Electricity Generation in a Microbial Fuel Cell: Study of Two Proton Exchange Membrane Diameter

Oji Akuma.[1ϒ], Briggs Tobinson[2] and Ighabor U. T. [1]
[1]Department of Chemical Engineering,
[2]Department of Mechatronics Engineering,
University of Port Harcourt, Port Harcourt, Nigeria,

Abstract

Dual chamber Microbial Fuel Cell (MFC) with saline catholyte was used in this laboratory scale study on the effect of Proton exchange membrane (PEM) diameter on energy output. Two different agar-agar salt-bridges PEM of diameters 1/2inch and 1inch were used in a plastic Microbial fuel cell unit with electrodes manufactured to the same dimensions (area of $1.33\times10^{-2}m^2$). Brewery waste water was used as the substrate, with its microorganism as the biocatalyst. The cells were operated at room temperature and pH of 7.0±0.3. The cells were operated for 21days while the performance was monitored every three days. The set-up of 1/2inch PEM produced the maximum voltage of 47mV between the 13^{th} and the 15^{th} day while the MFC units with a 1inch PEM produce maximum voltage of 57mV between the 19^{th} and the 21day. The over potential in the MFC with 1inch was reduced with large proton transfer space giving the unit a better performance.

Key words
Microbial fuel cell, proton exchange membrane, charcoal, cement.

Introduction

The quest for alternative sources of energy is pertinent at this period of our history when concerns about global warming are causing topical and sensitive debate worldwide (Momoh and Neayor, 2010; Kasongo and Togo, 2010). Energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. Economic growth crucially depends on the long term availability of energy from sources that are affordable, accessible and environmentally friendly. Due to global environmental concerns and energy insecurity, there is emergent interest to find sustainable and clean energy source with minimal zero use of hydrocarbon (Ghangrekar and Shinde, 2008). Current reliance on fossil fuels is unsustainable due to pollution and finite supply. Much research is being conducted into a wide range of energy sources. No one energy supply solution appears to be able to replace fossil fuel in its entirety, prompting the need for a combination of various alternatives to provide the necessary solution (Frank and Nevin, 2010). Production of Energy from the abundant renewable biomass and other feed stocks holds great potential to meet the needs in terms of its sustainable and environmentally sound manner with additional advantage of resultant reduction on fossil fuel energy dependence. Energy generation from ‘‘negative value’’ waste streams can simultaneously help meet the worlds energy needs, reduce pollution, and reduce cost of water and wastewater treatment (Kelly, 2007; Mathuriya and Sharma, 2010).

Microbial fuel cells (MFC) have attracted global interest as a source of energy supplying electricity generated from organic and inorganic matters in wastewater, while concurrently treating the wastewater. A microbial fuel cell is a device that employ microorganisms to generate electric current from side to side the oxidation of organic materials which results to reduction in wastewater contaminants. Microorganism in microbial fuel cell metabolizes fuels or substrates and shuttle transfers electrons to the surface of the electrode (Mathuriya and Sharma, 2009). The oxidation of the substrate releases both electrons and protons from the oxidized substrate (see figure 1). Electrons thus produces are shuttled to the anode electrode from where it is transferred to the cathode through an electrical network. The proton diffuses form the anode chamber to the cathode chamber through the proton exchange membrane (salt bridge). In the cathode chamber, the electron combine with the proton and the catholyte to produce current while simultaneously treating the wastewater. The power output from the microbial fuel cells (MFCs) is lower than the than other sources requiring adequate improvement and optimization of the MFC configurations and proper material selection for optimum electricity production and wastewater treatment with reduction in cost of treating primary effluent wastewater and generation / production of electricity (Mohan et al., 2007). The objective of this work is to design a microbial fuel cell using wastewater as substrate (Brewery wastewater) to produce or generate electricity at the same time treating the wastewater, varying diameter of the proton exchange membrane (salt bridge).

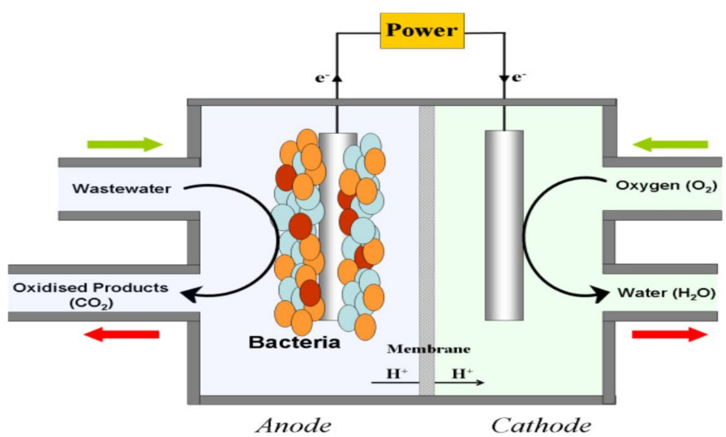

Figure 1: Schematic of Microbial Fuel Cell (Rengaraj, 2011)

MATERIALS AND METHODOLOGY

The wastewater used for this study was brewery wastewater obtained from Brewery Company in Port Harcourt, Nigeria. It was stored in the refrigerator at 4^{o} C for prior to usage. The two chambers (anolyte and catholyte) were of equal volume of 1.75 ml. Each MFC setup was run for thirty (30) days. High strength brewery wastewater as anodic substrate and Two different agar-agar salt-bridges PEM of diameters ½ inch and 1inch were used in a plastic Microbial fuel cell unit with electrodes manufactured to the same dimensions (area of $1.33\times10^{-2}m^{2}$)

CELL 1 = ½ inch

CELL 2 = 1inch

Power generation Measurement

The microbial fuel cell was operated with close circuit resistor of 150 ohms resistor. Voltage and current was measured using ADA DT-830D digital multi-meter Current (I) and Voltage (V) of both set ups, were measured daily and average for three day was recorded the digital multi-meter. Power density (P, mW/m^{2}) for the various data measured was calculated as described by Liu and Logan (2004) and Oji and Opara (2011).

$$P = IV/A$$

Where; I = the Current in mili Amperes (mA)

V = The Potential Difference (PD) in volts (V).

A = Electrode projected surface area (m^{2}).

RESULTS AND DISCUSSION

The generation of electricity from high strength brewery wastewater as anodic substrate, salt and distilled water as catholyte was observed for two setup of CELL 1(½ Inch) and CELL 2 (1 Inch). After twenty one (21) days of monitoring, observation and operation the following results were obtained as shown in the graphs in figures 2 to 4.

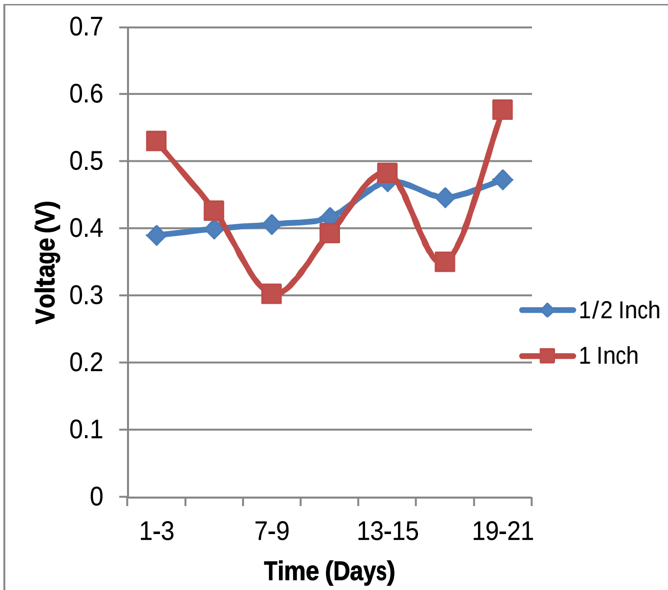

Figure 2: Voltage against Time

Voltage and Current generation

The graph of a plot of the trend of voltage (v) against time (Day) shows (see figure 2) that the voltage is stable for the Cell one, ½ inch diameter PEM pipe. While the Cell two 1 inch diameter PEM pipe produced undulating voltage higher than the ½ inch diameter PEM. The highest voltage for the ½ inch diameter PEM is 0.47volts during the last three days of the operation from the lowest value of 0.39volts during the first three days. The 1inch diameter cell recorded the lowest voltage of 0.30volats and a maximum voltage of 0.57volts during the last three days.

The current trend is as shown in figure 3. The 1nch diameter PEM recorded high current better than the ½ inch diameter PEM. The current was with 0.038±2mA throughout the duration of the cell. The maximum current for the 1inch diameter PEM recorded a maximum of 0.11mA between the 7 and 9th day while the current was lowest on the last three days recording 0.04mA.

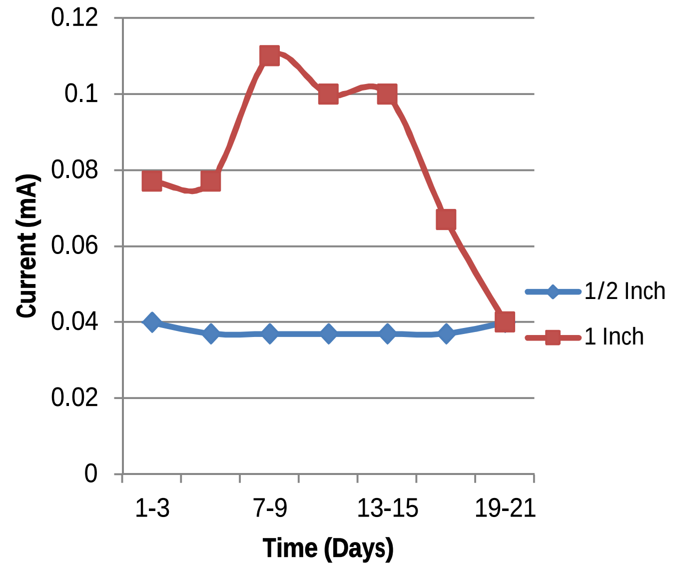

Figure 3: Current against Time

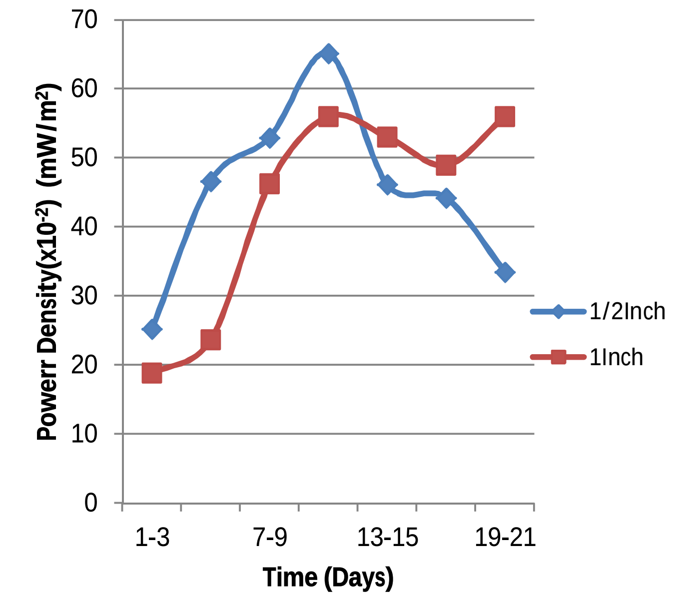

Figure 4: Power against Time

Power density

Cell one (1), ½ inch diameter PEM pipe produced highest power of $65.17x10^{-2}$ mW/m^2 between the 10 to 12th days on the operation which started with a value of $25.22x10^{-2}$

mW/m^2, for the first three days and dropped to 33.54x10^{-2} mW/m^2 while the 1inch PEM diameter pipe produced maximum power of 56.04x10^{-2} mW/m^2 during the last three days after recording a minimum of 18.81x10^{-2} mW/m^2 during the first three days this result show that there is a significant effect on the diameter of a PEM diameter on the generation of power.

Discussion

There is a significant difference in power generation between the ½ inch and the 1inch diameter PEM. This may not be unconnected with the need to diffuse the proton produced at the anode chamber to avoid over potential which resulted to a better power generation using the 1inch diameter PEM. The cumulative total of power generated is 0.24w for the 1inch diameter PEM while the ½ inch diameter PEM records a cumulative total of 011w.

CONCLUSION AND RECOMMENDATION

CONCLUSION

Microbial fuel cell (MFC) technology shows considerable promise for power generation in the future. The volume of power generated in relatively low but can be harnessed. The MFC constists mainly of a Anode and cathode chamber, a Proton exchange membrane (PEM) the external load, the anode and cathode electrode and the substrate. It is important to that to improve on the volume of power generated from MFC, the system needs to be optimized in terms of configuration material and parts. Power generation in microbial fuel cell (MFC) may provide a new method to power generation with wastewater treatment which may reduce cost of operating a wastewater treatment more affordable for developing and developed nations of Africa and the rest of the world. This experimental research report investigates the effect of two different diameters of Proton exchange membrane on the power generated from an MFC.

From this experiment, it was observed that ½ inch PEM diameter pipe produced the maximum power density Cell one (1), ½ inch diameter PEM pipe produced highest power of 65.17x10^{-2} mW/m^2 between the 10 to 12th days on the operation which started with a value of 25.22x10^{-2} mW/m^2, for the first three days and dropped to 33.54x10^{-2} mW/m^2 while the 1inch PEM diameter pipe produced maximum power of 56.04x10^{-2} mW/m^2 during the last three days after recording a minimum of 18.81x10^{-2} mW/m^2 during the first three days this result show that there is a significant effect on the diameter of a PEM diameter on the generation of power. Therefore, using brewery wastewater and cheap catholyte (distilled water and salt) in microbial fuel cell is an efficient means of generating electricity and simultaneous treatment of wastewater. Hence, a combination of wastewater treatment along with electricity production may help reduce the cost of wastewater treatment, power failure and pollution from combustion of fuel reducing "Green House Effect"**.**

10.2 RECOMMENDATION

For full understanding of microbial fuel cell (MFC), knowledge of multiple technological disciplines is required, such as electrochemistry, microbiology, material science and engineering, molecular biology and environmental engineering. It is a challenge for any research team or student to completely understand all of the theories and techniques used in the study of microbial fuel cells. Electrochemical / analytical techniques have an essential role to play in this continuous process; they are vitally important in the analyzing the limiting performances of each component, to optimize MFC operation, and to allow continued innovation. The continuous and long term operation of MFCs mandates that systems must be run under conditions that are generally predefined by the requirements for optimal microbial growth and sustainability. Typical conditions such as ambient temperatures and pressures, electrolyte and p^H. There are many factors that affect MFC performance and even one small, seemingly insignificant substantial deterioration in performance. The correct choice of experimental technique for any research objective is very important.

The fact that microbial fuel cell is capable of generating electricity no matter how small, shows that microbial fuel cell could help in reducing the damage to our environment and household appliances. Therefore, I recommend this technology to all power generating plants and government parastatals. I recommend this technology to all industries and domestic wastewater treatment plants who undertake treatment of any kind of wastewater.

Research is a vital tool for any meaningful development. To this end I recommend the governments and companies to intensify research into this field, in terms of financing, equipments of laboratories and encouragement of young minds, to produce a viable clean and sustainable energy source to save our planet. I strongly recommend that microbial fuel cell power generation using brewery wastewater and cheaper catholyte (Distilled water and salt) be encouraged under the guidance of experts in the field.

Reference

Franks A. E., and Nevin K. P., (2010), Microbial Fuel Cells, A Current Review, *Energies* , *3*, 899-919

Ghangrekar M.M. and Shinde V.B.(2008) Simultaneous sewage treatment and electricity generation in membrane-less microbial fuel cell, Water Sci. Technol. 58, 37–43

Kasongo J and Togo C.A (2010); "The Potential of Whey in Driving Microbial Fuel Cell: A dual Prospect of Energy Recovery and Remediation." African Journal of Biotechnology Vol 9 (46) PP. 7885-7890.

Kelly S., (2007) "Microbial Fuel Cells: Design Elements and Application of a Novel Renewable Energy Source". MMG 445 Basic Biotechnology eJournal.

Liu, H., and Logan, B. E. 2004. Electricity generation using air-cathode single chamber microbial fuel cell in the presence and absence of a proton exchange membrane. Environ. Sci. Technol. 39, 5488-5493.

Mathuriya A. S., and Sharma V.N., (2010), Treatment of Brewery Wastewater and Production of Electricity through Microbial Fuel Cell Technology Int. J. of biotechnol & Biochem Vol. 6 No. 1, 71–80

Mathuriya A.S and Sharma V.N; (2009) "Bioelectricity Production from Paper Industry Waste Using a Microbial Fuel Cell by Clostridium Specie" J Biochem Tech (2009), 1(2) pp.49-52.

Min B., Cheng S., Logan B.E. (2005), "Electricity Generation using Membrane and salt bridge Microbial fuel cells", Water Research Vol. 39, PP 1675-1686.

Mohan S.V.; Raghavulu S.V; Srikanth S.; Sarma P.N. (2007), "Bioelectricity Production by mediatorless microbial fuel Cell Under Acidophilic Condition Using wastewater as substrate: Influence of substrate loading Rate", Bioengineering and environment center, Indian institute of Chemical Tech, Hyderabod 200,007; India, vol. 92, PP.12, 25.

Momo, O.L.Y, Nyeayor B., (2010); Generation of electricity from Abattoir Waste Water with the Aid of a Relatively Cheap Source of catholyte; J. Appl. Sci. Environ. Manage. Vol. 14 (2) 22-27.

Oji A., and Opara C. C. 2011: Electricity Production from Brewery waste water using Water as Catholyte in a dual chamber microbial fuel cell (MFC), Proceedings of the 41th Annual Conference of the Nigerian Society of Chemical Engineers, Nov 9-12, 2011.

Rengaraj, S.,(2011), Bioelectrochemical films on electrodes for application to biofuel cells Thesis Submitted for the Ph.D Degree by Research of The National University of Ireland School of Chemistry, National University of Ireland, Galway.