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IMPACT OF SOIL TEXTURE AND NUMBER OF CELLS ON ELECTRICITY GENERATION UNDER CLOSED SYSTEM

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Abstract

This study aimed to investigate the effect of three textured soils on electricity generation using a different number of cells (2, 4, 6, and 8) under a closed system. The voltage and current readings were measured at an interval of every 24 hours for ten days, using a voltmeter, electric light bulb, and a hand calculator. Experimental results indicated that voltage values were found in the same range for the different soils and cells number. When using 2 and 4 cells, the voltage reading remained stable until the end of the experiment, giving the lowest values for voltage and current. Maximum voltage and current were achieved with 8 cells. In general, the voltage, current, and power reading decrease with decreasing number of cells. The best soil to use for generation of electricity was the silty clay loam (S3), delivering a peak voltage of 3.297 mV, a peak current of 0.039 mA, and a power of 0.115 mW after 240 hours. The power obtained was the same as a trend of the current.

Keywords: Renewable Energy, Soil, Texture, Number of Cells, Closed System

INTRODUCTION

After the huge increase in population, the world today faces three main problems, the first of which is the availability of fresh water, the second is how to reduce pollution, and the third is energy generation (Dhingra et al, 2018). The increase is expected to continue and may rise faster than before (Shiu and Lam, 2004). Global energy demand is growing at a rate of 1.8% annually(Dong et al, 2016)and underground gas, minerals, and heat may not be enough to support additional electricity production requirements in the future (Chansri andYoul-Moon, 2014). Therefore, we have to find new sources or new alternative sources to reduce the use of main energy sources (Gish 1931; Sathitthum 2013; Pakpoom et al, 2013). Wind power, solar power, and hydropower are usually regarded as renewable because they make use of energy sources that are renewed and therefore won't be depleted (Helder, 2012), but it depends on the conditions of nature (Leo, 2011). Therefore, there was an urgent need to find a source of alternative energy to meet the future demand for electricity.

Microbial fuel cells (MFCs) are one solution to mitigate this problem that can provide enough power to electric light bulbs, charge mobile phone batteries, recharging batteries for use in cameras, medical devices, or power sensors (Shiu and Lam, 2004; Prathipa, 2015). Fuel cells include an anode and a cathode electrode, with an electrolyte in between, similar to a battery (Merewether, 2003). The material used for the electrolyte and the design of the supporting structure determines the type and performance of the fuel cell (Leo, 2011). A Microbial Fuel Cell (MFC) is a device in which microorganisms consume organic compounds as a source of nutrients and discharge electrons to the electrode, thus generating electricity (Saha et al, 2019).

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It was reported by (Logan, 2009; Rachinski et al, 2010) that even in the absence of oxygen, certain bacteria can transfer electrons from organic compound oxidation to systems outside the cell. These bacteria, known as exoelectrogenic bacteria, have found application as biological catalysts in MFCs.

Energy from the soil is used to produce electricity, although it is not sufficient to meet the demand for electricity, but can reduce dependence on primary energy (Chansri, 2013). The microbial cell uses the (dirty) earth/mud soil to produce energy along with clean water and also treats waste. Soil is available everywhere and microbes are present in all types of soil/clay. The microbial fuel cell generates no hazardous waste, provides clean water and clean energy (Dhingra et al, 2018). Using soil in a Microbial Fuel Cell (MFC) is a good way to generate green and renewable electricity. Different types of soil have different ability to generate electricity. Therefore, the performance of the MFC is likely to depend on the type of soil used in the anodic compartment and the proportion of the mixture thereof (Fosso-Kankeu, et al, 2015).In this study, three different textured soil types will be used to investigate and compare the different performances of electricity generation using number of cells under closed systems.

MATERIALS AND METHODS

Three different textured soil samples, sandy loam (S1), silty loam (S2) and silty clay loam (S3) were collected from Duhok governorate to study the impact of soil type on electricity generation. Composite surface soil samples (0-30 cm, depth) were taken to represent the sites; then air dried, ground, and sieved to pass through a 2 mm sieve. A homogenous represented sub sample was taken from each soil and store for routine analysis according to (Page et al, 1982) (Table, 1). Soil PH and EC were measured in extract of 1:2 (soil: water), soil organic matter was determined by oxidation method according to (Walkley and Black, 1947). Ca and Mg were determined by titration with EDTA. Flame photometer was used for determining Na and K. The soil particles size distributions were determined by hydrometer method. Soil maximum water holding capacity was also determined. Equivalent calcium carbonate was measured by calcimeter. Eight plastic jars were filled with 300g (for each jar) of each soil type and placed in plastic container with 30.3 cm length, 23 cm wide and 14 cm height as shown in Fig (1). In each jar an anode made of carbon with an area of 3.909 cm2 and a 16.4 cm2 cathode made of zinc were inserted in the soil of each jar and tap water was gently poured. About 142, 172 and 175 ml of water were added to S1, S2 and S3 respectively depending on the maximum holding capacity of each soil.

The two electrodes were connected to a wire and placed in series connection for the flow of electrons to produce electricity. These electrodes were connected to external circuit with resistance using a wire. The cells were connected respectively and each soil replicated three times and placed under laboratory temperature. The container of the jars set up closed using lids to keep the system closed through the experiment Fig (1). Voltage and current were recorded every day using a voltmeter. Electrons produced are transported from cathode to anode through external circuit and light up the electric light bulb connected to it (or a hand calculator) in the circuit. The light emitting diode (electric light bulb) was linked with the end

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of the wires connecting to anode and cathode electrodes to measure the current. The voltage over the load (the resistor) was measured. The relationship between voltage, current and resistance is known as Ohm's law (Huang et al 2011).

$E=IR_{ext}$
E; is the cell potential
I; is the current
Rext; is the external resistance (in ohms).
When calculating the power, the following relationship was used:
$P=IE_{MFC}$
Where **P** is the power (in Watts)
E_{MFC}**;** is the measured voltage across the external load.

After ten days, the soil in each jar was air dried and sieved through a 2 mm diameter mesh to measure the soil properties using same procedures as mentioned in materials and methods previously.

Table 1. Some physiochemical properties of studied soils before conducting the experiment

Properties	Units	S 1	S 2	S 3
PH		7.88	7.91	7.83
EC	dSm^{-1}	0.244	0.503	0.236
K	Soluble ions $mmole_c l^{-1}$	0.09	71	0.11
Na		1.09	1.66	0.93
Ca		2.8	4.4	2.8
Mg		1.2	3.2	1.6
Organic matter	$g\ kg^{-1}$	3.1	2.1	8.5
Total CaCO3		37.7	32.0	81.0
Sand		636.70	154.54	53.04
Silt		285.10	703.70	566.80
Clay		782.00	141.75	380.16
Texture		Sandy loam	Silt clay	Silt clay loam

RESULTS AND DISCUSSION

The present study investigated the generation of electricity by using three types of soils and different number of cells under closed system figure (1). The results showed that the values of voltage were found within the same range for the different soils and cells (figure 2).

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Fig 1. Layout of the experiment

i.e. it was between (0.5-1.0 mV), about (1.5 mV), (2.0-2.5 mV) and (3.0-3.5 mV) for the 2, 4, 6 and 8 cells respectively. There was a decline in voltage reading with decreasing number of cells. In general, the voltage values for the 2 and 4 cells remained stable until the end of the monitoring period. The 6 cells showed a slight decrease with time especially with S1. Maximum voltage achieved by using 8 cells for all soils, these values deceased with time for S1 and S2, but with S3 there was a peak after 96 hours followed by a decrease onward, when the voltage values of all soils were below 3.0 mV, this may be due to the effect of the existing a considerable amount of clay content in S3 that can be considered as a major source of charge in the soil.

In figure (3), the electricity production was almost followed linear curve over the period of ten days, when using 2 and 4 cells for all soils (S1, S2 and S3), the values were less than 0.002 mA. The 6 and 8 cells of S1 registered the highest initial values about 0.02 mA and 0.35 mA respectively. The current output of the S1 using 6 cells was decreased from 0.02 mA to 0.006 mA at the end of the experiment, however, the values of the same cells of S2 flocculated throughout the time; while with S3 there was a decrease after 72 hours followed by an increase

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to the final reading. Despite the highest initial current recorded in S1 by using 8 cells, a decline was observed after 48 hours onward, presumably due to the reduction of substrate available for microorganisms (Fakhirruddin et al, 2018) in S1 soil because it was a sandy loam with low organic matter Table (1). However, lower initial values with 8 cells of S2 and S3 were recorded, but their values continued to increase about 96 hours after beginning until the end of the experiment, giving the highest values, probably, this period was required by microorganisms to adapt to the culture medium (Passos et al, 2016). It was also concluded by [1] that limitation of substrate available may be the cause of decline in power output. Peak current was defined as the maximum current obtained when a load is applied between the anodes a d cathode of the fuel cell (10). The maximum current occurred after 240 hours when using 8 cells with S3, delivering a peak of 0.04 mA compared to less than 0.035 mA for S2 and about 0.035 mA for S1. S3 produced the highest peak current and is, therefore, the best soil to use for electricity generation purposes, this result agreed with Rachinski et al (2010) who found that clay produces the best results. This could be due to the effect of both organic and mineral colloids (organic matter and clay minerals) that contain an abundance of charges and play an important role in the sustainability of electric generation in fine soil texture (S3) as comparison compared with coarse soil texture (S1).

The power was calculated using Ohms law for the total experimental period. As seen in figure (4), the three soils varied in their peak power and also the time from the beginning to the peak. It took 240 hours for S3, while it was only after 24 hours for S1. The power values obtained throughout the experiment were in the same trend as the current, figure (3). Considering the three soils (S1, S2 and S3), S3 was the most promising, with a peak power of 0.115 mW when 8 cells were used. The power output of the 8 cells for S3 was increased from 0.062 mW to 0.115 mW, for S2 from 0.0725 mW to 0.093 mW and for S1 decreased from 0.034 mW to 0.108 mW. Power recorded from the 2 and 4 cells was very low for all soils. The soil physiochemical properties varied between soils table (1). Before starting the experiment, the pH, EC and soluble ions in S2 soil were higher than in other soils. S2 had higher PH but lower organic matter. The results of (Jiang et al, 2016) showed that soils with higher organic carbon content and lower PH generated higher voltage. After 240 hours of operation, the pH, EC and soluble ions declined for all the soils used.

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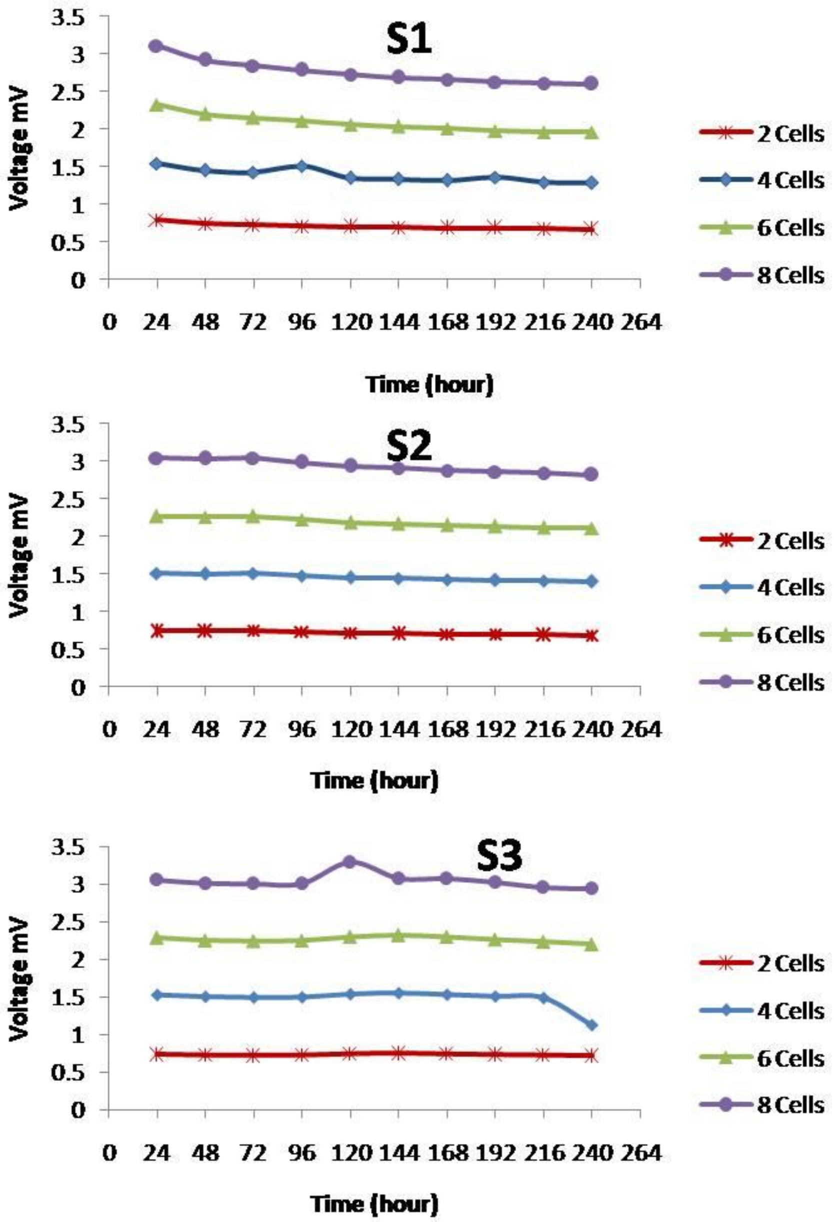

Fig 2. Voltages of different cells number and soil types with time

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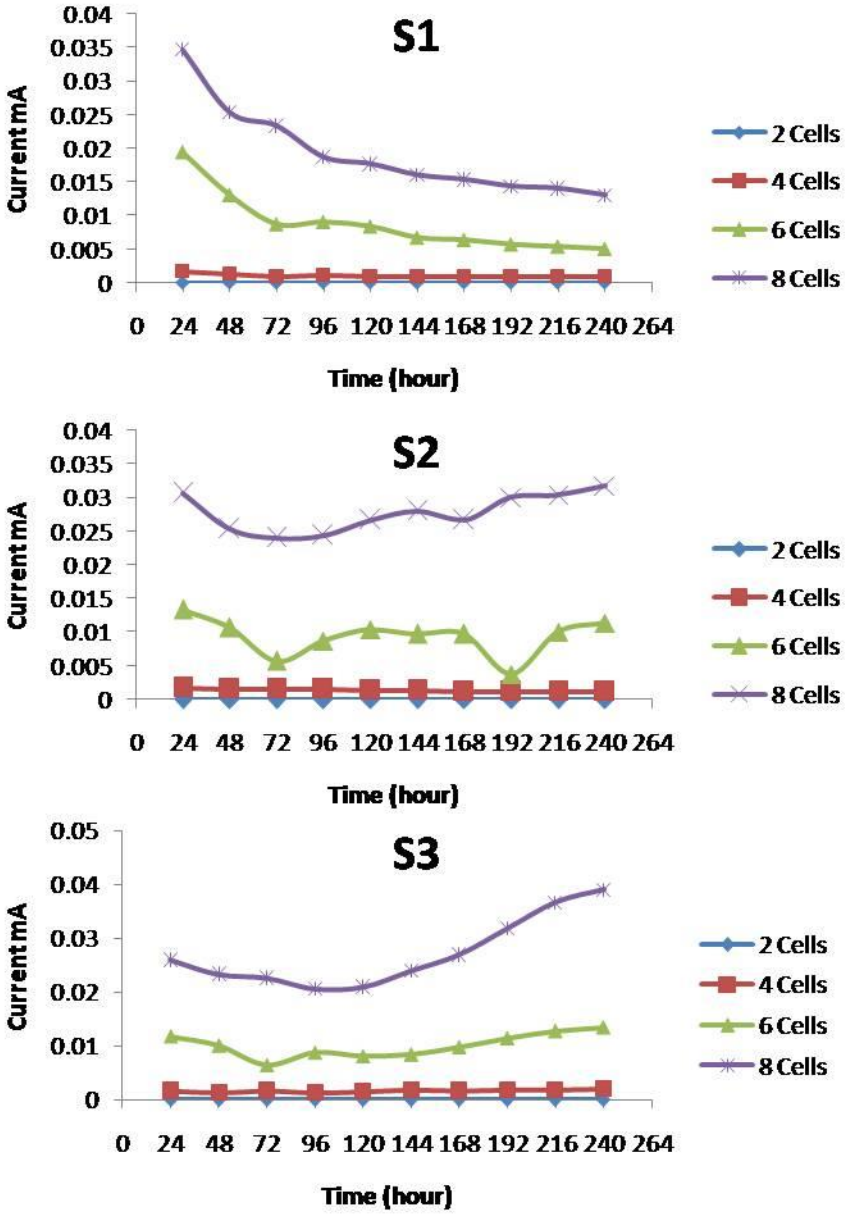

Fig 3. Current of different cells number and soil types with time

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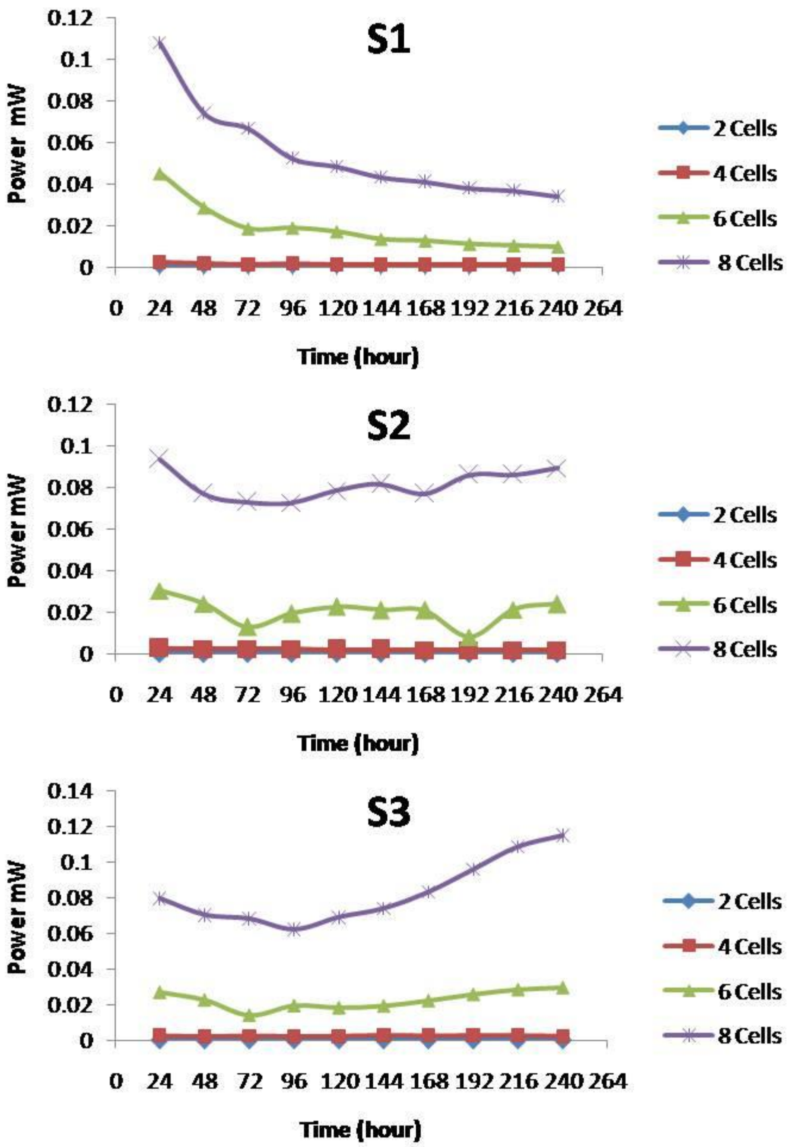

Fig 4. Power of different cells number and soil types with time

Table 2. Some chemical properties of studied soils after the Experiment

Properties	Units	S1	S2	S3
PH		7.45	7.35	7.35
EC	dS.m^{-1}	0.317	0.487	0.329
K		0.154	0.356	0.261
Na	Soluble ions mmole$_c$l^{-1}	1.24	1.756	1.049
Ca		0.36	0.48	0.44
Mg		0.36	0.54	0.34

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CONCLUSIONS

Experimental data obtained from this study showed that S3 is better than S1 and S2 in electricity generation. Using 8 cells gave the best values of voltage, current and power. We hope that these results can be a basic for more studies on large scale as a new sustainable energy sources, and at the same time effort should be made to study all soil criteria affecting the performance of electrical generation.

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