DEVELOPMENT OF LABORATORY SCALE OF PALM OIL MILL EFFLUENT (POME) TREATMENT PLANT BY USING *ELAEIS GUINEENSIS* BIOSORBENT

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ABSTRACT

This thesis discussed on the application of new biosorbent as an alternative to treat the palm oil mill effluent. Palm Oil Mill Effluent (POME) has a very high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which is 100 times more than the municipal sewage. Currently, palm oil industries are facing tremendous challenges to meet the increasingly stringent environmental regulations. Hence, this study aims to help reducing the amount of potentially harmful compounds in Palm Oil Mill Effluent (POME) using *Elaeis Guineen*sis biosorbent before being discharged. Fourier Transform Infrared Spectroscopy (FT-IR) was used for identification of chemical properties of the *Elaies Guineensis* biosorbent. A laboratory scale plant prototype is developed to determine its ability to treat the palm oil mill effluent and operated at fixed condition as being studied by Aziela L. et al. Three times run of POME treatment were set at fixed contact time (25 minutes), pH of effluent (pH 2), mass of biosorbent (1.0 g), volume of effluent (1L) and feeding rate (200 rpm). The *Elaies Guineensis* biosorbent is used as the media for the reactor. The treatment prototype plant performance was studied by observing the wastewater parameters namely Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and the color of POME. FT-IR spectra analysis shows the chemical properties of *Elaeis Guineensis* biosorbent to be from the carboxylic acids (carboxyl, hydroxyl), alkanes (alkyl), amides (carboxamide), nitro compounds, amines, esters and halides group. The mean influent concentration of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were 103.0 mg/L and 2805.0 mg/L respectively. After treatment, the percentage of removal for BOD is ranged between 68% - 75%. Meanwhile, the percentage removal range varied from 8 % - 25 % was attained for COD. The color removal stood at range of 64% - 78%. Based on the results obtained, it can be concluded that *Elaies Guineensis* biosorbent can be used as an alternative and environmentally friendly way to treat Biochemical Oxygen Demand and for color removal of POME.

ABSTRAK

Tesis ini membincangkan aplikasi penjerapan bio yang baru sebagai alternatif untuk merawat efluen sawit. Efluen sawit (POME) mempunyai Keperluan Oksigen Biokimia (BOD) dan Keperluan Oksigen Kimia (COD) yang tinggi iaitu 100 kali ganda lebih banyak daripada kumbahan perbandaran. Pada masa ini, industri minyak sawit menghadapi cabaran yang besar untuk memenuhi peraturan alam sekitar yang semakin ketat. Oleh itu, kajian ini bertujuan untuk membantu mengurangkan jumlah sebatian yang berbahaya di dalam efluen sawit denagn menggunakan penjerapan bio *Elaeis Guineensis* sebelum efluen tersebut dilepaskan. Fourier Transform Infrared Spectroscopy (FT-IR) telah digunakan untuk pengenalpastian ciri-ciri bahan kimia di dalam penjerapan bio *Elaeis Guineensis*. Satu prototaip berskala makmal telah dibangunkan untuk menentukan keupayaan prototaip tersebut bagi merawat efluen sawit dan beroperasi dengan tetapan seperti yang dikaji oleh Aziela L. et al. Sebanyak tiga kali rawatan POME telah di jalankan dengan tetapan masa (25 minit), pH efluen (pH 2), jisim penjerapan bio (1.0 g), isipadu efluen (1L) dan kadar putaran (200 rpm). Penjerapan bio *Elaies Guineensis* digunakan sebagai media untuk reaktor. Prestasi loji rawatan prototaip telah dikaji dengan menilai produk akhir selepas rawatan iaitu Keperluan Oksigen Biokimia (BOD), Keperluan Oksigen Kimia (COD) dan warna POME. Spektra FT-IR menunjukkan ciri-ciri bahan kimia yang terdapat di dalam penjerapan bio *Elaies Guineensis* adalah dari kumpulan asid karboksilik (karboksil,hidroksil), alkana (alkil), amides (karboksamida), sebatian nitro, amina, ester dan bahan halida . Keperluan Oksigen Biokimia (BOD) dan Keperluan Oksigen Kimia (COD) efluen sawit sebelum rawatan adalah sebanyak 103.0 mg/L dan 2805,0 mg/L. Selepas rawatan, peratus penyingkiran bagi BOD adalah di antara 68% - 75%. Sementara itu, pelbagai peratusan penyingkiran berjulat dari 8% - 25% telah dicapai untuk COD. Penyingkiran warna berada pada julat 64% - 78%. Berdasarkan keputusan yang diperolehi, dapat disimpulkan bahawa penjerapan bio *Elaies Guineensis* boleh menjadi salah satu cara alternatif untuk merawat Keperluan Oksigen Biokimia (BOD) dan untuk penyingkiran warna efluen kilang sawit.

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LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
TSS	Total Suspended Solids
POME	Palm Oil Mill Effluent
FT-IR	Fourier Transform Infrared Spectroscopy
OLR	Organic Loading Rate
HRT	Hydraulic Retention Time
SEM	Scanning Electron Microscopy
TSS	Total Suspended Solids
APHA	American Public Health Association
P	Dilution Factor
Vs	Volume of Sample
Vdw	Volume of Dilution Water
DO1	DO of the diluted sample about 15 minute after preparation (mg/L)
DO5	DO of diluted sample after incubation for 5 days, (mg/L)

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter provides the general ideas on the subjects studied including the objectives, problem statement, scope of study, and significance of study.

1.2 BACKGROUND OF STUDY

Oil palm is one of the most versatile crops in tropical countries. Palm oil industry is one of the most important contributors to Malaysia economy. Today, Malaysia currently accounts for 39 % of world palm oil production and 44% of world exports. If taken into account of other oils and fats produced in the country, Malaysia accounts for 12% and 27% of the world's total production and exports of oils and fats. Being one of the biggest producers and exporters of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global need for oils and fats sustainably (Malaysian Palm Oil Council, 2013).

Malaysia's total oil palm planted area in 2008 expanded by 4% or 183,000 hectares. The total planted area in the country was at 4.49 million hectares against 4.30 million hectares in 2007. The expansion in oil palm area continued to be concentrated in the state of Sarawak while in the Peninsular and Sabah, planted area recorded only marginal increases (Malaysian Palm Oil Association, 2008).

The production of crude palm oil continued to increase for seven consecutive years reaching 15.0 million tons in 2005 from 14.0 million tons in the previous year. Therefore, a great action needs to be taken in order to guarantee the sustainable development in palm oil production.

Palm oil industries are facing tremendous challenges to meet the increasingly stringent environmental regulations. Over the past decades, several cost-effective treatment technologies comprising anaerobic, aerobic and facultative processes have been developed for the treatment of the waste-water generated from this industry called palm oil mill effluent (POME). POME is an oily wastewater generated by palm oil processing mills and consists of various suspended components. POME has a very high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which is 100 times more than the municipal sewage (Zafar, 2013). More than 85 % of palm oil mills use solely ponding systems due to their low costs. It has been reported that only a few mills are equipped with biogas recovery systems.

The environmental impact of POME cannot be over emphasized; hence there is need for treatment measures to reduce these impacts before discharge. The treatment of POME using Elaies Guineensis biosorbent is seen as one of the solution for the problem and concern arises. Through this research, wastewater treatment plant by using a new biosorbent is proposed. This initiative and alternative way of POME treatment is to be met and also aiming to meet-up with increasingly stringent environmental regulations.

1.3 PROBLEM STATEMENT

Palm oil mill effluent (POME) is the wastewater discharged from the sterilization process, crude oil clarification process and cracked mixture separation process. On average, palm oil mill in Malaysia produced 0.68 ton POME for each ton of FFB (fresh fruit bunches) processed (Abdul R. Z., 2015). A standard palm oil mill generate about 1 tons of liquid waste with Biochemical Oxygen Demand (BOD) 27 kg, Chemical Oxygen Demand (COD) 62 kg, Suspended Solids (SS) 35 kg and Oil and Grease (O&G) 6 kg. According to World Oil Data 2006, potential POME produced from all Palm Oil Mills in Indonesia was 34 million m^3 in 2005. This is equivalent to total COD loading of about 1.7 million tons resulting in 350,000 tons of methane (Zafar, 2013).

Palm Oil processing gives rise to highly polluting waste-water, known as Palm Oil Mill Effluent (POME) that produced huge amount of methane gas from its anaerobic process and has 21 times Global Warming Potential (GWP) compared to the other gasses. This waste-water then is often discarded in disposal ponds. This will result in the leaching of contaminants that pollute the groundwater and soil, and in the release of methane gas into the atmosphere. Such POME is a non-toxic waste, as no chemical is added during the oil extraction process, but will pose environmental issues if discharged directly due to its high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) concentration. This will cause large oxygen depleting capability in aquatic system due to organic and nutrient contents.

Wastewater treatment facility is amongst the most important component in the palm oil mill system. This is because the facility is used to treat palm oil mill effluent (POME) that is being generated in large volume during the production of crude palm oil (CPO). An increasingly stringent environmental regulations in view of the government's commitment to the conservation of the environment and increased public awareness of pollution problems caused the palm oil industries facing tremendous challenges as POME is a highly pollutant effluent.

1.4 RESEARCH OBJECTIVES

1.4.1 Main objective:

To study the feasibility of Palm Oil Mill Effluent (POME) treatment by using *Elaeis Guineensis* biosorbent.

1.4.2 Specific objectives:

- To determine the chemical characteristic of *Elaeis Guineensis* biosorbent;
- To develop a laboratory scale of POME treatment plant prototype by using *Elaeis Guineensis* biosorbent.

1.5 SCOPE OF STUDY

This study is conducted in order to study the feasibility of Palm Oil Mill Effluent (POME) treatment by determining the chemical characteristic of *Elaeis Guineensis* biosorbent and development of laboratory scale POME treatment plant. The Palm oil mill effluent (POME) is acquired from local palm oil industry for the study.

The chemical properties of *Elaeis Guineensis* biosorbent is examined using Fourier Transform InfraRed (FT-IR). A sample of Elaeis Guineensis biosorbent is tested in the laboratory to acquire the chemical properties.

The development of laboratory scale POME treatment plant is the main focus of this study. A laboratory scale treatment plant is designed and fabricated to study its feasibility for POME treatment by using *Elaeis Guineensis* biosorbent. The treatment plant is operated under fixed conditions as studied by Aziela L. et al; Application of *Elaies Guineensis* Leaves in Palm Oil Mill Effluent Treatment.

In this part of study, the effectiveness of POME treatment using the *Elaeis Guineensis* biosorbent is tested with three test parameters which are Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and the color changes. An experimental test is conducted to test the parameter chosen using guidelines set by APHA Standard Method (20th Edition) - Examination for water and wastewater.

1.6 SIGNIFICANCE OF STUDY

This study aims to help reducing the amount of potentially toxic compounds in Palm Oil Mill Effluent (POME) using Elaeis Guineensis biosorbent before being discharged. The study on the chemical characteristic of *Elaeis Guineensis* will provide a better understanding on the biosorbent used which is *Elaeis Guineensis* biosorbent.

Besides that, the palm oil industry will have an economical and effective alternative for removing toxic compounds from their industrial wastewater. As this study is important to find an effective alternative method for treating Palm Oil Mill Effluent (POME), it will also help the palm oil industry to meet with the regulations implemented by the Department of Environment.

Finally, this study will provide information for future research. It can be a baseline data for future research related to Palm Oil Mill Effluent (POME) treatment. An environmental friendly wastewater treatment plant can help preserve the environment and reduce the high cost of wastewater treatment nowadays.

1.7 SUMMARY

This study aims to help reducing the amount of potentially toxic compounds in Palm Oil Mill Effluent (POME) using *Elaeis Guineensis* biosorbent before being discharged. The problems rise due to highly polluting waste-water, known as Palm Oil Mill Effluent (POME) which produced huge amount of methane gas, Biochemical Oxygen Demand and Chemical Oxygen Demand from its anaerobic process will increased perpendicularly with the increase in production of crude palm oil. Hence, the use of *Elaies Guineensis* biosorbent is seen to be one of the economical and an environmental friendly way to treat the wastewater from the process.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides the review of past literature and relevant studies on palm oil mill effluent generally and the treatment of the effluent in specific.

2.2 MALAYSIA PALM OIL INDUSTRY

Malaysia is the second largest exporter of palm oil in the world after Indonesia. In year 2010, the number of palm oil products exportation was rocketed to achieve 16.5 million tones (A. H. Ibrahim et. al., 2012). Malaysia currently accounts for 39 % of world palm oil production and 44% of world exports. If taken into account of other oils and fats produced in the country, Malaysia accounts for 12% and 27% of the world's total production and exports of oils and fats (Malaysian Palm Oil Council, 2014). Table 2.1 shows the percentage of world palm oil production in 2008.

Table 2.1: 2008 World palm oil productions

Countries	Tones ($x10^3$)	% Share
Indonesia	19000	44.5
Malaysia	17735	41.3
Thailand	1160	2.7
Nigeria	860	2.0
Columbia	800	1.9
Others	3250	7.5

Source: A. H. Ibrahim et. al., 2012

2.3 PALM OIL

Palm oil is derived from the flesh of the fruit of the oil palm species E. Guineensis. In its virgin form, the oil is bright orange-red due to the high content of carotene. Palm oil is Nature's Gift to Malaysia, and Malaysia's to the World. Palm oil is semi-solid at room temperature; a characteristic brought about by its approximate 50 percent saturation level. Palm oil and its products have good resistance to oxidation and heat at prolonged elevated temperatures; hence, making palm oil an ideal ingredient in frying oil blends. Manufacturers and end-users around the world incorporate high percentages of palm oil in their frying oil blends for both performance and economic reasons. In fact, in many instances, palm oil has been used as 100 percent replacement for traditional hydrogenated seed oils such as soybean oil and canola. Products fried in palm oil include potato chips, French fries, doughnuts, ramen noodles and nuts (Malaysian Palm Oil Council, 2014).

2.4 PALM OIL MILL EFFLUENT (POME)

Huge quantities of waste are produced in the palm oil mill industry. The process of oil extraction results in generation of liquid waste commonly named as palm oil mill effluent (POME). POME is a thick brownish viscous liquid waste which is nontoxic but has unpleasant odor which contains soluble materials that may have a significant impact on the environment. POME mainly in formed of colloidal suspension of 95 - 96% water, 0.6 - 0.7% oil and 4 - 5% total solids including 2 - 4% suspended solids originating from the mixing of stabilizer condensate, separator sludge and hydro cyclone wastewater that are mostly debris from palm fruit mesocarp (Mohammed, 2013). In year 2008, there were approximately 53 million tons of POME were generated in Malaysia (A. H. Ibrahim et. al., 2012). Palm oil mill effluent is generated mainly from oil extraction, washing and cleaning processes in the mill and these contains cellulosic material, fat, oil and grease (P. F. Rupani et. al., 2010). Among the waste generated, palm oil mill effluent (POME) is considered the most harmful waste for the environment if discharged untreated.

2.4.1 CHARACTERISTICS OF POME

Characteristics of palm oil mill effluent depend on the quality of the raw material and palm oil production processes in palm oil mills. In general appearance, palm oil mill effluent (POME) is a yellowish acidic wastewater with fairly high polluting properties, with average of 25,000 mg/l Biochemical Oxygen Demand (BOD), 55,250 mg/L Chemical Oxygen Demand (COD) and 19,610 mg/l Suspended Solid (SS). This highly polluting wastewater can cause several pollution problems. Therefore, direct discharge of POME into the environment is not encouraged due to the high values of COD, BOD and SS (A. H. Ibrahim et. al., 2012). Typically, palm oil mill wastewater is low in pH because of the organic acids produced in the fermentation process, ranging about 4-5. It also contains large amounts of total solids (40,500 mgl^{-1}), oil and grease (4000 mgl^{-1}) (P. F. Rupani et. al., 2010). The comparison of POME characteristics from previous research data are presented in Table 2.3.

Table 2.3: Measured Parameter of Malaysian POME from Previous Characteristic Studies

Parameters	Ma and Ong	Ahmad et al.	MPOB	Zinatizadeh et al.	Wu et al.	Vijayaraghavan. K., et al.	Wood et al.; Wong. et al.
BOD5	25000	25000	25000	22700	-	25545	21500 - 28500
COD5	-	50000	50000	44300	70900	55775	45500 - 65000
TS	-	40500	45000	-	-	-	33790 - 37320
SS	19000	18000	18000	19780	25800	18479	15660 - 23560
O&G	8000	4000	4000	4850	-	8020	1077 - 7582
TN	770	750	750	-	-	711	500 - 800
pH	4.5	4.7	4.7	4.05	4.52	3.4 - 3.6	4.15 – 4.45
Temp(°C)	80 - 90	-	-	-	-	83 - 85	-
VSS	-	-	-	-	-	-	27300 - 30150

(All parameters in mg/L, except pH)

Source: A. H. Ibrahim et. al., 2012

2.5 REGULATORY STANDARD

Malaysian palm oil industry is a highly regulated industry. Due to that environmental impact factors, industries should preserve the sustainability of environmental for future generation. There is always a need for concern over the protection and management of water resources. In 1975 the Department of Environment (DOE) was established and in 1977, DOE announced standards for the quality of POME discharge into watercourses that became increasingly stringent (A. H. Ibrahim et. al., 2012).

Currently, the industry is adhered to more than 15 laws and regulations including the Land Acquisition Act 1960, Environmental Quality Act 1974, Environmental Quality (Clean Air Regulations) 1978, Pesticides Act 1974 (Pesticides Registration Rules), Occupational Safety and Health Act (1977), and Protection of Wildlife Act 1972. The industry is also complying with Hazard & Critical Control Points (HACCP) and the Environmental Impact Assessment (EIA) requirements (Malaysian Palm Oil Council, 2014). The parameter limits for water discharge of effluent from palm oil industry are presented in Table 2.4.

Table 2.4: Parameters limit for water discharge of effluent from palm oil industry

Parameters	Units	Parameters limit for POME discharge	Remarks
Biochemical Oxygen Demand BOD3; 3days at 30 °C	mg litre^{-1}	100	-
Chemical Oxygen Demand	mg litre^{-1}	*	-
Total Solids (T.S)	mg litre^{-1}	*	-
Suspended solid	mg litre^{-1}	400	-
Oil and Grease (O&G)	mg litre^{-1}	50	-
Ammoniacal nitrogen	mg litre^{-1}	150	Value of filtered sample (GF/B)
Total nitrogen	mg litre^{-1}	200	Value of filtered sample (GF/B)
pH	-	5-9	-
Temperature	°C	45	-

Note: *No discharge standard after 1984

Source: L. S. Keang et. al. , 2009

2.6 POME TREATMENT METHOD

Currently, one of the challenging problems faced by Malaysia and many countries in the world is how to manage all type of wastes especially liquid wastewater. Many researchers around the world have studied the characteristics and treatments of various type of liquid wastewater, including synthetic wastewaters. There are basically two types of treatment method which are the aerobic method and anaerobic method.

2.6.1 Aerobic Treatment Method

Aerobic treatment is a process where bacteria utilize oxygen to degrade organic matter (generally quantified as biochemical oxygen demand or BOD) and other pollutants involved in various production systems. Aerobic digestion of waste is the natural biological degradation and purification process. During oxidation process, pollutants are broken down into carbon dioxide (CO2), water (H2O), nitrates, sulphates and biomass (microorganisms). By operating the oxygen supply with aerators, the process can be significantly accelerated (Haandel & Lubbe, 2007). The two most common types of aerated wastewater systems are activated sludge systems and aerated stabilization basins (ASBs). ASBs are commonly found as treatment systems in the pulp and paper industry and are used in some municipalities, as well as other industries (EBS, 2014). Aerobic digestion does not produce methane as a by-product (WasteWater System, 2013).

2.6.1.1 Aerobic Digester

Aerobic digesters are usually constructed as completely mixed reactors. The reactor may be fed continuously or intermittently with excess sludge. The objective of the digestion is to reduce the fraction of biodegradable organic material to a level that the digested sludge can be disposed of without problems. The design of aerobic digester are important which considers the flow and composition of the sludge to be digested, maximum allowable fraction of active sludge remaining after digestion, the digestion temperature and the configuration of the aerobic sludge digester (Haandel & Lubbe, 2007).

2.6.1.2 Aeration System

Aeration system is the core of biological treatment process using oxygen consuming bacteria similar to the unit processes taking place in an aerobic digester or if large area of land is available. Aeration system using medium sized basin usually have much lower capacity with detention time that goes up to only 12 to 48 hours and thus the F/M ratio is much lower. Typical design using diffusers must be able to supply at least 2 to 3 lb of oxygen and same goes if surface aerators are installed instead (WasteWater System, 2013).

2.6.1.3 Activated Sludge Systems

In a wastewater treatment plant, it is important to control the Activated Sludge Process because this is the step whereby significant reduction in BOD and COD will take place. To ensure best performance, several control measures must be put in place such as ensuring that there is sufficient level of dissolved oxygen in the aeration tank and also adjusting the return and take off rate of activated sludge and waste sludge from the system (WasteWater System, 2013).

Activated sludge settlers are applied to effect the separation of the solid (sludge) and the liquid phase of the mixed liquor. Settlers are operated as continuous units, discharging an effluent that is substantially free of solids, while the settled solids are recycled to the aeration tank. Activated sludge settlers are also called final or secondary settlers or clarifiers to distinguish them from primary settlers that are used for settling of raw waste water. Activated sludge settlers perform two functions simultaneously which are the clarification of the liquid-solid separation necessary to produce an effluent free of suspended solids and the thickening; the increase of the suspended solids concentration in the return sludge flow during its passage through the final settler (Haandel & Lubbe, 2007).