ODOUR EMISSION FROM PALM OIL MILL WITH DIFFERENT EFFLUENT TREATMENT SYSTEM

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By

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ABSTRAK

Bau yang disebabkan daripada kilang kelapa sawit telah menjadi isu utama alam sekitar dalam industri kilang kelapa sawit di Malaysia. Kolam efluen adalah sumber utama bau. Ia dianggap bahawa perlepasan dari kolam terutamanya didorong oleh kadar pemprossesan. Bau yang tidak diingini ini bukan sahaja memberi kesan kepada kebimbangan kualiti udara tetapi juga kawasan sekitar perumahan dan institusi. Oleh itu, perlaksanaan kolam tertutup dan tangki telah diperkenalkan untuk menghilangkan bau daripada kolam anaerobik kilang kelapa sawit. Penutup kolam dan tangki digunakan secara meluas di seluruh dunia dalam usaha menangani masalah bau, tetapi penggunaannya di Malaysia masih rendah, terutamanya kilang kelapa sawit. Dalam kajian ini, tiga kilang kelapa sawit yang berbeza telah dipilih iaitu kolam terbuka, kolam bertutup dan tangki percerna untuk membandingkan perlepasan bau dari tiga sistem yang berbeza ini dan untuk mengenal pasti had bau untuk kilang kelapa sawit. Penilaian bau telah dilakukan di lokasi menggunakan olfaktometer SM-100 disebelah kolam anaerobik yang terbuka, kolam anaerobik yang bertutup dan tangki pencerna anaerobik. Selain penilaian bau di tapak, fluk hood dan ruang vakum telah digunakan untuk persampelan bau di kolam penyejukan dan sampel akan dihantar ke makmal untuk dianalisis of olfaktometer dinamik. Ujian kepekatan ammonia dan hidrogen sulfida juga telah dijalankan keatas sampel persempelan bau untuk mengenal pasti jumlah ammonia dan hidrogen sulfida telah dilepaskan ke atmosfera. Sampel POME juga telah diambil di tiga tiga kolam penyejukan untuk mengenal pasti ammonia, hidrogen sulfida dan jumlah pepejal. Berdasarkan kepada keputusan, had bau untuk kilang kelapa sawit adalah 57,000 OU/m³. Purata jumlah bau yang dilepaskan kolam tidak bertutup adalah 3387 OU/m³, kolam bertutup sebanyak 185 OU/m³ dan tangki percerna sebanyak 4.0 OU/m³. Apabila menggunakan kolam bertutup, jumlah pengurangan perlepasan bau adalah sebanyak

95% and 99% apabila menggunakan tangka percerna. Oleh itu, dengan pengunaan perlindungan bagi sistem rawatan efluen, dapat mengawal perlepasan bau ke atsmofera.

ABSTRACT

Odours caused by Palm Oil Mill operations have become a major environmental issue in the Palm Oil Mill industry in Malaysia. Effluent pond is the major source of odours. It is assumed that the odour emission from ponds are mainly driven by pond loading rate. This undesirable odour will not only affect the air quality concern but also the surrounding residential and institutional area. Therefore, the application of pond cover and tank digester had been implement to remove the odour from palm oil mill anaerobic pond. Pond cover and tank digester is widely used over the world in dealing with odour problems but the use of this system in Malaysia is still low, especially for Palm Oil Mill. In this study, three different Palm Oil Mill had been choose open pond, covered pond and tank digester to compare the odours emission from this three different system and to identify odour limit for palm oil mill effluent. Odour assessment was performed on site, using the SM-100 In-field olfactometer next to the anaerobic pond, anaerobic covered lagoon and anaerobic tank digesters. In addition to in-field odour assessments, flux hood and vacuum chamber being used for odour sampling at the cooling pond and sample had been send to laboratory for dynamic olfactometry analysis. Ammonia test and hydrogen sulfide concentration were also done on odour sampling sample to identify amount of ammonia and hydrogen sulfide had been released to atmosphere. POME sample were also being collected at this three cooling pond to identify ammonia, hydrogen sulphide and total solid. Based on the result, the odour limits for palm oil mill effluent is 57,000 OU/m^3. Average of odour emission from uncovered lagoon is 3387 OU/m^3, covered lagoon is 185 OU/m^3, and for tank digester is 4.0 OU/m^3. Total reduction of odour emission when using the covered lagoon is about 95% and 99% when using the tank digester. Therefore, by using cover and tank digester for effluent treatment system, can control the odour emission to atmosphere.

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LIST OF NOMENCLATURES

NH_3	Ammonia
CO_2	Carbon Dioxide
H_2S	Hydrogen Sulfide
CH_4	Methane

LIST OF ABBREVIATIONS

COD	Chemical Oxygen Demand
CPO	Crude Palm Oil
DOE	Department Of Environment
DO	Dissolved Oxygen
EGSB	Expanded Granular Sludge Bed
HRT	Hydraulic Retention Time
HUASB	Hybrid Up-flow Anaerobic Sludge Blanket
MPOM	Malaysia Palm Oil Mill
OLR	Organic Loading Rates
POME	Palm Oil Mill Effluent
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TS	Total Solid
VFA	Volatile Fatty Acid
WWTP	Waste Water Treatment Plant

CHAPTER 1

INTRODUCTION

1.1 Background

Palm oil is one of the most widely produced vegetable oils in the world and currently its production is being boosted with extending their use in making biodiesel (Lim and Teong, 2010). In 2012, Malaysia was recorded as the world's second largest producer of palm oil with the production of 18.7 million tons on crude palm oil (CPO) (MPOB, 2012). However, the unsustainability of palm oil production has been constantly criticized because the large quantities of biomass residues almost 5 times the weight of oil production are a serious threat to the environment (Ahmed et al., 2003).

Generally, the palm oil milling process can be categorized into a dry and a wet (standard) process. The wet process of palm oil milling is the most common and typical way of extracting palm oil, especially in Malaysia (Salmiati et al., 2010). According to the industrial standard, the milling process produces wastewater in the range of 0.44 to 1.18 m^3/tonne fresh fruit bunches (FFB) with the average figure of 0.87 m^3/tonne FFB. It is estimated that for each tonne CPO that is produced, 5 to 7.5 tonnes of water are required, and more than 50% of this water ends up as palm oil mill effluent (POME) (Ahmed et al., 2003).

In particular, palm oil mill effluent (POME) causes a greater impact than the other by-product of palm oil production, of which estimated amount is 3 times more than that of crude palm oil (Wu et al.,2010; Yeoh et al., 2011). POME is a viscous brown liquid with fine suspended solid at pH ranging between 4 to 5 (Najapour et al., 2006). Moreover, POME is a liquid that containing high concentrations of organic acids with a COD level higher than 20,000 mg/l (Lam and Lee, 2011; Najafpour et al., 2006). POME sludge has malodour as a result of its high content in total nitrogen, total phosphorus and potassium. Most of the odorous substances derived from anaerobic decomposition of organic matter contain sulfur and nitrogen (Parivesh et al, 2008). As the population is increasing together with the urbanization in the nearby area around the plant palm oil mill, odour problem should be controlled to provide cleaner and fresh environment.

On the other hand anaerobic treatment is favorable for POME treatment as it can remove much more organics even with limited available nutrients. Therefore, anaerobic treatment processes have primarily been adopted for POME in the field (Poh and Chong, 2009).

Facultative ponds and open digesting tanks are the most commonly used anaerobic processes for the treatment of POME (Yacob et al., 2005). Although these conventional processes require relatively little energy to operate, they demand extensive land area and long retention time (Lam and Lee, 2001; Wu et al., 2010). Besides, a large quantity of greenhouse gases including methane and carbon dioxide is produced from open ponds and tanks these gases are emitted directly into the atmosphere.

1.2 Problem Statement

Based on previous researches, it is proven that the effluent produced during palm oil production emits a highly unpleasant odour which will cause discomfort to the neighbouring areas especially housing and commercial areas. When the effluent is discharged it will produce the emission of greenhouse gases such as methane and carbon dioxide to atmosphere and polluting the air quality no matter how effective the method of processing. Therefore, balancing the environmental protection, economic viabilities and sustainable development can be a difficult challenge to the palm oil mill industries.

In Malaysia, there is yet any limitation imposed for odour emission from palm oil mill effluent pond. Plus, there is no proper guideline yet how to reduce the odour. Apart from that, pond cover and anaerobic tank digester have been used widely in many countries such as Thailand and Indonesia in dealing with industrial odour problem. However, the awareness regarding its application in industrial field in Malaysia currently is very low. There is a lack of researches to substantiate the effectiveness of pond cover and tank digester in reducing odour from the palm oil mill effluent.

1.3 Objectives

This research is based on two main objectives, which are:

i. To determine the odour emission limit from the Palm Oil Mill Effluent pre-treatment pond at Taclico Co. Sdn. Bhd, Malpom Industries Sdn. Bhd and Tian Siang (Air Kuning) Sdn, Bhd.

ii. To determine and compare the odour emission from different anaerobic treatment systems which is uncovered anaerobic pond, covered anaerobic pond and anaerobic tank digester

1.4 Scope of the study

In this study, three sites have been chosen; Tian Siang (Air Kuning) Sdn. Bhd, Malpolm Industries Sdn. Bhd, and Taclico Co. Sdn Bhd with different types of effluent treatment system. Odour assessment was performed in-situ, using the Scentroid SM100

In-field olfactometer in conjunction with odour intensity and descriptor nearby the open, covered anaerobic pond and tank digester.

In addition to in-field odour assessment, odour samples were also collected from the uncovered ponds and analysed in the USM odour Laboratory within 24 hours. Samples were collected primarily from cooling and acidification pond. Odour concentration will be determined using dynamic olfactometry. Palm Oil mill effluent samples were also collected for each site to determine its Chemical Oxygen Demand (COD), Total Solid (TS), Ammonia and Hydrogen Sulphide.

1.5 Importance and Benefits of the study

This research focuses on evaluating the effective of using covered anaerobic that will act as an odour control in reducing the odour level produced by POME and this study also to determine an odour limitation for palm oil mill effluent and at the same time it will helping Department of Environment (DOE) to proposed odour limit for palm oil mill, as well as recognizing odour control techniques for odorous area within a palm oil mill. It is very important to tackle odour pollution resulting from treatment ponds of palm oil mill which almost caused a less comfortable in all areas around the plant.

Therefore, this study aimed to help to reduce the odour resulting from waste treatment ponds of palm oil mill. With the establishment of this odour barrier the problem of odour resulting from the treatment pond plants can be controlled from spreading and almost caused severe odour problems to the neighboring area including villages, residential areas, and institutions. In addition, from this research also could help oil palm industry in forming a way to curb the problem of smell that produce from palm oil mill.

1.6 Dissertation Outline

This dissertation is divided into five chapters as a whole. The first chapter describes the background of POME and system to be used for treating odors generated by the POME. The problem statements of why this study is conducted and a description of the objectives of this study is also discussed. In addition, the effects and benefits that can be gained from this study are presented in this chapter.

Next is Chapter Two, which reviews previous studies that have been carried out in connection with this study such as Malaysia palm oil mill, palm oil mill effluent, and effluent treatment.

The next chapter is Chapter Three. This chapter is an important chapter in which it describes in detail how the study was conducted, the methods used, as well as all the equipment involved throughout the study. The experimental procedures, collection of odour sample from the POME sample are also elaborated in this section.

Chapter Four presents all the result obtained and the analysis that have been conducted which include results from the experiments of ammonia test, COD test, sulfide test, total solid test and personal olfactometer test.

The last chapter is Chapter Five. This chapter describes the conclusions of all findings of this study and will show that the objective of this study successfully met. Some suggestions are also proposed in this section to improve the study in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explains about the treatment of Palm oil mill effluent (POME) and the environmental problem involved in this treatment. One of the highlighted in this chapter is POME odour problem where it reviews the compounds in POME malodour emission and the odour control that have been implemented in the recent years by the palm oil mill industries.

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2.2 Palm Oil Industry in Malaysia

In 2012, Malaysia was recorded as the world's second largest producer of palm oil with the production of 18.7 million tons of crude palm oil (CPO) (MPOB, 2012). This crude palm oil was produced from 429 palm oil mills located all over Malaysia. Figure 2.1 shows the number of palm oil mills in Malaysia by year, and the trend shows that the number of mills is increasing over the year (Taha and Ibrahim, 2013).

The growth of the palm industries in Malaysia has been phenomenal. From a mere 400 hectare planted in 1920, the hectarage increased to 54000 hectares in 1960 whereas in 2011 the hectarage of palm oil in Malaysia was up to 5 000 109 hectares. Since then, many more areas have been opened for oil palm cultivation, either from jungles, or from the conversions of the plantations that originally supported rubber or other crops (MPOB, 2014). However, while the oil palm industries have been recognized for its contribution towards economic growth and rapid development, it has also contributed to the environmental pollution due to production of huge quantities of by-product from the oil extraction process (Rupani et al., 2010).

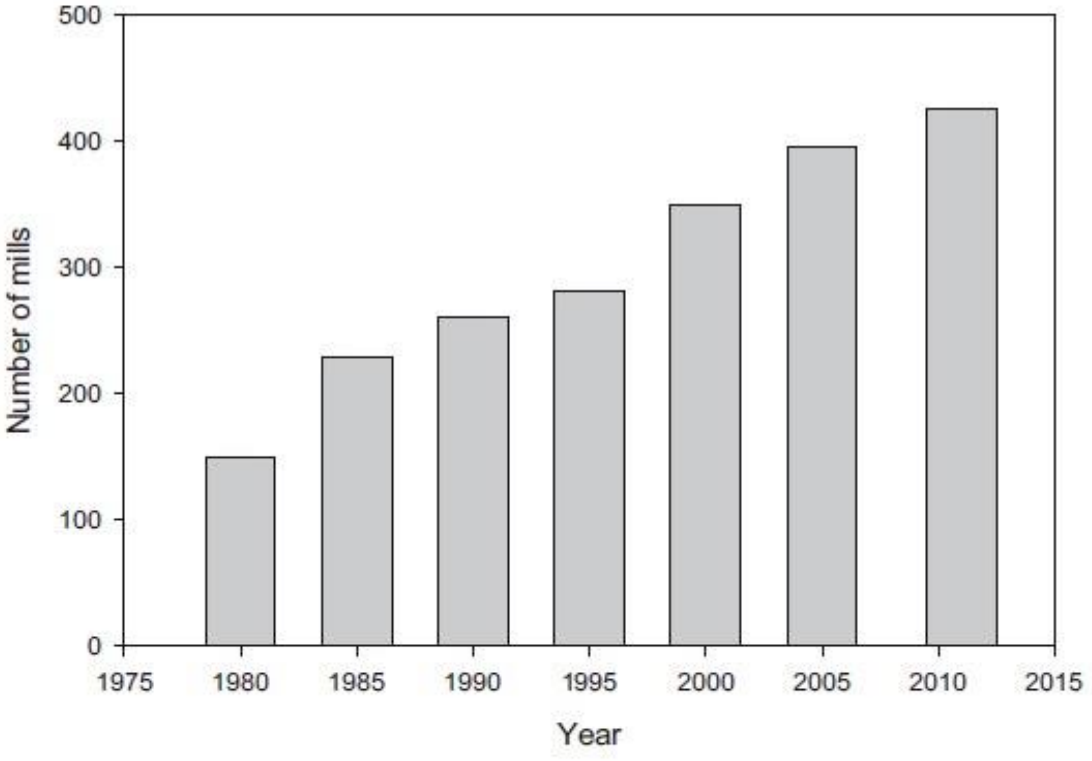

Figure 2.1: Number of Mills in Malaysia by Year
(Taha and Ibrahim, 2013)

2.2.1 Environmental Problem

There are many environmental problems related to POME such as discharging of palm oil mill wastewater without proper treatment will damage the environment by polluting water and causing a foul smell in the neighbourhoods of a factory. According to Hassan et al. (2013) that had conducted a research on POME, this wastewater is viscous brownish liquid and contains substantial quantities of solid which are left after the treatment which are commonly known as POME sludge. Hassan et al. (2013) also stated that due to the large quantity of POME production each year, the amount of sludge increases, respectively that results in bad odour and considered as a pollutant.

Chin et al. (2013) reported in their research that the generations of palm oil mill effluent (POME) together with the production of crude oil have polluting characteristics that create environmental issues for the palm oil in Malaysia. Wu et al. (2010) said that ponding system is the most conventional method implemented for POME treatment in Malaysia due to low operating cost. Yacob et al. (2006) reported that treating POME using ponding and or open digesting tank system produces the emission of greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2) to the atmosphere and has been recently reported as a source of air pollution from the palm oil mills. Thus, there is an urgent need to find an efficient and practical approach to preserve the environment while maintaining the sustainability of the economy (Lorestani, 2006).

Kun and Abdullah (2013) stated that palm oil wastes such as fiber and shell are used as fuel to generate energy to run the palm oil mill and the utilization of these wastes as boiler fuel is creating a serious emission problem in the industry. The emission are not only posing threat to human health, but also affecting agricultural crops, forest species and ecosystems (Kun and Abdullah, 2013).

2.3 Palm Oil Mill Effluent (POME)

The liquid waste generated from the extraction of palm oil of wet process comes mainly from oil room after separator or decanter. This liquid waste combined with the wastes from sterilizer condensate and cooling water is called palm oil mill effluent (POME) (Salmiati et al., 2010). POME comprises a combination of the wastewaters which are principally generated and discharged from the following major processing operations as follows (Salmiati, 2010):

a) Sterilization of FFB - sterilizer condensate is about 36% of total POME or about 0.9 tonnes POME for each produced tonnes of palm crude palm oil.
b) Clarification of the extracted crude palm oil (CPO) - clarification wastewater is about 60% of total POME (approximately 1.5 tonnes of sludge obtained per tonnes of produced crude palm oil).
c) Hydrocyclone separation of cracked mixture of kernel and shell hydrocyclone wastewater is about 4% of total POME.

2.3.1 Characteristics of POME

The palm industry has contributed significantly towards Malaysia foreign exchange earnings and the increase in standard of living of its population (Yusoff and Hansen, 2007), however the effluent from the industry is known to be an environmental pollutant based on its high compositions of total solids, suspended organic solids, dissolved organic matter among others as represented in Table 2.1. Characteristics of palm oil mill effluent depend on the quality of the raw material and palm oil production process in palm oil mills (Esa et al., 2010).

Other important parameters that were seldom considered in the characterization of POME are as follows total phosphorus (TP), total organic carbon (TOC), total Kjeldahl nitrogen (TKN), lignin and sulfate concentrations, and toxicity (Yong et al., 2010). Yong et al. (2010) also highlighted that these parameters are very vital in determining the suitable treatment method for industrial-scale Waste Water Treatment Plant (WWTP) designs besides detecting the operational problems of the selected treatment system due to the characteristics of POME.

Table 2.1: Characteristics of POME (Poh, Yong and Chong, 2010)

Parameter	Ahmed et al. (2003)	Najafpour et al. (2006)	Choorit & Wisamwan (2007)
pH	4.7	3.8-4.4	4.24-4.66
Oil and Grease (mg/L)	4000	4900-5700	8845-10052
Biological Oxygen Demand (mg/L)	25000	23000-26000	62500-69215
Chemical Oxygen Demand (mg/L)	50000	42500-55700	95465-112023
Total Solids (mg/L)	40500	-	68854-75327
Suspended Solids (mg/L)	18000	16500-19500	44680-47140
Total Nitrogen (mg/L)	750	500-700	1305-1493
Total Volatile Solids (TVS) (mg/L)	34000	-	4045-4335

**All units in mg/L exclude pH

2.3.2 Regulatory Standard for Palm Oil Mill Effluent

The regulation implemented for wastewater discharge from palm oil industry under Environmental Quality Act (EQA) 1974 [ACT 127] is called the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulation 1977 (DOE, 1999). Environmental quality regulations for oil palm industry are become stringent in Malaysia. Effluent standard and effluent charges under licensing system were operated under Malaysia government in the early 90's (Igwe and Onyegbado, 2007).

Typical parameter limits for wastewater of palm oil mill which stated in Second Schedule of Regulation 12(2) and (3) of Environmental Quality (prescribed Premises) (Crude Palm Oil) Regulations 1977 is shown as Table 2.2 (DOE, 1999). The parameters shown in Table 2.2 are the key point of decision on whether the wastewater is allowed to be discharged into watercourse. For the environmentally sensitive areas in Sabah and Sarawak, for example Kinabatangan River, DOE has stricter the effluent limit for BOD which cannot exceed 20 mg/L since 2006 (Madaki and Seng, 2013a). Effluent charges or penalty will be imposed on industry which has not fulfilled the wastewater discharge standards.

Table 2.2: Effluent Discharge Standards for Wastewater from Palm Oil Mill (DOE, 1999)

Parameters	Allowable limits
Biochemical oxygen demand	100
Chemical oxygen demand	1000*
Total solids	1500*
Suspended solids	400
Amminiacal Nitrogen	150
Oil and grease	50
Total nitrogen	200
pH	5.0-9.0
Temperature	45

*No change in discharge standard after 1982 (Aris et al., 2008)

**All units in mg/L exclude pH

2.3.3 Relationship between Effluent Characteristics to Odour Production

Odours can be generated and released from virtually phases of wastewater collection, treatment, and disposal. The potential for the initial release or later development of odours begins at the point of wastewater discharge from homes and industries. Hydrogen sulfide, a major odour source in wastewater treatment systems. Metallic sulfide compounds in wastewater produce a black colour, indicating the presence of dissolved sulfide (Process et al., 2007). Ammonia and organic odours are also common. Effluent had high COD level which means a greater amount of oxidizable organic material reduce the dissolved oxygen (DO) levels. A low level of dissolved oxygen creates anaerobic condition, commonly predominates by anaerobic bacteria and other microbes that produce CH_4 and H_2S with bad smells (Forman, 2014).

2.4 Waste Generation by the Palm Oil Industry

The palm oil industry wastes were generated, first at the oil palm plantations during pruning (fronds), harvesting (fronds), and replanting (trunks). It is generated, second, at the palm oil mills, which includes biogas and biomass.

2.4.1 Solid Waste

The oil palm plantations generate huge amounts of waste such as trunks, fronds, empty fruit bunches, shells, and fibers. These wastes comprise biomass in the form of lignocelluloses, which have potential for generating energy, according to Goh et al. (2010). The total area of oil palm cultivation in the year 2007 in Malaysia was 4,304,914 hectares.

Oil palm frond is one of the most abundant agricultural by-products in Malaysia. Almost all pruned fronds are discarded in the plantation, mainly for nutrient recycling and soil conservation. Oil palm frond has great potential for use as a roughage source or as a component in compound feed for ruminants.

2.4.2 Wastewater

Palm oil mill effluent, or POME, is the effluent generated from the final stages of palm oil production in the mill. For every tonne of crude palm oil extracted from milling, about 2.5 tonnes of POME is generated (Sulaiman et al., 2009), and in 2005, about 66.8 million tonnes of POME were produced (Vairappan & Yen, 2008). If it is discharge directly into receiving waterways, it has the pontential to cause adverse environmental consequences. In addition, palm oil mill effluent has a foul smell and can cause odour pollution.

2.4.3 Gaseous Emissions

The two major problems associated with air emission are biogas released by POME in the pond during anaerobic digestion and boiler ash. At the milling stage of palm oil production, the boiler is the most significant contributor of air pollutants (Yusoff & Hansen, 2007). The composition of boiler ash is a mix of clinkers and ash. Typically, the Malaysian palm oil mills burn some of the wastes to produce electricity and steam required for sterilization of the fresh fruit bunches (Yusoff, 2006). This is economically efficient but the combustion process of the boiler releases emissions such as particulate matters, CO, SO_2 and NO_x (Ahmad et al., 2004). The biogas is a mixture of mainly methane and carbon dioxide, methane, a greenhouse gas, is 20 times more harmful than carbon dioxide on climate change. The non-recovered biomethane emission from POME contributed the highest impact towards the environment and makes the overall processes not environmentally friendly.

These are two principle sources of air pollution in the mills that are caused by incomplete combustion of the solid waste materials (Thani et al., 1999). The main practice of treating POME is by using ponding and/ or open digesting tank systems (Ma et al., 1999). The emission of greenhouse gases (CH_4 and CO_2 from these systems to the atmosphere has been recently reported as a source of air pollution from the palm oil mills (Yacob et al., 2005).

2.5 POME Treatment

There are many technologies introduced to treat POME. Conventional biological treatments are aerobic digestion, anaerobic digestion as well as combined aerobic anaerobic digestion system. Bioreactor system has also been introduced in POME treatment with its advantages. Anaerobic Expanded Granular Sludge Bed (EGSB) reactors is investigated to achieve the better enhancement on COD removal of POME. Chemical treatments like coagulation-flocculation and membrane separation technologies are also the current treatment for POME. Advantages and disadvantages of anaerobic and alternative treatment method are shown Table 2.3.

Table 2.3: Advantages and Disadvantages between Anaerobic and Alternative Treatment Methods (Abdulrahman et al., 2013)

Treatment Types	Advantages	Disadvantages	Reference
Membrane	• Produce consistent and good water quality after treatment • Smaller space required for membrane treatment plant • Can disinfect treated water	• Short membrane life, membrane fouling • Expensive compared to conventional treatment	Ahmed et al., (2006) Metcalf et al., (2003)
Anaerobic	• Low energy requirement (no aeration), Producing methane gas as valuable end product • Generated sludge from process could be used for land applications.	• Long retention time, large area required for conventional digester, slow start-up (granulating reactors)	Metcalf et al., (2003) Borja et al., (2006)
Evaporation	• Solid concentrate from process can be utilized as feed material for fertilizer manufacturing	• High energy consumption	MA et al., (1997)

Aerobic	• Shorter retention time, more effective in handling toxic waste	• High energy requirement (aeration), rate of pathogen inactivation is lower in aerobic sludge compared to anaerobic sludge, thus unsuitable for land application	Doble et al., (2005)

2.5.1 Open Ponding and Open Tank System

The raw effluent is treated using a ponding system comprising three phases (i.e., anaerobic, facultative, and algae processes) as shown in Figure 2.2. Although the system takes a longer retention time of 90 days, it is less sensitive to environmental changes, stable, efficient, and could guarantee excellent pollutant biodegradation efficiency of above 95% (APOC, 2011).

Figure 2.2: Stabilization Lagoon (Ponds)
(*Palm Oil Mill Effluent Treatment*, 2015)

Ponding is a general term which includes waste stabilization lagoons (ponds) and oxidation ponds. The term oxidation pond has also been loosely used and can mean aerobic, facultative, maturation, or sometimes it may even be used for anaerobic pond. Ponding essentially employs a biological method of treatment for wastewaters. It is also used where land space is available. It can achieve a reasonable degree of treatment, is low in construction and operating costs and is easily maintained, as the technology required is relatively unsophisticated. Ponds have been used extensively in several other countries for the treatment of industrial wastewaters amenable to biological treatment (Wong, 1980). The odour from anaerobic pond has been reported by Chotwattanasak and Puetpaiboon (2011) as a nuisance to the neighbouring community.

From the baseline study (Yacob et al., 2006a) of methane emission from anaerobic ponds of POME treatment from two anaerobic ponds in Felda Serting Palm Oil Mill, Negeri Sembilan, Malaysia for 52weeks, the methane content was between 35.0% and 70.0% and biogas flow rate ranged between 0.5 and 2.4 L/min/m^3. The total methane emission per anaerobic pond was 1043 kg/day. The total methane emission calculated from the two equations derived from relationships between methane emission and total carbon removal and POME discharge were comparable with field measurement. This study also revealed that anaerobic pond system is more efficient than open digesting tank system for POME treatment.

Modification on conventional treatment is one of solution to improve the quality of POME wastewater discharge, Ismail et al. (2013) introduced the combined system which is conventional ponding system and adsorption as POME treatment in mill. Zeolite was the adsorbent used in adsorption process because it has potential to reduce heavy metal. A significant reduction in BOD concentration, heavy metals and turbidity in POME has resulted under adsorption treatment.

2.5.2 Closed Digester System

Bioreacter or tank system is also applied in palm oil industry nowadays in order to capture the biogas for electric energy production. It has advantages such as less land is required, short HRT and more environmentally sound (Narasimhulu and Nanganuru, 2010). Wang et al, (2015) treated POME using anaerobic expanded granular sludge bed (EGSB) reactors and about 94.89% COD removal was achieved with 3587 mg/L COD of effluent. Another research was hybrid up-flow anaerobic sludge blanket (HUASB) reactor equipped with anaerobic filter and removed up to 97% COD of POME (Badroldin, 2010).

POME generated through oil extraction processes has a great impact to the industry. Owing to its chemical properties and volume of discharge, a large wastewater treatment is required to reduce the polluting strength of POME, before safe discharge. Thus, the selection and performance of the treatment system determine the quality of wastewater discharged. A simple and innovative bioreactor process that is capable of treating POME efficiently is superior to the conventional system, as it operates with very short hydraulic retention times, takes high organic loading, requires less space, and is more environmentally friendly.

500 m^3 closed digester was constructed to evaluate the POME treatment efficiency for a comparison study with open digester system a Felda Serting Hilir, Negeri Sembilan, Malaysia. Prior to actual treatment, the closed digester was subjected to a start-

up operation, which is crucial to the overall POME treatment. During the start-up operation, the system demonstrated a remarkable performance of high COD removal efficiency (up to 97%) and satisfactory ratio of volatile fatty acid:alkalinity (VFA:Alk) between 0.1 and 0.3. The lowest hydraulic retention time (HRT) at 17 days was achieved in less than 3 months. Initial biogas production rate was high, however it declined during higher organic loading rates (OLR). This was attributed so sudden variations of POME chemical properties that affect the system stability. The start-up strategy used for this process has achieved its objectives by creating an active microbial population which was expressed in terms of key performance parameters such as % COD removal efficiency, pH, VFA:Alk, and HRT (Yacob et al., 2006b).

2.6 Odour from Anaerobic Pond

In most cases, odours from anaerobic pond created by incomplete anaerobic break-down of the organic manure. Anaerobic break-down occurs in the absence of free oxygen and uses microorganisms that thrive in these conditions. Aerobic breakdown can occur if there is sufficient oxygen to support aerobic microorganisms. Aerobic breakdown produces more CO_2 and less CH_4 than anaerobic digestion. Generally, aerobic digestion does not produce the offensive odours associated with incomplete anaerobic break-down (FSA Environment, 2000).

2.6.1 Anaerobic Digestion Process

Generally, the treatment system for POME are operated on two-phase anaerobic digestion process followed by natural aeration process. This two-phase anaerobic process gives excellent pollutant destruction efficiency of above 95%, while natural aeration ensures that the final pollutant levels in the effluent are within the limits set by Department of Environment (DOE). Anaerobic digestion occurs when organic material is broken down by bacteria in four major processes: hydrolysis, acidogenesis, acetogenesism and methanogenesis. Hydrolysis is the process in which carbohydrate, proteins, fats are converted to sugars, fatty acid and amino acids. Acidogenesis is the process in which the sugars, fatty acids, and amino acids are converted to carbon dioxide, ammonia, and acids, Acetogensis is the process which creates acetic acid and carbon dioxide. The final process, methanogenesis is when biogas is formed. Biogas contains a mixture methane and carbon dioxide gases. The volatile acids are then converted into methane and carbon dioxide (APOC, 2011). Figure 2.3 show the anaerobic digestion processes.

The advantages of anaerobic digestion system are:

- The two phase system allows greater control of digester environmental conditions
- Long solid retention times allow better biodegradation efficiencies
- Additional settling of liquor ensures minimum loading to the aerobic process
- There is capability to cope with full effluent load, regardless of fluctuation

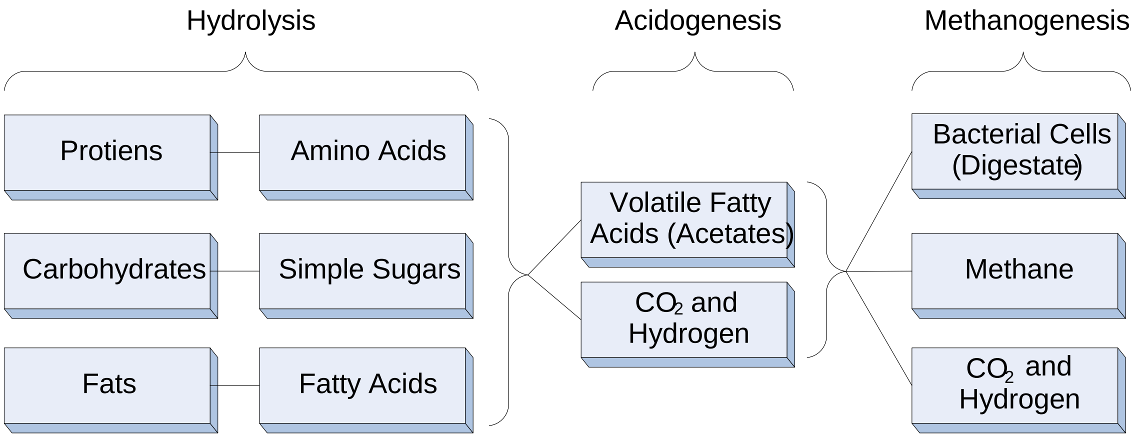

Figure 2.3: Anaerobic Digestion phase (Khanal, 2008)

Odorous compounds include organic or inorganic molecules. The two major inorganic odors are hydrogen sulfide and ammonia. Hydrogen sulfide is the most common odorous gas found in wastewater collection and treatment systems. Its characteristic rotten-egg odour is well known. The gas is corrosive, toxic, and soluble in wastewater. Ammonia also sources of malodour and its characteristic sharp, and pungent. Nagata, Y. (2003) stated that the odour threshold of ammonia is 1.5ppm and for hydrogen sulfide is 0.00041ppm.

2.6.2 Factors Affecting Odour Emissions from Effluent Ponds

Bio degradation processes in ponds depend primarily on the aerobic or anaerobic microbial activity. Odour is largely a result of this microbial activity due to the biological nature of the process, a large number of factors affect odour emission from effluent ponds. The main factors include:

- Loading rate;
- Temperature;
- Start-up conditions;
- pH; and
- purple Sulphur bacteria

2.6.2.1. Loading Rate

The loading rate of an effluent pond system is expressed as the mass of volatile solids per cubic meters of pond volume added per day. It has a major impact on the amount of odour that is generated from the system. Several field studies have shown a clear relationship between loading rate and odour emissions. Chastain & Henry (1999) indicated that at high loading rates (*i.e.* 480 g VS/m^3day), significant odour will produced near the pond 80 % of the time. If loading rate is reduced to 30 g VS/m^3day, the odour will be insignificant. This suggests that one way to control odour is to use a very small loading rate.

2.6.2.2. Temperature

There are three major temperature ranges in the anaerobic digestion processes. Psychrophilic is operated below 25ºC, mesophilic range is between 25ºC to 40ºC and the optimum is at 30ºC to 35ºC. The thermophilic is operated at temperature greater than 45 ºC (El-Mashad et al., 2004). The main contributions of the thermophilic anaerobic process are higher stability for solids reduction, higher biogas production improvement of the energy balance of the treatment plant, high resistance to foaming, less odour and high effect of destroying pathogens in the thermophilic digesters (Zábranská et al., 2002). One of the imperative parameter to anaerobic treatment is operating temperature that selects the dominant bacterial flora and determines microbial growth rate (Patel and Mandawar, 2002). Biogas production from the thermophilic anaerobic digestion treating fruit and vegetable wastes was higher on average than psychrophilic and mesophilic by 144% and 41% respectively (Bouallagui et al., 2004). Temperature- phased anaerobic digester was developed with combination of mesophilic and thermophilic process to enchance the treatment performance.

2.6.2.3. Start-up Condition

A new pond should be filled to 50 percent of its permanent volume with liquid before manure loading begins. Start-up during warm weather and seeding with bottom sludge from a working pond will speed establishment of a stable bacterial population. Manure should be added to anaerobic ponds in a regular stream without ‘shock’ loadings, which can cause sharp increases in odour production and wide fluctuations in nutrient content. Liquid levels should not be allowed to fall below the design treatment level, so that adequate pond volume is maintained for optimum bacterial digestion (NCSU, 1998).

2.6.2.4. pH

An anaerobic pond that is operating properly will have a pH ranging from 7 to 8 (Tchobanoglus & Burton, 1991). When the anaerobic pond is operated properly, the biochemical reactions will maintain the pH in the proper range. If imbalance develops, the acid forming bacteria exceed the methane formers causing a build-up of volatile acids in the pond. If this continues, the buffer capacity is exceed causing the pH to drop below 6.0. Under this condition, the anaerobic ponds start to produce odours.

pH has a strong interaction with the concentration of volatile organic acids. The lowest pH values occur when the volatile organic acids are at maximum concentration. The pH in new ponds without adequate dilution water or in overloaded ponds can be reduced to 6.5 or less (acidic), thereby causing odour problem.

2.6.2.5. Purple Sulphur Bacteria

Main ponds exhibit a purple colour in the liquid, caused by naturally occurring purple Sulphur bacteria. These are phototropic organisms that oxidise sulphide under anaerobic conditions. When these organisms are dominant, pond odour, ammonium nitrogen and soluble phosphorous are reduced. The purple colour is a good indicator of a pond working at its optimum (NCSU, 1998).

To encourage desirable purple sulfur bacteria, the first factor is proper pond size in terms of the amount of manure produced. Ponds with small permanent pools often tend to produce odour because they are too small to adequately handle wastewater. Pond with a large permanent pool have less odour problems.

2.7 The Treatment of Odour from Anaerobic Ponds

Industrial odours are a major environmental problem. Emissions of many odorous compound are produced from biological activities or chemical processes. Most of the odorous substances derived from anaerobic decomposition of organic matter contain sulfur and nitrogen (Bhawan et al., 2008). These malodourous compounds can create an unpleasant working environment, which is obviously a concern to those who are working there and the residents who live near industrial premises.

Many techniques have been applied to manage odour pollution. Table 2.4 below displays the summary of odourous air treatment which is commonly implemented in the industrial field.

Table 2.4: Summary of Odorous Air Treatment Alternatives (Water Environment Federation, MOP-22, 1995)

Technique	Frequency of Use	Cost Factors	Advantages	Disadvantages
Packed-tower wet scrubber	High	Moderate capital and O&M cost	Effective and reliable, long track record	High chemical consumption, not effective for VOCs
Fine-mist wet scrubber	Medium	Higher capital cost than packed towers	Lower chemical consumption, can be design for VOC removal	Water softening required for scrubber water, larger scrubber vessel
Activated carbon absorbers	High	Cost effectiveness depends on frequency of carbon replacement	Simple, few moving part	Only applicable for relatively dilute air stream in order to ensure long carbon life
Bio-filters	Medium	Low capital costs	Simple, minimal energy, effective for VOCs	Effective with a range of odours, requires monitoring for bed moisture, required periodic media replacement
Thermal oxidizers	Low	Very high capital cost	Highly effective for VOCs and odour	Only economical for high-strength, difficult to treat air streams
Diffusion into activated sludge basins	Low	Economical if existing blowers diffusers are used	Simple, low energy, effective	Concern for blower corrosion, may not be appropriate for very strong odour
Odour masking agents	High	Cost depends on chemical usage	Low capital cost, easy to obtain	Only mask odours, no VOC control

2.7.1 Volatilization of Odour from Surface

Emission of odour from liquid sludge occurs by volatilization. Volatilization or evaporation of chemical substance in water is influenced by air temperature and humidity, and wind speed, and turbulence in the water body (Berkeley; and King, 1981). Oxygen is present in the upper portions of pond, so aerobic processes occur here. There