Faculty of Engineering

DEVELOPMENT OF A SMALL MICROBIAL FUEL CELL PLANT FOR WASTEWATER TREATMENT

Kua Ming Sheng

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Alamat tetap:

No. 150 Bintawa Fishing Village
93450 Kuching, Sarawak

Dr. Hj. Mohammad Omar Abdullah
Nama Penyelia

Tarikh: 16/6/2010

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Name : Kua Ming Sheng

Matric No. : 16474

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Project Supervisor

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DEVELOPMENT OF A SMALL MICROBIAL FUEL CELL PLANT FOR WASTEWATER TREATMENT

KUA MING SHENG

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To my beloved family and friends

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ABSTRACT

Wastewater is a source of energy as research had been done to extract the potential in it to produce electricity. The objectives of this project are to design, fabricate and commence testing on Microbial Fuel Cell for electricity generation from wastewater. There are three phase were involved in this project. Phase 1 was design and fabricate MFC continues with Phase 2, conduct testing on MFC. Finally Phase 3 involves test POME samples' parameter. The characteristics of power generation were also determined. The source of wastewater used was palm oil mill effluent from Kota Samarahan district. The maximum voltage attained was 425 mV with aeration compared to 175 mV without aeration. The maximum power density attained was 41.2 mV/m^2 with aeration (experiment 3). The samples of before and after samples of palm oil mill effluent was tested on suspended solid, total solid, BOD_5 and COD parameter. There are reductions in suspended solid, total solid, BOD_5 and COD.

ABSTRAK

Air sisa merupakan sumber tenaga yang telah dilakukan kajian untuk mengestrak potensi di dalamnya untuk menghasilkan elektrik. Objektif projek ini adalah untuk mereka, memfabrikasi dan menguji *Microbial Fuel Cell* untuk penjanaan kuasa dari air sisa. Terdapat tiga fasa terlibat dalam projek ini. Fasa 1 adalah rekaan dan fabrikasi MFC berlanjut dengan Fasa 2, melakukan ujian pada MFC. Akhirnya Fasa 3 melibatkan pengujian parameter sampel POME. Ciri-ciri penjanaan kuasa juga telah dikenalpasti. Sumber air sisa yang digunakan adalah effluen kilang kelapa sawit dari distrik Kota Samarahan. Voltan maksimum yang dicapai adalah 425 mV dengan aerasi dibandingkan dengan 175 mV tanpa aerasi. Ketumpatan kuasa maksimum adalah 41.2 mV/m^2 tercapai pada eksperimen 3. Sampel sebelum dan selepas efluen kilang kelapa sawit diuji pada parameter pepejal terampai, pepejal keseluruhan, BOD_5 dan COD. Terdapat pengurangan dalam pepejal terampai, pepejal keseluruhan, BOD_5 dan COD.

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AN	-	*Ammoniacal Nitrogen*
BOD	-	*Biochemical oxygen demand*
CAD	-	*Computer Aided Design*
COD	-	*Chemical oxygen demand*
FELCRA	-	*Federal Land Consolidation and Rehabilitation Authority*
MFC	-	*Microbial Fuel Cell*
PEM	-	*Proton exchange membrane*
POME	-	*Palm oil mill effluent*
TKN	-	*Total Kjeldahl Nitrogen*

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The background of study discuss about different aspects that related to the Microbial Fuel Cell (MFC). In general, the history, the development and the application are essential to outline the complete introduction to this title.

1.1.1 Environment and Biotechnology

With an increasing emphasis on the quality of our environment, many recognize that science can play a vital role in the improvement of our air, soil and water. Bioremediation is the use of biological system to degrade or remove noxious pollutants from the environment. Biotechnology is becoming important in this field as well (Borem et al. 2003).

Environmental pollution is the result of population growth and technological progress. The main objective of technology is to reduce the impact of pollution to the environment and human beings. Pollution can be seen of felt everywhere. It is not absurd to think that the technology advancements that have contributed to the problem might also be the source of the problem (Borem et al. 2003).

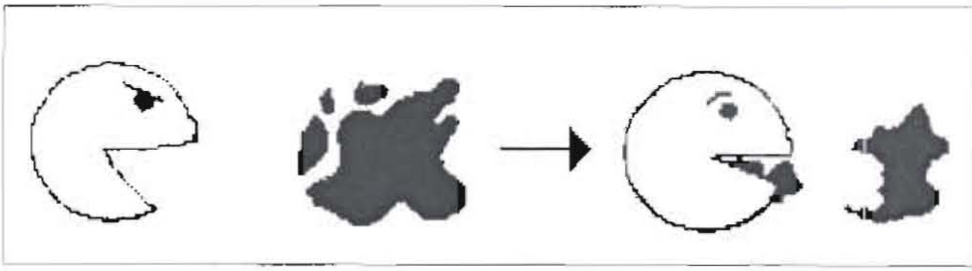

Figure 1.1: Different bacteria have the capability to transform different substances into energy in their growth (Borem et al. 2003).

In service industry, biotechnology has been used as a solution to control the environment pollution by processing waste and water treatment. In long term time span, biotechnology could used as a medium to solve a few of global problems which involving medical, shortage of food, environmental pollution control and creation of new energy resources (Omar 2002).

1.1.2 Discovery of Bioelectric

Luigi Galvani observed the bioelectric phenomenon first in 1790, but it was not until the beginning of the 20th century that MFCs were discovered. Generally speaking, a MFC is a bioreactor that converts chemical energy stored in the chemical bonds of organic compounds to electrical energy through catalytic reactions of microorganisms. The earliest work on MFC dates back to 1912 and is due to Potter. He described the production of electrical energy from living cultures of Escherichia coli and Saccharomyces. His work was not to receive any considerable attention until 1931, when Cohenwas able to produce a voltage larger than 35 V from MFCs connected in a series (Rinaldi et al. 2008).

1.1.3 Continuous Development

MFCs became popular in the 1960s, when the National Aeronautics and Space Administration in USA carried out further research to assess their application in space missions. However, relatively little was understood about how these MFCs functioned and about fuel oxidation. New insight came from the studies by Allen and Bennetto in the 1980s, who discovered that current density and power output could be greatly enhanced by using electron mediators to accelerate the electron transfer rate from microbes to the anode substrate (Rinaldi et al. 2008).

Unfortunately, toxicity and instability of synthetic mediators are major impediments to their use for practical MFC applications. More recently, though, scientists found out that some microbes can use ''safe'' natural compounds as mediators, such as their own microbial metabolites (endogenous mediators). The next significant advance occurred when some microbes were found to transfer electrons directly to the anode, rendering MFCs a viable technology to generate electric power from biomass (Rinaldi et al. 2008).

1.1.4 Variations of Application of MFC

A MFC is a bioreactor that converts chemical energy in the chemical bonds in organic compounds to electrical energy through catalytic reactions of microorganisms under anaerobic conditions. It has been known for many years that it is possible to generate electricity directly by using bacteria to break down organic substrates. The recent energy crisis has reinvigorated interests in MFCs among academic researchers as a way to generate electric power or hydrogen from biomass without a net carbon emission into the ecosystem. MFCs can also be used in wastewater treatment facilities to break down organic matters. They have also been studied for applications as biosensors such as sensors for biological oxygen demand monitoring (Du et al. 2007).

1.1.5 Partnership of Various Fields

MFC research is a rapidly evolving field that lacks established terminology and methods for the analysis of system performance. This makes it difficult for researchers to compare devices on an equivalent basis. The construction and analysis of MFCs requires knowledge of different scientific and engineering fields, ranging from microbiology and electrochemistry to materials and environmental engineering (Logan et al. 2006).

The development of MFC was rapidly ongoing since they know this alternative could yield renewable energy. To date, the MFC is still in research and still have big potential for improvements. In the past, MFC was developed mostly by biologists rather than engineers. But now the knowledge of microbes made universally available through the internet around the world which aids non-biologist to continue the development of MFCs.

1.1.6 Waste Processing in Malaysia

In Malaysia, biotechnology method applied in waste processing aims for safety and hygiene. Usage of biology system in waste processing does not pose side problems in terms of collection of toxic biology agent in environment because it is effectively biodegradable (Omar 2002).

1.2 The Need of Study

A MFC is a device that uses bacteria as catalysts to oxidize organic and inorganic matter and generate current (Logan et al. 2006). Due to their capability of simultaneously producing electricity and achieving wastewater treatment, the MFCs are a promising technology for the production of sustainable energy (He et al. 2005; Min et al. 2005). At present, however, the low power output caused by various potential losses limits scale-up and field implementation of MFC technologies (Logan et al. 2006; Rabaey & Verstraete 2005).

1.3 Objectives

The objectives of this study are aimed to:

i. Review the different design of MFC in water treatment applications.
ii. Design and produce a pilot, small scale MFC.
iii. Determine the characteristics of power output by conducting testing.

1.4 Problem Statement

MFCs have been widely researched and it is growing in popularity in term of developments towards clean and renewable energy. However, the question is why MFC are still not successfully commercialized and use in large applications such as food industries, municipals or plantations. Many believe that MFC is still a new technology in electricity production and not yet reach a reliable stage. Although many researches had been done, there are many parameters and the relations which are still undefined due to different kinds of material used. It is known that fuel cell is act like a battery supplying power to devices, but MFC seems to have far less current supply compared to eg. AA sized battery. Perhaps by more understanding of microorganism behavior and the bacteria life cycle will lead to the improvements. This works therefore aim to throw some light on investigation of a small MFC and the behavior of the electricity characteristics.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A MFC is a bioreactor that converts chemical energy in the chemical bonds in organic compounds to electrical energy through catalytic reactions of microorganisms under anaerobic conditions. It has been known for many years that it is possible to generate electricity directly by using bacteria to break down organic substrates. The recent energy crisis has reinvigorated interests in MFCs among academic researchers as a way to generate electric power or hydrogen from biomass without a net carbon emission into the ecosystem. MFCs can also be used in wastewater treatment facilities to break down organic matters. They have also been studied for applications as biosensors such as sensors for biological oxygen demand monitoring. Power output and coulombic efficiency are significantly affected by the types of microbe in the anodic chamber of an MFC, configuration of the MFC and operating conditions (Du et al. 2007).

2.2 Working Principals

A basic double-chambered MFC consists of anode and cathode compartments

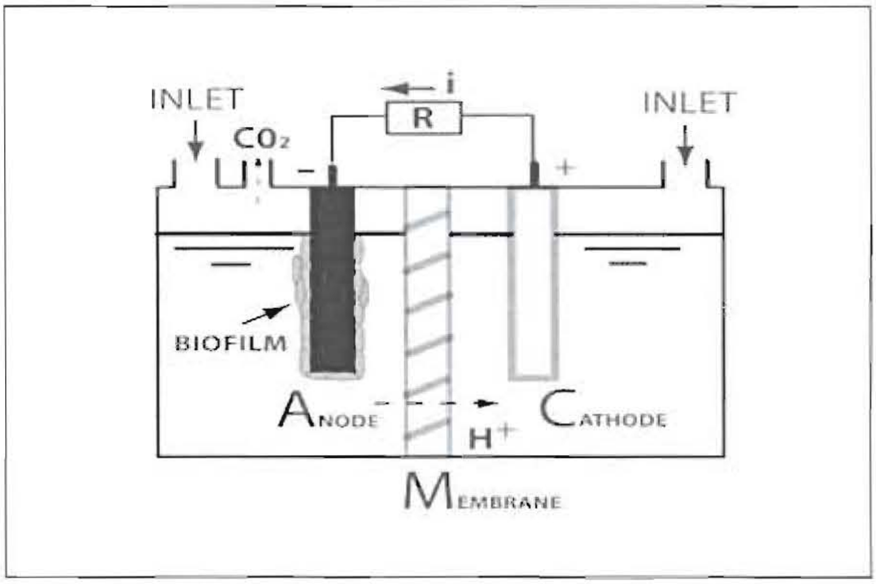

Figure 2.1: Schematics of a double-chamber MFC with a PEM membrane and oxygen reduction at the cathode (Rinaldi et al. 2008)

separated by an ion exchange membrane (or alternatively by a salt bridge) and connected by an external electric circuit (Figure. 2.1). In the anode compartment a biofilm, of bacteria (the catalysts), is laid upon an anode substrate to form a bioanode immersed in a solution of organic matter (fuel) fed to the compartment in either continuous or batch mode. Some of the bacteria involved in catalysis might also reside in the electrolyte solution. The bacteria, first oxidize the fuel (the electron donor) through their metabolism, freeing electrons, protons and/or other cations, and then transfer these electrons to the anode substrate through a number of mechanisms, e.g. direct contact, nanowires or mobile electron shuttles (mediators). The electrons from the bioanode pass to the cathode compartment through the external electric circuit, while selected ions move across the electrolyte membrane to close the circuit. A reduction reaction takes place in the cathode compartment, mostly in the presence of oxygen. For example, when a proton exchange membrane is used, migrated protons and electrons combine with oxygen to form water at the cathode. A biofilm