

## Electricity Generation and Wastewater Treatment Using Membrane-Less Microbial Fuel Cell (MFC)

Raudzah Mohd Zahir<sup>1,2,\*</sup>, Soon-An Ong<sup>1,2</sup>, Yee-Shian Wong<sup>1,2</sup>, Nabilah Aminah Lutpi<sup>1,2</sup>

<sup>1</sup>Faculty of Civil Engineering & Technology, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia

<sup>2</sup>Centre of Excellence for Water Research and Environmental Sustainability Growth (WAREG), Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, Malaysia

KEYWORDS	ABSTRACT
Microbial fuel cell (MFC) Wastewater treatment Membrane-less Electricity generation Chemical oxygen demand	Microbial fuel cells (MFCs) have emerged as a promising technology for sustainable energy generation and wastewater treatment. In this study, a membrane-less MFC was designed and evaluated for its performance in electricity production and organic matter removal. The system demonstrated a maximum voltage output of 516.7 mV and achieved a chemical oxygen demand (COD) removal efficiency of approximately 76% indicating effective biodegradation of organic substrates. The negative oxidation-reduction potential (ORP) of -130 mV recorded in the anode region confirmed a strongly reducing and anaerobic environment favorable for electrogenic bacterial activity. These results highlight the capability of the membrane-less MFC to simultaneously generate bioelectricity and treat wastewater efficiently, suggesting its potential as a cost-effective and environmentally friendly alternative for sustainable wastewater management.

### 1. INTRODUCTION

Microbial fuel cell (MFC) has attracted a lot of interest from researchers as it showed a remarkable ability in generating electricity while simultaneously treating wastewater. MFCs use bacteria to convert wastewater into clean energy while offering advantages such as low sludge production and less energy consumption during wastewater treatment [1,2]. MFC generally consists of an anode chamber and a cathode chamber that contain an anode and a cathode electrode, which are separated by a membrane. The electrodes are externally connected by a conductive material with a resistor. The electroactive bacteria in the anode chamber oxidize organic substrates to produce electrons and protons [3]. Electrons produced at the anode flow through the external circuit to the cathode, generating electricity. Simultaneously, protons pass through the membrane and react with electrons and oxygen at the cathode. The anode operated under anaerobic conditions, while the cathode works under aerobic conditions [1].

An ion exchange membrane is one of the key components in MFC that is used to sustain the electricity generation by preventing interference between the anode and cathode chambers in MFC. It serves to stop the organic substrate from diffusing into the cathode, limit dissolved oxygen transfer to the anode and maintain ion balance and pH stability. However, the membrane has some limitations, such as high internal resistance which reduces the output voltage and also increases the cost of an MFC [4]. Therefore, developing cost-effective, durable and permeable separators is important for the stable operations of MFC.

In this study, a single chamber up-flow membrane-less microbial fuel cell (ML-MFC) was developed to investigate the simultaneous bioelectricity generation and wastewater treatment performance. The membrane-less MFC performance was identified by observing the voltage, power density, chemical oxygen demand (COD) removal efficiency and oxidation-reduction potential (ORP) for over two weeks.

### 2. EXPERIMENTAL PROCEDURE

#### 2.1 Inoculum and Substrates Preparation

Mixed-culture activated sludge from a rubber glove industry's wastewater treatment plant, Shorubber (Malaysia) Sdn. Bhd was used to inoculate polypropylene biofilm carriers and electrodes. The polypropylene carriers and carbon felt electrodes were inoculated in an airtight container for 25 days. Synthetic wastewater was prepared to serve as the nutrient source for the microorganisms in the MFC reactor.

**2.2 Reactor Configuration and Operation**

In this study, a single chamber ML-MFC with a height of 40 cm and a diameter of 8 cm was constructed using a polyacrylic plastic column. Inoculated polypropylene carriers were used as the packing materials in the anodic region, with a layer of sponge separating the anode and cathode. Three anodes were positioned at 4 cm, 12 cm and

20 cm, while a single cathode was placed 30 cm from the bottom of the MFC. The MFC was operated for 15 days. Air was supplied to the cathode region through a diffuser, with a 50 mL/min air flow rate using a flow meter. The synthetic wastewater flowed upward from the anode to the cathode region, and the effluent flowed out from the top of the MFC. An external 1kΩ resistor was continuously monitored

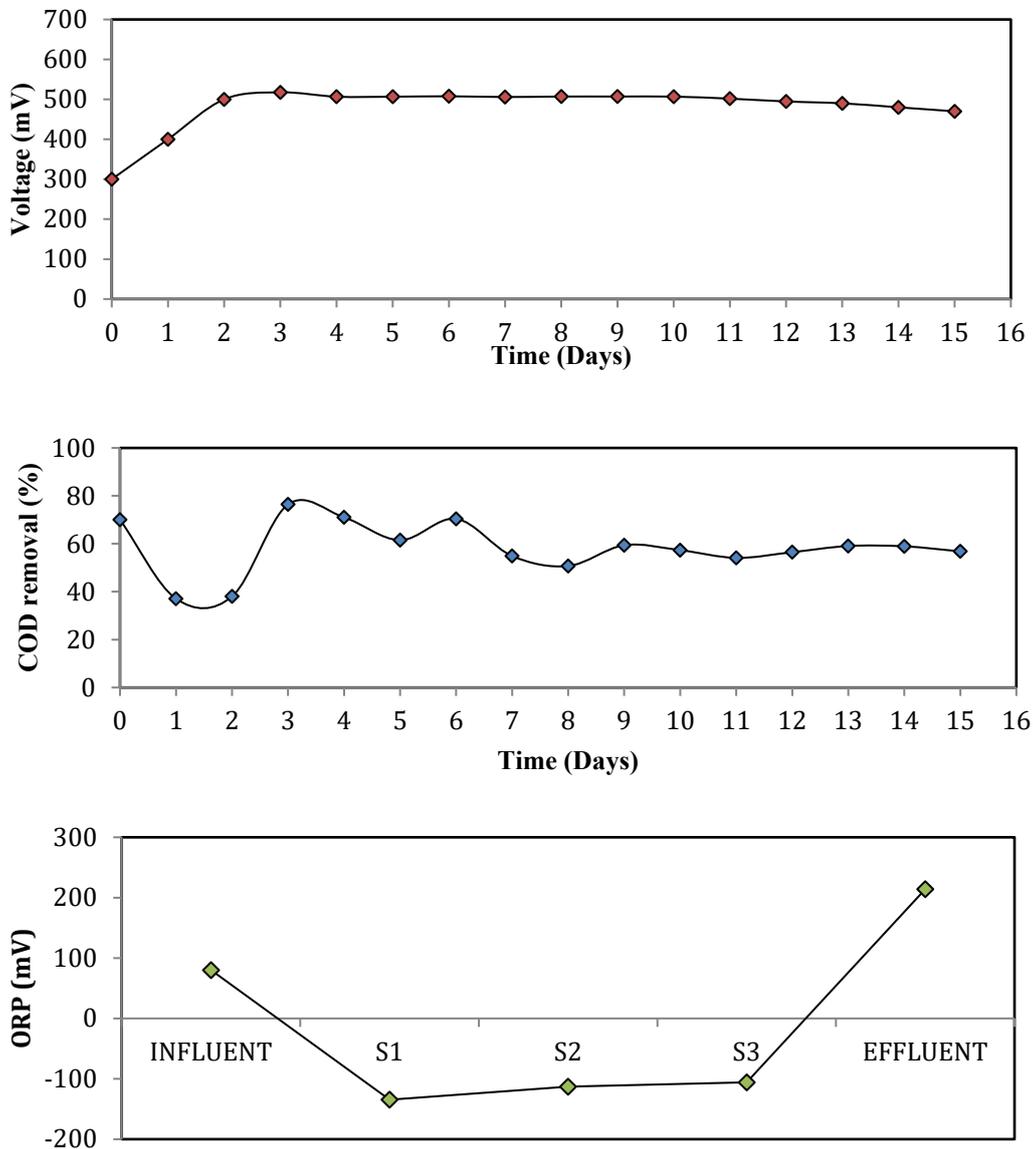


Figure 1. (a) Voltage generation of ML-MFC; (b) COD concentration with time of ML-MFC; (c) ORP profiles of ML-MFC.

**2.1 Analytics and Calculation**

Output voltage was continuously recorded every 10 minutes using a data logger. Wastewater samples were collected daily from the effluent. The samples were centrifuged at 4200 rpm for 10 minutes before COD analysis. The COD concentration was measured using a spectrophotometer. The oxidation reduction potential

(ORP) was routinely measured with an ORP meter to ensure optimal reactor conditions.

### 3. RESULTS AND DISCUSSION

#### 3.1 Bioelectricity Generation Performance

Figure 1(a) illustrates the electricity generated by ML-MFC in 15 days. The voltage started at 300 mV and rapidly rose to 500 mV on day 2 of operation. The MFC produced the highest voltage on the third day of operation, which is about 517.6 mV. The voltage from the fourth day until the last day of operation shows a stable performance with a gradual decrease in voltage. This indicated that the electrogenic bacterial population attached to the anode had reached the optimum population size [5].

#### 3.2 Chemical Oxygen Demand (COD) Analysis

Figure 1(b) shows the COD removal of the ML-MFC for 15 days. The highest COD removed by the MFC was on the third day which is 76%. The maximum COD removal was achieved on the same day maximum voltage produced by the MFC. This indicates that the higher the COD removed, the greater the voltage generated by the MFC as more organic matter degraded, thus releasing more electrons. The COD removal value becomes stable until day 15. On the last day of operation, the COD removed by the MFC was 57% which can be considered a good removal as it is more than 50%.

#### 3.3 Oxidation Reduction Potential (ORP) Profile

The ORP (mV) indicates the electron transfer potential and redox conditions within the MFC system [6]. Figure 1(c) illustrates the ORP values of samples collected from the influent, sampling points 1 (S1), 2 (S2), and 3 (S3), and the effluent. The ORP value was the lowest at S1 which is -134.6 mV, while the highest ORP value was at the effluent which is 214 mV. The negative value of ORP below -100 mV displayed at S1 proved that the anode environment is anaerobic, which promoted the organic matter degradation and electron production [7].

### 4. CONCLUSION

In this study, the membraneless MFC achieved a maximum voltage output of 517.6 mV and a COD removal efficiency of approximately 76%. The negative ORP value observed in the anode compartment is believed to have facilitated and enhanced the COD degradation, thus contributing to higher electricity generation. Therefore, these findings suggest that the membraneless MFC configuration exhibits significant potential for wastewater treatment and bioelectricity production.

### ACKNOWLEDGEMENT

This research was funded by the Ministry of Higher Education Malaysia on the FRGS - FRGS/1/2024/TK08/UNIMAP/01/1.

### REFERENCE

- [1] Reda, S., Safwat, S. M., Elawwad, A., & Abdel-Halim, H. (2025). Dual-chamber microbial fuel cells for enhanced bioelectricity generation and chemical oxygen demand removal from sludges: A comparative study of different real sludge generated from a wastewater treatment plant. *Biomass and Bioenergy*, 201(June), 108063.
- [2] Pugazhendi, A., Al-Mur, B. A., & Jeyakumar, R. B. (2025). Cosmetic industrial wastewater treatment and bioelectricity production in upflow microbial fuel cell (UMFC) using extremophilic bacterial consortium. *Journal of the Taiwan Institute of Chemical Engineers*, 166(P2), 105438.
- [3] Bhaduri, S., Ghosh, R., Kumar, S., & Behera, M. (2025). Photosynthetic microbial fuel cells for wastewater treatment and electricity production. *Journal of the Indian Chemical Society*, 102(10).
- [4] Luo, Z. Y., Wang, R. X., Yang, X. L., Wang, Z. J., Zhai, S. Q., & Sun, Y. (2025). Long-term operational characteristics of microbial fuel cells based on novel biofilm-separated membrane. *Journal of Water Process Engineering*, 73(January).
- [5] Abdelmohsen, H. M., & Elawwad, A. (2025). Performance investigation of osmotic microbial fuel cell under different operational conditions : Effect of aeration mode , external resistance , and substrate concentrations. *Desalination and Water Treatment*, 323(August), 101382.
- [6] Shabangu, K. P., Chetty, M., & Bakare, B. F. (2024). Optimization and Modeling of a Dual-Chamber Microbial Fuel Cell (DCMFC) for Industrial Wastewater Treatment: A Box- Behnken Design Approach. *Energies*, 17(2740).
- [7] Tan, S., Ong, S., Ho, L., Wong, Y., Thung, W., & Teoh, T. (2020). The reaction of wastewater treatment and power generation of single chamber microbial fuel cell against substrate concentration and anode distributions. *Environmental Health Science and Engineering*, 18, 793–807.