



Faculty of Engineering

**LEACHATE TREATMENT BY USING PARALLEL CONFIGURATION
MICROBIAL FUEL CELL (MFC)**

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LEACHATE TREATMENT BY USING PARALLEL CONFIGURATION MICROBIAL FUEL CELL (MFC)

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A dissertation submitted in partial fulfillment
of the requirement for the degree of
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Every challenging work needs self-efforts as well as the guidance of elders, especially those who were very close to our hearts. My humble effort I dedicate to my sweet and loving Father and Mother whose affection, love, encouragement and prayers of day and night make me able to complete this final year project report, Along with hard-working and respected supervisor, Madam Noraziah Abdul Wahab

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ABSTRACT

The rapid development of Malaysia has contributed to the abundance of landfill leachate generated day by day. Leachate consists of toxic organic pollutants that can contaminate the ground and surface of waters if discharged without complying with the requirements Environmental Act 1974. One of the treatments that can be used to treat leachate is by using Microbial Fuel Cell (MFC). The microbial fuel cell is a device that consists of a bio-electrochemical system that converts chemical energy into electrical energy. MFC needs to be scaled-up to implement the systems for large-scale use. The study on the parallel configuration MFC and individual-double chamber MFC was examined. The Parallel Configuration MFC does not have a significant effect on the performance of treating landfill leachate than the Individual Dual Chamber MFC. Besides, this study demonstrated that Parallel Configuration MFC unable to scale-up the power density as the Individual Dual-Chamber MFC generated more significant power density compared to the Parallel Configuration MFC. Other than that, the employment of leachate as substrates in MFC has proved a significant enhancement in generating power density compared to the reported studies in which natural wastewaters were employed as substrates in MFCs.

Keywords: Microbial Fuel Cell, Leachate, Parallel Configuration, Dual-Chamber.

ABSTRAK

Perkembangan pesat Malaysia telah menyumbang kepada banyaknya larutan pembuangan sampah yang dihasilkan dari hari ke hari. *Leachate* terdiri daripada bahan pencemar organik beracun yang dapat mencemari tanah dan permukaan perairan jika dibuang tanpa mematuhi kehendak Akta Alam Sekitar 1974. Salah satu rawatan yang boleh digunakan untuk merawat larut lesap adalah dengan menggunakan sel bahan bakar mikrob (MFC). Sel bahan bakar mikroba adalah peranti yang terdiri daripada sistem bio-elektrokimia yang mengubah tenaga kimia menjadi tenaga elektrik. MFC perlu ditingkatkan untuk menerapkan sistem untuk penggunaan skala besar. Kajian mengenai MFC konfigurasi selari dan MFC ruang individu-dua telah diperiksa. MFC konfigurasi selari tidak mempunyai kesan yang signifikan terhadap prestasi mengolah pelupusan sampah di tempat pembuangan berbanding dengan Individual Dual Chamber MFC. Selain itu, kajian ini menunjukkan bahawa MFC konfigurasi selari tidak dapat meningkatkan ketumpatan kuasa kerana *Individual Dual-Chamber MFC* menghasilkan kepadatan kuasa yang lebih ketara berbanding MFC konfigurasi selari. Selain itu, penggunaan larutan lesap sebagai substrat di MFC telah membuktikan peningkatan yang signifikan dalam menghasilkan kepadatan kuasa berbanding dengan kajian yang dilaporkan di mana air buangan semula jadi digunakan sebagai substrat di MFC.

Kata kunci: Sel Bahan Bakar Mikrob, *Leachate*, Konfigurasi Selari, *Dual-Chamber*

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ABBREVIATIONS

AAS	-	Atomic Absorption Spectroscopy
Al	-	Aluminum
ASP	-	Activated Sludge System
Ba	-	Barium
BOD	-	Biological Oxygen Demand
CEM	-	Cation Exchange Membrane
CO ₂	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
Cu	-	Copper
DO	-	Dissolved Oxygen
Fe	-	Iron
H ₂ O ₂	-	Hydrogen Peroxide
H ₂ SO ₄	-	Sulphuric Acid
MFC	-	Microbial Fuel Cell
Mn	-	Manganese
MSW	-	Municipal Solid Waste
NH ₃ -N	-	Ammoniacal Nitrogen
PEM	-	Proton Exchange Membrane
PVC	-	Polyvinyl Chloride
RBC	-	Rotating Biological Contractor
Si	-	Silicon
TAN	-	Total Ammoniacal Nitrogen
TSS	-	Total Suspended Solids
VFA	-	Volatile Fat Acids

LIST OF SYMBOLS

A	-	Ampere
°C	-	Degree Celsius
cm	-	Centimetre
GW	-	Gigawatt
mg/L	-	Milli gram per litre
ml	-	Milli litre
Mt	-	Megatonnes
mW/m ²	-	Milli watt per area
V	-	Volt
W/m ³	-	Watt per volume
Ω	-	Ohm

CHAPTER 1

INTRODUCTION

1.1 Electricity Sources

According to de Lira Quaresma et al. (2018), in 1973, non-renewable sources accounted for 87.6 % of the global energy mix, and the percentage decreased to 86.2% in 2014. Even though there is a sign of depletion of non-renewable sources, the energy demand is getting higher due to global economic growth and resulting in the elevation of the amount of greenhouse gas emissions.

Numerous countries have been escalating the number of renewable energy sources in their energy mix to minimize the emission of carbon dioxide and meet the requirements of international agreements. The introduction of renewable energy sources resulting in the diversification of electricity generation sources. Electricity generation sources are wind, solar energy, hydropower, and biomass.

However, utilizing renewable energy as fuel to generate electricity faced some challenges due to the effect of the irregular alternation phases, specifically for (wind and sun) and the merit order on electricity prices. Thus, the reliability of the electricity by using renewable energy sources supply may be reduced. Overloading tariff payments on the customer might occur due to the inefficient support systems for renewables energy in generating electricity. On the other side, solar PV power generation of electricity could improve economic activity (Marques et al., 2019).

1.2 Electricity Sources in Malaysia

Fossil fuels dominate the electricity sector in Malaysia, and this may result in increasing the volume of CO₂ and other pollutants. Malaysia's demand for electricity has grown tremendously for 33 years until now, and the energy conservation policy (Energy

Commission Act 2001) in Malaysia has improved along these lines (Shekarchian et al., 2011). Malaysia has implemented extensive energy conservation to minimize the rate of growth in the consumption of energy. Malaysia has a variety of power plants such as biomass, mini-hydro, gas turbine, conventional thermal, and diesel hydro. A few examples of Malaysia's power plant can be found in **Table 1.1**. Recently, the country has decided to use coal as the primary source of energy gas to minimize fossil-fuel reliance (Shekarchian et al., 2011).

Table 1.1 List of Power Plants in Malaysia

Type of Power Plant	Location	Reference
Hydropower	Bakun Dam, Sarawak	(International Hydropower Association, 2020)
Biomass	Bentong Biomass Energy Sdn. Bhd.	(Babcock and Wilcox Volland, 2015)
Gas-fired	Sepanggar Bay Power Plant, Sabah	(Mahpar, 2016)
Oil-fired	Sandakan Power Corporation Plant, Sabah	(Global Energy Observatory, 2013)
Coal-fired (Thermal)	Sejingkat Power Corporation Plant, Sarawak	(Baruya, 2010)

Throughout 2013, apart from hydro, the share of renewables in the power mix was only 0.2% (Energy Commission, 2012). Malaysia also ranks third after Indonesia and Thailand as the main carbon dioxide emitters in South East Asia. In 2013, there was a significant increase in the amount of CO₂ emissions where it quadrupled the number of emissions in 1990 from 56.6 Mt to 236.5 Mt. In comparison, 54.8% of gross CO₂ pollution accumulated in 2013 alone in the energy sector (The World Bank Data, 2019). Malaysia has signed the Paris Agreement, where 35% of greenhouse gas emissions are unconditionally eliminated and 10% of greenhouse gas emissions from advanced countries by 2030 relative to 2005 rates (Haiges et al., 2017).

Malaysia has to reduce the negative environmental impact of generating electricity while providing adequate electricity to escalate economic growth. To do that, the most effective, quickest, and most inexpensive method is to decarbonize the electric

power sector (Carlsson, 2014). Hydropower is deemed the front-line contender in the decarbonization campaign among the numerous renewable electricity sources available.

Hydropower is the most preferred source of renewable energy in generating electricity. It emits negligible amounts of CO₂ pollution and can help to reduce the environmental issue caused mainly by fossil fuel burning in generating electricity. Besides, implementing a hydropower system may reduce the cost of tariffs since it does not depend on volatility in global fossil fuel market prices (Bello et al., 2018).

1.3 Waste as Alternative Energy

The US Department of Energy stated that municipal solid waste (MSW) can be used as an alternative source of energy and has several advantages on the production of fuel and electricity (USDOE, 2017). For instance, leachate is available at affordable prices and can also be collected by using the existing waste collection and separation system.

In terms of industrial, waste feedstocks from landfills can be used as the fuel in generating electricity through the process of bio-electrochemistry where it can reduce the cost and simultaneously prevents or reduce the pollution that might occur with landfill. Greenhouse gas emissions generated from landfills has been emitted 115.7 Mt CO₂ in 2005 (USEPA, 2017). Waste-derive fuels can be used as alternative energy sources since they can be more economic-environmentally friendly compared to fossil fuel.

Several biochemical processes and thermochemical processes are currently in progress to take advantage of these benefits (Lee et al., 2016). For example, anaerobic digestion has been used to produce biogas and renewable natural gas from food waste. Fermentation processes producing bioethanol from municipal solid waste also had been explored.

Municipal solid waste can be converted to fuel through the process of redox reaction (Chen et al., 2014). Other than that, waste can be converted to bio-oil, where it can be further hydro-processed to produce gasoline and diesel (Wang et al., 2015). Syngas is generated through the gasification process and can be converted into various fuels such as Fischer-Tropsch diesel and jet (Lee et al., 2014).

1.4 Microbial Fuel Cell (MFC)

A microbial fuel cell (MFC) is a device that consists of a bio-electrochemical system that utilizes the power of aerobic microbe to generate electricity in wastewater (Santoro et al., 2017). In general, the MFC is a fuel cell that uses oxidation-reduction reactions to turn chemical energy into electricity.

There are many different possible configurations for MFCs. A commonly used and inexpensive model is a dual-chamber MFC designed which usually consists of two bottles or cube boxes made of plexiglass connected by a separator pipe that is generally a cation exchange membrane (CEM) or known as proton exchange membrane-like Nafion, Ultrex or a plain salt bridge. The PEM is installed in the middle of the tube connecting the chamber. However, the tube itself is not necessary, as long as the two chambers are separated. The simple H-shape systems MFC is shown below in Figure 1.1.

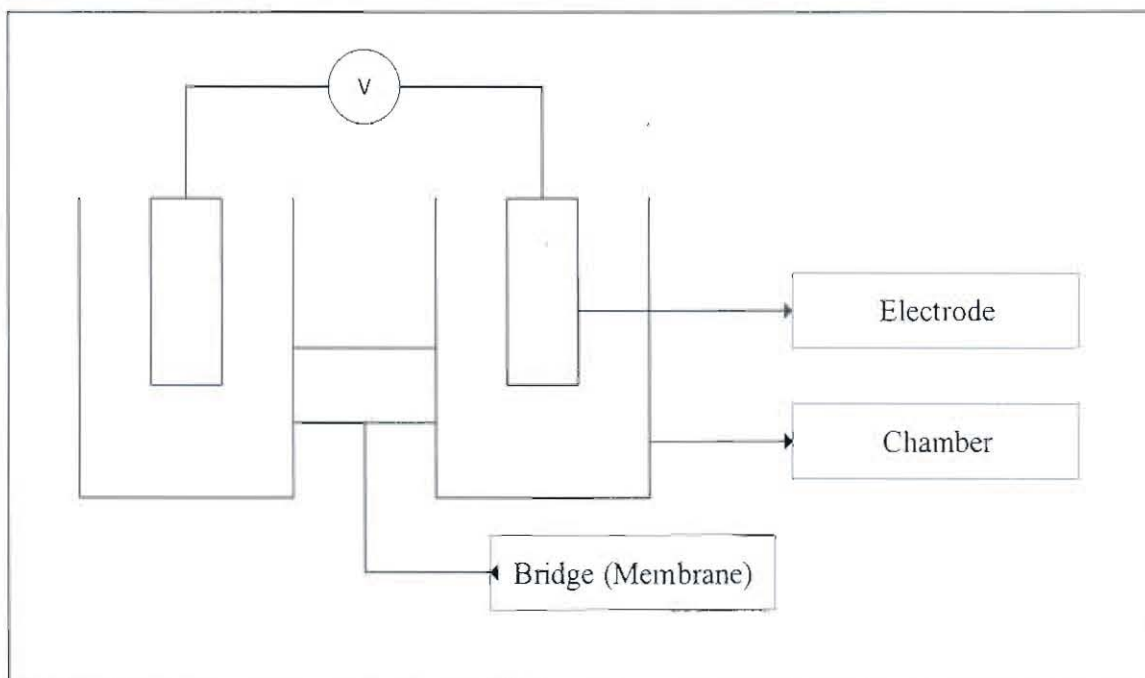


Figure 1.1 Simple H-shape systems MFC (Yi & Harper, 2009)

1.5 Problem Statement

Oil and gas are estimated to decline in 30 more years at current resource level growth. Malaysia has to restructure its balance of electricity generation to address the threats mentioned above. The government of Malaysia has decided to build a 2.0 GW

nuclear power plant as part of the solution, which is expected to be in service by 2030 (Ali et al., 2012).

After the 2011 nuclear disaster in Fukushima Daiichi, some countries were forced to close their nuclear plant as a security act to their nation. This accident has raised the perception of Malaysians that nuclear technology has its existing risks. Therefore, the possibility of a nuclear power supply is no longer acceptable to the community. Other long-term viable solutions for generating electricity in Malaysia need to be explored (Haiges et al., 2017).

MFC has been considered as one of the effective ways to generate electricity efficiently with low cost and environmentally friendly. MFC can generate electricity and treat wastewater simultaneously. Therefore, leachate can be used as the substrate as the amount of leachate in Malaysia has been increasing due to urbanization. Landfill leachate is an environmentally hazardous effluent and is creating a massive problem for landfill operators and the environment. Interest in treating this effluent is growing economically and environmentally towards sustainable solutions (Gálvez et al., 2009).

MFCs scalability is heavily studied to implement the system for a more significant scale application (Logan, 2010). Previous studies that related to scaling up MFC have shown that larger volume MFC systems often faced several limitations. Nevertheless, the maximum current densities produced by MFC between 10 and 25 A/m² are recorded, showing an unreasonable amount of power for small electrical appliances (Rabaey et al., 2010).

Electric connectivity is one of the possible arrangements in scaling up the systems. The MFC system can be connected in series or Parallel or the combination of Parallel and series depending on the desired output of voltage (Liu et al., 2008). The electrical configuration affects the ionic cross-conduction and resulting in the generation of the total production of power (Zhuang and Zhou, 2009).

Based on the previous studies, multiple MFCs with the larger electrode surface area were connected in series fluidically improved power output and efficiencies in treatment (Gálvez et al., 2009). Scaled-up sediments MFCs were electrically connected in Parallel, and the comparison between scaled-up and single-equivalent sediments MFC has been made. Based on the outcome of the study, the power output for both systems is similar for five months. After five months, the sediments MFCs that connected in Parallel

started to deliver higher power output (Ewing et al., 2014). Another study showed parallel-connected MFCs outperformed MFC connected in series during the treatment of swine wastewater in their set-up (Zhuang et al., 2012).

In response to this problem, a study proposed that it is possible to scale up power by using smaller-sized individually operated dual-chamber MFC as the enlargement of the size of the reactor decreases the power and current densities significantly (Gajda et al., 2018). To demonstrate the electronic scale-up approach, dual-chamber MFC was operated (called a dual-chamber MFC), and two independent dual-chamber MFC (called scaled-up MFCs) and leachate were used as the substrate.

1.6 Research Objectives

This project aims to treat leachate by using parallel configuration MFC and generating electricity simultaneously. This research focused on three objectives, and it is as follows:

1. To study the performance of Parallel Configuration MFC in leachate treatment;
2. To investigate the influence of MFC configuration towards wastewater parameters using statistical analysis and
3. To study the capability of Parallel Configuration MFC with leachate substrate in generating electricity.

1.7 Scope of the Study

The main focus of this research is on treating landfill leachate by using parallel configuration Microbial Fuel Cell (MFC) and generating the electricity simultaneously. The selected parameters such as the initial and final for Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), pH, Iron (Fe) and Manganese (Mn), Total Ammoniacal Nitrogen (TAN). The comparison between Individual Dual-Chamber MFC and Parallel Configuration MFC was made to determine the performance of both configurations in treating landfill leachate and generating the electricity simultaneously.