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JUDUL: **A COMPARATIVE STUDY ON ANAEROBIC TREATMENT METHOD BETWEEN PONDING SYSTEM AND DIGESTER TANK SYSTEM FOR PALM OIL MILL EFFLUENT (POME) TREATMENT**

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A COMPARATIVE STUDY ON ANAEROBIC TREATMENT BETWEEN PONDING SYSTEM AND DIGESTER TANK SYSTEM FOR PALM OIL MILL EFFLUENT (POME) TREATMENT

INTAN SAFINAZ BT ISMAIL

UNIVERSITI MALAYSIA PAHANG

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the Degree of Civil Engineering & Earth Resources''.

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A thesis submitted in fulfillment of the requirement for the award of the degree of Bachelor of Civil Engineering & Earth Resources

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NOVEMBER 2010

I declare that this thesis entitled *"A Comparison Study on Anaerobic Treatment between Ponding System and Digester Tank System for Palm Oil Mill Effluent (POME) Treatment* "is the result of my research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Palm oil is one of the important industrial sectors in Malaysia. Every year, the production of palm oil increased rapidly. As the production of palm oil increased, more palm oil mill effluent (POME) is generated annually. The total annual quantity of wastewater generated is estimated to be $1.8 \times 10^6 m^3$. This situation contributed to more study on the technology of treatment of the POME. Raw POME comprises of water-soluble components of the palm fruits as well as some suspended materials like palm fibre and oil and it cannot be discharged into the watercourse directly. The effluent must be treated to acceptable quality before it can be discharged. Comparison on conventional system and alternative system for anaerobic treatment between ponding system and digestion tank treatment system was used for treatment POME. The resources of this data are taken from the selected Palm oil Mill Plantations. The main parameters for POME are BOD, COD, Suspended Solid, and Oil & Grease. The reduction of main parameters for Ponding System and Digester Tank System was determine which is BOD, 96.88% and 98.06%, COD, 90.60% and 92.70%, SS, 94.03% and 96.83% and O&G, 97.21% and 81.33%. Meanwhile, the quality, effectiveness and the advantages and disadvantages for both systems also were determined. The findings show that alternative treatment system which is Digester Tank System having efficiency, effective and ability to treat POME better than conventional treatment system.

ABSTRAK

Minyak kelapa sawit adalah salah satu sektor industri yang penting di Malaysia. Setiap tahun, kadar pengeluaran minyak sawit adalah semakin meningkat pesat. Semakin meningkat kadar pengeluaran minyak sawit, semakin meningkat sisa kilang kelapa sawit (POME) yang dihasilkan setiap tahun. Jumlah tahunan air sisa yang dihasilkan dianggarkan dalam $1.8 \times 10^6 m^3$. Situasi ini memberi sumbangan lebih lanjut untuk mempelajari tentang teknologi perawatan POME tersebut. POME mentah terdiri daripada bahagian-bahagian larut air dari buah kelapa sawit serta beberapa bahan terampai seperti serat kelapa dan minyak dan tidak boleh dibuang ke anak sungai secara langsung. Efluen harus dirawat dengan kualiti yang dibenarkan sebelum ia boleh dilepaskan. Perbandingan sistem konvensional dan sistem alternatif untuk memproses anaerobik antara sistem kolam dan sistem tangki rawatan telah digunakan untuk rawatan POME. Sumber data ini diambil dari kilang minyak sawit yang telah dipilih. Parameter utama untuk pome adalah BOD, COD, Suspended Solid, dan Oil & Grease. Kadar penurunan parameter utama untuk Ponding Sistem dan Digester Tank Sistem telah ditentukan dengan bacaan untuk BOD, 96.88% dan 98.06%, COD, 90.60% dan 92.70%, SS, 94.03% dan 96.83% dan O&G, 97.21% dan 81.33% . Sementara itu, kualiti, keberkesanan dan kelebihan dan kekurangan untuk kedua-dua sistem juga ditentukan. Penemuan menunjukkan bahawa sistem rawatan alternatif iaitu Digester Tank Sistem mempunyai kecekapan, berkesan dan kemampuan untuk mengubati pome lebih baik daripada sistem rawatan konvensional.

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LIST OF ABBREVIATIONS/ SYMBOLS/ TERMS

POME	-	Palm Oil Mill Effluent
BOD	-	Biological Oxygen Demand
COD	-	Chemical Oxygen Demand
TSS	-	Total Suspended Solid
SS	-	Suspended Solid
O&G	-	Oil & Grease
AN	-	Ammonia Nitrogen
TN	-	Total Nitrogen
DO	-	Dissolved Oxygen
PVC	-	Polyvinyl Chloride
EFB	-	Empty Fruit Bunch
HRTs	-	Hydraulic Retention Times
OLR	-	Organic Loading Rate
DOE	-	Department of Environment
MPOB	-	Malaysian Palm Oil Board
PORIM	-	Palm Oil Research Institute of Malaysia
CO_2	-	Carbon Dioxide
D.T.S	-	Digester Tank System
P.S	-	Ponding System
A.P	-	Anaerobic Pond
A.D.T	-	Anaerobic Digester Tank

CHAPTER 1

INTRODUCTION

1.0 Introduction

Palm oil is one of the important industrial sectors in Malaysia. Every single year, the production of palm oil increased rapidly (Wah *et al.*, 2002). In 1998, Malaysia had produced 7,425,000 tonnes of palm oil for worldwide export, while in 2001, the amount of crude palm oil production increased to 985,063 tonnes per month which contributed to total amount of more than 12 million tonnes in a year (Palm Oil Link, 2001).

The palm oil sector contributes significantly to the economy of Malaysia. It accounts for approximately 2.93% or RM6.4 billion of the gross domestic productivity of Malaysia in 2002. Providing a yield of 10 times more than most of the other oil crops, oil palm is the most efficient in land and resource utilization and contributing effectively to sustainable development (NVT, 2003).

As the production of palm oil increased, more palm oil mill effluent (POME) is generated annually. Currently about 3.0 million hectares of land are under palm oil cultivation with 300 palm oil mills processing the fresh fruit bunches of palm. The total annual quantity of wastewater generated is estimated to be $1.8 \times 10^6 m^3$ (Ahmad *et al.*, 2003). This situation contributed to more study on the technology of treatment of the POME, due to the large amount of water needed for palm oil mill extraction and the discharge of partially treated effluent into public watercourses.

Palm oil mill effluent is extremely rich in organic content that needs to be properly treated before discharge into rivers. It contains lignocellulosic wastes with a mixture of carbohydrates and oil. Chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of POME are very high (Oswal *et al.*, 2002). Incomplete extraction of palm oil from the palm nut might increase COD values substantially.

The palm oil industry should now look beyond their obligation to comply with the requirements of Environmental Quality Act 1974 in the management of POME. The future growth of the industry sector will require further enhancement in their environmental management practices and in advancing their social and sustainability development responsibility. Appropriate technologies are rapidly evolving in the local scene to meet the demands of the industry.

In Malaysia, the Department of Environment (DOE) has enforced the regulation for the discharge of effluent from the crude palm oil industry. The regulations are based on the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Order and Regulations 1977. Figure 1.0 show the Production of Crude Palm Oil by States in 2001.

Currently, there are various treatment methods are being practiced by the palm oil mills in an effort to reduce pollution to the environment POME. Among the common system is the ponding system, digester tanks, extended aeration and thermophilic anaerobic contact process. In this study, POME will be analyzed by using the methods of anaerobic treatment.

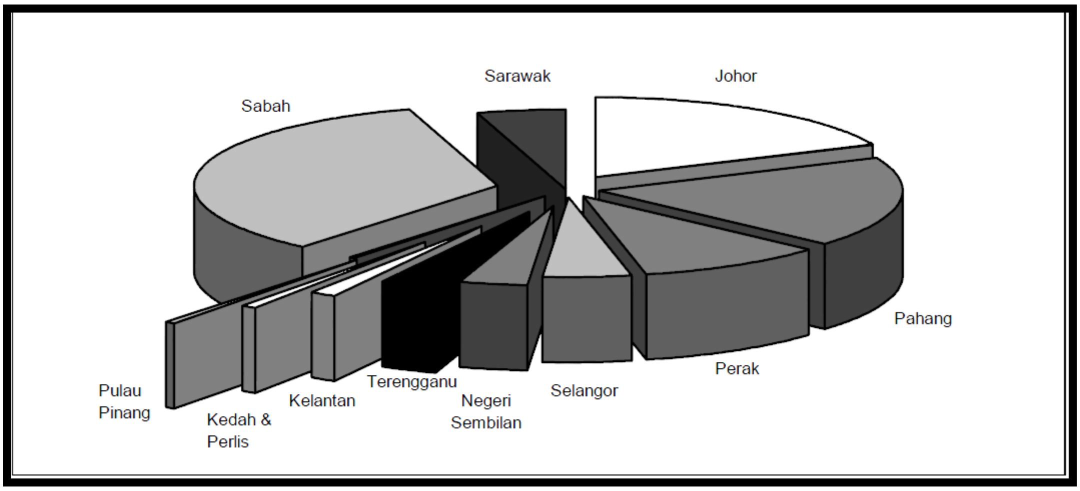


Figure 1.0: Production of Crude Palm Oil by States in 2001

1.1 Problem Statement

Nowadays, Malaysia is currently the largest producer and exporter of palm oil. The implication of this scenario, Malaysia has to play important role in fulfil the needs of palm oil industry. In the processing of palm oil fruit, large quantities of wastewater are generated from the sterilization and oil clarification sections. Raw palm oil mill effluent comprises of water-soluble components of the palm fruits as well as some suspended materials like palm fibre and oil. These components are non-toxic in nature (Golden Hope, 2004). However, palm oil mill effluent cannot be discharged into the watercourse directly. The effluent must be treated to acceptable quality before it can be discharged.

Environment Department has classified the palm oil industry as the largest source of water pollution in the country in 1982 (Agamuthu, 1995). By the year 2001, a total of 15.2 million barrels of oil palm waste water generated from the 250 palm oil mills in Peninsular Malaysia (Ahmad Zuhairi et. Al, 2001)

POME is the wastewater from the production of palm oil has a value of BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) levels. POME is a new release is a colloidal liquid is dark brown, containing oil and fine suspended solids, acidic, and has a temperature in the range of 80C - 90C. A survey by the PORIM / RRIM was conducted on 40 plant oil palm and its findings are shown in the following table:

Table 1.1: Percent reduction for POME

Parameter	Effluent	Discharge	Percent reduction (%)
BOD	10250 – 47500	28 – 1800	99.1
COD	15500 – 106360	210 – 19680	96.6
TSS	11450 – 164950	100 – 23050	87.2
SS	410 – 60360	8 – 14850	94.5
O&G	130 – 86430	0 – 500	99.5
AN	0 – 110	0 – 300	214.3
TN	180 – 1820	20 – 1070	72.7
pH	3.8 – 4.5	6.6 – 9.0	-

**all parameter in mg/L except for pH*

Recently, various treatment processes have been designed to encounter the problem issued from POME. Biological treatment is the commonly used method as POME has high organic content which can be degraded by microorganisms (Kon, 2006). However, the application of biological processes is normally incapable of complying with the standard requirements set by the regulator (Ooi, 2006).

Direct discharge of POME into the environment is not encouraged due to the high values of COD and BOD. Furthermore, with the introduction of effluent discharge standards imposed by the Department of Environment in Malaysia, POME has to be treated before being released into the environment (Federal Subsidiary Legislation, 1974).

In this study, comparison on conventional system and alternative system for anaerobic treatment between ponding system and digestion treatment system was used as method for treatment palm oil mill effluent (POME). More than 85% of palm oil mills in Malaysia have adopted the ponding system for POME treatment (Ma et al. 1993) and this method was the conventional method for POME treatment while digesting tank (Yacob et al., 2005) are the currently available alternative method for anaerobic POME treatment. Both methods are particularly to develop the comparison on efficiencies of treatment technologies for palm oil mill effluents industrial

1.2 Objectives of Study

In executing this project, a few lines of objective have been listed out for the purpose of the studies. The objectives of this study are:

i) To determine the effectiveness system for treatment palm oil mill effluent (POME).
ii) To determine the advantages and disadvantages for both system.
iii) Determine the quality of effluent and percent reduction for anaerobic treatment.

1.3 Scope of study

This research focuses more on industrial waste for palm oil mill effluent (POME) treatment system. The data resources for each characteristic that influent in POME will be obtained from several nearest palm oil plantations in Pahang, which currently applied this system. The main scope of study in this research is to determine the comparison of anaerobic treatment system between conventional method – ponding system and alternative method – digesting tank system for POME.

The comparisons of this study were basically based on their main parameters, which is pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Suspended Solid (SS), Ammoniacal Nitrogen (AN) and Total Nitrogen (TN), but in this case, their operational cost of the system, period of hydraulic retention time (days), the efficiency of the process, organic loading rate (OLR), the ease of operation of the systems and methane composition also will be compare too.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Wastewater

Wastewater is a combination of liquid wastes or water generated from residences, institution and businesses, along with water on the earth. Wastewater can be classified into physical, chemical and biological. In the physical aspect, the wastewater can be determined by the color, smell, temperature, turbidity and total solids. From the chemical, the important aspects should be referred to as organic matter content, inorganic and dissolved gases in the wastewater. Examples of the organic matter in waste water are as carbohydrates, fats, protein, cellulose, oil and etc. while compounds such as phosphorus, nitrogen, sulfur and heavy metals are examples of non-organic substances contained in waste water. Regular gases dissolved in the wastewater are hydrogen sulfide, methane, ammonia, carbon dioxide and nitrogen. For the biological aspects, the wastewater can be classified according to the types of microorganisms (Mecalf & Eddy, 2004)

Initially, the waste water discharged directly into rivers because the river was still able to perform self-purification. Self purification is actually a natural ability to reduce river pollution. When the effluent discharged into a river, it put on demand for oxygen source stream. The removal of the DO (dissolved Oxygen) for waste stabilization must be balanced by the addition of oxygen. The process of reoxygenation of the river is dependent on the mass transfer of oxygen from the atmosphere into the water. However, when the organic strength in the river water is too high, the river no longer able to self purification and the DO content in the river will be at a very low level. At this stage, the river is considered contaminated and is an active medium for the spread of disease (Duncan Mara. 1976)

Now, the government has set all the remaining water must be treated in detail in order to avoid adverse effects on the environment and humans, such as odor problems, health problems and discomfort for the residents living near the dumping of waste water. Enforcement of the Environmental Quality Act 1974 has proved that the government is very concerned with the problems associated with water pollution.

2.2 Industrial Wastewater

Industrial wastewater is wastewater generated from manufacturing processes in factories. Characteristics of industrial wastewater are dependent on the type of industry. Typically, more polluted industrial waste water from domestic wastewater as the elements contained therein are more complex. Some of wastewater containing toxic and organic materials which may not be biodegradable (for example, polyvinyl chloride - PVC, organic dyes, etc.) those require special treatment before being discharged.

In Malaysia, for controlling water pollution, Environment Department has determined that the discharge of industrial wastewater must comply with the Environmental Quality (Sewage and Industrial Effluent) Regulations, 1978.

2.3 Palm Oil Industry Background

In the early 1970s, Malaysia's economic development was based on the agricultural sector. Palm oil is the largest plantation grown in Malaysia due to its commercial value on the world stage. Large areas of forest were converted into oil palm estates. By the end 1980s, the oil palm estate covered one third of the country's cultivated area. As a result of expansion in oil palm based industry, during 1975-1985, crude palm oil production rose from 1.3 million tonnes to 4.1 million tonnes making it the country second largest earner of foreign exchange by 1984 (ESCAP, 2005). Fresh fruit bunches are produced within 25 to 36 tonnes per hectare, depending on soil conditions, temperature and other factors (Agamuthu, 1995). The process of crude palm oil production can be summarized as follows:

a) sterilization of fresh fruit bunches
b) separation of the tank were a stripper
c) digestive units forfeited
d) extraction and digestion (pressing)
e) purification of crude palm oil

Like other manufacturing industries, palm oil production also resulted in the effluent. Palm oil waste water effluent of POME is the main palm oil processing industry. Other waste is also produced as a tree trunk, empty fruit bunches (EFB), fiber and shell (Agamuthu, 1995). Figure 2.0 shows the processes involved in palm oil industry.

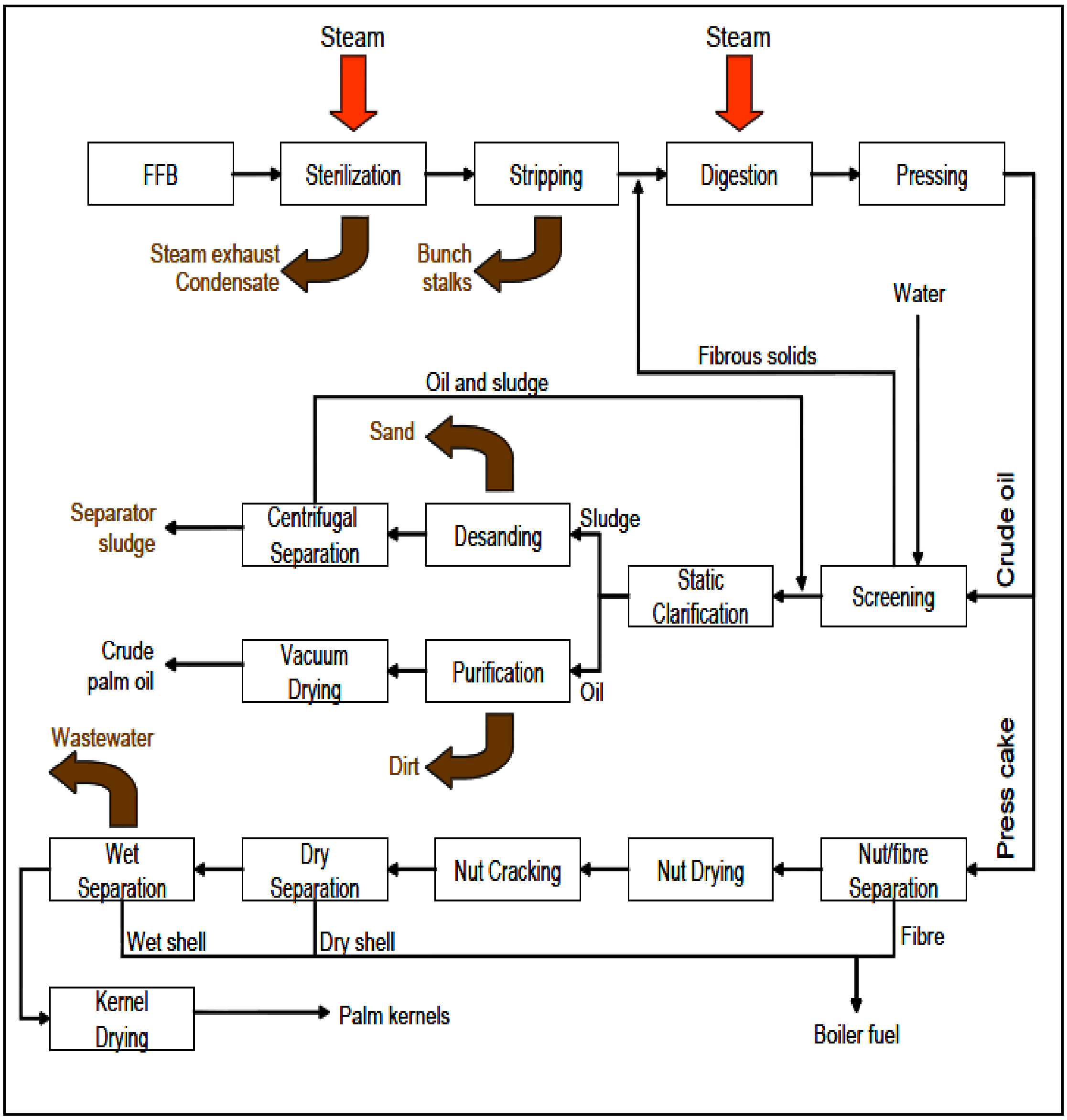


Figure 2.0: Typical Process of Palm Oil Industry (MPOB, 2000)

With the growth of agro based industries, the palm oil related industries become a major pollution problem. By 1970s, 42 rivers in Malaysia were severely aerobically polluted by untreated effluents (ESCAP, 2005). Consequently, this situation led to significant impacts on coastal areas and rivers, which in turn affected the socio-economy of the local communities. The industry has made tremendous strides towards the treatment of liquid effluents since 1977 till now. A variety of processes are now available for the treatment of the liquid waste.

In 2004, more than 40 million tonnes of POME was generated from 372 mills in Malaysia (Hassan *et al.*, 2004). In order to prevent pollution from this effluent, POME has to be treated to fulfil a few characteristics as which have been stated by Department of Environment Malaysia. The respective standard for discharge limit is shown in Table 2.0.

Table 2.1: Characteristics of POME and its respective standard discharge limit by the Department of the Environment in Malaysia (Ahmad *et.al,* 2005)

Parameter	Limits
pH	5.0 – 9.0
BOD, (mg/L)	100
COD (mg/L)	
Total Suspended Solid (mg/L)	
Suspended solids (mg/L)	400
Oil and grease (mg/L)	50
Ammonical nitrogen (mg/L)	150
Total nitrogen (mg/L)	200

2.4 Palm Oil Wastewater (POME)

Water used in the production process of palm oil is in large quantity, which is about 1.0 - 1.5 tonnes to process 1 tonnes of Fresh Fruit Bunches. Approximately 0.5 tonnes of water used as boiler feed water and other water used in processes such as melting, cleaning and so forth. Almost half of the water will be water remaining after the processing of palm oil.

In the palm oil mills, waste water generated as a result of several processes. These processes are as the sterilization of fresh fruit bunches crude palm oil purification process and the kernel and shell. In the process, the purification process of crude palm oil to produce the most waste water that is 60% of the total waste water.

POME has a BOD value in the range of 25,000 - 31000mg / L and COD values in the range of 62000mg / L (Agamuthu, 1995). Because of high organic strength, POME must be treated before being discharged. In Malaysia, palm oil mill effluent quality that has been treated to comply with the Environmental Act (Authorised Premises) (Crude Palm Oil) 1979. Table 2.1 shows the standards for POME to be discharged into water sources.

2.5 Characteristics of Palm Oil Mill Effluent

Fresh POME is thick brownish slurry as show in figure 2.1 and figure 2.2. Its temperature is around 80 to 90ºC, acidic with pH 3.8 to 4.5 and contains very high concentration of organic matter (COD = 40,000 to 50,000 mg/L, BOD = 20,000 to 30,000 mg/L) (Aris et al. 2007). The effluent is non-toxic as no chemical was added in the oil extraction process.

Palm oil effluent is a colloidal suspension of 95 – 96% water, 0.6 – 0.7% oil and 4 – 5& total solids including 2 – 4 % suspended solids originating from the mixture of a sterilizer condensate, separator sludge and hydrocyclone wastewater (Ahmad et. al, 2003).

The typical characteristics of POME have been given in Table 2.1. The raw or partially treated POME has an extremely high content of degradable organic matter, which is due in part to the presence of unrecovered palm oil. This highly polluting wastewater can therefore cause severe pollution of waterways due to oxygen depletion and other related effects (Ahmad *et.al,* 2003).

The oil droplets of POME can be found in two phases. They either suspend in the supernatant or float on the upper layer of the suspension. The residue oil droplets in POME were solvent extractable. The extract of the oil droplets consists of 84 wt% neutral lipids and 16 wt% of complete lipids (6 wt% glygolipids and 10 wt% phospholipids). The neutral lipids consist of 74.7% triglycerides, 8% diglycerides, 0.5% monoglycerides and 0.8% free fatty acids. POME also contributes a high concentration of surface active compounds like phospholipids (10 wt %) and glycolipids (6 wt %) (Ahmad *et.a.* 2005).

As mentioned earlier, POME is characterized by high temperature (80-90oC), acidic (pH 3.8 to 4.5) and contains high organic content with BOD and COD ranging from 20, 000 mg/L to 30, 000 mg/L and 40, 000 mg/L to 50, 000 mg/L respectively.

Table 2.2: Standards for disposal of POME into the watercourse (JAS)

Parameter	Limits the period of release					
	1.7.1978 – 30.6.1979	1.7.1979 – 30.6.1980	1.7.1980 – 30.6.1981	1.7.1981 – 30.6.1982	1.7.1982 – 31.12.1983	1.7.1978 and forward
pH	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0	5.0 – 9.0
BOD	5000	2000	1000	500	2500	100
COD	10000	4000	2000	1000	-	-
TSS	4000	2500	2000	1500	-	-
SS	1200	800	600	400	400	400
O&G	150	100	75	50	50	50
AN	25	15	15	10	150*	150*
TN	200	100	75	50	300*	200*

Figure 2.1: Fresh POME discharge from plant.

Figure 2.2: Thick brownish slurry fresh POME with high temperature.

2.6 Palm Oil Mill Effluent Treatment

Nowadays, there are various treatment processes have been studied to treat the POME. Conventional biological systems are the most commonly used method in treating POME involving the use of aerobic, anaerobic and facultative ponds. Alternatively the uses of coagulation, Fenton Oxidation Systems, as well as membrane technology have been reported. The final discharge of POME treatment must follow the standard before it can be discharge to the public watercourse.

2.6.1 Aerobic Treatment System

Various aerobic treatment systems for palm oil mill wastewater are readily available. The common system is the aerobic pond system with only little palm oil mills using the more advanced active sludge system. (Environment Advisory Assistance for Industry, 1997)

Different aerobic pond systems, which vary in the type of the oxygen supply system (aeration system) and the design loading rates, are facultative ponds (maturation ponds), oxidation ponds, aerated lagoons and polishing ponds. Facultative ponds, oxidation ponds and polishing ponds established oxygen supply by photosynthetic activities of algae and plants and by absorption of oxygen from the atmosphere. However, aerated lagoons are artificially aerated. The high temperature of the pond content does enhance the biochemical reactions, resulting in increased substrate removal even at the lower solubility of oxygen in water at increased temperature (Environment Advisory Assistance for Industry, 1997).

2.6.2 Anaerobic Filtration

Anaerobic filter has been applied to treat various types of wastewater and it's including anaerobic filter for POME treatment. Borja and Banks (1994b, 1995b). The packing allows biomass to attach on the surface when raw POME feed enters from the bottom of the bioreactor while treated effluent together with generated biogas will leave from the top of the bioreactor.

Anaerobic filter is selected for wastewater treatment because (i) it requires a smaller reactor volume which operates on a shorter hydraulic retention times (HRTs) (ii) high substrate removal efficiency (Borja and Banks, 1994b), (iii) the ability to maintain high concentration of biomass in contact with the wastewater without affecting treatment efficiency (Reyes et al., 1999; Wang and Banks, 2007), and (iv) tolerance to shock loadings (Reyes et al., 1999; Van Der Merwe and Britz, 1993). Besides, construction and operation of anaerobic filter is less expensive and small amount of suspended solids in the effluent eliminates the need for solid separation or recycle (Russo et al., 1985).

However, filter clogging is a major problem in the continuous operation of anaerobic filters (Bodkhe, 2008; Jawed and Tare, 2000; Parawira et al., 2006). So far, clogging of anaerobic filter has only been reported in the treatment of POME at an organic loading rate (OLR) of 20 g COD/l/day (Borja and Banks, 1995b) and also in the treatment of slaughterhouse wastewater at 6 g COD/l/day. This is due to the fact that other studies were conducted at lower OLR which had lower suspended solid content compared to POME.

In general, anaerobic filter is capable of treating wastewaters to give good effluent quality with at least 70% of COD removal efficiency with methane composition of more than 50%.In terms of POME treatment, the highest COD removal efficiency recorded was 94% with 63% of methane at an OLR of 4.5 kg COD/m3/day, while overall COD removal efficiency was up to 90% with an average methane gas composition of 60% (Borja and Banks, 1994b).

Investigations have been done to improve the efficiency of anaerobic filtration in wastewater treatment. For instance, Yuet al. (2002a) found that operating at an optimal recycle ratio which varies depending on OLR will enhance COD removal. However, methane percentage will be compromised with increase in optimal recycle ratio. Higher retention of biomass in the filter will also lead to a better COD removal efficiency. In order to optimize the retention of biomass on the filter media surface and trapped suspended biomass within the interstitial void spaces, Show and Tay (1999) suggested the use of support media with high porosity or open-pored surfaces. It was also suggested that continuously fed system gives better stability and greater degradation efficiency in anaerobic filters (Nebot et al., 1995).

2.6.3 Membrane Technology

In reclaiming the drinking water from POME, removal of pollutant is required. Membrane technology (ultrafiltration and reverse osmosis) coupled with coagulation/flocculation as pre-treatment was applied to recover drinking water from POME (Ahmad et al, 2006). The analyses of the reclaimed water show that the water quality fulfilled the drinking water standard set by the US Environmental Protection Agency. The performance of the membranes with coagulation/flocculation showed great potential to recover drinking water form POME with 78% water recovery. The study show that membrane fouling was reversible and primarily due to cake formation (Ahmad et, 2006).

Membrane technology shows high potential to treat POME for eliminating the environment problem, and in addition, this alternative treatment system offers water recycling. The treated effluent has a high quality and crystal clear water that can be used as the boiler feed water or as the source of drinking water production. In a study conducted by Ahmad (2003), a pilot plant was designed and constructed for coagulation; sedimentation and absorption play their roles at first stage as membrane pretreatment process, and ultrafiltration and reverse osmosis membranes are combined for the membrane separation treatment. Results from the total treatment system show a reduction in turbidity, COD and BOD up to 100%, 98.8% and 99.4%, respectively with a final pH of 7. Thus, the results show that this treatment system has a high potential for producing boiler feed water that can be recycled back to the plant.

Membrane ultrafiltration is used as the tertiary treatment method in a study reported by Wong et al. (2002). Combination of filtration-ultrafiltration treatment gave the best overall treatment efficiency, with an overall reduction 93.4% for total nitrogen, suspended solids turbidity and colour content. For the treatment combination of centrifugation-ultrafiltration, the average removal efficiency was only 86.4% while coagulation-ultrafiltration treatment only managed to achieve an average of 67.1% removal.

2.6.4 Extended Aeration

Extended aeration is the most popular applications on wastewater treatment of small quantities, for example, wastewater from the school and the village. Aeration basin is probably the concrete cast-in-situ or tanks made from plants. Perfect continuous mixing obtained by mechanical aerators or diffused water. Recycling of sludge into the aeration chamber is through a narrow channel or by using air-lift pump. To complement the systems, mechanical surface earators can be introduced at the aerobic ponds. This effectively reduces the BOD through aerobic process. The aerators are normally installed at the end of the ponding system before discharge. However, this happens only where land area is constraint and does not permit extensive wastewater treatment. Otherwise, aerators must be provided to meet DOE regulations.

2.7 Conventional Treatment System

Surveys conducted by the Malaysian Palm Oil Board (MPOB), previously known as Palm Oil Research Institute of Malaysia (PORIM), have shown that most of the palm oil mills (more than 85%) were using ponding system for the treatment of POME and this is also known as conventional treatment system.

2.7.1 Ponding System

According to Ma et al., (1993) Ponding system is the most common treatment system that is employed in palm oil mills to treat POME with more than 85% of the mills having adopted this method. Ponding system comprises of de-oiling tank, acidification ponds, anaerobic ponds and facultative or aerobic ponds (Chan and Chooi, 1984), each pond show in figure 2.3 – 2.7. Number of ponds varies according to the capacity of the palm oil mill. Facultative or aerobic ponds are necessary to further reduce BOD concentration in order to produce effluent that complies with Federal Subsidiary Legislation, 1974 effluent discharge standards.

In the ponding system approach, raw POME is allowed to go through a cooling/de-cooling tank/pond (1 day hydraulic retention time or HRT), acidification pond (2 – 4 days HRT) before feeding to anaerobic pond 5 – 7 metres depth (30 – 45 days HRT). The anaerobic process in deep ponds breakdowns a high proportion of the organic matter into methane, CO_2 and small amount of hydrogen sulphide. Methane generated normally uncontrolled and escaped directly to the atmosphere. The treated effluent is further subject to aerobic or facultative treatment in shallow ponds (1.5m) in order to meet the required discharge standards.

The raw effluent is treated using a ponding system comprising of three phases, i.e. anaerobic, facultative, and algae processes. Although the system takes a longer retention time of 90 days, it is less sensitive to environment changes, stable, efficient and could guarantee excellent pollutant biodegradation efficiency of above 95%. Operational efficiency of the pond system is dependent on the initial procedure, pool dimensions, the quality of effluent, the retention time, pH, organic loading rate and maintenance (Agamuthu, 1995). Figure 2.8 shows a ponding system flow diagram for the treatment of POME.

Figure 2.3: Mixing Pond

Figure 2.4: Anaerobic Pond

Figure 2.5: Facultative Pond

Figure 2.6: Algae pond

Figure 2.7: Dry Bed Pond in Ponding System

2.7.2 Anaerobic Pond

Anaerobic pond is a system which is mostly used to treat wastewater, for it can digest high amount of solids and is an economical system. In constructing the pond, the depth is crucial for determining the type of biological process. The number of ponds will depend on the production capacity of each palm oil mill. The length and width differs based on availability of land.

For anaerobic pond the optimum depth ranges from 5 – 7m. A typical size of an anaerobic pond in a palm oil mill which has a processing capacity of 54 tons per hour is 60.0 x 29.6 x 5.8 m (length x width x depth) (Yacob et al., 2006a) which is approximately equivalent to half the size of a soccer field. Size of pond depends on the capacity of the palm oil mill as well as the area available for ponds as show in figure 2.3 – 2.4. Anaerobic ponds have the longest retention time in ponding system which is around 20–200 days (Chan and Chooi, 1984).

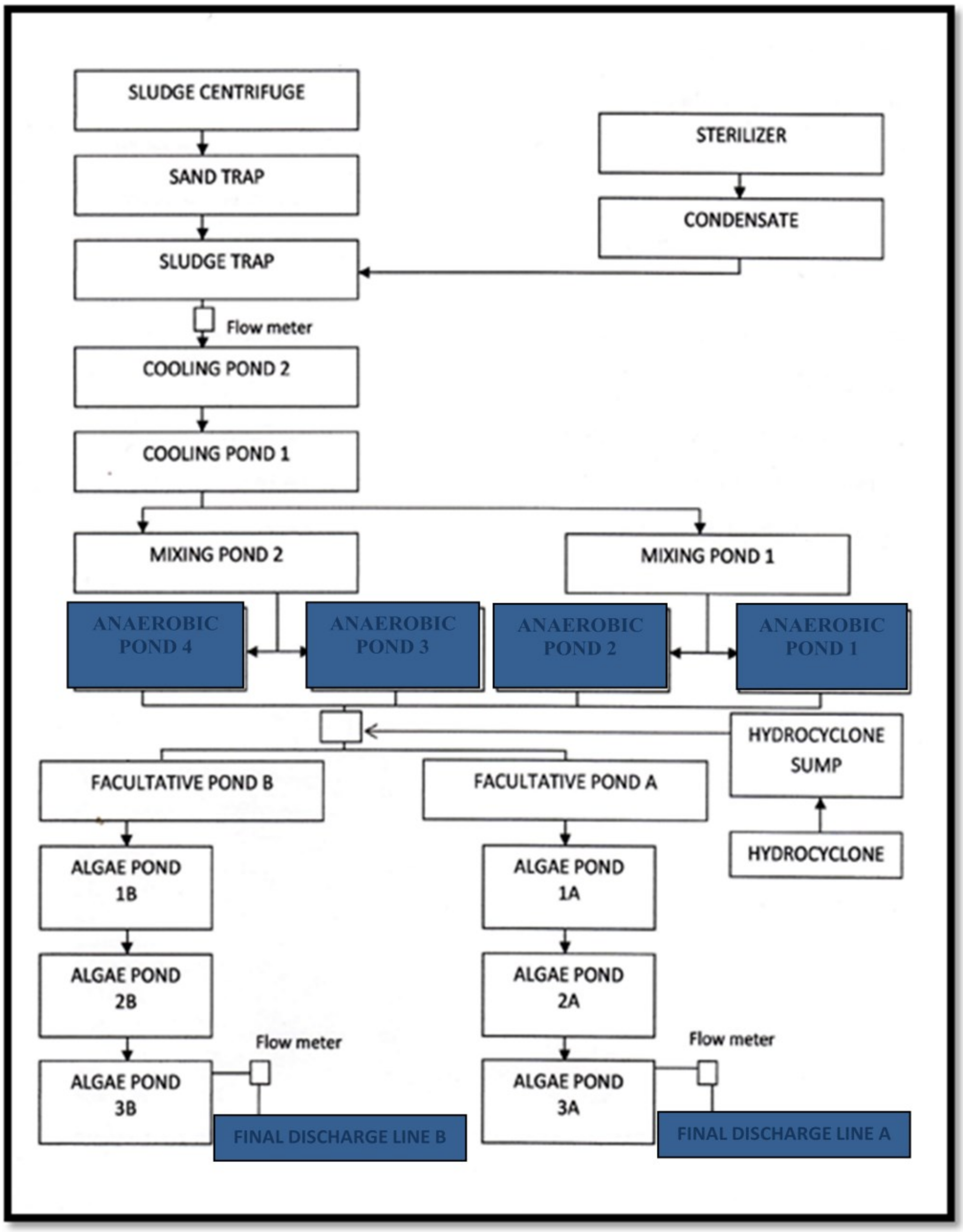


Figure 2.8: Ponding System Flow Diagram

2.7.3 Advantages and Disadvantages of Ponding System

Advantages

- low in construction and operating costs and is easily maintained
- Can achieve a reasonable degree of treatment
- Low energy requirements (no aeration)
- Producing methane gas as a valuable end product
- Generated sludge from process could be used for land applications.
- Generally produces a reasonable quality wastewater with an acceptable BOD to be discharged into the water courses

Disadvantages

- Long retention time
- Slow start-up (granulating reactors)
- Large area required for conventional digesters
- Difficult to control and monitor
- Ponds are difficult to maintain given the oil accumulates with the solids, forming an oily and sticky scum, which is difficult to remove

2.8 Digester Tank System

This system is a combination of an open digester tank and a series of ponding system. The anaerobic digestion is carried out in the digester, then in the facultative anaerobic and algae pond.

2.8.1 Closed Tank Digester

Closed anaerobic tank digester method has also been developed but application has only been reported in two or three palm oil mills (Quah and Gilles: 1981, 1984; Chua and Gian, 1986). The biogas generated is captured and directed to flaring or used as boiler fuel or for power generation. The treated effluent from the anaerobic digesters may be discharged for land application or further treated by aerobic/facultative or extended aeration system to meet the effluent discharge standard of the Department of Environment.

2.8.2 Open Tank Digester

A significant number of mills (5-10%) have built open top tanks instead of ponds for the anaerobic digestion process. Tank digesters have been built with about 20 days HRT. Similar to the ponding system, mixing is limited as this is affected mainly by the biogas generated, although the influent and effluent flow helps to a small extent. Similar to the ponding system, methane generated is uncontrolled and escapes directly to the atmosphere.

The tank approach facilitates easier removal of solids build-up at the bottom on a regular basis, and thus maintaining the desired treatment efficiency. The digested effluent is further treated by the aerobic or facultative ponds or extended aeration system with approximately 20 days HRT. The effluent from the anaerobic digesters may also be diverted for land application. Open digesting tanks are used for POME treatment when limited land area is available for ponding system.

2.8.3 Anaerobic Digester Tank

Anaerobic digester is considered to be an effective treatment process for palm oil mill effluent (POME). This involves a consortium of microorganisms catalysing a complex series of biochemical reactions that mineralise organic matter producing methane and carbon dioxide. The key factors to successfully control the stability and efficiency of the process are reactor configurations, hydraulic retention time (HRT), organic loading rates (OLR), pH, temperature, inhibitor concentrations, and substrate composition. In order to avoid a process failure and/or low efficiency, these parameters require an investigation so that they can be maintained at or near to optimum conditions.

Although the digester system has been proven to be superior to anaerobic ponds, it also has similar problems of scum formation and solid sludge accumulation. Another serious problem is the corrosion of the steel structures due to long exposure to hydrogen sulfide. Figure 2.9 show the example of steel tank used to treat the anaerobic treatment for digester tank system. Incidents such as burst and collapsed digesters have been recorded. Accumulated solids could be easily removed using the sludge pipe located at the bottom of the digester. The dewatered and dried sludge can then be disposed for land application.

For the controlled anaerobic tank digester method with mixing, the gross treatment efficiency has been estimated to be in the range of 90 – 95 % in terms of BOD removal (Yeoh and Chong, 1985). Corresponding COD treatment efficiency is expected in the range of 80 – 90 %. Methane content in the biogas generated has been reported (Quah and Gilles, 1981) in the range of 54 – 70 % with an average of

64 %. The major part of the balance of the biogas is CO2 (36%) with traces of hydrogen sulphide (up to 2500 ppm).

The data reported by Ma et al (1993) in a survey of 17 palm oil mills show that the overall treatment efficiency for BOD and COD removal, combining anaerobic digestion and aerobic or facultative treatment for both the ponding and tank systems, was very high (>99% for BOD and ~97.5% for COD). However, considering the poor definition of the pond configuration, high bottom solids build up and scum forming in the ponding system treatment approach, the rate of biogas or methane generation from anaerobic digestion could be significantly lower than the theoretical potential based on COD removal.

The data in the same report on BOD and COD removal for open tank digestion followed by land application appears to be more directly applicable for the estimation of methane production potential based on the rate of COD removed during the anaerobic digestion process (97.7% for BOD from 22,380 mg/l to 513 mg/l; ~93% for COD from 63,800 mg/l to 4,550 mg/l). However, as mentioned earlier, it is not clear whether the BOD and COD values were the actual concentrations of the effluent being fed to the digester tanks. The open tank digesters apparently are more efficient and may be measured more readily. Figure 3.0 shows a digester tank system for the treatment of POME.

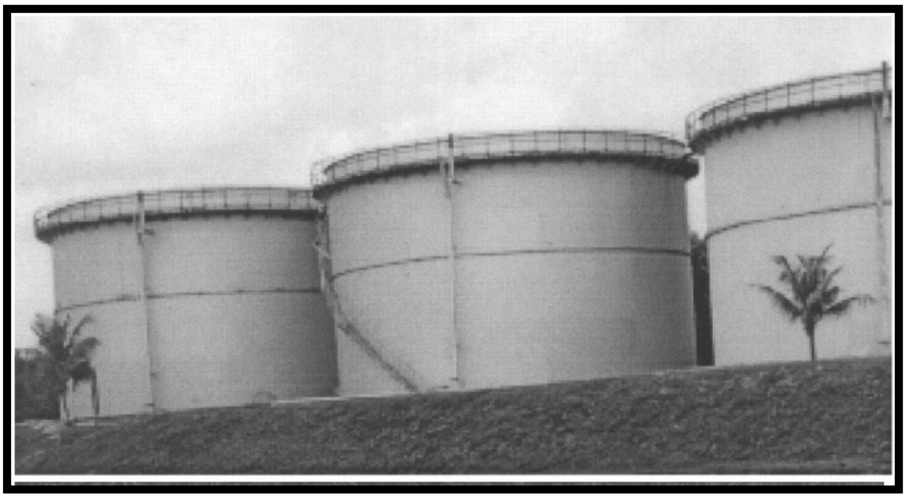


Figure 2.9: Example of Digester Tank Used in Anaerobic Treatment

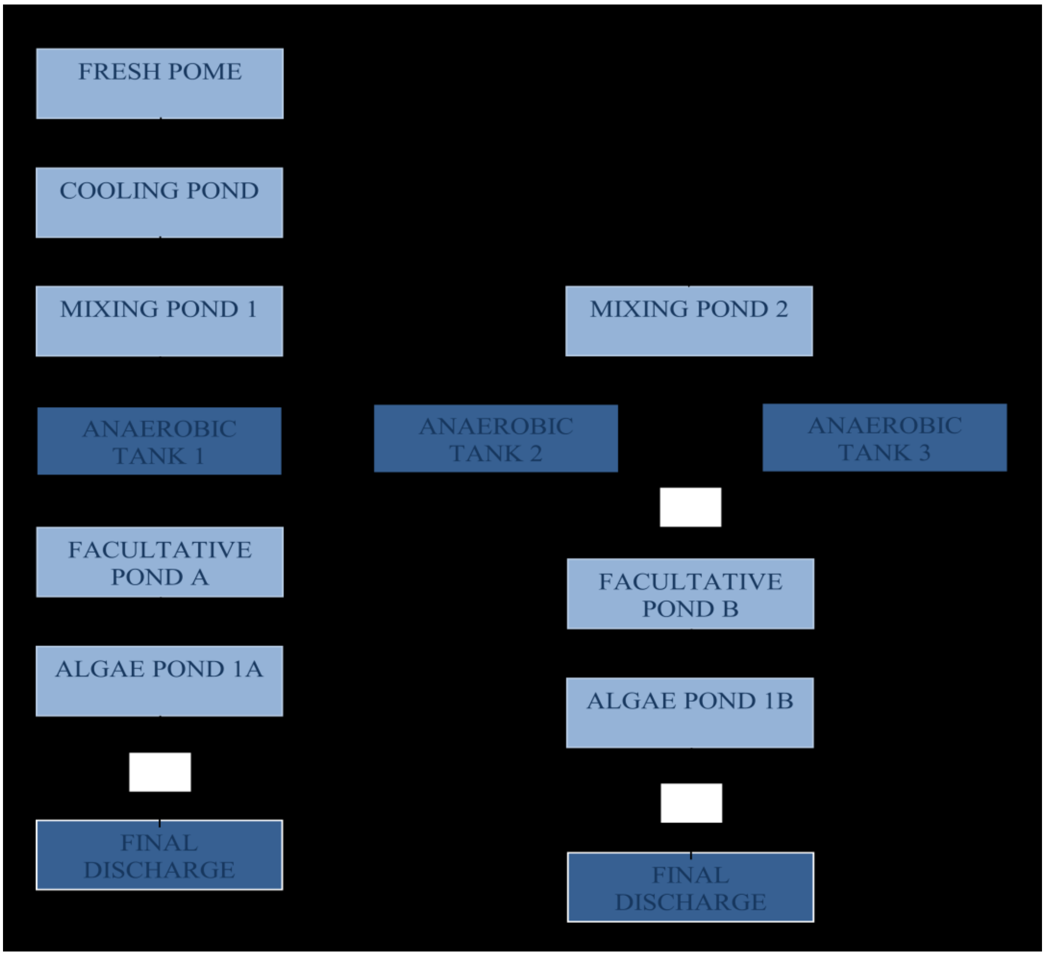


Figure 2.10: Digester Tank System Flow Diagram

2.8.3 Advantages and Disadvantages of Digester Tank

Advantages

- Short retention time
- Apply when limited area
- A better reduction of BOD can be achieved in a shorter time
- 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

Disadvantages

- High in construction and operating costs and is easily maintained
- Sensitive to pH changes and methanogens are affected to a greater extend
- The corrosion of the steel structures due to long exposure to hydrogen sulfide

2.9 Comparison between Performances on POME Treatment

In constructing the ponds, the depth is crucial for determining the type of biological process. The length and width differ based on the availability of land. For anaerobic ponds, the optimum depth ranges from 5 – 7 m, while facultative anaerobic ponds are 1 – 1.5 m deep. The effective hydraulic retention time (HRT) of anaerobic and facultative anaerobic systems is 45 and 20 days, respectively. A shallower depth of approximately 0.5 – 1 m is required for aerobic ponds, with an HRT of 14 days. The POME is pumped at a very low rate of 0.2 to 0.35 kg BOD/m^3 a day of organic loading. In between the different stages of the ponding system, no pumping is required, as the treated POME will flow using gravity or a sideways tee-type subsurface draw-off system. Under these optimum conditions, the system is able to meet the requirement of DOE. The number of ponds will depend on the production capacity of each palm oil mill.

One problem faced by pond operators is the formation of scum, which occurs as the bubbles rise to the surface, taking with them fine suspended solids. This results from the presence of oil and grease in the POME, which are not effectively removed during the pretreatment stage. Another disadvantage of the ponding system is the accumulation of solid sludge at the bottom of the ponds eventually the sludge and scum will clump together inside the pond, lowering the effectiveness of the pond by reducing the volumetric capacity and HRT. When this happens, the sludge may be removed by either using submersible pumps or excavators. The removed sludge is dewatered and dried before being used as fertilizer. The cleanup is normally carried out every 5 years or when the capacity of the pond is significantly reduced.

The anaerobic digestion is carried out in the digester, then in the facultative anaerobic and algae ponds. It has been shown that by using an open digester, a better reduction of BOD can be achieved in a shorter time. Digesters are constructed of mild steel at various volumetric capacities ranging from 600 up to 3600 m3. The treatment of treated POME from the digester will start at the facultative ponds, followed by the algae ponds. A description of the ponding systems is outlined in the previous section "Pretreatment."

The HRT of the digester is only 20–25 days and has a higher organic loading of 0.8 – 1.0 BOD kg/m^3day compared to anaerobic ponds. With minimal financial input from the operators, no mechanical mixing equipment is installed in the digesters. Using the same principle as anaerobic ponds, mixing of POME is achieved via bubbling of biogas. Occasionally, the mixing is also achieved when the digester is being recharged with fresh POME. The treated POME is then overflowed into the ponding system for further treatment

Table 2.3 show short lists the performance between anaerobic pond and anaerobic digester tank for treatment methods of POME

Table 2.3: Comparison between anaerobic pond and anaerobic digester tank

	OLR (kg BOD/m^3day)	Hydraulic retention time (days)	Methane composition (%)	COD removal efficiency (%)	Reference
Anaerobic pond	0.2 to 0.35	40 – 45	54.4	97.8	Yacob et al. (2006a)
Anaerobic digester	0.8 – 1.0	20 – 25	36	80.7	Yacob et al. (2005)

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this study, all data related with Palm oil mill effluent (POME) was obtained from selected palm oil mill industry. POME data was taken from the anaerobic system and final effluent discharge. Ponding system and Digestion tank treatment system are 2 main system used in this study to determine which is the most efficiency system to treat POME. Among the data to be analyses on the following POME are:

i) pH
ii) Biological Oxygen Demand (BOD)
iii) Chemical Oxygen Demand (COD)
iv) Total Suspended Solids (TSS)
v) Suspended Solid (SS)
vi) Oil and Grease (O & G)
vii) Ammonical Nitrogen (AN)
viii) Total Nitrogen (TN)

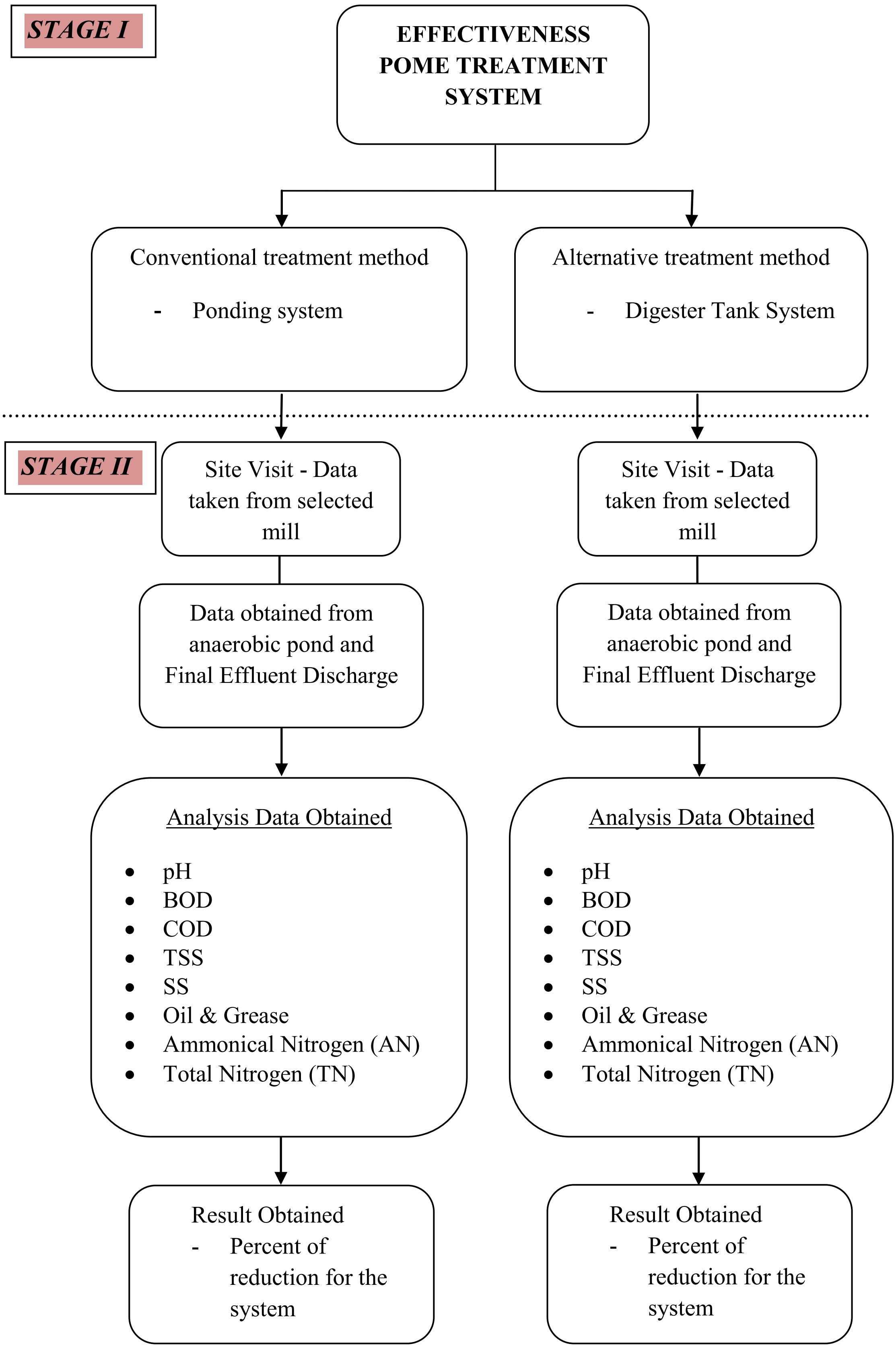
There are 3 main steps in this study, which is gathered and collected information about POME wastewater treatment system from any journal, books, article and etc, site visit to the selected palm oil mill to get data related, and analysis on the data obtained.

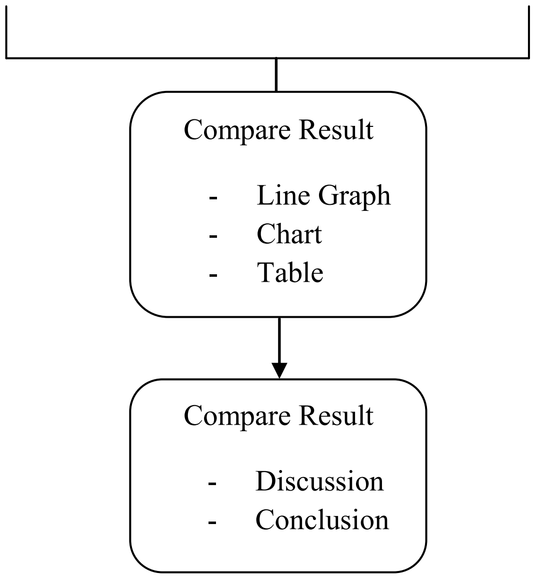
3.2 Site Visit

Site visits to selected palm oil mills will be conducted to obtain data related to the POME. The selected palm oil mills are located at the Pahang states. The main purposed to do site visit is to get the data for both system which is at anaerobic treatment for ponding system and digester system and also at their final effluent discharge.

Other than that, the purposed of doing this site visit is to know more details about the system choose and to gather more information about the system directly by doing some interview with the owner or manager of the mills. During the site visit, permission to look more closely at the treated POME will be done. All figure during site visit show in figure 3.0 – 3.4 below.

3.3 Flow Chart





3.4 Analytical Techniques

Analytical methods were carried out to measure the properties of POME: pH, COD, BOD, oil and grease, total suspended solids (TSS), Ammonial Nitrogen (AN), and Total Nitrogen (TN) are based on standard method (APHA, 1998).

3.4.1 pH

The term pH is traditionally used as a convenient representation of concentration of hydrogen ion. For example, neutral water has pH of 7, which means that the hydrogen ion concentration is 10^{-7} mol/L. If pH scales ranges from 1 – 14, with a neutral reading of 7. Reading below 7 indicates an acidic condition, and those above 7 indicate a basic condition. The pH is extremely important in biological wastewater treatment, because the microorganisms remain sufficiently active only within a narrow range, generally between pH 6.5 and 8. Outside this range, pH can inhibit or completely stop biological activity. Nitrification reactions are especially pH – sensitive. Biological activity declines to near zero at pH below 6.0 in unacclimated systems.

Raw wastewater typically has a pH near 7. Although significant departures may indicate industrial or other non domestic discharges, there are other conditions that can cause pH to deviate norm. Anaerobic conditions lower the pH of a wastewater. Low Ph value, coupled with other observations, such as sulphide odors and black color, provide evidence of septic conditions in the collection system or within the treatment process. Only nitrification in the secondary aeration basins may reduce the pH enough to inhibit biological activity in some low – alkalinity systems. Conversely, denitrification reaction (by them) will increase pH. Covered high – purity oxidation systems can also lower pH as a result of the build up of carbonic acid.

3.4.2 Chemical Oxygen Demand (COD)

Chemical oxygen demand (C0D) is defined as the amount of a specific oxidant that reacts with the sample under controlled conditions. The quantity of oxidant consumed is expressed in terms of its oxygen equivalence.

COD is a defined test; the extent of a sample oxidation can be affected by digestion time, reagent strength and sample COD concentration. COD is often used as a measurement of pollutants in wastewater and natural waters. HACH program (HACH® DR/4000) was used to measure the diluted POME sample for its COD reading.

3.4.3 Biochemical Oxygen Demand (BOD)

The biochemical demand (BOD) determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents and polluted waters. The test has its widest application in measuring waste loadings to treatment plants and in evaluating the BOD-removal efficiency of such treatment systems. The test measures the molecular oxygen utilized during a specified incubation period for the biochemical degradation of organic material (carbonaceous demand) and the oxygen used to oxidize inorganic material such as sulphides and ferrous iron.

3.4.4 Oil and Grease

Oil and grease is defined as any material recovered as a substance soluble in the solvent. It includes other material extracted by the solvent from an acidified sample and not volatilized during the test. In the determination of oil and grease, an absolute quantity of a specific substance was not measured. Rather, groups of substances with similar physical characteristics were determined quantitatively on the basis of their common solubility in an organic extracting solvent.

3.4.5 Total Suspended Solids (TSS)

Suspended solid is the portion retained on the filter. The type of filter holder, the pore size, porosity, area and thickness of the filter and the physical nature, particle size, and amount of material deposited on the filter are the principal factors affecting separation of suspended from dissolved solids.

$$TSS = \frac{[(\text{weight of filter + dried residue}) - \text{weight of filter}] \times 1000}{\text{Sample volume, mL}}$$

3.4.6 Suspended Solid (SS)

Suspended solid was analysed using gravimetric method (APHA, 1985). A filter paper was weighted and placed on a furnel. 100 mL sample was then poured into the pump vacuum and left it for a few minutes. After the sample was pumped entirely then the filter paper was placed in an oven for 1 hour at 105$_o$C. The filter paper was weighted for second time. The mass of the suspended solids was measured by subtracting the first measuring mass from second measuring mass.

3.4.7 Ammoniacal Nitrogen (AN)

It is component of nitrogen referred as ammoniacal nitrogen, which is adopted as an indicator to determine pollution by sewage. Other component of nitrogen includes organic nitrogen, Kjeldahl Nitrogen, Nitrate and Nitrite. It is a natural product of decay of organic nitrogen compounds and one of the many contaminants in water supplies.

The ammoniacal nitrogen in effluent discharged from sewage treatment plants is gradually diluted in the waterways and is reduced to a less toxic compound. Ammoniacal Nitrogen is extremely soluble in water, reacting with water to produce ammonium hydroxide and one of the transient constituents in water as it is part of the nitrogen cycle, which is influenced by biological activity.

3.4.8 Total Nitrogen (TN)

Typical ranges of nitrogen concentrations in raw domestic wastewater are 20 to 85 mg/L for total nitrogen (the sum of organic nitrogen, ammonia, nitrate, and nitrite – nitrogen); 8 – 35 mg/L organic nitrogen; and 12 – 50 mg/L ammonia - nitrogen. Much lower nitrite- and nitrate – nitrogen concentrations are present. If the plant treats industrial flows with high BOD and low nitrogen levels, the wastewater may become nitrogen – limited, if so, complete stabilization of the BOD would require nitrogen addition from another source.

An analysis of nitrogen in wastewater involves several procedures and techniques. The organic nitrogen level is determined by performing a Kjeldahl nitrogen analysis, which measure both the organic nitrogen and ammonia, and then subtracting the ammonia value, which is measured separately. Nitrite – nitrogen is measured directly. The nitrate concentration is determined by a procedure that measures total nitrate and nitrite and then subtracts nitrite. Ammonia – nitrogen may also be measured directly using electrode.

Figure 3.0: Checking pH and temperature parameter at the final effluent discharge.

Figure 3.1: pH meter and temperature for ponding system.

Figure 3.2: final effluent discharge by watercourse

Figure 3.3: final effluent discharge at ponding system

Figure 3.4: Site visit to Akademi Latihan Felda, Bukit Goh, Kuantan

CHAPTER 4

DATA ANALYSIS

4.1 Introduction

As the objective of this research, is to determine the detail analysis of secondary data that will be proceed. Data will analyze to determine the parameter tested at effluent after go through the treatment process. The secondary data are taken from early 6 months (January, February, Mac, April, May, June) of 2010 sampling result. The resources of this data are taken from the selected Palm oil Mill. With all this data and the analysis process, the objective of this research will be determined.

4.2 Comparison of Parameter Data

Data from different Palm Oil Mill plant are collected and analysed. The selections of Palm Oil Mill Plant are made to compare the data between 2 different systems which is by using Digester Tank System (D.T.S) and Ponding System (P.S). The data are shown in the Table 4.1 and 4.2. The treatment plants of sampling point for this data are also shown in Figure 4.1 and 4.2. This data consist of month of

January, February, Mac, April, May and June 2010. The comparison is made for final effluents discharge from these mills. 8 parameters will be analysed, it is pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Suspended Solid (SS), Ammoniacal Nitrogen (AN) and Total Nitrogen (TN).

Table 4.1: Final Effluent Discharge Samples for Digester Tank System (D.T.S)

	pH	BOD	COD	TSS	SS	OG	AN	TN
	LIMIT	< 100			< 400	< 50	< 150	< 200
JAN	7.32	15	157	740	12	4	11	21
FEB	7.80	28	274	1618	80	4	29	37
MAC	7.45	5	211	875	11	6	22	66
APRIL	7.77	14	184	1630	36	2	12	16
MAY	7.69	15	140	1904	37	4	8	17
JUNE	8.34	34	320	3054	97	5	13	29

**parameter in mg/L except for pH*

Table 4.2: Final Effluent Discharge Data for Ponding System (P.S)

	Ph	BOD	COD	TSS	SS	O&G	AN	TN
	LIMIT	< 100			< 400	< 50	< 150	< 200
JAN	8.30	65.5	554.5	3095	181.5	7.5	82	109
FEB	8.60	77.5	687	4587.5	356	6.0	55	84.5
MAC	8.80	148.5	1361	5947.5	611	4.0	43	82
APRIL	8.60	139	1276	6991	692	7.0	75	129
MAY	8.55	125	815	6138	476	4.0	58	104
JUNE	8.56	95	1092	5932	512	8.0	51	90

**parameter in mg/L except for pH*

The data from different Palm Oil Mill plant are collected and analysed. For this analysis, data from different system of anaerobic stage are taken and the comparisons are made between Anaerobic Pond (A.P) and Anaerobic Digester Tank (A.D.T). The data are shown in the Table 4.3 and 4.4. This data consist month of January, February, Mac, April, May and June 2010. 8 parameters will be analysed, it is pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Suspended Solid (SS), Ammoniacal Nitrogen (AN) and Total Nitrogen (TN).

Table 4.3: Anaerobic Data for Anaerobic Digester Tank (A.D.T)

	pH	BOD	COD	TSS	SS	OG	AN	TN
JAN	6.69	6270	8040	14686	9730	848	115	151
FEB	7.12	4440	11916	13294	8960	143	87	120
MAC	7.33	1850	13160	14497	9380	153	112	193
APRIL	7.46	3250	10811	13063	8220	47	126	171
MAY	7.08	2600	8802	13862	7740	79	133	148
JUNE	7.26	2410	8809	9123	3360	41	188	213

**parameter in mg/L except for pH*

Table 4.4: Anaerobic Data for Anaerobic Pond (A.P)

	Ph	BOD	COD	TSS	SS	O&G	AN	TN
JAN	7.70	811	2910	6698	1340	22	224	283
FEB	7.66	588	2095	6044	770	18	179	221
MAC	7.77	973	2522	6228	967	25	168	204
APRIL	7.61	2160	3489	7348	2510	21	283	311
MAY	7.53	395	3185	6437	1315	19	207	258
JUNE	7.67	806	3413	6480	1715	30	193	235

**parameter in mg/L except for pH*

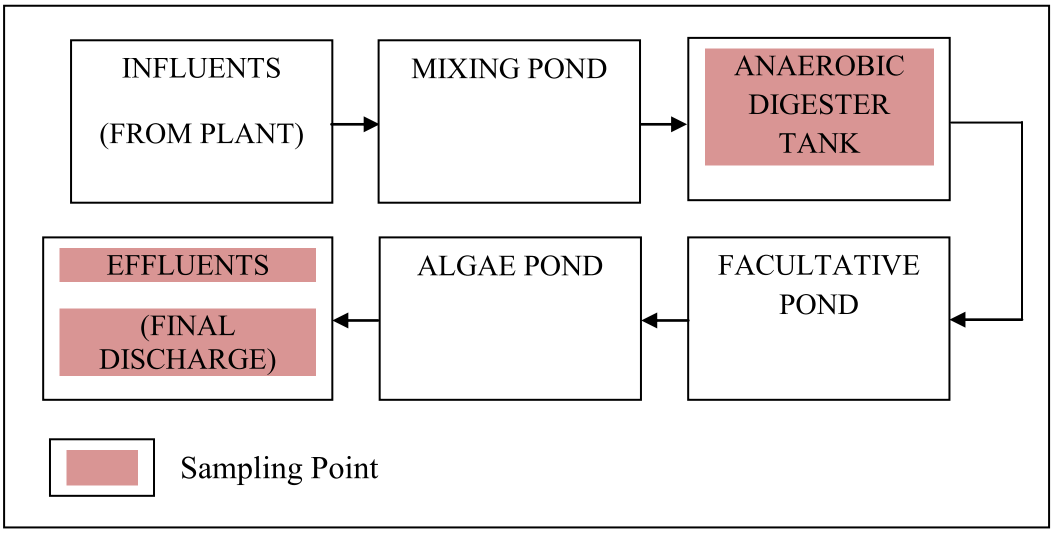


Figure 4.1: Treatment Plant of Digester Tank System

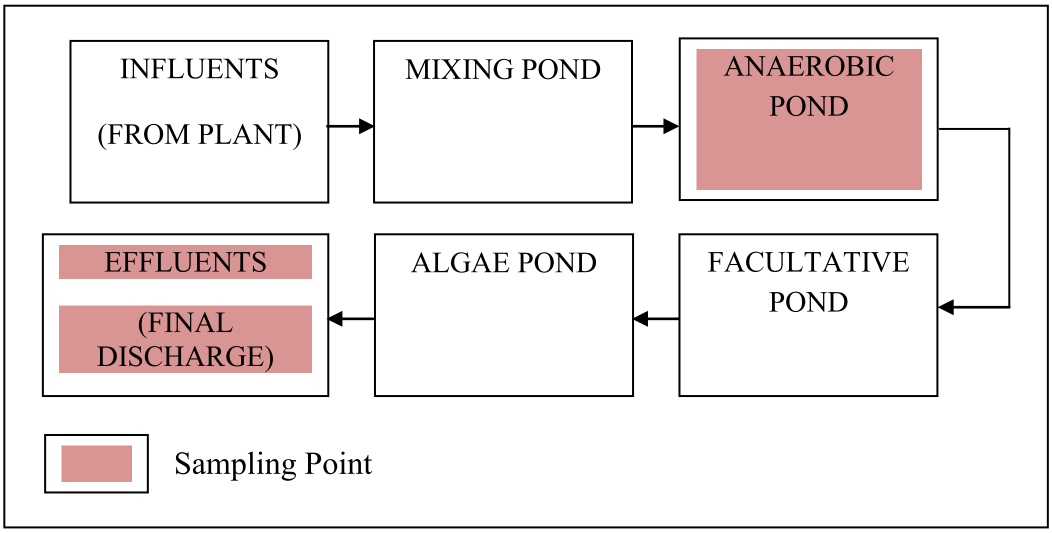


Figure 4.2: Treatment Plant of Ponding System

4.2.1 Result of pH

Table 4.5: The differences of pH values between data A.P and A.D.T

	Anaerobic Pond (A.P)	Anaerobic Digester Tank (A.D.T)	% Different
Jan	7.7	6.69	13.1
Feb	7.66	7.12	7.0
Mar	7.77	7.33	5.7
Apr	7.61	7.46	1.9
Mei	7.53	7.08	5.9
June	7.67	7.26	5.3

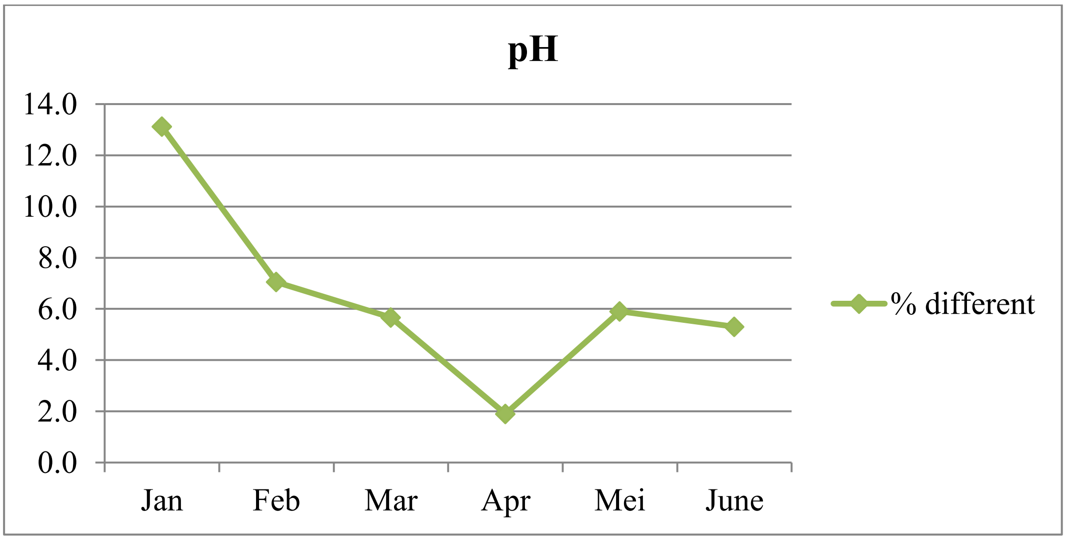


Figure 4.3: The percentage differences of pH values for anaerobic stage

Table 4.5 shows the data and percentage of differences between A.P and A.D.T. From figure 4.3, the highest percentages of differences are 13.1% that is for month of January. The second highest are in the month of February with 7.0%. For month March, May and June that differences are 5.7%, 5.9% and 5.3% while the lowest percent of differences are in the month of April with only 1.9%.

Table 4.6: The differences of pH values between data P.S and D.T.S

	Ponding System (P.S)	Digester Tank System (D.T.S)	% Different
Jan	8.3	7.32	11.8
Feb	8.6	7.8	9.3
Mar	8.8	7.45	15.3
Apr	8.6	7.77	9.7
Mei	8.55	7.69	10.1
June	8.56	8.34	2.6

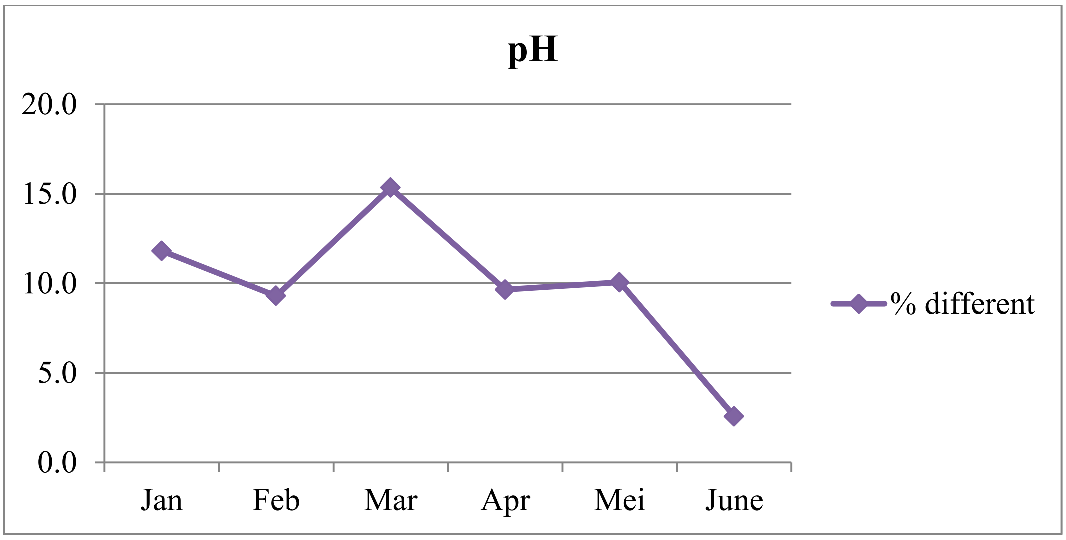


Figure 4.4: The percentage differences of pH values for Final Effluent Discharge

Table 4.6 shows the data and percentage of differences between P.S and D.T.S. From figure 4.4, the highest percentage of differences are 15.3% that is for month of March while the lowest percent are in the month of June with 2.6% only. The second highest are in the month of January with 11.8%. In the month of February, April and May, the percentage differences are 9.3%, 9.7% and 10.1%.

4.2.2 Result of Biological Oxygen Demand (BOD)

Table 4.7: The differences of BOD values between data A.P and A.D.T

	Anaerobic Pond (A.P)	Anaerobic Digester Tank (A.D.T)	% Different
Jan	811	6270	87.1
Feb	588	4440	86.7
Mar	973	1850	47.4
Apr	2160	3250	33.5
Mei	395	2600	84.8
June	806	2410	66.6

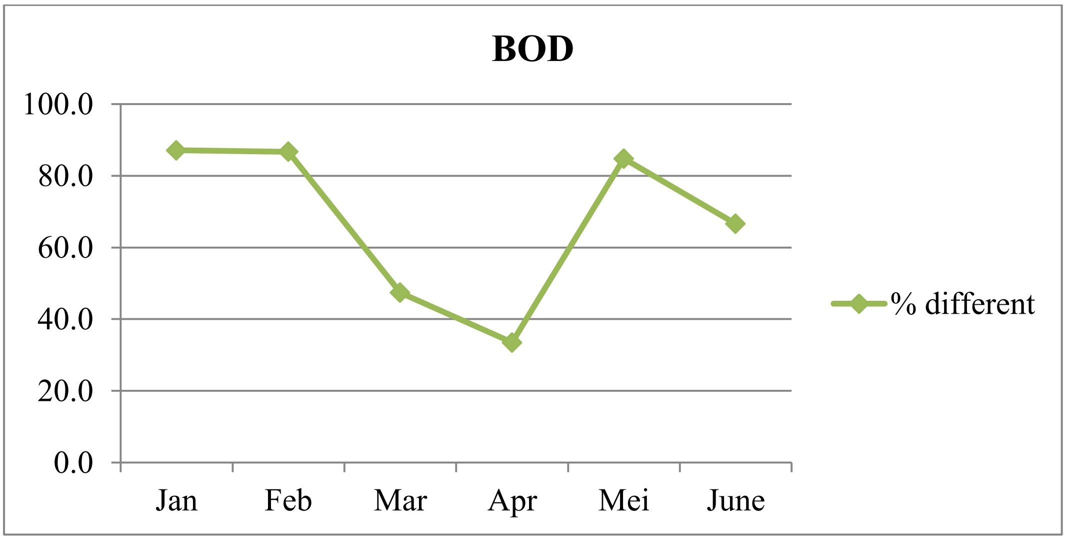


Figure 4.5: The percentage differences of BOD values for anaerobic stage

Table 4.7 shows the data and percentage of differences between A.P and A.D.T. In the month of January, February and May, the percentages of differences are not much different as show in figure 4.5. The percentages are 87.1%, 86.7% and 84.8% and January give the highest percentages of difference among all month. In the month of June the percentage differences are 66.6% while 47.4% difference are in the month of March. The lowest percentage differences for anaerobic stage are 33.5% which is in the month of April.

Table 4.8: The differences of BOD values between data P.S and D.T.S

	Ponding System (P.S)	Digester Tank System (D.T.S)	% Different
Jan	65.5	15	77.1
Feb	77.5	28	63.9
Mar	139	14	89.9
Apr	148.5	5	96.6
Mei	139	14	89.9
June	95	34	64.2

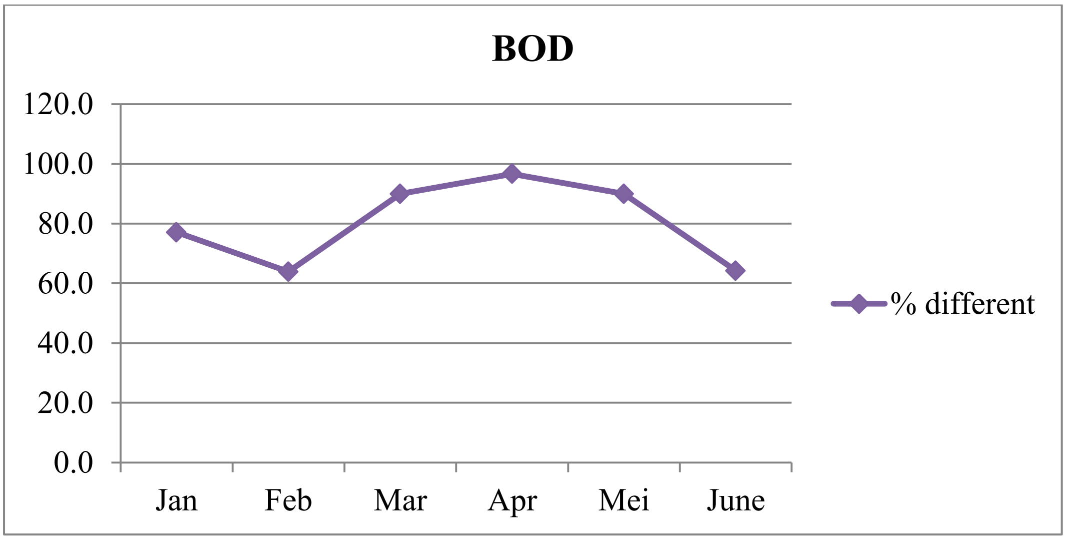


Figure 4.6: The percentage differences of BOD values for Final Effluent Discharge

Table 4.8 shows the data and percentage of differences between P.S and D.T.S. The acceptable range for BOD are <100mg/L. From table 4.8, show that in the month of March, April and May for P.S the value is >100 then in the month of June the value back in the acceptable range but the values are still high compare to D.T.S. The percentage differences graphs are show in the figure 4.6. From the figure, the highest percentages are in the month of April with 96.6%, followed with March and April with the same difference, 89.9%. In the month of January and June the percentage of differences are 77.1% and 64.2%. The lowest differences are in the month of February with 63.9%.

4.2.3 Result of Chemical Oxygen Demand (COD)

Table 4.9: The differences of COD values between data A.P and A.D.T

	Anaerobic Pond (A.P)	Anaerobic Digester Tank (A.D.T)	% Different
Jan	2910	8040	63.8
Feb	2095	11916	82.4
Mar	2522	13160	80.8
Apr	3489	10811	76.7
Mei	3185	8802	60.4
June	3413	8809	61.3

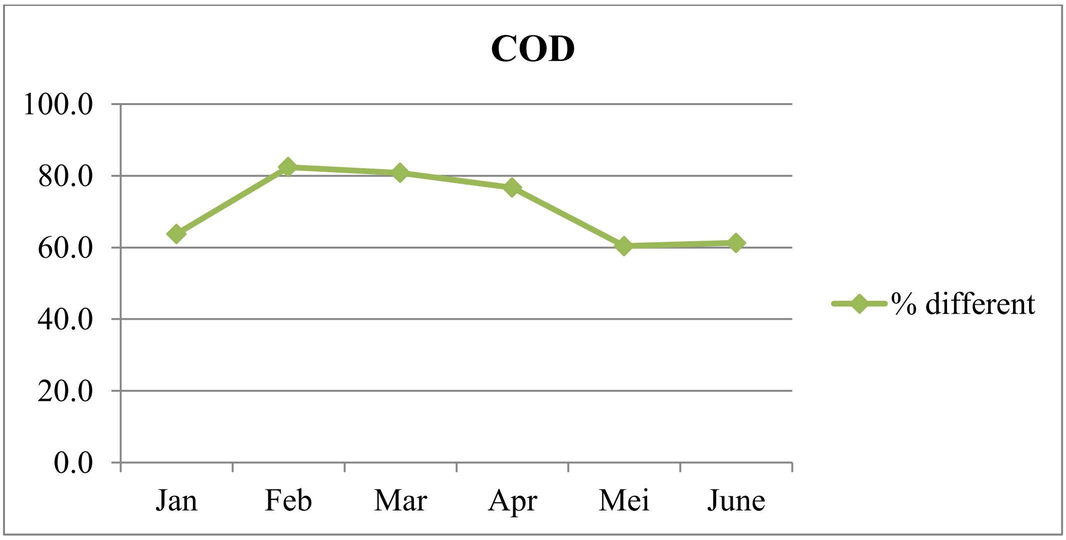


Figure 4.7: The percentage differences of COD values for anaerobic stage

Table 4.5 shows the data and percentage of differences between A.P and A.D.T. From figure 4.7, the highest percentages of differences are 13.1% that is for month of January. The second highest are in the month of February with 7.0%. For month March, May and June that differences are 5.7%, 5.9% and 5.3% while the lowest percentage of differences are in the month of April with only 1.9%.

Table 4.10: The differences of COD values between data P.S and D.T.S

	Ponding System (P.S)	Digester Tank System (D.T.S)	% Different
Jan	554.5	157	71.7
Feb	687	274	60.1
Mar	1361	211	84.5
Apr	1276	184	85.6
Mei	815	140	82.8
June	1092	320	70.7

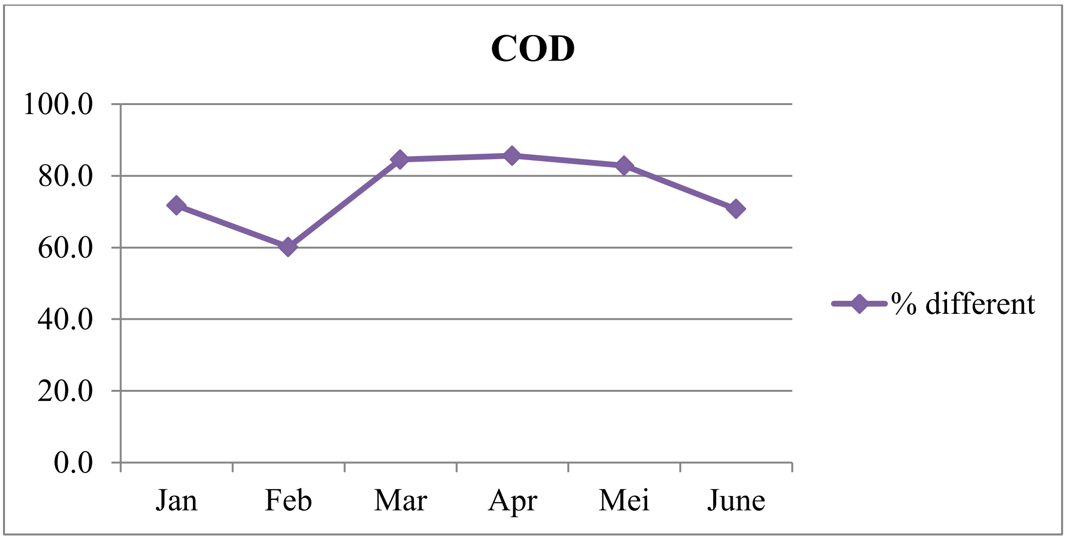


Figure 4.8: The percentage differences of BOD values for Final Effluent Discharge

Table 4.10 shows the data and percentage of differences between P.S and D.T.S. From figure 4.8, there are 3 month give differences in almost same range of percentage which is month if May, March and April with the percent of difference are 82.8%, 84.5%, and 85.6% and April give the highest differences. While June and January also give almost same range of percentage which is June with 70.7% and January with 71.7%. The lowest percentage differences are February with 60.1% only.

4.2.4 Result of Total Suspended Solid (TSS)

Table 4.11: The differences of TSS values between data A.P and A.D.T

	Anaerobic Pond (A.P)	Anaerobic Digester Tank (A.D.T)	% Different
Jan	6698	14686	54.4
Feb	6044	13294	54.5
Mar	6228	14497	57.0
Apr	7348	13063	43.7
Mei	6437	13862	53.6
June	6480	9123	28.9

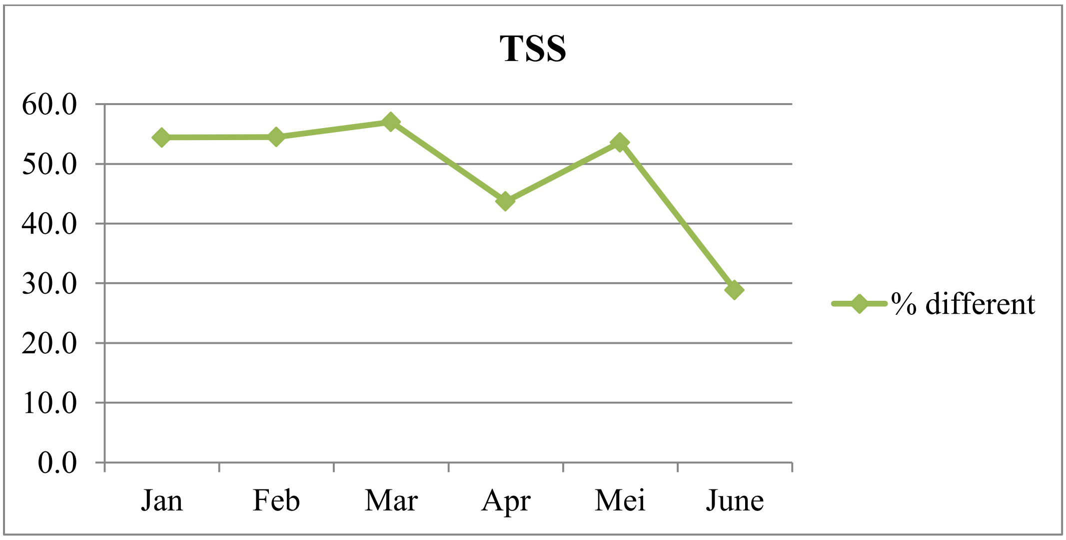


Figure 4.9: The percentage differences of TSS values for anaerobic stage

Table 4.7 shows the data and percentage of differences between A.P and A.D.T. According to the figure 4.9, the percent of different between months are so obvious because there are 4 month, that is January, February, March and May gives almost in the same range of percentage which is 54.4%, 54.4%, 57.0% and 53.6% and March give the highest percentage of difference. The lowest percent is in the month of June, 28.9%.

Table 4.12: The differences of TSS values between data P.S and D.T.S

	Ponding System (P.S)	Digester Tank System (D.T.S)	% Different
Jan	3095	740	76.1
Feb	4587.5	1618	64.7
Mar	5947.5	875	85.3
Apr	6991	1630	76.7
Mei	6138	1904	69.0
June	5932	3054	48.5

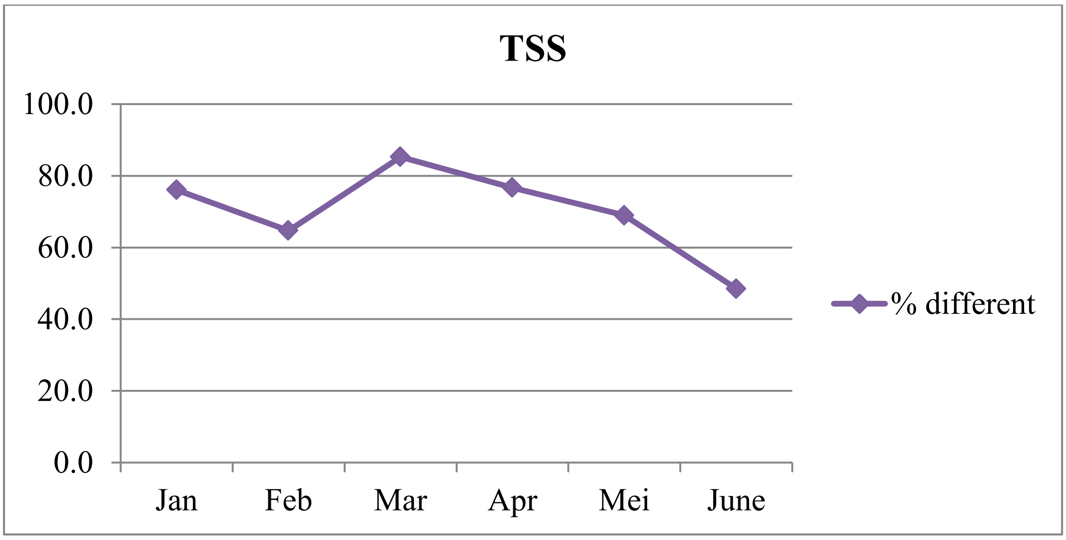


Figure 4.10: The percentage differences of TSS values for Final Effluent Discharge

Table 4.10 shows the data and percentage of differences between P.S and D.T.S. From the figure 4.10, percent of each data are not consistent. This is because the highest percent of different are 85.3% in the month of March while the lowest differences are 48.5% in the month of June. While the percentage of difference for January is 76.1%, February is 64.7%, April is 76.7% and May is 69.0%.

4.2.5 Result of Suspended Solid (SS)

Table 4.13: The differences of SS values between data A.P and A.D.T

	Anaerobic Pond (A.P)	Anaerobic Digester Tank (A.D.T)	% Different
Jan	1340	9730	86.2
Feb	770	8960	91.4
Mar	967	9380	89.6
Apr	2510	8220	69.5
Mei	1315	7740	83
June	1715	3360	48.9

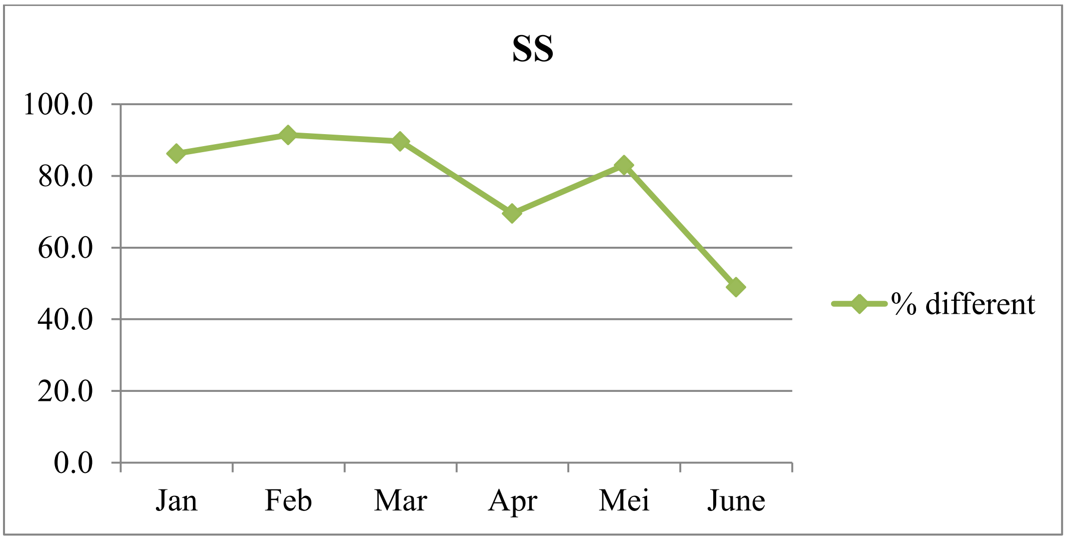


Figure 4.11: The percentage differences of SS values for anaerobic stage

Table 4.13 shows the data and percentage of differences between A.P and A.D.T. As shown in the figure 4.11, the percentage differences for 3 month, which is January, February and March are constant but starting of April the percentage became inconstant. The highest percentages of difference for SS are in month of February with 91.4%, next is March with 89.6%, January with 86.2% and May with 83%, while April is the second lowest differences with 69.5% and the lowest are in the month of June with 48.9%.

Table 4.14: The differences of SS values between data P.S and D.T.S

	Ponding System (P.S)	Digester Tank System (D.T.S)	% Different
Jan	181.5	12	93.4
Feb	356	80	77.5
Mar	611	11	98.2
Apr	692	36	94.8
Mei	476	37	92.2
June	512	97	81.1

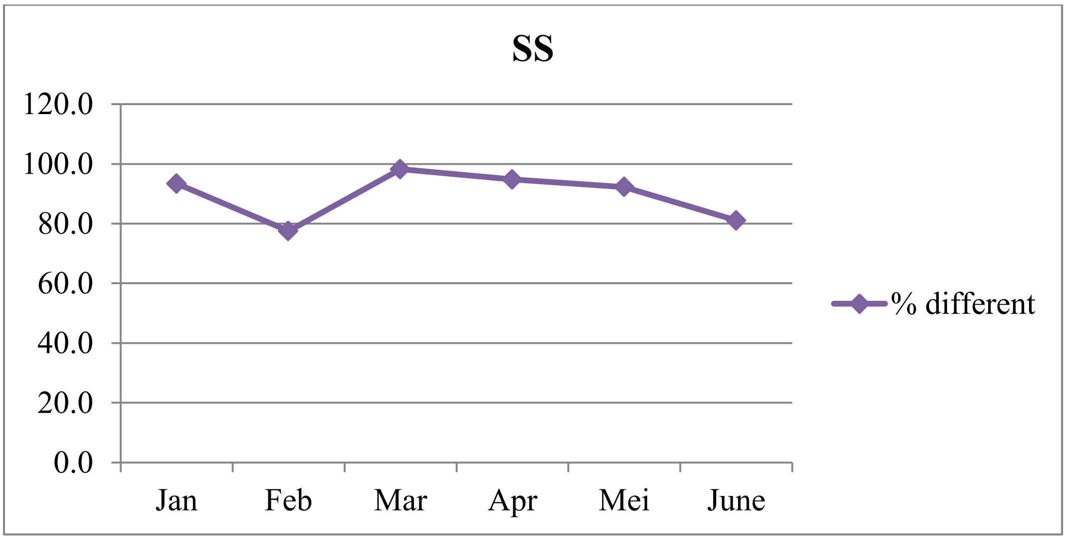


Figure 4.12: The percentage differences of SS values for Final Effluent Discharge

The differences between P.S and D.T.S for monthly data and percent of different are show in the table 4.14. The acceptable range for SS is <400mg/L, according to the table, P.S are totally out of range and this gives a very high percent difference. However, from figure 4.12, the highest percent difference for final effluent is 98.2% which is in the month of March while the lowest difference is 77.5% in month of February.

4.2.6 Result of Oil & Grease (O&G)

Table 4.15: The differences of O&G values between data A.P and A.D.T

	Anaerobic Pond (A.P)	Anaerobic Digester Tank (A.D.T)	% Different
Jan	22	848	97.4
Feb	18	143	87.4
Mar	25	153	83.7
Apr	21	47	55.3
Mei	19	79	75.9
June	30	41	26.8

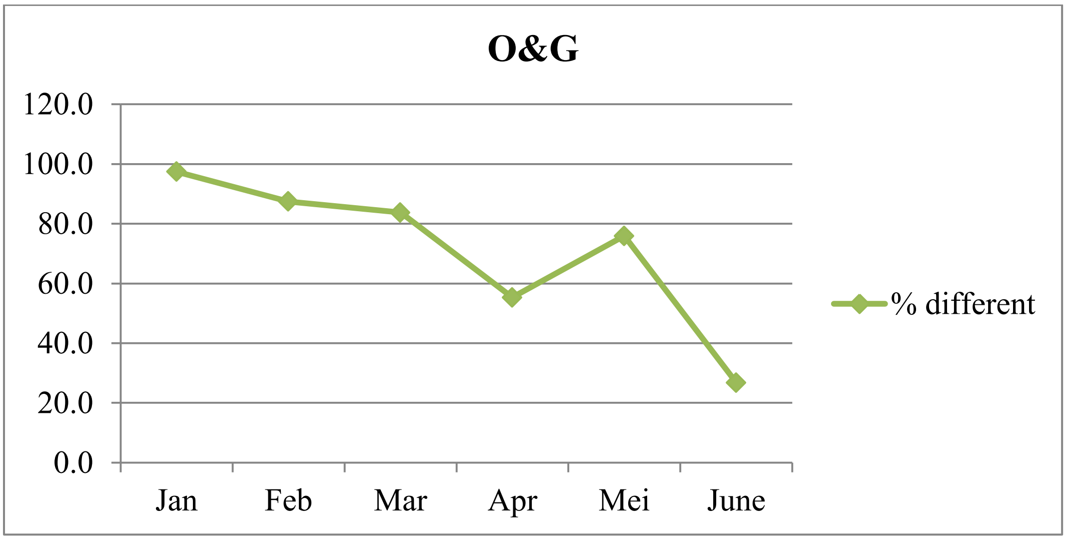


Figure 4.13: The percentage differences of O&G values for anaerobic stage

Table 4.15 shows the data and percentage of differences between A.P and A.D.T. From figure 4.13, the highest percentages of differences are 97.4% that is for month of January. The second highest are in the month of February with 87.4%. For month March, May and April that differences are 83.7%, 75.9% and 55.3% while the lowest percent of differences are in the month of June with only 26.8%.

Table 4.16: The differences of O&G values between data P.S and D.T.S

	Ponding System (P.S)	Digester Tank System (D.T.S)	% Different
Jan	7.5	4	46.7
Feb	6	4	33.3
Mar	4	6	33.3
Apr	7	2	71.4
Mei	4	4	0.0
June	8	5	37.5

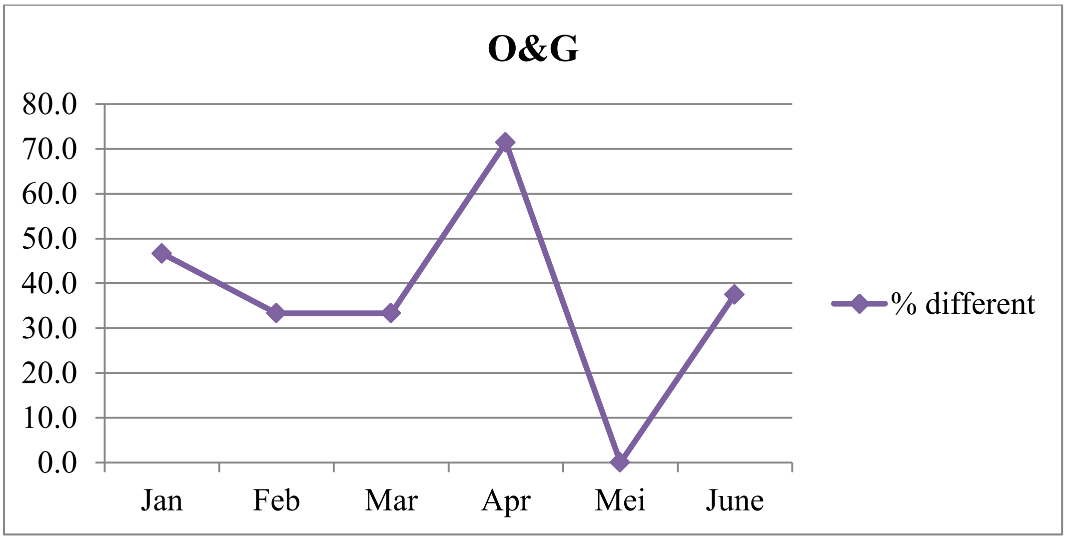


Figure 4.14: The percentage differences of O&G values for Final Effluent Discharge

The differences between P.S and D.T.S for monthly data and percent of different are show in the table 4.14. The acceptable range for O&G is <50mg/L, and according to the table, all the data are at acceptable range. In the figure 4.14, there are no differences at all the month of May and in the month of February and March; the percent of differences are same, 33.3%. April gives highest of differences with 71.4% while at January and June, the difference is 46.7 % and 37.5%.

4.2.7 Result of Ammonia Nitrogen (AN)

Table 4.17: The differences of AN values between data A.P and A.D.T

	Anaerobic Pond (A.P)	Anaerobic Digester Tank (A.D.T)	% Different
Jan	224	115	48.7
Feb	179	87	51.4
Mar	168	112	33.3
Apr	283	126	55.5
Mei	207	133	37.7
June	193	188	2.6

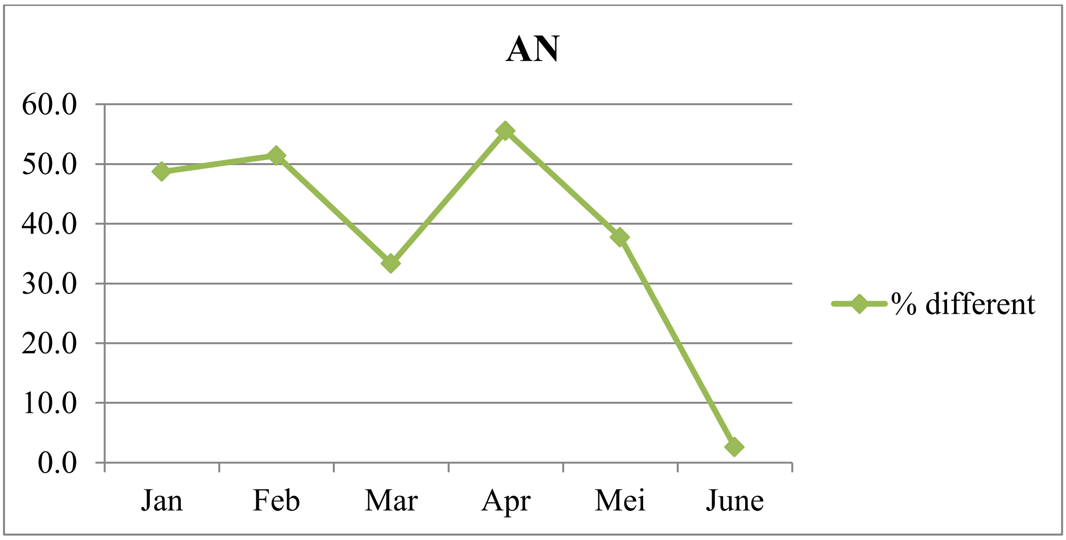


Figure 4.15: The percentage differences of AN values for anaerobic stage

Table 4.17 shows the data and percentage of differences between A.P and A.D.T. From figure 4.15, the highest percentages of differences are 55.5% that is for month of April. The second highest are in the month of February with 51.4%. Follow by month January, May and March, which is the differences are 48.7%, 37.7% and 33.3% while the lowest percent of differences for AN are in the month of June with only 2.6% only.

Table 4.18: The differences of AN values between data P.S and D.T.S

	Ponding System (P.S)	Digester Tank System (D.T.S)	% Different
Jan	82	11	86.6
Feb	55	29	47.3
Mar	43	22	48.8
Apr	75	12	84.0
Mei	58	8	86.2
June	51	13	74.5

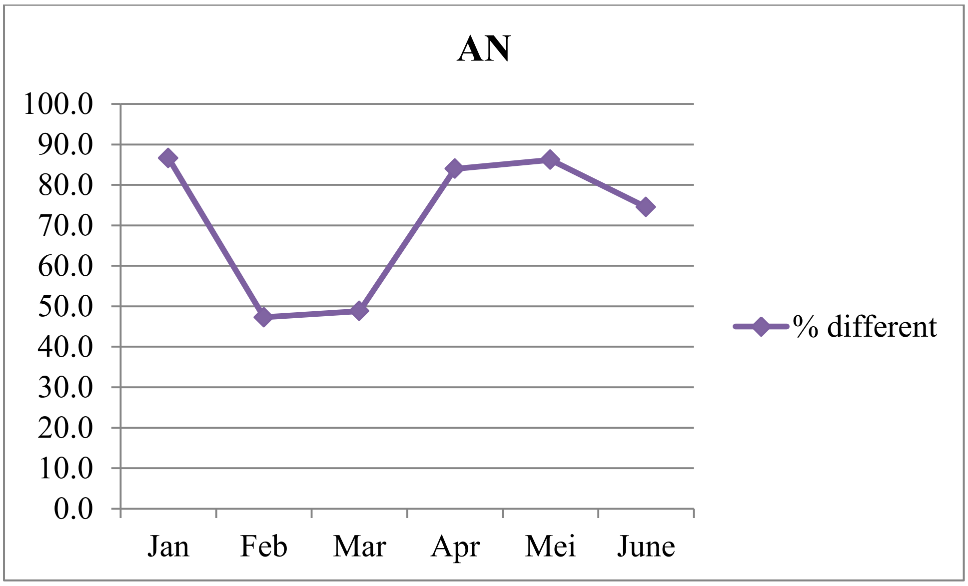


Figure 4.16: The percentage differences of AN values for Final Effluent Discharge

The differences between P.S and D.T.S for monthly data and percent of different are show in the table 4.18. The acceptable range for AN is <150mg/L, and according to the table, all data are at acceptable range. As show in figure 4.16, there is not much difference for month of January, May and April. The percent of difference for this 3 month are 86.6%, 86.2% and 84.0%, while in June the difference is 74.5%. The lowest percentage also almost same with March is 48.8% and February is 47.3%.

4.2.8 Result of Total Nitrogen (TN)

Table 4.19: The differences of TN values between data A.P and A.D.T

	Anaerobic Pond (A.P)	Anaerobic Digester Tank (A.D.T)	% Different
Jan	283	151	46.6
Feb	221	120	45.7
Mar	204	193	5.4
Apr	311	171	45
Mei	258	148	42.6
June	235	213	9.4

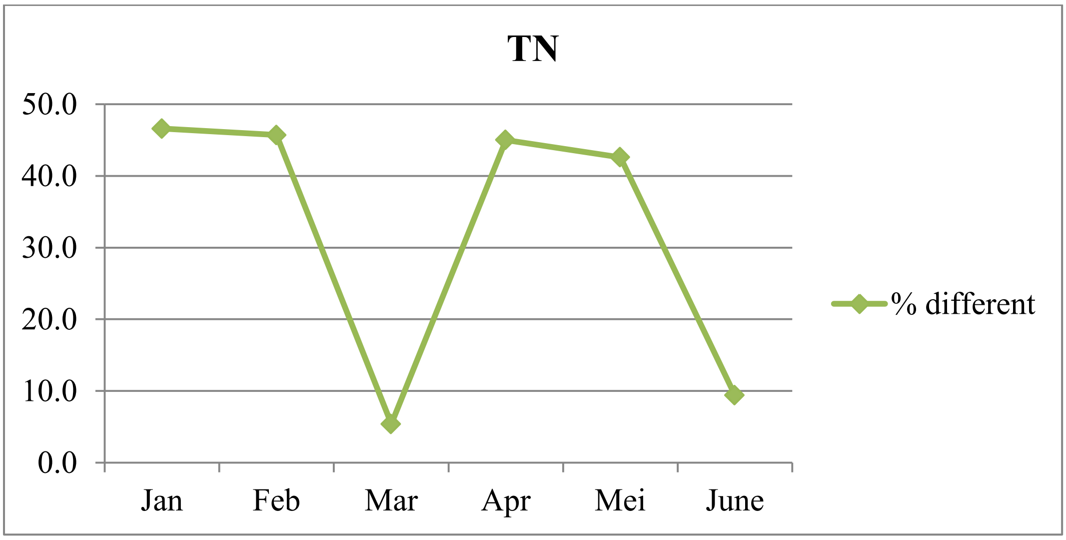


Figure 4.17: The percentage differences of TN values for anaerobic stage

Table 4.19 shows the data and percentage of differences between A.P and A.D.T. In the month of January, February, April and May, the percent of differences are not much different from each other as they are in the same range and it show in figure 4.17. The percentages are 46.6%, 45.7%, 45% and 42.6% and January give the highest percentages of difference among all month. However, the lowest percentage differences for anaerobic stage are 4.5% only which is in the month of April.

Table 4.20: The differences of TN values between data P.S and D.T.S

	Ponding System (P.S)	Digester Tank System (D.T.S)	% Different
Jan	109	21	80.7
Feb	84.5	37	56.2
Mar	82	66	19.5
Apr	129	16	87.6
Mei	104	17	83.7
June	90	29	67.8

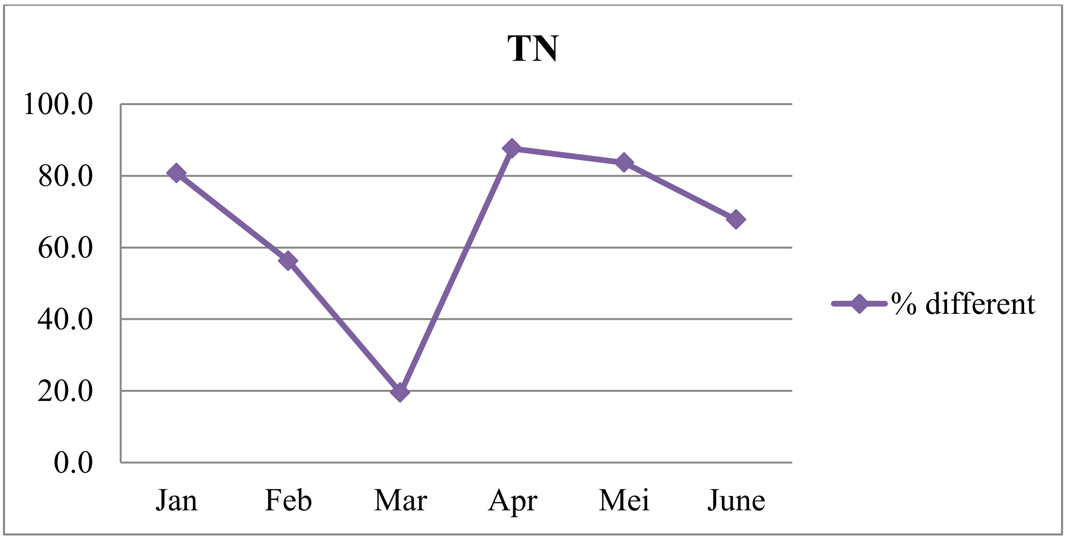


Figure 4.18: The percentage differences of TN values for Final Effluent Discharge

Table 4.20 shows the data and percentage of differences between P.S and D.T.S. The acceptable ranges for TN are <200mg/L and all data are still in the acceptable range, as show in table 4.20. From figure 4.18, the highest percent of difference are 87.6% in the month of April, while the lowest differences are 19.5% only.

4.3 Analysis of Data

Data from anaerobic pond and anaerobic digester tank will be analyzed. After POME in anaerobic stage goes through into the next treatment process, the final effluent will be discharge into nearest river or by using land irrigation, if only the data are fulfil with the standard requirement by DOE. So, the percent of reduction will be determined.

Table 4.21: Average Data of Ponding System between Anaerobic Pond and Final Effluent Discharge

Parameter	Anaerobic	Final Discharge	% of Reduction
pH	7.2	8.6	-19.44
BOD	3470	108.4	96.88
COD	10256.3	964.3	90.60
TSS	13087.5	5448.5	58.37
SS	7898.3	471.4	94.03
O&G	218.5	6.1	97.21
AN	126.8	66.7	47.40
TN	166	99.8	39.88

Table 4.22: Average Data of Digester Tank System between Anaerobic Digester Tank and Final Effluent Discharge

Parameter	Anaerobic	Final Discharge	% of Reduction
pH	7.7	7.7	0.00
BOD	955.5	18.5	98.06
COD	2935.7	214.3	92.70
TSS	6539.2	1636.8	74.97
SS	1436.2	45.5	96.83
O&G	22.5	4.2	81.33
AN	209	15.8	92.44
TN	252	31	87.70

Table 4.23: Comparison for % of reduction at Anaerobic between Ponding System and Digester Tank System

Parameter	% of Reduction	
	Ponding System	Digester Tank System
pH	-19.44	0.00
BOD	96.88	98.06
COD	90.60	92.70
TSS	58.37	74.97
SS	94.03	96.83
O&G	97.21	81.33
AN	47.40	92.44
TN	39.88	87.70

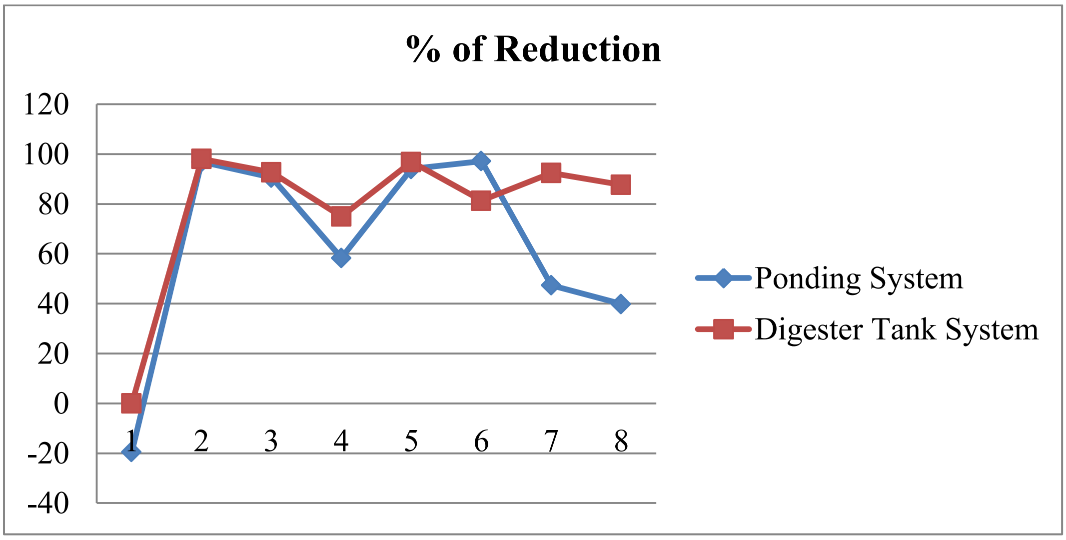


Figure 4.19: % of reduction for Anaerobic Treatment

4.3.1 Analysis Percent Reduction of Anaerobic Pond (A.P) and Anaerobic Digester Tank (A.D.T)

From the result show in the table 4.21 and table 4.22, percent of reduction for each parameter between 2 systems are higher. In pH analysis, percent of reduction for A.P is -19.44%. This is because, pH at final discharge is larger than anaerobic pond and supposedly the pH value at the final must be less than anaerobic pond. However, percent of reduction at A.D.T are same, 0.0%. This means, pH value at A.D.T are constancy. In BOD analysis, percent of reduction for A.D.T is 98.06% which is higher than A.P with 96.88%. COD analysis also show that A.D.T gives higher reduction percent compare to A.P which is, the value is 92.7% and 90.6%. In TSS analysis, the difference of percent reduction between A.P and A.D.T are quite obvious, which is percent reduction for A.P is 58.37% while for A.D.T is 74.97%. For SS analysis, the higher percent reduction also at A.D.T with 96.83, while for A.P the percent of reduction are 94.03%. However, in the O&G analysis, A.P gives higher percent of reduction with 97.21% compare to A.D.T, 81.33%. For AN and TN analysis, the higher percent of reduction also at A.D.T with 92.44% and 87.7% while for A.P, percent of reduction are only 47.4% and 39.88%. So, from this analysis, we can conclude that, the higher percent of reduction is, the higher efficiency of the system will be.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

Since the technologies always change, the further research needs to be done to determine the better method to treated waste, especially in Palm Oil Mills Effluent (POME) to ensure the optimum result in all aspect will be achieve.

5.2 Conclusion

From the data obtained, analysis on the 8 parameters; pH, BOD, COD, TSS, SS, AN and TN was successfully done and has achieved their objectives as state before. From this study also, the most efficiency of the systems was determined. However, there are several conclusions that can be drawn. There are as follows:

i) From the data obtained, range data of parameter at the anaerobic pond is much higher than anaerobic digester tank but when it comes to the final effluent discharge, data at the anaerobic digester tank are more acceptable than anaerobic pond.

ii) Digester tank system showed better results than the ponding system, which is the percent of reduction for each of its parameter is higher than the ponding system.

iii) By using digester tank, retention of time are more shorter than pond system, however in term of cost, ponding system are known as most economical system for treat POME.

iv) As conclusion, Digester Tank System (D.T.S) is more efficient than Ponding System (P.S) and can be used as alternative Palm Oil Mill Effluent (POME) treatment system.

5.3 Recommendations

There are so many ways to studies about POME treatment plant systems. Some recommendations were provide in order to improve this treatment.

1) There are many alternative treatment system nowadays which is provided good treatment for POME rather than ponding system.

2) Ponding system should always be monitor to prevent leakage on the pipe connection and overflow of the pond.

3) Further investigation on of digester tank system for palm oil mill effluent can improve the efficiency of the system.

REFERENCES

1. Ronald L. Droste (1997). Theory and Practice of Water and Wastewater Treatment. John Wiley & Sons, Inc., 18:622-663

2. Christopher Froster (2003). Wastewater Treatment and Technology ., Thomas Telford., 9: 253–270

3. Mahzad Hojjat, Sa'ari b. Mustapha, Mohamad Amran Mohd Salleh (2009). "Optimization of POME Anaerobic Pond". EuroJournals Publishing, m.s .455-459

4. K. K. Wong (1980). "Application of Ponding Systems in the Treatment of Palm Oil Mill"., Rev: 3(2), 133-141

5. P.E. Poh, M.F. Chong (2009) " Development of anaerobic digestion methods for palm oil mill effluent (POME) treatment". ScienceDirect-Bioresource Technology 100 (2009) 1–9

6. Abdul, K. Mohamed, I. and Kamil, A.Q.A. (1989). "*Biological treatment of palm oil mill effluent using Trichoderma viride".* Boil. Wastes 27:143-152.

7. Mark J. Hammer (1986) "Water and Wastewater Technology." John Wiley & Sons, 2nd Edition, m.s 411 – 425

8. Metcalf and Eddy (2004), "Wastewater Engineering Treatment and Reuse." Mc Graw Hill, 4th Edition, m.s 425 – 447

9. Lawrance K.Wong, Yung-Tse Hung, Howard H.Lo, Constantine Yapijakis (2006), "Waste Treatment in the Food Processing Industry." Boca Raton : Taylor & Francis Group, m.s 100-109

10. Udo Wiesmann, In su Choi, Eva-Maria Dombrowski (2007), "Fundamentals of Biological Wastewater Treatment." Wiley-Vch, m.s 99-110

11. P.Agamuthu, C.A. Sastry and M.A. Hashim (1995), "Waste Treatment Plant." New Delhi, India: Norosa Publishing House, Chapter 25, m.s 338–357

12. Chan, K. S., Chooi, C.F. (1982). "Ponding System for Palm Oil Mill Effluent Treatment. In: Proceedings of Regional Workshop on Palm Oil Mill Technology and Effluent Treatment." PORIM Malaysia: 185 – 192

13. J.C. Igwe and C.C. Onyegbado (2007). "A Review of Palm Oil Mill Effluent (Pome) Water Treatment". Global Journal of Environmental Research, 1 (2): 54-62, 2007

14. Novaes, R.F.V. (1986). *Microbiology of anaerobic digestion.* Water Sci. Technol.18:1-4.

15. Quah, S.K. Lim, K.H. Gillies, D. Wood, B.J. and Kanagaratnam. (1982). *Regional Workshop on Palm Oil Mill Technology and Effluent Treatment*. PORIM, Kuala Lumpuer, 193-200.

16. K. Vijayaraghavan, D.A., Mohd Ezani B. Abdul Aziz (2007). "Anaerobic Treatment of Palm Oil Mill Effluent." Environment Management 82, m.s 24 – 31.

17. Ahmad Zuhairi Abdullah, Mohd. Omar Ab. Kadir, Muhammad Hakimi Ibrahim dan Mohd. Nazri Mahmud (2001), "Treatment of POME Anaerobic Pond Supernatant Using Trickling Filter." The International Water and Wastewater Management for Developing Countries, proceeding Volume 2 (29 – 31 Okt 2001, PWTC), m.s. 76 – 82.

18. Tay, J.H., 1991. Complete reclamation of oil palm wastes. Resources Conservation and Recycling 5, 383–392.