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ELECTRIC GENERATION FROM SOIL BY USING DIFFERENT TYPES AND SIZES OF CATHODES

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Abstract

The world as a whole is struggling with the same problems, which can be summed up in one phrase: the energy crisis. It is important to highlight the fact that the microbial fuel cell, also known as an MFC, was developed with the intention of producing energy. This study investigated the impact of cathode types (Zn, AL, and Cu) and sizes (800, 520, and 260) mm^3 on voltage, current, and power generation during 240 hours. The results indicated that the Zn cathode with a size of 800 mm^3 achieved the maximum current and power density after 24 hours, which was (0.641 mA and 5.396 mW) respectively. While the same treatment reached the maximum voltage of 8.693 mV after 192 hours. The type of cathode is more effective than the size in electric current generation from the soil, with time, soil electricity is decreased but in different intensities. Although this MFC technology presents many advantages; it still needs to be used in combination with other processes to enhance power output.

Key Words: Voltage, Current, Electric Power, Size, Types, Cathode, Soil.

1 INTRODUCTION

Our primary energy sources are nonrenewable resources including oil, natural gas, and fossil fuels. Due to the world's enormous global demand and subsequent impact on the environment, there is an energy crisis. To fulfill energy demand and reduce environmental pollution, it is vital to discover a reliable alternative source of energy production. Renewable energy sources including solar power, wind power, water power, and biological fuel cells may hold the key to resolving the current energy issue [1].The current and power densities grew roughly five days after the process began the current increased throughout the first five hours, it took over 35 hours for it to reach its maximum., according to [2]. Most likely, the bacteria needed this time to adjust to the culture media. Current was flowing through the PMFC1 (Plant Microbial Fuel Cell) at a rate of 100.12 mA/m^2, which was high than the current that was flowing through the PMFC2 at a rate of 81.48 mA/m^2. Electric power production was monitored before, during and after the experiment, according to [3].

The maximum average of 9.6mW/m^2 was attained. The average amount of power produced per square meter was0.4 ± 0.1 mW/m^2 [4]. Microbial fuel cells have the ability to fight two global issues—waste pollution and the need for energy-there has been an upsurge in interest in these cells over the last few years. In spite of these benefits, it is still subject to constraints in terms of power output and current density, which results in lower production values than other types of renewable technology [5]. The power generation per cathode area as well as the volumetric power density was measured by [6], they did not found significant effect in power generation between treatments.

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Following the enrichment of the anode microbiomes, the results show that the cathode is the limiting factor in the RPF-MFCs (Rice paddy-field microbial fuel cells) to produce energy [7]. When MFCs are linked in series and parallel, they provide high power density, which results in higher useful voltages and currents [8].The anode volume has an impact on the amount of power is produced, and there are significant differences between the values. The MFCs operating at (4 and 8) cm^3 had the greatest cell voltage (87 mV and 117 mV) respectively, while the fuel cell operating at (20 cm^3) cm^3 had the lowest (21 mV) [9]. The MFC with a graphite-copper electrode of 31.4 cm^2 and a substrate-RM ratio of 1:10 shows the highest performance, with a maximum power density of (700 mW m^{-2}) and a current density of (318 mA m^{-2})[10].

The study of [11] showed that clay produces a peak voltage of 644 mV in contrast to 348 mV from silt and 336 mV from sand at a ratio of 1 to 1, compost to soil, which is the best soil to use for electricity-generating purposes. The clay is the best soil to use for electricity generating purposes, delivering a peak voltage of 644 mV compared to 348 mV from silt and 336 mV from sand at a ratio of 1 to 1, compost to soil. Clay soil produced the highest peak voltages at all three ratios and is therefore the best soil to use for electricity generating purposes in a SMFC soil microbial fuel cells (SMFC), reported by [12].

It was observed that the anode position, external load, and cathode modification with platinum catalysts had a large impact on the power output [13].The greatest power produced by the copper-zinc electrode's 51 cm^2 surface area was 137.85 mW/ m^2, while the highest power produced by 88 cm^2 of electrode surface area was 146.0 mW/ m^2 [14]. Increasing the cathode surface area improves significantly the power generation doubling cathode surface area increases maximum power by +23.3% and triple increase the power by +59.8%). Increasing anode surface area also affect power performance. Doubling it raises maximum power by +37.8%, while tripling it only increases it by +39.3% [15]. In principle, the internal resistance of an electrode is influenced by its material composition, which may result in a reduction in power output to increase the power density of the system, certain aspects of an electrode, such as surface area, electrical conductivity, stability, and durability, should be addressed [16]. Maximum power density of MFC with carbon cloth electrode was 1221.91mW/m^2, which was 2.69 and 8.49 times greater than carbon brush and felt electrodes, respectively. In microbial fuel cells, the anode and cathode electrodes are linked with an external resistance to produce closed-cell operation [17]. The objectives of this study was to investigate the effect of type and size of cathode on electric generation.

2 MATERIAL AND METHODS

This experiment was conducted in a laboratory at the College of Agricultural Engineering Sciences, University of Duhok, using three different metal plate types (Zn, Al, and Cu) in three different sizes (800, 520, and 260) mm^3, as well as a carbon anode with a volume of 318 mm^3 for 240 hour. Soil samples were collected from the college's field at a depth of 0 to 30 cm, the soil analyzed for soluble ions (Na, Ca, K, and Mg) and PH, EC, organic matter and texture (table 1). Afterward, eight jars filled with 300 g of soil per jar, and 200

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ml of water is added to each, were put in a plastic container that has 30.3 cm in length, 23 cm in width, and 14 cm in height, Figare(1). The electrodes were connected to a copper wire with a diameter of 0.75 mm. The cells were connected in series to produce electricity. Each two boxes were connected in parallel. These electrodes are connected to an external circuit with digital water flow meter that used with drip irrigation system, and digital multimeter system attached to the end of the wires connected with anode and cathode electrodes to measure the voltage and electric current.

Table 1: Some Physiochemical Properties of Studied Soils before Conducting the Experiment

Properties	Units		S 3
PH			7.83
EC	$dS.m^{-1}$		0.236
K	Soluble ions	$mmole_c l^{-1}$	0.11
Na			0.93
Ca			2.8
Mg			1.6
Organic matter	$g\ kg^{-1}$		8.5
Total CaCO3			81.0
Sand			530.00
Silt			560.80
Clay			380.16
Texture			Silt clay loam

The voltage and current were recorded every day. The electrons produced are transferred from the negative electrode to the positive electrode via an external circuit and power the circuit. Each sample was repeated three times under laboratory temperature.

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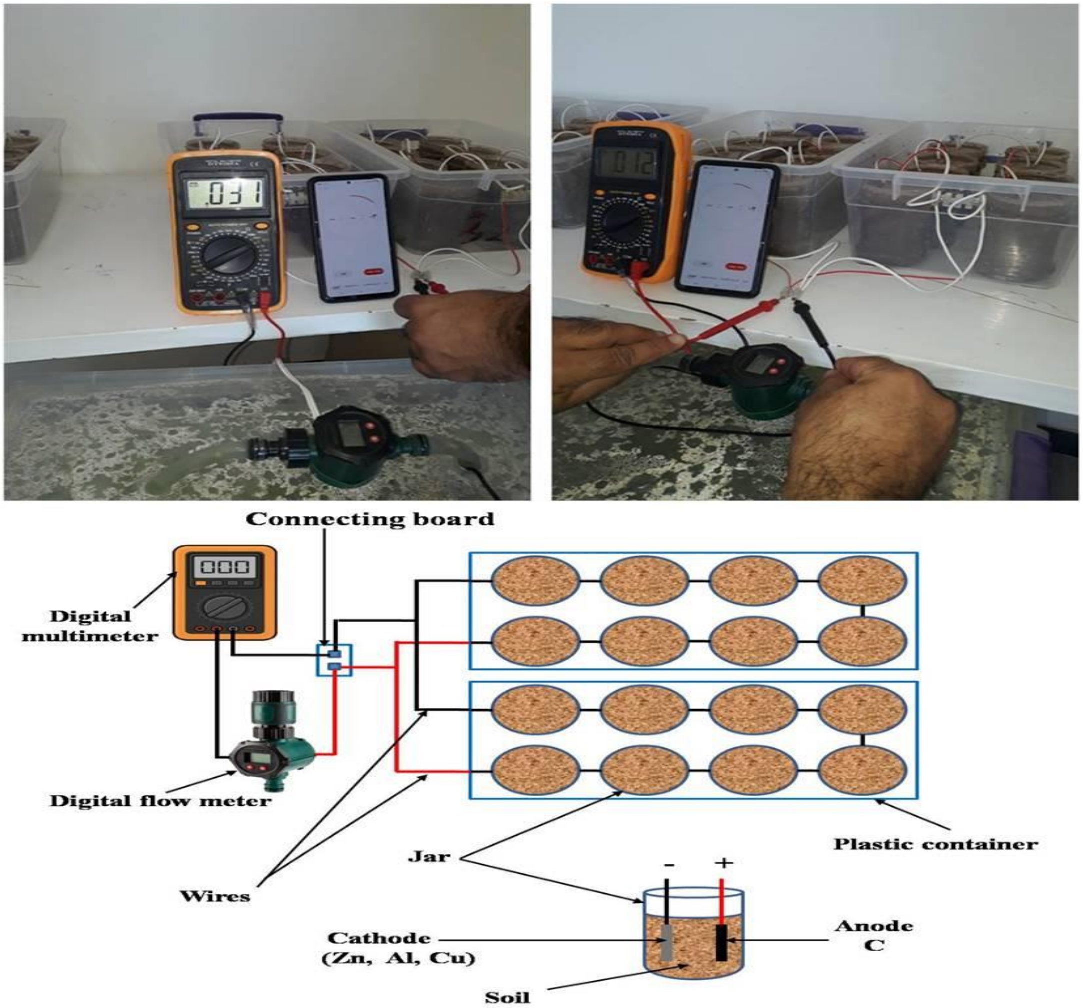
Figure (1): Layout of the experiment



The voltage across the external resistor in an MFC can be measured using a multi meter. Voltage measurements are converted to current values using Ohm’s law [19]:

$V = I \times R$

Where

V = voltage, mV

I = current, mA

R = resistance, mΩ

The power output from an MFC is calculated as

$P = I \times V$

Where

P = power, mW.

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3 RESULTS AND DISCUSSION

The experiment was conducted for 240 hours, and different cathode types and sizes were examined to show how the intensity of electricity production was affected by the MFC system (figure 2). The results showed that the voltage values were within the same range for each cathode types and sizes (figure 2), it was between (6.93 - 10.57 mV), (3.25 - 6.70 mV), and (0.05 - 2.37 mV), for Zn, Al and Cu respectively. The maximum value of voltage obtained during a period of 24 hours using 520 mm^3 for Zn. While for Al cathodes was 6.70 mV. But the maximum value obtained over the period of 72 hours using a Cu cathode of the same size (2.37 mV). This result aggreed with [12].

Figure (3) shows that over the period of 240 hours, different cathode types and sizes create different electric current. The highest value was for the Zn cathode with the size of 800 mm^3, which was 0.641 mA and the lowest value was 0.259 mA with the size 520 mm^3. With Al cathode, the size 800 mm^3 produced the maximum value of the current, which was 0.065 mA, and the size 260 mm3 produced the lowest value, which was 0.008 mA, however, the highest production of electric current for the Cu cathode was 0.008 mA with a size of 520 mm^3, while the lowest production was 0 mA with a size of 800 mm^3. This may be due to fluctuation characteristic of biological processes, which can be explained in terms of the multiplicity of processes happening simultaneously in the MFS, the result agreed with [9]. The production of electrical power was affected by the use of cathodes of varying types and sizes, as seen in figure (4). The highest Zn cathode production was at the size of 800 mm3, which was 5.396 mW and the lowest value, was at the size of 520 mm^3, which was 1.812 mW. For the Al cathode, the size 800 mm^3 produced the maximum value for the electrical power generation, which was 0.237 mW, while the size 260 mm^3produced the lowest value, which was 0.029 mW, while the electrical power production for the Cu cathode reached its highest with the size 520 mm^3, which was 0.033 mW, and it was at zero with both the sizes 800 and 520 mm^3.

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Figure (2): Voltages of different types and sizes of cathodes with time

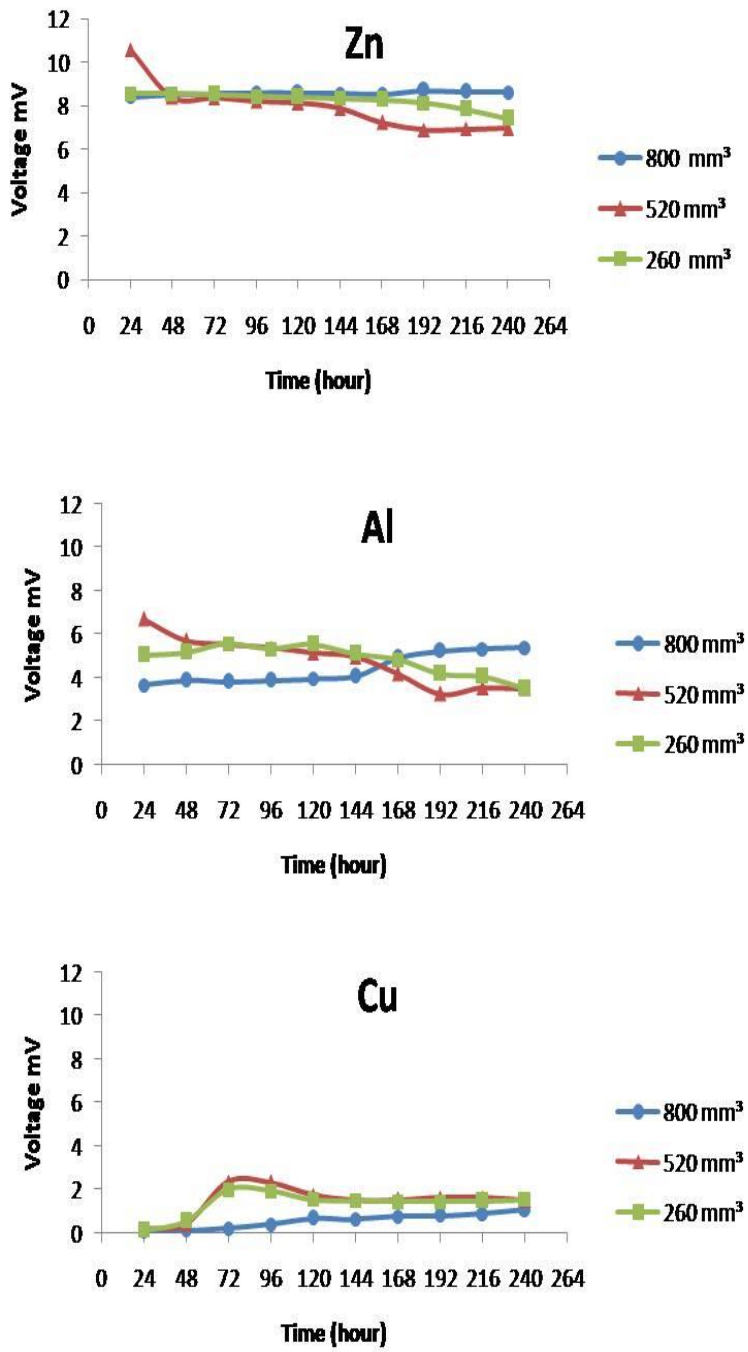

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Figure (3): Currents of different types and sizes of cathodes with time

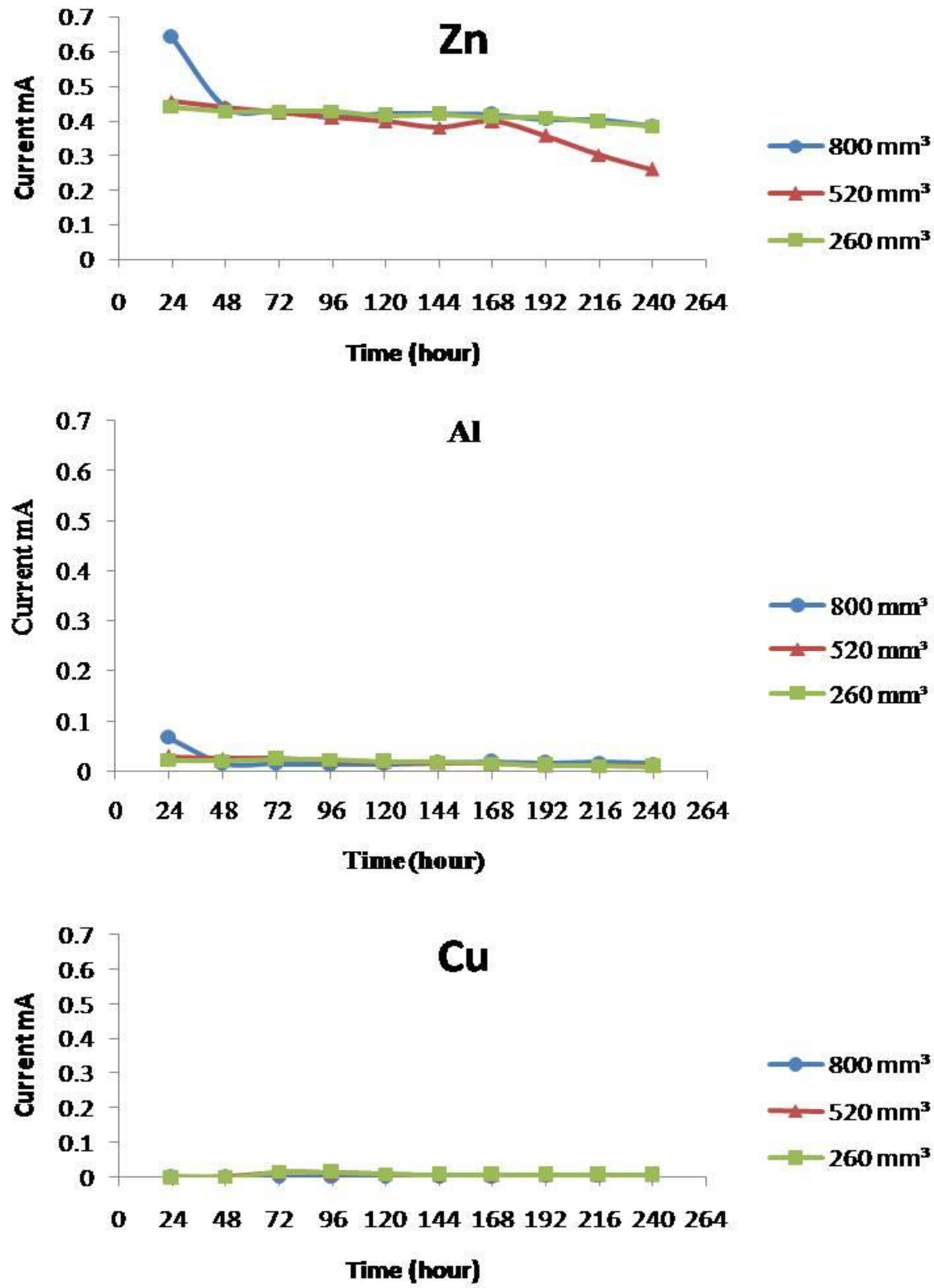

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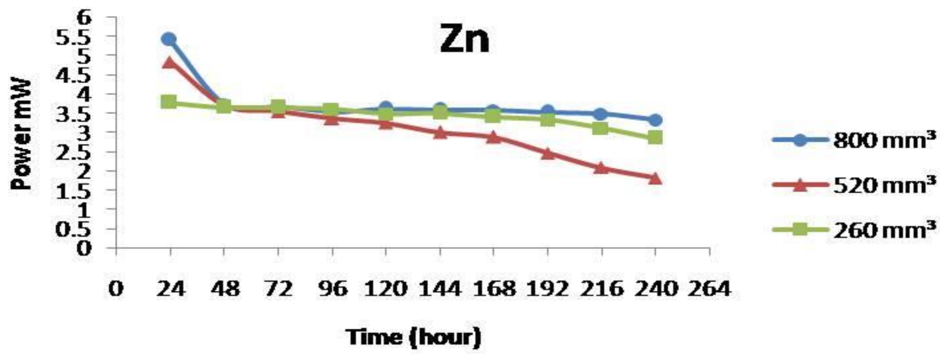
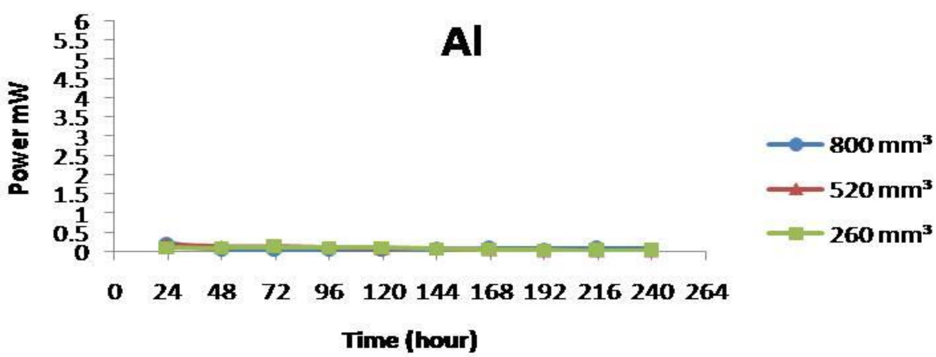
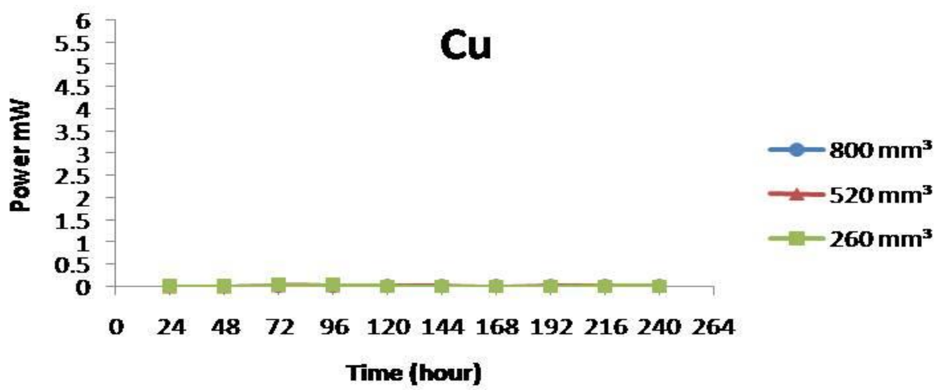
Figure (4): Powers of different types and sizes of cathodes with time







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4 CONCLUSIONS

This experiment demonstrates that the MFC is suitable for being used for the creation of electric power. And it can be used to operate simple systems in agricultural works and can compete with energy produced from other sources. The result showed that the type of cathode, as well as the size, influenced the amount of electricity generation and the type is more effective than size. Our research conclusively showed that an MFC with such a Zn cathode is preferable compared to others in terms of its ability to generate electricity. Soil electricity decreased but in different intensities. However, further research is required to eliminate some of the limitations associated with the application of MFC.

References

1. M. Rahimnejad, A. Adhami, S. Darvari, A. Zirepour, S.E. Oh. Microbial fuel cell as new technol ogy for bioelectricity generation: A review. Alexandria Eng J. Vol. 54, no. 3, pp. 745-756, Sep. 2015, doi.org/10.1016/j.aej.2015.03.031
2. V. F. Passos, S. A. Neto, A. R. Andrade and V. Reginatto. Energy generation in a Microbial Fuel Cell using anaerobic sludge from a wastewater treatment plant. Sci. agric. (Piracicaba, Braz.). Vol. 73, no. 5, pp. 424-428, Sep./Oct. 2016, doi.org/10.1590/0103-9016-2015-0194
3. H. U. D. Nguyen, D. T. Nguyen and K. Taguchi. A Novel Design Portable Plugged-Type Soil Microbial Fuel Cell for Bioelectricity Generation. Energies. Vol. 14, no. 553, pp. 1-6, Jan. 2021, doi.org/10.3390/en14030553
4. E. Sudirjo, P.Jager, C. J. N. Buisman and D. P. Strik. Performance and Long Distance Data Acquisition via Lora Technology of a Tubular Plant Microbial Fuel Cell Located in a Paddy Field in West Kalimantan, Indonesia. Sensors. Vol. 19, no. 21, pp. 1-18, October 2019, doi:10.3390/s19214647
5. J. V. Boas, L.R.C. Marcon, A. M.F.R. Pinto, V.B. Oliveira and M. Simões. Optimization of a single chamber microbial fuel cell using Lactobacillus pentosus: Influence of design and operating parameters. Science of The Total Environment Vol. 648, no. 1, Aug. 2018, doi:10.1016/j.scitotenv.2018.08.061
6. B. E. Logan, M. J. Wallack, K. Y. Kim, W. He, Y. Feng and P. E. Saikaly. Assessment of Microbial Fuel Cell Configurations and Power Densities. Environ. Sci. Technol. Lett. Vol. 2, pp. 206−214, July, 2015, doi: 10.1021/acs.estlett.5b00180
7. N. Ueoka, N. Sese, M. Sue, A. Kouzuma and K. Watanabe. Sizes of Anode and Cathode Affect Electricity Generation in Rice Paddy-Field Microbial Fuel Cells. Journal of Sustainable Bioenergy Systems, Vol.6, pp. 10-15, March 2016, dx.doi.org/10.4236/jsbs.2016.61002
8. P. Aelterman, K. Rabaey, H. C. Pham, N. Boon and W. Verstraete. Continuous electricity generation at high voltages and currents using stacked microbial fuel cells.Environ Sci Technol, Vol. 40, no. 10, pp. 3388-3394, May2006, doi: 10.1021/es0525511
9. E. D. Penteado, C. M. F. Marchante, M. Zaiat, E. R. Gonzalez and M. A. Rodrigo. Optimization of the performance of a microbial fuel cell using the ratio electrode – surface area /anode compartment volume. Brazilian Journal of Chemical Engineering, Vol. 35, no. 01, pp. 141 – 146, Janu. – March, 2018, dx.doi.org/10.1590/0104-6632.20180351s20160411
10. K. Prabowoa, A. P. Tiarasukmaa, M. Christwardana and D. Ariyanti. Microbial Fuel Cells for Simultaneous Electricity Generation and Organic Degradation from Slaughterhouse Wastewater. Int.

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Journal of Renewable Energy Development, Vol. 5,no. 2, pp.107-112, August 2016, dx.doi.org/10.14710/ijred.5.2.107-112

11. E. F. Kankeu, S. Marx, F. B. Waanders and V. Jacobs. Impact of soil type on electricity generation from a Microbial Fuel Cell. pp. 73-77, Nov. 2015 (Conference proceedings)
12. J. Zhang, X. Cao, H. Wang, X. Long and X. Li. Simultaneous enhancement of heavy metal removal and electricity generation in soil microbial fuel cell.Ecotoxicology and Environmental Safety. Vol. 192, no. 13, Apr. 2020, doi:10.1016/j.ecoenv.2020.110314
13. K. Takanezawa, K. Nishio, S. Kato, K. Hashimoto and K. Watanabe. Factors Affecting Electric Output from Rice-Paddy Microbial Fuel Cells. Biosci. Biotechnol. Biochem, Vol 74, no. 6, pp. 1271–1273, Jun. 2010, doi:10.1271/bbb.90852
14. S. K. Sahari, M. Z. F. Rosli, A. M. Butit, K. Kipli, M. Anyi, A. Awang, M. Sawawi, M. R. Mahmood, L. Hasanah, A. R. Kram, Z. Embong and H. Nahrawi. Fabrication of Single Chamber Microbial Fuel Cell (SMFC) Using Soil as a Substrate. Pertanika J. Sci. & Technol. Vol. 30, no. 2, pp. 1103 – 1114, Mar. 2022, doi.org/10.47836/pjst.30.2.14
15. J. Papillon, O. Ondel, E. Maire. Scale up of single-chamber microbial fuel cells with stainless steel 3D anode: Effect of electrode surface areas and electrode spacing. Bioresource Technology Reports. Vol.13, no. 12, Jan. 2021, doi:10.1016/j.biteb.2021.100632
16. H. Eom, H. J. Joo, S. C. Kim and S. S. Kim. Properties of carbon-based nanofiber with Pd and its application to microbial fuel cells electrode. Environmental Technology & Innovation. Vol. 19, Aug. 2020, doi.org/10.1016/j.eti.2020.100800
17. C. Fang and V. Achal. The Potential of Microbial Fuel Cells for Remediation of Heavy Metals from Soil and Water – Review of Application. Microorganisms. Vol. 7, no. 12, Dec. 2019, doi: 10.3390/microorganisms7120697
18. S. Raj, J. Solomon, A. Kumar. PRODUCTION OF ELECTRICITY FROM AGRICULTURAL SOIL AND DYE INDUSTRIAL EFFLUENT SOIL USING MICROBIAL FUEL CELL. International Journal of Research in Engineering and Technology. Vol. 2, no. 10, pp. 140-148. Oct. 2013, dol:10.15623/ijret.2013.0210019