

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 3, March 2020

## A Review on Green Energy Production Using Microbial Fuel Cell (MFC) Technology

A. Sam Sushmitha <sup>1</sup>, Dr. G.L. Sathyamoorthy <sup>2</sup>

P.G. Student, Environmental Engineering, Department of Civil Engineering, Kumaraguru College of Technology,  
Coimbatore, India<sup>1</sup>

Professor, Department of Civil Engineering, Kumaraguru College of Technology, Coimbatore, India<sup>2</sup>

**ABSTRACT:** Globally the demand for electricity is pretty high. In order to overcome the dependence of fossil fuel and to provide alternative renewable energy generations, Microbial Fuel Cell (MFC) Technology could be adopted. MFC Technology employs microorganisms for the production of electricity in which the organic matter present in the waste/wastewater first converted to chemical energy and thereby it converted to electrical energy including the treatment of waste/wastewater to the desirable limit. In general, Microbial Fuel Cell consists of an anode and a cathode compartment which undergoes oxidation and reduction respectively and this helps in the flow of electrons to produce electricity. These two compartments are separated by proton exchange membrane or salt bridge for transfer of protons. In this paper an extensive review of literature has been carried out focusing on low cost electricity production from various kinds of wastes/wastewater using inexpensive electrodes and components.

**KEYWORDS:** Electricity, Microbial Fuel Cell (MFC), Wastewater, Microorganisms, Anode, Cathode, Proton

### I. INTRODUCTION

As worldwide energy production and utilization are the major hitch that are increasingly day by day which eventually leads energy demands in the modern world. The primary energy consists of original/readily available or unconverted fuel which includes energy generated from natural gas, coal, crude oil, hydro power and as well as by other means such as nuclear energy, wind power, geothermal power. The secondary energy consists of resources that have been converted or stored. Secondary energy includes the fuel production with low calorific value such solar energy, bio energy. The secondary energy is converted from primary energy. As the demand for energy increases, researchers have moved forward to find a solution for alternative and renewable energy sources i.e. Microbial Fuel Cell Technology. Microbial Fuel cell is a promising technology for energy generation which comes under secondary energy production. Microbial Fuel Cell has the potential to concurrently treat wastewater and generate electricity. In Addition, Microbial Fuel cell is considered to be environmental friendly and alternative energy resource to fossil fuel. Microbial Fuel cells seem to resolve our twin problems of increasing pollution and diminishing the dependence of fossil fuel. It is very fine alternate energy with high Efficiency and economically priced.

Microbial fuel cell is a fuel cell which converts chemical energy into electrical energy by means of microorganisms. Microbe uses substrates as fuel (wastewater) from renewable sources, convert them into benevolent by-products & generate electricity. Microbial fuel cell (MFC) is a device that converts chemical energy released as a result of oxidation of complex organic carbon sources which are utilized as substrates by micro-organisms to produce electrical energy. This further proved to be an efficient means of sustainable energy production. In Microbial Fuel cell, a chemical reaction is replaced by microbial reaction on account of production of electrons due to their metabolic activities and organic load of wastewater is used as a fuel.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 3, March 2020

Due to their microbial activity, electrons are generated which is the source for the production of electricity. Microorganism can metabolize the elements by generating electrons which can be yielded and utilized by connecting them through a circuit. This elemental set up grouped together and named as microbial fuel cell which is a main source of Bio energy. It is important to maintain an anaerobic condition of substrate for the microorganism for the generation of electrons during their metabolic process [1]. The process mentioned above show the metabolic reactions carried out by the microorganisms firstly in the Anaerobic condition and then in the aerobic condition [2].

## II. MICROBIAL FUEL CELL

Microbial fuel cell is a type of Bioelectro chemical system (BES) which oxidise substrate and produce electricity [3]. In addition, apart from other efficient waste treatment plant, MFCs are able to provide clean energy which is a sustainable energy production. Microbial fuel cell provides a solution by treating the waste as well as generating electricity [4] Thi et al. (2015) have publicized that power production from food waste using anaerobic digestion provided inequitable power supply for lots of countries such as China, Japan and US[5].

### 2.1 DESIGN

Microbial fuel cell design is of different types depending upon the mode of operation, chambers namely single chamber, dual chamber and stacked MFC.

#### 2.1.1 Single chamber

In single chamber both electrodes are placed in the same container. In dual chamber anode and cathode are placed in different container. An ideal MFC assemble consists of electrodes such as anode and cathode which are connected externally by an external circuit. These two electrodes are separated by a proton exchange membrane in single chamber Microbial Fuel cell. In single chamber it is necessary to provide air cathode i.e. one half of the anode is exposed to electrolyte and the other half is exposed to air. A typical single chamber MFC is shown in Fig1.

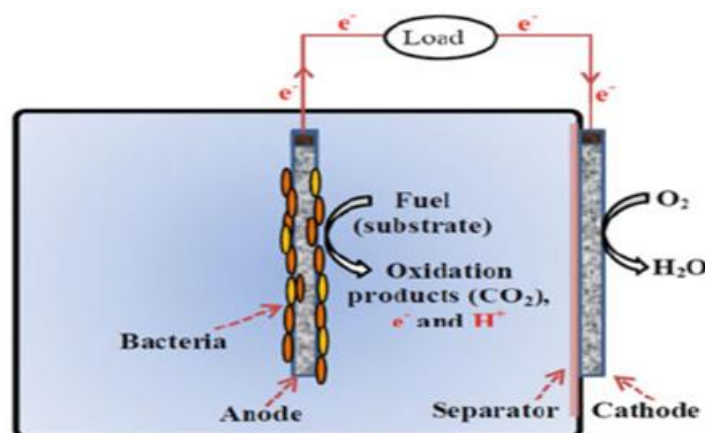


Fig. 1 Schematic representation of Single Chamber MFC [10]

#### 2.1.2 Dual chamber

In dual chamber MFC, these two electrodes are separated by salt bridge or proton exchange membrane. One chamber of the solution is filled with wastewater (anode) while the other chamber (cathode) is filled with distilled water. It is important to maintain an anaerobic condition for the anode in order to carry out the metabolic activities for the microorganisms. The cathodic chamber is aerobic either in the form of open air or with help of external supply of

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 3, March 2020

oxygen. The cathode may be fully immersed in the electrolyte solution or it can be an air cathode. A diagrammatic representation of Dual chamber MFC with proton exchange membrane is shown in Fig 2.

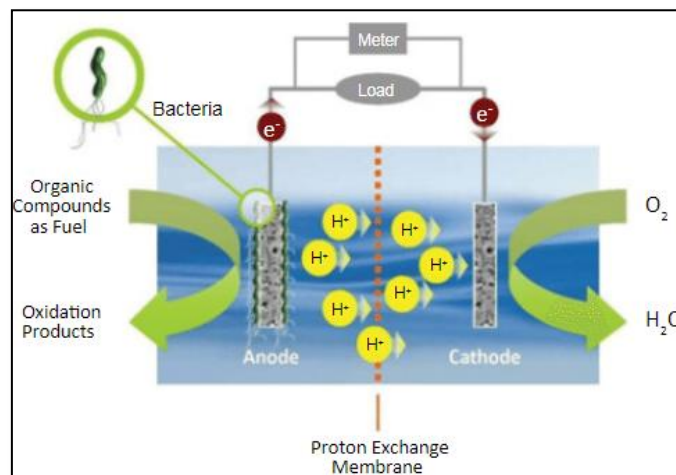


Fig. 2 Schematic representation of Dual Chamber MFC [4]

### 2.1.3 Stacked MFC

Stacked MFC are nothing but the multiple MFCs connected in series or parallel individually in order to enhance the power output. When multiple MFCs are connected as stack, Voltage reversal may lead to a polarity reversal and power voltage reduces. Voltage reversal generally occur when extreme current is haggard from the fuel cell, at a elevated rate than its fuel release can support, consequently this leads to an rise in the anode potential and thus voltage reversal occurs [6].

## 2.2 ELECTRON TRANSFER MECHANISM

Based upon the mechanism of electron transfer, Microbial fuel cell is of two types such as mediated MFC and non-mediated MFC. During oxidation of microbes, it releases electrons and protons. Electrons are moved to the anode and protons move towards cathode. In mediated MFC, electricity is generated by means of electron/proton carrier. There are different kinds of mediators such as trypan blue, neutral red, Methylene blue, Methylene orange, Bromocresol Blue as electron carriers. Babanova et al. (2011) reported the order of mediators as Bromocresol Blue < Neutral Red < Methyl Red < Methyl Orange < Methylene Blue in terms of power generation in MFC. During oxidation of microorganism, electrons and protons are generated. These Electrons in the MFC may require a mediator to get transferred to the electrode. Those electrons in the MFC which directly transfer the electrons to the electrode without any mediator are called non mediated MFC. An ideal Mediator in the Microbial Fuel cell should posses some of the characteristics such as (i) should form a reversible reduction and oxidation couple at the electrode (ii) should have a linkage to NADH (Nicotinamide adenine Dinucleotide) and have a high negative  $E_0^-$  value (iii) should be steady in both oxidized and reduced form (iv) soluble in aqueous systems [8]. But the uses of these types of dye mediators are toxic and harmful to the cells may lead to cell damage or cell death. Hence mediators are used rarely and also expensive in nature. The other mediators, which transfer protons upon releasing during oxidation of microorganisms to the cathode by the use of salt agar bridges. These types of proton carrier mediators can be adopted in dual chamber MFC and require cells to be maintained at anaerobic conditions. This kind of mechanism is functional only where the organisms with less or no electrochemical activities are used [9]. In non-mediated MFC, electrons are directly transferred to the anode. The mechanism is based on the ability of microorganism which directly transfers electrons

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 3, March 2020

upon oxidizing the waste organic matter directly to the anode. This process is also called as Direct Electron transfer. The microorganisms which directly transfer electrons are named as electrigenes, exoelectrogenes, electrogenes, Anode respiring bacteria, anotheles and electrochemically active bacteria (EAB) [10]. This method is highly efficient as it utilizes the oxygen from the atmosphere along with the ions present in the wastewater. This type of mechanism is functional only where the organism with high electrochemical activities is utilized [9].

## 2.3 ELECTRODE MATERIALS AND ITS PERFORMANCE

The main components in the MFC are anode and cathode for the flow of electrons to generate electricity. The type of material used as current collector depends upon various factors such as size, shape, surface area, type of material, low cost and highly efficient. Electrode material should consist of following features such as strong biocompatibility, good electrical conductivity and low resistance, chemical stability, anti-corrosion, mechanical strength and toughness, Durability, low cost & availability, porosity. The electrode materials and its performance to enhance the reactions are discussed below.

### 2.3.1 Anode materials and its performance

The electrons released as a result of oxidation of microbes get transferred to anode for the flow of electrons to get transferred to the electrode. Electrodes in the anode play an important role as the bacteria gets adhere to the anode surface [11]. The anodic chamber should be maintained under anaerobic condition and the materials used in the MFC should be conductive, bio compatible and chemically stable in a reactor solution mainly includes carbon based compounds. Anode chamber should be completely maintained in anaerobic condition. Oxygen in the anodic chamber inhibits the electricity production thus a pragmatic system must be considered to keep the bacteria detached from oxygen. The surface area of the anode materials plays a major role in generation of electricity in MFC. A three-dimensional anode material would prove to be highly effective toward electricity generation. Greater the surface area, greater the attachment of microbes. This further leads to the increases in the higher rate of oxidation in the anodic chamber [11]. Carbon based materials from graphite (Highly defined carbon) to less defined carbon such as graphite (rods, brushes, paper, felts, foam, plate), Carbon cloth, carbon paper, Carbon mesh. In order to get high performance efficiencies in small MFC devices, carbon materials can be used in a two-dimensional thin morphological structure like carbon cloth, carbon mesh, carbon paper. So far, only few metals such as stainless steel and titanium are used as anode materials because metals should be more conductive and non-corrosive. Metals can relatively reduce cost of operation as the carbon-based products are much higher. Metals alone cannot be used as anode. The surface areas of the metals are smooth which does not facilitate the bacterial adhesion [12] Therefore, metals like stainless steel or titanium can be combined with carbon-based products to enhance the anodic performance of MFC. This further reduces the cost of the MFC.

### 2.3.2 Cathode materials and its performance

The protons released in the anode are transferred to the cathode through proton exchange membrane or salt bridge. Power generation in the MFC is also influenced by one the factor is surface area of the cathode. The cathodic chamber is maintained as aerobic condition. So that, the hydrogen ions coming from the anode chamber combines with oxygen to form water [1]. The oxygen provided in the cathode chamber is either atmospheric oxygen or through aeration. The cathode materials used should be of low cost as well as high efficiency. Cathodes used in MFC are generally platinum, carbon or platinum coated carbon electrodes immersed in the cathodic solution. Air cathode can also increase the efficiency as well as improving the cathodic performance. Air cathode is used in MFC is nothing whose one half of the cathode is exposed to cathodic solution and the other half is exposed to air. In cathode, conductivity of ions is enviable to assist the triple phase boundary conditions [12]. Since, platinum is the most precious and costliest metal alternative metals like stainless steel and titanium mesh can be adopted.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 9, Issue 3, March 2020

## 2.4 SUBSTRATE

Several structures of MFC exist with different type of substrates. It is found from the literature that only a few researches are being carried out using raw food waste as substrate. Therefore, an attempt has been made to review about the generation of electricity from food waste [12]. Washington et al., adopted a Sediment microbial fuel cell with organic waste such as fruits and vegetables mixed along with the high Andean soils. The resulting output voltage was found to be 330mV with carbon fibre as anode and cathode. Kamau J.M et al. (2018) investigated that voltage obtained was highest in avocado waste at 0.357V and lowest in water melon waste at 0.009V. The power and current density for all the fruits were in the range of 0.060856 to 22.53043 $\mu$ W/M<sup>2</sup> and 0.751315 to 63.11044 mA/m<sup>2</sup> respectively [13]. Anand Prakash researched about four different kinds of waste such as Agro waste, Dairy waste, Distillery waste and Municipal waste with the maximum voltage recorded as 599mv, 900mv, 656mv,678mv respectively [14]. Since the voltage obtained with food waste was less than 0.5V, it can be mixed with other kinds of waste such a diary wastewater, sludge from sewage treatment plant can be investigated.

## III. CONCLUSION

Microbial Fuel Cell (MFC) is a fuel cell which comes under Bio electrochemical system and helps to reduce the waste concentration in the substrate and generate electricity simultaneously. MFC Technology could be used as sustainable/renewable technique in generating clean energy and has got huge potential to produce power from all the organic wastes. MFC Technology could also be used as a low cost electricity production technique from the readily available food waste at home. The usage of MFC guarantees the fewer disposals of waste into the environment and encourages the conversion of waste into wealth as well.

## IV. ACKNOWLEDGEMENT

The authors wish to thank the Kumaraguru College of Technology (KCT) management and Civil Engineering Department for providing necessary facilities/support to carry out the research/paper works.

## REFERENCES

1. Akshay D. Tharali, Namrata Sain & W. Jabez Osborne Microbial fuel cells in bioelectricity production, *Frontiers in Life Science*, 9:4, 252-266, 2016.
2. Moqsud AM, Omine K, Yasufuku N, Hyodo M, Nakata Y "Microbial fuel cell (MFC) for bioelectricity generation from organic wastes" *Waste Management* .33:pp.2465–2469,2013.
3. Cheng S, Liu H, Logan BE. "Increased performance of single-chamber microbial fuel cells using an improved cathode structure" *Electrochem Commun.*8(3) : pp.489–49, 2006..
4. Anbazhagi Muthukumar, Shilpa, V. & Muthukumar Muthuchamy "Green Energy Recovery from Food Waste Using Microbial Fuel Cell - A Mini Review" *CPQ Nutrition*, pp. 15-21, 2018.
5. Thi, N. B. D., Kumar, G. & Lin, C. Y. "An overview of food waste management in developing countries: current status and future perspective", *Journal of environmental management*, 157, pp. 220-229,2015.
6. Anthony J. Slatea, Kathryn A. Whiteheada, Dale A.C. Brownsona, Craig E. Banksa, "Microbial fuel cells: An overview of current technology" *Renewable and sustainable energy reviews* 101, pp. 60-81,2019.
7. Babanova S, Hubanova Y, Mitov M. "Influence of artificial mediators on yeast-based fuel cell performance" *JBiosci Bioeng.*112(4): pp.379–387,2011.
8. park dh, zeikus jg "Electricity generation in microbial fuel cells using neutral red as an electronophore" *Applied environmental microbiology* , Volume 66.issue 4,pp.1292–1297,2000.
9. Saeed Harshad Thakur, Pallavi Patil, Sunil Sangam "Design of Microbial fuel cell (MFC)" *International Journal of Engineering Research and Technology*. Volume 10, Number 1 ,2017.
10. Soumya pandit, Kuppam Chandrasekhar, Ramesh Kakarla, Abudukeremu Kadier, and Velpuri Jeevitha., "Basic principles of Microbial fuel cell: Technical Challenges and economic Feasibility" *Microbial fuell applicarions in Bioremediation and Bioenergy*, Vol 1,2017.
11. Di Lorenzo M, Scott K, Curtis TP, Head IM."Effect of increasing anode surface area on the performance of a single chamber microbial fuel cell" *Chemical Engineering Journal* 156(1): pp.40–48,2010.

## International Journal of Innovative Research in Science, Engineering and Technology

*(A High Impact Factor, Monthly, Peer Reviewed Journal)*

Visit: [www.ijirset.com](http://www.ijirset.com)

**Vol. 9, Issue 3, March 2020**

12. Usha kumari, Ravi Shankar, Prasenjit mondal "Electrodes for Microbial fuel cell" Progress and Recent Trends in Microbial Fuel Cells ,pp.125-141,2018.
13. Kamau J.M, Mbui D.N, Mwaniki J.M, Mwaura F.B "Characterization of Voltage from Food Market Waste: Microbial Fuel Cells"., International Journal of Biotechnology and Bioengineering Volume 4 Issue 3, pp. 37-43,2018.
14. Anand prakash "Utilization of Different Types of Wastewater for Production of Electricity Using Non-Mediated Microbial Fuel Cell" MOJ Proteomics Bioinform , 4(1): 00107,2016.
15. Washington Logrono, Geovany Ramirez, Celso Recalde, Magdy Echeverría, Ana Cunachi "Bioelectricity generation from vegetables and fruits wastes by using single chamber microbial fuel cells with high Andean soils" Energy Procedia 75 ,2015.
16. Rami M. M. Ziara, Bruce Dvorak, Jeyamkondan Subbiah "Sustainable Waste-to-Energy Technologies", In book: Sustainable Food Waste-To-energy Systems, pp.111-140,2018
17. Rohit Rathour, Vidhi Kalola, Jenny Johnson, Kunal Jain, Datta Madamwar, Chirayu Desai "Treatment of Various Types of Wastewaters Using Microbial Fuel Cell Systems", Microbial Electrochemical Technology ,pp.665-692,2019. electricigens" or "exoelectrogens" or "electrogens" or "anodophiles" or "anode-respiring bacteria" or "electrochemically active bacteria, EAB"