Microbial Fuel Cell Study for the Generation of Electricity Using Waste Water

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Abstract: ***The resources deficit and the electricity demand have been suddenly increasing. The technologies do have the restrictions due to their energy limit and the cost - intensive for attaining the conversion target of the waste - water recovery. It is necessary to develop a technology that will bring about an alternatives - conventional energy sources in a sustainable way. The current work dealed with the fabrication of a laboratory scale - double chambered microbial fuel cell (MFC) to generate the electricity from the domestic waste water. The experiment was performed to generate the electricity from locally available domestic waste as a substrate using the fabricated MFC. For MFC1, the device was utilised at an anaerobic condition at a different time interval of every 10th day and reading were recorded. For MFC2, the device was set up at varying time interval of everyday and readings were taken. Required graphs of Voltage v/s Current density, Power density v/s Current density were plotted. All the general parameters like Voltage, Current, Current density, Power, Power density shown the maximum values at 20th - day. A sudden reduce in value was observed after 21st - day. The corresponding maximum values are 0.188 V, 18.8 mA, 14674.89 mA/m^2, 3.53 mW and 2757.81 mW/m^2 respectively. Similarly, for MFC 2, the corresponding maximum values are 1.02 V, 62.5 mA, 8320.02 mA/m^2, 63.8 mW and 8486.42 mW/m^2 respectively. Thus, this study has revealed that the fabricated MFC can be used for the electrical energy generation from the cow - dung and various other bio - waste.***

Keywords: Waste - water, Microbial Fuel cell

1. Introduction

There are many researches and much advancement in technology that was developed in the field of the renewable energy sources. This is mostly due to the increased utilization of the fossil fuel - based energy sources which was constantly increasing the value that is oil. On the top due to its un - sustainability and due to overpriced, this is also a prime reason of Greenhouse Gas emissions (GHG) in the atmosphere which has some remarkable impacts on environment. According to Moqsud et al., the microbial fuel cell facilitated this particular process and have acquired a lot of observation, currently as a mode of conversion of the organic matter into the generation of the sufficient amount of electricity. An advantage of the more number of micro - organisms breaks down into the substrates was found in the various places such as waste - water, sludge, sediments under the sea and other different places where the bacteria growth is maximum. This particular methodology of utilizing microbe as the catalysts in the fuel cells was been surveyed as long back in the early - 1970s. The microbial fuel cells with an improvised power output have been progressed which provided the various opportunities for different practical applications. The microbial fuel cell is a biological electrical system, where the bacteria's are used to transformed organic material into the generation of electricity. The fuel cell are made up of four parts - that are the anode, the cathode, the proton exchange membrane and the external circuit. During the oxidation process, the electrons are dragged out as the released energy and then the release energy converted into the electron acceptor via an external circuit. The protons then passes through the ion/ proton exchange membrane and further reacted with the electrons during the reduction process in the cathode, thus completed the circuit. This is an easy process which is commonly found in most of the fuel cells that is battery cells, hydrogen fuel cells which can be optimized for an efficient electricity generation. A study was carried out by DelDuca et al. that the amount of hydrogen which are manufactured by the fermentation of the glucose by Clostridium butyricum as the reactant at the anode of a hydrogen and the air fuel cell. In the late of 1970s, a minute clarity was observed about how the microbial fuel cells functioned in a proper way. This particular idea was considered then by Robin M. Allen and later by H. Peter Bennetto. The researchers saw that the fuel cell as being an feasible method for the generation of electricity for most of the developing countries.

1.1 Objective of the Project

This project addressed three important issues with respect to MFC technology development:

1) The reactor beds in this research are seeded with domestic waste - water; a wide variety of bacteria inherent in it are used.
2) This study used the domestic wastewater.
3) This study focused on developing the new electrode materials and the MFC configurations that would be easier for the waste - water treatment plant for different retrofit applications.
4) Generation of electricity

1.2 Scope of the Project

1) Build a microbial fuel cell which is capable of illuminating an LED using domestic sludge.
2) To generate more energy by changing certain parameters of the fuel cell.
3) To design and construct a fuel cell - reactor
4) To study on the different parameters of MFC
5) To build a low cost waste - water treatment along with electricity generation in the developing countries and in the rural areas.

6) To compare the current production in the different waste - water using PEM MFC.

2. Materials and Methodology

Various MFCs design have been developed in past two decades including, single chamber, double chamber and many others. Among the various MFCs configurations, we have considered double chambered MFC which is "H" shaped, it consisted of 2 bottles which are attached by a tube that contained a separator which is a cation exchange membrane (CEM) such as Ultrex / plain salt bridge. The microbial Fuel Fell produced a power due to the presence of the high internal resistance. The H - shaped systems which are accepted for the basic parameter such as surveying of the power production using different new materials or the different varieties of microbial communities that arises when the compounds started degrading. They produced the low power densities. The total power generated in these particular systems that are affected by the surface area of the cathode which is relative to that of the anode and to the surface of the membrane.

For the MFC - 1, the 2 - 400 mL bottles were prepared which were an anode chamber and a cathode chamber. For the MFC2, the two 850 mL bottles were prepared as an anode chamber and a cathode chamber. In the bottle cap there were 2 small holes were made so that it will easier to insert the wire through the 2 holes. The wire used the slips made up of aluminium and that was attached to the graphite electrodes. For MFC1 anode chamber was then filled with the 250ml of domestic waste –water (substrate) and for MFC2, 1500ml of domestic waste water was filled. For MFC1 the cathode chamber was filled with 250ml of plain water and for MFC2, 1500ml of plain water was filled. The two ends of the wires were attached to the digital multimeter for the further readings.

The components of MFC are electrodes, external circuit and dimension of MFC. The anaerobic anode component is filled with the substrate, the microorganisms and the anode electrode functioned as the electron acceptors. The same aforementioned anode materials can be used for cathodes. The most common material which is used for the construction of the cathode is Ferri - cyanide. The other alternative materials which are used for the cathode construction are carbon material, graphite material, plate material and rod material. The MFC requires the use of the proton exchange membrane to be functional which are referred as the ion - selective membrane and this separated the cathode from the anode but it allowed the flow of the protons from the anode to the cathode to maintain the flow of the current. For MFC1 the cotton string soaked with NACL solution was used and for MFC2, a solution was prepared from a mixture of agar and salt water was used. The substrate used which serves as the energy source for the micro - organisms present in it. The acetate glucose was used as a substrate in most of the research works. But for this research, the kitchen waste - water (domestic) was used for both the MFC1 and MFC2. The electrode always improves the efficiency of the performance of MFC. In this project, the graphite - rods were used as the electrodes in both the anode and cathode chamber. The use of digital multimeter is important to detect the further data.

Figure 1: **Preparation of Salt Bridge**

Figure 2: Sewage Sludge

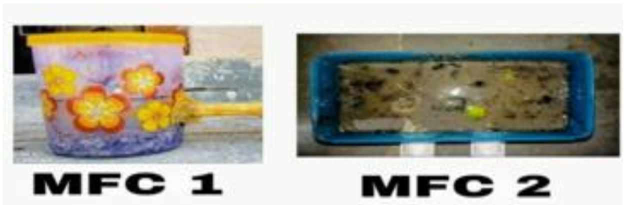

Figure 3: Full set up of MFC

Table 1: Dimension of Components

Dimension of Components	MFC 1	MFC 2
Type of Chamber	Cylindrical	Rectangular
Anode Chamber	17cm long, 11cm (Día)	30.5cm X 17.9cm X 12cm
Cathode Chamber	17cm long, 11cm (Día)	30.5cm X 17.9cm X 12cm
Salt Bridge	10cm long, 1.5cm (Día)	12cm long
Water content to Length	8cm	10.5cm
Bio waste content to length	8cm	10.5cm
Electrode	10cm long, 0.4cm (Día)	15.2cm long, 1.5cm (Día)

3. Result and Discussion

3.1 General

The aim of this study was to demonstrate the power generating capabilities of a particular bacteria and the utilization of the microbial fuel cell to facilitate this particular process. Setting up an external circuit using an accurate multimeter to measure the voltage and the overall cell resistance, the current can be calculated using the formula,

Ohm's law: **I=V/R** and the power can be calculated using

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the formula, **P= I*V**.
Where I= Current
R= External resistance

3.2 Data - Collection and Analysis

The power - output of the MFC was determined as follows:

$$P = \frac{E^2 cell}{R}$$

Where E= Cell Potential
R= Applied External Resistance

In the MFC, the electromotive force (EMF) was explained as the voltage, V that calculated the current value, I, the EMF was divided by the external resistor. The "standard cell electromotive force" is often defined as E0emf.

The standard cell electro - motive force was determined as follows:

$$E^0 emf = \frac{\Delta G^0}{nf}$$

Where: ΔG^0 - "the Gibbs free energy" (under the conditions of 298.15 K and 1 bar pressure). n - number of the electrons/ reaction mole of the substrate.
F - Faraday's constant - 9.64853 × 104 C /mol.
P = Voltage (V) x Current (I)

$$\text{Power Density} = \frac{\text{power}}{\text{anodic area } (mm^2)}$$

Surface - area of each of the electrode was calculated as follows:

$$A = 2\pi r^2 + \pi DL$$

Table 2: MFC1

TIME (DAY)	CURRENT (mA)	VOLTAGE (V)	RESISTANCE (Ω)	POWER (mW)	POWER DENSITY (mW/m^2)	CURRENT DENSITY (mA/m^2)
10th	1.16	0.116	100	0.1346	1390.625	905.471
20th	18.8	0.188	10	3.53	2757.8125	14674.89
30th	7.00	0.175	25	1.225	957.031	5464.05
40th	3.02	0.151	50	0.456	356.25	2357.34

Table 3: FOR MFC2

TIME (DAY)	CURRENT (mA)	VOLTAGE (V)	RESISTANCE (Ω)	POWER (mW)	POWER DENSITY (mW/m^2)	CURRENT DENSITY (mA/m^2)
1	16.3	0.254	15.58	4.1402	551.15	2169.86
2	22.8	0.312	13.68	7.1136	946.96	3035.2
3	34.4	0.55	15.99	18.92	2518.63	4579.33
4	47.8	0.69	14.43	32.98	4390.6	6363.15
5	54.7	0.851	15.6	46.6	6196.72	7281.69
6	62.5	1.02	16.32	63.8	8486.42	8320.02
7	59.4	0.89	15.0	52.86	7037.54	7907.34
8	44.9	0.77	17.14	34.57	4602.37	5977.10
9	44.3	0.713	16.10	31.58	4204.74	5897.23
10	43.1	0.65	15.08	28.015	3729.36	5737.486

Graphical Representation

Polarization Curves:
Using the EXCEL graphing tools, the polarization curves were generated for all the Microbial Fuel Cells.

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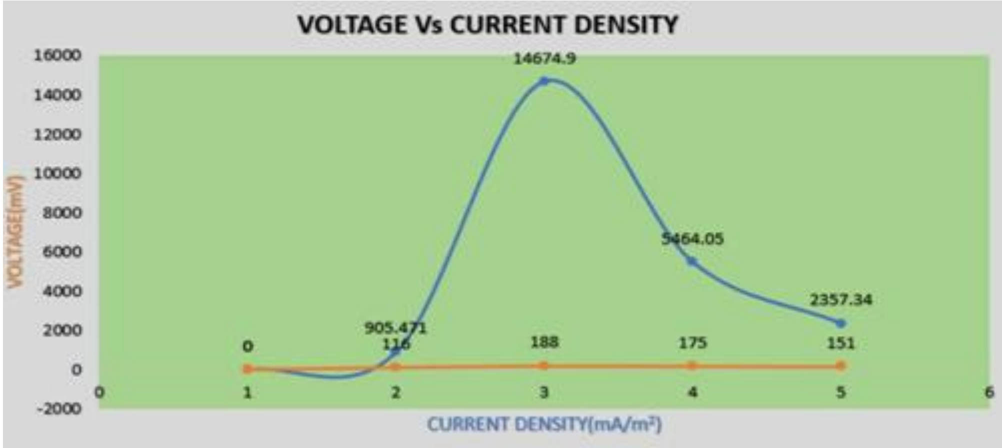

Figure 4: Polarization - Curve for MFC1

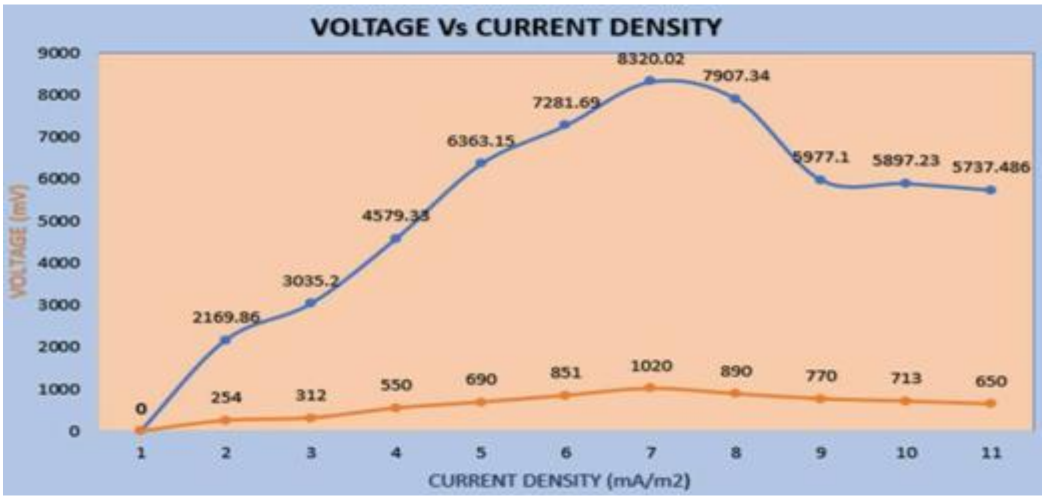

Figure 5: Polarization - Curve for MFC2

These plots demonstrated that how well MFC upholds the electric - potential as a function of the current density. For all MFCs, each plot illustrated a linear region (region 2) along with a constant voltage drop. Voltage values of **188 mV, 1020 mV** represented the maximum voltage for MFC1, MFC2 respectively.

For MFC1, the voltage falls to **175 mV** corresponding value to a current density of **5464.05 mA/m2**. For MFC2, there is a sudden drop to **890 mV, corresponding** value to a current density of **7907.34 mA/m2**. It was observed that when there is a increase in the resistance, there is drop in the value of the voltage. There is a linear decrease in the electric potential. After the linear decrease, there is a rapid potential drop at low value.

To determine the maximum power for all the MFCs, it was determined by plotting graphs, the power density as a function of the current density for each fuel cell.

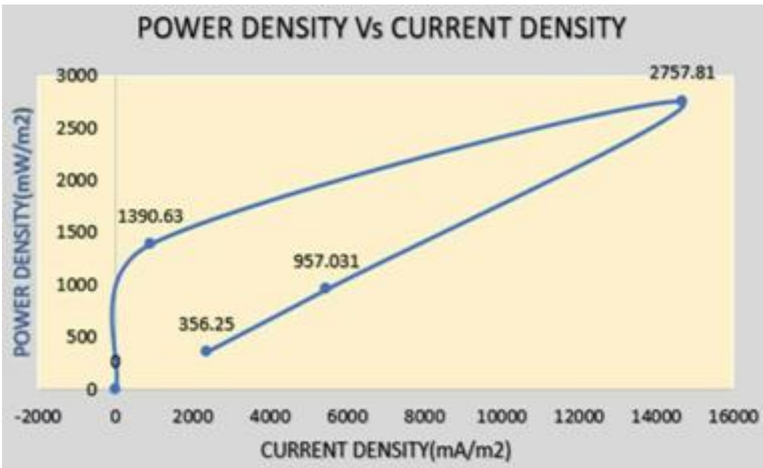

Figure 6: Power density curve for MFC1

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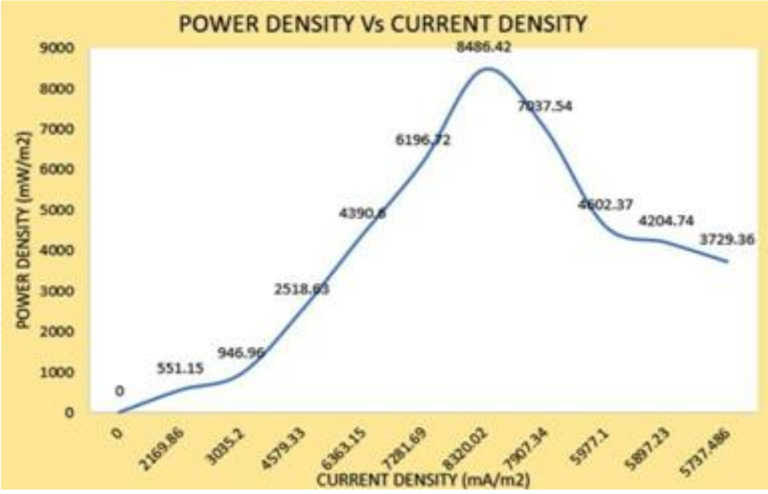

Figure 7: Power density curve for MFC2

The highest maximum power is noted for MFC1, MFC2 with a value of **2757.81 mW/m2** and **8486.42 mW/m2** respectively corresponding to current density values of **14674.89 mA/m2** and **8320.02 mA/m2.**

The internal Resistance affected the MFC's performance. . Electric circuit's principles show a maximum power can be recorded when **Rint= Rext;** therefore

$$Pmax = \frac{OCV^2}{4X\ R\ (int)}$$

This equation was useful in identifying the internal resistance of the MFC. By recorded value of the maximum power and the matching to the applied external resistance, the internal resistance was found. According to the figures 6 and 7, the respective internal resistances of the MFCs are **30.17 and 5.92** respectively. The reduction of the internal resistance in the fuel cell was the main objective. The MFC2 was found to be the best. The maximum power was achived for MFC2.

Coulombic Efficiency:

	MFC 1	MFC 2
Coulombic Efficiency	11.45%	63.49%

The highest Coulombic efficiency pertain to MFC2.

Table 4: Result Summary and Scale up

	MFC 1	MFC 2
Substrate	Sewage	Sewage
Anode Material	Graphite	Graphite
Cathode Material	Graphite	Graphite
Anode Surface Area (cm^2)	12.11	75.124
Cathode Surface Area (cm^2)	12.11	75.124
OCV (mV)	188	1020
Max. Power Density (mW/m^2)	2757.81	8486.42
Internal Resistance (ohm)	30.71	5.92
Coulombic Efficiency	11.45%	63.49%

4. Conclusion

From testing various sizes of electrodes, the substrates in 2 different MFCs, the MFC2 produces more useful energy as compared to MFC1. During an operational waste - water treatment, the MFC have been developed as a new source for the generation of the electricity. The cost of the conventional fossil - fuel, there is an alternative needed. MFC can be used as an alternative.

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