Water Quality Management Practices
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Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Dhar bhowmick from the Department of Agriculture and Food Engineering of Indian Institute of Technology Kharagpur. In continuation with our earlier discussion on the bioelectrochemical systems, we discussed in last lecture about the microbial fuel cell. So, here we will be discussing more about some hybrid structure, hybrid configurations of bioelectrochemical systems along with the existing treatment facilities. So, the concepts that we will be covering today in today's lecture are the introduction of the this hybrid systems, microbial fuel cell with anaerobic digester, microbial electrolysis cell with anaerobic reactors, microbial desalination cell, constructed wetland based bioelectrochemical systems, algae based microbial fuel cells and the sediment microbial fuel cells. These are all very advanced bioelectric advanced treatment units the wastewater treatment unit that we all should get to actually you know understand actually it is better for us to you know if we have a little bit of knowledge about those things because believe me you will hear about this technologies a lot in coming future.

To start with we know that our target in the bioelectrochemical systems or in general suppose in any biological treatment systems are to treat the wastewater to treat the pollutant present in the wastewater by some biological means by some microbial activity right. So, this microbial activity to treat the wastewater treat the pollutant present in the wastewater is also the one of the major criteria for the this kind of hybrid systems. So, to start with we know that the in case of bioelectrochemical systems we treat the wastewater and we generate the electricity out of it right. So, the moment we however, there are some limitations we know the first limitations in microbial fuel cell or this kind of bioelectrochemical system is the scaling up.

One of the major problem with this kind of system is a scaling up because I mean like it needs some intrigue part like intricate parts like you know like the cathode anode of the electrode like I mean like this different kind of electrode material, proton exchange membrane, the type of the construction material for this bioelectrochemical systems will also influence its performance. So, in general and also the catalyst the different type of catalyst that we may need to use in this kind of bioelectrochemical systems is one of the major disadvantages of it to be used for scaling up like you know for it to scale up in a in a real real life situations. So, in order to nullify this issues plus the there is some lacunas with the existing treatment system also because it is a energy intensive systems like the aerobic treatment systems it needs the aeration to take place and continuously. So, because of that also it consumes a huge amount of electricity. So, all these things like all these lacunas and all and at the same times the problem the disadvantages of bioelectrochemical systems.

If we merge these two technologies together there are recent studies which they have found that it actually eventually kind of you know nullify each others drawbacks and actually come out as a very efficient waste water treatment systems. I mean like whether it be say aerobic treatment unit along with the bioelectrochemical systems it can be anaerobic treatment unit along with the bioelectrochemical systems. We will discuss about it what are the different types of it, but before that it is very important for you to understand that what is the reason why we are hybridizing why we are trying to design one modular structure with each of this component along I mean like aerobic or anaerobic treatment systems along with the bioelectrochemical systems that we understood in last lecture. Other advantages of this hybrid bioelectrochemical system is hybrid bioelectrochemical systems are that it can extract it can help you extracting the valuable resources such as the methane or hydrogen gas from the waste water plus it will also let us extract some amount of some kind of it is a microbial electrochemical cell or microbial to synthesis cell. We can actually get some valuable byproducts like you know which can be used for further uses like you know butanol, ethanol etcetera and all butanol propanol that can be.

So, carbon dioxide can be converted into this kind of byproducts and so, because of that the carbon dioxide carbon sequestration is also happening plus this valuable byproducts is also having its own benefits own uses in the industries ok. So, try to understand. So, there are multiple verticals of this bioelectrochemical system and the existing waste water treatment systems. The problems that is associated with the existing waste water treatment systems and the problems that is associated with the bioelectrochemical systems can be nullified if we made the hybrid system of hybrid of this to this both the systems. To start with the first one is microbial fuel cell with anaerobic digester.

The synergistic effect of this microbial fuel cell or MFC in short and the anaerobic digestion it leads to the improved removal of the organic pollutants and higher degree of waste water treatment. Just try to understand. Suppose in microbial fuel cell what is happening in the anodic chamber it is an anaerobic chamber itself right other than methanol analysis we are promoting all the rest of the pathway to be finished right in anaerobic digestion pathway to be finished. Then that waste water even if they still have some amount of organic matter left in it if it will go to the next stage of anaerobic digestion system. In the anaerobic digestion systems what will happen it will further reduce the pollutant load or the other way round you can do you can have first let it go through the anaerobic digestion system then it will go to the it will reach to the MFCs.

So, because of this two stage treatment the organic load can be drastically reduced. If organic load is drastically reduced that means, the COD BOD value will reduce so that means, the efficiency of removal the removal efficiency is much higher you understand. Furthermore this biogas that is produced from the anaerobic digestion plus ah the electricity that bioticity that is generated from the microbial fuel cell both are providing an additional sustainable energy source to the system. So, not only it is providing some greener it is coming up as a greener and sustainable approach, but also it I mean like because of its energy efficiency because of its the resource optimised resource uses all these things. And it actually helps us to you know to follow the circular economic principle by extracting the energy from the waste.

So, if you can see it can be of this design. So, if you see we have the say like we have a primary we have the waste water coming to the primary settling tank and the primary settling tank from the bottom from the sludge region you can have it you can use that sludge for the stow white precipitation because it is a high phosphate waste water just for this particular sample suppose it has a high amount of phosphate. So, you can you can actually go for the stow white precipitation method and this stow white can be used for fertilizer as a fertilizer in the agricultural practices. Then from the top from the supernatant low strength waste water will come directly to the USB or it will it can directly go it can go to the USB MFC as well. So, one part of it will go to the MFC and from there MFC the whatever the rich I mean like the waste water from the bottom it will come back to the USB again.

And also from the after the primary the for this stow white precipitation whatever the rest over of the waste water which is almost in the column region that column region that high strength waste water can come to the anaerobic digestion system as well. So, in this case the digestion unit is a flow anaerobic sludge blanket reactor you remember we designed it right. So, in this USB reactor so, if this high strength waste water is coming plus this MFC this rich organic like best like you know press like you know the effluent will come to the USB and from the supernatant which is like almost the void of organic matter it will go to the membrane filtration unit. In the membrane filtration unit what is happening it further reduces the chances of solid it literally filtered out all those possible solid from the waste water and then the final water that will be getting it is a clean water. So, this is a very very effective design of a design scheme like treatment scheme for a high phosphate waste water in any say like you know in a in a industrial build or suppose in a agriculture runoff ok.

So, agriculture runoff it still it is like the it is not in some cases it is not suitable because of less amount of organic matter present there, but for the industrial waste water which does have a high amount of phosphate this kind of treatment scheme is very efficient you understand. So, it is literally we are having a hybrid system. So, one first stage treatment by USB second stage treatment by MFC or microbial fulsal ok. And the third stage third stage polishing treatment by the membrane filtration unit where we can have literally supply some some kind of membrane which will actually separate out the solids from the system and finally, you will get the clean water out of it ok. So, from there what are the additional by product that we are getting we are getting some biogas from the USB and from the MFC also we are getting biogas plus ammonia plus we we are not getting the bio which we only get the ammonia and also the bioretricity.

So, all these things are actually giving us some additional value to the system right. So, the resources that we are using so, it can be if this kind of because of the production of this bioretricity and the because of the production of this biogas which also have some basic calorific value which can be used for heating or some other electricity generation purposes. So, those are actually like reducing the actual impact on the environment and by it will reduce the it will make it optimize the resource optimization process also can be well very healthy in this kind of systems. It can be used for majorly for the decentralized wastewater treatment systems because in the centralized wastewater treatment systems you can the load I mean like you know I mean like it needs some further treatment units as well. So, in case of decentralized wastewater treatment systems when specifically specifically providing certain smaller communities or say like industrial applications it is very suitable this kind of designs ok.

So, it also focus on the efficiency scalability and the economic viability of the MFC. So, with this integrated with the anaerobic digestion the still research is going on and hope like in future this kind of systems will be more in common in our daily like you know in our STPs and all you will see it more frequently. In recently the advancements in the electrode materials the microbial consortia selection you remember the inoculum that we provide and the system design it also contribute to the continuing development of this technology. Other than that further research and technology innovations are likely to expand this further application of this kind of integrated approach and in Kharagpur also in IIT Kharagpur we are also working on this kind of design this kind of system of this different modular structure of this microbial fuel cell along with other anaerobic digestion systems. Another hybrid type of structure is microbial electrolysis cell with anaerobic reactor reactors.

So, what is happening in the electrolysis cell electrolysis cell it is a combination of microbial fermentation of the anaerobic in anaerobic condition plus the electrochemical reactions which will enhance the overall treatment efficiency of the wastewater ok. In case of anaerobic reactor we know that it facilitates the microbial breakdown of organic matter and producing the substrate that can be further utilized in the microbial electrolysis cells ok. So, microbial community present in this anaerobic reactor it produces the electron rich substrate that serve as a fuel for the this MECs for promoting the further aleticity generation. Also this what happens in anaerobic reactor it break down this complex organic molecule in the first stage. So, in the next stage it will help the MEC to further oxidize it to into further intermediates which overall improve the treatment efficiency.

In case of in this both the both this type of reactors it actually produces the hydrogen gas as a byproduct of microbial fermentation and the electrochemical reaction. And this byproduct this hydrogen gas is like prominently predominant like prominently used nowadays for hydrogen fuel cells and also we use it this hydrogen for further like in further uses. I mean like you know we have we can use it you know as a fuel we can use it we can use it for research purposes and every and some other places as well. In methane also has a because of its calorific value it can also be used. So, overall first stage treatment in anaerobic digestion we have a substrate which will reduce it down to the substrate will converted into volatile fatty acids and the CH_4.

The CH_4 will escape from the system this volatile fatty acids will come here. So, it will further produce some metabolites some and the electron formation electrons and protons and the electrons will pass through this power supply to the cathode and the ions protons will also pass directly. So, in this proton what in this cathode what is happening the H plus and electron they come they will react with each other I mean like they will form the H_2. So, this additional amount of additional amount of hydrogen is getting generated in this kind of microbial electrolysis cell where we are additionally supplying the power from the external sources ok. So, this additional amount of power can also be supplied from the you know the methane based bioticity that will generate from there also you can supply the power in this microbial electrolysis cells.

So, this is how it works. So, the fastest treatment in anaerobic digestion system then next followed by the microbial electrolysis cells ok. So, in this kind of cells it is allow the recovery of the valuable nutrients such as phosphorus and nitrogen from the in the form of stuobite or other precipitates. This kind of systems also help to help to mineralize the organic matter which will reduce the overall sludge volume in the systems which is one of the major problem with the conventional anaerobic treatment systems or the aerobic treatment systems for it is more prominent. Major challenge is the optimizing the microbial community in the MEC, managing the reactor conditions and the maximizing the electron transfer efficiency in the MECs. So, for that lot of research is being going on now where people are trying to find out the like perfect type of catalyst which will actually help reducing the I mean like you know first of all reducing the over potential losses and also it will help to increase the power output from the this kind of systems and specifically the hydrogen production rate from this kind of systems.

Further research still going it is still going on to improve the efficiency and the scalability of microbial electrolysis cells for broader application in the wastewater treatment systems and all. Another very interesting system interesting technology is the microbial desalination cell. In the microbial desalination cell what is happening we from the name itself you can understand it is desalinating that means, it is reducing the it is removing the salt from the saline water ok by leveraging the energy produced during the microbial metabolism ok. So, this microbial desalination cells it is normally we normally provide like you know with not only for reduce removing the salt water removing the saline the saline I mean like the salt present in the saline water plus it also used for treating the wastewater simultaneously I will show you the design how it will look like. But in MDC one of the major cost intensive component is the ion selective electrodes or ion selective membranes.

Obviously, electrodes are also there, but ion selective membranes are very important because this ion selective membranes whether it be cation exchange membrane or anion exchange membrane it will help you know split like help the splitted ions to pass through its consecutive like you know respective electrodes ok. This electrochemical gradient it created during this microbial processes drive the movement of ions and its results in the desalinated water. So, why this ions are moving from either side of the either side of the chamber because of the electrochemical gradient that we create during the microbial processes in the anodic chamber. And also this microbial MDCs microbial desalination cells it demonstrated a promising results in terms of say desalination efficiency and for it will be very useful for the places which faces the like you know water scarcity and all. If you see this structure how it works you have a influent salt water this chamber is called the desalination chamber then you have a cathode chamber you have a anode chamber ok.

So, in the desalination chamber what is happening? So, we introduce the salt water NaCl suppose ok. Here in this side we have a cation exchange membrane in this side we have an anion exchange membrane. So, this NaCl because of this potential gradient. So, what will happen it will it will split into like you know say Na sodium and the chloride ion. This sodium ion will pass through this cation exchange membrane to the cathodic side and the chloride ion will pass through this anion exchange membrane to the anodic side.

So, just realize why we need this anode exchange anion exchange membrane here. So, so that it will selectively pass only the anions ok. So, same as same is reason is valid for the cation exchange membrane as well. So, the moment it will come this chloride ion chloride ion is will come to the anode structure and the anode in the electrode. So, what will happen here it will reduce it will release some amount of and also in this chamber anode chamber chloride ion is also coming as well as the waste water is also introduced we are introducing the waste water also here.

So, waste water and it reacts with the it actually helps the bio frame consumes the pollutant present in the waste water and it will also generate some amount of electrons. So, this additional amount of electrons that is present that is coming from the desalinated water as well as from the waste water it will help it will pass through this external resistance to the cathode ok. And in the cathode what is happening in the cathode this sodium plus ion it is coming here as well as it also has like you know this you know this oxygen that is we are supplying through the external aorta. So, this oxygen it reacts with this H plus ion and which the electron that is coming from the anodic chamber anode to the cathode. So, it reacts with them and it forms the H 2 O.

So, it will not only forms the H 2 O, but also it actually it directly forms the from because of the aqueous cathode condition it forms H 2 O and it is a in the air cathode it also forms the H 2 O, but only the oxygen present in the air just try to understand. So, one side of this cathode is aqueous and one side of the cathode is air that is why it is called air cathode this side and this side is the aqueous cathode. In the aqueous cathode what is the source of oxygen the dissolved oxygen in the air cathode the source of oxygen is the air present oxygen present in the air. So, here because of this because of this fundamentals we are producing the H 2 O and because of that the oxygen is getting reduced and the system will keep on going. So, with time what is happening we are reducing the pollutant load because of the bio frame microbiol bio frame that is present there.

It will reduce the pollutant load it will the system desalination chamber will desalinate the water I mean at after desalinated desalination is done the treated salt water will having a will be having a less amount of it is salinity will be much less than the influent wastewater influent desalinated water. So, this is what call the microbial desalination cell. In one chamber itself you are having the wastewater to wastewater will be purified the electricity is getting generated plus the this the salt water can be like salinity can be reduced. So, you just imagine like it has a multiple uses ok. So, this kind of systems are quite effective for especially when suppose you want to treat the water from the your I mean say like you know it is from the sea water you can treat the sea water and this kind of systems and you can reduce the you can reduce it down to the you can do the desalination procedure in this kind of MDC systems.

So, now, we are in IIT Kharagpur we are also working on this kind of desalination cell, but in a much smaller sized material. So, make it in a microfluidic chamber literally and we are trying to achieve the goal anyway. So, this is how the microbial desalination chamber works ok. So, it can be integrated into the existing treatment plants which provide the additional method for both wastewater treatment as well as desalination. It is energy efficient nature because microbial process is there and involved and integration of desalination it reduces the carbon footprint.

Despite the promising results there are some challenge first is the scalability second is the cost effectiveness and the optimization of the technology in real world applications. Scalability is a biggest issue and one of the then that is what we are working on people from all over the world different scientists are working on it. So, trying to find out the optimal design of this kind of microbial desalination cell. So, that it will be effective for you know for application for real life applications. So, another impact of this kind of microbial desalination cell is like you know when it is used for suppose you have a tight fed farm ok.

So, you have a tight fed or the pump fed farm right next to the coastal region for say like you have for stream culture and all. So, what happened there you need the salt water right saline water. So, you can design it such a way that the salt water will come to your farm, but it is not only the salt water, but there is a chance obviously, for running the regular activities in the farm you also need the fresh water source. But however, it is very difficult to get a fresh water source right next to the oceanic regions ok. I mean like so, in that case what you what you can do you can have installed this kind of desalination cell it will it will reduce the salinity level of some amount of water which the you based on your demand you can structure it you can design the hydraulic retention time as well as the volume of the desalination chamber.

And then the final water will be having a less amount of it is like salinity level. So, this less less saline water or this desalinated water can be used for some further purposes can be used for even diluting the the the the the the farm water itself for some at some maturation stage of the of your rearing species. So, there are different uses of this kind of MDCs in in a real life scenarios as well. Next one is the constructed wetland based biotechnical systems we already know we already designed one constructed wetland if you remember. So, constructed wetland we all know and we know that it can increase the ah the the pollutant it can reduce the pollutant load from the waste water like anything.

Now, imagine if you have if you design a constructed wetland along with the microbial fulsar. So, microbial fulsar itself have ah has some capacity to reduce the pollutant load and also increase the also generate the electricity bioticity out of it. So, plus when you design it along with the constructed wetland which also ah is successfully proven to be ah reducing the pollutant load from the system. So, obviously, it will be much more ah useful ok. This kind of ah integrated systems where this constructed wetland plus biotechnical systems it will effectively remove the nutrients such as nitrogen and phosphorus as well.

It also helps to mitigate the environmental impact on the waste water discharge by treating their pollutant and promoting the sustainable water management practices. It also reduce the reduce the reliance ah on the external energy sources contribute to the lower environmental impact ah than the traditional waste water treatment methods because this biotechnical systems it it it actually produces some amount of electricity some amount of bioticity. So, not only it does not require any additional sources of energy, but rather it produces some amount of energy ok. If you see this structure so, we know this is the constructed wetland type systems. We have the on the top we have this constructed plants wetland plants and we have certain heights.

So, in the on the bottom definitely we know that it will there will be like anaerobicity that will be prevailing on the bottom and on the top because of you know we you remember we discussed about it that this kind of wetland plant plant they can release some amount of oxygen it makes a little bit of aerobic environment on its root zone right next to your root zone plus it is almost at the top this cathode. So, it there will be exchange of air also on on the very first few centimeter from the surface. There we place the cathode so, that cathode will have ample amount of oxygen ah to get reduced by into by consuming the electrons that is coming from the anode. So, this is how a natural systems just imagine in future there will be there will be time where you know you just convert the regular right next to the drainage system like suppose you have a drainage system right next to the I mean like you have it suppose in the right next to the street. So, from the drainage systems you can design in such a way in the bottom of the drainage systems which definitely will prevail in anaerobic condition.

So, you can have a electrode or some electron collector and on the top you can have a floating cathode and you can place a lot of this constructed wetland plant there. So, what will happen it will this kind of treatment systems it will reduce it will increase the this is chances of electricity generation plus it will make it more nicer ah order free ah it will look very aesthetically beautiful plus the electricity that you will get that can lead the ah the street lights ok. You can store it somewhere in the super capacitor and then you can use it in the evening for the ah leading the street lights it will drastically reduce the ah the electricity load I mean like the the the power consumption ah by your city city area and all. So, this is like the futuristic model that people are working on there are some structures which are already there at place and some more modifications needs to be done to make it to the real life scenario. So, this kind of systems can be used for both centralized as well as a decentralized wastewater treatment systems.

It can be applied with the different settings including the municipal wastewater treatment, industrial waste wastewater treatment or the small scale community applications. There are research going on all over the world where they are trying to we are trying to optimize the design and the performance of this constructed wetland micro bulb also to mini maximize the both wastewater treatment efficiency plus the electricity generation. There are some challenges that needs to be ah well understood it is first of all the problem with the scaling the micro bulb community and third is the addressing the potential limitation regarding the pollutant removal rates which are already we are working on it and people are actually we have already there are literatures which are available they mention that this limitations are can be actually ah like you know it is not it is not ah like you know now those problems are not there anymore because if you can design it perfectly the constructed wetland can drastically reduce the organic load and plus it will also help the micro bulb also this bioretrogonal systems which as attached along with it. So, it will also increase the chances of anaerobic digestion in the anodic the in the anodic chamber or the anodic side of the constructed wetland because of this electrochemical additional electrochemical potential differences and all and also this kind of the affinity of this specific type of biofilm this exo-illotogens which will consume huge amount of ah organic matter and it will further increase the potential of using this kind of systems in real life scenarios. Then there comes the algal microbial fuel cells where ah we are integrating the both the capabilities of algae as well as the microbial fuel cell for treating the wastewater.

So, how algae is useful we know that the algae is can ah first of all it can consume the carbon dioxide that is generated that is being generated from the microbial fuel cell. So, it will further reduce the pollutant load by this kind of systems. Second thing this algae also also consuming some amount of ah pollutants some amount of nutrient from the wastewater and it will do further polishing treatment to the MFC treated water or the ah bio-autochemical system treated water. So, it not it so, first of all it ah ah this it algae it is a it plays a crucial role ah by harnessing the solar energy through the photosynthesis and converting the light energy into organic matter plus it presents in the bioreactor it produces the biomass it contribute to the removing nutrients as I mentioned nitrogen and phosphorus. It ah it further it help to remove the organic pollutant as well from the systems it reduces the heavy metal load because of the algal the algae present there.

And overall this overall this ah algae can also used as a carbon sequestration ah process as a I mean like because it convert it consumes the carbon dioxide coming out of this microbial fuel cells. So, if you see this design in the right side we have this anodic chamber ok, in the left side we have a say we have this algal chamber ok. So, what is happening in this chamber in the anodic chamber it is a it is an anaerobic in nature. So, we introduce the feed we introduce the waste water. So, waste water is consumed by the exiloptrogens it produces electricity electrons that electron will go to the cathode.

In the cathode we have a attached or say like you know suspended algae even algae population this algae population it will what it does it also help the like you know carbon dioxide that is generated from this system which will you can supply this carbon dioxide which used and it will be converted to oxygen and this oxygen will be used for ah obviously, because of the photosynthesis process it will release the oxygen this oxygen can be used for reduction for reducing the ah electrons the for reducing the oxygen by consuming the electrons ah from the cathode systems and it will convert into a H2O. So, this is the very holistic approach if you see it not only reduces the ah carbon dioxide load from the system from the bio hetero chemical systems it increases the power performance of the system plus the whatever the residue of this ah feeds for this algal residue which the diet algae they can be again supplied as a feed to the system. This diet algae is also as a it is a resource of ah biomass it is like you know it is like a closed system it is a closed system it is feels like a closed systems the same algae it is the dead biomass is actually helping the provide the electrons this electrons will come here and the carbon dioxide will generate that will come here that will also help and plus light energy is there. So, light energy is keep on converting into some biomass which biomass is supplied to the anodic chamber from the anodic chamber the electrons come here and it will ah oxygen will reduce be reduced by consuming this ah taking this electrons and form the H2O. So, it is like a very holistic approach of a system that we can actually design this algae based microbial fuel cells and all.

So, there are multiple researchers working in the in this field and there are lot of ah high like you know field scale models are also in the picture already in the market and it will be the future I mean like I am telling like lot of discussion will be made in near future about using it in this kind of systems as in a conventional wastewater treatment systems ok. So, it can be used for different type of wastewater treatment facilities it can potentially reduce the sludge production compared to the traditional systems and also it can recover the valuable resources such as nutrients and metals from the wastewater and optimize the performance of the systems for ah practical applicability of ah this kind of microbial fuel cell ok. Another system that we need to understand is called as sediment microbial fuel cell. So, we know that the sediment ah like you know pond sediment and all where the culture is going on the fish culture is going on. So, this pond sediment is actually rich in as rich in you know and like you know different diversified microbial community.

This diversity diverse microbial community can be ah we can make use of this diverse microbial community and they can actually help us ah getting some ah electricity out of it, bio electricity out of it plus that by sediment will also get treated it can be treated a little bit. So, what is happening your pond bottom where there is a lot of benthic population will go and collected ah detrituses will be there and because of that it will prevail a anaerobic system anaerobic ah environment. In this anaerobic environment you place the anode ok and on the top you place the cathode in the aerobic environment in the top of the surface of the water. So, because of this ah this change in the anaerobic city anaerobic city to aerobic city and as well as the electrodes that is present there which will really use the which will be ah like in a perfect ah building place for ah the how to say this ah different ah exerotogen to grow there. It will definitely consume a huge amount of ah this pollutant organic pollutant that is present there and it will also help this kind of system will also help to reduce the pollutant load over time ok.

Otherwise what happen this pollutants will release a huge amount of methane to the system and actually it does not give any help to the I mean like any help to the community. So, in this, but rather in this sediment once we place the electrode and we use it as a ah combination of bio electrochemical system it will help us to you know get ah more ah some amount of ah ah electricity out of it, bio electricity out of it and it will reduce the overall impact on the environment. If you see it looks like this on the bottom on the sediment we have the anoxic zone where you can place the anode and this anode because of the redox because of its high redox potential what is happening it is it will be there will be like additional amount of ah electrons that will be generated here like by cons by the biofilm present there that will consume the ah organic matter present here and it will then pass it through the resistance to the cathode which will in that which will be in the oxygen on that water on the top where the water oxygen present in the aqueous condition will actually converted into H 2 O 2 in this kind of case or H 2 O. If it is a 2 electron transfer process is H 2 O 2 it is a 4 electron transfer process it is H 2 O. So, this is the process how it looks like and this process is just simply placing some electrode you can start getting the electricity.

Those electricity can be stored in a super capacitor and it can be used for ah like you know powering the small sensors in the remote test of the locations ok. So, that is why the future of this treatment systems are ah leading now. ah This kind of integrations are quite effective for existing wastewater treatment system also you can retrofit it. This can also increase it aligns with the environmental sustainability it the some challenges are still there like scaling up issues I told you, but this can be easily addressed with time and we are ah working on it. So, ah in conclusion we ah discussed about the combination of ah 2 or 3 different units in a same along with the biotechnical systems which will ah help combining the biological and electrochemical process for treating the wastewater generating the electricity and recover the valuable resources.

We discussed about different types of hybrid biotechnical systems including the MFC ah with anaerobic digester MEC with anaerobic reactor ah MDC constructed wetland based BES algae assisted MFC sediment MFC etcetera. What are the advantages we discussed like this hybrids are this hybrid systems which actually includes like you know ah improve wastewater treatment efficiency reduces the energy consumption and the environmental impact it enhances the resource recovery and the potential for decentralized and modular applications. However, the challenges major challenges and research directions ah include the optimizing the system performance, scaling up for the large larger applications and addressing the technical and the economical barriers and exploring diverse microbial communities and their interactions at this moment are the major research problems that if you are interested in doing research in this field you can work on it and actually come up with some solutions. So, that it the technology readiness level of this kind of systems can make to do up to 9 8 to 9. This is the references I hope you get to know some very interesting fact about ah some hybrid biotechnical systems I hope you get learn something very new and very interesting. So, thank you so much ah see you on the next video.