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MICROBIAL FUEL CELL POTENTIAL IN AUGMENTING NIGERIAS' ENERGY MIX

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ABSTRACT: Nigeria generates less than 10000MW of electricity. There is a pressing demand for the increase in power generation for domestic and industrial application. Energy mix is a solution to generate more power. Different technologies harness different energy stored in different element. The microbial fuel cell (MFC) harnesses the energy from organic matter. In this study, three single chamber MFCs and an organic battery was built and organic waste matter used as an energy source to power multiple LED indicator bulbs functioning as road traffic lights. The average power generated by the MFCs and microbial fuel battery (MFB) during the period under investigation was 3.27V and 8.15V daily. Materials selected for the electrodes were cylindrical graphite rods and aluminium plates, while the organic matter used as electrolyte was a mixture of cow dung and water in the ration of 4:1 by weight. Tests and experiments indicated the MFC can be used in a redesigned road traffic light and safety signs to function from power generated from the MFC. Results indicated the use of organic waste matter in the MFC can serve to augment Nigeria's energy mix while simultaneously managing organic waste matter generated and improving the state of the economy.

Keywords: Microbial Fuel Cell, Mediatorless, Organic Matter, Power, Voltage, Current, LED bulbs, Traffic Lights, Energy Mix

1. INTRODUCTION

There is global concern about the negative effects on the environment from the continued use of fossil fuels for power generation; hence identification of renewable energy sources and the development of technology's used in harnessing such energy for power generation is of great importance to scientist and engineers globally [4,8]. Nigeria, a sub-Sahara African country with a population of over 180 million has electric power generation capacity of 10000MW and transmits about 4000MW. It has been identified that economic viability of a nation is dependent on the electric power generated, transmitted and utilised [9].

Electric power can be generated via coal, oil and natural gas; hydro-power, water turbine; nuclear power; solar-wind or water wave turbine; solar thermal generator and solar voltaic generator; however, Nigeria generates power from gas-fired and hydro-electric turbines for bulk generation. The amount of electric power generated from these sources is insufficient to meet domestic, industrial and social demand; hence other energy sources need to be harnessed to improve the power generation in Nigeria [10].

Waste is regarded as unwanted material which is disposed of or cannot be reused after primary use [17]. The amount of waste generated annually in Nigeria exceeds 30 million tonnes and over 50% is organic in nature. Organic matter can be used to generate electricity with the use of MFC. Though the electric power generated is low, it however finds applications in wastewater treatment, environment sensors for geographical weather monitoring, bioremediation and hydrogen production. Waste generated is improperly managed in Nigeria, with more that 80% not collected for recycling or proper disposal. Failure to properly manage waste generated leads to environmental dilapidation as well as a threat to public health safety [18].

Social energy demand such as energy required for functionality of road traffic lights, road safety signs which helps check road user is often times not available. Due to the current challenges of inability to meet the energy requirement for development and its sustenance such as that required for the powering of road traffic lights and road safety signs, the Federal, State and Local government have resulted to using solar power system to meet this energy demand; however, the solar power system is under threat of theft as a result of the high cost of procurement and the high demand, and the environment as it dependent on the availability of sunlight (insolation). This leads to unchecked road traffic, use of human capital in road traffic control, thereby reducing human productivity. An alternative clean energy source that is cheap readily available and suitable is required to meet the social energy demand. The microbial fuel cell can be utilized in road traffic while simultaneously helping to manage the organic waste generated.

The microbial fuel cell is a device which is used to harness the stored chemical energy in organic matter by converting it directly to electrical energy. There are two types of MFC i.e. mediator and mediatorless MFC [3,19]. Power generated from the MFC is in microwatts but currently finds application in geographical environmental sensors. It can also find application for different social energy demand, for example, in the redesign of road traffic light and safety signs that requires micropower for operation. The MFC has an energy conversion rate of machine or device, hence, there is therefore the need to harness the chemical energy stored in organic waste matter and convert it to electrical energy in the MFC to augment the energy mix for increased power generation while simultaneously efficiently and effectively managing the organic waste generated.

While the current power generated in Nigeria is below the demand, distribution companies resolve to distributing power on an intermittent basis leading to economic stagnation. A stand-alone road traffic or street light powered solely from the electrical energy harnessed from a microbial fuel battery built from waste materials and agricultural waste (cow dung) will reduce the current load on the infrastructure in the power sector as there will be no direct connection with the nation's power grid. This will enable the rerouting of the power utilized for operating road traffic or street light to other production industries and technologies for economic growth and development.

The MFC technology is a maturing industry with positive prospects with regards to economic development. With further development, MFCs have the potential to produce hydrogen for fuel cells, desalinate sea water, and provide sustainable energy sources for remote areas.

2. METHODS

The materials and method applied in the execution of this work is tabulated and explained below.

Three single chamber microbial fuel cells labelled I, II and III respectively were built and connected in series. Scrap aluminium plates were collected from a manufacturing warehouse, cut and folded into multiple rectangular plates which were used as the anode electrode. Cylindrical graphite rods were purchased from a local dealer and were used as the cathode electrode in the each MFC. 8, 6 and 4 electrodes each of aluminium plates were together connected in series respectively thereby increasing the surface area. 8, 6 and 4 graphite rods were also together connected in series with the same motive of increasing the surface area. The ratio of aluminium electrode to graphite electrode used for the three cells was 2:1. The series connections of the various respective aluminium and graphite electrodes were placed in three separate plastic containers and prevented from touching each other with the use of a cut out rubber separator. Cow dung was collected from an abattoir and charged into each MFC. Functionality of the MFCs was tested with an LED indicator bulb. From experimental results, an organic fuel battery was built and used to power a multiple LED indicator bulbs arranged in the form of a road traffic light. The voltage and current output data was measured with a multimeter and the pH level of the organic matter was measured using a pen-type pH meter. The setup was monitored for a period of 28 days.

Table 1. Material used and their function

S/N	Material/Equipment	Function
1	72 polyethylene (PET) bottles	Each PET bottle functioned as one MFC chamber
2	Electrodes (Aluminium plates and cylindrical graphite rods)	The electrode is to establish the presence of a potential difference which the microbes transfer the released electrons to.
3	Organic matter (cow dung + blended fruits)	The organic matter is the source of fuel in the MFC.
4	Flexible copper wires	Connected between both electrodes, its function is to transfer the electrons deposited at the anode electrode through the equipment or machine to be powered and then through to the cathode electrode.
5	LED bulbs	Used to test the functionality of the MFC.
6	Pen-type pH meter	Used to obtain the pH value of the organic matter.
7	Electrical multimeter	Used to obtain voltage and current parameters of the organic matter.

3. EXPERIMENTAL

Mathematical formulae were used to obtain the values of parameters such as power and power density as expressed in (3) and (4) respectively.

$$\text{Area of aluminium electrodes } (A_a) = 2 * l * b \quad (1)$$

$$\text{Area of graphite electrode } (A_g) = 2\pi r(r + h) \quad (2)$$

$$\text{Power (P)} = \text{voltage (V)} * \text{current (I) i.e. } P = VI \quad (3)$$

$$\text{Power density (Pd)} = \text{(Power (W))} / \text{(Total surface area (mm2))} \quad (4)$$

$$\text{Volume of containers (V)} = \text{length (l)} * \text{breadth (b)} * \text{height (h)} \quad (5)$$

3.1 Series and Parallel Connection of MFCs

The microbial fuel cell is similar to other electrical cell. The MFC obeys the principles of electricity and therefore may be connected in same way other electrical cells are connected. Figure 1 shows the series connection of the MFCs. Equation 6 and equation 7 shows the mathematical relationship of the total voltage output obtained from the resulting series connection. Equation 8 shows the mathematical relationship of the total current output ($MFC_{t.current}$) obtained from the resulting series connection.

Figure 2 show the parallel connection of the MFCs. Equation 9 and equation 10 shows the mathematical relationship of the total voltage output obtained from the resulting parallel connection. Equation 11 show the mathematical relationship of the total current output ($MFC_{T.current}$) obtained from the resulting parallel connection.

3.1.1 Series Connection

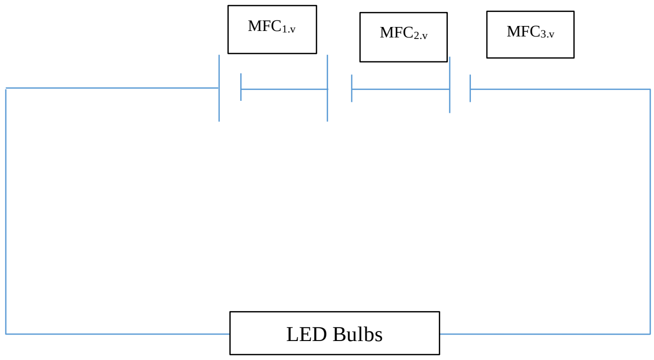

Figure 1. Series connection of the MFCs

Total MFC voltage output ($MFC_{T.volt}$) = $MFC_{1.v} + MFC_{2.v} + MFC_{3.v}$ (6)

Total MFC current output ($MFC_{t.current}$) = $\frac{1}{MFCt.current} = \frac{1}{MFCI1} + \frac{1}{MFCI2} + \frac{1}{MFCI3}$ (7)

Total current output ($MFC_{T.current}$) = $\frac{(MFCI2 \ X \ MFCI3)+(MFCI1 \ X \ MFCI3)+(MFCI1 \ X \ MFCI2)}{(MFCI1 \ X \ MFCI2 \ X \ MFCI3)}$ (8)

3.1.2 Parallel Connection

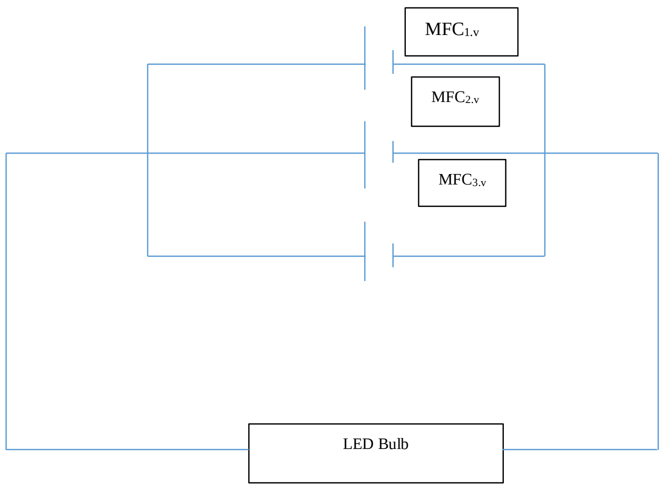

Figure 2. Parallel connection of MFCs

Total voltage output ($MFC_{t.volt}$)

$$\frac{1}{MFCt.volt} = \frac{1}{MFC1.v} + \frac{1}{MFC2.v} + \frac{1}{MFC3.v} \quad (9)$$

$$MFC_{t.volt} = \frac{(MFC2.v \ X \ MFC3.v)+(MFC1.v \ X \ MFC3.v)+(MFC1.v \ X \ MFC2.v)}{(MFC1.v \ X \ MFC2.v \ X \ MFC3.v)} \quad (10)$$

Total current output ($MFC_{T.current}$) = $MFC_{I1} + MFC_{I2} + MFC_{I3}$ (11)

3.2 Microbial Fuel Battery (MFB) Specification

In this research work, the fabricated fuel battery specification was obtained from the data collected. This is presented below. Table 2 show the volume of electrolyte in each MFC of the MFB

Number of stacked MFC = 6

Number of single cells in each microbial fuel battery = 12

3.2.1 Volume Calculation

The plastic container used for each single cell in the MFB was of the same type and dimension. Plastic containers used were a hollow rectangular shape having dimensions of 65mm by 65mm by 130mm.

Volume of single cell container = 65mm * 65mm * 130mm

$= 549250mm^2$

Volume of single cell electrolyte (slurry) = 65mm * 65mm * 120mm

$= 507000mm^2$

Table 2. Volume of electrolyte in the MFC of the MFB

S/No	Microbial Fuel Cell	Volume of Electrolyte (mm^3)
1	Cell 1	507000
2	Cell 2	507000
3	Cell 3	507000
4	Cell 4	507000
5	Cell 5	507000
6	Cell 6	507000
7	Cell 7	507000
8	Cell 8	507000
9	Cell 9	507000
10	Cell 10	507000
11	Cell 11	507000
12	Cell 12	507000
Total		**6084000**

3.2.2 Electrode Specification

Total area of aluminium electrode (mm^2) = $74496mm^2$

Total area of graphite electrode (mm^2) = $35152.42mm^2$

Ratio of graphite to aluminium electrode = 1 : 2

4. RESULTS

Table 3. Readings from MFC 1.

Sample Description and Parameters	The cathode is graphite and the anode aluminium. The electrolyte is cow dung mixed with water.					
	Average area of graphite electrode				1.91 square cm	
	Total area of graphite electrode				15.26 square cm	
	Average area of aluminium electrode				30.94 square cm	
	Total area of aluminium electrode				247.5 square cm	
	Mass of dung				4kg	
	Mass of water added				1kg	
	Total Mass				5kg	
Day	pH	Volt (V)	Current (mA)	Power (mW)	Power Density (mW/mm^2)	LED Bulb Status
1	5.42	0.73	10.87	7.94	0.106	ON
2	5.57	0.72	10.53	7.58	0.101	ON
3	5.71	0.71	10.46	7.42	0.099	ON
4	5.96	0.65	8.63	5.61	0.075	ON
5	6.03	0.67	6.12	4.1	0.055	ON
6	6.14	0.68	6.2	4.22	0.057	ON
7	6.38	0.65	5.87	3.82	0.051	ON
8	6.41	0.65	4.81	3.13	0.042	ON
9	6.59	0.65	4.39	2.85	0.038	ON
10	6.71	0.6	4.2	2.52	0.034	ON
11	9.39	0.6	7.26	4.36	0.058	ON
12	9.17	0.55	6.38	3.51	0.047	ON
13	8.92	0.54	6.83	3.69	0.049	ON
14	8.83	0.53	6.67	3.54	0.047	ON
15	8.55	0.51	6.11	3.12	0.042	ON
16	8.31	0.5	6.53	3.27	0.043	ON
17	8.16	0.49	5.7	2.79	0.037	ON
18	7.97	0.48	5.4	2.59	0.035	ON
19	7.68	0.41	5.23	2.14	0.029	ON
20	7.42	0.41	5.59	2.29	0.031	ON
21	7.31	0.4	5.43	2.17	0.029	ON
22	7.25	0.39	4.32	1.68	0.023	ON
23	7.18	0.36	4.88	1.76	0.024	ON
24	7.14	0.35	5.21	1.82	0.024	ON
25	7.11	0.32	3.63	1.16	0.016	ON
26	7.09	0.32	3.72	1.19	0.016	ON
27	7.06	0.27	3.93	1.06	0.014	ON
28	7.04	0.26	3.2	0.83	0.011	ON

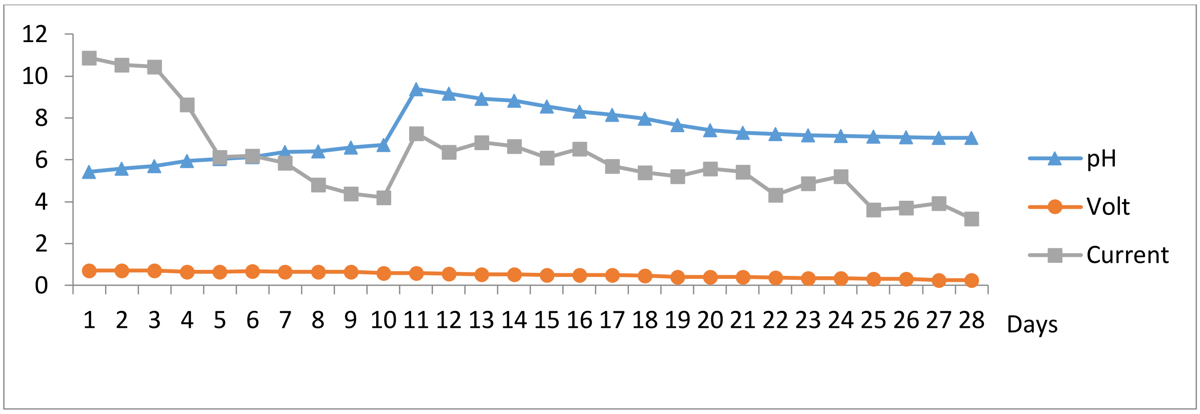

Figure 3. Graph of pH, voltage and current readings from Table 2.

Table 4. Readings from MFC 2.

Sample Description and Parameters	The cathode is graphite and the anode aluminium. The electrolyte is cow dung mixed with water.					
	Average area of graphite electrode				2.29 square cm	
	Total area of graphite electrode				13.75 square cm	
	Average area of aluminium electrode				32.5 square cm	
	Total area of aluminium electrode				195 square cm	
	Mass of dung				4kg	
	Mass of water added				1kg	
	Total Mass				5kg	
Day	**pH**	**Volt (V)**	**Current (mA)**	**Power (mW)**	**Power Density (mW/mm^2)**	**LED Bulb Status**
1	5.53	0.7	9.82	6.31	0.110	ON
2	5.61	0.69	8.29	5.72	0.099	ON
3	5.73	0.67	7.02	4.7	0.081	ON
4	5.89	0.67	6.92	4.64	0.080	ON
5	6.01	0.67	5.73	3.84	0.066	ON
6	6.23	0.65	4.82	3.13	0.054	ON
7	6.47	0.65	5.88	3.82	0.066	ON
8	6.65	0.64	5.61	3.59	0.062	ON
9	6.86	0.64	5.83	3.59	0.062	ON
10	9.13	0.63	4.83	3.04	0.052	ON
11	9.47	0.61	8.15	4.97	0.086	ON
12	9.25	0.61	6.56	4.00	0.069	ON
13	9.11	0.6	6.24	3.74	0.064	ON
14	9.03	0.59	5.18	3.06	0.053	ON
15	8.97	0.55	6.84	3.76	0.065	ON
16	8.91	0.53	6.4	3.39	0.058	ON
17	8.63	0.52	5.66	2.94	0.051	ON
18	8.42	0.48	6.2	2.98	0.051	ON
19	8.27	0.48	5.88	2.82	0.049	ON
20	7.94	0.46	5.11	2.35	0.041	ON
21	7.68	0.46	4.8	2.21	0.038	ON
22	7.31	0.41	4.75	1.95	0.034	ON
23	7.23	0.41	5.29	2.17	0.037	ON
24	7.21	0.37	5.63	2.08	0.036	ON
25	7.20	0.36	4.52	1.63	0.028	ON
26	7.19	0.32	4.4	1.41	0.024	ON
27	7.16	0.3	4.57	1.37	0.024	ON
28	7.12	0.3	3.22	0.97	0.018	ON

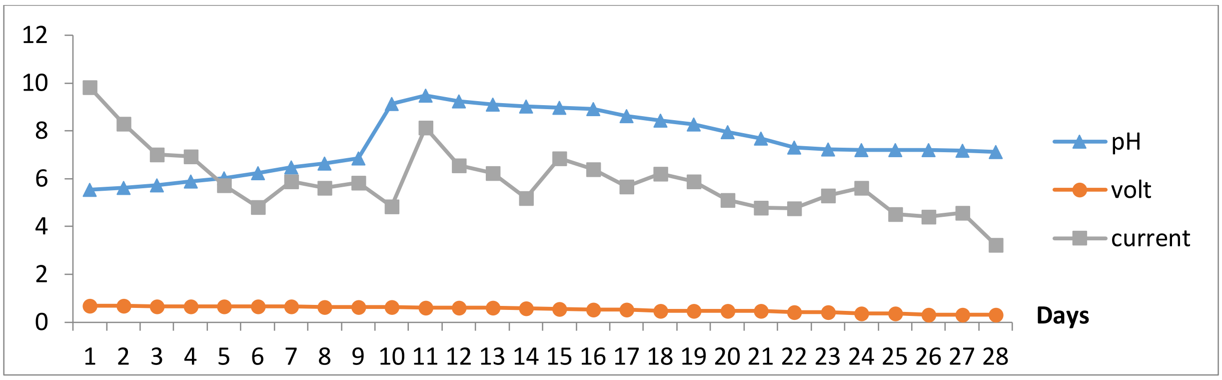

Figure 4. Graph of pH, voltage and current readings from Table 3.

Table 4 show the maximum voltage obtained was 0.7V with a corresponding maximum current of 9.82mA. The minimum voltage and minimum current obtained were 0.3V and 3.22mA respectively. The voltage drop was 0.4V during the period under investigation. The average voltage and average current and average power obtained were 0.53V, 5.86mA and 3.22mW respectively. Figure 4 show the curve pattern of pH, voltage and current data obtained from the experiment conducted. The graph shows the current having a fluctuating but decreasing trend. The voltage showed a steady and gradual decrease. The pH showed a steady and gradual increase until a sudden climb followed by a gradual decrease due to the change in the organic decomposition stage.

Table 5. Readings from MFC 3.

Sample Description and Parameters	The cathode is graphite and the anode aluminium. The electrolyte is cow dung mixed with water.	
	Average area of graphite electrode	2.19 square cm
	Total area of graphite electrode	8.77 cm
	Average area of aluminium electrode	29.5 square cm
	Total area of aluminium electrode	118 square cm
	Mass of dung	4kg
	Mass of water added	1kg
	Total Mass	5kg

Day	**pH**	**Volt (V)**	**Current (mA)**	**Power (mW)**	**Power Density (mW/mm^2)**	**LED Bulb Status**
1	5.48	0.69	9.96	6.87	0.190	ON
2	5.66	0.67	9.76	6.54	0.180	ON
3	5.93	0.67	9.53	6.39	0.180	ON
4	6.27	0.67	8.82	5.91	0.160	ON
5	6.41	0.64	7.53	4.82	0.130	ON
6	6.54	0.63	6.63	4.18	0.110	ON
7	6.62	0.62	6.43	3.99	0.110	ON
8	6.73	0.58	5.32	3.09	0.085	ON
9	6.88	0.57	6.01	3.43	0.094	ON
10	8.76	0.57	6.15	3.51	0.096	ON
11	9.31	0.52	8.63	4.49	0.120	ON
12	9.11	0.52	8.15	4.24	0.120	ON
13	8.86	0.51	6.78	3.48	0.096	ON
14	8.77	0.51	6.16	3.14	0.086	ON
15	8.63	0.51	6.05	3.09	0.085	ON
16	8.52	0.5	5.58	2.79	0.077	ON
17	8.44	0.49	6.11	2.99	0.082	ON
18	8.19	0.47	5.23	2.46	0.068	ON
19	7.91	0.47	5.21	2.45	0.067	ON
20	7.83	0.45	5.09	2.29	0.063	ON
21	7.67	0.43	4.93	2.13	0.059	ON
22	7.48	0.42	4.51	1.89	0.052	ON
23	7.39	0.41	4.31	1.77	0.049	ON
24	7.31	0.41	3.88	1.59	0.044	ON
25	7.27	0.41	3.57	1.46	0.040	ON
26	7.22	0.38	3.31	1.26	0.035	ON
27	7.17	0.35	3.26	1.14	0.031	ON
28	7.13	0.34	3.08	1.05	0.029	ON

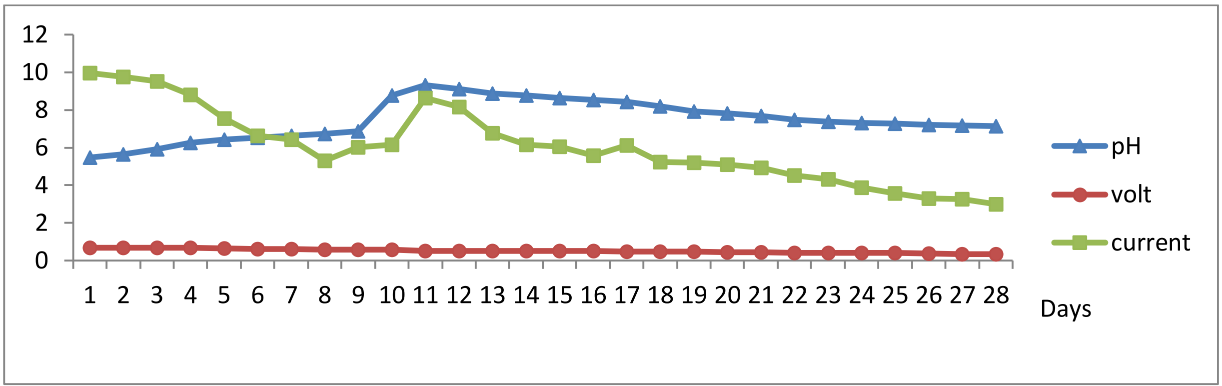

Figure 5. Graph of pH, voltage and current readings from Table 4.

Table 5 show the maximum and minimum voltage obtained were 0.69V and 0.34V respectively. The voltage drop in the cell during the period under investigation was 0.35V. The average voltage, average current and average power obtained was 0.51V, 7.08mA and 3.30mW respectively. Figure 5 shows the curve patterns exhibited by the pH, voltage and current data obtained. The voltage curve pattern shows a gradual and steady decrease. A gradual and steady increase of pH value was observed with a sudden climb followed by a gradual and steady decrease during the period under investigation. The curve pattern exhibited by the current showed a decrease followed by a sudden climb which was then accompanied by a gradual fall. The graph shows one point of intersection between the pH and current curves. The point of intersection occurred at a value of 6.59.

From Table 3, Table 4 and Table 5, the surface area of electrode had an effect on the output of the MFC. The result indicated that the MFC with the largest surface area had the highest voltage drop of 0.47V. This could be as a result of the microbes having more electrode surface area to attach themselves to, thereby transferring more energy.

From Figure 3, Figure 4 and Figure 5 exhibited similar curve patterns indicating that the organic matter undergone through the decomposition process and also the current output is dependent on the stages of these processes.

Table 6. Readings from MFC 1, MFC 2 and MFC 3 connected in series.

Sample Description and Parameters	The cathode is graphite and the anode aluminium. The electrolyte is cow dung mixed with water.	
	Average area of graphite electrode	2.1 square cm
	Total area of graphite electrode	37.78 square cm
	Average area of aluminium electrode	31.14 square cm
	Total area of aluminium electrode	560.5 square cm
	Total Mass of dung	12kg
	Total Mass of water added	3kg

Day	Volt (V)	Current (mA)	Power (mW)	Power Density (mW/mm^2)	LED Bulb Status
1	2.06	9.71	20.00	0.082	ON
2	2.01	9.59	19.28	0.150	ON
3	1.93	8.46	16.33	0.097	ON
4	1.92	9.98	19.16	0.110	ON
5	1.73	6.45	11.16	0.066	ON
6	1.81	9.85	17.83	0.110	ON
7	1.61	7.89	12.7	0.075	ON
8	1.90	7.95	15.11	0.089	ON
9	1.60	6.12	9.79	0.058	ON
10	1.23	4.98	6.13	0.036	ON

11	0.96	4.00	3.84	0.023	ON
12	0.95	4.24	4.03	0.024	ON
13	1.03	3.42	3.52	0.021	ON
14	0.99	4.63	4.58	0.027	ON
15	0.93	4.43	4.12	0.024	ON
16	1.10	4.41	4.85	0.029	ON
17	0.62	3.60	2.23	0.013	ON
18	0.76	4.80	3.65	0.022	ON
19	0.79	5.01	3.65	0.022	ON
20	0.77	5.33	4.1	0.024	ON
21	0.80	5.14	4.11	0.024	ON
22	0.93	5.23	4.86	0.029	ON
23	0.92	5.12	4.71	0.028	ON
24	0.92	5.53	5.03	0.030	ON
25	0.91	6.16	5.61	0.033	ON
26	0.91	6.70	6.1	0.036	ON
27	0.91	6.40	5.82	0.034	ON
28	0.89	6.50	5.79	0.034	ON

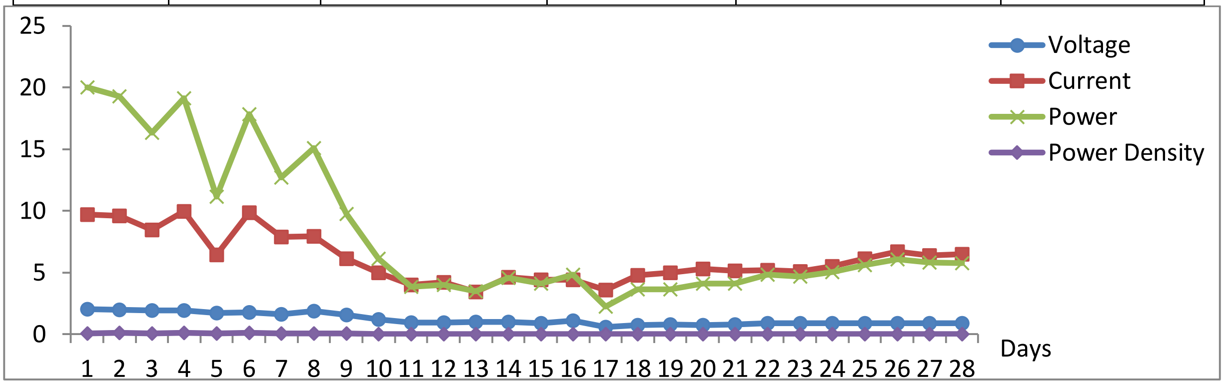

Figure 6. Graph of voltage, current, power and power density of MFCs connected in series

Table 6 shows the maximum voltage obtained was 2.06V. This showed that when MFCs are connected in series, the voltage increased, implying that MFCs obey the principles of electricity. The minimum voltage obtained was 0.89V. The voltage drop over the period under investigation was 1.17V. The average voltage and average current obtained were 1.21V and 6.13mA respectively. Figure 6 shows the different curve patterns obtained for the voltage, current, power and power density respectively. The curve pattern shown by the voltage reveals a gradual and steady decline with little fluctuations which then seemed to flatten out at the latter end of its curve. The power and current curve patterns have similar trend. Various points of intersection can be seen to occur in both the curve pattern of power and current having values between 3.84 and 2.23. Comparing results from Table 3, Table 4, Table 5 and Table 6, it can be seen that the voltages from MFC1, MFC2 and MFC3, gave a total combined output when connected in series considering resistance as would be expected indicating that the organic fuel cell obeys the principle of electricity.

5. DISCUSSION

Results indicate that the MFC can be used in road traffic applications. Road traffic light and indicator signs help maintain safety for road users by checking their speed, awareness and consideration of other road users. The use of MFC in enabling the continuous functionality of these road traffic light and indicator signs will help reduce road accident and the probability of it occurring. Other equipment such as reading lamps, traffic signal wand and flash lights can be designed to function on the power generated from the MFC. This will help reduce the amount of energy required and used in producing chemical cells and batteries for same purpose. The saved energy can be redirected for other energy requirements. The MFC can also be used to meet some of the energy requirement in tourist events such as "Light Carnivals". This attracts tourists, brings in revenue as well as saves costs in using other energy source to meet same demand.

6. CONCLUSION

The current threats to public health and safety from organic waste matter as well as the economic threat as a result of the insufficient energy supply leads to economic woes. The MFC can be used to manage the organic waste matter making it an attractive energy source in augmenting Nigeria's energy mix while simultaneously helping improve the economy of Nigeria. Cow dung was investigated to examine its potential as a source for generating electrical energy with a single chamber MFC and the result indicated it is a viable resource for power generation. Results indicated that the MFC generated more power when it the organic matter used as the energy source was acidic. The surface area of electrodes also affected the power output of the system. The use of organic waste as an energy resource in the MFC makes organic waste an attractive energy resource which is readily available, hence, stand-alone road traffic lights can be redesigned to operate on the energy output from MFC, thereby making all road traffic lights run on renewable energy from organic source. Moreover, reading lamps, geographical sensors etc. can also be redesign to run on the energy produced from single chamber MFC. The MFC can help attract tourist by using it in "Light Carnivals" as well as in the decoration of trees and flowers in open parks thereby giving the environment an attracting sight. The microbial fuel cell technology is the most efficient and effective means of organic waste treatment while profiting from it.

REFERENCES

[1] Claudine Ellyin (2012). "Small Scale Waste-To-Energy Technologies". International Journal of Engineering Research and Science. Vol. 7, No. 8.

[2] Diji, C.J. (2013). "Electricity Production from Biomass in Nigeria: Options, Prospects and Challenges". International Journal of Engineering and Applied Sciences. ISSN2305-8269, Vol. 3, No. 4, June.

[3] Kun Guo, Daniel J. Hassettb and Tingyue Guc (2012). "Microbial Fuel Cells: Electricity Generation from Organic Wastes by Microbes". ISBN: 978-1845939564, pp 164-189. CAB International, Oxon. United Kingdom.

[4] Ismail Bozkurt (2010). "Energy Resources and Their Effect on Environment". WSEAS Transaction on Environment and Development. Issue 5, Vol. 6. ISSN: 1790.5079.

[5] Mokhtarian N., Rahimnejad M., Najafpour G.D., Wan Ramli Wan Daud, Ghoreyshi A.A.,(2012). "Effect of Different Substrate on Performance of Microbial Fuel Cell". African Journal of Biotechnology Vol. 11(14), pp. 3363-3369, 16 February.

[6] Matteo Daghio, Isabella Gandolfi, Giuseppina Bestetti, Andrea Franzetti, Edoardo Guerrini and Pierangela Cristiani (2015). "Anodic and Cathodic Microbial Communities In Single Chamber Microbial Fuel Cells". New Biotechnology Volume 32, Number 1.

[7] Osueke C.O. and Ezugwu C.A.K. (2011). "Study of Nigeria Energy Resource and Its Consumption". International Journal of Scientific and Engineering Research, Vol. 2, Issue 12. ISSN: 2229-5518.

[8] Dincer I. and Zamfirescu C. (2011). "Sustainable Energy Systems and Applications". Springer Science and Business Media. DOI: 10.1007/978-0-387-95861-3.2.

[9] Ajayi, O.O., and Ajanaku K.O (2010). "Nigeria's Energy Challenge and Power Development: The Way Forward". Energy & Environment · Vol. 20, No. 3.

[10] Osueke C.O. and Ezugwu C.A.K. (2011). "Study of Nigeria Energy Resource and Its Consumption". International Journal of Scientific and Engineering Research, Vol. 2, Issue 12. ISSN: 2229-5518.

[11] You, J. (2016). “Waste and Wastewater Cleanup Using Microbial Fuel Cells”. University of the West of England. Available from: http://eprints.uwe.ac.uk/26953.

[12] Sridhar M.K.C., and Hammed T.B. (2014). “Turning Waste to Wealth in Nigeria: An Overview”. Journal of Human Ecology, 46(2): 195-203.

[13] Simonyan K.J., and Fasina O., (2013). “Biomass Resources and Bioenergy Potentials In Nigeria”. African Journal of Agricultural Research. Vol. 8(40), pp.4975-4989. DOI:10.5897/AJAR2013.6726.

[14] Samuel Mark Maton, Davou Daniel Dabi, Juliet Dingsten Dodo, Ruth Asheazi Nesla (2009). “Environmental Hazards of Continued Solid Waste Generation and Poor Disposal in Municipal Areas in Nigeria”. Journal of Geography, Environment and Earth Science International.

[15] International Renewable Energy Agency (2012). Renewable energy technologies: Cost Analysis Series, Volume1: Power Sector, Issue 3/5 Hydropower. 1 (3).

[16] Igbinomwanhia D.I., Obano A.I., Olisa Y.P., Akhator P.E., (2016). “Evaluation of Waste To Energy Potential of Domestic Solid Waste In Benin Metropolis”. Journal of Applied Science and Environmental Management. Vol. 20 (4) 1089-1092.

[17] Babayemi, J.O., Dauda, K.T. (2009). “Evaluation of Solid Waste Generation, Categories and Disposal Options in Developing Countries: A Case Study of Nigeria”. Journal of Applied Science and Environment Management. Vol. 13(3) 83 – 88. ISSN:1119-8362.

[18] Njoku N., Lamond J., Everett G., and Manu P., (2015). “An Overview of Municipal Solid Waste Management in Developing and Developed Economies: Analysis of Practices and Contributions to Urban Flooding in Sub-Saharan Africa”. University of West England. 2015. (pages 203-204).

[19] Bruce E. Logan and John M. Regan. (2006). “Microbial Challenges and fuel cell applications. Environmental Science and Technology”.