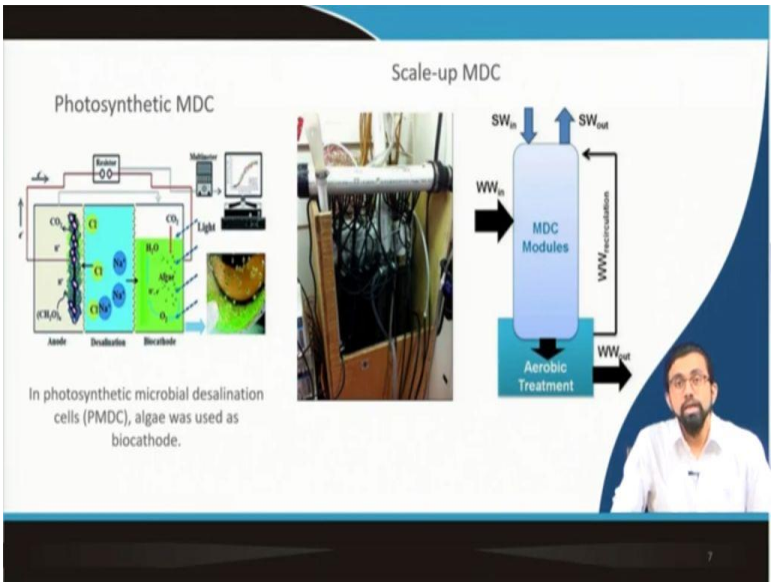


Then, there come this osmotic osmotic MDCs and all, where it is it is actually; this is actually more suitable for very high saline water with a very high stronger flux that you can apply. It can remove up to 60 percent of the conductivity of the seawater okay. So, in general, suppose you are supplying 30 PPT of seawater, saline water; it can give you the removal of almost it at the end the water that will be getting, it will be having 12 PPT or so. So, just to give you some rough understanding about how this works okay.

So, you can, you normally talk about in a electro conductivity this these parameters and all. In case of bipolar MDC and all, you can use the bipolar membrane, cation exchange membrane or anion exchange membrane like say you know or bipolar members; so, which can give you higher amount of acid and alkaline production in either of the chamber. You can use the biocathode MDC, where in the cathode, even introduced with the aerobic microorganisms. So, this aerobic microorganisms which will keep on consuming more amount of you know ; it will, first of all it will produce it; suppose, you are introducing algae okay. So, once you introduce algae in your cathode, what will happen?

The production, because anyway, you are introducing aeration right. So, this algae what it will initially what it will do? It will also produce some additional oxygen from there; and you can, it can that oxygen can be helpful for your performance to enhance further. So anyway, this is a, these are the different types of MDCs those are available.

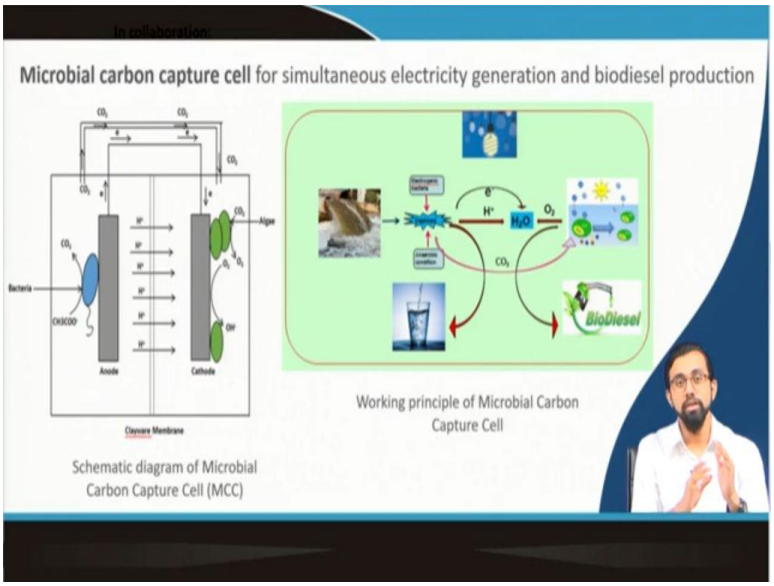
(Refer Slide Time: 14:27)



There is this photosynthetic MDC, this specific type of biocathode MDC is called this photosynthetic MDC, where instead of in the cathode, we have introduced the algae. This algae is actually used, they used as a bio cathode; and it is actually providing the oxygen, that is necessary to be act as a as a terminal electron acceptor okay. Then, this scale-up MDC, if you see it is here; we have this same system. But, you have to introduce, you we have it is done in a larger scale almost 100 liter in volume. So, there are a lot of experiments going on all over the world, where people have used much larger sized MDCs as well.

However, the work is still not in a stage that it you can say it is scalable like you know in the maximum size to the best of my knowledge is not more than 200 liter. So, it can be if you want to treat like in a meter cube per day level; then, we have to still work on it. And there are people working on it, and even you know IIT Kharagpur also we are working on it. How it can be scalable? It can be made scalable, and it can be made useful; and people can use it in the near future.

(Refer Slide Time: 15:39)



Next very interesting technology is microbial carbon capture cell okay. In the microbial carbon capture cell, it has almost a similar functionality like the photosynthetic microbial desalination cell. If you remember the last slide in the MDC, what we did? We introduced algae in the cathodic chamber. Here also we introduced algae in the cathodic chamber. This algae what it will do? It will not only you know help to increase the level of oxygen in your cathodic chamber, but also it will consume the carbon dioxide which is generated from in the anodic chamber.

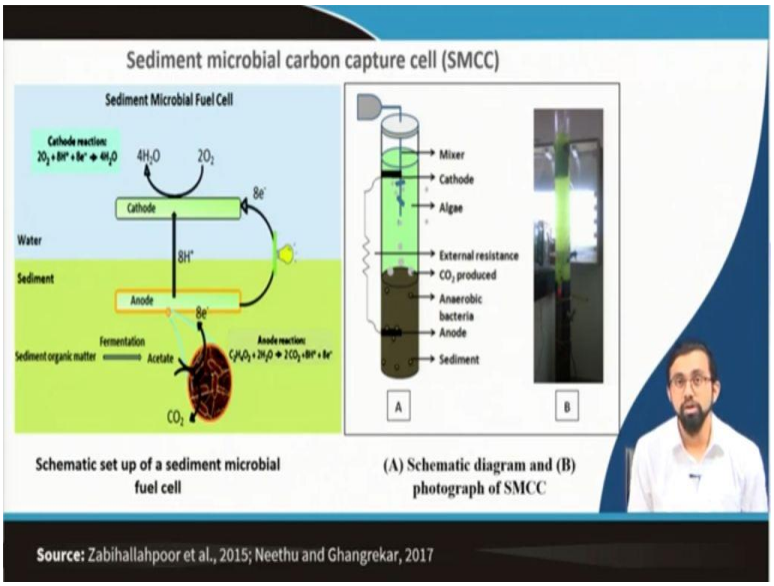
So, it will reduce its carbon footprint further. So, it is utilizing the carbon dioxide which is which is getting generated in the anaerobic chamber; I mean anaerobic anodic chamber. So, it will consume that carbon dioxide, plus it will reproduce the oxygen; that oxygen is helpful. And it will help you to get rid of any kind of any other any requirement of aerator in your system. So, first of all it is acting in a different very like lot of different ways, by which it is actually contributing to reduce the carbon footprint of the system.

First, the carbon dioxide is getting consumed; second, the production of oxygen is surpassing the; because of that it is eradicating the need of aerator in the cathodic chamber okay. I hope you understand. So, you have the at the end, this micro this algae can be extracted; and then it can be used for production of biodiesel and all. So, it is working and then after the extraction lipid extraction is done, that wasted biomass is algal biomass. The lipid extracted biomass that can be used as a forage material you know that can be used for to livestock feed and all. Even that can

be used even in the anodic chamber itself again as a anodic, the food for the anodic microorganisms.

So, it is like a circular economy we can generate out of it. So, that is the beauty of these new technologies that people are working all over the world that it is. We have, we want to make it completely you know sustainable the whole system.

(Refer Slide Time: 17:53)



Sediment microbial capture carbon capture cell. In order to start with, remember we have discussed; last slide we have discussed about microbial carbon capture cell. Here what is the difference between microbial carbon capture cell and sediment microbial carbon capture cell? So, in order to understand that, you need to first understand what is sediment microbial fuel cell? In the left side if you see this picture is actually showing the setup, schematic setup of sediment microbial fuel cell; where if you see like it is like a pond.

Suppose you have a pond, you know the benthic zone of the pond in the bottom; it is normally aerobic in nature. If you go further at least couple of centimeters below that level; it will definitely it is an anoxic an anoxic in anoxic zone is prevailing there. There you can put one electrode okay; because we know it is like simple example. Like it is like simply you are replicating the microbial fuel cell in natural environment. So, you put your what put one electrode in the in the anodic site I mean like then in just a couple of centimeters below the surface of the benthic zone in the pond.

And suppose you put another electrode on the top of it or near to the surface of the water, where there is complete aeration is provided you know in the pond. What will happen? Because of the change, because of this this different positioning of different electrode; you will get some potential difference out of it; that potential difference is utilized. And it is not only helpful like you know, it is not only helpful in getting electricity; but also it will help you to get rid of a lot of different organic matter present in the sediment. It is actually somehow helpful, it is because of this connection, you are actually enhancing the organic matter decomposition in the sediment.

So, because of the presence of because of these electrodes are placed, so the the all the electrolytic microorganisms, they will come in contact with the electrode; and they will enlarge, they will reproduce, and they will become a very thick biofilm layer on the surface of the anode. Because of this thick biofilm, they will consume more amount of organic matter from the sediments on the nearby vicinity. And because of that, the sediment organic load will be reduced. And because of that, they it is this kind of system can be used for somehow help you to get rid of the like you know the harmful effect of the bottom of the benthic zone of the ponds and all; which get very much.

How to say like it is like get a get, get a lot of sediment time to time; and that can that should be utilized, in order to go for further treatment of the (air). Because, otherwise, it will again come in contact with the water due to some turbulence or something; and it will keep on polluting the water in general. So anyway, so this is the fundamentals of sediment microbial fuel cell okay. In the same fundamentals, we have replicated in a microbial carbon capture cell; and then we call them. And in in we call them sediment microbial carbon capture cell. In the sediment microbial carbon capture cell what we are doing?

We have a sediment in the bottom, then we have a layer of you know the water which is completely covered, which is completely there are algae; algae is suspended or present there. And this algae what is it doing? First you see the anode which is present in the in the sediment; you have the cathode on the top, you have this mixture which is helping the algae to be in suspended condition. Then, the carbon dioxide which is getting produced from the system is utilized by the algae. And definitely, whatever the algae present there, they will contribute to the oxygen; which will help to you know to do for the whole system to work much better way.

So, in general it is a this is this is the kind of a complete system which we can build, which will help to understand, involving all the all our understanding on microbial fuel cell, sediment microbial fuel cell, microbial carbon capture cells. And at the end, we can make it as a, we can we can coin; we can name it as a sediment microbial carbon capture cell. What are the benefits? Your sediment is getting treated; your wastewater is getting treated. You can get algae, and that algae can be used for the biodiesel production.

This after the biodiesel production like I mean, after you extract the lipid for the biodiesel production; that lipid extracted biomass has a lot of a lot of applications. Fourth, the bioelectricity generation; the electricity that it generates, that can be utilized for small low energy uptaking devices. Fifth, the no (nee) in there, the reduction in the need of external sources of energy; because, there is algae. So, you do not have to provide it with the aeration to supply with the oxygen, for as it, which can act as a terminal electron acceptor. So, it has a multi facet you know applications and it has a benefit for to be used as a in this kind of treatment unit; and it is very much useful for aquaculture purposes as well.

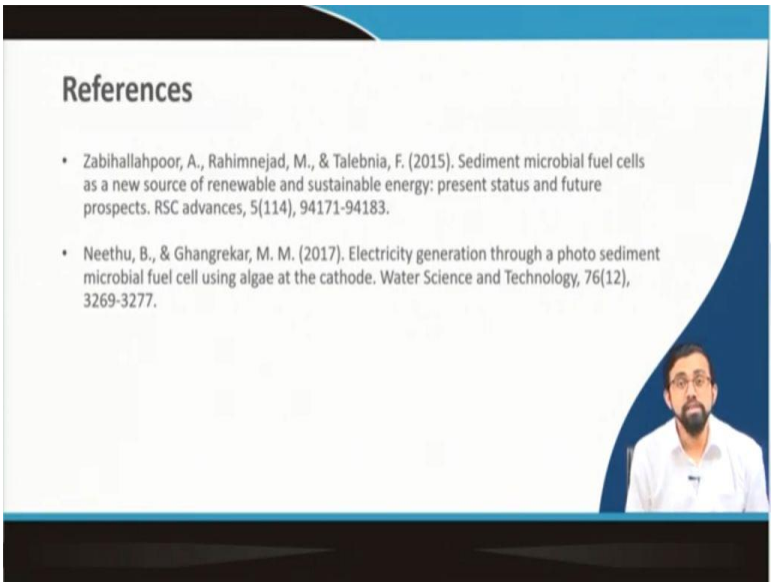
In it has a lot of lot of futuristic application in aquaculture practices, where people will be using in future these kind of systems, to generate electricity from the pond itself; from the pond bottom itself that can be replenished. And the whole pond can be utilized for generating electricity and all. The system is still the people are still working on it, we are working on it; different experts from all over the world working on this kind of technology, and this is the future. And I am pretty much hopeful that it will within a couple of years or so. So, it will become a very ready practice for all the farmers like the features all over the world who are working on this kind of technology; who can utilize this kind of technology and all.

(Refer Slide Time: 23:57)

So, in so I hope you got to know some very important details about MDC and SMFC and also SMCC. So, these technologies have a lot of tremendous amount of application in different industry purpose, municipality purpose; and also you can be utilized in the aquaculture wastewater treatment as well. Not only that it can be used for fish processing industry effluent treatment, and that electricity can be utilized for small energy uptaking devices and all. So, this is the end of this module. I hope you got to know some very interesting information about the some futuristic technology that is that people are working all over the world.

And experts are actually working all over the world. How they are doing it? What what are, what are the fundamentals; and so that it will, it will make you enthusiastic enough to pursue your career on this kind of technology. Or, you can think about it how we can develop further; and I will be very happy to help you with any extent okay.

(Refer Slide Time: 25:05)



These are the references that you can follow to understand more in details about this technology. And I hope you get to know some very important information from this module on wastewater treatment in aquaculture; and will be seeing you in the coming lecture in video. Thank you so much.