TREATMENT OF PALM OIL MILL EFFLUENT (POME) USING MEMBRANE BIOREACTOR

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“Saya/Kami* akui bahawa saya telah membaca karya ini dan pada pandangan saya/kami* karya ini adalah memadai dari segi skop dan kualiti untuk tujuan Penganugerahan Ijazah Sarjana Muda Kejuruteraan Kimia.”

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DEDICATION

This thesis is a symbol of appreciation for my most beloved parents, Mr. Haris Bin Liew and Mrs. Fatimah Binti Abdullah, my brothers Faizal and Zarid Izwan.

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ABSTRACT

Malaysia is the largest producer and exporter of palm oil. The serious problems in the palm fruit processing is the managing of the wastes generated during the processes. The wastes consist of a significant amount of solid wastes and a wastewater called palm oil mill effluent (POME). POME is a thick brownish liquid that contains high amount of total solids (40,500 mg/L), oil and grease (4000 mg/L), Chemical Oxygen Demand (50,000 mg/L), and Biochemical Oxygen Demand (25,000 mg/L). This highly polluting effluent is becoming a major problem to environment as if it not being treated well before discharged based on standard limit imposed by The Malaysian Department of Environment for effluent discharged. A POME treatment based on membrane technology, which is also an alternative treatment, shows highly potential to overcome the environment problem. Before membrane bioreactor pilot plant system is being introduced, a bioreactor in lab-scale is being set-up to determine the vital information regarding the most effective way to treat the wastewater. Samples from mixing ponds which act as activated sludge are collected and being analyze using water analyzer method to obtain parameters such as BOD, COD, suspended solid, turbidity and pH. Wastewater sample from facultative ponds is also being analyzed than mix with activated sludge treated in the bioreactor. Result from lab-scale bioreactor is used in membrane bioreactor pilot plant system to treat the wastewater. Result from bioreactor treatment in pilot plant scale show a decrement 61.2 % of BOD and 58.9% of COD, suspended solid and turbidity is also reducing up 35.3% and 20.4% with pH in range of 5-9. After the wastewater was treated in the ultrafiltration membrane system, high quality water with total of deterioration for all parameter is up to 99.9% and pH up to 7.39. This results show that the membrane bioreactor treatment system is highly effective in treating POME.

ABSTRAK

Malaysia adalah pengeluar dan pengeksport terbesar minyak kelapa sawit. Masalah yang kritikal dalam pemprosesan minyak kelapa sawit adalah pengurusan buangan hasil pembuatan minyak kelapa sawit itu sendiri. Sisa-sisa itu mengandungi sejumlah besar sisa pepejal dan sisa air tercemar itu dikenali sebagai effluen kilang minyak kelapa sawit atau POME. POME merupakan cecair likat keperangan yang mengandungi jumlah pepejal yang tinggi (40,500 mg/L), minyak dan gris (4000 mg/L), Pemintaan Oksigen Kimia atau COD (50 000 mg/L) dan Permintaan Oksigen Biokimia atau BOD (25 000 mg/L). Efluen yang mencemarkan ini bakal menjadi masalah besar kepada alam sekitar sekiranya tidak dirawat sebelum dibebaskan berdasarkan nilai yang ditetapkan oleh Jabatan Alam Sekitar Malaysia. Rawatan POME menerusi teknologi membran, yang merupakan rawatan alternatif, menunjukkan potentsi yang tinggi dalam mengatasi masalah pencemaran ini. Sebelum sistem membran bioreaktor diperkenalkan, bioreaktor skala makmal disediakan bagi menentukan maklumat penting bagi mencari cara paling efektif untuk merawat sisa tersebut. Sampel dari kolam campuran yang bertindak sebagai lumpur aktif dikumpul dan dianalisa menggunakan kaedah penganalisa air bagi menentukan BOD, COD, pepejal termendap, kekeruhan dah pH. Sisa buangan dari kolam fakultatif juga dianalisa dan kemudian dicampur bersama dengan lumpur aktif untuk dirawat di dalam bioreaktor. Keputusan dari skala makmal kemudian digunakan dalam skala besar membran bioreaktor untuk merawat sisa buangan tersebut. Keputusan dari rawatan bioreaktor menunjukan penurunan 61.2% bagi BOD dan 58.9% bagi COD, pepejal termendap dan kekeruahan juga menurun 35.3% dan 20.4% dengan pH dalam skala 5-9. Setelah sisa tersebut dirawat menggunakan penapisan ultra, air yang berkualiti tinggi diperoleh dengan jumlah penurunan sebanyak 99.9% bagi semua parameter dan pH 7.39. Keputusan ini menunjukan bahawa sistem membran bioreaktor ini sangat berkesan dalam merawat POME.

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CHAPTER I

INTRODUCTION

1.1 Introduction

The history of palm oil can be traced back to the days of the Egyptian paraohs 5000 years B.C. It was introduced to Malaysia at the start of the 20th century and commercially produced in 1917. Palm oil's unique composition makes it versatile in its application in food manufacturing and in the chemical, cosmetic and pharmaceutical industries. Its semi-solid physical properties are needed in much food preparation. Its non-cholesterol quality and digestibility make it popular as source of energy, while its technical and economic superiority makes it preferable as base material in the manufacture of various non-edible products.

The Malaysian experience in effluent control in the palm oil industry due to the opening of the factory vastly. Palm oil mill effluent (POME) contains a high concentration of organic matter. This polluting effluent with its high content of chemical oxygen demand (COD), 50,000 mg/L, biological oxygen demand (BOD), 30,000 mg/L, oil and grease, 6000 mg/L, suspended solids, 59,350 and 750 mg/L of total nitrogen can easily cause severe pollution of waterways due to oxygen depletion and other related effects [1].

Malaysia’s daily newspaper New Straits Times Press (NSTP) has published an article by S. Ching Ji stated that in 1977, the Asian Institute of Technology (AiT), based in Thailand, and the Division of Environment (DOE) of the Ministry of Science, Technology and Environment of Malaysia began a study to identify appropriate palm oil treatment technologies. In 1979, IDRC provided a grant that enabled researchers to assess the available technologies, and determine the most feasible for further development.

Membrane technology is a highly potential solution for the treatment of POME since the current conventional treatment system shows its lack of efficiency and this unfortunately leads to the environmental pollution issues. The conventional system based on biological treatments of anaerobic and aerobic systems need proper maintenance and monitoring as the processes depend solely on microorganisms to degrade the pollutants. Membrane bioreactor systems (MBRs) have, over the past ten years, emerged as an effective solution to transforming various wastewaters into high quality effluent suitable for discharge into the environment and increasingly into a reusable product.

A membrane bioreactor (MBR) combines the activated sludge process with a membrane separation process. The reactor is operated similar to a conventional activated sludge process but without the need for secondary clarification and tertiary steps like sand filtration. Low-pressure membrane filtration, either microfiltration (MF) or ultrafiltration (UF) is used to separate effluent from activated sludge [2]. The two main MBR configurations involve either submerged membranes or external circulation (side-stream configuration).

Alternative process that can be used to treat POME is by evaporation. Using POME containing 3-4% total solid as feed, about 85% the water in the POME can be recovered with distillate. Unfortunately, the energy requirement is a major constraint in this process, whereby under standard condition, specific energy consumption is very high where 1 kg of steam is required per 1 kg of water evaporated [3].

1.2 Problem Statement

Today, Malaysia and Indonesia dominate the Palm Oil industry but, this may not be for long. By 1997 (oil palms) occupied 6.5 million hectares and produced 17.5 million tonnes of palm oil and 2.1 million tonnes of palm kernal oil a year [4]. The processing of the oil releases some 2.5 tonnes (of effluents into the water) for each tonne of oil processed [5].

The membrane bioreactor (MBR) concept has received considerable attention from design engineers, public health professionals and research workers interested in process alternatives for industrial wastewater treatment such as POME [6]. Worldwide MBR inventory in centralized industrial wastewater applications has increased considerably since 1995, and the volume of water treated by MBR plants is estimated to be growing by 20% per year.

POME is a waste that came from palm oil industry and it is compulsory to treat the waste before it being release into the environment. In the recent time, ponding system has been use to treat POME. The decision on whether or not to use this system depends on many factors. The main factors are land price, conditions of the surrounding area and the loss of biogas as a source of energy. The main problem faced by palm oil industry in Malaysia is requirement of large scale of land. Because of that factor, high cost of maintenance such as labor monitoring will be needed by the industry in order to treat the waste.

Therefore, membrane bioreactor was introduced as an addition to improve current method-ponding system. This MBR system can be used to decrease the number of ponds which help industry to reduce their cost of maintenance.

1.3 Objective

The purpose of this thesis is:

(1) to treat wastewater from Palm Oil Mill Effluent (POME) using membrane bioreactor in order to achieve DOE standard before discharging to the river.

1.4 Scope of the research work

In order to achieve the target, extra effort and focus have to be done:

(1) to determine characteristic POME from ponding system before and after entering the bioreactor

(2) to study the bioreactor system before introducing to membrane system using lab. scale

(3) to apply finding parameters in lab. scale in actual membrane bioreactor pilot plant

CHAPTER II

LITERATURE REVIEW

2.1 Palm Oil

The history of palm oil can be traced back to the days of the Egyptian paraohs 5000 years B.C. The palm oil, however, is a native of West Africa. It was introduced to Malaysia at the start of the 20th century and commercially produced in 1917. Today Malaysia's palm oil plantations cover 40% of its cultivated land, and it has become the world's largest producer and exporter of palm oil. The palm oil, Elaeis guineensis, is native to Africa. Its commercial value lies mainly in the oil that can be obtained from the mesocarp of the fruit - palm oil - and the kernel of the nut - palm kernel oil. Palm oil is used mainly for cooking (cooking oil, margarine, shortening, etc.) and has non-food applications (soap, detergent, cosmetics, etc.).

2.2 POME (Palm Oil Mill Effluent)

In Malaysia, the palm oil industry was the worst source of water pollution. Pollution caused by the organic wastes from palm oil mills was equivalent to pollution generated by a population of more than 10 million people (nearly as large as the entire population). Palm oil mill effluent (POME) contains a high concentration of organic matter. COD concentration is in the range of 45,000 to 65,000 mg/l, 5-day BOD 18,000 to 48,000 mg/l and oil and grease greater than 2,000 mg/l. The COD: N: P ratio is around 750:7.3:1.

The process to extract the oil, which is used in the manufacturing of margarine and other edible products, requires large quantities of water for steam sterilizing the palm fruit bunches resulting in concomitant production of wastes in the forms of palm oil mill effluent (POME), empty fruit bunches, mesocarp fibre and shell, and clarifying the extracted oil. Malaysia experience in effluent control in the palm oil industry demonstrates that a set of well-designed environmental policies can be very effective in controlling industrial pollution in a developing country.

The Malaysian government's effort to reduce the effluent from the palm oil industry has been implemented through a licensing system, which mainly consists of effluent standards and effluent charges. Progressively stringent effluent standards were stated in a government environmental quality regulation and were implemented in four stages. Specifically, after being given one year to install treatment facilities, palm oil mills were required to reduce their wastewater discharges, taking biological oxygen demand (BOD) concentration as the key parameter, from 25,000 mg/l untreated effluent to 5,000 mg/l in 1978/79, to 500 mg/l by 1981, and to 100 mg/l by 1984 onward.

It is apparent that the oil palm industry is ecofriendly in every aspect of its activities. Right from the plantation to the refinery, the industry's commitment for cleaner environment is unquestionable. The achievement in controlling POME pollution bears testimony on the seriousness of both the government and the private sector to see a greener Malaysia. Together they formed a synergistic teamwork that tackled the problem in record time. Indeed, the solution to POME problem paved the way for growth of the industry to what it is today. Therefore, there are several techniques that could be practiced in treating POME, which are Anaerobic Digestion System, Extended Aerobic Process, Ponding System, Composting System and Bioreactor System.

2.3 Treatment of POME (Palm Oil Mill Effluent)

Treatment of palm oil mill wastewater has the following two main objectives:

1. To adjust the existing insufficient quality of POME to a load level (i.e. oil and grease) suitable to the individual fertilizing conditions; here partial treatment would be sufficient. This treatment will not significantly reduce the content of dissolved mineral substances.
2. To meet the requirements for effluent discharge into surface waters; in this case full treatment would be necessary.

The decision for selection of the most suitable wastewater treatment system has to be based on the wastewater characteristics of the particular factory. Other factors which have to be considered are: flow rate pattern, available space and location of wastewater treatment plant, required degree of treatment, fixed and operating costs of treatment, type of operation method and experience of the operator.

2.4 Primary Wastewater Treatment

2.4.1 Segregation of Wastewater Streams

The wastewater from the palm oil industry has the following effluent streams that is high polluted effluent; i.e. effluent from sterilizer and oil room, low polluted effluent; i.e. steam condensate and indirect cooling water from oil dryer/cooler; boiler house discharge (except if it contains high concentrations of phosphorus or other inhibitors), and sanitary effluent; i.e. toilet, bathrooms and canteen. Therefore, minimize overall treatment costs the different wastewater streams should be collected and treated separately.

The highly polluted wastewater streams from a palm oil mill have different suspended solid contents, which influence the effectiveness of the pre-treatment system. The highly polluted effluent streams, therefore, should be further classified into two categories:

1. Low suspended solids content wastewater; i.e. sterilizer condensate, and oil discharged from leakage
2. High suspended solids content wastewater; i.e. oil room effluent

Because of the significant difference in quality and treat ability, the two waste streams should be collected separately as follows:

1. combine all streams with little or no suspended solids (SS)
2. combine the remaining effluent streams with high SS concentration
   - avoid recirculation of streams with high SS content with raw wastewater streams for oil recovery (i.e. never utilize the water phase of the centrifuge/separator for dilution purposes in the settling tank)

2.4.2 Oil Separation

In order to make oil separation/recovery as efficient as possible, the different wastewater streams should be treated separately in gravity type oil separators. The removal/recovery of oil by means of gravity separator pre-treatment contributes to improved production yield and minimizes the organic loading to the subsequent biological treatment system. Because of the high oil content in the raw wastewater, the remaining oil content in the pre-treated effluent will still be rather high at > 250 mg/l. However, these conditions have to be accepted and considered for the subsequent methods of effluent utilization or treatment:

2.4.2.1 Low Suspended Solids Content Wastewater

Since the oil in this type of wastewater is mainly in the free form, removal/recovery can be easily achieved in gravity type oil separators. The pre-treated wastewater could be recycle/reuse in the mill. Design criteria for gravity type oil separator:

1. The oil trap should be designed for the maximum flow rate
2. Permissible surface loading rate: 2 to 6 m3/(m2*h) depending on results from lab tests (separation speed)
3. Accidental discharge of oil through leakage or equipment failure should be considered in the design
4. Installation of an automatic oil skimming device will help to recover good quality oil

Oil separation efficiency for this wastewater stream by gravity type oil trap is in the range of 60 to 90 %.

2.4.2.2 High Suspended Solids Content Wastewater

Since this wastewater is generated by oil separation equipment using very high acceleration forces compared with the gravity oil trap, further oil removal by gravity separation will be marginal. However, installation of gravity type oil traps for this type of wastewater is recommended mainly as a safety device for cases of accidental oil discharge from equipment failure or other types of oil leakage.

1. Design criteria:

- The oil trap should be designed for the maximum flow rate (as liter/second).
- Permissible surface loading rate 0.5 m3/ (m2*h)
- For storage and thickening of settled solids the depth of the trap should be considered carefully. The trap should be divided into several compartments by either bottom baffles (for bottom sludge) or surface baffles (for detention of floating oil).
- Installation of an automatic oil skimming device will help to recover good quality oil.

2.5 Secondary Wastewater Treatment

The most appropriate secondary treatment method for palm oil mill wastewater is biological digestion. Preconditions are mainly organic substances are to be treated, and absence of substances toxic to biological decomposition; operational difficulties for palm oil mills can be expected only in case of excessive oil discharge. If the anaerobically treated effluent is used for irrigation, no secondary treatment is necessary. However, if the final effluent is discharge to a public watercourse, secondary treatment in the form of an aerobic treatment step is necessary after anaerobic treatment.