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Electricity Generation from Septic Waste Water Using Septic Tank as Microbial Fuel Cell

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Abstract The use of microbial fuel cell (MFC) for electricity generation from septic waste water was carried out for 12 weeks retention period. In this study, the microbial fuel cells were designed and loaded with a 1000 Ω external load (resistor). Electrical voltage, current, power output was measured on weekly basis. Current density and power density were calculated. Wastewater qualities such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS) and pH of the raw wastewater were determined in the laboratory on weekly basis. pH values were constant (8.2) while the BOD, COD and TSS decreased. The performance of the MFC showed 92.7%, 93.9% and 98.6% reduction in BOD, COD and TSS respectively indicating that this process was efficient in the biodegradation of the septic waste water. The maximum voltage reading of 3.029V was obtained on the 6^{th} week but gradually decreased due to the formation of biofilm and reduction of substrate (food) in the cell. The linear correlation between voltage and the other parameters (current, current density and power density) have R^2 values of 0.9301, 0.9303 and 0.6274 respectively. The MFC design provides a solution for power generation from wastewater in homes. This single multistage MFC produced 3.029V of electricity which was able to power a 2.0 V LED bulb.

Keywords: *microbial fuel cell, septic tank, current density, power density, waste water*

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1. Introduction

The excessive utilization of energy to a greater extent around the world has contributed significantly to energy crisis, especially from the environmental perspective. The world all over depends on energy from coal and fossil fuels which cause environmental concern and pollution due to accumulation of harmful gases in the air. This phenomenon has resulted in global warming, acid rain, climate change, emission of harmful gases, and other environmental problems [1,2,3]. The high demand of fuel and renewable energy sources which are eco-friendly has led researchers into developing renewable energy as alternative energy sources. Apart from the environmental concern and energy crisis, there is increased interest to discover sustainable and clean source for electricity generation with little hydrocarbons [4,5,6,7]. Recently, many renewable energy sources have come up such as solar energy, hydroelectric energy and bio-electrochemical energy sources [2]. Bio-electrochemical energy sources constitute an emerging alternative energy sources which make use of microbes for the generation of electricity. This source of renewable energy explores the interaction between microbes, wastewater and electron acceptor. The most described type of bio-electrochemical source of energy is the Microbial Fuel Cells [8,9,10]. Microbial Fuel Cells are bio-electrochemical transducers that convert organic matter into electricity using bacteria as catalysts. MFCs are devices capable of directly transforming chemical energy into electrical energy via electrochemical reactions involving biochemical pathways and biological enzymatic catalysts [11]. The use of MFCs as alternative source for power generation is considered as a clean, reliable, efficient process which utilizes renewable methods and does not generate any toxic by-products [12,13]. Researchers had utilized wastewater and biodegradable organic rich materials such as anaerobically digested distillery wastewater [1], tapioca waste water [14], sewage sludge [15], artificial waste water [16], domestic wastewater [7] and biowaste [17] in MFCs to generate electricity. The wastewater generated in homes is channeled into septic tanks and it contains biomass which may be exploited to generate electricity. This wastewater and some organic wastes contain certain biomass such as *S. Putrefaciens, G. Sulferreducens, Aeromonas hydrophilic, Geobacter metallic reducens, Geobacter sulferreducens, Rhodoferax-ferrireducins, Clostridium butyricum,* etc. which transfer electrons directly to the anode [18,19]. The microorganisms oxidize the substrates in the anodic chamber producing electrons and protons as well as carbon (IV) oxide as the oxidation product. At the cathode, water is produced. In MFCs micro-organisms act as electrons carrier or transporter to anodes. The transport of the electrons is due to electron shuttles present in a soluble form in bulk solution or transport units in the extracellular matrix. This extracellular matrix forms a bio-film in the anode [20,21]. The aim of this research is to generate electricity using the septic waste water that is abundant from the female hostel utilizing the microbial fuel cell technology. The electricity generated will be used to power any small device in the hostel.

2. Materials and Methods

2.1. Materials

Concrete Septic tanks, 100 - 1,000 ohms resistors, Variable resistance box, digital Multimeter (DT 9205A), Connecting wires, Graphite plates, PVC pipes with control valves, Septic wastewater (from the female hostel).

2.2. Construction of the MFC

The construction and use of MFCs requires knowledge of both scientific and engineering fields from microbiology and electrochemistry to materials and environmental engineering. The choice of electrode materials in this construction is very crucial. Metal electrodes if used should be non-corrosive and chemically resistant [22]. Copper has been noted to cause toxicity [23,24] to many bacteria and should be avoided. Graphite or carbon materials give better results when compared to aluminum, stainless steel or iron electrodes [25]. Construction of the concrete septic tank involved making provision for both inlet and outlet openings for the waste water from the septic reservoir in the female hostel of the institution. The measurement of the cathode chamber was 0.216 m^3 and 0.648 m^3 for the anode chamber. The graphite plates were placed at equal spacing and connected with copper wires. This is the anode chamber. The cathode chamber was constructed using another concrete tank and filled with hypochlorite solution to increase conductivity. The three anode chambers were connected to the cathode by copper wires from the anode terminals to the multimeter then to the resistor and finally to the cathode terminal.

Figure 1. The constructed four chambers

Figure 2. Filling the cathode chamber with hypochlorite solution

Figure 3. Connecting a generator to the septic waste at the female hostel

Figure 4. Preparing the feed line for the delivery of the septic waste into the anode chambers

3. Results and Discussions

3.1. Results

The physicochemical characteristics of the septic wastewater used in this research are presented in Table 1.

Table 1a. Characteristics of the Septic Waste Water

Parameter	Retention Time (weeks)						
	0	1	2	3	4	5	6
pH	7.9	8.1	8.1	8.0	8.1	8.2	8.1
TSS (mg/L)	1038	430	310	264	196	133	107
BOD (mg/L)	271	253.1	203.9	120.3	84.5	43.2	40.1
COD (mg/L)	430.2	404.9	346.6	187.7	143.6	68.8	62.6

Table 1b. Characteristics of the Septic Waste Water.

Parameter	Retention Time (weeks)					
	7	8	9	10	11	12
pH	8.1	8.2	8.2	8.1	8.2	8.2
TSS (mg/L)	82.5	64.4	53.5	38.7	21.6	15.0
BOD (mg/L)	37.6	35.5	30.0	27.1	22.1	19.8
COD (mg/L)	58.7	55.1	46.1	41.7	33.0	26.4

Table 2. Results of retention time (weeks) and electrical voltage (V)

Retention Time (week)	Electric Voltage (V)
0	0.207
1	0.685
2	1.220
3	1.749
4	2.175
5	2.373
6	3.029
7	2.829
8	2.964
9	2.720
10	2.420
11	1.915
12	1.720

Table 3. Polarization Data for the MFC with an External Resistance of 1000 ohms

Current (mA)	Voltage (mV)	Resistance (Ω)	Power (mW)	Current Density (mA/m^3)	Power Density (mW/m^3)
0.90	1673	1000	810.00	8.88	7996.0
0.99	1466	900	882.09	9.77	8707.6
1.11	1381	800	985.68	10.95	9730.3
1.2	1350	700	1008.00	11.84	9950.6
1.3	1304	600	1014.00	12.83	10009.8
1.32	1278	500	871.20	13.03	8600.1
1.33	1256	400	707.56	13.12	6984.7
1.35	1231	300	546.75	13.32	5397.3
1.37	1207	200	375.38	13.52	3705.6
1.38	1173	100	190.44	13.62	1879.9

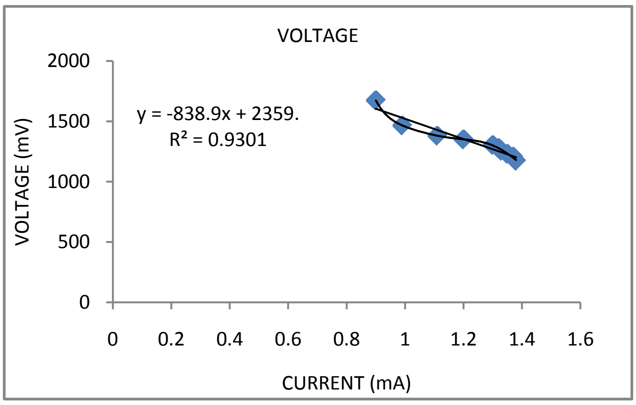

Figure 5. Polarization curve for MFC with a 1000Ω resistor load

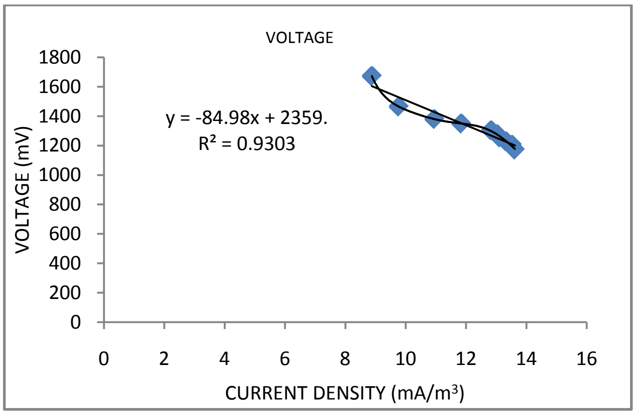

Figure 6. Relationship between voltage and current density

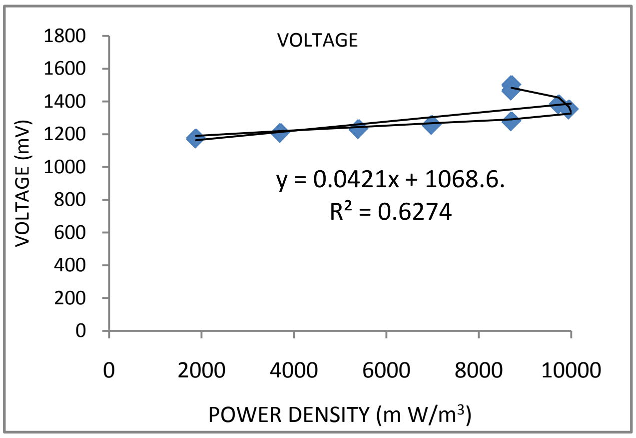

Figure 7. Relationship between voltage and power density

3.2. Discussion

The MFC performance and efficiency was evaluated in terms of electrical parameters namely; power density, current density, internal resistance and polarization. The biodegradation efficiency was measured using the COD and BOD. Table 1 shows the values of the pH, COD, BOD and TSS obtained in this study. The pH values were observed to be constant from week 1 to week 12 with an average of 8.2. The total suspended solids (TSS) had the highest value of 1038 mg/L on the first day. By the end of week 1, this value had reduced by 58.6 % and on week 6 by 89.7 %. At week 12, the TSS value obtained was 15 mg/L showing that 98.6 % of the substrate was used up. The BOD and COD showed a similar trend in decrease of values obtained as the weeks progressed. The MFC was able to reduce the BOD and COD by 92.7 % and 93.9%.These values compare favorably with those reported by [15,26,27]. Table 2 shows the electricity generated in terms of voltage on weekly basis. The maximum voltage of 3.029 V produced at week 6. The voltage increased from 0.207 V on the initial day to 3.029 V and gradually decreased in the weeks following. This is due to the formation of biofilm and reduction of substrate (food) in the cell. This is observed in the results obtained for BOD and COD in Table 1. These two parameters are indicators that aid in the determination of the availability of substrates for the microbes. The polarization data for the MFC with an external resistance of 1000 ohms is presented in Table 3. The plot of open circuit voltage (OCV) and the internal resistance of cell operated at this load are presented in Figure 1. The Open circuit Voltage (OCV) is 2359.6 mV and the internal resistance (IR) of the fuel cell is 838.94 Ω. The EMF of the cell is calculated using the equation:

$$EMF = OCV - IR.$$

The relationship between voltage and current density is presented in Figure 2. From this figure, it is observed that with increase in current density, there is a corresponding decrease in voltage. The relationship between power density and voltage is presented in Figure 3 showing that an increase in power density also causes an increase in voltage. Studies carried out using waste water as source of mixed microbial inocula for bio-electricity production reported considerable efficient power densities of 432 mW/m^2 [28], 230 mW/m^2 [29] and 88990 mW/m^2 [22]. In this work, the highest power density was 10009 mW/m^2. The maximum voltage output was 1673 mV which compares favorably with the value (1652 mV) obtained by [15] using sewage sludge. In order to use the designed and constructed MFC to power a LED bulb of 2.0V, a single MFC was loaded with a 1000Ω resistor and allowed to produce the maximum power of 3.029V of electricity. On production of the over 3.0V electricity, the resistor was removed and the LED bulb was connected. The cell automatically powered the bulb.

4. Conclusion

The application of Microbial Fuel Cell for electricity generation using septic waste water provides a solution for power generation. This technology can be used for wastewater treatment systems in homes and its biodegradation efficiency can be evaluated by measuring the COD. MFCs can be used as bio-sensors by monitoring the BOD in the waste water. By this process, the conversion of waste to wealth has been achieved. A single multistage MFC produced approximately 3.0V of electricity; this implies that when four of the MFCs are connected in parallel, it can produce up to 10.5V of electricity.

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