PERFORMANCE OF DOUBLE CHAMBER MICROBIAL FUEL CELL BASED ON DIFFERENT TYPE OF WASTEWATER AND ELECTRODES

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DECLARATION

I declare that this thesis entitled “PERFORMANCE OF DOUBLE CHAMBER MICROBIAL FUEL CELL BASED ON DIFFERENT TYPE OF WASTEWATER AND ELECTRODES“ is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : --

Name : --

Date : --

APPROVAL

I hereby declare that I have checked this report entitled "Performance of Double Chamber Microbial Fuel Cell Based on Different Type of Waste Water And Electrodes"and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

For their endless love, support and encouragement

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ABSTRACT

Energy is the quantitative property that must be transferred to an object in order to perform work on, or to heat the object. Energy is a conserved quantity; the law of conservation of energy states that energy can be converted in form but not created or destroyed. Living organisms require available energy to stay alive, such as the energy humans get from food. Human civilization requires energy to function, which it gets from energy resources such as fossil fuels, nuclear fuel, or renewable energy. Many research and technological advancements have been made in the area of renewable energy sources and technology. This is due to the rapid exhaustion of the fossil fuel based energy sources which continuously increase in cost. The energy demand also will increase and will continue in near future due to the increase of population of the world. Therefore, there is need to develop alternative sources of sustainable energy especially a renewable energy. The aim of this project is to find the new source of renewable energy and to prove and demonstrate the generate electricity from wastewater by using Microbial Fuel Cell (MFC). The methodology of this project is to design, develop, enhance and experiment of the MFC and to identify the maximum production of voltages, current and power that can be produced from MFC. Various types of test using double chamber MFC were utilized to obtain the maximum amount of power production such as types of water (i.e., fertilize water, lake water and soil water), distance of electrodes and thickness of electrode. The comparative result shows that the fertilize water generate the higher amount of power compared to soil and lake water.

ABSTRAK

Tenaga adalah nilai kuantitatif yang mesti dipindahkan ke objek untuk melaksanakan kerja, atau untuk memanaskan objek itu. Tenaga adalah kuantiti yang dipelihara dimana undang-undang pemuliharaan tenaga menyatakan bahawa tenaga boleh ditukar bentuk tetapi tidak dicipta atau dimusnahkan. Organisme hidup memerlukan tenaga yang ada untuk terus hidup, seperti tenaga manusia terhasil daripada makanan. Tamadun manusia memerlukan tenaga untuk berfungsi, yang diperolehi daripada sumber tenaga seperti bahan api fosil, bahan api nuklear, atau tenaga boleh diperbaharui. Banyak penyelidikan dan kemajuan teknologi telah dibuat di kawasan sumber tenaga dan teknologi yang boleh diperbaharui. Ini disebabkan oleh jumlah bahan api fosil yang semakin berkurangan berasaskan bahan api fosil yang terus meningkat dalam kos. Permintaan tenaga juga akan meningkat dan akan berterusan dalam masa terdekat disebabkan peningkatan populasi di dunia. Oleh itu, terdapat keperluan untuk membangunkan sumber alternatif tenaga lestari terutamanya tenaga boleh diperbaharui. Tujuan projek ini adalah untuk mencari sumber tenaga baru yang boleh diperbaharui dan membuktikan serta mendemonstrasi penghasilan tenaga elektrik dari air buangan dengan menggunakan sel bahan bakar mikrob. Metodologi projek ini adalah untuk merekabentuk, membangunkan, meningkatkan dan mencuba sel bahan bakar mikrob dan mengenal pasti pengeluaran maksimum voltan, arus dan kuasa yang boleh dihasilkan dari sel bahan bakar mikrob. Pelbagai jenis ujian menggunakan ruang ganda MFC telah digunakan untuk memperoleh jumlah maksimum pengeluaran kuasa seperti jenis air (iaitu, air baja, air tasik dan air tanah), jarak elektrod dan ketebalan elektrod. Hasil perbandingan menunjukkan bahawa air baja menghasilkan kuasa yang lebih tinggi berbanding dengan air tanah dan air tasik.

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CHAPTER 1

INTRODUCTION

1.1 Background

Figure 1.1 shows the energy consumption of the world starting from 1990 until 2015 and the future projection of energy consumption of world from 2020 until 2040 [1]. The figure shows that the energy consumption was increase rapidly throughout the years especially for non-renewable energy such as natural gas, coal and petroleum and other liquids.

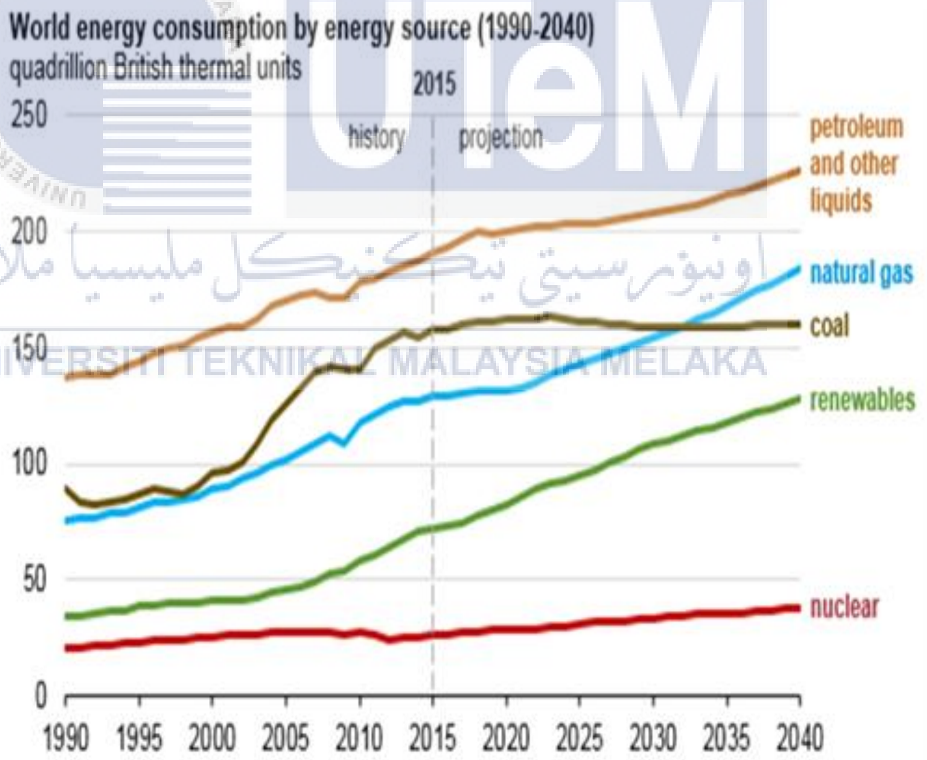


Figure 1.1: World energy supply consumption (1990-2040) [1]

However, in Malaysia specifically the energy production is based on oil and natural gas [2]. The buildings in Malaysia consume 48% of the electricity generated in the country. [3]. Commercial buildings consume a maximum of 38,645 GWh while residential buildings consume 24,709 GWh. The country's demand for electricity is expected to increase from 91.539 GWh in 2007 to 108.732 GWh in 2011. [4]. By 2020 Malaysia's energy demand is projected to reach 116 million tons of oil equivalents (Mtoe). Meanwhile, the total electricity generation for 2007 is 108,732 GW / h with a total consumption of 97,113 GW / h or 3,570 kWh per capital, where 51% of natural gas is used for electricity generation as shown in Figure 1.2 [4].

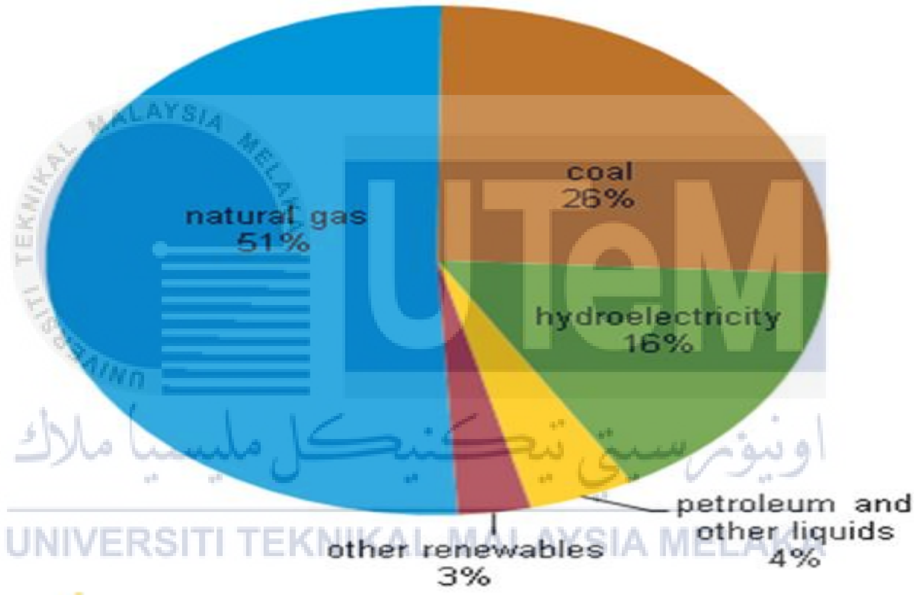


Figure 1.2: Electricity generation in Malaysia, end-2014 [4]

Malaysia, however, has only 19 years of oil reserves and 33 years of natural gas reserves, while energy demand is growing rapidly. As a result of this problem, the Malaysian government is becoming renewable energy sources. 16% of Malaysian electricity generation is currently hydroelectric, while the remaining 84% is thermal [5]. The energy sector as a whole is regulated by Suruhanjaya Tenaga, a statutory energy commission in the peninsula and Sabah, in accordance with the Electricity Commission Act of 2001, whereas the oil and gas industry in Malaysia is currently dominated by the state - owned Petronas [6].

Figure 1.3 shows the production of petroleum and other liquids in Malaysia starting in year 2002 to 2016 [7]. From the Figure 1.3, at first 9 years the increments of oil production are increase rapidly throughout 2002 until 2010. However, starting 2011, the petroleum and other liquids production are started to be decrease while the consumption is increase exceeding the value of production until 2015 [7].

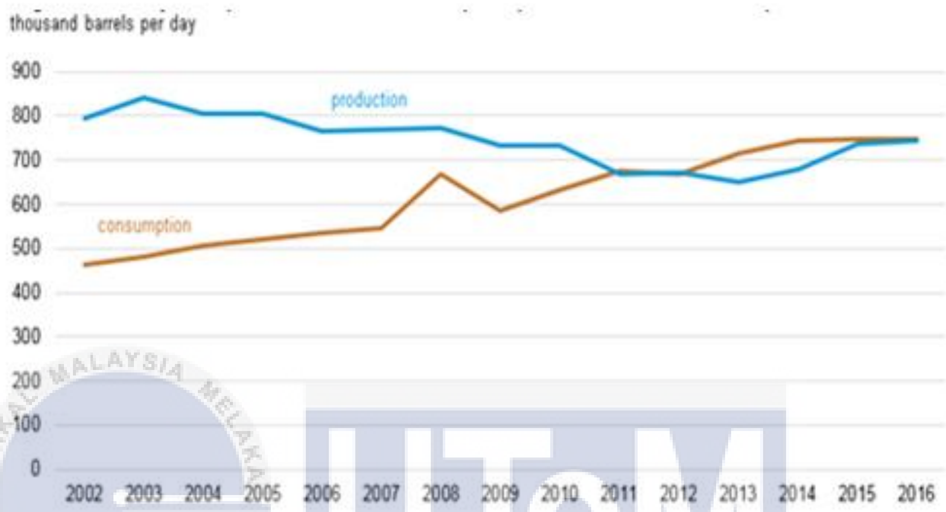


Figure 1.3: Data from statistical report 2017 [7]

In 2007, the country as a whole consumes 550 000 barrels (23.6 million tons) of oil daily compared to 755 000 barrels (34.2 million tons) of oil per day [7]. It shows that the oil production in Malaysia cannot support the oil consumption needed in the near future. Therefore, Malaysia need to find another ways to supply energy and does not relay on oil only.

One of the ways to supply energy so that Malaysia does not relay on oil only is through renewable energy. A minimum of 168 million tons of biomass waste is generated in Malaysia annually [7]. Burning biomass emits carbon emissions but is classified as a renewable energy source in the European Union and the United Nation, because plant stocks can be replaced by new growth. Biomass can be converted to biofuel using various methods that are widely classified as: thermal, chemical and biochemical [8]. Therefore, Microbial Fuel Cell (MFC) as one of biomass energy is introduced in harnessing the power of metabolism for electricity.

Microbial fuel cells are devices that use bacteria to turn the energy stored in chemical bonds into electrical current that can be used without the need for combustion [9]. Although the energy produced is not yet practical on a scale larger than simple demonstrations, a thorough understanding of how bioenergy works and how it could one day be integrated into our energy generation systems is helpful.

1.2 Problem Statement

The new source energy needs to be developed to support the Malaysia's energy consumption. Focus on renewable energy is the alternative way to solve the problem. The benefit of renewable energy is that it is safe, plentiful and clean to use in comparison with fossil fuels. Renewable energy provides the basis for independence from energy sources. The development of renewable energy resources enables countries to work towards energy independence with a diversified access portfolio. Renewable energy is stable even more importantly. When renewables generate energy, the power generated is stable and usable, just like any other "traditional " form of power. It is a reliable resource if it is supported by an infrastructure. Jobs are also created in the sector and at the same time stability is created in the local economic sectors.

Although there are many advantages on the renewable energy, it also has its own disadvantages. Not every form of renewable energy is commercially viable, and one of the disadvantages of renewable energy. A further disadvantage of renewable sources of energy is that many forms of renewable energy require storage. A home or business is connected to a local distribution grid with traditional power resources so that it can be accessed 24/7. Backup and storage resources must be included in the energy generation opportunity when using a renewable energy resource. At night, sunlight doesn't happen. Wind speeds don't always match. The required storage capacity can drive the cost of a new renewable energy system beyond the average person or community.

Waste water has a limitless supply because it is generated from residential, commercial and industrial sources. In Malaysia, the disposal of municipal solid wastes is one of the most critical problems. Waste generation is on the increasing trend due to exponentially increasing population growth. In Melaka state alone, there are landfills that are full of solid wastes. It is very important for these issues to be reduced or fix in order to maintain a stable economic growth and prevent any health problems.

Rather than wasting these materials, more research is needed to further develop the potential of the materials. These solid waste and high organic wastewater stand to be a larger source of usable energy. However, this chemical energy can only be used efficiently in few systems. As such, the biological treatment processes of bio-hydrogen fermentation in dark and acidic conditions, can process complex organic substrates into a simpler, more homogenous mixture of Fatty acids like acetic acid and butyric acid are short-chain.

1.3 Objectives

The objectives of the research are described as follows:

i) To study and understand the MFC concept for the wastewater electricity harvest component.

ii) To develop an effective MFC system model using double chamber model.

iii) To obtain the maximum amount of power density production by evaluating the performance of double chamber MFC based on different types of wastewater, different thickness of anode and distance of electrode

1.4 Scope of Study

The main objective of this project is to develop wastewater energy using a MFC or biological fuel cell. A systematic approach of MFC is developed to explore the initiative of generated energy from waste water using a double-chamber model. Therefore, this project will focus on the making of MFC and increase it performances based on different types of waste water, varies the distance of electrode and the thickness of anodes. Types of waste water used are fertilizer water, lake water and soil water. The entire of the experiment will used copper electrode as an anode. The distance of electrode use are 25cm and 15cm. Lastly, the thickness of anode used in this experiment are 0.2cm and 0.6cm.

1.5 Summary

This thesis consists of five chapters, which organized as follows:

Chapter 1, which is current chapter, highlights the research background, problem statement, objective and scope for this research. **Chapter 2** provides the literature review of this project. This chapter will highlight all the theories and the overview of the MFC and how it can generate energy from waste water. This section also includes the research study. **Chapter 3** describes the development of the proposed generate energy from waste water, where it's covered the methodology of the MFC that has been applied for generate energy from waste water. **Chapter 4** presents the analysis of the result obtains from the development of the generated power sources from waste water. The obtain result of the energy produce from different type of solution and material of the MFC are then compared and analyzed. Finally, **Chapter 5** concludes on the important achievement of the studies and investigates the scope of the research carried out and reported in the thesis. At the end, some possible directions are highlighted for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the use of MFC to design the MFCs with certain systems and designs to help users and retailers. All the technologies like anode, cathode, microorganism, stability and power generator are also elaborate.

2.2 Microbial Fuel Cell

A MFC is a device that converts energy into electrical energy through the actions of microorganisms. MFCs are built using a bio anode and/or bio cathode. Most MFCs are separated by a proton exchange membrane (PEM), also known as a salt bridge, to separate anode compartments (where oxidation occurs) and cathode compartments (where reduction occurs). MFC works only if the microbes are kept alive. The wide range of "fuel "which can be used to generate electricity is one of the advantages of MFC. MFC applications such as power generation, bio-sensor, education and wastewater treatment have been numerous. MFCs are attractive for power generation applications that require only low power, but where replacement batteries, such as wireless sensor networks, can be impractical. Power plants can be built on aquatic plants like algae.

The MFC system can share its electricity lines if it is located next to an existing power system. Wastewater is commonly assessed for its biochemical oxygen demand (BOD) values for biosensors. A MFC BOD sensor can provide BOD values in real time. Oxygen and nitrate are electron acceptors preferred over the electrode, which reduces current MFC generation. For education, MFC based on soil serve as educational tools covering several scientific disciplines (microbiology, geochemistry, electrical engineering, etc.) and it can be made using commonly available materials, such as refrigerator soils and items. Finally, MFCs are used in water treatment to harvest energy using anaerobic digestion for waste water treatment. Pathogens can also be reduced through the process. It does, however, require temperatures above 30 C and requires an additional step to convert biogas into electricity.

2.3 Effect of Anode in Microbial Fuel Cell

The anode material and its configuration are an important parameter in a MFC because they influence the development of the microbial community involved in electrochemical bio-reactions. In the anode chamber, microorganisms play important roles and generate electrons. These electrons are used to reduce the cathode electron acceptors once they have passed through external circuits. In order to complete the circuit produced by the protons, the exchange membrane (PEM) from the anode to the cathode must also be bored. It follows logically from what has been said that this process leads to contemporary electricity and the removal of organic waste.

As mentioned above, the anode compartment of Anaerobic is one of the main parts of MFCs. The anode chamber contains all the essential conditions for the degradation of biomass. This compartment has a substratum, a mediator (optional), a microorganism and anode electrode as an electron. Changing the anode electrode may help to promote the performance of MFCs. In this regard, several researchers have recently begun to modify anode using different nanotechnology techniques that make electron transfer easier.

Moreover, for enhancing the power density and enlarging the capability of electron accepting heterogeneous fabrication methods and modification manners involving nanomaterials have been tried.

2.4 Effect of Cathode in Microbial Fuel Cell

Cathode performance is considered the main limitation. The design of a cathode is an immense challenge to make an MFC scalable. However, the cathode surface has insignificant effects on power output and can improve cathode efficiency with high surface materials or granular materials (e.g. Graphite). In contrast, one of the major challenges in the configuration of MFCs is to identify materials that maximize power generation and columbic efficiency while minimizing costs. Some of used materials in cathode are: carbon paper, carbon felt, carbon brush, carbon fiber, graphite of various type, Pt (Pt is commonly used as cathode catalyst, while alternative polymer binders have also been assayed, such as perfluorosulfonic acid (Nafion), Cu, Cu–Au, tungsten carbide, granular graphite (reported as excellent material), reticulated vitreous carbon (RVC). The key difference in the use of these materials for cathode is the requirement for catalysts

2.5 Microorganism in Development of Microbial Fuel Cell

MFC uses an active micro-organism as a biocatalyst in an anaerobic anode compartment to produce bioelectricity. There are two categories of microbes that can be used in MFC, microbes that can directly transmit electrons to anode using anode as terminal electron acceptors and microbes that transmit electrons to anode using mediators.

Mixed microbial culture is usually used for the anaerobic digestion of the substratum, as a complex mixed culture allows the wide use of the substratum. However, there are certain regular designs of MFCs that explore the metabolic tendency of single microbial species to generate power. Rich sources of organic components (sea sediment, soil, wastewater, fresh water sediment and activated sludge) are a rich source of microbes used in the catalytic unit of MFCs. Bacteria used with or without mediators in MFCs have been extensively investigated and investigated. Metal reduction and anodophilic microorganisms offer better opportunities for the operation of an MFC without any mediator.

2.6 Enhanced Stability and Power Generation by Microbial Fuel Cell

The major cause of deformation and damage to the cathode is the large difference between water and air pressure in the microbial fuel cells. To avoid deformation of the cathode, high porosity plastic mesh spacers have been proposed that can fit between adjacent cathodes and provide structural support while allowing passive air flow between the electrodes [10]. However, due to the lack of sufficient air flow, the use of plastic mesh spacers was found to inhibit power production [11]. In a larger MFC (200cm^2 effective cathode area), rigid wire spacers with a higher porosity and excellent mechanical strength were found to produce much better performance. However, larger reactors needed to further scale these systems could have cathode areas of 1 m^2, which would be even more challenging to allow air flow while preventing cathodic deformation due to increased water pressure.

Cathode performance usually limits the production of power by MFCs. Improvements in cathode materials and designs have led to significant increases in power density in MFCs. Many materials, including carbon tissue and carbon mesh with platinum catalysts, have been used to make cathodes. Stainless steel mesh and carbon catalysts activated and nickel foam carbon cathodes. Of these materials, the greatest promise for economic cathodic construction and long - term performance is that they are made from activated carbon with current collectors in stainless steel. One challenge to build larger cathodes using these materials is to maintain efficiency with higher hydraulic pressures resulting in larger systems. Hydraulic pressure can deform the hydrophobic diffusion layer and lead to water leakage, cathode flooding and structural deformation of the cathode.

2.7 Review of Microbial Fuel Cell

This section describes a review of various materials that can be implemented into the MFC. Various purposes such as increase the power produce and reduce the financial for creating the component are also reviewed in the subsequent sections.

2.7.1 Review of Microbial Fuel Cell Scheme Based on Material Plate

The project of Performance of Membrane-Less Microbial Fuel Cells Treating Waste Water and Effect of Electrode Distance and Area on Electricity Production by MM Ghangrekar and V.B Shinde (14 November 2006) used different electrode distance and different surface area for their MFC. For different electrode distance, both anode and cathode are at the same size which is 210.64 cm^2. The power produced for 20cm, 24cm and 28cm distance of electrode is 10.9mW/m^2, 8.6mW/m^2 and 7.4mW/m^2. For different surface area of anode which is 70.21cm^2, 140.43cm^2, 210.64cm^2, the surface area of cathode is constant that is 210.64cm^2. The power produced for 70.21cm^2, 140.43cm^2 and 210.64cm^2 surface area of anode is 10.13mW/m^2, 6.45mW/m^2 and 4.66mW/m^2. The design of MFC used for this project is illustrated in Figure 2.1.

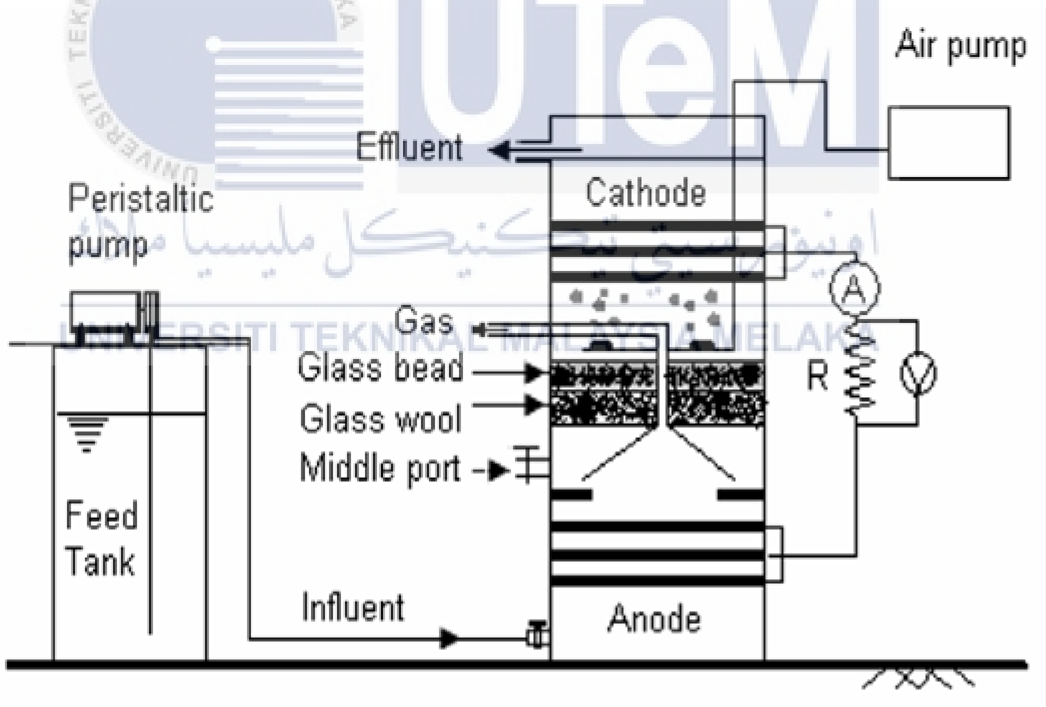


Figure 2.1: The design of Microbial Fuel Cell used for this project

Microbial Fuel Cells for Wastewater Treatment by Peter Aelterman, Korneal Rabaey, Peter Clauwaert and Willy Verstraete (February 2006) using same type of plate which is graphite rod. Both anode and cathode are at the same size which is 5mm diameter. They use different type of wastewater which is domestic wastewater, hospital wastewater and influent from anaerobic digester. The power density generated varies with the different type of wastewater. The power produced for domestic wastewater, hospital wastewater and influent from anaerobic digester is 11.7W/m^3, 14±1W/m^3 and 58±8W/m^3. The principle of MFC used for this project is shown in Figure 2.2.

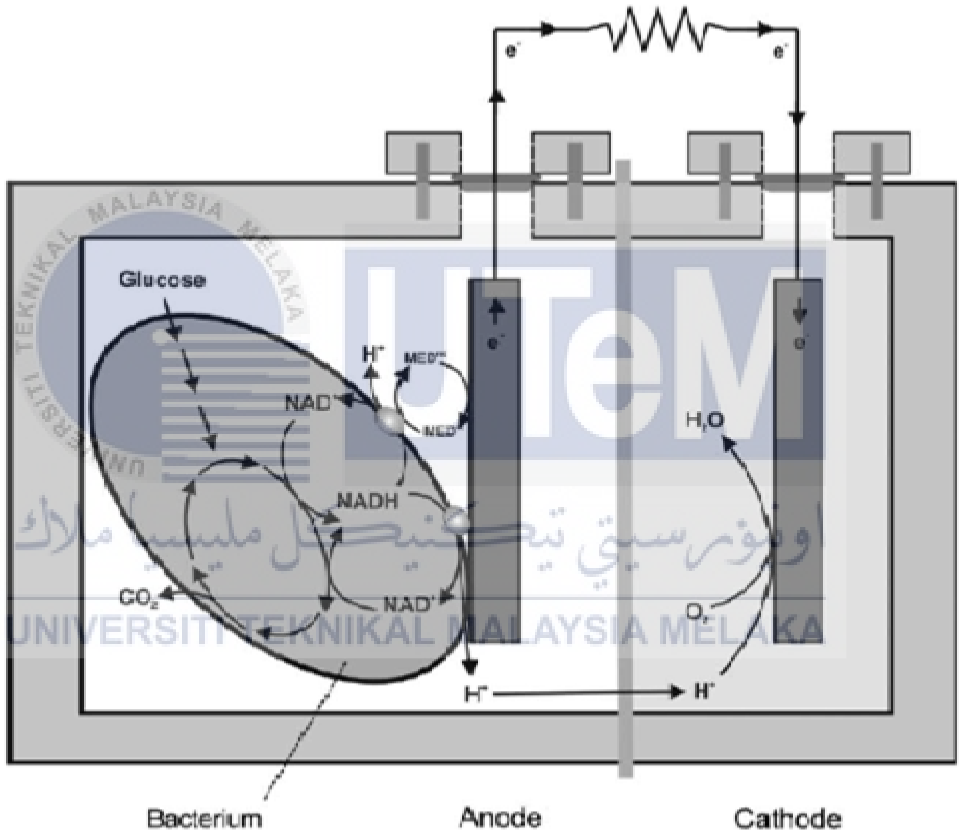


Figure 2.2: The Principle of MFC used for this project [12]

The project of Increased Performance of Single-Chamber Microbial Fuel Cells using an Improved Cathode Structure by Shaoan Cheng, Hong Liu and Bruce E. Logan (11 January 2006) used a wet-proofed carbon cloth with a different structure with diffusion layer (DL) and without diffusion layer. The material used for the anode is non-wet proved carbon cloth. Both anode and cathode are at the same size which is $7cm^2$. The power density produced for cathode with diffusion layer is $766mW/m^2$ while cathode without diffusion layer produced power density of $538mW/m^2$. The single schematic MFC showing relative location of DL and catalytic layers on the cathode for this project is illustrated in Figure 2.3.

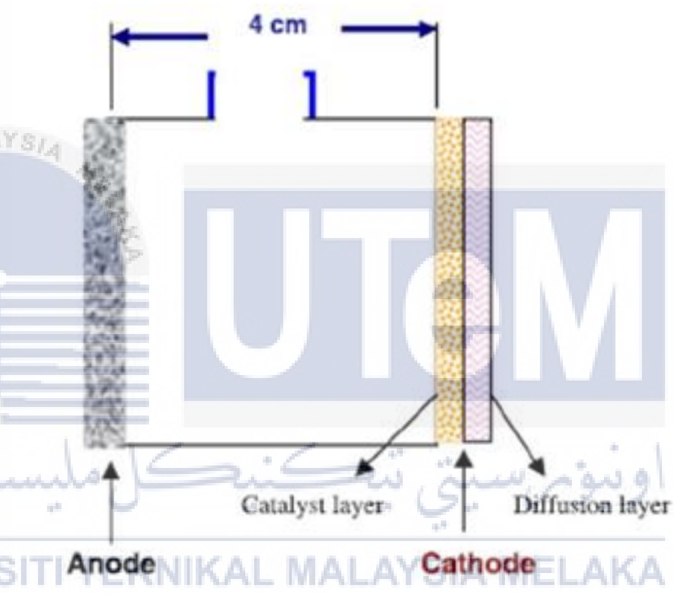


Figure 2.3: Single chamber schematics MFC showing relative location of DL and catalytic layers on the cathode for this project [13]

Table 2.1: Summary of Review

ARTICLE	MFC USED	MATERIAL FOR PLATE		SIZE OF PLATE	LIMITATION	POWER DENSITY PRODUCED
		ANODE	CATHODE			
[11]	Membrane-less MFC	graphite rod	graphite rod	For Electrode Distance: • anode: $210.64cm^2$ • cathode: $210.64cm^2$ For Different Surface Area of Anode: • anode: $70.21cm^2$, $140.43cm^2$, $210.64cm^2$ • cathode: $210.64cm^2$	• expensive due to use of many electrodes at anode • need a bigger space to fit the 3 electrode	For electrode distance: • for 20cm: $10.9mW/m^2$ • for 24 cm: $8.6mW/m^2$ • for 28cm: $7.4mW/m^2$ For different surface area of anode • for $70.21cm^2$: $10.13mW/m^2$ • for $140.43cm^2$: $6.45mW/m^2$ • for $210.64cm^2$: $4.66mW/m^2$

ARTICLE	MFC USED	MATERIAL FOR PLATE		SIZE OF PLATE	LIMITATION	POWER DENSITY PRODUCED
		ANODE	CATHODE			
[12]	• domestic wastewater • hospital wastewater • influent from anaerobic digester	graphite rod	graphite rod	• anode: 5mm diameter • cathode: 5mm diameter	• Several obstacles need to be addressed, such as the need to implement sustainable cathodes, the fate of certain organics in sewage and the elimination of residual nutrients.	• domestic wastewater: $11.7W/m^3$ • hospital wastewater: $14\pm1W/m^3$ • influent from anaerobic digester: $58\pm8W/m^3$
[13]	Domestic waste water Pennysylvania State University Waste Water Treatment plant	non-wet proved carbon cloth	wet-proofed carbon cloth (with diffusion layer and without diffusion layer)	• anode: $7cm^2$ • cathode: $7cm^2$	• Power increase can partially offset the increased oxygen flow, as higher power density reduces the overall time required to degrade the substrate completely	• with DL: $766mW/m^2$ • without DL: $538mW/m^2$

2.8 Summary

The evaluation of several projects is important for the development of projects. MFC is a project that combines mechanism, hardware development and software development to generate energy from waste water.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the development and implementation of propose generating electricity via three different type of wastewater. Section 3.2 explains the tools and various methods used in proposed method for this project. For Section 3.3, it describes the general materials and appliances used in MFC to prepare the cell and the method used to understand the principle of electricity generation using the principle of transferring electrons obtained from microorganisms in the metabolism of organic matter. MFC is a devise used to collect electrons from wastewater and transfer the electron from anode to cathode through a wire. It starts from understanding the basic concept of how the MFC works to the final stage of implementation hardware. The applications of MFC for this project are presented in this section.

3.2 Tools and Methods Used in Proposed Method

This section describes the analysis of various tools and procedures that have been used in application of generated electricity from wastewater using the MFC. Tool and method that applied to develop for generated energy from wastewater is double-chamber MFC device. Section 3.2.1 explains about the main theory of MFC. MFC was explained in this section and how it prepared. Meanwhile, Section 3.2.2 illustrates the development of the project flow for 4 different experiment tests.

3.2.1 Microbial Fuel Cell (MFC) Scheme

This section describes the overview of numerals tools and procedures that have been applied in implementation of MFC for generating electricity. The focuses for MFC in this project are the different type of water used in anaerobic chamber, the type of metal use for the anode and cathode for the harvest the electrons, the distance of electrode and thickness of electrode in both anaerobic and aerobic chamber. To know the best condition to enhance the performance of MFC is by doing variable experiment. The result of these experiments then evaluated and compared. First of all, to create the experiment, the basic theory must be discerned. MFC consist of two types: Need small energy to produce new element or generated energy. For this project, it focuses on MFC that generated electricity.

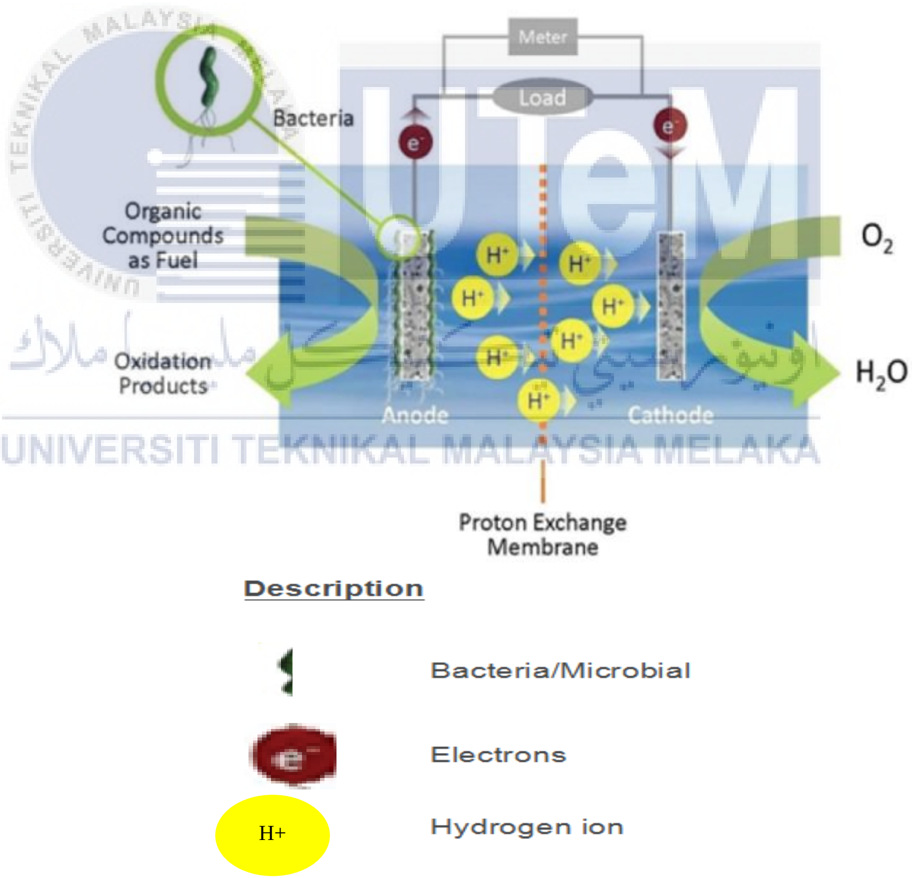


Figure 3.1: Concept of Microbial Fuel Cell

As shown in Figure 3.1, MFC consists of two chambers which are aerobic chamber and anaerobic chamber. Aerobic chamber being continuously supply with oxygen while anaerobic chamber being sealed to avoid oxygen. Anode electrode is place at anaerobic chamber which contain wastewater while cathode electrode is place at aerobic chamber that contain distilled water. The bacteria or microbes inside the wastewater attached to anode metal. These bacteria slowly decomposed organic matter and free electron, hydrogen and carbon dioxide. Equation (3.1) summarizes the general reaction in the anode chamber [10].

Active Microorganism

$$\text{Biodegradable Organic} \longrightarrow Co2 + H^{+} + e^{-} \qquad (3.1)$$

Anaerobic environment

The electrons produced by the bacteria's decomposition attracted to the anode electrode, sometimes supported by a mediator molecule. It then flows into the cathode from the anode, through a wire. These electrons that need to harvest to generate electricity. For the hydrogen ions, it will flow through the exchange membrane to the aerobic chamber. This process is driven by the electro-chemical gradient resulting from the high concentration of Hydrogen ions near the anode. For hydrogen ions it flows into the aerobic chamber via the exchange membrane. The electrochemical gradient that results from the high concentration of hydrogen ions near the anode drives this process. The cathode electrons combine pure H2O or pure water with dissolved oxygen in the aerobic chamber and hydrogen ions. Equation (3.2) summarizes the general reaction in the cathode chamber.

$$2O2 + 8H^{+} + 8e^{-} \longrightarrow 4H_2O \qquad (3.2)$$

Aerobic environment

The power density and the current density are determined in this project to understand the relationship between the voltage generations. Power density is the amount of power per unit area. The equation for the power density is summarized to equation (3.3) and equation (3.4).

$$P_D = \frac{P_{out}}{A} = \frac{V_{out} I_{out}}{A} \tag{3.3}$$

$$I_d = \frac{I_{out}}{A} \tag{3.4}$$

Where Power Density (P_D) represents the power density in watt/m^2, P_{out} represent the power produce by the MFC in watt (W) and "A" represents the electrode surface area in m^2. V_{out} represent the voltage output in volt (V), I_{out} represents the current output in ampere (A), while I_d represents the current density in ampere/m^2.

3.2.2 Process Involve in the System

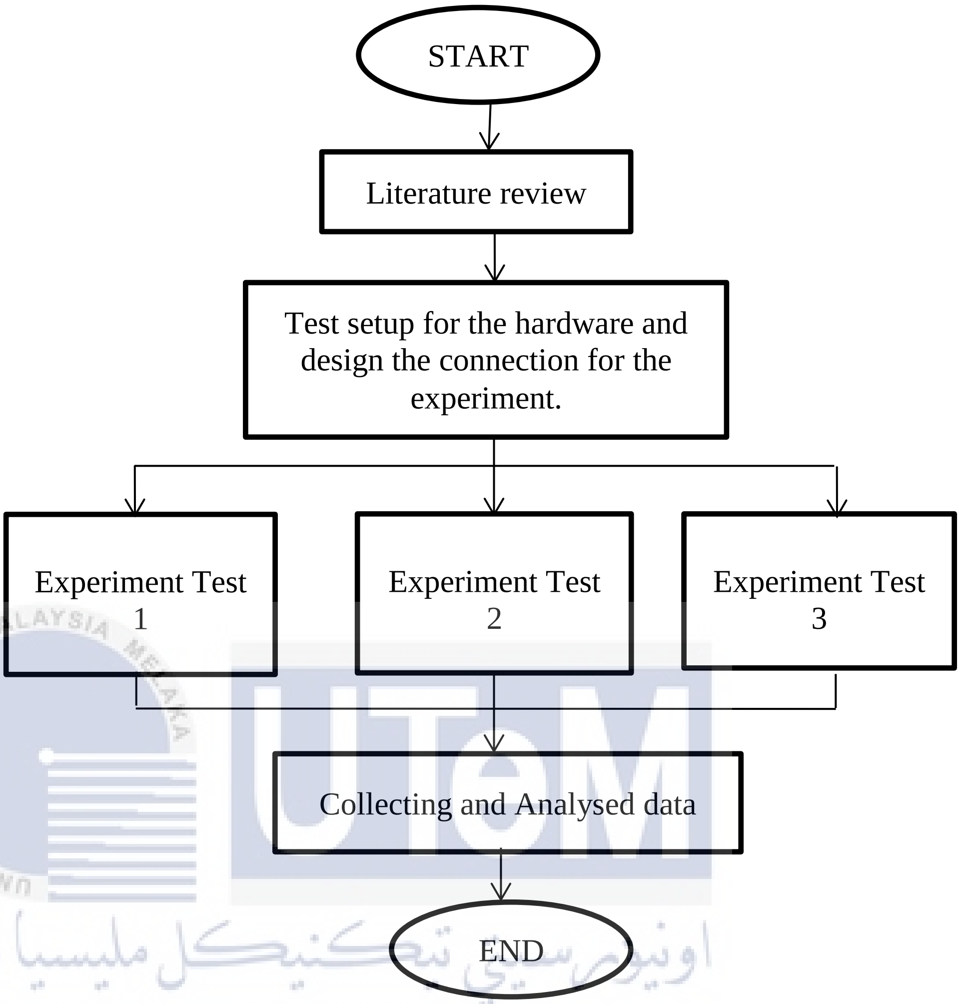


Figure 3.2: Process involve in the system

Figure 3.2 illustrates the process involve in the system for this final year project. This project is started by making the literature review from the article about MFC scheme based on material plate. After that, the hardware and connected design is set up based on the selected design for MFC which is double-chamber. This experiment is divided into three type of experiment test. Experiment Test 1 is about the different types of wastewater used to determine the performance of MFC which are fertilizer water, soil water and lake water. Experiment 2 uses different thickness of anode, which is 0.6cm. Experiment 3 is using a different distance of electrode which is 15cm.

3.3 General Material and Apparatus

This section describes the overview of numeral tools, materials and procedure that has been applied in generating electricity from wastewater using the MFC. Several experiments were conducted and evaluated to find the best and suitable ways to generated electricity for this project. The apparatus used in the experiment is shown in Table 3.1. The experiment was set up with chamber containing metal at each chamber act as anode and cathode respectively. These chamber then connected by the pipe as the chemical exchange membrane also known as salt bride for the hydrogen ion to flow through. The anode metal is connected to the cathode metal by crocodile clip with wire for the electrons to flow through. Both anode and cathode have total surface area of 36 cm^2. Each chamber is filling with the 500ml volume of distilled water and wastewater.

Table 3.1: Apparatus used in experiment

Apparatus used in experiment
• Container • PVC pipe with 20mm diameter • Tank connector • Crocodile clip with wire • Copper electrode • 500ml distilled water • 500ml different type of wastewater • Gelatin • Salt

3.3.1 Experiment 1 (Different Types of Water)

These apparatus is being constructed based on several step to create a general set up for the Experiment 1 that uses different types of wastewater. The implementation steps to assemble the Model 1 can be described as follows and in a flowchart shown in Figure 3.4.

Step 1:Making the Proton Exchange Membrane (PEM) or Salt Bridge. Prepare the salt bridge. Heat the gelatin over the stovetop and dissolve the salt as you can. Pour the boiled gelatin and salt mixtures into the holes of the container sides

Step 2:Obtaining culture media (wastewater: i.e. fertilizer water, soil water and lake water). Such a source will probably contain a lot of anaerobic bacteria

Step 3:Constructing the electrodes with original thickness of 0.2cm. Fold copper plate a few times and connect with large clips of paper. The entire electrode surface area is 36cm2. The strip ends with the copper wire and is connected to both electrodes. Insert copper wire on lids into drilled holes.

Step 4:Assembling the reactor part, which is aerobic chamber and anaerobic chamber. Both chambers are connected by the PEM or salt bridge.

Step 5:Operate MFC for 40 days. The resistance of 100Ω is connected between the cathode and anode by crocodile clip.

Step 6: Collect the data from MFC by measuring the voltage across the resistor and calculate the current, power and power density of three different type of wastewater.

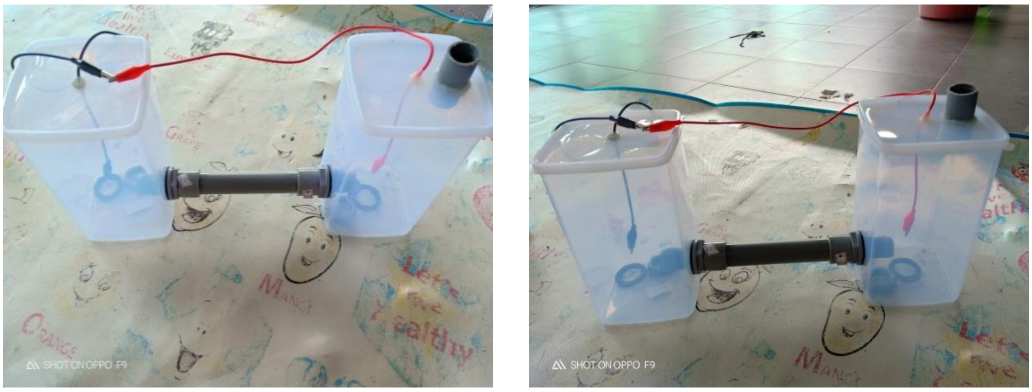


Figure 3.3: Design of Microbial Fuel Cell Model 1

Figure 3.3 shows the design of MFC for Experiment 1 after the implementation steps is completed. Design for the MFC Model 1 is the basic design that will be used in Experiment 2 and Experiment 3. Same design is used for Experiment 2 and Experiment 3 because the variable that will be manipulated in this project is only the anode in the anaerobic chamber and distance of electrode. Figure 3.4 illustrates the process involve in general apparatus prepared for Experiment 1.

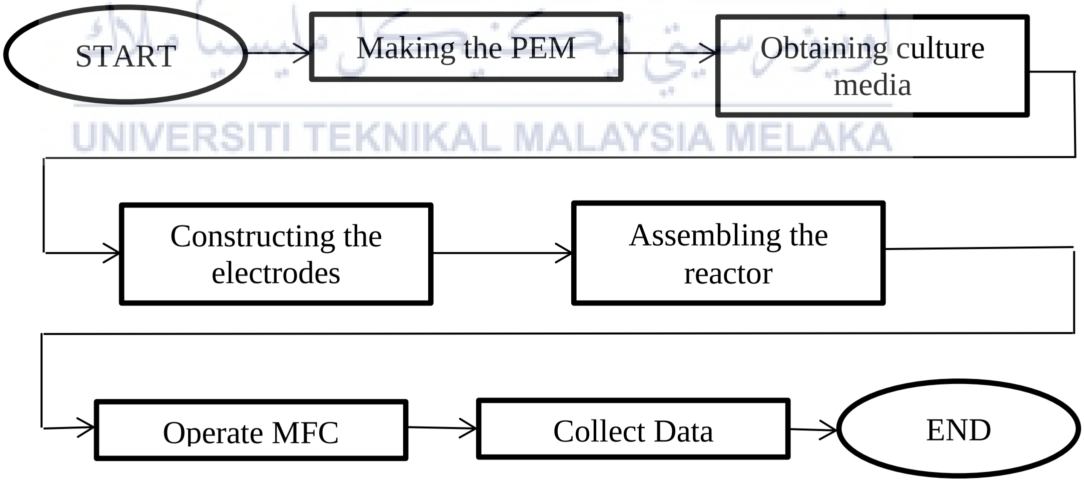


Figure 3.4: Process involve in general appartus prepared for Experiment 1

3.3.2 Experiment 2 (Thickness of Anode)

The apparatus is being constructed based on several step to create a general set up for the Experiments 2. The implementation steps to assemble the Model 2 can be described as follows and process involve in general apparatus prepared for Experiment 2 is illustrates as Figure 3.5.

Step 1:Repeat Steps 1 and Steps 2 of Experiment 1. This is because Experiment 2 uses same preparation of PEM and same culture media, which are fertilizer water, soil water and lake water.

Step 2:Constructing the different thickness of anode. Anodes are prepared with thickness of 0.6cm compared to the original thickness of anode used in Experiment 1 that is 0.2cm. The entire electrode surface area is 36cm2. The strip ends with the crocodile clip with wire and is connected to both electrodes.

Step 3: Steps 4, Step 5 and Step 6 of Experiment 1 is repeated. Assembling reactor part, operate the MFC and collect the data is same for this experiment.

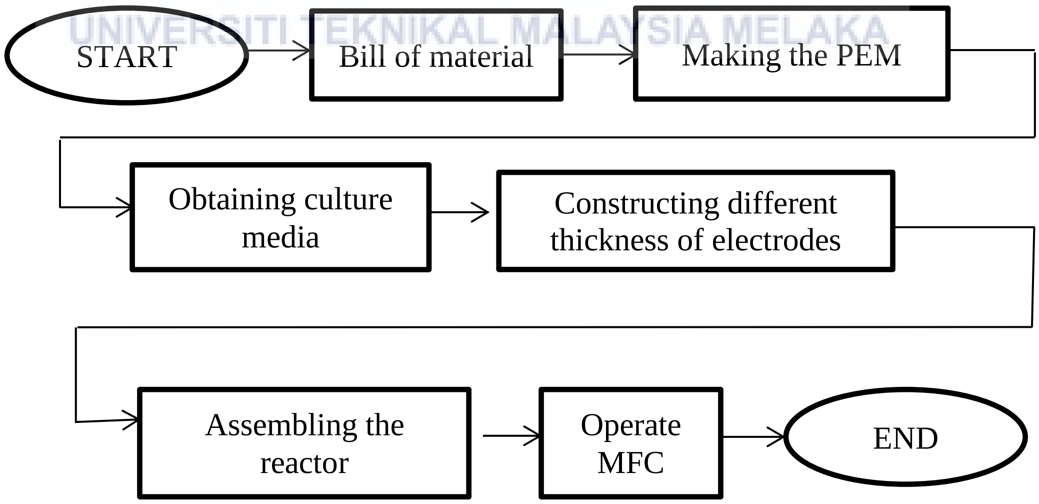


Figure 3.5:Process involve in general apparatus prepared for Experiment 2

3.3.3 Experiment 3 (Distance of Electrode)

These apparatus is being constructed based on several step to create a general set up for the experiments. The implementation steps to assemble the setup can be described as follows and process involves in general apparatus prepared for Experiment 3 is shown in Figure 3.6.

Step 1:Repeat Steps 1 and Steps 2 of Experiment 1. This is because Experiment 2 uses same preparation of PEM and same culture media which are fertilizer water, soil water and lake water.

Step 2:Constructing the different distance of electrode. Another electrodes are prepared with different a distance which is 15cm. The entire electrode surface area is 36cm2. The strip ends with the crocodile clip with wire and is connected to both electrodes.

Step 3: Steps 4, Step 5 and Step 6 of Experiment 1 is repeated. Assembling reactor part, operate the MFC and collect the data is same for this experiment.

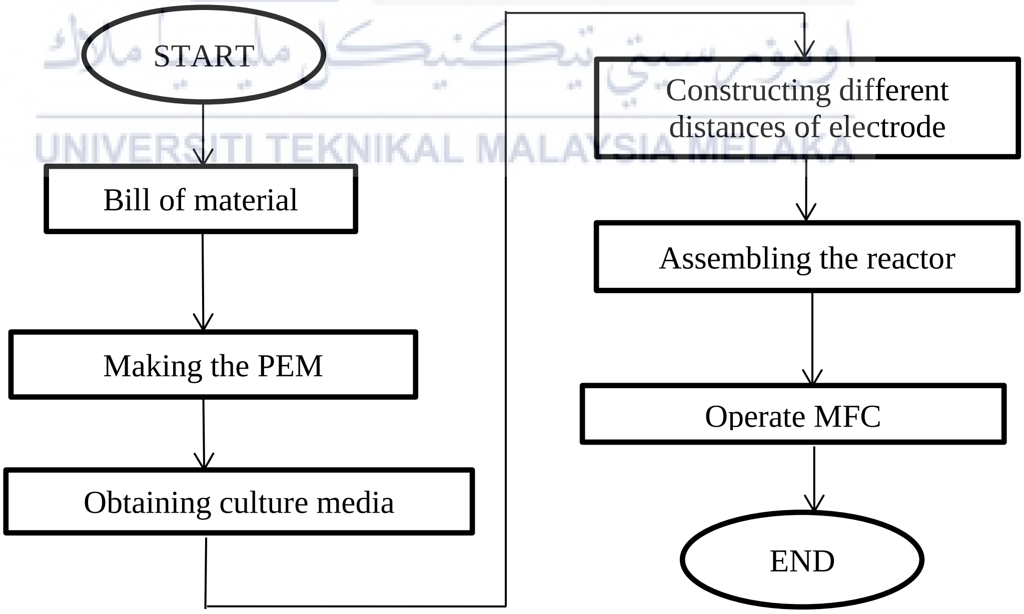


Figure 3.6: Process involve in general apparatus prepared

3.4 Performance Evaluation of Wastewater

This section describes the evaluation for the performance of wastewater based on electrode surface area, thickness of anode and the distance of electrode.

3.4.1 Electrode Surface Area

The measurement for the total surface area of electrode is calculated by adding the surface area for front side and the backside of the copper plate. The height of electrode is 4.5cm and the length is 4cm. The surface area for the front side is 18cm^2. Figure 3.7 shows that both side of the copper plate has the same dimension which make the total surface area for copper plate is 36cm^2.

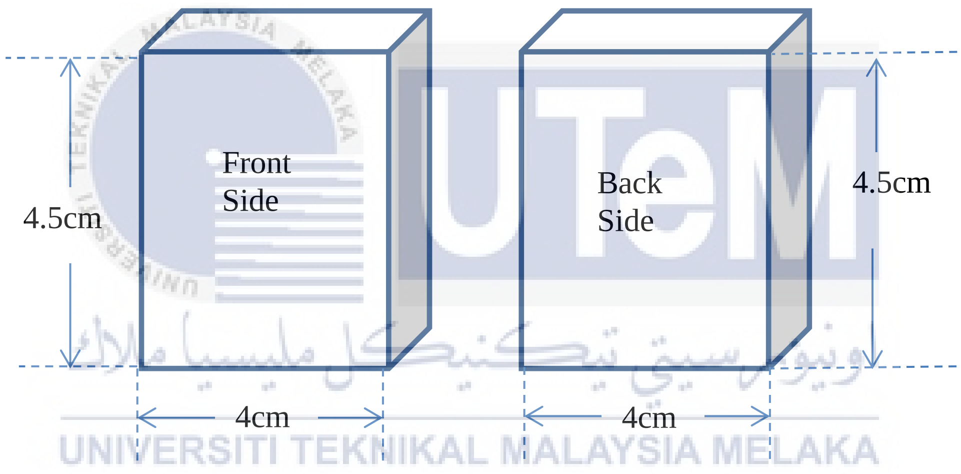


Figure 3.7: Dimension of Copper plate

3.4.2 Thickness of Anode

Different thickness of anode is used in this experiment. For Experiment 1 and 3, the thickness of anode used is 0.2cm. Then, the thickness of anode for Experiment 2 is 0.6cm by stacking the 3 layer of 0.2cm thickness of copper plate. The thickness of anode for all experiments is illustrated in Figure 3.8.

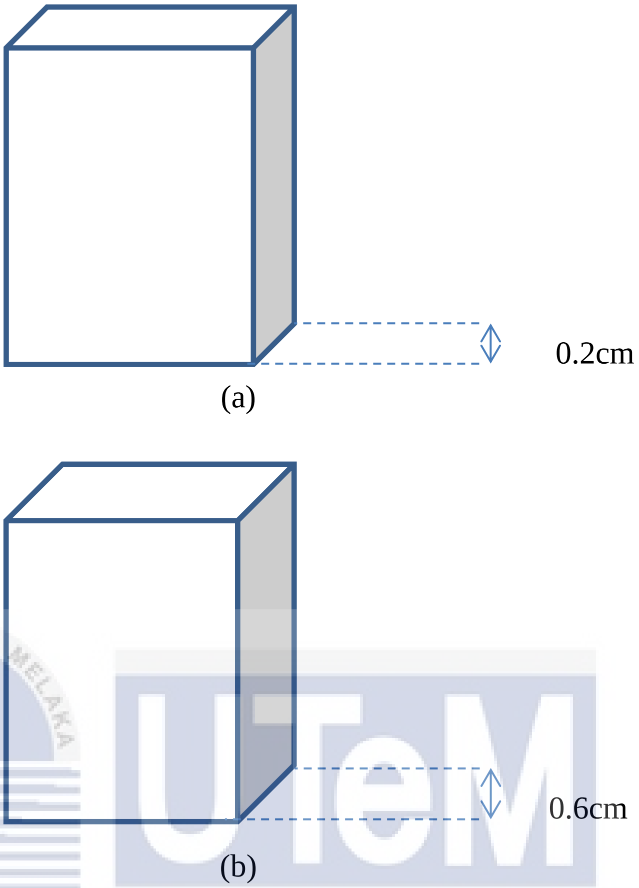


Figure 3.8: Thickness of Anode based on: (a) Experiment 1 and 3 (0.2cm) and (b) Experiment 2 (0.6cm)

3.4.3 Distance of Electrode

Different distances of electrode are used for this Final Year Project. For Experiment 1 and 2, the distance of electrode used is 25cm while for Experiment 3 is 15cm. Distance of electrode is being measured by setting the distance between anode in anaerobic chamber and cathode in aerobic chamber, Distance of electrode for Experiment 1, 2 and 3 is shown in Figure 3.9.

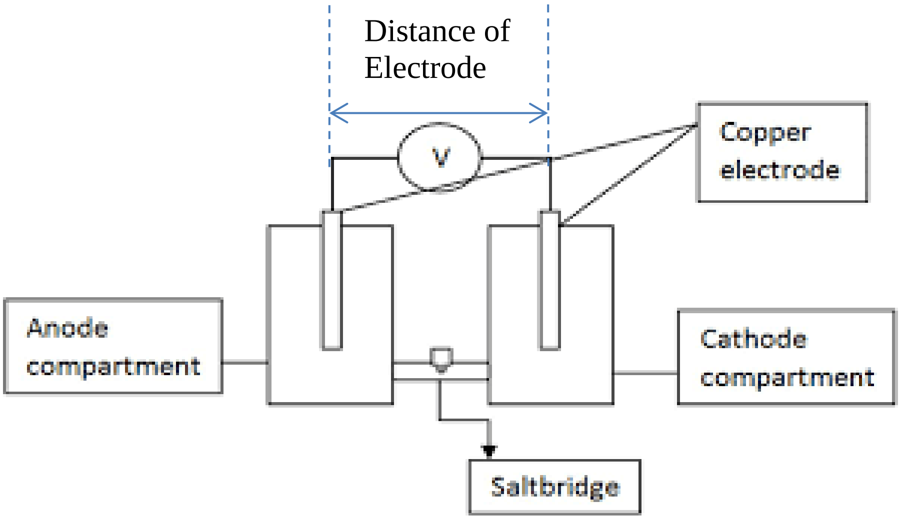


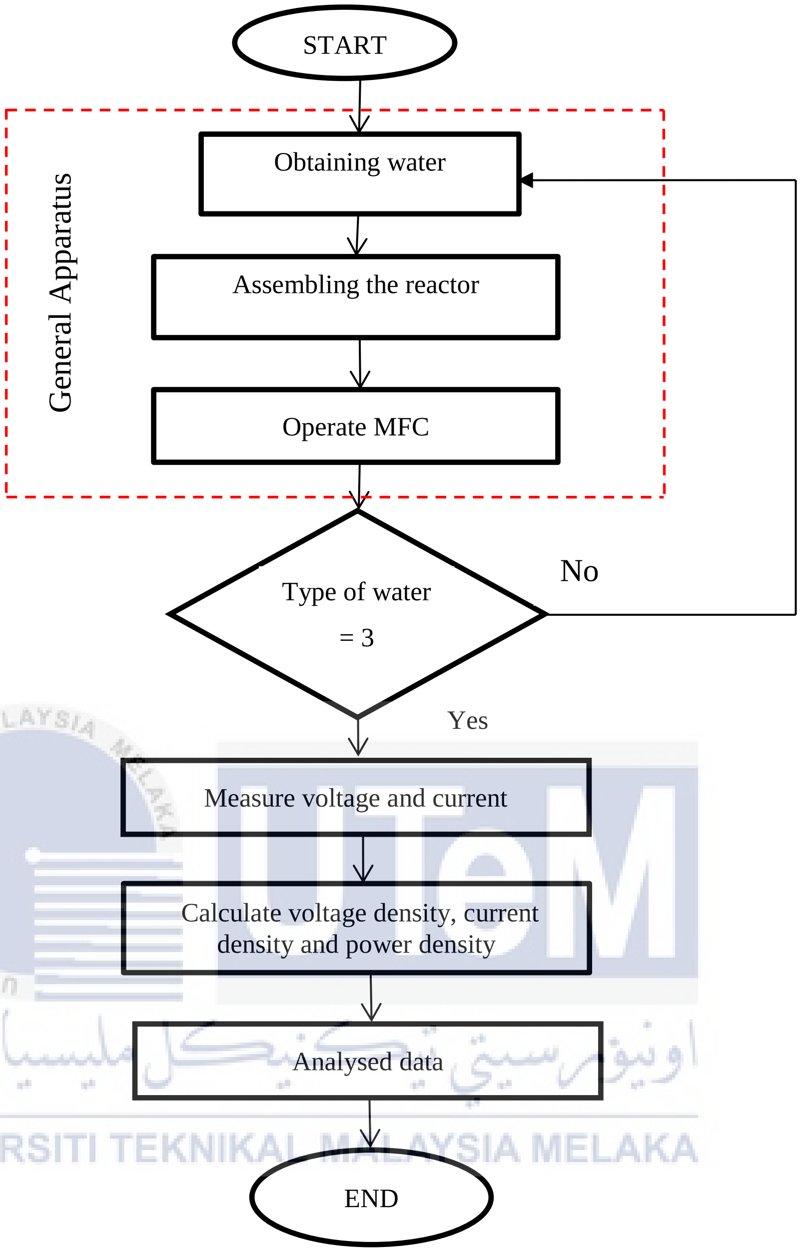
Figure 3.9: Distance of electrode for 15cm and 25cm

3.5 Performance of Wastewater

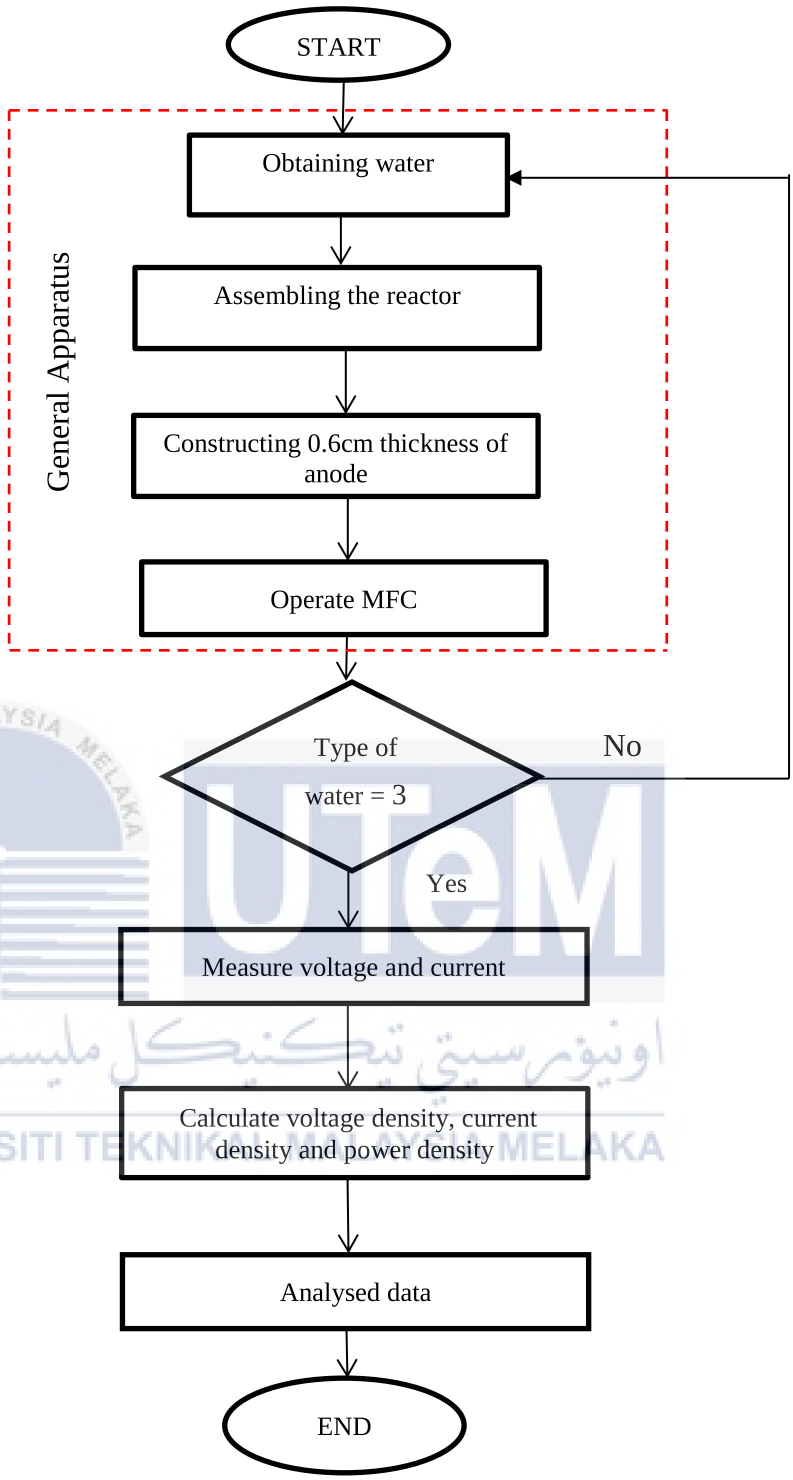
The performance of the wastewater is tested using three main experiments labelled as Experiment 1, Experiment 2 and Experiment 3, which is different types of water, thickness of anode and distance of electrodes. The three type of wastewater were decided that is:

- The mixture of soil and water
- The mixture of fertilize and water
- Lake/river water

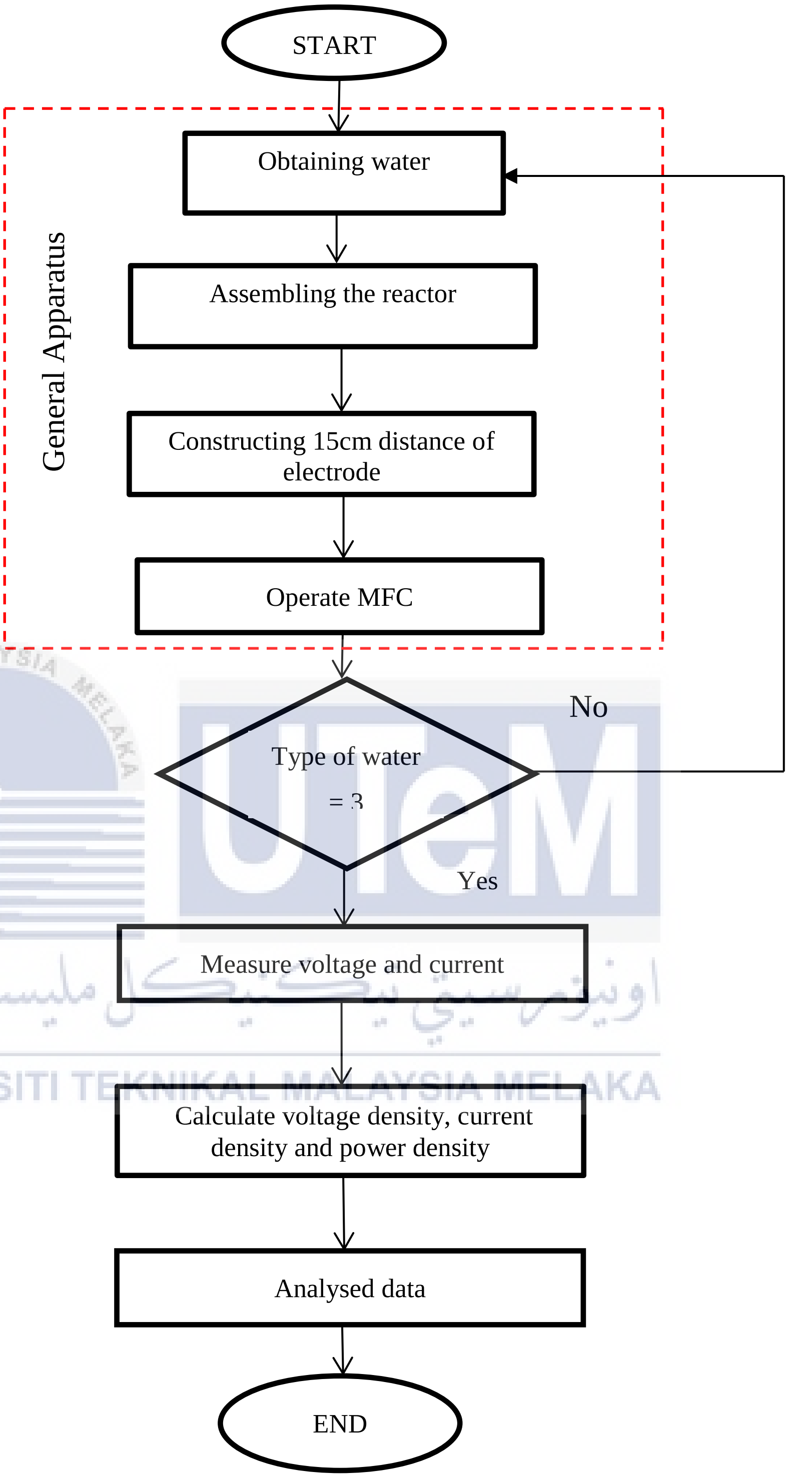
The experiment is done at the same time for each different types of wastewater, where the measurement of voltage and current are recorded every 24 hours within 40 days using multimeter. The resistor connected to the MFC is 100 Ω. Next, the voltage density, current density and power density is calculated. Finally, the data is analyzed by plotting the graph of voltage output, current output, power output and power density output. The flowchart for implementing the MFC based on Experiment 1, 2 and 3 are shown in Figure 3.10.


START
General Apparatus
Obtaining water
Assembling the reactor
Operate MFC
Type of water
= 3
No
Yes
Measure voltage and current
Calculate voltage density, current
density and power density
Analysed data
END

(a)


START
General Apparatus
Obtaining water
Assembling the reactor
Constructing 0.6cm thickness of anode
Operate MFC
Type of water = 3
No
Yes
Measure voltage and current
Calculate voltage density, current density and power density
Analysed data
END

(b)



(c)

Figure 3.10: Implementing the MFC based on: (a) Different types of wastewater, (b) Different thickness of anode and (c) Diferent distance of anode

CHAPTER 4

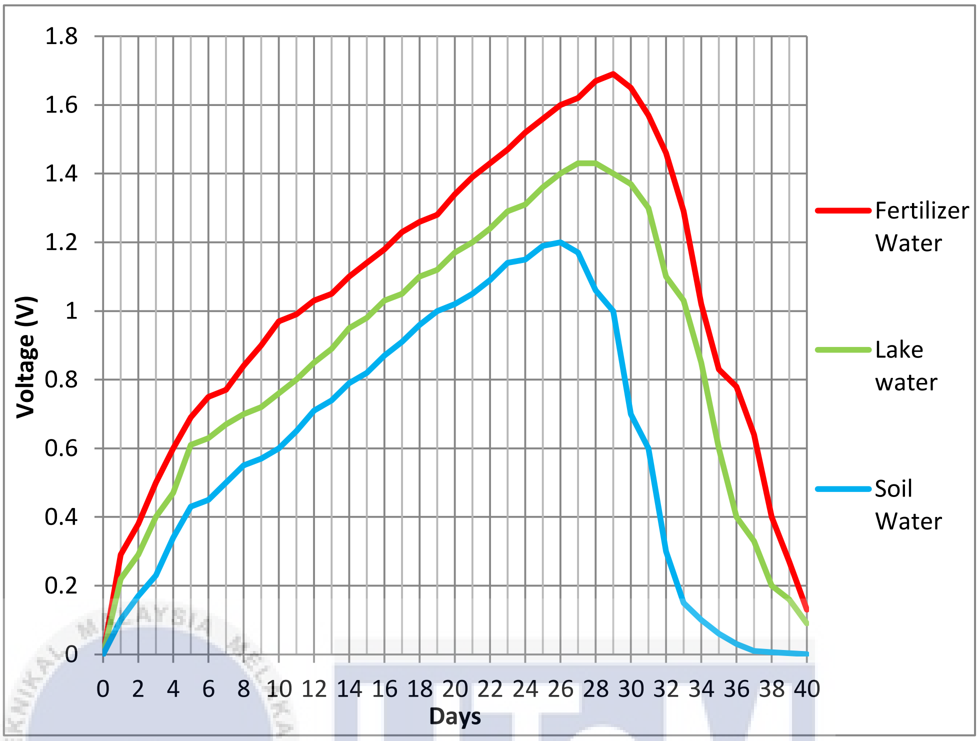
RESULTS AND DISCUSSIONS

4.1 Introduction

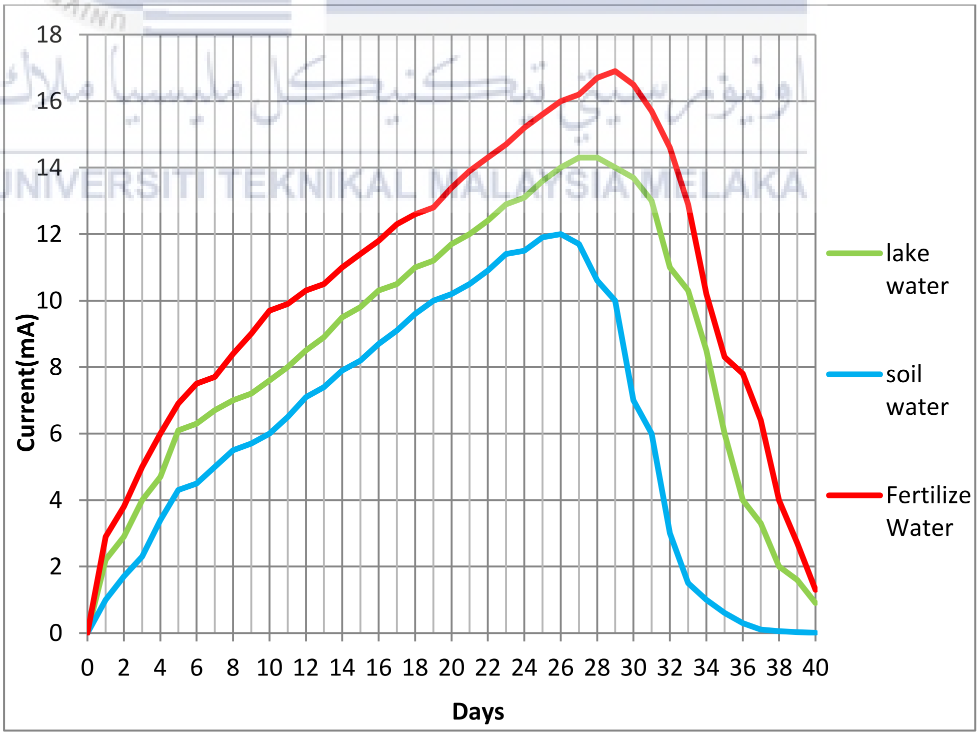
This chapter has implemented the results discussed in Chapter 3 to achieve the aim of this study. The final result shows the data of the voltage (V), current (I) and power density (PD). For this Final Year Project, the experiment focuses on the variable that increases the performance of MFC. The data shows the difference type of wastewater, the distance of electrode and the thickness of anode that can affect the produce of electricity. This data will be collected to determine the effect difference wastewater in MFC, the effect of thickness of anode and distance of electrode and the result was been analyses.

4.2 Performance Result for Different Type of Wastewater

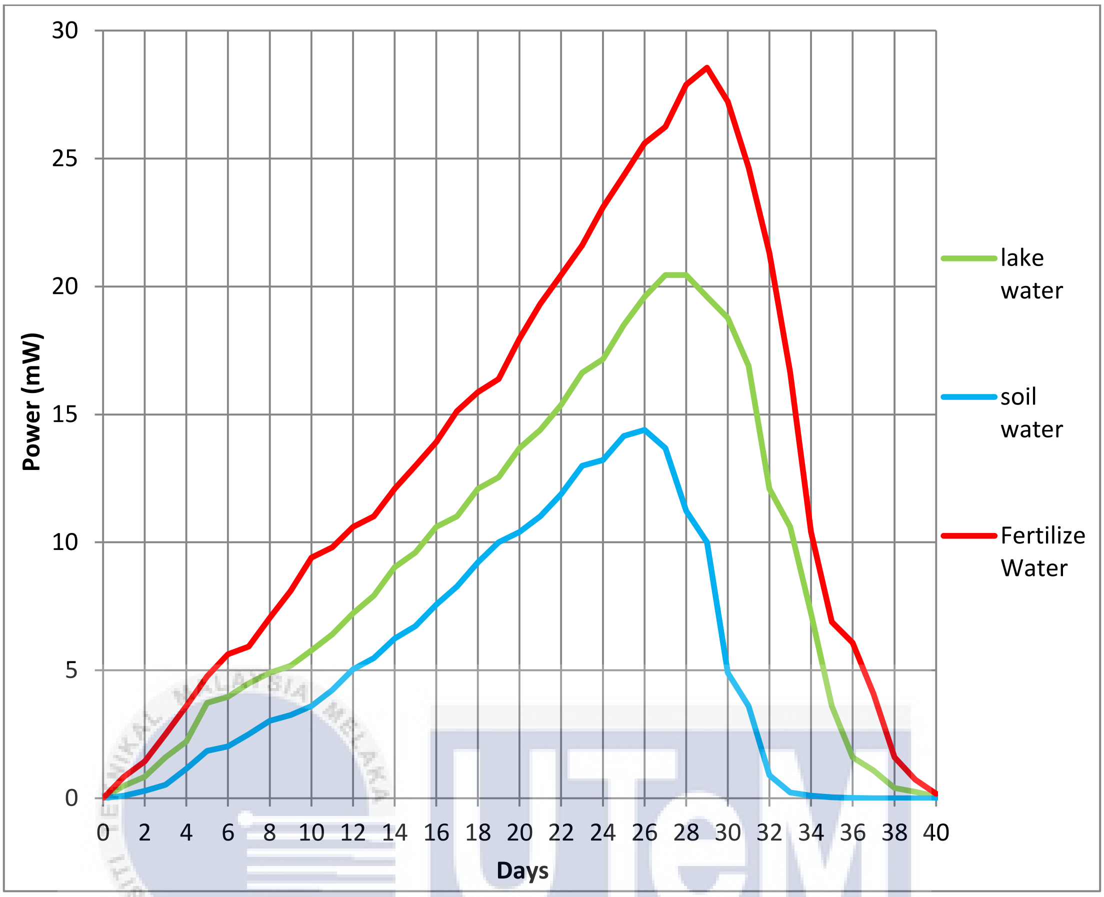
For this experiment, it focuses on the types of wastewater as the variable on the MFC. The types of wastewater used are the combination of water and soil, the lake water and fertilizer water. The electrode used for this experiment was copper electrode for both anode and cathode with a total surface area of $36cm^2$.


Voltage (V)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Days
Fertilizer Water
Lake water
Soil Water

(a)


Current(mA)
18
16
14
12
10
8
6
4
2
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Days
lake water
soil water
Fertilize Water

(b)



(c)

Figure 4.1: Performance of different type of waste water based of: a) Voltage, (b) Current and (c) Power

Figure 4.1 shows that different types of wastewater will produce different voltage, current and power output. It can be seen that fertilizer water produces more voltage and current output compared to soil water and lake water. Moreover, when the current and voltage output increase, the power output also will increase.

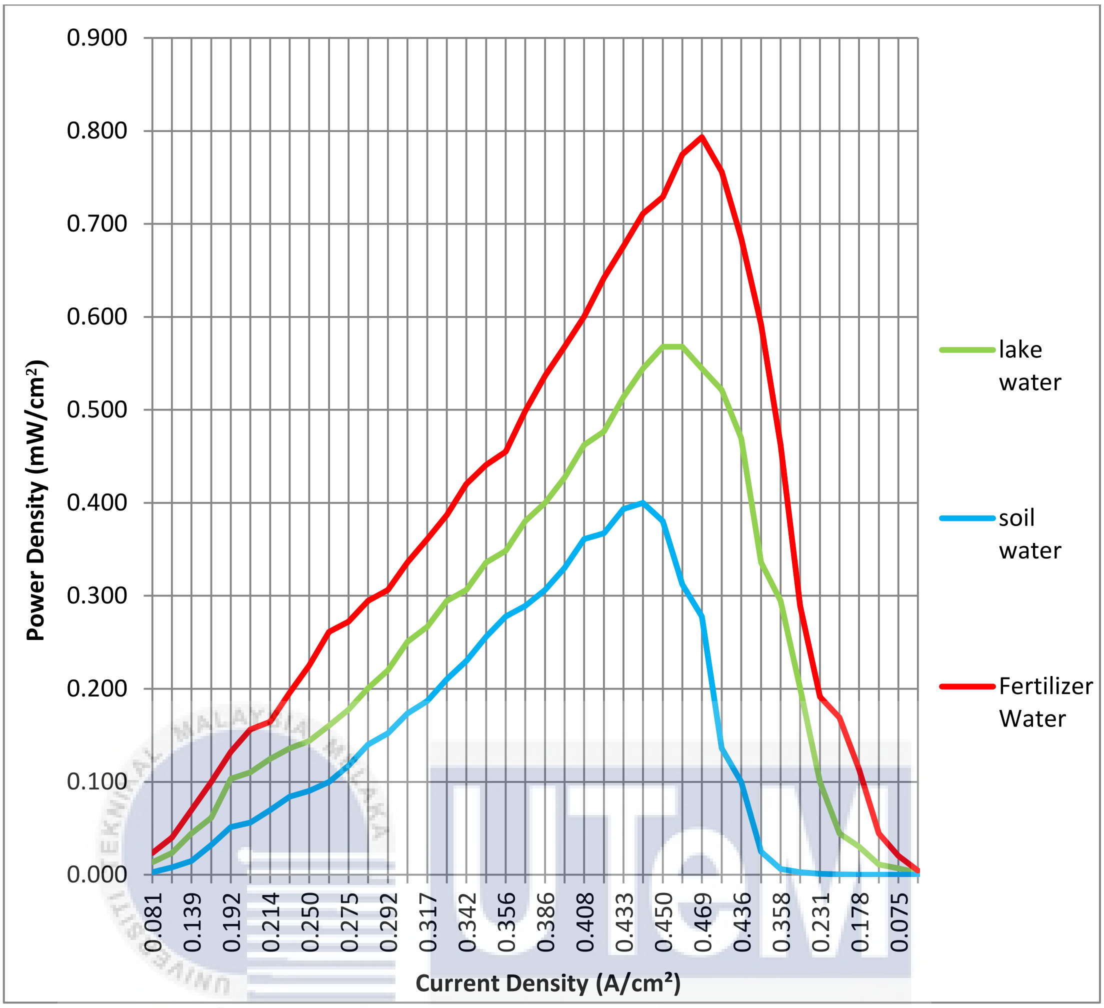


Figure 4.2:Performance of different waste water test

Figure 4.2 plots the comparison of the power density for fertilizer water, soil water and lake water. It can be seen that the power density of the fertilizer water is higher than lake water and soil water. Therefore, the finding prove that the fertilizer water is the most effective type of wastewater in producing voltage compared to soil water and lake water.

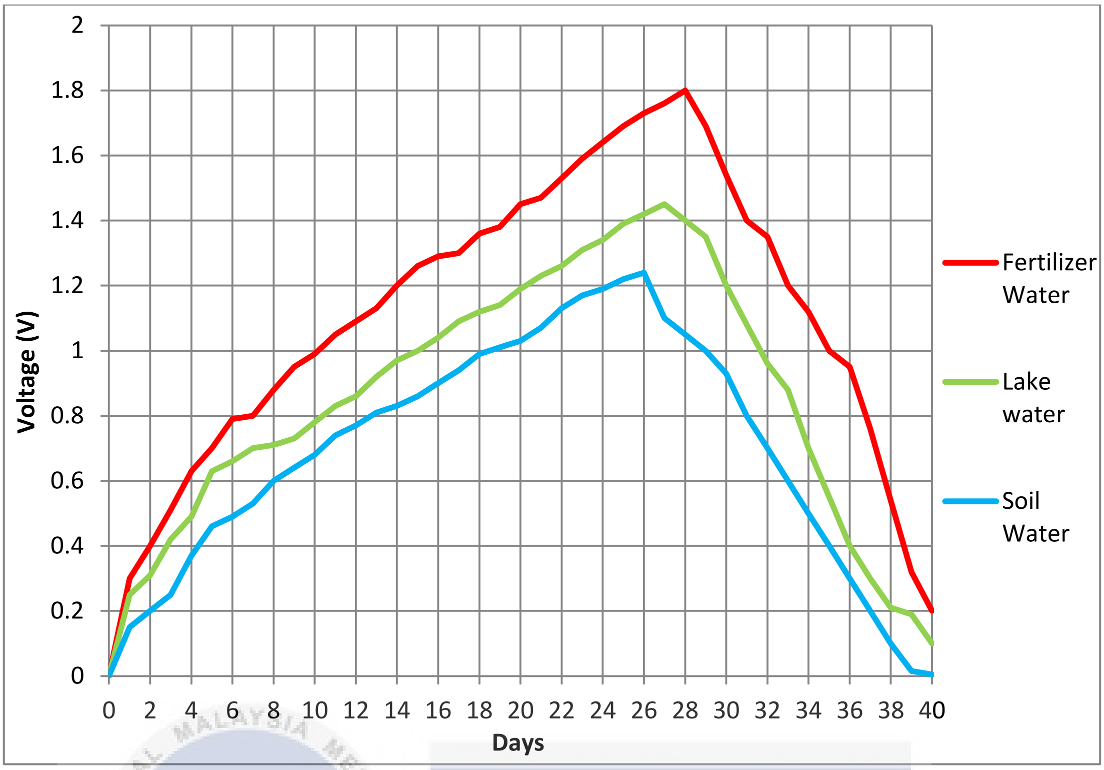
Table 4.1: The Maximum voltage, current, power and power density produced for 3 different type of wastewater

Experiment	P (mW)	V (V)	I (mA)	P_D (mW/cm^2)
Soil Water	14.4	1.2	12	0.400
Lake Water	20.449	1.43	14.3	0.568
Fertilize Water	28.561	1.69	16.9	0.793

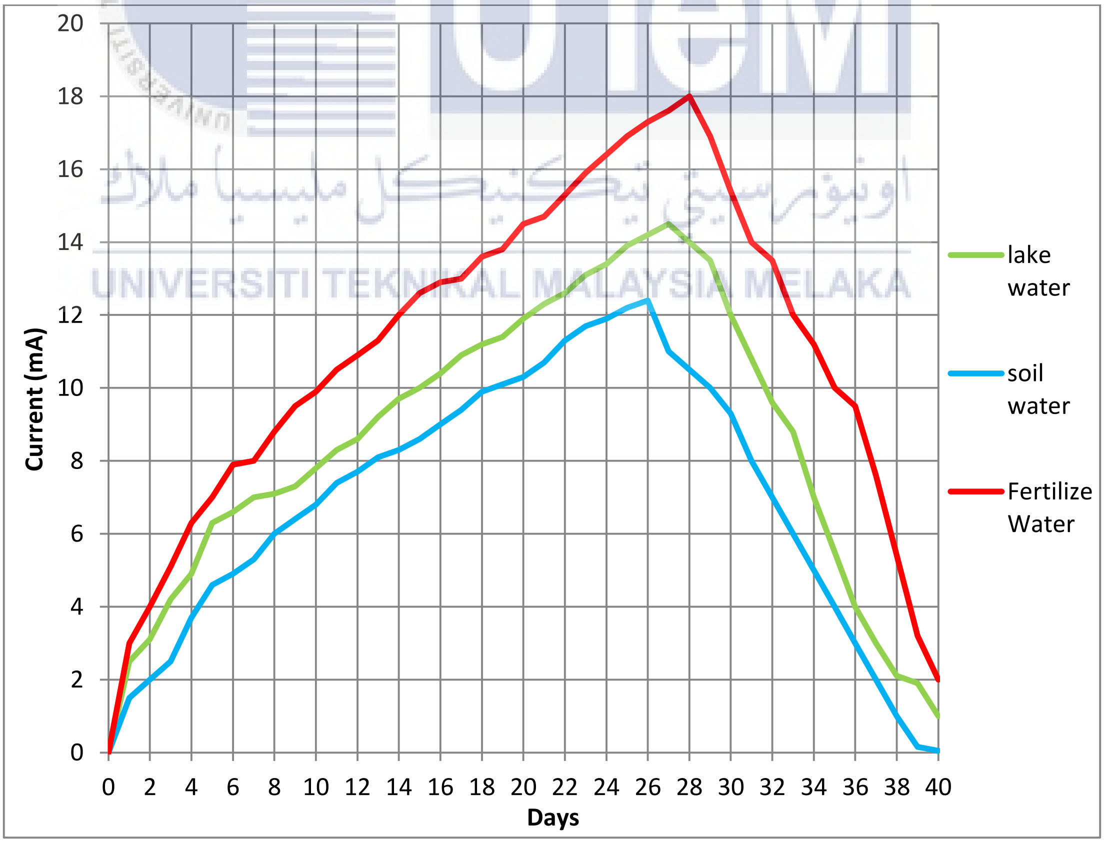
Table 4.1 show the data maximum of the voltage, current, power and power density produced with the used of soil water, lake water and fertilize water respectively. From the Table 4.1, the higher rate of output is when the MFC use fertilizer water as their wastewater. However, after each different type of water reaches the maximum performance or maximum voltage at the certain point, the graph start to slightly decrease. This is due to the fewer amounts of microbes left after the decomposition of microbes take place in anaerobic chamber. Fewer electrons is produced after the bacteria start to feed each other, thus the performance of MFC slightly decrease until 40 days. The hypothesis that can be made from the experiment for the 40 days is different type of wastewater effect the efficiency of the MFC to generate energy. This is due to the fertilize water has more organic matter that can be decompose by microbe and bacteria.

4.3 Performance Results for Thickness of Anode

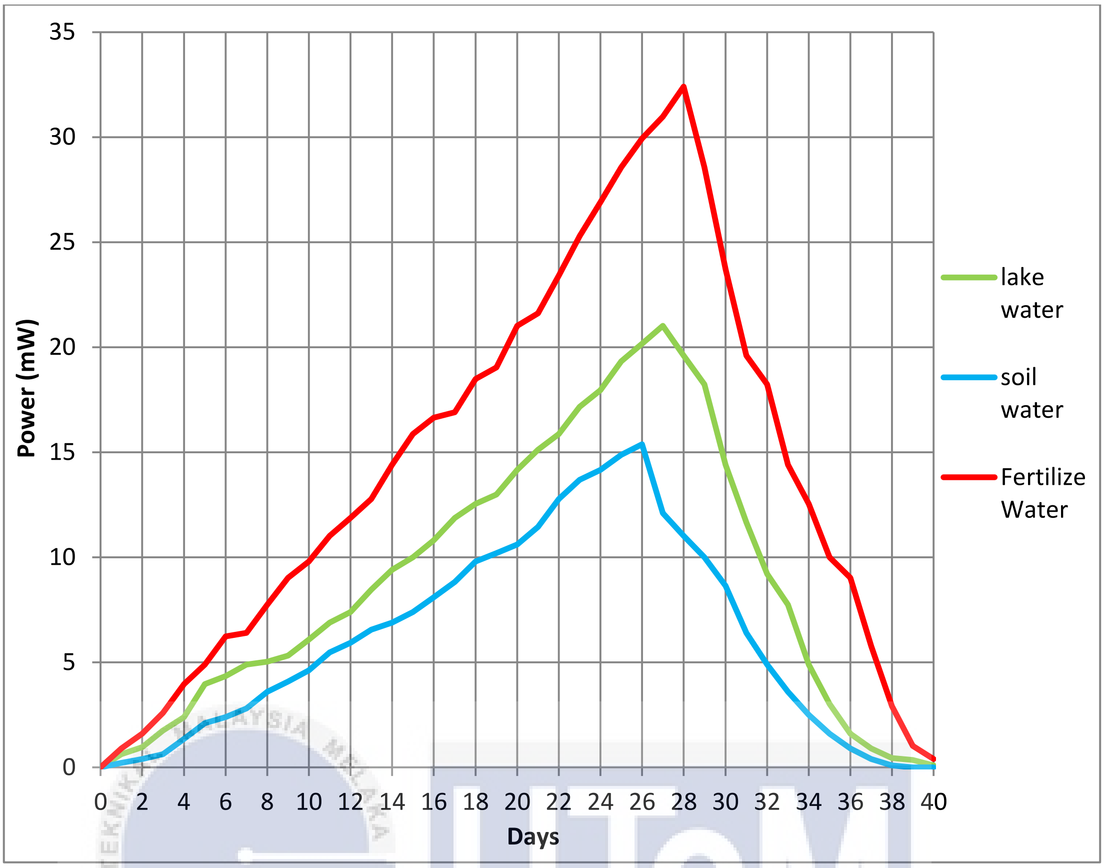
For this experiment, it focuses on the thickness of anode as the variable on the MFC. The types of wastewater used are the combination of water and soil, the lake water and fertilizer water with increasing 0.6cm thickness of anode. The electrode used for this experiment was copper electrode for both anode and cathode with a total surface area of 36cm^2.


Voltage (V)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Days
Fertilizer Water
Lake water
Soil Water

(a)


Current (mA)
20
18
16
14
12
10
8
6
4
2
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Days
lake water
soil water
Fertilize Water

(b)



(c)

Figure 4.3: Performance of thickness of anode based of: a) Voltage, (b) Current and (c) Power

Figure 4.3 shows that different types of wastewater with increasing the thickness of anode by 0.6cm will produce different voltage, current and power output. It can be seen that fertilizer water produces more voltage and current output compared to soil water and lake water. Moreover, when the current and voltage output increase, the power output also will increase. However, after each different type of water reaches the maximum performance or maximum voltage at the certain point, the graph start to slightly decrease. This is due to the fewer amounts of microbes left after the decomposition of microbes take place in anaerobic chamber. Fewer electrons is produced after the bacteria start to feed each other, thus the performance of MFC slightly decrease until 40 days.

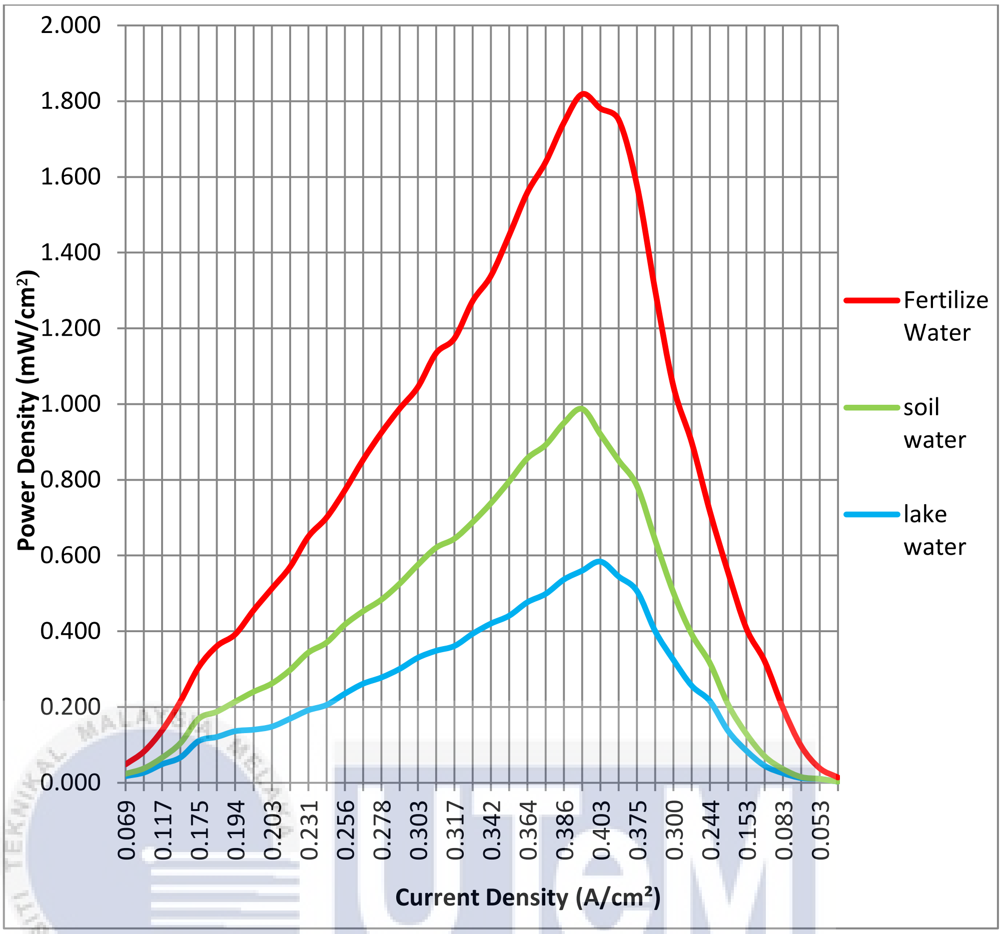


Figure 4.4: Performance of different thickness of anode

Figure 4.4 plots the comparison of the power density for fertilizer water, soil water and lake water. It can be seen that the power density of the fertilizer water is higher than lake water and soil water. Moreover, the graphs from Figure 4.4 increase rapidly when the thickness of anode is increase by 0.6 cm. Therefore, the increasing in the thickness of anode will further increase the voltage, current and power of the MFC used in this experiment which is soil water, lake water and fertilizer water.

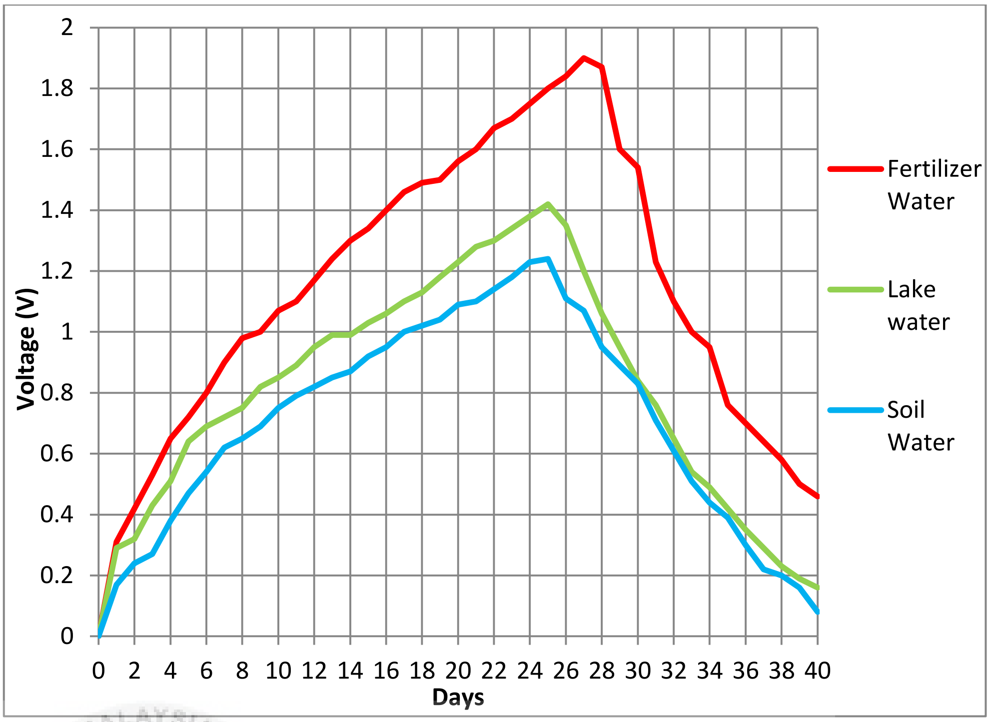
Table 4.2: The comparison of maximum performance of MFC between Experiment 1 and Experiment 2

Experiment 1	**P (mW)**	**V (V)**	**I (mA)**	**P_D (mW/cm^2)**
Soil Water	14.4	1.2	12	0.400
Lake Water	20.449	1.43	14.3	0.568
Fertilize Water	28.561	1.69	16.9	0.793
Experiment 2	**P (mW)**	**V (V)**	**I (mA)**	**P_D (mW/cm^2)**
Soil Water	15.38	1.24	12.4	0.427
Lake Water	21.03	1.45	14.5	0.584
Fertilize Water	32.40	1.80	18	0.900

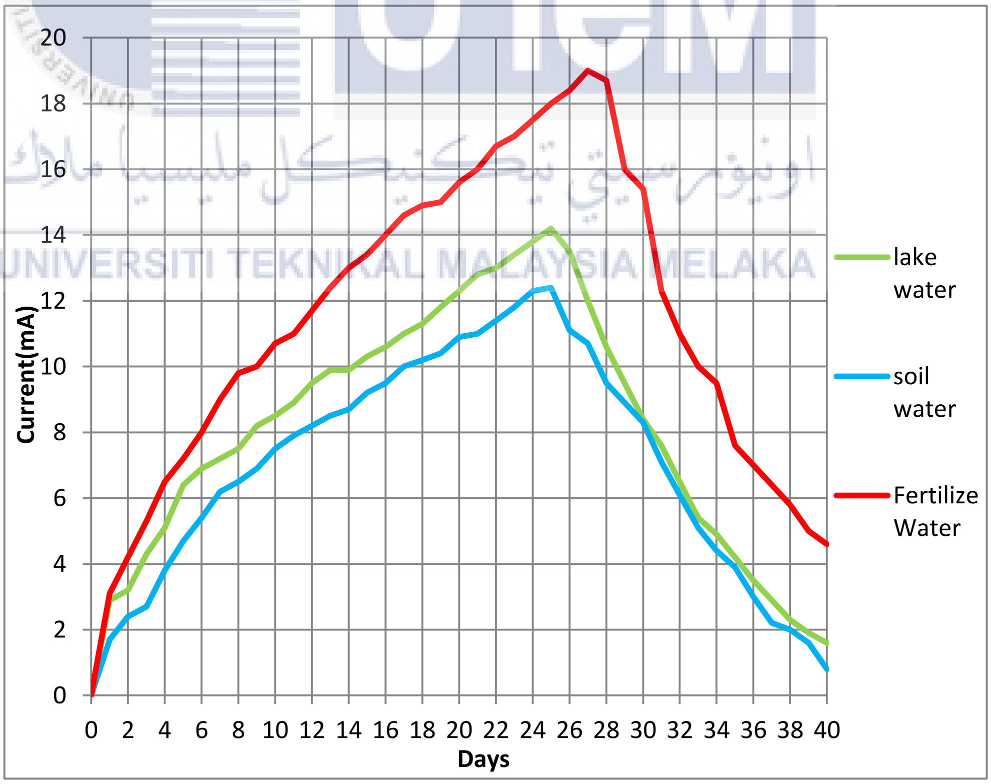
Table 4.2 show the comparison of maximum results between Experiment 1 and Experiment 2 in term of power, voltage, current and power density. When both experiments are compared, it can be seen that the maximum voltage, current, power and power density for Experiment 2 is 13.49% more than Experiment 1. The hypothesis that can be made from the Experiment 2 for the 40 days is different thickness of anode effect the efficiency of the MFC to generate energy. The use of a thicker anode is an important factor in power production not only because this increases the surface area for bacterial growth but also because the thick anode could provide an environment whereby the bacteria on the inside of the anode can remain in a highly anoxic environment compared to bacteria on the outside of the electrode.

4.4 Performance Results for Distance of Electrode

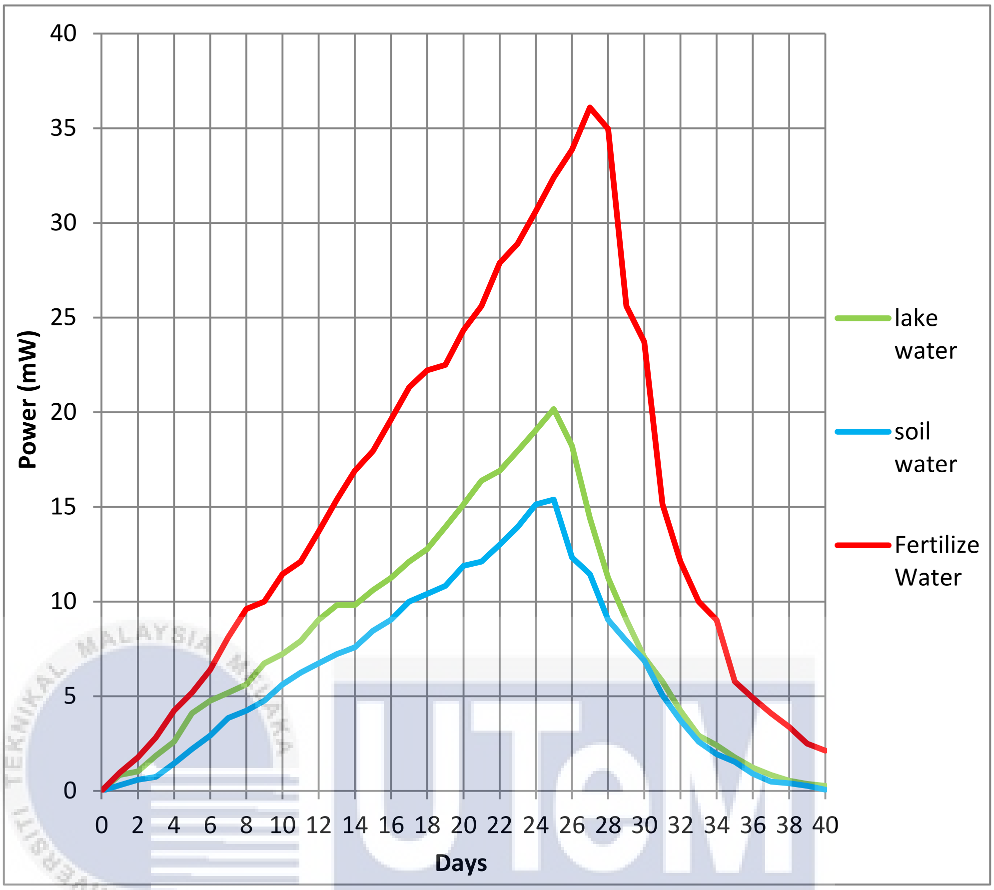
For this experiment, it focuses on the distance of electrode as the variable on the MFC. Same types of wastewater used which are the combination of water and soil, the lake water and fertilizer water. The electrode used for this experiment was copper electrode for both anode and cathode with a total surface area of 36cm^2 but the distance between the electrodes is decreased from 25 cm to 15 cm.


Voltage (V)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Days
Fertilizer Water
Lake water
Soil Water

(a)


Current(mA)
20
18
16
14
12
10
8
6
4
2
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Days
lake water
soil water
Fertilize Water

(b)



(c)

Figure 4.5: Performance of distance of electrode based of: a) Voltage, (b) Current and (c) Power

Figure 4.5 shows that different types of wastewater with the distance of electrode decreased by 15 cm will produce different voltage, current and power output. It can be seen that fertilizer water produces more voltage and current output compared to soil water and lake water. Moreover, when the current and voltage output increase, the power output also will increase. However, after each different type of water reaches the maximum performance or maximum voltage at the certain point, the graph start to slightly decrease. This is due to the fewer amounts of microbes left after the decomposition of microbes take place in anaerobic chamber. Fewer electrons is produced after the bacteria start to feed each other, thus the performance of MFC slightly decrease until 40 days.

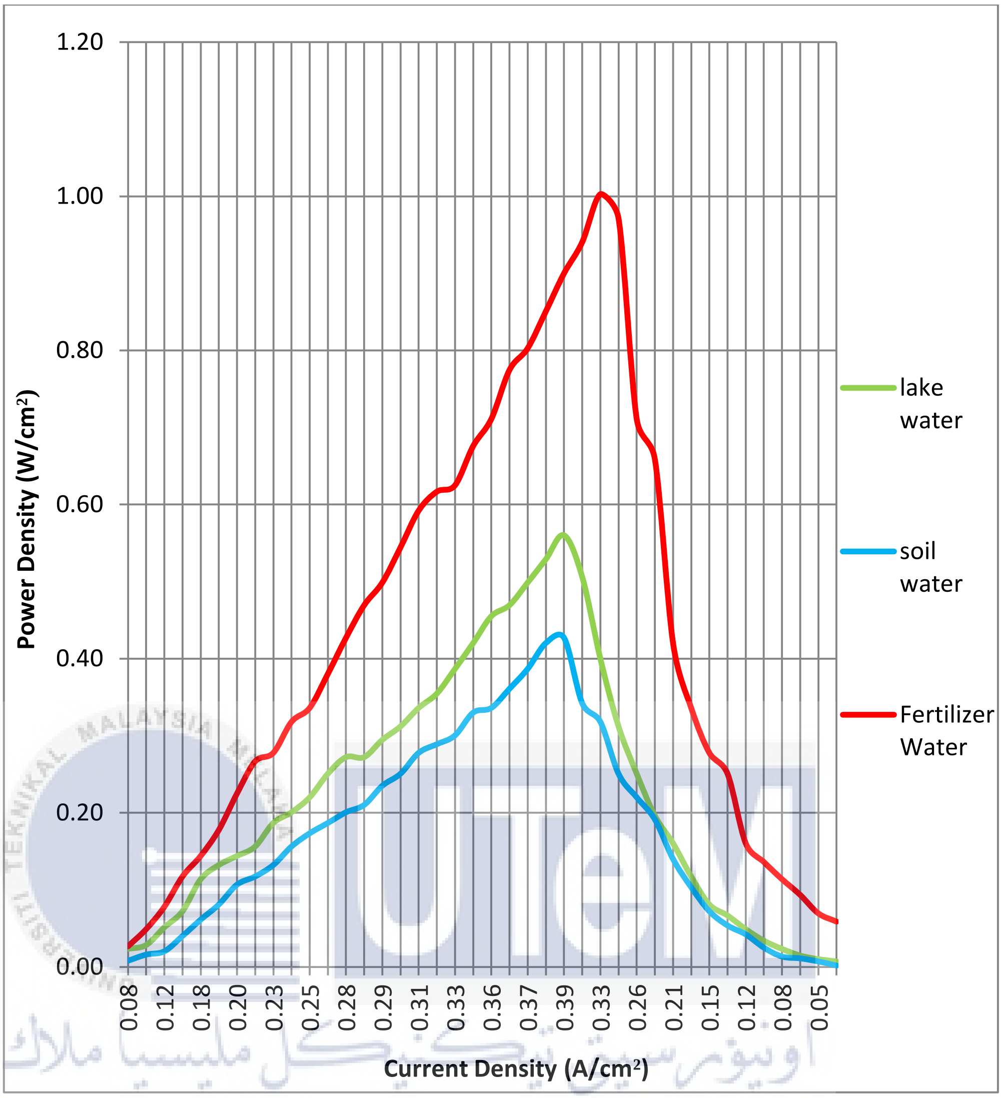


Figure 4.6: Performance of different waste water test

Figure 4.6 plots the comparison of the power density for fertilizer water, soil water and lake water when the distance of electrode is decreasing to 15cm. It can be seen that the power density of the fertilizer water is higher than lake water and soil water. Therefore, the finding prove that the fertilizer water still the most effective type of wastewater in producing voltage compared to soil water and lake water.

Table 4.3: The comparison of maximum performance of MFC between Experiment 1 and Experiment 3

Experiment 1	**P (mW)**	**V (V)**	**I (mA)**	**P_D (mW/cm^2)**
Soil Water	14.4	1.2	12	0.400
Lake Water	20.449	1.43	14.3	0.568
Fertilize Water	28.561	1.69	16.9	0.793
Experiment 3	**P (mW)**	**V (V)**	**I (mA)**	**P_D (mW/cm^2)**
Soil Water	15.376	1.24	12.4	0.427
Lake Water	20.164	1.42	14.2	0.560
Fertilize Water	36.1	1.9	19	1.002

Table 4.3 show the comparison of maximum results between Experiment 1 and Experiment 3 with the used of soil water, lake water and fertilize water respectively. When the results are compared, it can be seen that the maximum voltage, current, power and power density for Experiment 3 is 26.36% more than Experiment 1. The hypothesis that can be made from the Experiment 3 for the 40 days is different distance of electrode effect the efficiency of the MFC to generate energy. This small distance may lead to better transfer of electrons and protons from the bacteria to the anode or from the anode to the cathode due to the smaller ohm resistance. When a gap is present between the anode and the membrane, protons that are generated by the bacteria cannot move directly to the membrane. Thus, the protons will be carried by the wastewater in the anode chamber.

4.5 Summary

This chapter provided the result for this project. The data has been obtained in this experiment only used to determine either the MFC can be used to generate electricity from wastewater. Various ways had been implemented to increase the voltage output by using different type of wastewater, by increasing the thickness of electrode and by decreasing the distance of electrodes.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This thesis focused on the development of electricity generation from wastewater using MFC. Three research objectives have been presented, the first objective is to study and understand the concept of a MFC for the wastewater electricity harvesting component. The second objective in the meantime was to develop an effective system model for microbial fuel cells using a simple concept of biological fuel cells. Finally, the third objective is to improve the power produced by the development of microbial fuel cells based on different types of wastewater, different types of anode, electrode distance and electrode thickness.

In order to achieve the first objective, a lot of research has been carried out to understand the ways in which MFC is designed. The prior research and thesis will also be learned before the MFC is designed. Due to various researches, the MFC can be designed and developed to generate wastewater energy. The MFC is designed and created to determine the range of voltage by using a MFC double chamber. Many experiments have been carried out. The results of this experiment have been collected and evaluated in order to improve electricity efficiency and generation.

When the first objective is achieved, it shows that it is not impossible to generate electricity from wastewater using an MFC. There are several ways to maximize the power produced by MFC for the second objective. These methods have been tested to demonstrate whether the theory is correct or not. The result was then assessed.

The best wastewater that can be used for MFC is fertilizer water as a final result of this thesis for this final year project. The experiment for different types of waste water concludes that fertilizer water is the most effective type of waste water in producing voltage, current and power compared to lake water and soil water. This is because the fertilizer water has more organic matter that can be decompose by microbe and bacteria.

Moreover, some improvements have been made to the anode to improve the performance of MFC. The performance of MFC is increased because the voltage, current and power at the maximum point is higher than Experiment 1. Thus, the increase in the thickness of anode can improve the performance of MFC.

Lastly, the other factor that successfully increased the performance of MFC has been adopted in this Final Year Project. Distance of electrode or more specific is the distance between the cathode and anode has been decreased to 15cm from its original distance used in Experiment 1 which is 25cm. By decreasing the distance of electrode, the voltage, current and power output is increased compared to Experiment 1. This can be seen from the maximum output of the three different types of water.

5.2 Recommendations

This study presented a new renewable energy that can be creating without the harm of environment thus creating save and free energy for mankind. MFC still lack of technology to act as the main source of generator. Many study still need to be done to accomplish the goal and target of MFC. With the new technology, the energy demand of the world can be fulfilled and at the same time resolve the wastewater treatment in the world. With further improvements and optimization, it could be possible to increase power generation. Thus, the combination of wastewater treatment along with electricity production might help in compensating the cost of wastewater treatment. There is a necessity to talk about low power densities in MFC operation by existing optimization of the design to reduce the losses affected by activation, ohm, and concentration over potentials [15]. Further, losses caused by unnecessary reactions, for example, the direct oxidation of fuel by O_2 diffusion into the anodic chamber or microbial metabolic reactions. On the other hand, increasing the system volumetric capacity must be attained short of internal energy losses. In this direction, stacking MFCs is a common choice to evade catastrophic losses. Furthermore, tubular and other stacked methodologies continue to be explored. Also, the action is essential to raise the exoelectrogenic microbial population density, which seems to be restricted for causes excluding the accessibility of attachment positions on the electrode surface, and possibly will control by bio augmentation and possible field effects existent in the electrode by the advantage of its morphology and conductivity. Ongoing efforts are being made to establish better transfer mechanisms among the electrode and the biocatalyst by the modification of electrode surfaces and also by applying active catalyst coating on the electrode surface.

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