

Effects of Complex Outdoor Factors on Voltage, and Power Generation of Plant Microbial Fuel Cell by Embedded Cathode Structure

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1. Introduction

Plant Microbial Fuel Cell (PMFC) is a bio battery which generates electricity by specific bacteria's metabolism and plant activities. Since this battery is considered to have sustainability as well as lower environmental load, many researches have been conducted including implementation of PMFC into a real society such as green infrastructure [1]. However, it is pointed out that PMFC's power can be easily influenced by various outdoor factors[2]. PMFC's current and water content in the soil was found to have significant correlation, however, the relationship between voltage is still unclear[3]. It is essential to study how much impact PMFC's voltage can be caused by natural environmental factors for introduction of PMFC to society.

In addition, conventional PMFC cathode electrodes are placed on the surface of ground since this design allows cathode to be aerobic condition. However, this structure is considered to be vulnerable to outdoor factors.

Therefore, the main objectives in this study are to investigate effect of complex outdoor factors on PMFC's voltage, and to develop and evaluate new PMFC design which doesn't have cathode electrode on the ground.

2. Materials and Methods

Figure 1 illustrates diagram of PMFC in this study. The main components of PMFC in this study are plant, soils, and electrodes. *Yucca plant* was chosen due to the fact of that this plant has high tolerance to dry and humid environment, which enables *Yucca* to grow anywhere in outdoor and indoor.

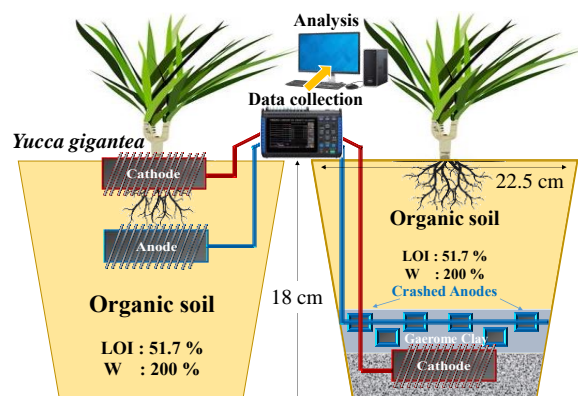


Fig 1. Diagram of PMFC

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Table 1. Location and Environmental Factors of each PMFC

Environmental Factors	PMFC Model			
	Embedded Cathode 1	Embedded Cathode 2	Surface Cathode 1	Surface Cathode 2
Location of PMFC	Outdoor	Indoor	Outdoor	Indoor
Direct radiation	○	○	○	○
Rainfall / Irrigation	○	×	○	×
Inconstant Wind	○	×	○	×
Inconstant Humidity	○	×	○	×
Inconstant Temperature	○	×	○	×

Organic soil for agriculture was used for improving power generation. Bamboo charcoals were coated by iron and manganese, then used in anode. Left picture in Figure 1 illustrates conventional PMFC having surface cathode. On the other hand, right picture shows new design in which cathode is embedded under the ground. Hereinafter, each PMFC is referred to surface cathode PMFC and embedded cathode PMFC respectively. *Gaerome* clay in anode, and crushed bamboo charcoals in cathode were placed in embedded cathode model in order to enhance anaerobic condition in anode and aerobic condition in cathode area.

Methods and Evaluation Process

Two surface cathode PMFCs and two embedded cathode PMFCs were constructed and placed indoor and outdoor in order to investigate how much effects each PMFC can be caused by outdoor factors. Table 1 shows location and environmental factors. Indoor PMFCs were affected constant environment. In contrast, there were varied rainfall, temperature, wind, humidity in outdoor PMFCs. The

comparison of voltage in each PMFC model affected different environment will show the effect of complex outdoor impact on voltage. Voltage data was collected in 5 minutes, and 1 hour rainfall data was provided by Ube city meteorological agency. These data were shown in box plot in 1 hour to visualize voltage fluctuations.

3. Results

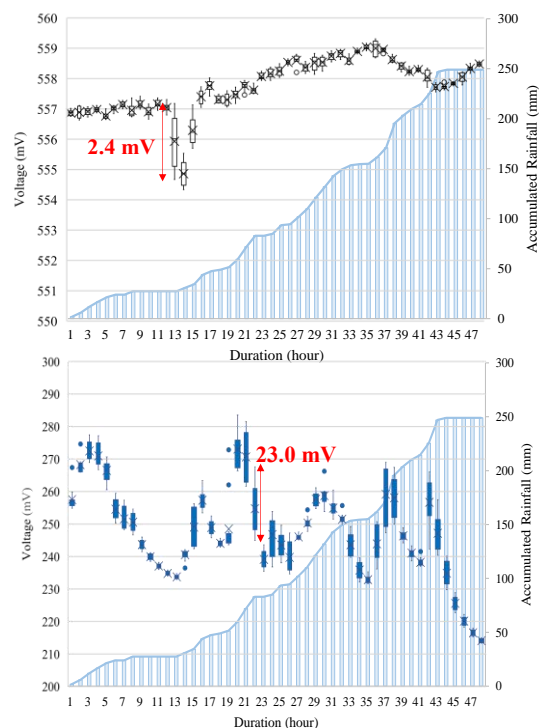


Fig 2. Voltage variation in Surface Cathode PMFC

Figure 2 explains conventional surface cathode PMFCs' voltage variation. The

top graph is PMFC located indoor, and bottom graph is outdoor PMFC. It was observed that indoor surface cathode PMFC voltage experienced gradual increase trend in the whole period. The initial voltage was 556.9mV, which raised up to 558.5mV in the end. This slight voltage growth implies bacterial activity in PMFC, that breaks down organic matter released by plant and causes voltage generation. In 13 hours, however, this cell showed temporal voltage decline, which can be caused by contact failure of surface cathode to ground due to the bend of bamboo electrode. The largest voltage fluctuation, defined as voltage which experienced most voltage variation in 1 hour, was 2.4mV.

The lower graph in figure 2 explains outdoor surface cathode PMFC. As opposed to indoor cell, the voltage of this PMFC shows large fluctuations and its voltage trends to be decreased as time passes. The highest voltage was 283.5 mV, generated at 20 hours and lowest voltage was 214.1 mV which was monitored in the final stage of period.

Although the largest fluctuation of indoor cell was 2.4mV, this outdoor PMFC showed 23.0mV, which meant outdoor complex environmental effects can deteriorate PMFC voltage stability. In this study, conventional design (surface cathode) PMFC voltage deteriorated 9.6-fold due to the outdoor

effects. As other researchers point out, PMFC is vulnerable to meteorological effect, however, this surface cathode PMFC seems to be caused much stronger impact by rainfall. Since cathode electrode is placed on the surface, it can be flooded easily in the raining which leads anaerobic condition in cathode and lead to lower voltage generation.

Figure 3 explains voltage variation in Embedded cathode PMFCs.

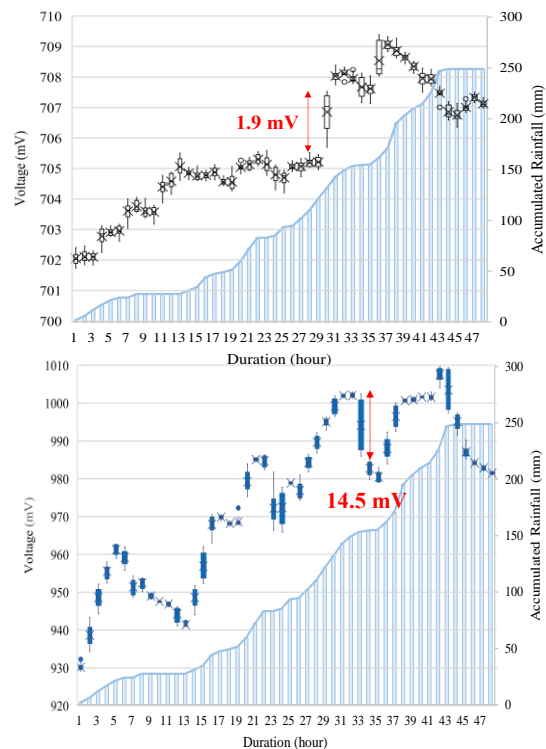


Fig 3. Voltage variation in embedded Cathode PMFC

The top graph and bottom graph illustrate indoor cell and outdoor cell respectively. When it comes to indoor cell, voltage experienced gradual growth trend which was similar to indoor surface cathode PMFC. Besides,

the largest voltage fluctuation was relatively small which was 1.9 mV. This means that, as mentioned above, PMFC performed electricity generation stably due to no environmental effects.

Turning to outdoor Embedded cathode PMFC, voltage changed with some extent of fluctuations as time passes just like surface cathode PMFC. However, this Embedded cathode cell trended to escalate its voltage even with the environmental effects, which was unique and never observed in surface cathode PMFC. Although the initial voltage was 930.1mV in this cell, it reached 1008.9mV, the highest voltage after 43 hours. The largest fluctuation showed 14.5 mV, which implies outdoor cell has 7.6 times larger voltage fluctuation than indoor cell. Consequently, embedded PMFC is considered to have higher stability against outdoor complex effects at 26%, calculated with each design PMFC's the largest voltage fluctuation. *Gaerome* clay in anode and void due to the crashed bamboo in cathode can be the reason of high performance. Moreover, rain effect may enable this design PMFC to improve its electricity generation for the reason of that upper anode react with water and anaerobic becomes predominant. Cathode, however, is surrounded by crashed bamboo which provide enough oxygen. This combination can be thought to

lead much higher voltage generation, and this relationship is shown in some part of figure 3.

4. Conclusion

This research was conducted in order to discover the effects of complex outdoor environment on PMFC voltage, and to develop a new PMFC design. The results revealed that outdoor factors can affect electrode contact, and especially, rainfall has a strong impact on surface cathode PMFC voltage. Embedded cathode cell, however, showed more stable voltage generation at 26% than conventional cell. This is considered to electrode placement design in which upper anode and lower embedded cathode.

5. Reference

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