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Available online: April 30, 2014

To cite this article:


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Electricity Generation from Soakaway Wastewater using Microbial Fuel Cell Technology

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(Received: 27 March 2014 / Accepted: 07 April 2014 / Published: 30 April 2014)

Abstract

Microbial Fuel Cell (MFC) system was developed and used to generate electricity from soak-away wastewater with 270mg/l of COD (Chemical Oxygen Demand). The MFC was run continuously for 10 hours at an average temperature of 27.4\textdegree C. Tests were carried out to assess the condition and rate of electrical conductivity for the bacteria within the MFC. The pH and EC increased with the increase in time of operation respectively (pH: 4.52 to 7.00 and EC: 70\textmu s - 287\textmu s), and the voltage output also increased from 0.09V to 0.19V at a HRT of 10 hours.

Keywords: Microbial Fuel Cell, Electricity, Wastewater

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Subject: 0314-0232
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Introduction
The energy crises and continued exponential growth in human population has created a corresponding increase in the demand for sustainable energy as well as the earth’s limited supply of freshwater. Thus, renewable energy sources are at the centre of attention globally as an alternative to conventional methods of producing electricity from fossil fuels; at the same time, protecting the integrity of water resources and improving the technology of wastewater treatment are also essential environmental issues in this century. Energy-generating systems based on the fossil fuel impose a burden of greenhouse gases on the environment and are thus problematic. For the purpose of sustainable developing, avoiding water scarcity and preventing worse degradation of water system, in addition to precaution and regulation, technologies are urgently needed to improve wastewater treatment for providing people with safe and high-quality water production. Among the requirements of high-standard receiving water for potable use or non-potable uses such as agriculture irrigations, satisfying removal efficiency of COD (chemical oxygen demand) is required. With an ideal combination, Microbial Fuel Cell becomes the most promising and interesting technology as it is one of the most significant methods to generate energy from wastewater and organic solid wastes and it has gained considerable interests among academic researchers in recent years (Aelterman, et al., 2006b; Chaudhuri and Lovley, 2003; He, et al., 2005; Logan, et al., 2006b; Min and Angelidaki, 2008; Rabaey, et al., 2005a; Thygesen, et al., 2009). MFC is a biochemical-catalyzed system which generates electrical energy through the oxidation of organic matter in the presence of fermentative bacteria under mild reaction conditions (Logan and Regan, 2006a). MFCs have been initially developed as a method for simultaneous wastewater treatment and electricity production (Logan, 2005; Rabaey, et al., 2005a). While interesting, many researchers are realizing that the economic and environmental value of electricity from MFC cannot compete that of other energy sources at this stage.

The present study aims at the use of microbial fuel cell to generate electricity and also to assess electrical conductivity of the wastewater sample used during operation.

Materials and Methods
To build an MFC can be challenging when low-cost and high efficient materials come in to consideration. Since MFC currently can generate very low energy in comparison with the cost of materials needed to build it, an effort was made to select the right kind of material which was low-cost, readily available and could maximize power generation. The materials selected for the construction of the reactor included 14 liters cylindrical container, 3 inches PVC pipes, 2 inches PVC pipes, graphite, PVC pipes locks, soldering lead, POP cement, Anode plates, PVC gum, Digital multimeter, copper wires, resistor. The substrate used for the experiment was collected from a wastewater soak-away within Port Harcourt Environment. The wastewater was collected with 50 litres gallon and left overnight under room temperature at Centre for Biotechnology before being used for the experiment. To make an MFC, all the necessary materials were collected. First the proton exchange membrane was cut and cast in circular shape so that the diameter is little bit less than the pipe diameter. The reason is that the diameter of proton exchange membrane increases when it is put in 5% NaClO solution which was used as electrolyte for 12hours. The construction lasted for 15days using the materials listed above, at Centre for Biotechnology, University of Port-Harcourt.

The pH-value tells us if the wastewater is acidic or basic and is based on the concentration of hydrogen ion (H+) in a given solution. The pH value has a scale of 0 - 14 and pure water has the pH value of 7 at 25 degree Celsius temperature. If the pH value of a wastewater lies between 7 - 0 the wastewater becomes more acidic as the value decreases towards zero. On the contrary if the pH-value lies within 7 - 14, the water becomes more basic as the value increases. The pH of the wastewater was measured by a standard pH meter. Temperature, generally speaking, is not that sensitive during both of chemical reactions and physical reactions. During the experimental period, the temperature ranged from 26°C to 29°C. The system (wastewater MFC system) temperature was almost very stable around 26.5°C to 28°C. Electrical conductivity is responsible for conductance of electric current. Both the parameters were estimated by using HANNA EC/TDS - meter and values were expressed in μs/cm. The electrical conductivity of wastewater gives the information about the availability of inorganic, ionic elements or compounds in it. As the amount of inorganic, ionic elements or compounds in the wastewater increases, the conductivity also increases. Conductivity also increases with temperature. The Electrical conductivity was measured during the experiments on 2hours interval.

The voltage across the MFC system is a function of the external resistance (Rex), in my case 500 ohms, or load on the circuit, and the current, I. The relationship between these variables can be defined as

\[ V = IR_{ex} \]

Where we use V for the cell potential. The current produced from a single MFC is not directly measured, but instead it is calculated by the measured voltage drop across the resistor as

\[ I = \frac{V}{R_{ex}} \]

The highest voltage produced by an MFC is the open circuit voltage, OCV, which can be measured with the circuit disconnected (infinite resistance, zero current). As the resistances are decreased, the voltage decreases. The power at any time is calculated as

\[ P = IV \]

Voltages were recorded continuously using a digital multimeter with data acquisition unit throughout the experiments by connecting across the 500 ohms external resistor.

During the MFC-experiment voltage and voltage drop across a resistor was recorded after every 2 hours. A 500 ohm external resister was used to get the voltage drop between anode and cathode. And then current and power were
calculated according to the Ohm’s law and Joule’s law respectively. The experiments were terminated after reaching the optimal power generation point by the MFC.

**Results and Discussion**

Since the main aim of this work was to assess the effectiveness of electricity generation from soak-away wastewater using a single-chambered microbial fuel cell, the properties such as pH, temperature and electrical conductivity, will be enough to give the assurance of effectiveness of MFC system in generating electricity. The wastewater substrate was collected at the inlet of wastewater soak-away pit representing a wastewater with a variety of pollutants. Therefore, pH and electrical conductivity were tested for the soak-away wastewater before and during the experiments on an interval of 2 hours and the results are shown in Table 1. A picture of sample before the experiment is shown in Figure 3. As it can be seen in Table 1 the pH-value of wastewater increased from 4.52 to 7.0. Conductivity was also increased from 70 µs to 287 µs at a percentage increase of 24.40%.

Electricity in the MFC was generated in the process of treating wastewater. The voltage across the circuit containing a 500 ohm resistor increased to 0.19 V producing up to 0.072 mW of power based on the anode surface area. Power output was a function of circuit load (500 ohm) in the system, consistent with trends observed by others in other MFC experiments (Kim, *et al.*, 2009). At a hydraulic detention time of 8 hours, power reached a maximum of 0.072 mW, with a current of 0.380 mA in the absence of forced air flow through the cathode. Voltage output appeared to follow saturation kinetics as a function of NaOCl concentration. It was also observed that Electrical conductivity increase with an increase in voltage output. These observations show that the resistance becomes the rate limiting steps. Even at the same resistance, low current production could be to the lower electron consumption rate at the cathode and the transfer rate from the external circuit. This might be due to limiting supply of proton or oxygen. The lower current production indicates some electrons are consumed by mechanism(s) other than expected cathode reaction. It is plausible that under the conditions of limiting electron disposal through the circuit with a high resistance, the electrons are consumed in the anode to reduce other electron acceptors or oxygen diffused from cathode compartment or dissolved oxygen present in the influent, or methane production in the anode compartment. Higher fuel oxidation by the microbes is expected at a low external resistance to remove organic contaminants at a high rate (Jang, *et al.*, 2004). While full-scale, highly effective MFCs are not yet economically feasible this technology holds considerable promise and major hurdles will be undoubtedly overcome by scientists and engineers.

**Conclusion and Recommendations**

Electricity generated by MFCs is reliable. The technology can be implemented at a small scale and the generated electricity can be used as an alternative energy source. This study shows that electricity was successfully generated with wastewater using microbial fuel cell system, and the microorganisms responsible for electricity generation were already present in the wastewater. Though, the microbial electricity technology is still in an early stage of development, but the study shows great promise as a new method to accomplish both wastewater treatment and electricity generation. Major issues to be solved for practical application are to overcome the activity loss, cost factor and incomplete utilization of wastewater. If power generation in these systems can be increased, MFC technology may provide a new method to offset environmental pollution and making power energy more affordable for developing and developed nations. Thus, the combination of wastewater along with electricity production may help in saving money in this present century.

**Acknowledgement**

Thanks are due to Prof. B. E Okoli and all the staff of Regional Centre for Biotechnology, University of Port-Harcourt for their encouragement and support.
References


Tables

Table 1: MFC Experimental Results.

<table>
<thead>
<tr>
<th>Time (hour)</th>
<th>Voltage (V)</th>
<th>EC (µs)</th>
<th>Temp. (°C)</th>
<th>pH</th>
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<td>0.00</td>
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<td>8.00</td>
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<td>258</td>
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<td>7.00</td>
</tr>
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<td>0.13</td>
<td>287</td>
<td>27.8</td>
<td>7.00</td>
</tr>
</tbody>
</table>

Figures

Figure 1: Voltage generated by MFC vs time of operation.

![Voltage (V)](image1)

Figure 2: Electrical Conductivity reaction during MFC operation.

![Electrical Conductivity (µs)](image2)