Journal of Energy Research and Environmental Technology (JERET)
p-ISSN: 2394-1561; e-ISSN: 2394-157X; Volume 3, Issue 2; April-June, 2016; pp. 127-130

http://www.krishisanskriti.org/Publication.html

An Approach for Electricity Generation using Microbial Fuel Cell Technology: A Green Energy Initiative

Ajay Agarwal[1], Gaurav Verma[2], Yogesh Singh[3], Anjali Kumari[4], Sanjeev Kumar[5], Om Ji Agnihotri[6], Sushmita[7], Nishika Sabharwal[8], Akshay Jha[9], Mansi Singh[10], Pawan Kumar[11], Inderbir Kaur[12], Ruchi Gulati Marwah[13], Geeta Mongia[14] and Avinashi Kapoor[15]

[1-10]*Student Research Group, Bhaskaracharya College of Applied Sciences, University of Delhi,*
[11]*Department of Instrumentation, Bhaskaracharya College of Applied Sciences, University of Delhi*
[12,14]*Department of Electronics, Bhaskaracharya College of Applied Sciences, University of Delhi*
[13]*Department of Microbiology, Bhaskaracharya College of Applied Sciences, University of Delhi*
[15]*Department of Electronic Science, South Campus, University of Delhi*

Abstract—*The most challenging issue today is production of clean yet sustainable sources of alternate and renewable energy as non-renewable sources of energy like petrol, oil, etc. are short lived, expensive and pollute the environment. To address these concerns, a major effort has been made towards clean and green electricity generation through Microbial Fuel Cell (MFC) technology. MFC is a bio-electrochemical device designed for the purpose of electricity generation in the process of wastewater treatment. It consists of four parts, (1) Anode chamber filled with organic matter (anaerobic condition), (2) Cathode chamber filled with water (aerobic condition), (3) Proton selective membrane separating two chambers and (4) external circuit connecting anode and cathode. Decomposition of organic matter by bacteria produces electrons that flow through external circuit and protons that pass through membrane thereby producing electricity. In the present work, waste water samples were collected from various locations and analysed for various parameters such as pH, Biological Oxygen Demand (BOD) and Colony forming Unit per ml (CFU/ml). A MFC was constructed and the collected sewage samples were used to determine the power generating ability of bacteria present inherently in the samples. Useful open circuit voltage was measured, which ensures MFC to be the one of the promising technology of future for cost effective clean electricity generation. MFC has various applications such as energy source for small electronic devices, bio-sensor for BOD measurement, wastewater treatment, hydrogen production, etc.*

1. INTRODUCTION

In today's Smart Hi-Tech Modern World, life is next to impossible without electricity. Due to rapid increase in demand of electricity, the world is going to face a grave energy crisis in future owing to the depletion of non-renewable energy resources [1]. Statistics reveals that per capita electricity consumption in India has reached to 1010KWh in year 2014-15 compared to 957 KWh and 915 KWh in year 2013-14 and 2012-13, respectively. Presently, in India, 72% of total Electricity Generation is done by non-renewable power plants and remaining 28% by renewable power plants [2]. These non-renewable energy sources are limited, costly and highly environment polluting. In order to build a sustainable society for our future generations, while simultaneously fulfilling the needs of increased demand of electricity, we require less dependency on fossil fuels and alternative cheap renewable sources of energy. Although, there exists various renewable sources of energy like wind, solar, geothermal, tides, biomass, etc.[3-5] yet one of the emerging, promising and practical sources of renewable energy is a Microbial Fuel Cell (MFC) that harnesses the power of bacteria to generate electricity from wastes water or sewage. The concept of Microbial Fuel Cell started back in 1911 by M.C. Potter, a Botany professor at the University of Durham. MFCs can be Mediated or Mediator-less [6]. Unmediated or mediator-less MFCs emerged in 1970's whereas Mediated MFCs were first demonstrated in early 20th century[7]. Bacteria in MFC breakdowns the organic matter present in the waste water or sewage under anaerobic conditions thus generating electrons and H^+ ions which move through different paths and produce electricity. Due to degradation of organic matter, MFC simultaneously clean the waste water or sewage. Thus, MFCs can bring down the waste water treatment cost to negligible. The Microbial Fuel Cell, which was a novelty in Science fair, is now a developing reality and an ideal solution for sustainable, renewable and carbon-neutral source of energy at reasonable cost. A continuous research is going on to use MFCs in various applications such as Power Generation, Biosensors, production of Hydrogen fuel, etc. [8, 9].

2. WORKING OF MFC

MFC converts the energy released due to metabolic activities of respiring bacteria present in the sewage or similar waste water into electricity. Under Anaerobic condition, the decomposition of organic matter by the bacteria results in generation of electrons, H+ ions and CO_2 as depicted by the chemical reaction in Equation 1[9, 10].

$C_2H_4O_2 + 2H_2O \rightarrow 2CO_2 + 8H^+ + 8e^-$ …….(Eq. 1)

Produced electrons are transferred to the cathode compartment through an external electric circuit, while protons are transferred to the cathode compartment through the membrane. Electrons and protons are consumed in the cathode compartment, combining with oxygen to form water as depicted by the chemical reaction in Equation 2 [9, 10].

$2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$ …………………(Eq. 2)

Organic matter serves as food for bacteria (in the anode compartment) from which they derive energy needed for their survival[11, 12]. If the generated electrons in anode chamber are transferred to anode directly without help of any external agent then the MFCs are called as Unmediated or Mediator Less MFCs. Bacteria in this case makes film on the surface of anode called biofilm for direct and faster transfer of electron or some bacteria have pilli on their surface that act as the conducting nanowires that serves as channel for electrons towards anode surface. If external agents like methylene blue, Potassium ferricyanide, Theonine, Neutral red are deliberately added into anodic chamber to improve the e-transfer rate to anode, then the MFCs are called as Mediated or Mediator MFCs [4, 5]. These agents act as electron shuttle and helps in the transfer of electron from within the cell membrane of bacteria to anode surface but these are toxic and expensive thereby increasing the overall cost of MFCs [6].The MFC and its working are depicted in the Fig. 1[9].

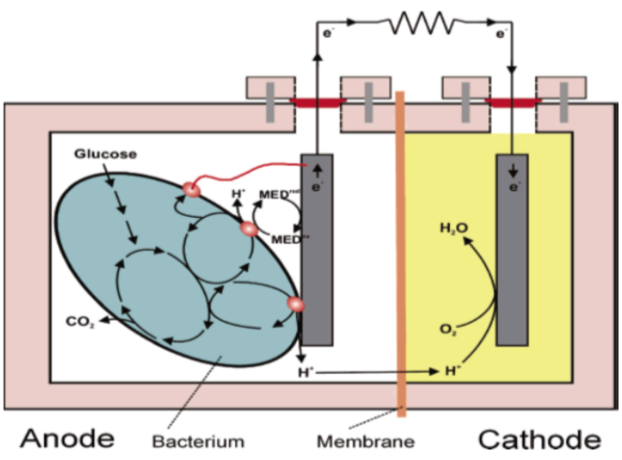

Fig. 1: Working of MFC

3. EXPERIMENTAL WORK

The prototype of MFC was fabricated and open circuit voltage (V_{OC}) was measured using digital multimeter fordifferent waste water samples collected from Delhi-NCR, India. At the same time, collected samples were alsoanalysed for various parameters i.e. Colony Forming Unit per ml (CFU/ml), Biological Oxygen Demand (BOD) and pH.

Fabrication of MFC

Many different configurations of MFC's are possible. A widely used and inexpensive design is a two chamber MFC built in a traditional "H" shape which consists of two glass bottles (chambers) connected by a tube containing a highly selective membrane called Cation Exchange Membrane (CEM) or Proton Exchange Membrane (PEM).The prototype of MFC was constructed on the same lines as that of Bio-photovoltaic cell (BPV) from our earlier research [13] and is shown in Fig. 2.

Constructed prototype of MFC consisted of the following four parts: (1)Anode chamber (Left chamber): which holds the carbon electrode, waste water (consisting of bacteria and organic matter) in an anaerobic environment, (2)Cathode chamber (Right chamber): which holds carbon electrode, a conductive saltwater solution; (3)Proton Exchange Membrane (Nafion-117), which separates the anode and cathode and allows protons to move between the two chambers and (4) an external circuit, which allows a path for electrons to travel from anode to cathode. In the present work, open circuit voltage is measured with the multimeter which is connected in the external circuit.

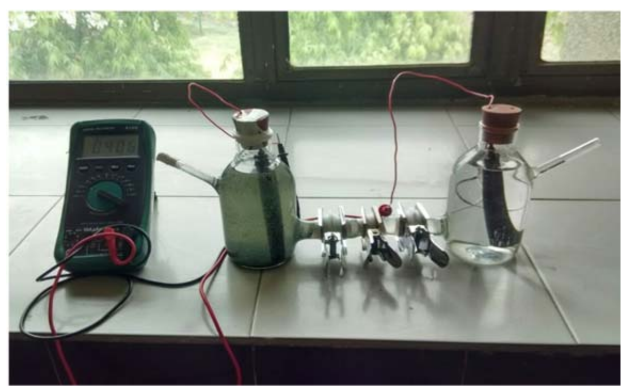

Fig. 2: Constructed Prototype of MFC

The most versatile electrode material for both anode and cathode is carbon as it has good conductivity, relatively inexpensive and easy to handle [9, 14]. Materials like, non-corrosive stainless steel mesh, copper etc. can be utilized as anode electrodes. But stainless steel is comparatively costly and copper is also not very useful as even traces of copper ions can be highly toxic to bacteria. There exists a variety of

PEM's apart from Nafion such as Ultrex, Zirfon, Hyflon, etc. each having unique properties [9]. These membranes only allow protons, to pass through but not the substrate (in the anode chamber) or electron acceptor (in the cathode chamber, typically oxygen). The membrane is clamped in the middle of the tube connecting the two chambers. An alternative and an inexpensive way to join the bottles is to use a glass tube that is heated and bent into a U-shape, filled with agar and salt (salt bridge functions as a Cation Exchange Membrane) and inserted through the lid of each bottle. The salt bridge MFC however, produces little power due to the high internal resistance[15].

CFU/ml Measurement

The microbial load of the sewage water samples was assessed by CFU/ml using spread plate method. The sewage samples were diluted in normal saline upto 10^7 dilutions and 0.1 ml of each dilution was plated on nutrient agar plates. The plates were incubated for 18-24 hours at 37°C. The number of colonies was formed on each of the plates and CFU/ml was calculated.

BOD Measurement

The volume of 5ml of the sewage sample was built up to 300ml (dilution factor of 60) with fresh distilled water in 300ml BOD bottle made of glass and it was tightly stoppered as well as completely covered with aluminium foil. The dissolved oxygen (DO) of the diluted sample was recorded (0 day reading) with probe based digital DO meter (Hanna Instruments Co. Ltd.) and then kept at 28°C in a BOD incubator for 5 days. DO was again measured on the 5^{th} day. Thus, BOD was calculated using the formula of Equation 3:

$$\mathrm{BOD} = (\mathrm{DO_0} - \mathrm{DO_5}) * \mathrm{P} \qquad \text{(Eq. 3)}$$

$\mathbf{DO_0}$**:**Dissolved oxygen in diluted sample on 0^{th} day

$\mathbf{DO_5}$**:**Dissolved oxygen in diluted sample on 5^{th} day

$$\mathrm{P\ (Dilution\ factor)} = \frac{\mathrm{Total\ Volume}}{\mathrm{Sewage\ Sample\ Volume}}$$

pH Measurement

ThepH was measured at the same time when DO was measured using the digital pH meter (LabIndiaCo.Ltd.).

4. OBSERVATIONS AND RESULTS

The Observation made for the parameters mentioned above are shown below in the Table 1.

Table 1

Sewage Water Sample	DO_0 (mg/L)	pH_0	DO_5 (mg/L)	pH_5	B.O.D (mg/L)	CFU/ mL	V_{OCM}
*S1	4.86	8.24	0.4	7.92	18.6	$5.7x10^9$	0.3V
**S2	4.79	8.3	3.61	7.87	70.8	$5.5x10^6$	0.6V
**S3	5.28	8.28	4.25	7.92	61.8	$3.6x10^6$	0.75V

$\mathbf{pH_0}$**:** pH on0^{th} day**,** $\mathbf{pH_5}$**:** pH on 5^{th} dayin sample from MFC, $\mathbf{V_{OCM}}$**:** Max Open Circuit Voltage
(***S1:**Sample 1, Lawrence Road Industrial Area, New Delhi)
(****S2:** Sample 2 (Phase I), Central Effluent Treatment Plant (CETP), Mayapuri, New Delhi)
****S3:** Sample 3(Phase II), Central Effluent Treatment Plant (CETP), Mayapuri, New Delhi)
The BOD came in the range of 18-71mg/litre and the CFU/ml of the sewage sample came out in the range of $3.5x10^6$ to $5.5x10^9$. These values of the sewage samples were found to be suitable for use in the MFC.

5. DISCUSSION AND CONCLUSION

The constructed prototype in our work was mediator less MFC as no external mediators were added to the sewage samples. Observed results revealed that pH decreased (sample becomes neutral) as the bacteria decomposed the organic matter in the sewage samples. The samples with higher BOD gave better electricity generation as shown the table. Higher BOD signifies more organic content in the given sewage sample, thus more generation of electrons and H^+ ions on decomposition and hence more electricity generation (or V_{OC}). A moderate amount of voltage was generated using sewage samples collected from Delhi-NCR regions. The results presented in this paper are a preliminary investigation on the electricity generating potential of bacteria inherently present in waste waters. Detailed investigations are being carried out by changing the type of CEM, electrodes etc. to enhance the voltage generated and to increase the practical feasibility of the technology. This technique can reduce waste water treatment plant operating costs if used in conjunction with waste water treatment on site, making it an affordable venture especially for developing countries like India [16].

6. ACKNOWLEDGMENT:

This research work was carried out at Bhaskaracharya College of Applied Sciences under DU Innovation project (2015-16). We are thankful to University of Delhi for providing financial support for the project.

REFERENCES:

[1] Verma,G., Singh, Y., Kumari, A., Sabharwal,N., Agarwal, A., Mongia, G., Kaur, I., and Marwah, R.G., A Short Review on Microbial Fuel Cell Technology and A Proposed approach for Generation of Electricity using Waste Water Treatment, Proceedings in *National Conference on Inspired Learning*, held at Maharaja Agrasen College, University of Delhi, 2015, pp.9-11.

[2] Singh, D., Pratap, D., Baranwal, Y., Kumar, B., and Chaudhary, R.K., Microbial Fuel Cells: A green technology for power generation, *Annals of Biological Research*, 2010, pp.128-138.

[3] Allen, R.M.,and Bennetto, H.P., Microbial fuel-cells: Electricity production from carbohydrates, *Applied Biochemistry and Biotechnology*, 2009, pp.27-40.

[4] Gil, G.C., Chang, I.S., Kim, M., Jang, J.Y., Park, H.S.,and Kim, H.J., Operational parameters affecting the performance of a mediator less microbial fuel cell, *Biosensors and Bioelectronics*, 2003,pp.327-334.

[5] Moon, H., Chang, I.S., and Kim, B.H., "Continous electricity production from artificial wastewater using a mediator-less microbial fuel cell". *Bioresource Technology*, 2006, pp.621-627.

[6] Sharma, V., and Kundu, P.P., "Biocatalysts in microbial fuel cells: A Review",*Enzyme and Microbial Technology*, 2010, pp. 179–188.

[7] Potter, M.C., "Electrical effects accompanying the decomposition of organic compounds", *Proceedings of the Royal Society*,1911, pp.260-276.

[8] Zhuwei, D., Haoran, L.,andTingyue, G., "A state of the art review on microbial fuel cells: A promising technology for wastewater treatment and bioenergy", *Biotechnology Advances*, 2007, pp.464-482.

[9] Rahimnejad, M., Adhami, A., Darvari, S., Zirepour, A., and Oh, S.E., "Microbial fuel cell as new technology for bioelectricity generation: A Review", *Alexandria Engineering Journal*, 2015, 745-756.

[10] Logan, B.E., and Regan, J.M., "Microbial fuel cells: Challenges and applications", *Environmental Science & Technology*, 2006, pp.5172-5180.

[11] Jessica L., "An Experimental Study of Microbial Fuel Cells for Electricity Generation: Performance Characterization and Capacity Improvement",*Journal of Sustainable Bioenergy System*, 2013, pp.171-178.

[12] Logan, B.E., Hamelers, B., Rozendal, R., Schroder, U., Keller, J.,Freguia, S.,Alterman, P.,Verstraete, W., and Rabaey, K., "Critical Review- Microbial Fuel Cells: Methodology and Technology", *Environmental Science & Technology*, 2006, pp. 5181-5192.

[13] Mongia, G., Kaur I.,and Marwah, R.G., "Algae: Power plant of Future", In Proceedings of *National Conference on recent trends in Future Instrumentation and Electronics,* held at Shaheed Rajguru College of Applied Science, University of Delhi on January 5-6, 2015.

[14] Logan, B., "Scaling up microbial fuel cells and other bio-electrochemical systems", *Applied Microbiology and Biotechnology*, 2010, pp.1665-1671.

[15] Muralidharan, A., Babu, O.A., Nirmalraman, K., and Ramya, M., "Impact of Salt Concentration on Electricity Production in Microbial Hydrogen Based Salt Bridge Fuel Cells", *Indian Journal of Fundamental and Applied Life Sciences*,2011, pp.178-184.

[16] Mahendra, B.G., and Mahavarkar, S., "Treatment of Wastewater and Electricity Generationusing Microbial Fuel Cell Technology", *International Journal of Research in Engineering and Technology*, 2013, pp.277-282.