DEVELOPMENT OF MEMBRANE ANAEROBIC SYSTEM MAS (MAS) FOR PALM OIL MILL EFFLUENT (POME) TREATMENT

NOR SHAFIQAH BINTI MOHD NASIR

A thesis submitted in fulfillment of the requirements for the award of the degree
Of Bachelor of Chemical Engineering (Gas Technology)

Faculty of Chemical & Natural Resources Engineering
Universiti Malaysia Pahang

FEBRUARY 2013

DEVELOPMENT OF MEMBRANE ANAEROBIC SYSTEM FOR PALM OIL MILL EFFLUENT (POME) TREATMENT

ABSTRACT

Palm oil is one of the world most rapidly expanding industries. Oil palm industry currently occupies the largest acreage farm land in Malaysia. This industry contributes towards economic growth and rapid development but unfortunately as well as environmental issues. One of the wastes generated from the palm oil industry known as palm oil mill effluent (POME) can contributes to the environmental issues if it is not treated properly before discharging to the environment. In this study, POME treatment was carried out in a laboratory scale membrane anaerobic system (MAS) that shows highly potential to overcome the environmental problems. The MAS consists of cross flow ultrafiltartion membrane for solid-liquid separation with operating pressure1.5 to 2.0 bars. The fed consists of 30 L of POME used inside the reactor and the hydraulic retention time (HRT) ranged between 1 to 4 days to allow the acclimization phase of the wastewater. Based on the results obtained, the percentage of methane production ranged from 60.00% to 69.79% per day. The overall percentage removal efficiency for the parameters measured in this experiment includes the percentage of BOD removal range from 61.45% to 72.66%, percentage of TSS removal range from 86.05% to 88.94%. There are also measurement for the percentage removal of ammonia with removal efficiency of 20% to 28.94% and the percentage removal of nitrate presence in the POME with removal percentage of 45% to 77.89% efficiency. The MAS performance was affected by the solid retention time, hydraulic retention time, organic loading rates, pH and operating temperature. Hence, MAS is the suitable alternatives for treating the wastewater. The production of methane gas from this process also can be considered as the valuable product and as one type of energy source.

PERKEMBANGAN OF SISTEM MEMBRAN ANAEROBIK UNTUK RAWATAN SISA KILANG KELAPA SAWIT (POME)

ABSTRAK

Minyak kelapa sawit merupakan salah satu daripada industri yang berkembang pesat di seluruh dunia. Industri kelapa sawit merangkumi keluasan tanah ladang terbesar di Malaysia. Industri ini menyumbang ke arah pertumbuhan ekonomi dan pembangunan yang pesat tetapi malangnya merangkumi isu-isu alam sekitar. Salah satu daripada sisa yang dijana daripada industri minyak sawit yang dikenali sebagai sisa kilang kelapa sawit (POME) yang boleh menyumbang kepada isu-isu alam sekitar jika ia tidak dirawat dengan betul sebelum dilepaskan ke alam sekitar. Dalam kajian ini, rawatan POME telah dijalankan di dalam sistem makmal membran skala anaerobik (MAS) yang menunjukkan petonsi yang tinggi bagi mengatasi masalah alam sekitar. MAS terdiri daripada ultra-penapisan membrane untuk pemisahan pepejal-cecair dengan tekana operasi 1.5 hingga 2 bar. 30 L POME yang digunakan di dalam reaktor dan masa penahanan hidraulik (HRT) adalah antara 1 hingga 4 hari untuk membenarkan fasa menyesuaikan diri untuk air kumbahan. Berdasarkan keputusan yang diperolehi, peratusan pengeluaran metana adalah dari 60.00% 69.79% setiap hari. Peratusan kecekapan penyingkiran yang diukur dalam kajian ini termasuk peratusan penyingkiran BOD dari 61.45% hingga 72.66%, peratusan penyingkiran TSS daripada 86.05% kepada 88,94%. Terdapat juga peratusan penyingkiran ammonia dengan kecekapan penyingkiran dari 20% hingga 28.94% dan penyingkiran peratusan kehadiran nitrat dalam POME dengan peratusan penyingkiran dari 45% hingga 77.89%. Prestasi MAS dipengaruhi oleh penahanan hyroulik pepejal, masa penahanan hydroulik dan tahap beban organik, pH dan suhu operasi. Oleh itu, MAS adalah alternatif yang sesuai untuk merawat air sisa kumbahan. Pengeluaran gas metana daripada proses ini juga boleh dianggap sebagai produk yang berharga dan sebagai satu jenis sumber tenaga.

TABLE OF CONTENTS

CHAPTER 3 MATERIALS AND METHOD

CHAPTER 4 RESULTS AND DISCUSSIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS/ABBREVIATIONS

BOD	-	Biological Oxygen Demand (mg/L)
COD	-	Chemical Oxygen Demand
CO_2	-	Carbon Dioxide
CUF	-	Cross Flow Ultrafiltration
CH_4	-	Methane
DO	-	Dissolved Oxygen
DOE	-	Department of Environment
EFB	-	Empty Fruit Brunches
FFB	-	Fresh Fruits Brunches
HRT	-	Hydraulic Retention Time (day)
H_2	-	Hydrogen
MAS	-	Membrane Anaerobic System
MWCO	-	Molecular Weight Cut Off
NaOH	-	Sodium Hydroxide
NH_3	-	Ammonia Gas
POME	-	Palm Oil Mill Effluent
SS	-	Suspended Solids
TSS	-	Total Suspended Solids
UF	-	Ultrafiltration Membrane
%	-	Percentage

CHAPTER 1

INTRODUCTION

1.1 Research Background

Palm oil was originally from the Egyptian pharaohs 5000 years B.C. the Frenchman Henri Fauconnier and his associate Hallet, is attribute for the development of the oil plam industry in Malaysia. The first commercial oil palm plantation was established around 1917. The oil palm contains a high nutrient which mainly depends on the yield potential determine by the genetic make-up of the planting material and yield limit set by climatic factor such as water, effective sunshine and temperature. Palm oil has composition that varies its application in food manufacturing, in the chemical, cosmetic and pharmaceutical industries.

Malaysia is the two largest oil palm producing countries includes Indonesia. Due to the rapid production of the palm oil in our countries, Malaysia has faced the effluent control in the palm industry. The process of oil extraction results in generation of liquid waste commonly named as palm oil mill effluent (POME) The direct discharge of palm oil mill effluent wastewater causes serious environmental pollution due to its high chemical oxygen demand (COD) and biochemical oxygen demand (BOD). The COD values greater than 80,000 mg/L and acidic pH values range from 3.8 to 4.5. POME is considered non toxic but it is identified as a major source of aquatic pollution by depleting dissolved oxygen when discharge.

There are many types of POME treatment that was introduced in Malaysia. The most regular treatment in Malaysia is the ponding system and about 85% POME producers in Malaysia have using this system due to its low capital and operating costs. Nowadays, the membrane technology has been introduced and has high potential to overcome the treatment for POME since the previous methods show many lack of efficiency.

In addition to that, a membrane anaerobic system (MAS) was used as an alternative for treating POME. It also consider as cost effective method. Therefore, membrane separation technique has the ability for separating biomass solids from digester suspensions and recycling them to the digester (Chiemchaisri et. al., 1992).

The studies that have been done before shows that membrane anaerobic system (MAS) processes retained and due to long solids retention times liquefied and decomposed all particulate matter. Throughout this research, a membrane anaerobic system (MAS) at steady state was operated continuously at different hydraulic retention time in order to study the performance of reactor in terms of methane production.

1.2 Problem Statement

The palm oil palm industries currently occupy the second largest acreage of farmed land in Malaysia. From 1997 to 2000, the total palm oil acreage has increased from 320 to 3338 hectares (Arif et. al., 2001). Due to its contribution towards economic growth and rapid development, oil palm industry has been recognized worldwide. However, from all the contribution, it also contributed to the environmental issues. Furthermore, from the production of large quantities of by-product from the oil extraction process, it can give bad impact to our environment. 381 palm oil mills in Malaysia generated about 26.7 million tones of solid biomass and about 30 million tons of palm oil mill effluent (POME) in 2004 (Yacob et. al., 2006).

Anaerobic process is a suitable treatment method due to the organic characteristics of POME (Perez et. al., 2001). Therefore, the easiest and cheapest way of discharging POME is to discharge it into river since POME is a non toxic oily waste. However, this method will contribute to the water depletion and severe aquatic pollution. Up to this point, there are a lot of researchers that still finding the best way for the treatment of POME. Moreover, there are also physical treatment of POME includes screening, sedimentation and oil removal prior to the secondary treatment in biological treatment system. Apart from all the methods, the most conventional method is the ponding system. The pond system has been applied in Malaysia since 1982 and classified as waste stabilization pond. However, this method the large scale of land and also long retention time (Oniya et. al., 2001).

The anaerobic process has considerable advantages over any other methods such as less energy demands, minimum sludge formation, no unpleasant odor and production of methane due to efficient break down of organic substances by anaerobic bacteria (Rincon et. al., 2006) Moreover, this membrane anaerobic system (MAS) can be used to decrease number of ponds which can help industry to reduce their maintenance cost.

1.3 Research Objectives

The objectives of this research:

- To study the performance of membrane anaerobic system (MAS) in treating POME.
- To evaluate the influence of retention times towards the respective parameters (COD, BOD, TSS, Ammonia Nitrogen and Nitrate)
- To produce methane gas from palm oil mill effluent wastes.

1.4 Scope of Research

The very high volume of wastewater produced by the palm oil industry make it very necessary to treat the wastewater before releasing it to the environment. The focus of this study is the anaerobic process. In order to achieve all the research objectives:

1. A laboratory scaled membrane anaerobic system (MAS) with an effective 100 liter volume used to treat the raw palm oil mill effluent.
2. The parameters that will be considered in this research are:
    - pH
    - Total Suspended Solids (TSS)
    - Chemical Oxygen Demand (COD)
    - Biochemical Oxygen Demand (BOD)
    - Colour

3. The effect of the hydraulic retention time (HRT), organic loading rate (OLR) and temperature was evaluated in order to study the performance on the MAS.

There are also some limitations involves in this study to ensure all results are based on parameters. The limitations in this study are:

- The optimum temperature for anaerobic digestion in the mesophilic range at around 25°C to 45°C.
- The pH must be maintain at 6.8 to 7.7
- The operating pressure is around 1.5 to 2.0 bar
- The hydraulic retention time for this process is 4 days.
- The volume of methane gas produced must be measured daily up to 10 days, using J-Tube analyzer
- 0.5 M sodium hydroxide (NaOH) is used as solvent to absorb the carbon dioxide (CO_2) produce from the reactor.

1.5 Rationale and Significant of Research

Rationally, this research can produce another environmentally friendly method to treat the wastewater before releasing to the environment. It also one of the alternatives to overcome the emission of green house gases like methane and carbon dioxide to the atmosphere. In addition to that, the anaerobic digestion produces biogas from the waste that can be broken down by bacteria or also known as biodegradable waste that can be used to generate electricity and used as vehicle fuel.

This anaerobic digestion process is known for its ability for the wastewater treatment and also biogas production for the renewable energy sources. This process results in many benefits such as:

1. Economical
    - Additional income
    - From waste to wealth
    - Low costs
2. Environmental
    - Production of biogas as the source of renewable energy
    - Reduction of pollution
    - Sustainable management of organic waste
    - Small space requirement of wastewater treatment

1.6 Thesis Layout

This thesis has 5 chapters. Chapter 1 introduces a background of the study and also about the problem of palm oil mill effluent whereas become an environment issues and the effects to human health and also the way to solve that problem. It is also includes research objective, scope and significance of study. Chapter 2 is about literature review which includes topic extensively researched of palm oil industry, palm oil mill effluent, the palm oil mill effluent wastewater treatment, anaerobic process and factors affecting the process, the membrane anaerobic system with the performance of ultrafiltration membrane. Literature research contains information relevant and directly related to research in this study. In Chapter 3, the methodology develops the steps needed to evaluate the parameters involves in this study including chemical oxygen demand, biochemical oxygen demand, total suspended solids, pH, temperature, and the collection of methane gas per daily will be discussed. Chapter 4 will be discussing about the results obtained from the research experiment. It includes the analysis on all the parameters involved in the experiment. The results and discussion will explain along with the related tables and graph. Lastly Chapter 5 will provide some concluding remarks of this research and also provide recommendations on how to improve the palm oil mill effluent treatment by using membrane anaerobic system.

CHAPTER 2

LITERATURE REVIEW

2.1 Palm Oil

The palm oil already known back to 5000 years B.C. of the Egyptian pharaohs. (Poku & Kwasi, 2002). The palm oil, however, is a native of West Africa. Malaysia has been introduced to the palm oil around 20th century and commercially produced in 1917 (Tate et. al., 1996). The palm oil, *Elaeis guineensis* originally belonging to the Palmae family, is the most productive oil producing plant in the world. According to Malaysian palm oil board, the global production of palm oil and the plantation area has been increased. Malaysia contributes 41% of the world production.

In addition to that, several unit operations are involved in order to extract palm oil after the fresh fruit bunches (FFB) are transported to the palm oil mills. The first type is the palm oil from the fibrous mesocarp and second type is lauric oil produce from the palm kernel. Palm oil is used mainly in cooking and also has other applications like in producing soap, detergents and cosmetics.

Oil palm is a monoecious crop as it bears both male and female flowers on the same tree. Each tree produces compact bunches weighing between 10 and 25 kilograms with 1000 to 3000 fruitlets per bunch. Each fruitlet is almost spherical or elongated in shape. Generally, the fruitlet is dark purple, almost black and the colour turns to orange red when ripe. Each fruitlet consists of a hard kernel (seed) enclosed in a shell (endocarp) which is surrounded by a fleshy mesocarp. Palm trees may grow up to sixty feet and more in height. The trunks of young and mature trees are wrapped in fronds which give them a rather rough appearance. The older trees have smoother trunks apart from the scars left by the fronds which have withered and fallen off.

Oil palm tree will start bearing fruits after 30 months of field planting and will continue to be productive for the next 20 to 30 years; thus ensuring a consistent supply of oils. Each ripe bunch is commonly known as Fresh Fruit Bunch (FFB).

In Malaysia, the oil palm trees planted are mainly the *tenera* variety, a hybrid between the *dura* and *pisifera*. The *tenera*variety yields about 4 to 5 tonnes of crude palm oil (CPO) per hectare per year and about 1 tonne of palm kernels. The oil palm is the most efficient oil-bearing crop in the world, requiring only 0.26 hectares of land to produce one tonne of oil while soybean, sunflower and rapeseed require 2.22, 2 and 1.52 hectares, respectively, to produce the same. (MPOC, 2009)

2.2 Palm Oil Industry in Malaysia

It was introduced to Malaysia by British in early 1870's as an ornamental plant. The first commercial planting took place in Tennamaran Estate in Selangor, laying the foundations for the vast oil palm plantations and the palm oil industry in Malaysia. The cultivation of oil palm increased at a fast pace in early of the year 1960 under the government's agricultural diversification programmed. Later in the 1960's, the government introduced the land settlement schemes for planting oil palm as a means to eradicate poverty for the landless farmers and smallholders. The palm oil plantations in Malaysia are largely based on the estate management system and smallholder scheme (MPOC, 2009).

Palm oil is one of the world's most rapidly expanding equatorial crops. Indonesia and Malaysia are the two largest oil palm producing countries and is rich with numerous endemic, forest-dwelling species. Malaysia has a tropical climate and is prosperous in natural resources. Oil palm currently occupies the largest acreage of farmed land in Malaysia (Arif, & Tengku Mohd Ariff, 2001).

Malaysia's palm oil industry is one of the important industries of the nation and it is the fourth largest contributor to the national economy. It currently accounts for RM53 billion in the Gross National Income (GNI). As of 2009, Malaysia has 4.7 million hectares of oil palm plantations, 416 mills, 43 crusher, 51 refineries, 18 oleo chemical plants and 25 biodiesel plants (MPOC, 2009).

2.3 Palm Oil Mill Process Flow Description

Palm Oil Milling Process involve physical extraction of palm products namely, crude palm oil and palm kernel from fresh fruit brunches (FFB). The wet palm oil milling process is the most common way of extracting palm oil from FFB, typically in Malaysia (Wu et. al., 2010). In involves several stages in which huge amount of water and stream are required for washing and sterilizing. Finally, this has produced a large amount of wastewater generated from palm oil mill known as POME.

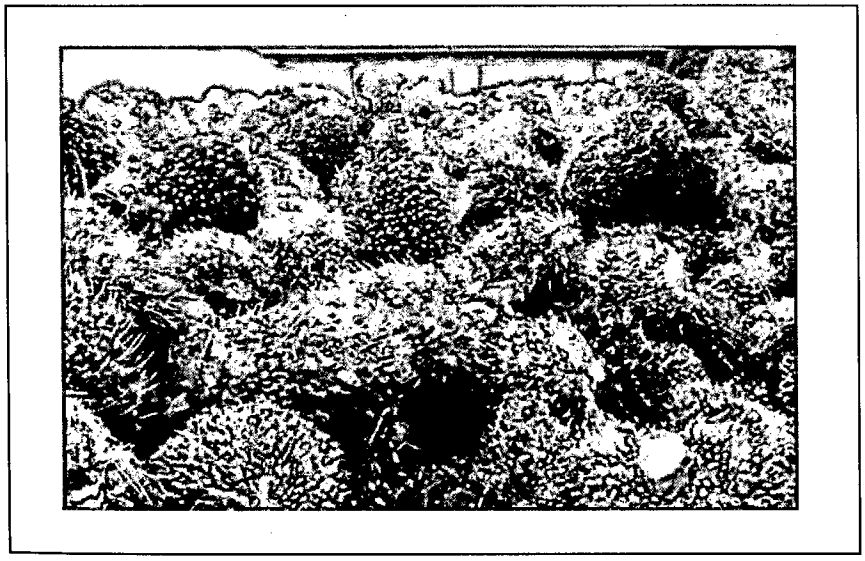

Figure 2.1 Fresh fruit bunches for processing at palm oil mill
(Sources: http://lipidlibrary.aocs.org/processing/palmoil/index.htm)

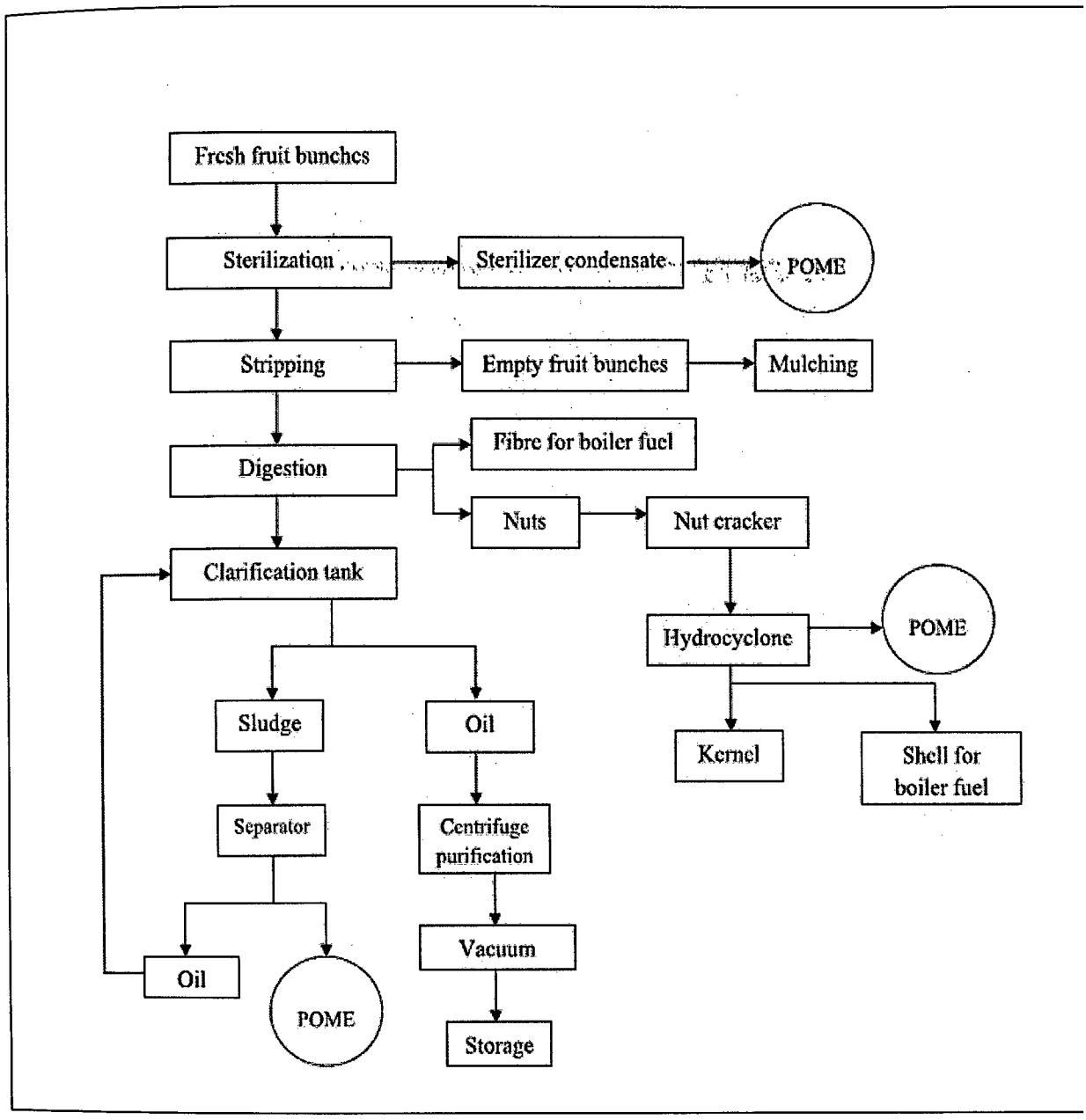

Figure 2.2 Simplified Flow Diagram of Palm Oil Mill

(Sources: Lam & Lee, 2011)

2.3.1 Sterilization of Fresh Fruit Brunches

During sterilization process, pressurized steam at pressure 300 kPa and at high temperature at 140°C is used to infuse moisture into the nuts that can cause it to expand (Wu et. al., 2010). Consequently, the contraction of the nut will cause the detachment of the kernel from the shell wall and resulting to loosen kernels within their shells (Poku, 2002). Furthermore, sterilization process is to destroy the oil splitting enzymes and thus slows down the formation of free fatty acids in the oil. So, it is really important to ensure that the air is evacuated from sterilizer in order to increase the efficiency of heat transfer and to avoid oil oxidation by air (Poku, 2002). Hence, the major sources of palm oil mill effluent, POME are the condensate coming out from the sterilizer constituents.

2.3.2 Stripping, Digestion and Pressing of Fruits

The stripping purposes is to separate the sterilized fruits from the bunch of stalks by using a rotary drum thresher (Wu, et. al., 2010). The stripped brunches or the detached fruits then transported to the digester to soft and mash by heated steam. Throughout this action, the mesocarp or the fruit outer layers are loosed from the nuts and be channel to a mechanical press to squeeze out the crude palm oil.