JIT Journal of Innovation and Technology
e-ISSN: 2721-8562; p-ISSN: 2721-8570
Vol. 7, No. 1, April 2026. Page: 11 – 18

CHEMICAL OXYGEN DEMAND (COD) REDUCTION AND ELECTRICITY GENERATION OF UNILA RETENTION POND WATER TREATMENT USING MICROBIAL FUEL CELLS (MFCs)

Siti Nurul Khotimah[1*], Syabrina Samsu Raudhatul Mawadah [1], Ihsanuddin Fadillah[1], Intan Suroya Hazlin[1], Mila Preselya[1], Andini Putri Karisma[1], M. Ridho Ulya[1], Ofik Taufik Purwadi[2],

[1] *Department of Environmental Engineering, Faculty of Engineering, Universitas Lampung, Gedung E Lt. 1, Jl. Prof. Soemnantri Brojonegoro No. 1, Bandar Lampung 35143, Indonesia*
[2] *Department of Civill Engineering, Faculty of Engineering, Universitas Lampung, Gedung E Lt. 1, Jl. Prof. Soemnantri Brojonegoro No. 1, Bandar Lampung 35143, Indonesia*

*Corresponding Author: siti.nurul@eng.unila.ac.id

Article history
Received: 29.12.2026
Revised: 01.02.2026
Accepted: 07.04.2026

DOI:10.31629/jit.v7i1.8417

Abstract
Unila retention pond water not only received stormwater but also greywater from Griya Kencana's drainage outlet. It might drive the to water quality degradation. Hence, the stacked Microbial Fuel Cells (MFCs) were utilized to treat the water. MFC utilize microbial activities to degrade the organic pollutant in wastewater while simultaneously generating bioelectricity through biochemical reactions. In this research, the MFCs was configured in series and parallel set up with overall number of cells was 12 for each configuration. But in parallel, it consists of two set of 6 cells series set up. The reactor consisted of graphite that function as the anode and zinc to work as cathode. The spacing between electrodes was 1 cm. Each cell of MFCs was design as air cathode system. The operation of MFCs was a batch system with Hydraulic Retention Time (HRT) 7 days. The research objectives were to evaluate the capability of stacked MFCS (series and parallel) to treat the water in term of Chemical Oxygen Demand (COD) Removal and to generate electricity. The results demonstrated that the stacked MFCs had successfully treated the water with efficiency of COD removal 22.34% for series configuration and 8.51% for parallel configuration. The systems also achieved electricity generation by maximum voltage 8.11 V and 4.12 V for series and parallel respectively. Maximum current value for series MFCs was 0.14 mA and parallel MFCs was 0.15 mA.

Keywords: Unila retention pond water, Stacked MFCs, water treatment, electricity generation.

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1. Introduction

Unila Retention Pond (known as Embung Rusunawa) is located next to Universitas Lampung (Unila)'s student dormitory. As a retention pond, it is designed as a permanent basin. The development of the pond has a goal to perform to a good stormwater management surrounding Unila [1]. It maintains the water level, treats water quality and prevents flooding in the downstream [2]. The pond functions not only receive runoff but also untreated greywater from Griya Kencana Residential area which its drainage outlet is located next to the pond [3]. Figure 1. Illustrates the existing condition of Unila Retention Pond.

Figure 1. Unila Retention Pond (Embung Rusunawa) [4]

As the pond receives the untreated greywater (domestic wastewater) from the surrounding residential area, it may exhibit elevated chemical oxygen demand (COD) concentration, thereby contributing water quality degradation [5]. Apart from causing water quality deterioration, domestic wastewater may also lead to eutrophication (due to the presence of phosphate and nitrogen compounds from detergents), triggering excessive alga growth and reducing the dissolve oxygen (DO) [6].

Naturally, the retention pond is capable of recovering from the water quality degradation through self-purification processes, as the pond behave similar to wetland which allow the aquatic microorganism breaks down the pollutant [7]. But another technology may be applied to treat the polluted water. Microbial Fuel Cell (MFC) is one of the innovative technologies to treat wastewater. MFC utilize microbial activities to degrade the organic pollutant in wastewater while simultaneously generating bioelectricity through biochemical reactions [8]. A Microbial Fuel Cell reactor consists of electrodes (anode and cathode) and external circuit [9]. During operation, the wastewater that naturally containing electroactive microorganism serves as substrate [10]. These microorganisms attach to the anode surface and form biofilm, where they oxidize organic matter and release electrons and protons. The electrons are transported to the anode and migrate through the external circuit to the cathode, generating an electric power [11]. By this process, MFCs promote a sustainable approach for simultaneous wastewater treatment and energy production.

In its development, MFC can be classified as single-chamber MFC, double-chamber (or dual-chamber) MFC, and stacked MFC. Primarily, the difference between single-chamber and double chamber MFC is in its structure. Single-chamber MFC designs featuring one compartment where both electrodes are placed, while dual-chamber designs separate the anaerobic anode and aerobic cathode into two distinct chambers [9]. Utilizing the single chamber MFC typically make it easier to scale and produce higher power of electricity, while dual chambers seem less in producing electricity power but it has better environmental control. Multiple MFC units can be configured in series or parallel as a stacked system. The stacked MFC might be a choice for the reason to generate more electricity voltage and to adjust better current of electricity.

A pioneering study on stacked MFCs was carried out. The researchers revealed that configuring multiple MFCs in series and parallel (the stacked system comprised six MFCs, each designed as double chamber MFC) remarkably enhanced voltage and current outputs compared to individual MFC. Their investigation was conducted within 10 hours. Their studies' results showed that the individual MFC produced about 110 Wm^{-3} at 20 mA, while the MFCs were configured in a stacked system, the power density increased until approximately 300 Wm^{-3} at a current of around 50 mA. Their results emphasized the potential of stacked MFCs to address the low power electricity investigated in single MFC [12]. Likewise, another research was also conducted stacked-air cathode MFCs that treated continuous flow domestic wastewater. There were two kinds of stacked MFCs (2 cells and 4 cells – series and parallel, each experienced 23^0C and 30^0C and different kind of hydraulic flow type). it showed stable electricity generation in parallel

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configuration and simultaneously reducing organic pollutants (about 44% COD reduction) [13].

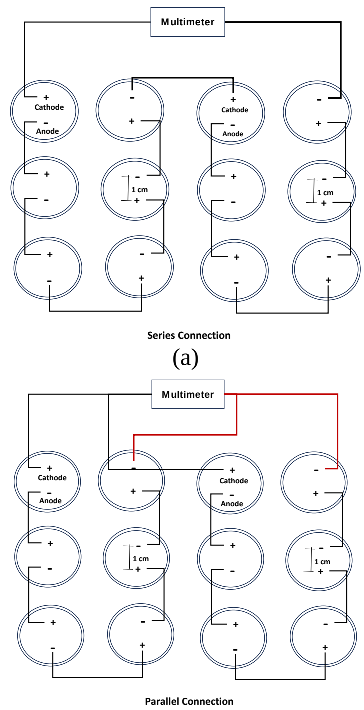
An investigation of a pilot-scale stacked MFCs (dimension: 90 x 40 x 5 cm and 80 x 30 x 5 cm) that operated with continuous flow and batch system was conducted in 2016. The study showed maximum power density ~50.9 W/m3 in fed-batch operation and ~42.1 W/m3 in continuous operation. COD removal rate was about 2.6 kg COD/ (m3 d). In another words, the study showed good results in wastewater treatment and electricity generation under practical conditions [14]. They stated the potential of MFC systems beyond laboratory-scale experiments. Similarly, A research studied continuous-flow air cathode stacked MFCs treating domestic wastewater was also performed. Their results revealed that reactors set up remarkably affected both COD reduction efficiency and electricity production performance. These outcomes indicates that optimal design of stacked MFCs is essential to make the system more effective [15].

A critical review of more than 100 previous studies investigated real wastewater revealed that MFC consistently achieved high COD reduction efficiency, some exceeding 60%, but electricity generation still insufficient to compete conventional energy power[16]. Likewise, another critical review article stated that pollutant removal and energy production maybe affected by operational conditions, wastewater characteristics, and reactor design [17].

Even though there have been numerous studies related to stacked MFCs treated domestic, municipal and industrial wastewater, utilizing retention pond water as a substrate for MFCs systems has receiving less attention. Retention pond water exhibits unique physicochemical features and indigenous microbial population that is very interesting to investigate. In addition, research about tropical retention pond water treatment using stacked MFCs remain limited. Hence this study has objectives to examine the COD reduction and its potential in generating electricity from laboratory-stacked microbial fuel cell using water collected from Unila retention pond. The aims of the research were to evaluate the performance of stacked MFCs both series and parallel configuration in treating the Unila retention pond and to observed the capability of tacked MFCs to generate electricity especially its voltage and current outputs.

2. Materials and Methods

Stacked MFCs were configurated into series and parallel. A series connection consisted of 12 single chamber MFCs, while parallel connection comprised of two series MFC configuration, each design constructed of six single chamber MFCs. Figure 2. illustrates the design of series (a) and parallel (b) stacked MFC configuration.



(b)

Figure 2. Stacked MFC in Series (a) and Parallel (b) Design Configurations

A single MFC unit was constructed by using a 25 ml capacity plastic cup with working capacity 20 ml and fitted with two electrodes. Graphite and zinc were used as anode cathode, respectively. The electrodes spacing was maintained at 1 cm facilitate electron transfer and minimize internal resistance. The schematic of a single MFC unit can be seen in Figure 3.

The stacked MFCs were operated under a batch system with substrate was water collected from Unila retention pond. There was no continuous flow of the pond water. The hydraulic retention (HRT) was set for 7 days. The performance of electricity generation was monitored from day 0 to day 7 by measuring the electricity voltage and current, while COD removal efficiency was performed on day 0 and day 7 (before and after the

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pond water was treated by Stacked MFCs). In addition, several psychochemical parameters, including temperature, pH and conductivity were monitored to assess their potential influence on the performance of the stacked MFC system.

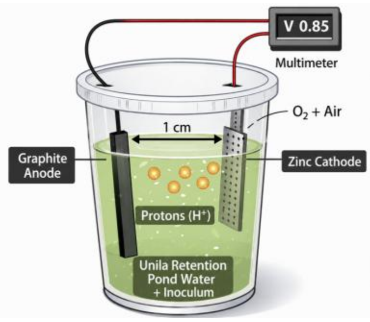


Figure 3. A single MFC Unit Design

3. Results and Discussion

3.1. Stacked MFCs Configuration

The Stacked MFCs (both series and parallel configurations) were set up on Styrofoam platform as illustrated in Figure 4. The image was captured on day 0, prior to the commencement of the treatment process. From the visual observation, it is obviously seen that the retention pond water had less turbidity and relatively clear.

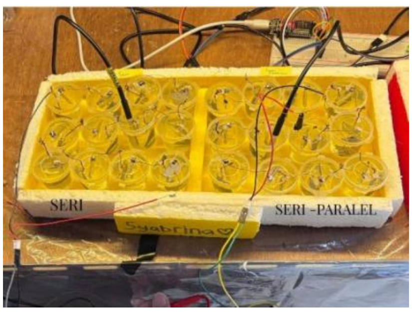


Figure 4. Series and Parallel Configurations of Stacked MFCs and Initial condition of Retention Pond Water Treatment.

3.2. Variation of pH During Treatment Using Stacked MFCs

The variation pH values during the treatment are illustrated in Figure 5. In general, both series and parallel MFC configurations showed that the pH values exhibited less fluctuations during 7-day treatment process. The series pH values ranged from 7.16 to 7.44 while the parallel pH values were between 7.24 to 7.54. Overall, both series and parallel stacked MFCs, the pH values were in neutral condition, favorable condition for microbial activities to have electrochemical processes.

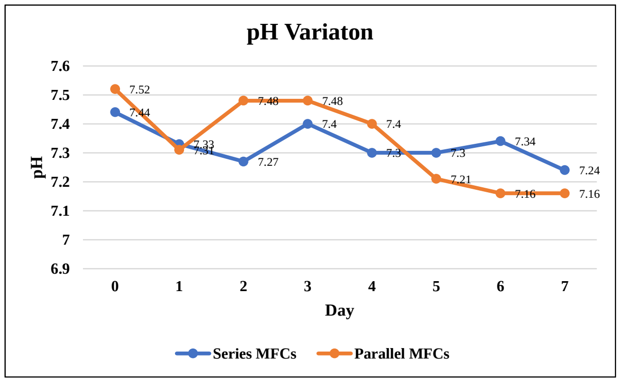


Figure 5. pH Variation During Treatment in Stacked MFC Reactors.

3.3. Variation of Temperature During Treatment Using Stacked MFCs

Based on the temperature variation graph (Figure 6.), the temperature measured in the stacked MFCs (both series and parallel configurations) had slightly fluctuated during the 7-day treatment process. The temperature ranges were about 26^{0}C to 28.3^{0}C indicating the MFC reactor operated under relatively stable condition

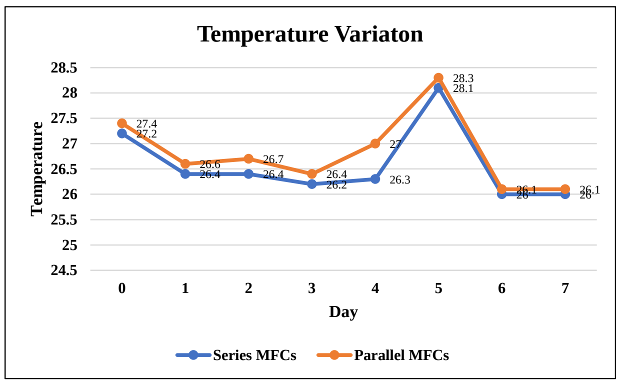
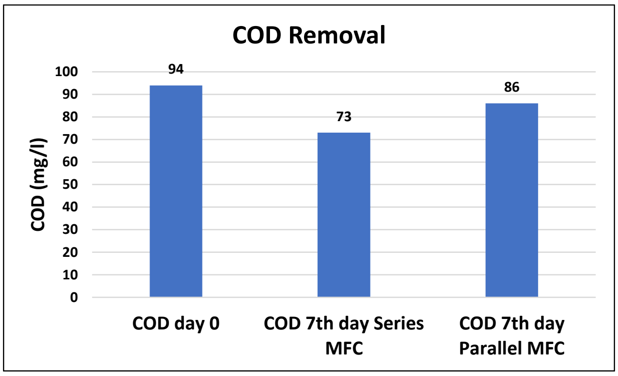


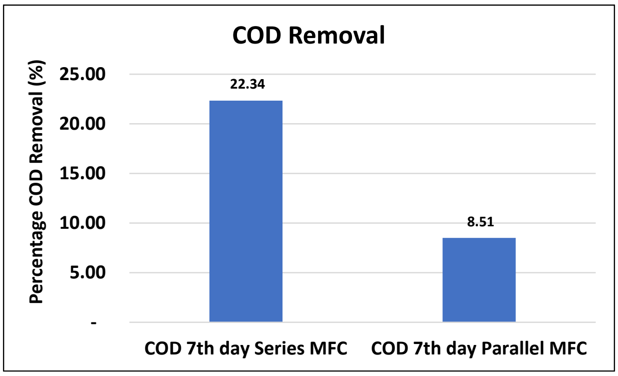
Figure 6. Temperature Variation During Treatment in Stacked MFC Reactors.

3.4. COD Removal

The treatment of Unila retention pond water using Stacked MFCs for this study focus on COD removal. The COD removal for series and parallel configuration is shown in Figure 7a and 7b. Figure 7a illustrated the COD concentration before and after the treatment while Figure 7b revealed how many percent the reduction of COD concentration both series and parallel MFC configuration After 7 days operation.



(a)



(b)

Figure 7. COD Removal Series and Parallel MFCs (a) The Percentage of COD Removal Series and Parallel MFCs

Initially the retention pond water was measured with the COD value 94 mg/l, after 7 days of the treatment using stacked MFC, the COD concentration getting lower, by 74 mg/l (22.34% COD removal) for series configuration and 86 mg/l for parallel configuration or about 8.51% efficiency COD removal.

The higher COD removal identified in the series configuration suggest that the series set up gave more favorable condition for microbial oxidation of organic compounds. During the process of water treatment for 7 days, electroactive microorganisms make use organic matter as a substrate and oxidize it at the anode, causing in the release of electrons and protons. Hence, more reduction of COD generally shows more effective in degrading the organic matter.

3.5. Electricity Production

Voltage and current of the electricity were the measured of electricity generation. The results were illustrated as seen in Figure 8 and Figure 9.

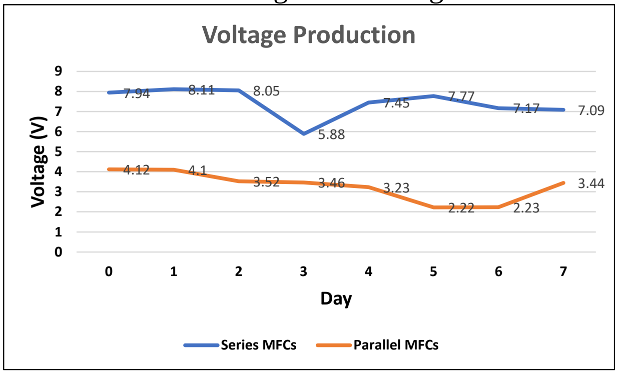


Figure 8. Voltage Generation in series MFCs and Parallel MFCs

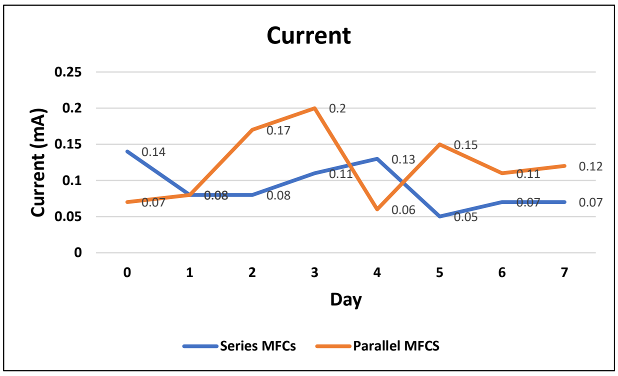


Figure 9. Current Generation in series MFCs and Parallel MFCs

Even though both series and parallel MFCs comprised of 12 MFC cells, their electrical outputs (voltages) different substantially. The series set up produced considerably higher voltages compare to the parallel set up during the experimental time. The voltage generated by the series configuration ranged from 5.88 to 8.11 V, while the parallel configuration produced voltages between 2.22 to 4.12 V. The difference may happen because of their cell arrangement rather that the number of cells employed. In the series set up, the voltages produced by individual cell that were accumulated, generating in a higher overall voltage output. In contrast, the parallel configuration was configurated by connecting two set of six cell series MFCs in parallel. Hence, despite containing the same number of cells, the series set up showed more voltage generation performance compared with the parallel set up.

DOI:10.31629/jit.v7i1.8417

In General, the trend of the voltages for both series and parallel MFCs demonstrates slightly decreasing trend. Initially (day 0) the series voltage was measured 7.94 V. Despite achieving its maximum value of 8.11 V on day 1, the voltage then exhibited a downward trend, declining to 8.05 on day 2 and continuing to decline throughout the remaining treatment time.

The parallel MFCs demonstrated a declining voltage trend throughout the initial stages of operation. Beginning from 4.12 V on day 0, the voltage gradually decreased and reached its lowest value of 2.22 on day 5. Nevertheless, recovery in voltage output was observed on day 6, with increasing to 2.23 until day 7 with 3.44 V. The increment may indicate temporary improvement in reactor condition that improved electron transfer in the system.

Figure 9 presents the current output for series and parallel MFCs. Overall, the two set up demonstrated different current production patterns during the experiment time.

The series MFCs produced an initial current of 0.14 mA on day 0 (the highest recorded current). The output subsequently declined to approximately 0.08 mA on day 1 to day 3. A short-term increase was observed on day 4, achieving 0.13 mA, before declining to 0.05 mA on day 5. Then, the current slightly recovered at approximately 0.07 mA until the end of experiment time.

In contrast, the parallel MFC demonstrated a general higher current result throughout experiment time. The current started from 0.07 mA on day 0 then it went up to 0.17 mA on day 2 until reaching its maximum current on day 3 with the value of 0.2 mA. However, a significant decrease happened on day 4, dropping to 0.06 mA. Next, the current increased to 0.15 mA on day 5 then remained stable in the ranges 0.11 and 0.12 during the final days of treatment.

The findings revealed that the parallel set up generated higher current output compare with series set up. This result is consistent with the fundamental principle of electrical circuits where parallel configuration was generally associated with higher current capacity.

Figure 10 to Figure 13 is the documentation of electricity measurement in last day treatment Unila retention pond water treatment using stacked MFCs.

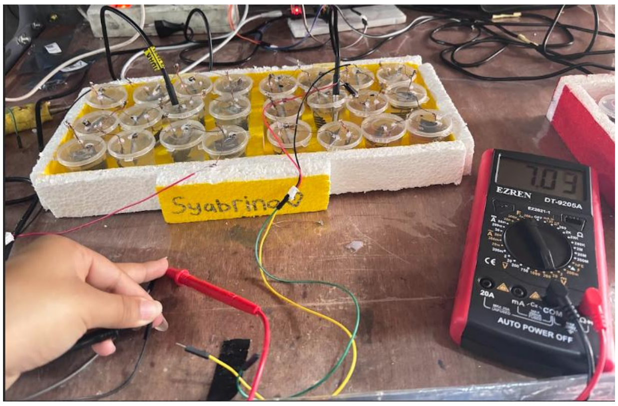


Figure 10. Voltage Generation Day 7 in series MFCs

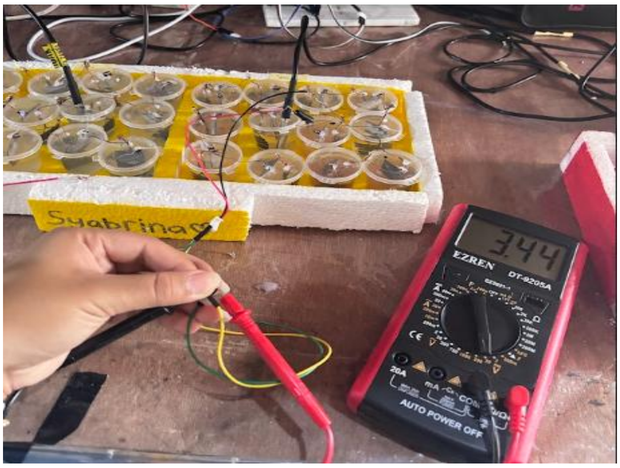


Figure 11. Voltage Generation Day 7 in Parallel MFCs

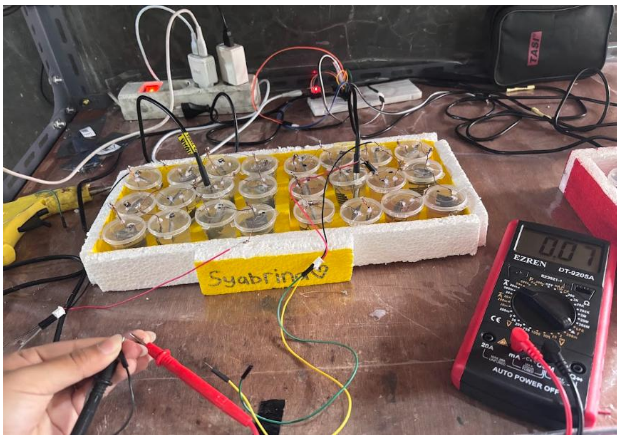


Figure 12. Current Generation Day 7 in Series MFCs

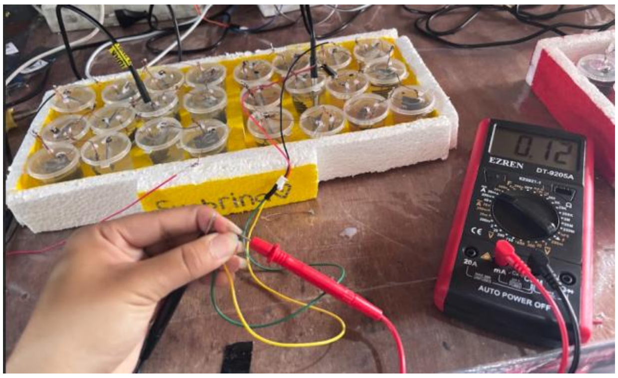


Figure 13. Current Generation Day 7 in Parallel MFCs

4. Conclusion

Based on the results of the research the following conclusions can be drawn:

1. The stacked MFCs had relatively stable operation condition during 7-day treatment time. It was shown by the minor fluctuation in pH and temperature which still within the range's microbial activities.
2. Both series and parallel MFCs were capable to treat UNILA retention pond water by reducing organic matter. The series MFCs had achieved a higher COD removal about 22.34% while parallel MFCS had efficiency about 8.51% in reducing COD.
3. Electricity had successfully generated by the stacked MFCs. The series MFCs maximum voltage value was 8.11 V while parallel MFCs had achieved 4.12 V. For current output, both series MFCs and parallel MFCs had different pattern in fluctuation. Maximum current value for series MFCs was 0.14 mA and parallel MFCs was 0.15 mA.

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