Power Upgrading by MICROBIAL FUEL CELL

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ABSRACT

Microbial fuel cell is a device which generates pollution free energy by converting bacteria into electrical energy by cleaning bacteria from waste and mud. In Recent times electricity playing a vital role for mankind in order to avoid shortage of electricity we are using renewable energy sources for generation of electricity. By using our technology organic materials are collected to get electrochemical reaction metabolism of microbes such as electrogenic bacteria Shewanella or Geobacter which causes proton Exchange Membrane (PEM)

Keywords: renewable energy technology, electrogenic bacteria, microbial fuel, PEM, shewenella, geobacter

I. INTRODUCTION

In olden days the electricity came from material amber. Now days there are many ways to generate electricity. In that conversion from bacterial energy to electrical energy to electrical energy in view of many outputs. Here we use a bacteria named as geobacter which is non harming bacteria to human and causes electro conversion. Basically we have two types of bacteria are there they are Aerobic bacteria and Anaerobic bacteria.

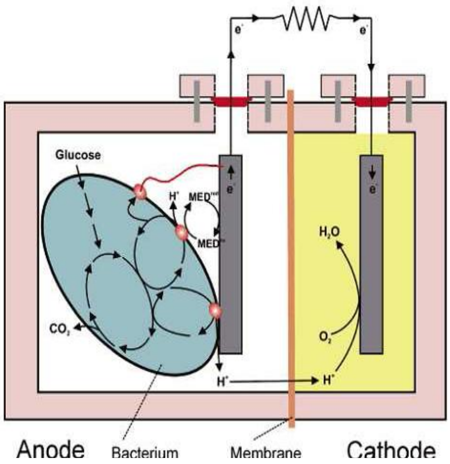
Many research and technological advancements have been made in the area of renewable energy sources and technology. This is due to the rapid exhaustion of the fossil fuel based energy sources which continuously increase in cost i.e. oil. On top of its unsustainability and high-cost, it is also a major cause of Greenhouse Gas emissions (GHG) in the atmosphere which has significant environmental impacts. There has been a significant shift of focus towards renewable technologies for many decades at this stage; from wind energy to wave energy, solar and even nuclear technology. This is indicative of the urgency to switch to a sustainable approach in generating power and there are legislations and directives such as the Kyoto Protocol to drive this in order to reach the goal of reducing GHG emissions by at least 18% below the 1990 levels by the year 2020.Another potential area of renewable energy source which has resurfaced in recent times as modern technology begins to accommodate and to explore its possibilities; is the generation of power using bacteria. According to Moqsud et al., microbial fuel cells (MFCs) facilitate this process and have gained a lot of attention recently as a mode of converting organic matter into electricity .It takes advantage of the sheer amount of microorganisms breaking down substrates found in places such as wastewater, sludge, sediments under the sea and any other places where bacteria growth is abundant. This concept of utilising microbes as catalysts1 in fuel cells was explored as far back as the early 1970s. "However, it is only recently that microbial fuel cells with an enhanced power output have been developed providing possible opportunities for practical applications."

The microbial fuel cell is a bio-electrical system in which bacteria is used to convert organic material into electricity. The fuel cell itself is made up of four parts; the anode, the cathode, the proton exchange membrane and the external circuit. The electrons are pulled out as released energy during the oxidation process and into the electron acceptor via an external circuit. The protons pass through the ion/ proton exchange membrane and react with the electrons during the reduction process in the cathode thus completing the circuit. This simple process which is common and found in most fuel cells i.e. battery cells, hydrogen fuel cells can be optimised for an efficient current generation. The exploration of various materials used in electrodes that balances efficiency and cost-effectiveness is the key to the potential large scale use of MFC particularly in wastewater treatment plants which is hoped to be a power generating plant as opposed to a power consuming plant.

II. MICROBIAL FUEL CELL DEVELOPMENT:

MFCs technologies represent the newest approach for generating electricity– bioelectricity generation by using bacteria. While the first observation of electrical current generated by bacterial is generally credited to Potter in 1911, very few practical advances were achieved in this field even 55 years later . However, in the past three to four years there has been Resurgence in microbial fuel cell research. Advances have included the development of what could be the first microbial fuel cell that can generate more conventional power sources for its designated application. Significant efforts have been undertaken for developing better systems for harvesting electricity from organic wastes and the discovery of microorganisms with enhanced capacities for sustained, efficient electricity production. Biological optimization implies the selection of suitable bacterial consortia and the bacterial Adaptation to the optimized reactor conditions. Although, the selection of the bacterial inoculums will largely determine the rate of enrichment, it does not determine the structural outcome of this Procedure. Based on a mixed anaerobic–aerobic sludge inoculums and using glucose as

feed, seven-fold increase in bacterial substrate to electricity conversion rates were observed after three months of microbial adaptation and selection. Much faster increase in electricity production was noted when larger anode surfaces were available for bacterial growth



Structure of mfc

Microbial fuel cells produce electricity from organic matters. Unlike conventional fuel

Cells, MFCs have certain advantages like high energy-conversion efficiency and mild reaction conditions. In addition, a fuel cell's emissions are well below regulations. MFCs also use Energy much more efficiently than standard combustion engines which are limited by the Carnot Cycle. In theory an MFC is capable of energy efficiency far beyond 50%. In fact, Using the new microbial fuel cells, conversion of the energy to hydrogen is 8 times as high as Conventional hydrogen production technologies.

In an MFC, bacteria are separated from a terminal electron acceptor at the cathode so That the only means for respiration is to transfer electrons to the anode. An MFC is thus a bioelectrochemical system that derives electricity by mimicking bacterial interactions found in nature. Microorganisms' catabolism compounds such as glucose, acetate or wastewater . It is a device that converts chemical energy to electrical energy by the catalytic reaction of microorganisms. A typical microbial fuel cell consists of anode and cathode compartments. In the anode compartment, fuel is oxidized by microorganisms, generating electrons and protons. Electrons are transferred to the cathode compartment through an external electric circuit, and the protons are transferred to the cathode compartment through a separator. Electrons and protons are consumed in the cathode compartment, combining with oxygen to form water. In general, there can be two types of microbial fuel cells: cells with mediator and cells without mediator. Such biological fuel cells take glucose and methanol from food scraps and convert it into hydrogen and food for the bacteria. The electrons gained from this oxidation are transferred to an anode, where they depart through an electrical circuit before reaching the cathode. Here they are transferred to a high potential electron acceptor such as oxygen. As current now flows over a potential difference, power is generated directly from microbial fuel by the catalytic activity of bacteria.

Microbes used in Mediator-less MFCs **Microbes**	**Substrate**	**Applications**
Aeromonas hydrophila	*Acetate*	*Mediator-less MFC [6]*
Geobacter metallireducens	*Acetate*	*Mediator-less MFC [7]*
Geobacter sulfurreducens	*Acetate*	*Mediator-less MFC [8]*
Rhodoferax ferrireducens	*Glucose, xylose*	*Mediator-less MFC [9]*
Shewanella putrfaciens	*Lactate, pyruvate*	*Mediator-less MFC [10]*

The microorganisms have the ability to produce electrochemically active substances that may be either metabolic intermediaries or final products of anaerobic respiration [8]. When microorganisms consume a substrate such as sugar in aerobic conditions they produce carbon dioxide and water. However when oxygen is not present, they produce carbon dioxide, protons and electrons [9].

$C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e$

2.MICROBES:

Firstly, in order to understand the fundamental function of the MFC, it is important to have a grasp in some of the basic functions of the bacteria. In essence, bacteria breakdown organic matter and release energy in the process. Extra attention will be paid to certain bacteria which have the ability to generate electricity and to transfer electron effectively in the anode[2]. This type of bacteria is called Exoelectrogens[3], "exo-"for exocellular and "electrogens" based on the ability to directly transfer electrons to a chemical or material that is not the immediate electron acceptor. There are many anaerobic bacteria that can only transfer electrons to soluble compounds such as nitrate or sulphate (not cell synthesised) that can diffuse across the cell membrane and into the cell. Exoelectrogenic bacteria are the most suited to function within an MFC due to their ability to transport electrons outside of the cell. This type of bacteria is useful in mediator-less MFC, a MFC system which do not require a 'mediator' to assist in electron transfer. Some mediators include, thionin, sulphate/sulphide methylene blue, pyocyanin etc., as well as others. These exoelectrogens can be sourced in a number of places, according to *Du et al*, they are found in soil, marine sediment, waste water, fresh water sediment and activated sludge, which are rich with these microorganisms.

An interesting relationship is found between exoelectrogens and fungi in recent studies which potentially increases stability in electron transfer as fungi act as a natural organic mediator.

This can be a significant step toward scaling up MFC systems as fungi and bacteria can be found naturally.

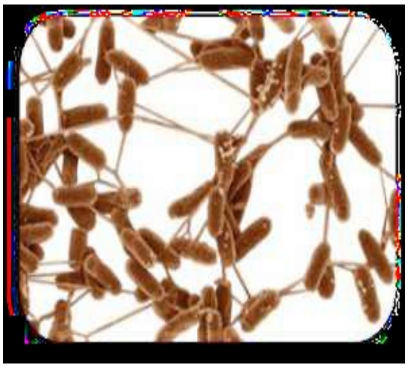
2.2 PRINCIPLE OF FUEL CELL:"Microbial fuel cells (MFCs) are electrochemical devices that use the metabolic activity of microorganisms to oxidise fuels, generating current by direct or mediated electron transfer to electrodes."[3], [12] The device comprises of an anode chamber, a cathode chamber, electrodes, proton exchange membrane[4] and an external circuit. The MFC convert a biodegradable substrate directly into electricity. [13] The anode holds the bacteria and the organic material in an anaerobic environment. The cathode holds a conductive saltwater solution in a double chamber type MFC or air if it's the single chamber. The bacteria generate protons and electrons as the organic substrate is being converted into energy. This energy is used and stored by the microbes for growth. The electrons are transferred directly to the anode electrode (in a mediator-less set-up) and to the cathode electrode via a copper wire or a conductive material. Protons pass through the ion exchange membrane to the cathode chamber to produce water as a result of the reduction process which is in terms of hydrogen transfer: Not all bacteria species are able to transfer electrons directly, therefore use of artificial chemicals such as "thionine, humicacid, neutral red, methyl blue and methyl viologen" is required. These are called redox mediators.

According to Logan5, the bacteria grow in the anode, oxidising matter and releasing electrons as they break down the substrate. Some bacteria require exoelectrogenic biofilms in order to effectively transfer the electrons to the electron accepter whereas some transfer electrons directly without the need of a mediator. The cathode is supplied with air or other inoculum to provide dissolved oxygen for the reaction of electrons via an external circuit, protons and oxygen at the cathode, completing the circuit and producing power.Chemical energy is converted into electricity by the microbes which releases electrons and hydrogen ions which from water. The oxygen is supplied in the cathode chamber by air or other oxygen source. The material used in the electrodes significantly influences the overall efficiency.

Objectives:

It is needless to stress on the universal fact that there is a lot of biowaste that could actually be considered as stored energy. This waste in liquid form could allow bacteria to Convert it to electricity. This aspect is worth researching indeed which is why it was chosen in our work. We have thus far mentioned that voltage generated in microbial fuel cells decreases with respect to time [48]. We have also come to know that a mixture of nutritional substrates can result even in higher extractable current than any single component [28]. It is therefore important to know in what way the voltage gets decreased. That would be known if we can fit a mathematical model expressing voltage as a function of time. From the model, we would be able to evaluate the rate of change of voltage with respect to time. We would further be able to see whether the rate of change is a constant or is time dependent,

and this would give us the mathematical model in terms of a differential equation. From the mathematical model, so as to have an idea practically how long a cell remains functional, to evaluate the rate of change of the generated voltage with respect to time, to extrapolate how long the microbial fuel cells stay functioning, and to observe whether a mixture of biowastes does actually resulting higher voltages.



MFC principals as described above, whereby Soil acts as the nutrient-rich anodic media, The inoculum and the proton-exchange Membrane (PEM). The anode is placed at a certain depth within the soil, while the cathode rests on top the soil and is exposed to the oxygen in the air above it MFCs generate maximum power when subjected to an external resistance that is equal to its own internal resistance. This internal resistance is a function of the ability of ions to diffuse through the MFC media from anode to cathode. The lower this internal resistance, the more power the MFC will produce. There are many ways to decrease this resistance, such as adding electrolytes (salts) to the media, and shortening the distance between the anode and cathode, while still ensuring that there is enough distance to achieve a suitable oxygen gradient.For more hints on how to minimize your internal resistance and maximize success with your **MudWatt MFC**.

To find the internal resistance of your Mud Watt as well as its maximum power output, you will need to perform a technique called "potentiometry" (also referred to as a "sweep"). This involves reading the voltage output from your MFC over various resistances. For your convenience, your MudWatt™ electronics includes a series of 5 resistances that can be easily switched on and off. Instructions for performing a "sweep" are provided in your instruction pamphlet. Once you've performed a "sweep" on your MudWatt™ MFC, you will be able to generate a power curve, like the one shown to the right, by simply using Ohms

P = Power (Watts)

V = Voltage (Volts)

R = Resistance (Ohms)

P=V.V/R (Watts)

Once a microbial community forms on the anode, its natural metabolic pathways begin to break down the nutrients within the surrounding media, generating highly reduced biomolecules (i.e. biomolecules with extra electrons attached to them). These biomolecules then donate their spare electrons to the anode in one of three ways, as diagramed below:

1) Direct transfer from the microbe's cell wall to the anode surface

2) Employing a secondary biomolecule to shuttle the electron to the
Anode

3) Transferring the electron through conductive appendages, termed"nanowires", grown by the microbial.

These nanowires can form vast conductive networks Known for their versatility, *Shewanella* species can be found almost **everywhere** on earth, from mountain soils, to ocean sediments. They have an ability to metabolize a wide variety of elements that are toxic to humans, yet they don't cause disease in humans. They even have the ability to metabolize radioactive **Uranium**, precipitating it out of contaminated waters.

These abilities make *Shewanella* an ideal bacterium for **bioremediation** processes**.** Known as the **"iron-breather"**, *Geobacter* species have the ability to "inhale" iron compounds and use them in a way similar to the way humans use oxygen.

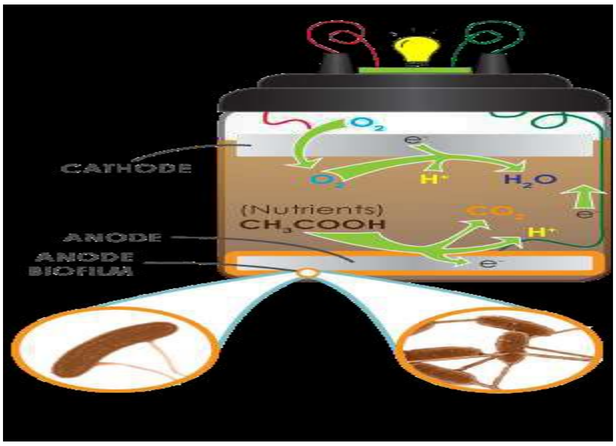
In fact, they prefer to live in environments where there is no oxygen, such as deep underground or within ocean sediments. *Geobacter* species have the ability to consume many environmental pollutants, including **petroleum** and **Uranium**, and have been used in many soil and water **bioremediation** efforts.

Standard Electrode Potentials. The reactions occurring in the MFC can be analyzed in terms of the half cell reactions,or the separate reactions occurring at the anode and the cathode. According to the IUPAC convention, standard potentials (at 298 K, 1 bar, 1 M) are reported as a reduction potential, i.e., the reaction is written as consuming electrons For example, if acetate is oxidized by bacteria at the anode we write the reaction as

2HCO3-+ 9H+ + 8*e*- f CH3COO- + 4H2O

material of construction of MFC

Anode: Anodic materials must be conductive, biocompatible and chemically stable in the reactor solution. Metal anodes consisting of non-corrosive stainless steel mesh can be utilized but copper is not useful due to the toxicity of even trace copper ions to bacteria. The most versatile electrode material is carbon, available as compact graphite plates, rods or granules, as fibrous material (felt, cloth, paper, fibers, foam) and as glassy carbon.



Bacteria in mfc

Cathode: Due to its good performance, ferricyanide (K3[Fe(CN)6]) is very popular as an experimental electron acceptor in microbial fuel cells. The greatest advantage of ferricyanide is the low over potential using a plain carbon cathode (Figure. 6), resulting in a cathode working potential close to its open circuit potential.

Reticulated Vitreous Carbon (RVC) with different pore sizes (10, 20, and 45 pores per inch)

The greatest disadvantage, however, is the insufficient reoxidation by oxygen, which requires the catholyte to be regularly replaced.

In addition, the long term performance of the system can be affected by diffusion of Ferricyanide across the CEM and into the anode chamber. Oxygen is the most suitable electron acceptor for an MFC due to its high oxidation potential, availability, low cost (it is free), sustainability and the lack of a chemical waste product (water is formed as the only end product). The choice of the cathode material greatly affects performance and is varied based on Application.

Membrane: The majority of MFC designs require the separation of the anode and the cathode compartments by a CEM. Exceptions are naturally separated systems such as

sediment MFCs or specially designed single-compartment MFCs. The most commonly used CEM is Nafion. Alternatives to Nafion, such as Ultrix CMI-7000 also are well suited for MFC applications and are considerably more cost-effective than Nafion. When a CEM is used in an MFC, it is important to recognize that it may be permeable to chemicals such as oxygen, ferricyanide, other ions, or organic matter used as the substrate. The market for ion exchange membranes is constantly growing, and more systematic studies are necessary to evaluate the effect of the membrane on performance and long-term stability

Thermodynamics and the Electromotive Force: Electricity is generated in an MFC only if the overall reaction is thermodynamically favorable. The reaction can be evaluated in terms of Gibbs free energy expressed in units of Joules (J), which is a measure of the maximal work that can be derived from the reaction calculated as

$$\Delta Gr=\Delta Gor+RTln(\Pi)$$

where ΔGr (J) is the Gibbs free energy for the specific conditions, ΔGo r(J) is the Gibbs free energy under standard conditions usually defined as 298.15 K, 1 bar pressure and 1 M concentration for all species, R (8.31447 J mol-1 K-1) is the universal gas constant, T (K) is the absolute temperature and Π (dimensionless) is the reaction quotient calculated as the activities of the products divided by those of the reactants.

Losses of mfc: every technology consists of losses in the same manner our mfc contains some losses are as follows

(i) Ohmic losses, (ii) Activation losses, (iii) Bacterial Metabolic losses and (iv)
Concentration losses.

Future scope: MFC designs need improvements before a marketable product will be possible. Both the issues identified above and the scale-up of the process remain critical issues. Most of the designs Reviewed here cannot be scaled to the level needed for a large wastewater treatment plant which requires hundreds of cubic meters of reactor volume. Either the intrinsic conversion rate of MFCs will need to be increased, or the design will need to be simplified so that a cost-effective, large scale system can be developed. Designs that can most easily be manufactured in stacks, to produce increased voltages, will be useful as the voltage for a single cell is low. In the long term more dilute substrates, such as domestic sewage, could be treated with MFCs, decreasing society's need to invest substantial amounts of energy in their treatment. A varied array of alternative applications could also emerge, ranging from biosensor development and sustained
energy generation from the seafloor, to bio-batteries operating on various biodegradable fuels

III. CONCLUSION

Microbial fuel cell is a device which generates pollution free energy by converting bacteria into electrical energy by cleaning bacteria from waste and mud. In Recent times electricity playing a vital role for mankind in order to avoid shortage of electricity we are using renewable energy sources for generation of electricity. Especially in India we can see lot of ponds and drain dumps where we can find bacteria which must be cleaned. The ultimate achievement in MFCs will be when they can be used solely as a method of renewable energy production. Thus, advancements in power densities, reductions in materials costs, and a global need to produce power without net CO_2 emissions may one day make MFCs practical just for electricity production. It will be a great success in the field of renewable energy production if we will integrate this small production of electricity in to powerful electricity.

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