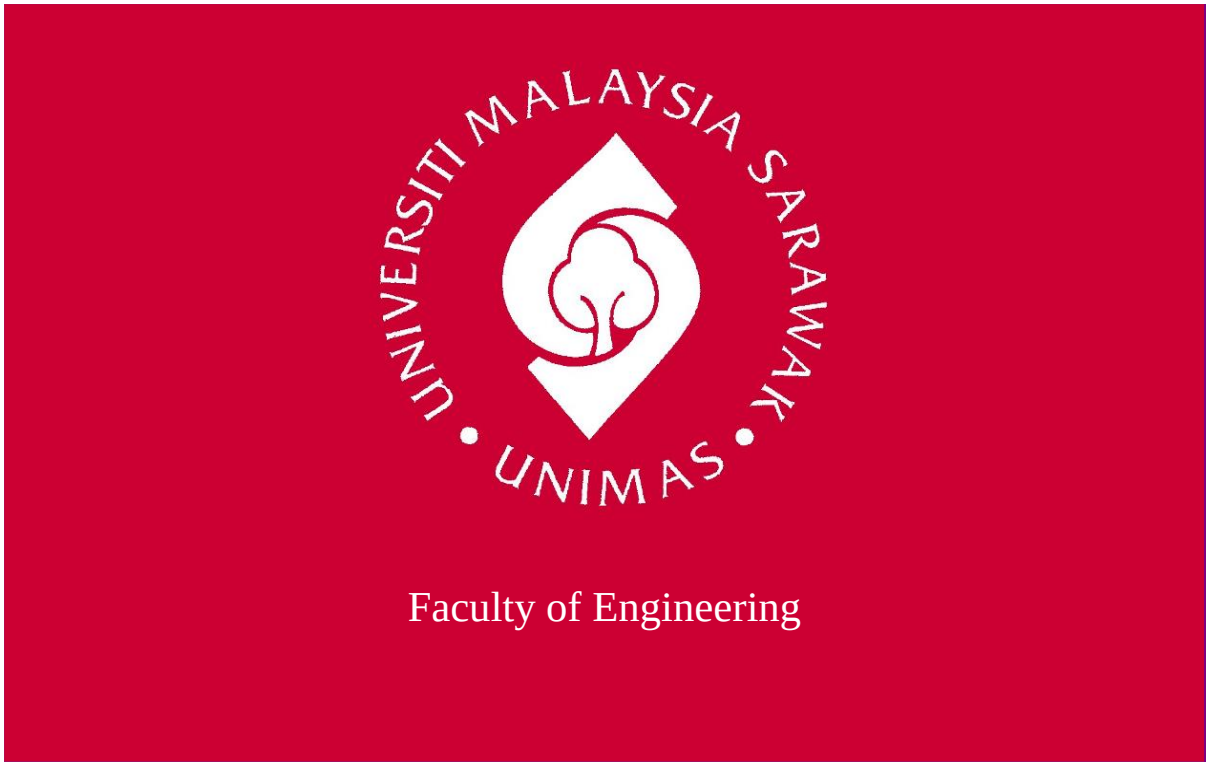

PALM OIL MILL EFFLUENT TREATMENT USING HYBRID MICROBIAL FUEL CELL-ACTIVATED CARBON SYSTEM

Noor Syazwani binti Salim

Bachelor of Engineering with Honours
(Chemical Engineering)
2017

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I, DR IVY TAN AI WEI hereby certificates that the work entitled, PALM OIL MILL EFFLUENT TREATMENT USING HYBRID MICROBIAL FUEL CELL-ACTIVATED CARBON SYSTEM was prepared by the above named students, and was submitted to the "FACULTY" as a * partial KNC 4344 Final Year Project Course fulfilment for the conferment of BACHELOR OF ENGINEERING WITH HONOURS (CHEMICAL ENGINEERING), and the aforementioned work, to the best of my knowledge, is the said student's work.

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APPROVAL SHEET

This project report which entitled **"Palm Oil Mill Effluent Treatment Using Hybrid Microbial Fuel Cell-Activated Carbon System"** was prepared by Noor Syazwani binti Salim (42776) is hereby read and approved by:

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DR IVY TAN AI WEI
(Supervisor)

25th JULY 2017
Date

PALM OIL MILL EFFLUENT TREATMENT USING HYBRID MICROBIAL FUEL CELL-ACTIVATED CARBON SYSTEM

NOOR SYAZWANI BINTI SALIM

A dissertation submitted in partial fulfillment

of the requirement for the degree of

Bachelor of Engineering with Honours

(Chemical Engineering and Energy Sustainability)

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2017

Dedicated to my beloved parents, my family and my friends who always bestow me sustainable motivations and encouragements

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ABSTRACT

Palm oil mill effluent (POME) is a thick brownish liquid which causes serious environmental pollution due to its high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) and POME can contaminate watercourses if discharged without proper treatment. Hybrid microbial fuel cell-activated carbon system is an innovative and progressive technology that brings many advantages in treating wastewater effectively, economically and environmental friendly. This study aims to investigate the feasibility of treating POME using hybrid microbial fuel cell-activated carbon (MFC-AC) system with methylene blue as mediator. The viability of the hybrid MFC-AC system in generating voltage, power density and current was also investigated. The air-cathode single chamber MFC-AC hybrid system with and without mediator was fabricated and the characterization of raw POME and treated POME were conducted by using COD, BOD, total suspended solids (TSS), ammoniacal-nitrogen (AN) and turbidity tests to evaluate the efficiency of the hybrid MFC-AC system to treat POME. From this study, 286.5 mV and 137.6 mV of voltage were generated in MFC-AC system with and without mediator respectively when using 50 Ω external resistances. The current generation of 5.73 mA and 2.75 mA and power generation of 2506.5 mW/m^3 and 577.9 mW/m^3 were produced respectively by the MFC-AC system with and without mediator. Other than that, these systems were able to reduce BOD up to 85.42% (39.38 mg/L) and 78.6% (58 mg/L), and COD up to 92.72% (48 mg/L) and 87.41% (83 mg/L) in the hybrid MFC-AC system with and without mediator, respectively. The TSS removal was 96.64% (9 mg/L) and 92.31% (36 mg/L) while turbidity removal was 96.75% (9 NTU) and 90.6% (26 NTU) in the hybrid MFC-AC system with and without mediator, respectively. The maximum AN removal of 46.48% (114 mg/L) was obtained in the hybrid MFC-AC system with mediator while for the system without mediator, the AN removal was 39.91% (128 mg/L). Overall, the MFC-AC system fabricated in this study was feasible to be applied for POME treatment as the effluent concentration was able to comply with imposed by Department of Environment, Malaysia.

ABSTRAK

Air Kumbahan Ladang Sawit (POME) adalah cecair keperangan pekat menyebabkan pencemaran alam sekitar yang serius disebabkan oleh kadar kandungan COD dan BOD yang tinggi dan dapat mencemarkan sumber air jika ia dikeluarkan tanpa rawatan yang betul., Kajian ini bertujuan untuk mengkaji kemungkinan merawat air kumbahan ladang sawit (POME) menggunakan hibrid microbial fuel cell-activated carbon (MFC-AC) sistem dengan dan tanpa pengantara. Perbandingan kebolehan hibrid MFC-AC sistem dengan dan tanpa pengantara dalam menjana voltan, ketumpatan kuasa dan arus. Sistem hibrid MFC-AC sistem berhawa ruang katod dengan dan tanpa pengantara adalah direka dalam kajian ini dan pencirian POME mentah dan POME dirawat dikenal pasti dengan menggunakan ujian kandungan kimia oksigen (COD), kandungan oksigen biologi (BOD), jumlah pepejal terampai (TSS), ammoniakal nitrogen (AN) dan kekeruhan untuk menganalisa kecekapan hibrid MFC-AC sistem untuk merawat POME. Sebanyak 286.5 mV dan 137.6 mV voltan telah dijana dalam sistem MFC-AC dengan dan tanpa pengantara, arus adalah 5.73 mA dan 2.75 mA dihasilkan dan penjanaan kuasa 2506.5 mW /m^3 dan 577.9 mW/m^3 dihasilkan dalam sistem MFC-AC dengan dan tanpa pengantara, masing-masing. Selain daripada itu, sistem ini dapat mengurangkan BOD sebanyak 85.42% (39.38 mg/L) dan 78.6% (58 mg/L), mengurangkan COD sebanyak 92.72% (48 mg/L) dan 87.41% (83 mg/L) dalam hibrid MFC-AC dengan dan masing-masing tanpa pengantara. TSS penyingkiran sebanyak 96.64% (9 mg/L) dan 92.31% (36 mg/L) manakala peratusan kekeruhan penyingkiran menunjukkan 96.75% (9 NTU) dan 90.6% (26 NTU) dalam hibrid sistem MFC-AC dengan dan tanpa pengantara masing-masing. Kepekatan AN telah terbaik dikeluarkan sebanyak 46.48% (114 mg/L) dalam hibrid sistem MFC-AC dengan pengantara manakala bagi tanpa pengantara, yang terbaik dikeluarkan bagi AN adalah sebanyak 39.91% (128 mg/L). Secara keseluruhan, sistem MFC-AC dibina dalam kajian ini boleh dilaksanakan untuk digunakan bagi rawatan POME dalam kepekatan efluen telah dapat mematuhi DOE melaksanakan had standard.

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ABBREVIATIONS

ACFF	Activated carbon fiber felt
AN	Ammoniacal nitrogen
BOD	Biochemical oxygen demand
CFB	Carbon fibre brush
COD	Chemical oxygen demand
EFB	Empty fruit bunch
FFB	Fresh fruit bunch
GAC	Granular activated carbon
GFB	Graphite fibre brush
HRT	Hydraulic retention time
MB	Methylene blue
MFC	Microbial fuel cell
MFC-AC	Microbial fuel cell-activated carbon
PAC	Powdered activated carbon
POME	Palm oil mill effluent
TSS	Total suspended solids

NOMENCLATURE

°C	Degree Celsius
µl/L	Microliter per liter
A	Ampere
cm	centimeters
cm^3	Cubic centimeters
g	Grams
h	Hours
I	Electric current
kg	Kilograms
L	Liters
L/min	Liters per minute
mA	Milliampere
mg/L	Milligram per liter
ml	Milliliters
mW/m^2	Milliwatt per square meter
mW/m^3	Milliwatt per cubic meter
mV	Millivoltage
NTU	Nephelometric Turbidity Unit
V	Volts
W/m^2	Watt per square meter
W/m^3	Watt per cubic meter
µA	Microampere
µl/L	Microliter per liter
µM	Micromolar
Ω	Ohms

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Palm oil mill effluent (POME) can be defined as a thick brownish color liquid that discharged from the palm oil processing process such as sterilization, crude oil clarification and cracked mixture separation that contribute as the biggest contributor of methane gas that has great impact on global warming (Sarawak Energy, 2013). Besides, when it is discharged into watercourses, it can pollute drinking water for human and animal communities due to its high acidity, temperature, biological oxygen demand (BOD), and chemical oxygen demand (COD) and also causing huge amount of algal growth on the surface of water and bringing harm to aquatic communities by creating highly acidic environment (Jia *et al*., 2010).

Treatment of POME has always been a topic of research due to its extremely rich in organic content that needs to be treated to minimize the environmental hazards before it is released to watercourses. Currently, there are several options available for treatment of POME. The most commonly used is ponding system due to its low cost, however, this treatment method requires high land of space (Wong, 1980). Other than that, anaerobic digestion such as anaerobic pond for the primary treatment of POME has also become one of the most common treatments used in palm oil mill to treat POME because it does not require additional energy and is easy to construct and operate. However, this treatment system requires long retention time, produces undesirable odors, shown the sizeable quantity of sludge deposit and can only reduce the small quantity of ammonia (Chin *et al*., 2013; Yacob *et al*, 2006). Next, the use of aerobic bacteria to treat POME which

involves the oxidation of all biodegradable organics, results in the biodegradation of the waste due to threaten the lives of the bacteria by death and this cause only few contaminants could be removed from POME. This biological treatment also causes problem of eutrophication in water bodies (Ademoroti, 1996).

Due to the adverse effects of the above mentioned techniques to treat POME, there is a crucial need to find an efficient and practical approach to preserve the environment while keeping up the supportability of the economy. Presently, the utilization of microbial fuel cell (MFC) as an alternative eco-friendly technique for removal of pollutants has been proven to be effective in treating POME and other wastewater. MFC is a device that uses bacteria as the catalyst to break down organic and inorganic matter to generate electric current by releasing the electrons to a mediator and mediator will transfer the electron to the anode electrode through proton exchange membrane (PEM) and appear in the cathode electrode linked by a conductive material containing a resistor (Roxby *et al*., 2014). Figure 1.1 shows the configuration of a typical MFC. Besides, MFC is capable of converting chemical energy into electrical energy where it utilizes the bacteria or microorganism in the substrate (such as POME or any other wastewater) to oxidize the organic substrate to create electrical power (Agarry *et al*., 2016).

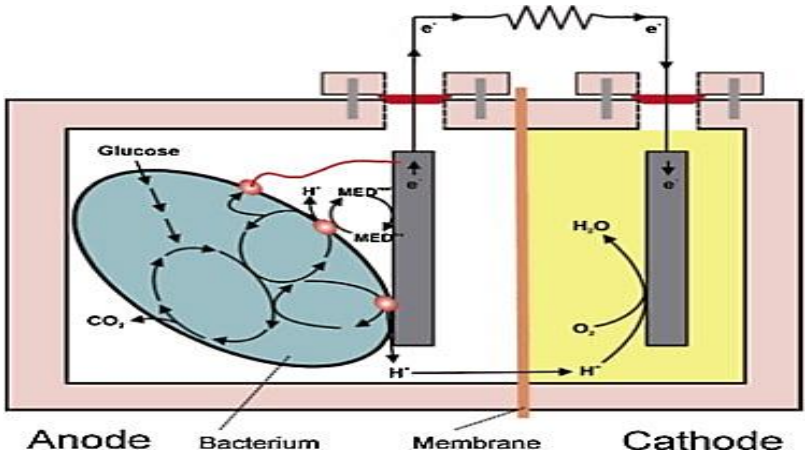

Figure 1.1: Microbial Fuel Cell System (Rahimnejad *et al*., 2015)

The utilization of MFC to treat wastewater seems to be conceivable because it is considered as a reliable, clean, efficient and economical process which utilizes renewable methods and does not generate any toxic by-product (Chaturvedi and Verma, 2016). Kong *et al*. (2010), Kalathil *et al*. (2011), Kalathil *et al*. (2012), Karra *et al*. (2012) and Tee *et al*. (2016b) stated in their studies that up to 70% of the chemical oxygen demand (COD)

could be removed from various wastewater by utilizing MFC. Additionally, MFC could be an effective technique to generate electricity and remove odor. Kim *et al*. (2008) demonstrated that MFC-based technology accelerated the rate of removing odor when the electricity generation achieved a higher of 228 mW/m^2. Puig *et al*. (2011) demonstrated that MFC used landfill leachate as a method of treating biodegradable organic matter and electricity production even with a high content of nitrogen and salinity. The amount of organic matter removed was 8.5 kg COD/m^3d when the power density was 344 mW/m^3.

MFC technology has been improved significantly in the recent decades to enhance its performance. By adding mediator into stand-alone MFC or integrating the stand-alone MFC to hybrid MFC are methods that can be used to improve and enhances the performance of MFC. Mediator such as methylene blue, natural red, tetramethyl-p-phenylenediamine, thionine and ferricyanide can enhance electron transfer from bacteria cell to the anode electrode in MFC and result in higher power generated (Bellucci, 2009). Furthermore, according to Tee *et al*. (2016a), stand-alone MFC can be categorized as under chemical-biological hybrid system while the hybrid MFC can be categorized as a physical-chemical-biological hybrid system with the addition of granular or powdered activated carbon as an adsorbent. Activated carbon is one of the effective adsorbents for contaminant removal that is widely used for water treatment plant in order to remove COD, TSS, toxicity, color, odor, and turbidity.

Integration of MFC with adsorption system (MFC-AC) and mediator has not been a new idea in the MFC designs because granular activated carbon (GAC) and mediator with MFC are able to deliver higher electricity generation at low COD concentration due to the adsorptive capacity of GAC that help in bacteria adhesion in the anode and mediator as electron promoter (Tee *et al*., 2016b; Rahimnejad *et al*., 2011). According to Tee *et al*. (2016b), typical biological electrochemical processes are not the only processes occur inside an MFC but physicochemical processes from the activated carbon play a significant role in the overall system because GAC acts as adsorbent and able to adsorb and remove a wide range of contaminants from the substrate which may not be able to remove through the stand-alone MFC. Thus, integration of MFC system with adsorption system can be a great hybrid system to improve the wastewater quality besides achieving bio-energy from the system.

In this study, integrated physical, chemical and biological treatment which is MFC-AC system is employed to adequately produce effluent that is superior compared to single methods. This physical-chemical-biological hybrid system consists of anode and cathode that separated by a proton exchange material. The anode side contains electrochemically active microorganisms or mediator while the cathode side is abiotic (Yan, 2013). The utilization of methylene blue as mediator in anode chamber of hybrid MFC-AC system is examined in this study because mediator has been conveyed to improve electricity generated in MFC and help the electrochemically active bacteria from POME to transfer the electrons to the electrode as well as to improve the performance of MFC by increasing the power output of the cell (Permana *et al*., 2015). The integration of MFC with adsorption system has been proven to be advantages compared to the stand-alone system of MFC which includes better overall treatment efficiency, energy saving potential and more stable and sustainable voltage generated (Tee *et al*., 2016b).

1.2 Problem Statement

Palm oil mill effluent (POME) is a thick brownish liquid which causes serious environmental pollution due to its high COD and BOD that will contaminate watercourses if it is discharged without proper treatment (Chin *et al*., 2013). Current technologies used to treat POME such as the bioremediation technology of ponding system majorly applied by almost over 85% of palm oil mills in Malaysia has several disadvantages which include large amount of land is required, long hydraulic retention time of 45 to 60 days, produces bad odor and difficult in maintaining the liquor distribution and biogas collection which gives bad impact to the environment (Rupani *et al*., 2010). Aerobic treatment system in the other hand acquires high energy for aeration process and is not suitable for land application due to its lower rate of pathogen inactivation that causes only little pathogen can be killed through this system (Abdurrahman *et al*., 2013).

Due to the adverse effects of these technologies, there is a surge for an eco-friendly method that can treat POME effectively and economically before being released into the receiving water bodies. Hybrid microbial fuel cell-activated carbon system is an innovative and progressive technology that brings many advantages in treating wastewater effectively, economically and environmental friendly. It minimizes odor

problem in the treatment system because it is operated as a closed system (Kim *et al*., 2008). It also acts as a bioenergy generation together with contaminant removal, where the current generation is dependent on the strength of wastewater and the power density. Besides, the cost can be reduced because by integrating MFC with AC, it will eliminate the aeration unit that consumes 50% of the electricity used at a treatment plant (Tee *et al*., 2016b).

Hybrid microbial fuel cell-activated carbon system has been proven effective in removing contaminants from POME and is capable to deliver higher electricity generation at low chemical oxygen demand (COD) concentrations due to the adsorptive capacity of granular activated carbon (GAC) (Tee *et al*., 2016b). Up to date, no study has been reported on the removal of contaminants in POME using hybrid MFC-AC system with addition of mediator. Methylene blue (MB) has been reported to improve the electricity generated in MFC by increasing the power generation. Therefore, in this study, the feasibility of using hybrid MFC-AC system with MB as mediator to treat POME is investigated.

1.3 Research Questions

The research questions to be addressed in this study are:

1. What is the treatment efficiency of hybrid MFC-AC system for palm oil mill effluent?
2. What is the effect of adding mediator on the electricity generated by the hybrid MFC-AC system?

1.4 Objectives

There are three objectives to be achieved in this research:

1. To fabricate a small-scale hybrid microbial fuel cell-activated carbon system for palm oil mill effluent treatment.

2. To investigate the performance of the hybrid MFC-AC system in removing the chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), ammoniacal nitrogen (AN) and turbidity from POME.
3. To compare the electricity generated by the hybrid MFC-AC system with and without mediator.

1.5 Scope of Study

Application of small-scale hybrid MFC-AC with and without mediator for the treatment of POME is the main focus of the present study. This small scale hybrid MFC-AC is fabricated to study its ability in treating POME obtained from Felcra Jaya Palm Oil Mill, Kota Samarahan. Water quality parameters such as BOD, COD, TSS, turbidity and AN of POME are measured and the comparison is done to analyze the ability of the system to remove pollutants in the POME. At the same time, the current, power density and voltage generated in the hybrid MFC-AC system with and without mediator are measured and compared.