# The Effect of Electrode Number in Electricity Generation by Using Different Type of Wastewater via Microbial Fuel Cell (MFC)

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**Abstract**

Instead of using energy to treat wastewater, it is feasible to generate energy from the wastewater itself as well as treating it using a Microbial Fuel Cell (MFC). MFC generates electricity from this huge amount and various type of wastewater with the help of bacteria. The objective for this experiment is to indicates the electricity generation as well as sewage treatment in the same period to observe how MFC could improve the wastewater to ensure it safe to be release to the open water. Four cells were used where two of them consisted with POME and the balance with leachate. For each of the wastewater it consisted of single and dual anodes but the same number of cathode. The cathode and anode are made of aluminum placed in two separate chambers and the cells is completed with salt bridge made of cotton rope covered with 120 mm plastic pipe and wire to connect with voltmeter for voltage monitoring. POME and leachate with COD of 49590mg/L and 25920mg/L respectively were introduced into the cells. Voltage measurement was made twice a day for 25 days and the average value is taken into the result. COD, CFU and pH value is taken from initial of experiment and at the end of the experiment. The last voltage generate for POME was 625mv and for leachate was 388mv with both have affected by formation of colony around the anode $903 \times 10^{11}$ CFU/mL in POME and $229 \times 10^{11}$ CFU/mL in the leachate. The formation of colony causes the COD in both wastewater decrease for about 52% to 61.2% percentage drop in leachate and POME. This asserted that MFC generated electricity as well as being better waste treatment devices than natural and constructed waste treatment ponds.

*Keywords:* electricity; microbial fuel cell; wastewater; salt bridge; POME; leachate; COD; CFU:

## 1.0 Introduction

The worlds' population is increasing and concentrating in urban centers. This trend is particularly intense in developing countries, where an additional 2.1 billion people are expected to be living in cities by 2030 (United Nations 2012). These cities produce billions of tons of waste every year, including sludge and wastewater. From the increase in population, large volume of wastewaters is expected to produce annually not only from residencies but also from industrial and agriculture operations. For example, Malaysia has a population of 28.3 million (Report of census, 2010) which contributes to the increasing amount of wastewater generated every year. The estimated volume of wastewater generated by municipal and industrial sectors is 2.97 billion cubic meters per year (E.A. Tuan Mat et al., 2011). These large number of wastewater released to open water is the basis that leads to negative impact caused to the environment such as acidification of water, acid rain etc.

At the same instance, fossil fuels have been the most important energy sources in the world. It is popular as it has composition that contains hydrocarbon which is essential to achieve electrical energy. Electric energy is vital in this era since it has been the sector that provides input to almost every section of economy (Bozkurt et al., 2010). Total world electricity consumption was 19,504 TWh in 2013, 16,503 TWh in 2008, 15,105 TWh in 2005, and 12,116 TWh in 2000. The trends have led researcher to find alternative energy sources that is renewable and environmental-friendly such as geothermal energy and tidal power which not only generates electric but also will not affect the environment.

Microbial Fuel Cell, MFC is one of the alternatives of energy source. Many researchers showed interest on the MFC because of its possibility to generate electricity from wastes and renewable biomass (Jafary et al., 2011). MFC is a technology that converts organic matter to energy (electricity) using microorganisms as the catalyst. Other than producing electricity, MFC is capable to treat the wastewater based on journal (Huang et al., 2011) and many factor such as the chemical oxygen demand (COD). MFCs consists of many types of reactor and all of it have the same principles which is having a pair of battery-like terminal consisting of anode and cathode electrode. MFCs are usually made of two chambers, anode and cathode chamber.

Palm oil mill effluent (POME) is one of the waste water that discharged from sterilization process and also produced large amount of methane gas from its anaerobic process. POME was also found as the highest contribution of pollutants discharged into rivers in Malaysia due to its high chemical oxygen demand (COD) and pH value. The process to extract the oil requires large quantities of water steam sterilizing the palm fruit bunches and clarifying the extracted oil. It is estimated that every 1 ton of crude palm oil produce, 5-7.5 tons of water required, and more than half of water used end up as palm oil mill effluent (POME). POME has a high organic content such as oil and fatty acid that enables it to support the bacterial growth which can reduce the polluting strength. The biogas produced from POME and potential utilization in electricity generation could reduce the demand of fossil fuels such as kerosene and diesel and could increase the renewable source of energy.

Wastewater is hold inside the anode chamber in an anaerobic environment while the cathode chamber holds water with aerobic solutions which is being exposed to air. Salt bridge acts as a connector between the two chambers and function as pathways for the transfer of protons. Electrons flow from anode to the cathode through external electrical connection (voltmeter) that includes resistor (Pradeep Kumar et al., 2010). When these electrons flow from the anode to the cathode, it generates the current and voltage to make electricity. (Logan et al., 2008)

Wastewater in the anode chamber will be oxidized and produce electrons as well as protons throughout the process. Carbon dioxide is produced as a result of oxidation process that occurs. The movement of electrons are from anode electrode through external circuit to the cathode. The protons move to the cathode through the salt bridge and will combine with oxygen to produce water resulting in complete circuit (Pham et al., 2006).

MFC is the chemical energy contained in organic matter are converted to electricity by means of catalytic (metabolic) activity of the living microorganisms in electrochemical device (Scholar & Technology, 2013). The (Mahendra et al., 2013) reported that, the organic substrate (sucrose) consume by the microorganism in aerobic condition produce $CO_2$ and $H_2O$.

$$C_{12}H_{22}O_{11} + H_2O + 18O_2 \rightarrow 12CO_2 + 12H_2O \quad (1)$$

The electrons will be trapped by mediator, if the mediator replaced the terminal electrons acceptor oxygen, which will get reduce and the electrons will transport to the electrode at anodic chamber. Carbon dioxide, protons and electrons will be produce when oxygen is not present (anaerobic condition) as described below:

$$C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e^- \quad (Anode) \quad (2)$$

$$48H^+ + 48e^- + 12O_2 \rightarrow 24H_2O \quad (Cathode) \quad (3)$$

## 2.0 Methodology

### *2.1 Discovering and Collecting Samples*

The substances that were chosen in this experiment were leachate and POME. These substances contain microorganisms that produce electricity due to organic matter composed. Leachate was collected from dumping pond and POME was collected from palm oil industry.

### *2.2 Preparing Materials and Apparatus*

Below are the materials and apparatus used for the experiment; two containers of a diameter of with sealable lids, 120mm PVC pipe for salt bridge, salt (NaCl), three carbons electrodes; two anodes and one cathode, air pump with plastic tubing, multimeter for electrical measurement, tap water, cooper wire, crocodile clip, cotton rope, pH indicator and spectrophotometer (HACH DRB 200).

### *2.3 Making the electrodes*

In this experiment, three carbons electrodes were used for transferring electron, one with two anode electrodes in it and the other one with only a cathode electrode. The positive terminal, anode is where the electrons are deposited while the negative terminal, cathode is where electrons were transferred from anode. Chamber containing POME with 1 anode is labelled as POME 1 while chamber containing POME with 2 anodes is labelled as POME 2. Same goes to another wastewater, leachate. Copper wire related to both the carbon electrodes which grooves on it.

### *2.4 Making of salt bridge*

The cotton rope was immersed in the salt solution (NaCl) for about a few minutes until it is soaked the solution. Then, it is inserted into the 120mm plastic pipe. The NaCl salt bridge purposed is to allow the movement of electron between the two electrodes. The electron flows from anode to the cathode.

### *2.5 Making anode and cathode chamber*

The diameter of pipe was measured to make a hole between it which correlates each other, so that the pipe can be connected between the two containers.

### *2.6 Procedure*

The leachate sample was used to start the experiment. Firstly, the initial reading of the pH value was taken where hydrochloric acid act as a controller. Next, chemical oxygen demand (COD) was analyzed from the leachate sample using a spectrophotometer. Half of the anode chamber was filled with leachate and placed into the anode container. Two electrodes were connected in the anode container. The lid of the anode was sealed as connecting wire was passed through a hole in it. This is so to obtain an anaerobic environment. Meanwhile, half of the cathode chamber was filled with water and air pump was submerged in it. The function of the air pump is to aerate the water in the cathode container to increase the oxygen contain. The connecting wire from anode and cathode was clipped to the voltmeter by using crocodile clips. For every consecutive two hours, the readings were taken from the voltmeter. After twenty-five days, the COD value was analyzed again to obtain the final reading. The experiment was repeated by using different type of waste water which is POME.

### *2.7 Preparation of COD Reagent*

In COD reagent, it consists of standard Potassium dichromate and concentrated Sulphuric acid that containing mercury sulphate. The prepared reagent was used for determining the COD levels in the sample A, B and the control.

### *2.8 Preparation of COD Sample*

30 ml of distilled water were poured into measuring cylinder and 1ml of POME and Leachate was added. 1ml of the dilution sample was added into the test tubes that contain HACH COD vials. The COD digester was heated until it reached 150°C. Then, the test tubes were transferred into the COD digester and heated for 120 minutes at 150°C. A blank which distilled water was used and transferred to the digester to be the control for the COD test. The digested samples were cooled for a few minutes. The COD test was carried out using HACH COD vials for high range measurements (0-1500mg/L) and DR 3900 spectrophotometer.

### *2.9 Preparation of Sample for CFU*

#### *2.9.1 Preparation of Agar Medium*

Agar medium that have been used is nutrient agar. This medium was prepared by mixed 40g of nutrient agar with 1L of distilled water in 1L conical flask and heated on hotplate. The conical flask then was covered with cotton wool and transferred into autoclave machine. The agar solution was poured into petri dish until 1/3 full. Then the solution was cooled and covered with parafilm.

### *2.9.2 Preparation of Salt Solution*

8.5g of NaCl was diluted in 1L of distilled water. 9ml of the solution was poured into universal bottle and 10 universal bottles were required for each dilution sample. All bottles were transferred into autoclave machine. The dilution process was done using standard method.

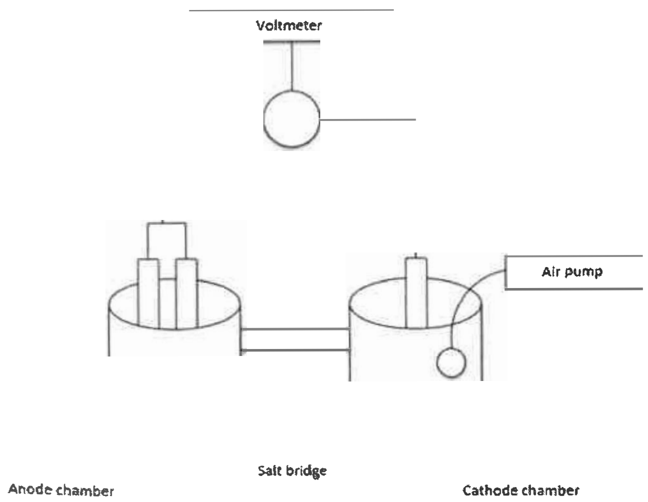



Figure 1: Microbial Fuel Cell Setup

## 3.0 Results and discussion

### *3.1 pH value*

Table 1. Initial and final pH value for different chamber

| Type of wastewater | Initial | Final | Percentage removal % |
|---|---|---|---|
| POME 1 | 4.85 | 3.87 | 20.2 |
| POME 2 | 4.85 | 4.56 | 5.98 |
| Leachate 1 | 8.30 | 7.94 | 4.34 |
| Leachate 2 | 8.30 | 7.96 | 4.10 |

The above presents the pH value that was recorded at the initial and final reading for both Palm Oil Mill Effluent (POME) and Leachate. POME shows a diminishing drop between the final and initial value which is about 20.2% in the single anode. The optimum pH value for bacteria growth is between 6.5-7.0 (Lumen et al., 2012). Since that an optimum growth of an acidophilic bacteria is at pH less than 5.5, thus it can be concluded that the bacteria which grows in the POME container is an acidophilic, which best growing in acidic conditions. (Passos, Neto, Andrade, & Reginatto, et al., 2016). The anaerobic growth of bacteria in POME container will accumulate at the anode side while electrons are being transferred through the salt bridge. This explains why the generation of voltage is showing elevating result for POME at the end of the process. In POME 2, 5.98% removal of pH value is recorded from initially 4.85 to 4.56. On the other hand, leachate shows oppose result in terms of pH value where it is likely to exhibit alkali properties based on the initial and final readings taken which is 8.30 and 7.94 respectively in the single anode container. For leachate 2, it shows a downtrend of 4.1% difference between the initial and final reading taken. This is because some bacteria produce acid as they grow. This acid is excreted and lowers the pH or the surrounding environment. This eventually brings bacterial growth to a halt unless something else in the environment neutralizes the bacterial acid.

### *3.2 Chemical Oxygen Demand*

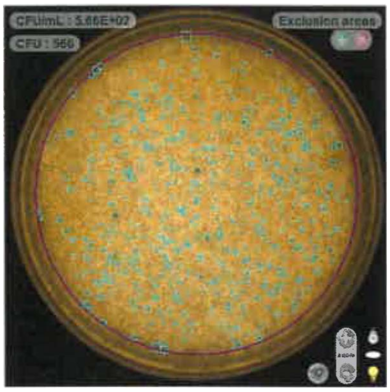
Table 2. Initial and final COD value for different chamber

| Type of wastewater | Initial (mg/L) | Final (mg/L) | Percentage removal % |
|---|---|---|---|
| POME 1 | 49590 | 23790 | 52.03 |
| POME 2 | 49590 | 19050 | 61.58 |
| Leachate 1 | 25920 | 16020 | 38.20 |
| Leachate 2 | 25920 | 14010 | 45.95 |

COD values for all cells are generally decreased with time as depicted in table 2. The COD reading of POME in single anode has significantly decreased from 49590mg/L to 23790mg/L and from 49590mg/L to 19050mg/ for POME in dual anode. This data was recorded for 25 days of MFC process. It shows that the POME chamber with dual anode have higher percentage COD removal of 61.5% compared to single anode with percentage removal of 52%. Meanwhile, leachate also experience the same decline of COD reading with initial reading of 25920mg/L to 16020mg/L in single anode and from 25920mg/L to 14010mg/L in dual anode. Leachate chamber with dual anode resulting in higher COD percentage removal of 45.9% compare to single anode which has the COD percentage removal of 38.2%.

### *3.3 Colony Forming Units*

a)




After 25 days