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.

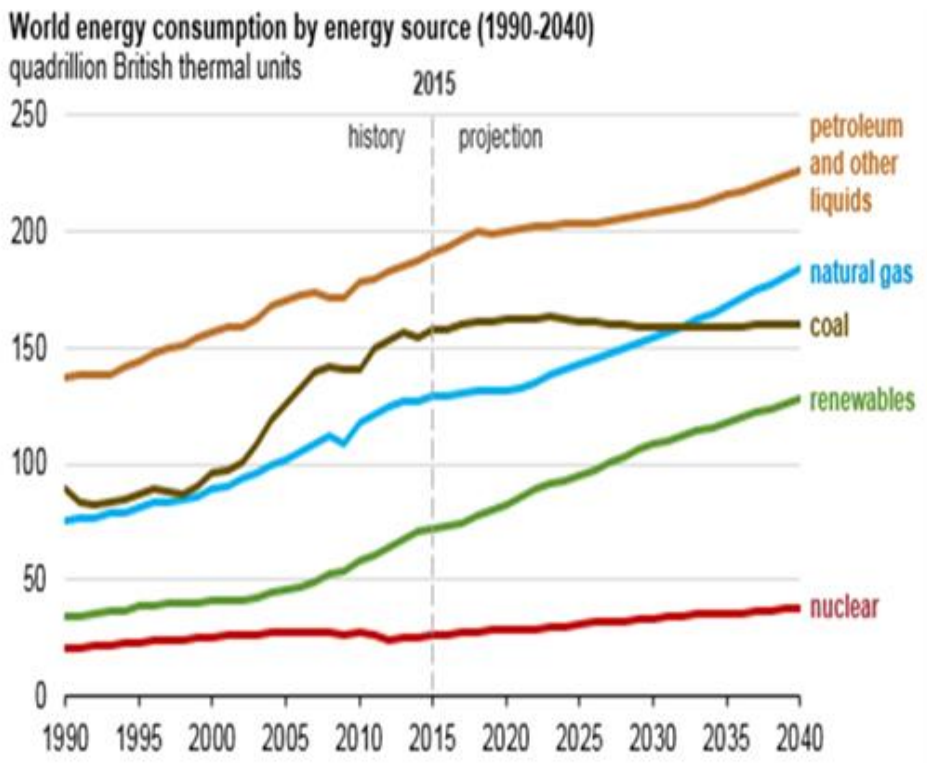

Figure 1.1: World energy supply consumption (1990-2040) [1]

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].

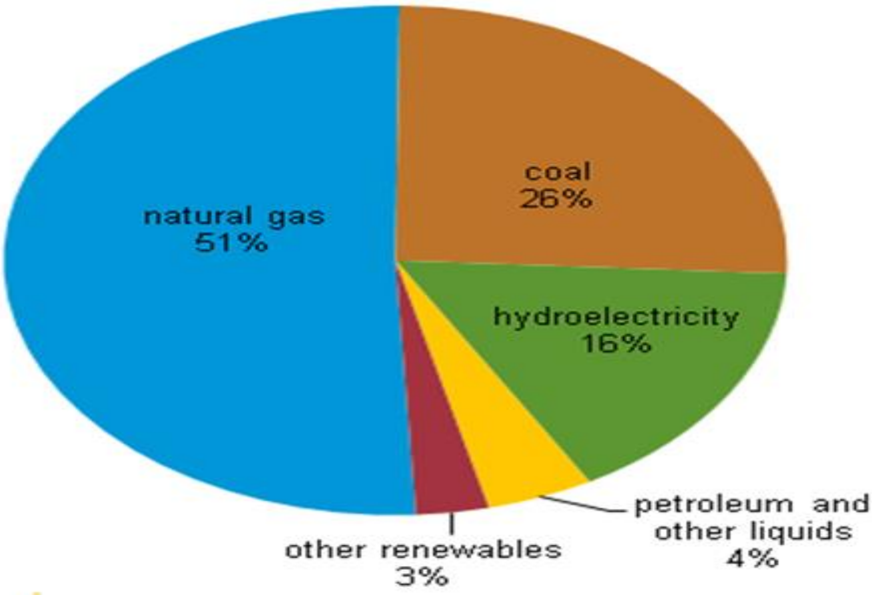

Figure 1.2: Electricity generation in Malaysia, end-2014 [4]

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].

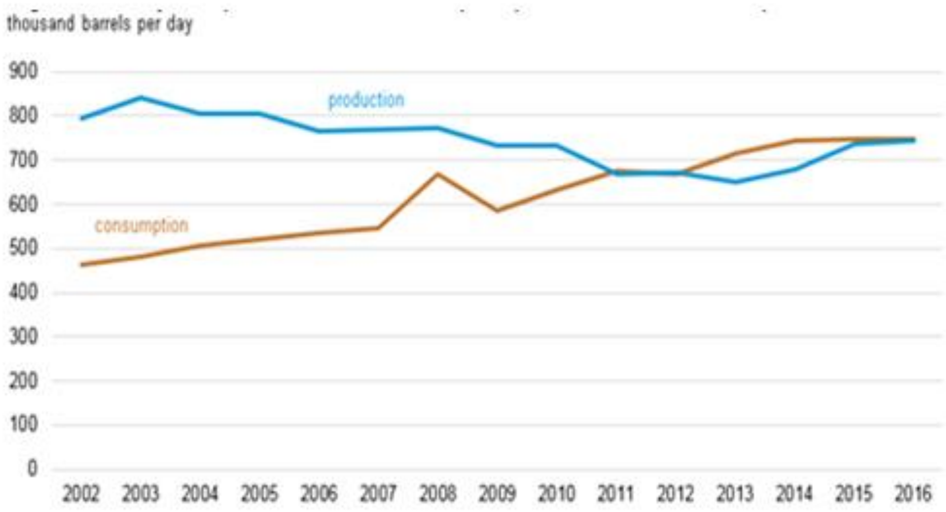

Figure 1.3: Data from statistical report 2017 [7]

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.

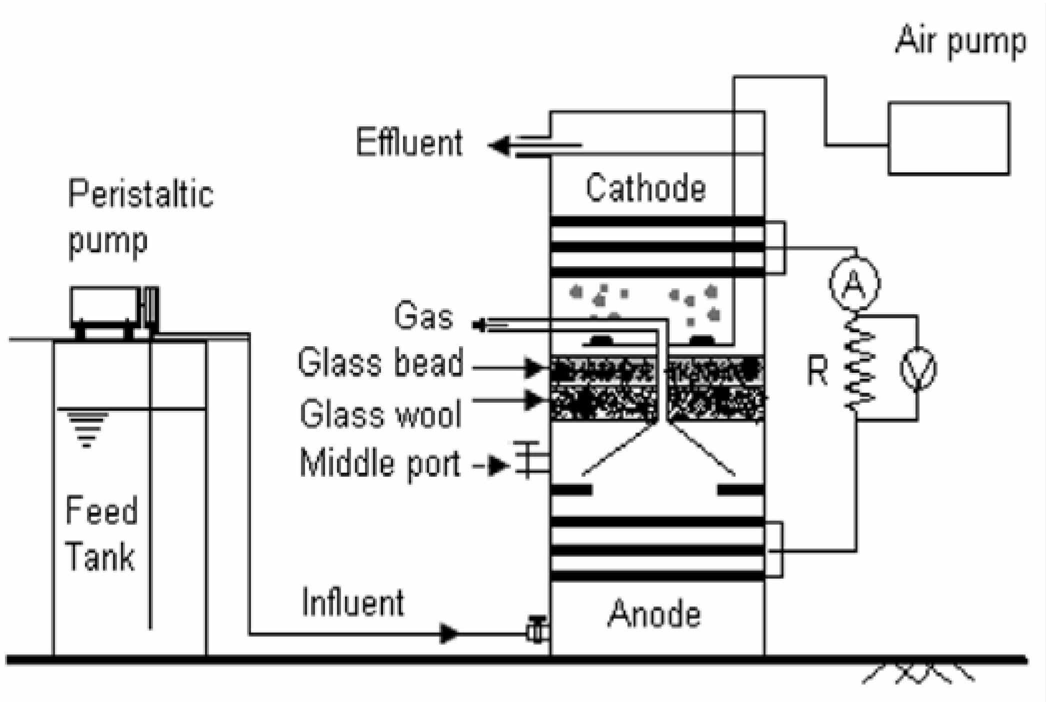

Figure 2.1: The design of Microbial Fuel Cell used for this project