CHAPTER 1

INTRODUCTION

1.1 Project Background

Over the last century, continued population growth and industrialization have resulted in the degradation of various ecosystems on which human life relies on. In the case of ocean and river quality, such pollution is primarily caused by the discharge of inadequately treated industrial and municipal wastewater (Chan et al., 2009). On initial discharge, these wastewaters can contain high levels of inorganic pollutants which can be easily biodegradable, but whose impact load on the ecosystems, either in Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD_5), or Chemical Oxygen Demand (COD), may be in the tens of thousands mg/L (Ng, 2006). This wastewater must undergo treatment in order to meet the specify standards. Anaerobic digestion is the degradation of complex organic matters under the absence of oxygen. This process is time consuming as bacterial consortia responsible for the degradation process requires time to adapt to the new environment before they start to consume on organic matters to grow (Poh and Chong, 2008). Anaerobic digestion technology is an ideal cost-effective biological means for the removal of organic pollutants in waste and wastewater which simultaneously produces gaseous methane as energy resources (Malakahmad et al., 2011).

Many applications of this digestion technology are the high-rate treatment of high-strength industrial organic wastewater and low-strength organic wastewater, complex wastewater containing persistent chemical compounds, sulphate-rich wastewater, wastewater discharged at temperatures ranging from psychrophilic to thermophilic and as well as offering potentials for the removal of metals, nitrates, and toxic substances (Metcalf and Eddy, 2004).

Among high rate reactors, the anaerobic baffled reactor was suggested by several researchers as a promising system for industrial wastewater treatment. Although there have been many anaerobic high rate designs developed, the ABR were extensively used in the treatment of synthetic tannery wastewater containing sulphate and chromium (III), textile dye, azo dyes containing wastewater, swine wastes, palm oil effluent wastewater, treating whisky distillery wastewater, sulphate containing wastewaters, pulp and paper mill black liquors, nitrogen containing wastewaters, landfill leachate and also domestic wastewaters (Kuscu and Sponza, 2005).

In the anaerobic baffled reactor (ABR) process, baffles are used to direct flow of wastewater in an up flow mode through a series of sludge blanket reactors. The sludge in the reactor rises and falls with gas production and flow, but moves through the reactor at a slow rate. Various modifications have been made to the ABR to improve the performance. The modifications include changes to the baffle design, hybrid reactors where a settler has been used to capture and return solids, or packing has been used in the upper portion of each chamber to capture solids (Barber and Stuckey, 1999). The advantages claimed for the ABR processes are simplicity, long SRT possible with low hydraulic retention time, no special biomass characteristics required, wastewater with a wide variety of constituent characteristics can be treated, staged operation to improve kinetics and stable to shock loads (Metcalf and Eddy, 2004).

However treatment of POME using anaerobic process alone is insufficient although high recorded reduction percentage between 75-97% has been obtained (Faisal et al., 2001). To meet the requirement standards set by the enforcement, further treatment must be applied. Aerobic treatment takes place here as a post treatment due to the lower organic content achieved by the anaerobic treatment making it suitable for biological process to occur.

Sequencing batch reactor technology has been developed on the basic scientific assumption that periodic exposure of the microorganisms to defined process conditions is effectively achieved in a fed batch system in which exposure time, frequency of exposure and amplitude of the respective concentration can be set independently of any inflow condition (Mohan, et al, 2005). The most obvious difference is that the reactor volume varies with time, whereas it remains constant in the traditional continuous flow system. From the process engineering point of view, the SBR system is distinguished by the enforcement of controlled short term unsteady state conditions leading in the long run to a stable steady state with respect to composition and metabolic properties of the microbial population growing in the reactor by controlling the distribution and physiological state of the microorganisms. The success of SBR technology depends upon the great potential provided by the possibilities of influencing the microbial system in the SBR and also upon the fact that SBRs are comparatively easy to operate and are cost efficient. SBR processes are known to save more than 60% of expenses required for conventional activated sludge process in operating cost (Chang et al., 2000). Interest has been growing worldwide both in scientific research and in practical application of SBR technology.

Sequencing Batch Reactor has been successfully applied for the treatment of domestic wastewater, medium and lower strength land fill leachates, simulated dye wastewaters and contaminated soils. However, a through literature search showed that SBR technology has not been investigated with complex chemical wastewaters such as pharmaceutical, drug and chemical manufacturing units so far. The wastewater generated from such industries constitute various organic substances used in the process, inorganic salts, organic solvents, etc. which result in high COD, low BOD, high salt content (TDS), toxic and inhibitory substances in wastewater which inhibit the biological process (Venkataa and Sharma, 2002)

1.2 Problem Statement

Malaysia is the largest producer and exporter of palm oil (Poh and Chong, 2009). Palm oil processing is carried out in palm oil mills where oil is extracted from a palm oil fruit bunch. Large quantities of water are used during the extraction of crude palm oil from the fresh fruit bunch, and about 50% of the water results in palm oil mill effluent (POME) (Wong et al., 2009). For every ton of palm oil fresh fruit bunch, it was estimated that 0.5-0.75 tonnes of POME will be discharged. POME is a thick brownish liquid that contains high amounts of total solids (40,500 mg/l), oil and grease (4000 mg/l), COD (50,000 mg/l) and BOD (25,000 mg/l).

Chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of POME are very high and COD values greater than 80,000 mg/l are frequently reported. Incomplete extraction of palm oil from the palm nut can increase COD values substantially. The disposal of this highly polluting effluent is becoming a major problem if it is not being treated properly besides a stringent standard limit imposed by The Malaysian Department of Environment for effluent discharged (Federal Subsidiary Legislation, 1974).

The purpose of this project is to study the efficiency of combined anaerobic-aerobic system in treating raw for Palm Oil Mill Effluent. It is also to prove through that it is vital and cost cutting in applying anaerobic treatment as a pre-treatment process and aerobic as post-treatment process. The effect for improper treatment will cause the effluent to not meet the standards required by DOE and also will increase operational cost. Hence the importance, of this case study to overcome future problems either in social, economy and most important environmentally.

1.3 Objectives

- To investigate the performance of an integrated anaerobic-aerobic system for treatment of palm oil mill effluent.

1.4 Scope of Study

In this case study, the application of integrated anaerobic baffled reactor – sequencing batch reactor was to reduce the amount of pollutant content in raw palm oil mill effluent (POME). Sample of untreated palm oil mill effluent and sludge was retrieved from anaerobic pond of Nasaruddin Palm Oil Mill located at Bota District in Perak. Anaerobic system (anaerobic baffled reactor) acted as the pre-treatment and anaerobic system acted as the post-treatment (sequencing batch reactor). The effluent was analysed for pH, BOD, COD, oil and grease, phosphorus and ammonia concentration. During operation, effluent of the system was analysed for pH, COD and methane gas production daily while sludge height of four-day interval. BOD, COD, pH, and methane gas were measures by using 5-day BOD test, APHA, HACH, and water displacement method respectively. The result was to measure the efficiency of combined anaerobic-aerobic system on treating raw palm oil mill effluent and methane gas production rate.

CHAPTER 2

LITERATURE REVIEW

2.1 Biological Treatment Systems

Wastewater collection systems (i.e., sewer networks) and centralized and decentralized treatment systems are designed and managed primarily to protect human and environmental health. The purpose of biological treatment of industrial wastewater is to remove or reduce the concentration of organic and inorganic compounds. Because some of the constituents and compounds found in industrial wastewater can be discharged to a municipal collection system. Biological wastewater treatment process involves the potentials of some living organisms to remove contaminants and sludge from wastewater in order to make it suitable for surface irrigation and other industrial use. Biological wastewater treatment involves the transformation of dissolved and suspended organic contaminants to biomass and evolved gases: CO_2, CH_4, N_2 and SO_2 (Wei et al., 2003). The principal processes for biological treatment of wastewater can be classified with respect to their metabolic function as aerobic processes, anaerobic processes, anoxic processes, facultative processes, and combined processes.

2.2 Integrated Anaerobic-Aerobic Treatment System

Over the past twenty years there has been an increasing demand for more efficient systems for the treatment of wastewaters due to increasingly stringent discharge standards now widely adopted by various national and international agencies. Various researches have been conducted for improvement of system in meeting the requirements. Unfortunately anaerobic treatment alone is insufficient in treating municipal wastewater as it removes the pollutant content by 80 – 90% on excellent running condition (Chan et al., 2012; Akunna and Clark, 2000; Bernet et al., 2000)thus cannot be discharge directly to receiving streams. However it can be employed as cost effecting pre-treatment ahead of aerobic treatment. The combination of these two processes brings two significant advantages; simple design technology and minimization of sludge production. Anaerobic pre-treatment followed by aerobic post-treatment of municipal wastewater is being used more frequently. Recent investigations in this field using an anaerobic fluidized field bed reactor/aerobic solids contact combination demonstrated the technical feasibility of this process (Motta et al., 2007). Also as agreed with Kassab et al. (2010) that if anaerobic-aerobic system compared with conventional aerobic technologies based on activated sludge processes, lower energy consumption and lower excess sludge production can be achieved with a high-rate anaerobic pre-treatment step.

Anaerobic digestion may be defined as the engineered methanogenic decomposition of organic matter. It involves different species of anaerobic microorganism that degrade organic matter (Caroline et al., 2006). In anaerobic process, the decomposition of organic substrate is carried out in the absence of molecular oxygen. The process is time consuming as bacterial consortia responsible for the degradation process requires time to adapt the new environment before they start to consume on organic matter to grow (Poh and Chong, 2009).the biological conversion of the organic substrate occur in the mixtures of primary settled and biological sludge under anaerobic condition followed by hydrolysis, acidogenesis and methanogenesis to convert the intermediate compounds into simpler end products as methance (CH_4) and carbon dioxide (CO_2) (Wong et al., 2009). Hydrolysis is where complex molecules (i.e. lipids, protein, and carbohydrates) are converted into sugar and amino acid. In the step acidogenesis, acidogenic bacteria will break down these sugars, fatty acid and amino acids which mainly consist of acetic acids (from acetogensis) together with hydrogen and carbon dioxide. Hydrogen and carbon dioxide will be utilized by hydrogenotropic methanogens while acetic acid and carbon dioxide will be utilized by acetoclastic methanogens to give methane as a final product (Poh and Chong, 2009).

2.3 Application of ABR

The ABR can be described as a series of UASBs, which does not require granulation for its operation (Barber and Stuckey, 1999). In ABR treatment, a series of vertical baffles are built inside the airtight reactor to force the wastewater to flow over and under it as it moves from the inlet to the outlet of the tank. The idea of ABR system was initially developed by McCarty and co-workers in Stanford University (Huang et al., 2004). Microorganism within the reactor will gently rise and settle due to flow of wastewater and gas production in each compartment. However, the microorganism will move vertically down the reactor. Therefore, the wastewater can come into intimate contact with a larger amount of active biomass as it passes through the ABR, while the effluent remains relatively free of biological solids. This configuration has been shown to result in a high degree of COD removal (Huang et al., 2004).

The most significant advantage of ABR is its ability to separate acidogenesis and methanogenesis longitudinally down the reactor (Weiland and Rozzi, 1991). The separation of acetogenic and methanogenic phases causes an increase in protection against toxic materials and higher resistance to changes in environmental parameters such as pH, temperature and organic loading.

Among high rate reactors, the anaerobic baffled reactor was suggested by several researchers as a promising system for industrial wastewater treatment. Although there have been many anaerobic high rates designs developed, the ABR were extensively used in the treatment of synthetic tannery wastewater containing sulphate and chromium (III) (Barber and Stuckey, 2000), textile dye wastewater (Bell and Buckey, 2003), azo dyes containing wastewater, swine wastes, palm oil mill effluent wastewater (Setiadi et al, 1996), treating whisky distillery wastewater, sulphate containing wastewaters, pulp and paper mill black liquors, nitrogen containing wastewaters(Bodik et al., 2003) landfill leachate (Wang and Shen, 2000) and also domestic wastewaters. It is known that a three-chamber reactor, together with physical modification, provided a longer solid retention time and superior performance than the reactor with only two compartments (Barber and Stuckey, 1999). The first compartment are adjusted to be twice the size of the other compartment, this is allow longer solids retention time and superior performance as compared, to react as natural filter and provided superior solids retention for the smaller particles. The main problem associated with strength materials in an ABR is its difficulty in breakdown of fat, protein and hydrocarbon molecules at early stage of anaerobic decomposition due to uncertain selection of Hydraulic Retention Time (HRT) and therefore Organic Loading Rate (OLR).

2.4 Application of SBR

Sequencing batch reactor (SBR) is a fill-and-draw activated sludge treatment system that could be applied for treating organic wastewater (Keller et at., 1997; Carucci et al.; 1999) and (Laughlin et al., 1999). The unit processes involved in the SBR and conventional activated sludge systems are identical. Aeration and sedimentation are carried out in both systems. However, there is one important difference. In conventional activated sludge plants, the processes are carried out simultaneously in separate tanks, whereas in SBR operation, the processes are carried out sequentially in the same tank. The SBR system could also be used to treat high nitrogen containing wastewater because such systems facilitate nitrogen removal by nitrification–denitrification ([Metcalf & Eddy, 1991] and [Sirianuntapiboon and Tondee, 2000]). But the system has to operate with a high amount of mixed liquor suspended solids (MLSS) to prevent high excess bio-sludge production and improve the sludge quality ([Berner et al., 2000], [Kagi and Uygar, 2002] and [Wilen and Balmer, 1998]). However, the operation with aerobic-SBR still has some problems such as the low settleablity of bio-sludge, high excess sludge production under high organic loading or hydraulic loading and less increase in the removal efficiency due to the limitation of the increasing of bio-sludge (Metcalf & Eddy, 1991).

2.5 Application of anaerobic-aerobic system

P. Zhou et al. (2006) investigated the treatment of high-strength pharmaceutical wastewater and removal of antibiotics in anaerobic and aerobic treatment processes. The result indicated that a combination anaerobic-aerobic treatment system was effective in removing organic matter from the high-strength pharmaceutical wastewater. The system reached total COD removal efficiency up to 97.8%; effluent COD varied between 250 and 350 mg/L when the system were used to treat the raw wastewater with COD ranging from 10,000 mg/L to 20,000 mg/L.

Tomei et al. (2011) studied the performance of sequential anaerobic/aerobic digestion applied to municipal sewage sludge. Through the investigation they have come up that the volatile solid removal efficiencies of 32% in the anaerobic phase and 17% in the aerobic one were obtained, similar COD removal efficiencies (29% anaerobic and 21% aerobic) were also observed. The aerobic stage was also efficient in nitrogen removal providing a decrease of the nitrogen content in the supernatant attributable to nitrification and simultaneous denitrification.

A study on application of anaerobic-aerobic sequential treatment system to real textile was done by Kapdan and Alparslan (2005). The experiment set up consists of an anaerobic packed column reactor, activated sludge unit and sedimentation tank. The general conclusion can be drawn from this is that anaerobic unit significantly improves the color removal but does not significantly help COD removal. However, it helps reducing the aeration time in activated sludge unit for organic substance removal. Because, almost the same effluent COD concentration was obtained in real textile wastewater treatment plant, which is aerated for 36 h, while in this study aeration period was only 10 h. So the addition of an anaerobic unit will not change the total HRT in the real textile wastewater treatment plant but will provide better effluent quality in terms of mainly color.

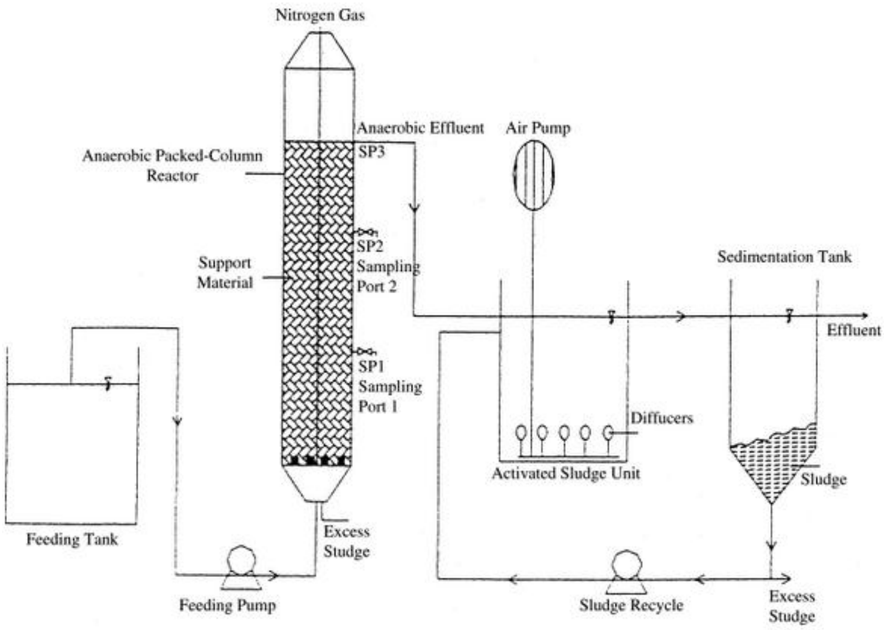

Figure2.1. Schematic experiment diagram of sequential anaerobic packed column reactor and activated sludge unit (anaerobic-aerobic system) in study of Kapdan and Alparslan (2005).

CHAPTER 3

METHODOLOGY

3.1 Project Activities

The project is divided into two phases, which are FYP I and FYP II. For FYP I, it is basically about research and information collection on the anaerobic-aerobic system and it application in POME. Sample of POME will be taken from Nasaruddin Palm Oil Mill and are then analyse to identify characteristics of the POME before it can be used for the second phase of the project. For the current work in FYP II, the operation of the anaerobic baffled reactor and aerobic sequencing batch reactor system is currently being conducted.

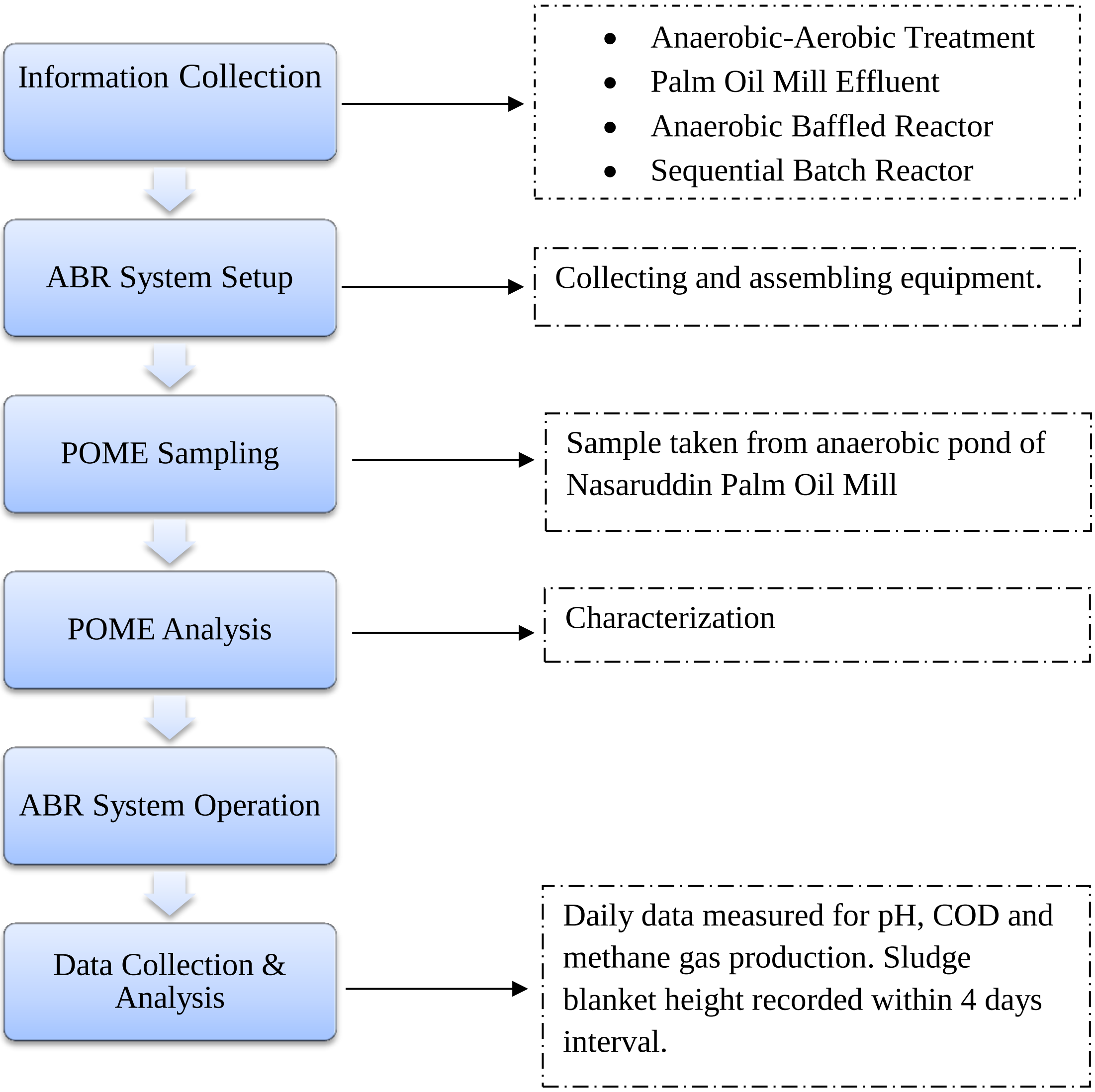

Figure3.1. Project Process Flow for FYP I: mainly focussing on sampling, setting up operation of ABR.

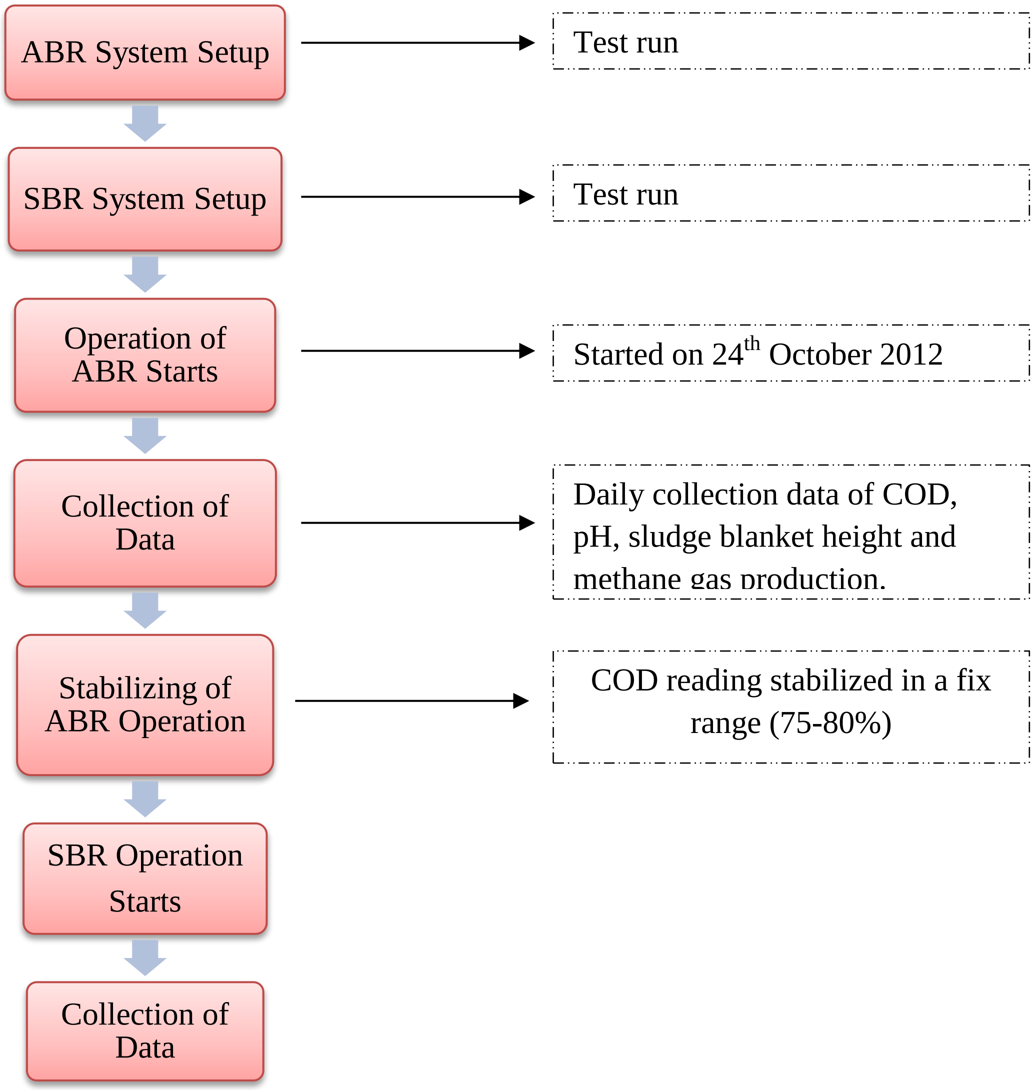

Figure3.2. Project Process Flow for FYP II: stabilization of ABR.

3.2 Wastewater Sample

The wastewater samples used in the project are Palm Oil Mill Effluent (POME) was retrieved from Nasaruddin Palm Oil Mill. The mill was chosen due to the factor that it practices anaerobic pond system to treat its wastewater.

After sampling, the wastewater samples must be directly placed in the cool storage at temperature of 4ºC to stop any microorganism’s reaction therefore no composition changes will happen in the sample. The pH was never adjusted and no chemicals were added to the wastewater, samples are to remain undisturbed after retrieving. This was to prevent the sample to deteriorate and to ensure accurate results for characterization.

The characteristics of the wastewater were determined before it was used in the ABR system to ensure it suitable for anaerobic operation. The wastewater will be analysed for the parameters of pH, BOD, COD, TKN, TSS and MLVSS. This was a vital step in ensuring that the condition of the sample was suitable to undergo anaerobic process which requires pH ranging from 6.8 – 7.1, as acidic sample can harmed the microorganisms, while other parameters are required in calculation of microorganisms volume in anaerobic baffled reactor.

3.2.1 pH determination

pH of the wastewater sample will be determined using a digital pH meter based on the HACH method.

3.2.2 COD determination

The palm oil mill effluent (POME) sample will be filtered to remove suspended solids in the sample and diluted to 1:50 before proceeding with the COD experiment. The COD of the wastewater sample will be then determined using the spectrophotometer based on the APHA method.

3.2.3 BOD determination

The of BOD was determined is determined using the equation of;

To determine the BOD value without seed correction:

$$\text{BOD} = \frac{(Initial\ dissolved\ oxygen) - (Final\ Dissolved\ oxygen) - (Blank\ correction)}{Sample\ size/300}$$

To determine the BOD value with seed correction and blank correction:

$$= \frac{(Initial\ dissolved\ oxygen) - (Final\ Dissolved\ oxygen) - (Seed\ \&\ blank\ correction)}{Sample\ size/300}$$

To determine the BOD value with the seed correction and blanket correction as well as dilution:

$$= \frac{(Initial\ dissolved\ oxygen) - (Final\ Dissolved\ oxygen) - (Seed\ \&\ blank\ correction)}{Sample\ size/300} \times Dilution$$

3.2.4 TKN determination

The TKN value was determined based on the formula;

$$\text{TKN} = \frac{v_1 - v_2}{v_0} \times C \times F \times 1000$$

Where:

V1 = mL of standard 0.20N H2SO4 solution used in titrating sample.

V2 = mL of standard 0.20N H2SO4 solution used in titrating blank.

N = normality of sulphuric acid solution.

F = miliequivalent weight to nitrogen (14mg).

V0 = mL of sample digested.

3.2.5 Total Suspended Solid Determination

Total suspended solid (TSS) is determined by filtering the 100 mL of wastewater samples using a 47 mm filter disc. The filter paper then dried in a drying oven of 105°C for 1 hour. After the filter paper is cooled off in a desiccator, the filter paper is weighed to determine the suspended solid of the wastewater. The TSS is determined by the following formula:

$$= \frac{(Weight\ of\ pan + filter\ paper\ after\ drying) - (Weight\ of\ pan + filter\ paper\ before\ drying)}{Sample\ size\ (L)}$$

3.2.6 MLVSS determination

The Mixed Liquor Volatile Suspended Solid (MLVSS) is determined by filtering the samples using a 47 mm fibre glass filter paper. Fibre glass filter paper is used in the experiment to avoid burning of filter paper when it is exposed to high temperature of 550ºC for 20 minutes. After being cooled off in a desiccator, the filter paper is weighed to determine the MLVSS of the samples. The determination of MLVSS is by using the following formula:

To determine the MLSS of the sample;

$$= \frac{(weight\ of\ pan + filter\ paper\ before\ drying) - (weight\ of\ pan + filter\ paper\ after\ drying)}{Sample\ size\ (L)}$$

To determine the MLVSS of the sample;

$$= \frac{(weight\ of\ pan + filter\ paper\ before\ furnace) - (weight\ of\ pan + filter\ paper\ before\ furnace)}{Sample\ size\ (L)}$$

3.3 Seeding

Sludge was taken from the Anaerobic Pond from Nasaruddin Palm Oil Mill. The sludge is taken from the same source of treatment policy to ensure that the microorganisms are familiar with the environment and characteristics of wastewater that it will encounter to shorten the duration for acclimatization of the sludge. It was then introduced equally to all 6 compartments of the ABR. The calculation of food-to-microorganism is depicted in Appendix.

$$\frac{F}{M} = \frac{S_0\ \theta}{V\ x}$$

Where:

$F = Food$

$M = Microorganism$

$S_o = BOD\ or\ COD\ concentration\ of\ influent, mg/L$

$\theta = Flow\ rate$

$x = concentration\ of\ volatile\ suspended\ solids\ in\ tank\ , mg/L$

$V = volume\ of\ reactor$

3.4 Reactor Characteristics and Operation

Anaerobic System (1st Part)

The reactor that was used in the experiment is a flexi glass cubic tank with 0.44 m in length, 0.21 m in depth and 0.29 in height and divided into 5 compartments. The volume of the first compartment is 0.0083 m^3, the next 3 compartments each having 0.0025 m^3 of volume and the last compartment with volume of 0.0065 m^3. The first compartment is design with bigger volume compared to the other 4 compartment acted as a natural filter and provided superior solids retention for the smaller particles as compared to reactor with similar size compartments (Barber and Stuckey, 1999). This configuration will collect more solid materials than having 5 equally divided compartments (Malakahmad, et. al, 2008).

Stirrer was added to the influent tank to continuously mix the wastewater in order to prevent sedimentation of particulate and to provide equal concentration throughout the operation time. Pump is used to keep a constant flow rate of feeding to the system.

Tubes will be installed at the middle elevation of the reactor in each compartment. The installation of the tube is for the purpose of taking samples in every compartment for pH reading. Samples were taken daily to analyse the COD of the POME to observe the behaviour and the performance of the ABR treatment system.

A cylinder shaped gas collection was designed to collect and measure the volume of methane gas produce from the system. Water displacement method was used to collect and determine the volume of methane gas produced by the steam. The collection chamber is filled with solution of Sodium Hydroxide (NaOH) in order to dissolve and separate the CO_2 in the biogas produced, leaving only the methane gas

(Gopala et al., 2008). The solution of NaOH is prepared by diluting NaOH of 47% into 2.5%.

The operation is maintained at room temperature; between 29ºC to 32ºC.

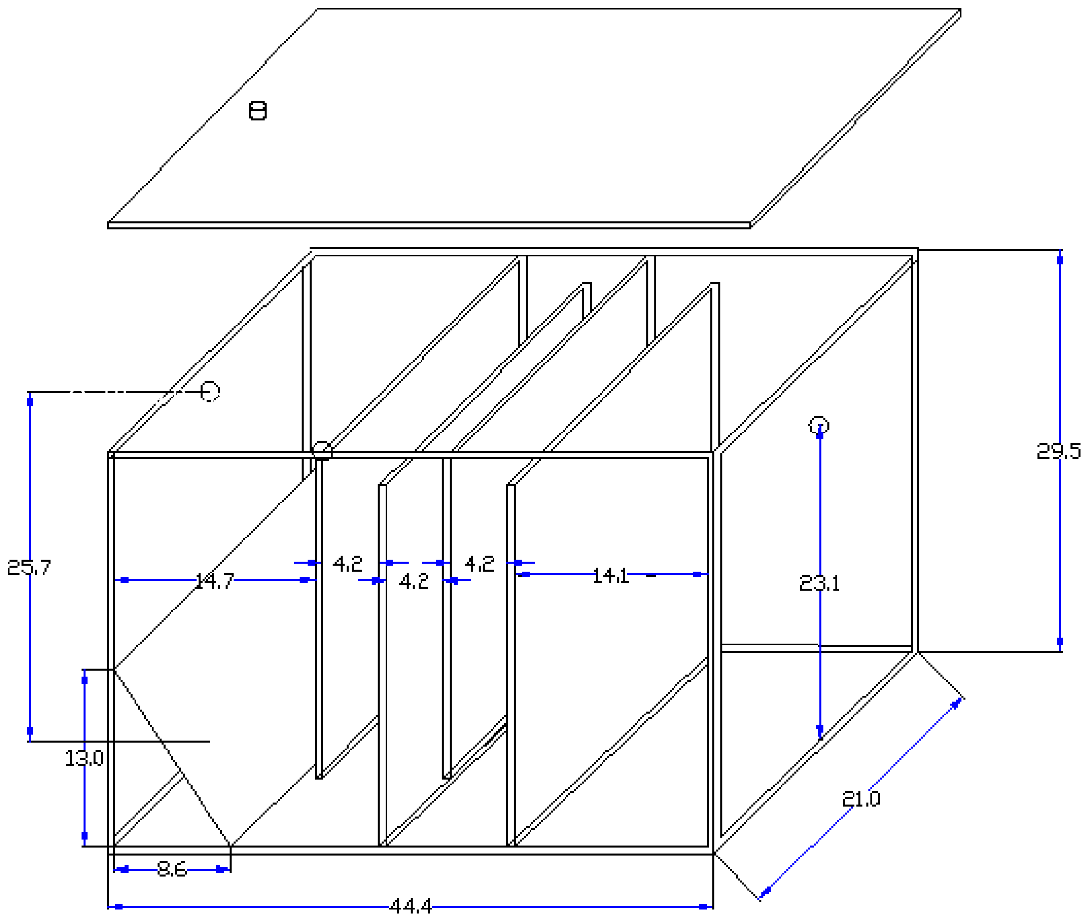

Figure3.3. Anaerobic Baffled Reactor Laboratory Size-Scale (Dimension in centimetre)

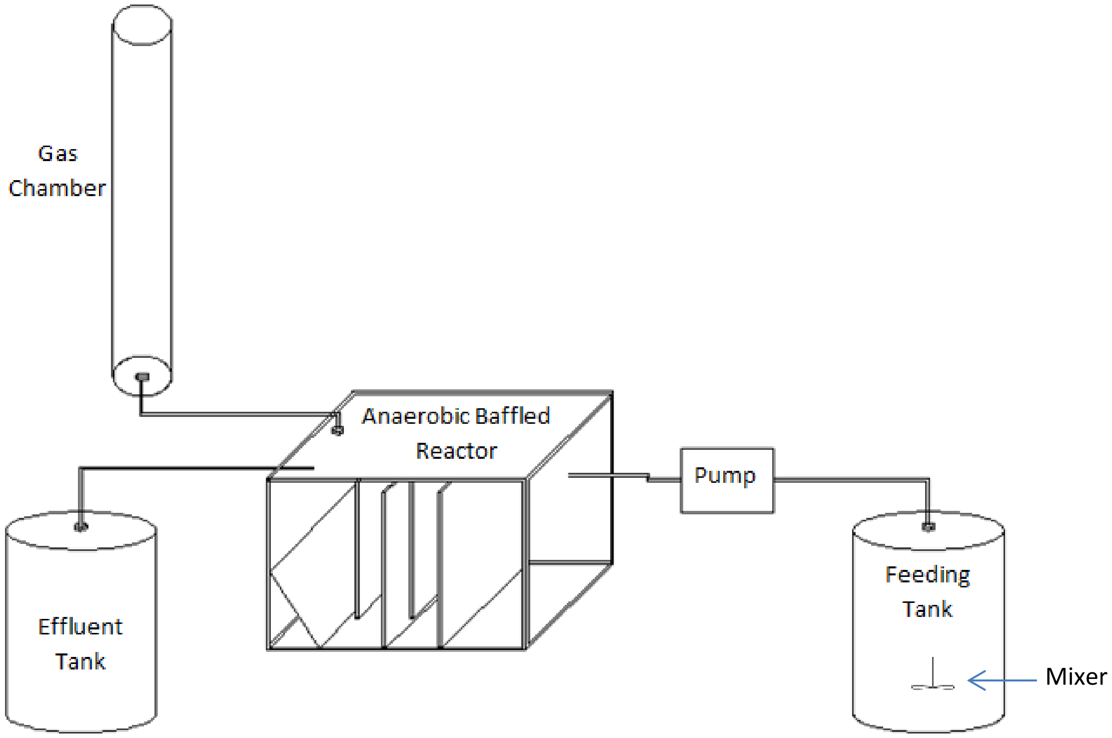

Figure3.4. Anaerobic System build of 21.26 L ABR capacity, Feeding Tank with POME maintained at pH level 6.8 - 7.1, using Pump (Master Flex Console Drive Cole Palmer; Model 7535-04) and Mixer (Stir-Pak Cole Palmer; Model 50002-07).

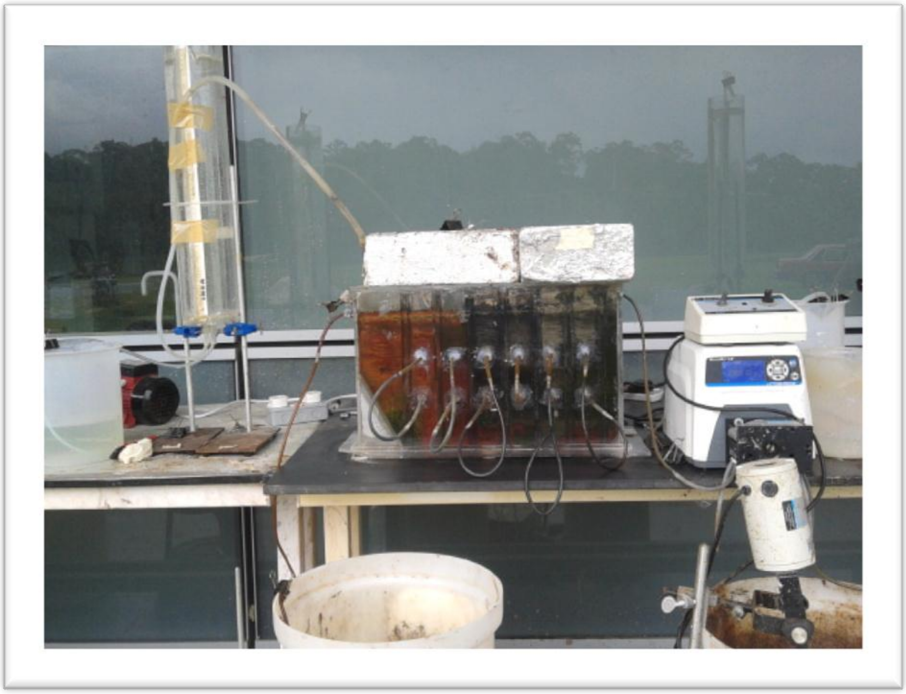

Figure3.5. Anaerobic system in operation.

Aerobic System (2nd Part)

After the anaerobic system has stabilized and reached reduction of COD upon 75% - 90% removals, the process of connecting the aerobic system (SBR) can be preceded.

The reactor that will be used is a used container with the capacity of 10 L. The SBR will be operated with Cycle Time (CT) of 6 hours; 4 cycles per day with Hydraulic Retention Time (HRT) of 24 hours. The Cycle Time consists of feeding (15 minutes), reacting (255 minutes), settling (60 minutes), decanting (15 minutes) and idling (15 minutes). Diffuser equipped with 4 air balls is used for the reaction phase of the SBR. The reactor will be operated in room temperature (29ºC - 32ºC) and pH is maintained at 6 – 8. The process is repeated until stable results are obtained.

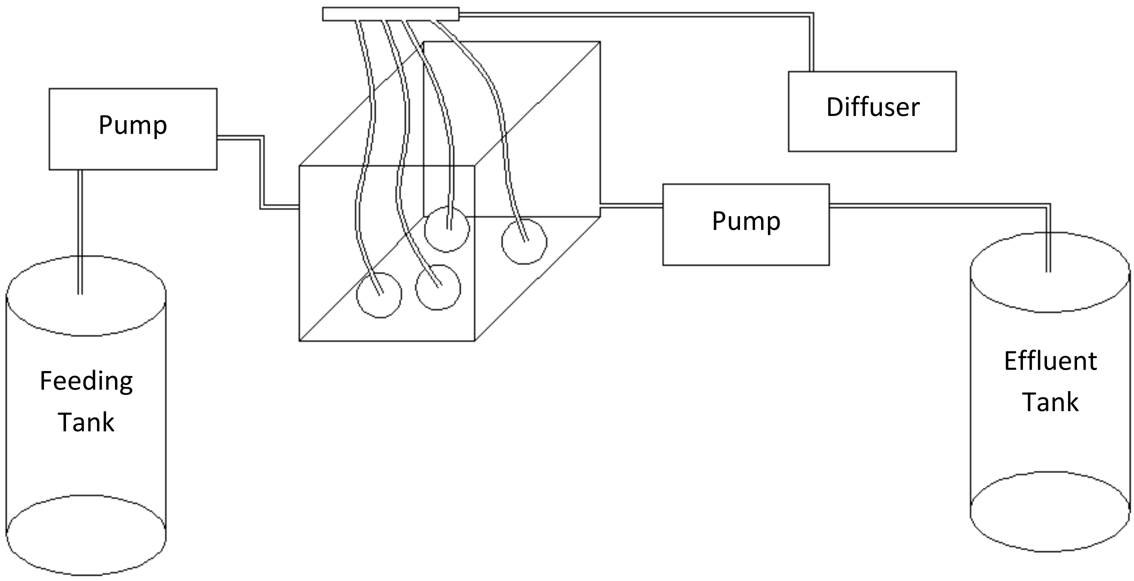

Figure3.6. Aerobic System build of a Reactor (Using used container, 10 L capacity), with Diffuser (Halilea® Aquarium Air Pump; Model ACO – 5505), Pump(Master Flex Precision Pump with Tubing L/S 16, Multichannel Pump; Model 7535-04) and 2 digital switch timer to ensure accurate transition of cycle on each pump and diffuser. Can be also referred to figure 3.7

Figure 3.7: Sequencing Batch Reactor run-up test for with tap water to ensure efficiency before running with sample.

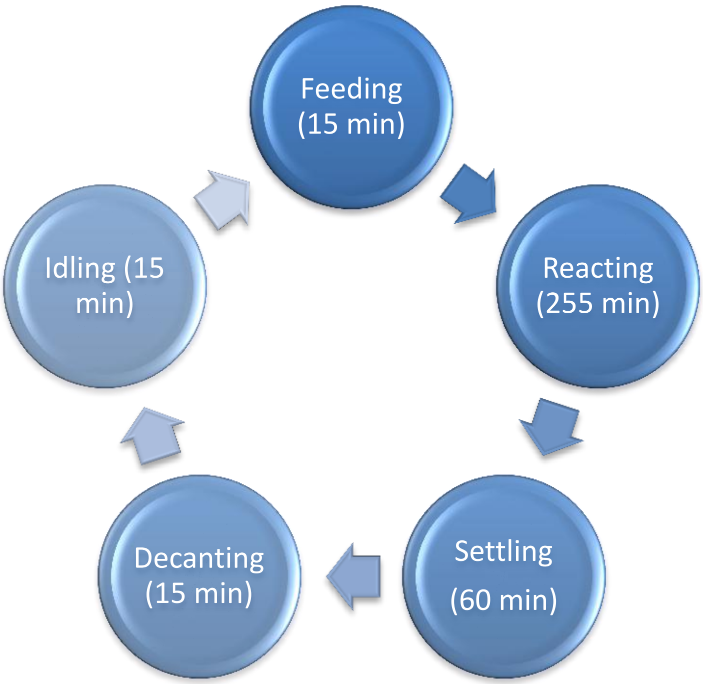

Figure3.8. SBR Cycles and Durations.

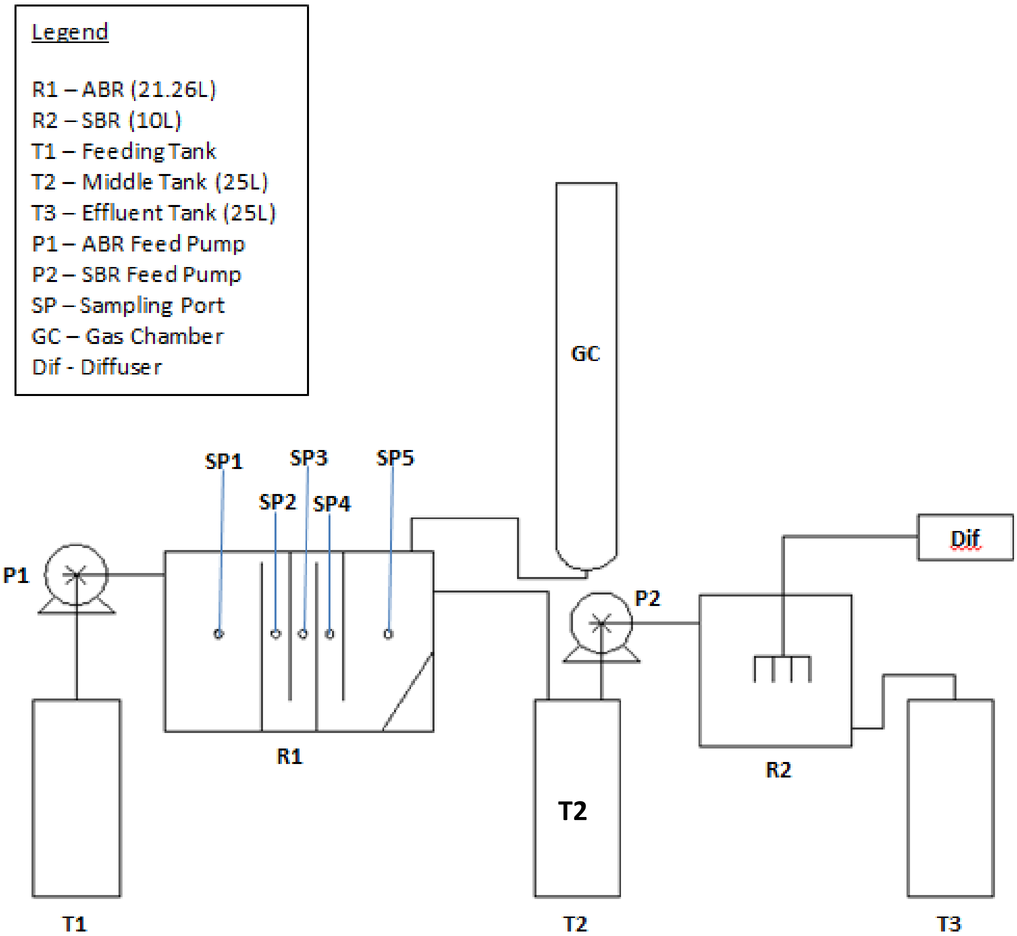

Figure3.9. ABR-SBR Schematic Diagram

3.5 Sampling and Analysis

The effluent of the system was monitored daily for pH, COD and biogas production. Sample is taken from the effluent tank and from each compartment of the reactor monitor behaviour of the treatment system. The sampling will be done by starting from the last compartment towards the first to prevent air intrusion and to maintain the anaerobic condition in the reactor (Gopala et al., 2008).

CHAPTER 4

RESULT & DISCUSSION

Before the POME samples were used in the ABR system, it was analysed to identify the characteristics by conducting several experiments. Table 4.1 shows the identified characteristics of the POME sample.

Table4.1. Characteristics of Raw POME

Parameter	Concentration
pH	3.9
COD (mg/L)	67, 500
BOD (mg/L)	29, 250
Oil and Grease (ppm)	238
Phosphorus (mg/L)	692.5
Ammonia (mg/L)	415
Nitrogen (mg/L)	346

The ABR system was monitored daily by taking samples of the POME from each compartment and also influent and effluent of the system. Figure 4.1 shows the COD concentration and reduction percentage. Figure 4.2 displays graph pH profile of each 5 compartment. Methane gas production was depicted in Figure 4.3 while sludge height is shown in Figure 4.4.

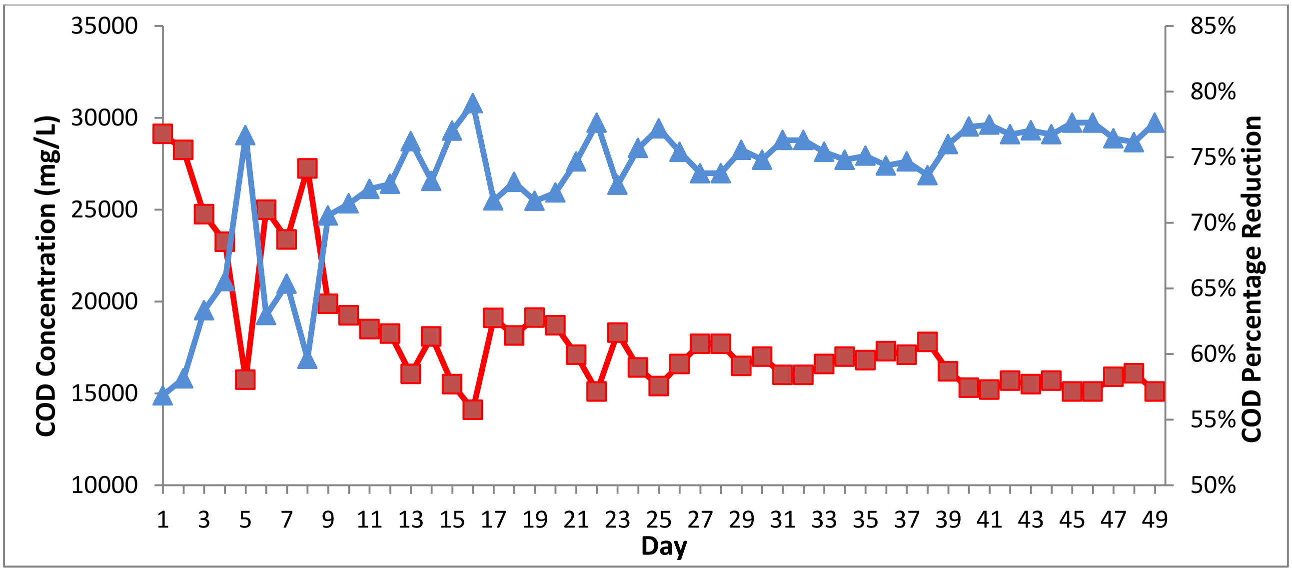

Figure4.1. COD daily concentration and reduction percentage in a 49-days period

Figure 4.1 shows the COD removal efficiency of the anaerobic baffled reactor. 3 readings are done for each sample for average. The percentage of COD reduction fluctuates in large range; 56% - 73%, from day 1 till day 18, this shows that the system is still acclimatizing. The microorganism at that period was adapting to the surrounding system. The COD reduction then further decrease and fluctuated in a much smaller range manner between 71% - 76% from day 19 to 31. From day 31 onwards the system is declared to achieve its stabilization stage when the COD reduction is recorded from 75% to 78%. It can be concluded that the ABR can achieved its stabilization stage in a short time duration; 31 days.

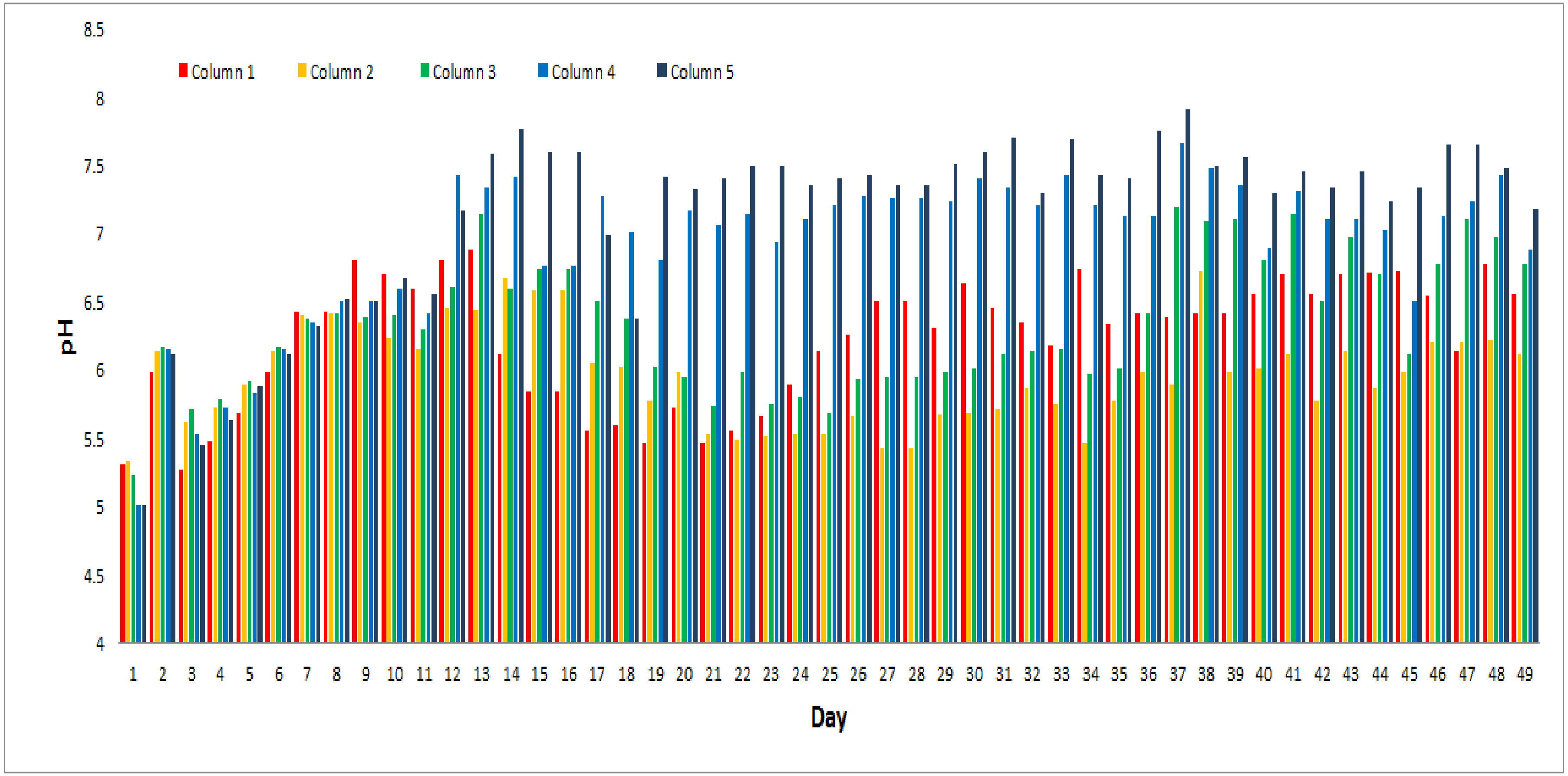

Figure4.2. pH profiles. C1, C2, C3, C4 and C5 indicate the compartment number 1 through 5, respectively

Figure 4.2 shows the pH value of each compartment during the process. The pH of the POME in the feeding tank is adjusted due to the acidic characteristics of the POME and maintained at 6.8 – 7.1.

From the figure it can observed that from day 1 to day 11, there is no variation in pH profile of the compartment 1 to 5. This is because the microorganism is still not well formed and distributed yet.

From day 11 to 49, the variation of pH profile was observed, the graph displays the pH decreases from compartment 1 to 2, but the pH value increase sharply from compartment 2 to 3 and the pH gradually increases in compartment 3 to 5.

Thus, it is postulated that the first two compartment shows the first two steps of anaerobic degradation, namely hydrolysis and acidogenesis, where complex organics in POME were first hydrolysed by enzymes, forming sugars, amino acids and fatty acids which were further degraded by acidogens and forming VFAs. The increase of pH of compartment 3 towards compartment 5 indirectly shows the occurrence of methanogensis. Here the methanogens are more active as most of the acetate and H_2/CO_2 produced from acetogenesis were converted to methane. A shift to slower growing scavenging bacteria that grow better at higher pH will occur towards the end of the reactor (Barber and Stuckey, 1999).

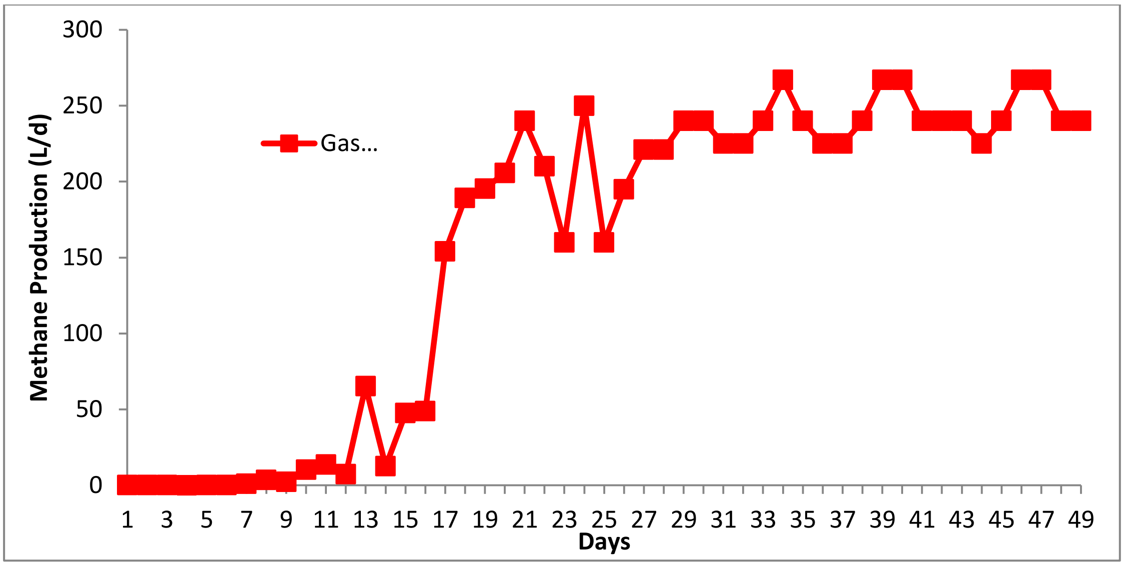

Figure 4.3; Methane gas production of ABR is continuously monitored during the experiment. Measurements are taken from 1500 – 1700 hours to achieve accuracy.

Figure 4.3 displays the methane gas production (L/Day). Raw biogas contains typically 60 – 70% methane and 30 – 40% carbon dioxide. During the methanogenesis stage, microorganisms convert the hydrogen and acetic acid formed by the acid formers to methane gas and carbon dioxide (Verma 2002). The bacteria responsible for this conversion are called methanogens and are strict anaerobes. The biogas produced in the ABR reacts with sodium hydroxide to produce sodium bicarbonate; the solution displacement in the gas chamber will then show the volume of methane gas only.

$$NaOH + CO_2 \rightarrow NaHCO_3$$

Based on the graph it shows the production of methane gas from starting day until day 12 shows no methane gas production. This is due to system is still adapting to the environment and the polymer particle is still large to break down to produce methane gas.

Methane gas production was detected on the 13th day and the production increased dramatically until day 21. The graph then display that it fluctuates in the range 150 – 250 L/day from day 22 until 25. The methane production shows stability in production on day 26 and afterwards. It can be concluded that methane gas production requires longer stabilization time compared to other parameters and when reached stability phase the production is very large.

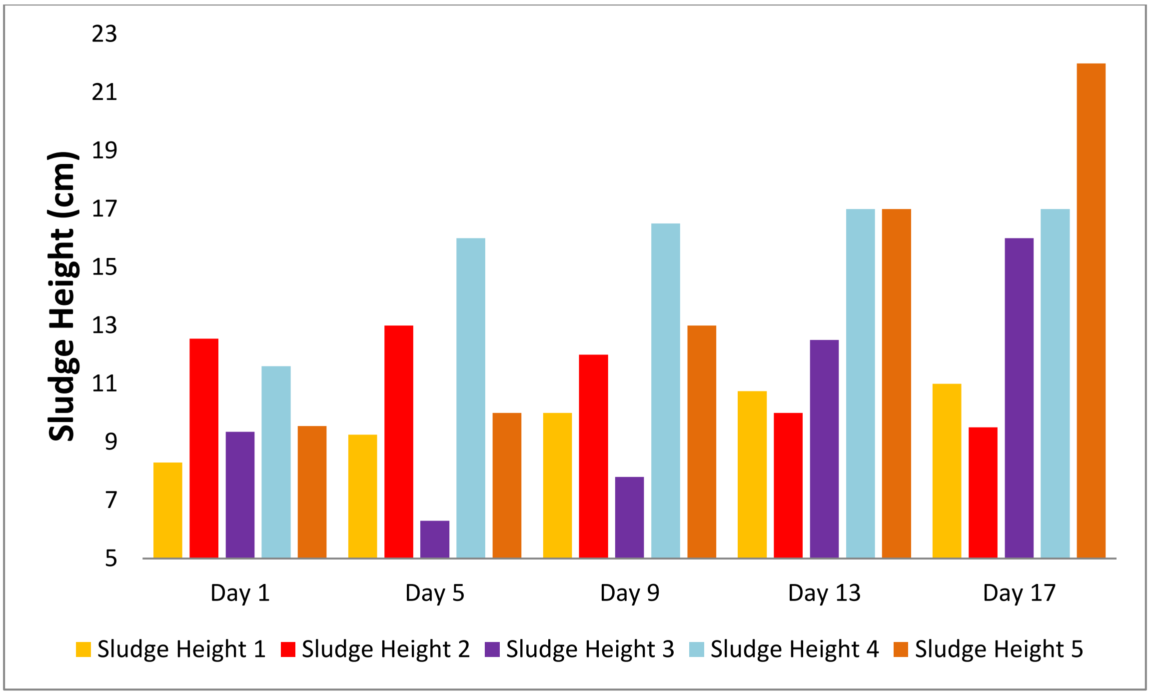

Figure4.4. Sludge blanket in each compartment of the ABR; C1, C2, C3, C4 and C5 indicates compartment 1 through 5, respectively. Measurements were taken within an interval of 4 days.

Figure 4.4 displays the sludge height for each compartment in the anaerobic baffled reactor. Measurements are recorded with 4 days interval. It can observe that the sludge blanket is increasing gradually due to the growth of microbe populations.

CONCLUSION

The study shows that anaerobic system is dependable as a post treatment in treating high pollutant content wastewater. It can also be concluded;

- An integrated anaerobic-aerobic system was designed to treat POME to meet the standard limits instructed by DOE and to produce methane as a renewable source of energy.
- pH profile indicate well separation of acid formers and methane formers in ABR's compartments which resulted in high COD removal efficiency and reasonable methane production rate.
- The performance of ABR with no dilution of POME indicates superior capability of the system compared to other biological methods.

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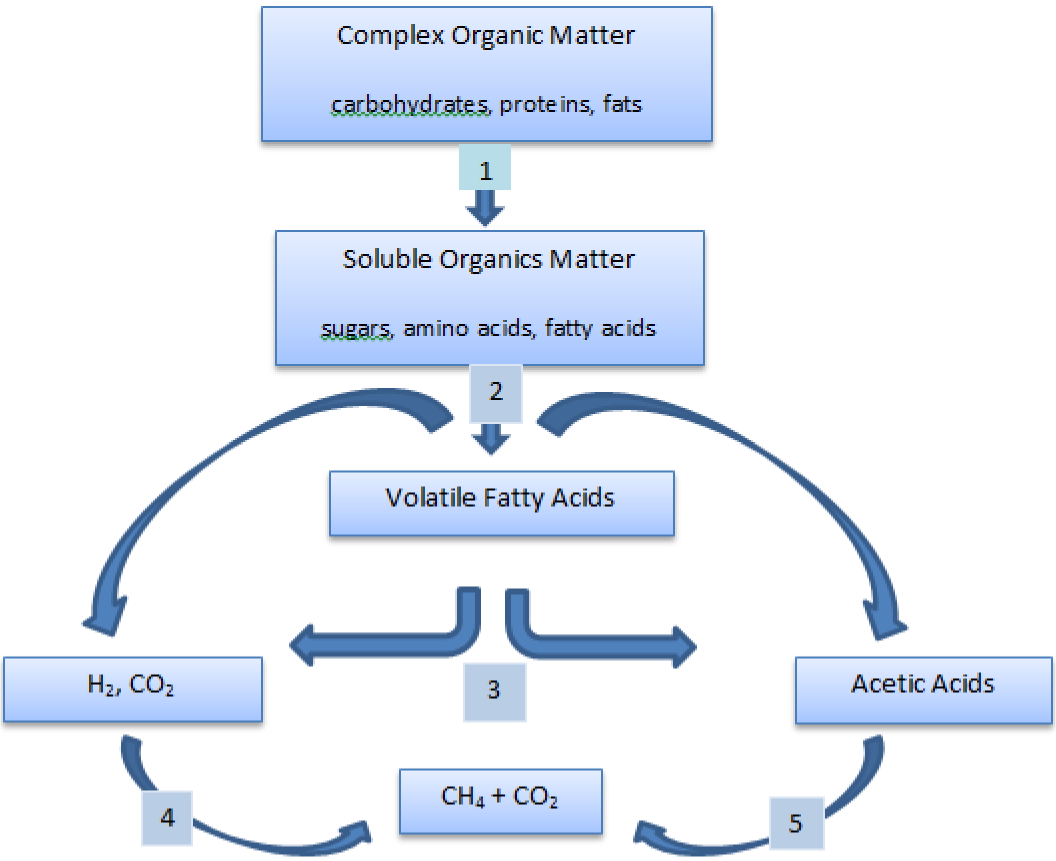
Appendix 1;

Figure 8.1. The Anaerobic Digestion Process



1. Hydrolysis
2. Fermentation
3. Acetogenesis
4. Methanogenesis

Appendix 2;

MLVSS Determination

MLSS

$$= \frac{1674\ mg - 1172\ mg}{0.025\ L}$$

$$= 20,080\ mg.L^{-1}$$

MLVSS

$$= \frac{1172\ mg - 950\ mg}{0.025\ L}$$

$$= 8,880\ mg.L^{-1}$$

Appendix 3

Table 8.1 COD Concentration and Reduction Percentage of Anaerobic Baffled Reactor Effluent.

Day	COD (mgL^{-1})	Reduction Percentage	Day	COD (mgL^{-1})	Reduction Percentage
1	29,125	56.85%	26	16,600	75.41%
2	28,250	58.15%	27	17,700	73.78%
3	24,750	63.33%	28	17,700	73.78%
4	23,250	65.55%	29	16,500	75.56%
5	15,750	76.67%	30	17,000	74.81%
6	25,000	62.96%	31	16,000	76.30%
7	23,375	65.37%	32	16,000	76.30%
8	27,250	59.63%	33	16,600	75.40%
9	19,875	70.56%	34	17,000	74.81%
10	19,250	71.48%	35	16,800	75.11%
11	18,500	72.59%	36	17,300	74.37%
12	18,250	72.96%	37	17,100	74.67%
13	16,050	76.22%	38	17,800	73.63%
14	18,100	73.19%	39	16,200	76.00%
15	15,500	77.03%	40	15,300	77.33%
16	14,100	79.11%	41	15,200	77.48%
17	19,100	71.70%	42	15,700	76.74%
18	18,150	73.11%	43	15,500	77.04%
19	19,120	71.67%	44	15,700	76.74%
20	18,700	72.30%	45	15,100	77.63%
21	17,100	74.67%	46	15,100	77.63%
22	15,100	77.62%	47	15,900	76.44%
23	18,300	72.89%	48	16,100	76.15%
24	16,400	75.70%	49	15,100	77.63%
25	15,400	77.19%			

Appendix 4

Table 8.2 pH Profile of Anaerobic Baffled Reactor

Day	Compartment 1	2	3	4	5
1	5.31	5.33	5.23	5.01	5.01
2	5.99	6.14	6.17	6.15	6.11
3	5.27	5.62	5.71	5.53	5.45
4	5.48	5.72	5.79	5.73	5.64
5	5.68	5.9	5.92	5.83	5.88
6	5.99	6.14	6.17	6.15	6.11
7	6.43	6.4	6.37	6.35	6.32
8	6.43	6.42	6.42	6.5	6.52
9	6.8	6.35	6.39	6.51	6.51
10	6.7	6.23	6.4	6.6	6.68
11	6.6	6.15	6.3	6.41	6.56
12	6.8	6.46	6.61	7.43	7.17
13	6.88	6.44	7.15	7.34	7.59
14	6.12	6.68	6.6	7.42	7.77
15	5.84	6.58	6.74	6.76	7.6
16	5.84	6.58	6.74	6.76	7.6
17	5.56	6.05	6.51	7.27	6.99
18	5.59	6.02	6.38	7.02	6.38
19	5.46	5.78	6.02	6.81	7.42
20	5.72	5.98	5.94	7.17	7.32
21	5.47	5.53	5.74	7.07	7.41
22	5.55	5.49	5.98	7.15	7.5
23	5.66	5.52	5.75	6.94	7.49
24	5.89	5.53	5.8	7.11	7.35
25	6.14	5.53	5.69	7.21	7.41
26	6.26	5.66	5.93	7.28	7.43
27	6.51	5.42	5.95	7.26	7.35
28	6.51	5.42	5.95	7.26	7.35
29	6.31	5.67	5.98	7.24	7.51
30	6.64	5.69	6.01	7.41	7.6
31	6.46	5.71	6.12	7.34	7.7
32	6.35	5.87	6.14	7.21	7.3
33	6.18	5.75	6.16	7.43	7.69
34	6.74	5.47	5.97	7.21	7.43
35	6.34	5.78	6.01	7.13	7.4
36	6.41	5.98	6.41	7.13	7.76
37	6.39	5.9	7.19	7.67	7.91
38	6.42	6.73	7.09	7.48	7.49
39	6.42	5.98	7.11	7.35	7.56
40	6.56	6.01	6.8	6.9	7.3
41	6.7	6.11	7.14	7.31	7.45
42	6.56	5.78	6.5	7.11	7.34
43	6.7	6.14	6.98	7.11	7.45
44	6.71	5.87	6.7	7.03	7.23
45	6.73	5.98	6.12	6.51	7.34
46	6.54	6.21	6.78	7.13	7.65
47	6.14	6.21	7.11	7.24	7.65
48	6.78	6.22	6.98	7.43	7.48
49	6.56	6.11	6.78	6.88	7.18

Appendix 5;

Table 8.3 Methane Gas Production of Anaerobic Baffled Reactor

Day	Gas (L/Day)	Day	Gas (L/Day)
1	0.226	26	195
2	0.09	27	221
3	0.079	28	221
4	0.045	29	240
5	0.17	30	240
6	0.2	31	225
7	0.9	32	225
8	3.55	33	240
9	2.3	34	267
10	10.18	35	240
11	13.57	36	225
12	7.23	37	225
13	65.28	38	240
14	12.55	39	267
15	47.5	40	267
16	48.86	41	240
17	154	42	240
18	189.2	43	240
19	195.4	44	225
20	205.7	45	240
21	240	46	267
22	210	47	267
23	160	48	240
24	250	49	240
25	160		

Appendix 6;

Table 8.4 Sludge Height Measurements

	Sludge Height				
	1	2	3	4	5
Day 1	8.3	12.55	9.35	11.6	9.55
Day 5	9.25	13	6.3	16	10
Day 9	10	12	7.8	16.5	13
Day 13	10.75	10	12.5	17	17
Day 17	11	9.5	16	17	22

Appendix 7;
Pictures

Figure 8.2 Process of Retrieving Sludge In Anaerobic Pond 6, FELCRA Nasaruddin

Figure 8.3 Raw POME

Figure 8.4 TKN Test for Initial Characterization.

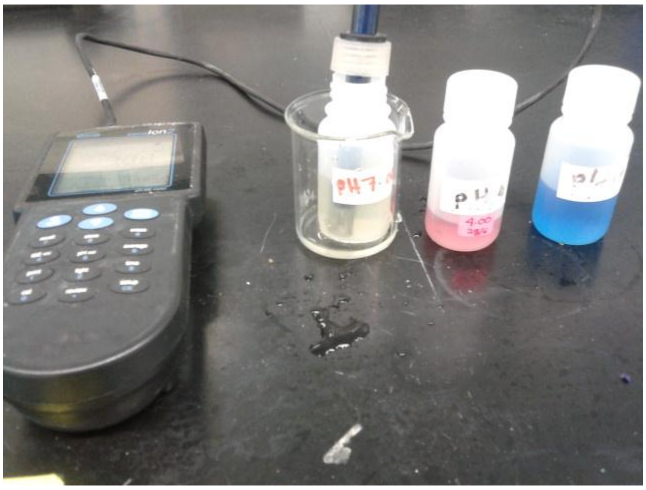


Figure 8.5 Calibration of pH Meter before Every Reading Taken

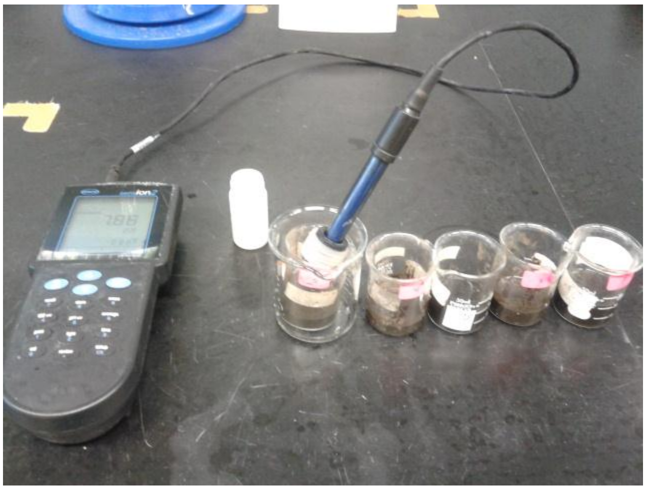


Figure 8.6 pH Reading

Figure 8.7 Daily COD Reading Taken For ABR Effluent