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EFFICIENCY OF ORGANO-FLOC AS A NATURAL COAGULANT IN THE TREATMENT OF PALM OIL MILL EFFLUENT

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FK 2015 129

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By

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Thesis Submitted to the School of Graduate Studies,
Universiti Putra Malaysia, in Fulfilment of the Requirements for the
Degree of Doctor of Philosophy

May 2015

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Doctor of Philosophy

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May 2015

Chairman : Profesor Luqman Chuah Abdullah, PhD
Faculty : Engineering

Palm Oil Mill Effluent (POME) contains high concentrations of chemical oxygen demand (COD), biochemical oxygen demand (BOD), and organic suspended solids (OSS) is a by product or waste of palm oil mill processing. It is compulsary to treat the POME before it can be discharged to any aqua systems. In this study, performance of *Organo-floc*, a natural coagulant, was evaluated as coagulation treatments for POME. The objective of the present study is to investigate the aerobic treatment of anaerobically digested POME by using a sequencing batch reactor (SBR).

The SBR performance was assessed based on COD, BOD and TSS removal. The coagulation studies were carried out using a conventional jar apparatus to study the effects of various parameters which are dosage, mixing time, and speed of stirrer on the COD and TSS removal efficiencies of the anaerobic POME wastewater. Optimization on coagulation process was performed by using Response Surface Methodology-Artificial Neural Network (RSM-ANN). The central composite design (CCD) of RSM using *Organo-floc* as the coagulant showed that at a dosage of 5.05 mg/L and stirrer speed of 75 rpm resulted in COD removal and suspended solid removal of 34.16 % and 65.67 %, respectively. On the other hand, the ANN showed that with 5.00 mg/L of *Organo-floc*, at the speed of 90 rpm, the COD removal and TSS removal were 33% and 69.38%, respectively. Further treatment on POME using SBR was also investigated. SBR's advantage is due to its simple single tank configuration and high efficiency in BOD and SS removal and cost effective treatment system for POME. Maximum COD (95 – 96 %), BOD (97 – 98 %) and TSS (98 – 99 %) removal efficiencies were achieved at optimum OLR and MLSS concentration ranges of 1.8-4.2 kg COD/m^3day and 500 – 2000 mg/L, respectively. The value of the BOD data after the completion of SBR showed a reading of 150 mg/L at day-30 and 300 NTU for turbidity. The anaerobic POME wastewater without *Organo-floc* showed a removal range between 50 – 60 % for COD, recorded a reading of 429 mg/L for BOD and turbidity of 422 NTU at day-30. The anaerobic POME wastewater, which was treated with *Organo-floc*

at optimal conditions prior to SBR, showed good removal efficiencies of TSS and COD when completed. Bacterial populations in the treated anaerobic POME were also studied through Denatured Gradient Gel Electrophoresis (DGGE) before and after the treatment of SBR. This was done for the purpose of improving reactor performance.

The microbial community analysis recovered three major phylogenies: *Firmicutes, Proteobacterium* and *Bacteroidetes*. Strains of *Rummeliibacillus suwonensis* and *Bacillus sp.* were found during the SBR treatment. *Comamonas*, *Bacillus subtilis* and *Caldanaerobius sp*. were detected at the early phase of the anaerobic POME wastewater. Uncultured *Bacteroidetes bacterium* and *Rummeliibacillus suwonensis* were found alive after the completion of SBR. The effluent quality remained stable and complied with the discharge limit regulated by EQA where the value of BOD is less than 100 mg/L, no specific standard of quality for TSS and COD but the suspended solid content have to be treated and shouldn't reach 400 mg/L. At the same time, the sludge showed good settling properties with average SVI of 65. It is envisaged that the SBR process with added *Organo-floc* could complement the anaerobic treatment to produce final treated effluent which meets the discharge limit.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

KEBERKESANAN *ORGANO-FLOK* SEBAGAI BAHAN PENGGUMPAL SEMULAJADI DALAM RAWATAN AIR BUANGAN AEROBIK SISA KILANG SAWIT

Oleh

HUSNA BT. AHMAD TAJUDDIN

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Efluen Kilang Minyak Sawit (POME), sebagai hasil pemprosesan kilang minyak sawit yang mengandungi Permintaan Oksigen Kimia (COD), Permintaan Oksigen Biokimia (BOD) dan Pepejal Terampai Organik berkepekatan tinggi. Terdapat keperluan untuk merawat POME sebelum ia boleh dilepaskan ke mana-mana sistem akua. Dalam kajian ini, prestasi alum dan *organo-flok*, iaitu bahan penggumpal semula jadi telah digunakan dalam rawatan penggumpalan POME. Objektif kajian ini adalah untuk mengkaji rawatan air POME dalam rawatan menggunakan Reaktor Kumpulan Penjujukan (SBR). Kelebihan SBR adalah kerana mempunyai ciri tangki konfigurasi individu dan nilai kecekapan tinggi dalam penyingkiran BOD dan SS serta berkesan dalam merawat POME. Kebolehrawatan SBR adalah dinilai berdasarkan pengukuran COD, BOD dan TSS. Kajian keadaan optimum penggumpal dengan menggunakan kaedah permukaan gerak balas-rangkaian neural buatan (RSM-ANN) juga telah dijalankan. Reka bentuk komposit pusat (CCD) bagi RSM dengan menggunakan *organo-flok* sebagai penggumpal menunjukkan bahawa pada dos 5.05 mg/L dengan 75 rpm kelajuan alat pengaduk, telah menyebabkan penyingkiran COD sebanyak 34.16 % dan penyingkiran pepejal sebanyak 65.67 %. Sebaliknya, penggunaan rangkaian neural buatan (ANN) menunjukkan bahawa dengan 5 mg/L *organo-flok* pada kelajuan 90 rpm, penyingkiran COD ialah sebanyak 33 % dan penyingkiran pepejal pula sebanyak 69.38 %. Hasilnya, kotoran dan jumlah pepejal terampai yang memasuki reaktor boleh dikurangkan. Rawatan lanjut pada POME menggunakan SBR juga diselidik. Nilai maksima COD (95 – 96 %), BOD (97 – 98 %) dan TSS (98 – 99 %) telah diperolehi pada nilai optima kadar kemasukan organik (OLR) dan campuran cecair pepejal terampai (MLSS) dalam bacaan 1.8 - 4.2 kg COD/m^3 hari dan 500 – 2000 mg/L masing-masing. Kesan parameter proses yang penting seperti kekeruhan, kepekatan oksigen terlarut (DO), BOD, dan COD dikaji dengan merawat POME anaerobik dengan SBR. 80 % daripada kecekapan penyingkiran COD ditunjukkan oleh pengurangan COD. Nilai data BOD menunjukkan bacaan 150 mg/L pada hari ke-30 dan 300 NTU bagi kekeruhan selepas proses SBR selesai. Air sisa

POME anaerobik tanpa *organo-flok* menunjukkan julat penyingkiran antara 50 % hingga 60 % bagi COD, mencatatkan bacaan BOD sebanyak 429 mg/L dan 422 NTU bagi kekeruhan pada hari ke-30. Air sisa POME anaerobik yang dirawat dengan organo- flok pada keadaan optimum sebelum ke SBR, menunjukkan kecekapan penyingkiran TSS dan COD yang baik apabila selesai.

Populasi bakteria dalam POME anaerobik yang dirawat turut dikaji melalui Elektroforesis Gel Kecerunan Ternyahasli (DGGE) sebelum dan selepas rawatan SBR untuk menyelidik struktur komuniti mikrob bagi tujuan meningkatkan prestasi reaktor. Analisis komuniti mikrob meliputi tiga filogeni utama: *Firmicutes, Proteobacterium* dan *Bacteroidetes*. Strain *Rummeliibacillussuwonensis* dan *Bacillus sp*. ditemui semasa rawatan SBR. *Comamonas sp* dan *Bacillus subtilis* dan *Caldanaerobius sp.* dikesan pada peringkat awal air kumbahan POME anaerobik.Tiada pengkulturan berlaku untuk *Bacteroidetes Bacterium* dan *Rummeliibacillussuwonensis* ditemui hidup selepas proses SBR selesai. Kualiti air sisa adalah stabil dan mematuhi limit pembuangan air sisa yang dikuatkuasakan oleh EQA di mana nilai BOD kurang daripada 100 mg/L, tiada standard kualiti khusus untuk TSS dan COD tetapi kandungan pepejal termendak hendaklah dirawat dan tidak melebihi daripada nilai 400 mg/L. Pada masa yang sama, enapcemar menunjukkan nilai bacaan yang baik iaitu 65 dalam unit Indeks Volum Enapcemar. Ini membayangkan bahawa SBR dengan menggunakan bahan penggumpal semulajadi organo-flok dapat merawat air sisa dan mematuhi piawaian.

ACKNOWLEDGEMENTS

بسم الله الرحمن الرحيم

All praises and thanks to Almighty Allah for giving me the opportunity to complete this work.

My deepest gratitude and sincere appreciation is owed to my supervisor **Professor Dr. Luqman Chuah Abdullah** for his invaluable guidance, continuous support and encouragement from the beginning till the end of this study. I would like to express my appreciation to Prof. Dr. Azni Idris, and Prof Dr. Thomas Choong Shean Yaw, Dr. Marcus Griffin for their great concern, valuable time and precious advices during the course of this study.

Special thanks are due to staff of Department of Chemical and Environmental Engineering, Faculty of Engineering for their help and cooperation during my experimental work. Thanks are extended to my friends and all my lab-mates in Analytical, Biochemical and Environmental Labs.

Love and thanks to my husband for his support, understanding, care and encouragement, which always strengthen me in happiness and sorrow. To my kids Galoh Adiba Sofea, Sayyid Jamadil Kubro and Galoh Salsabila Zara. To my beloved family, I would like to express my deepest affection for their never ending love and support.

Finally, thanks to the Universiti Putra Malaysia (UPM) for supporting this research.

الحمد لله

I certify that a Thesis Examination Committee has met on 14 May 2015 to conduct the final examination of Husna binti Ahmad Tajuddin on her thesis entitled "Efficiency of Organo-Floc as a Natural Coagulant in the Treatment of Palm Oil Mill Effluent" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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LIST OF ABBREVIATIONS

ABR	Anaerobic Bioreactor
ANN	Artificial Neural Networks
ANOVA	Analysis Of Variance
APHA	American Public Health Association
AS	Activated Sludge
BOD	Biochemical Oxygen Demand
CCD	Central Composite Design
COD	Chemical Oxygen Demand
CPO	Crude Palm Oil
CSTR	Continuous Stirred Tank Reactors
DGGE	Denaturant Gradient Gel Electrophoresis
DO	Dissolved Oxygen
DOE	Department Of Environment
EFB	Empty Fruit Bunch
EQA	Environmental Quality Acts
F/M	Food To Microorganism Ratio
FFB	Fresh Fruit Bunch
FISH	Fluorescent In Situ Hybridization
FNN	Feed-Forward Neural Network
g	Gram
GA	Genetic Algorithm
GAC	Granular Activated Carbon
h	Hour

HCL	Hydrochloric Acid
HRT	Hydraulic Retention Time
KDD	Knowledge Discovery In Databases
L_r	Loading Rate
MEGA	Molecular Evolutionary Genetics Analysis
mg/L	Milligram Per Litter
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
MOs	Microorganisms
NOM	Natural Organic Matter
NTU	Nephelometric Turbidity Units
O&G	Oil And Grease
OLR	Organic Loading Rate
PAC	Polyaluminum Chloride
PCR	Polymerase Chain Reaction
PCR-DGGE	Polymerase Chain Reaction-Denaturing Gradient Gel Electrophoresis
R^2	Correlation Coefficient
RMSE	Root Mean Square Error
RPM	Round per Minute
RSM	Response Surface Methodology
RSM-ANN	Response Surface Methodology – Artificial Neural Network
RT	Reacting Time
SBR	Sequencing Batch Reactor
SMP	Soluble Microbial Products

SRT	Sludge Residence Time
SS	Suspended Solids
SVI	Sludge Volume Index
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TSS	Total Suspended Solid
UASFF	Up-Flow Anaerobic Sludge Fixed-Film
VFA	Volatile Fatty Acid
VSS	Volatile Suspended Solids

CHAPTER 1

INTRODUCTION

1.1 Overview of the Study

The number of palm oil mills in Malaysia has increased tremendously. Palm oil is one of the most important agro-industries in the tropical regions, notably in Malaysia and Indonesia. Malaysia covered about 5 million hectares of the palm cultivated area with 426 operating mills in 2011 (Wang *et al.*, 2015). The Malaysian palm oil industry is growing rapidly and quickly becoming a significant agriculture-based industry in this country. Total production of crude palm oil in 2008 and 2009 were 17,734,441 and 16,044,874 tonnes, respectively (Wu *et al.*, 2010). However, associated with the production of such large amounts of crude palm oil are even larger amounts of POME. In 2008 alone, at least 44 million tonnes of POME were generated in Malaysia and the figures are expected to rise every year.

Generally, 1 tonne of crude palm oil production requires 5 - 7.5 tonnes of water; more than 50% of the water will end up as POME (Ahmad *et al.*, 2003a, 2003b). POME has been identified as one of the major sources of water pollution in Malaysia due to its high BOD and COD concentrations. Hence, the Malaysian government enacted EQA in 1978 and set parameter limits for the discharge of POME into the environment (Chan *et al.*, 2010).

Various treatment schemes have been investigated and proposed to deal with the environmental impact of POME. This includes coagulation (Ng *et al.*, 1987; Ahmad *et al.*, 2005) and a list of aerobic and anaerobic biodegradation (Oswal *et al.*, 2002; Zhang *et al.*, 2008; Faisal and Unno, 2001; Vijayaraghavan *et al.*, 2007). In POME treatment, coagulation-flocculation methods were often employed (Maisa *et al.*, 2014).

Conventional facultative lagoons and open digesting tanks are the most commonly used anaerobic processes for the treatment of POME; although these processes require relatively little operational cost and energy, they demand longer retention times often in excess of 20 days, even 60 days, and large area compared to recent developed treatment methods (Loh *et al.*, 2013; Choi *et al.*, 2013). Additionally, these conventional anaerobic digesters are difficult to collect and utilize the produced biogas, and the biogas mixture containing methane and carbon dioxide produced from open lagoons and tanks directly escaped into the atmosphere.

Anaerobic-aerobic processes using reactors in series are feasible for treating municipal and high organic strength industrial wastewaters which result in higher treatment efficiency, lower energy requirements, and less sludge production (Chan *et al.*, 2010).

In recent years, SBR has been employed as an effective technology for industrial and municipal wastewater treatment and in POME treatment process. SBR„s advantage is due to its simple single tank configuration and high efficiency in BOD and SS removal, 89 – 98 % and 85 – 97 %, respectively (Mahvi, 2008).

Microorganisms play a key role in wastewater bio-treatment processes and understanding the microbial community structure is of great importance to improve reactor performance. Moreover, start-up is an important step in establishing proper community structure in all kinds of biological treatment processes. Data of reactor performance and information of the microbes during this period is essential for revealing the correlation between contaminant removal and microbial community. According to several studies, molecular biological methods give a more accurate view of microbial communities than culture-based methods alone (Verdier *et al.*, 2014).

Anaerobic digesters often exhibit significant stability problems that may be avoided through appropriate bioprocess models and assessment of microbial communities involved in the complex process of pollutant removal. High quality microbiological information will provide an invaluable tool in the design and process control of anaerobic digestion application.

1.2 Problem Statement

Due to the increasing awareness about the toxicity of inorganic coagulants, several investigations have been done to replace/reduce inorganic coagulants with biodegradable and eco-friendly coagulants / flocculants. Pre-treatment of POME using coagulation and flocculation processes has become an important feature, in order to efficiently reduce the organic load prior to subsequent treatment processes. Aluminium sulphate (alum), an inorganic salt, is the most widely used coagulant in wastewater treatment, due to its proven performance, cost-effectiveness and availability. However, the usage of this coagulant ha been raised serious health and environment concerns. These coagulants create hazardous activated sludge which contains residual aluminium which may cause side effects when discharged into the open water course. Coagulation–flocculation treatment employing an environmental friendly coagulant could lead to improved effluent treatment as well as gaining benefits through the recovery and recycling of water to the plant with minimum treatment (Meyssami *et al.*, 2007). Natural organic coagulants have been studied as environmental friendly coagulants in recent years in water and wastewater treatment. Applying *Organo-floc* coagulant would be a reasonable alternative for the typical inorganic coagulants.

Organo-floc is a vegetable based cationic organic polymer that coagulates, flocculates and can be used as an auxiliary flocculation agent. It is a very active polymerized basic aluminum salt containing silicate, an effective polymeric mineral-bridging agent (KAM Biotechnology Ltd, 2012). *Organo-floc* neutralises charges while creating electronic bonds causing flocs to form in the water that is being treated (WaterChem Pte. Ltd, 2012). *Organo-floc* is cellulose like biopolymer of high molecular weight obtained from organic material. Characteristics of *Organo-floc* (exhibit as cationic polyelectrolytes) very attractive for flocculation and different kind of binding application. *Organo-floc* offers a broad range of applications favored by unique properties of functioning as coagulant and coagulant in one time, such as biocompatibility, biodegradation, biological activity, and non-toxicity, non-allergenic and ability for fibre and film formation. In water and wastewater treatment applications, *Organo-floc* has been used as an absorbent as well as primary coagulant or flocculent in oil industry but never applied yet in treatment of palm oil mill effluent (WaterChem Pte. Ltd, 2012). These products must be dissolved, for instance, and can therefore, be applied only within a normal range of pH. Two types of modifications are commonly adopted for the preparation of *Organo-floc* based sorbents. Cross-linking to improve its solubility and engineering properties and grafting of functional groups for enhancing the adsorption capacity and/or selectivity (WaterChem Pte. Ltd, 2012).

The classical method to optimize significant variables in the coagulation-flocculation process (one factor at a time) is an extremely time-consuming, expensive, and complicated process for a multivariable system. To overcome this difficulty, statistical experimental design techniques using the RSM and ANN are often applied. The aim of this study is to evaluate and optimize variables of the coagulation-flocculation process in wastewater in order to improve the process from the standpoint of a compromise between efficiency and operational cost prior to SBR treatment.

SBR has been proven to be a cost effective treatment system for POME (Chan *et al.*, 2010). POME possess high organic content with COD values ranging from 896 to 980 mg/L and BOD values ranging from 164 to 289 mg/L (Chin *et al.*, 2013). Nevertheless, the effluent is still unable to satisfy the discharge limit. SBR is an improved version of the activated sludge system and the sequence of its steps which occur within the same vessel: filling, aeration, settling and decantation. Its design is simple yet produces high quality effluent because the system acts as an equalization tank, reactor, as well as a clarifier. The flexibility in operation reduces costs without sacrificing effluent quality. Hence, it shows great potential to treat digested POME anaerobically.

However, very few studies have been conducted on the post-treatment of anaerobically digested POME using SBR but Chan *et al.* (2010) did a research on POME also using SBR. There was a study carried out by Fun *et al.* (2007) using a bench scale SBR to further treat the anaerobically digested effluent from an anaerobic pond. Promising results was achieved, with highest percentage removal of 62 % for TSS, and 82 % for COD at MLSS level of

2500 – 4000 mg/L and HRT as long as 3 days. Nevertheless, the effluent is still unable to satisfy the discharge limit. In fact, there is a scarcity of information on the post-treatment efficiency assessment for anaerobically digested POME utilizing aerobic processes to produce final effluent which conforms to current regulatory standards. In this study, a proposed integrated coagulation-flocculation process using organic coagulant (*Organo-floc*) with SBR was operated to treat wastewater for the simultaneous removal of COD and BOD. Poor understanding of the response of microbial communities to sudden changes in organic and hydraulic loads is one of the major reasons for the inability to prevent operational instabilities in anaerobic reactors. The effect of changes in HRT and OLR on reactor performance and its anaerobic microbial community were investigated at room temperature.

Identification of microorganisms by conventional methods requires the isolation of pure cultures followed by laborious characterization experiments. These procedures are therefore inadequate for study of the biodiversity of a natural or engineered ecosystem. A new set of molecular techniques developed during the 1990s revolutionized microbial ecology research.

The possibility of identifying specific populations of microorganisms in their native habitat / niche or environment without the need to isolate them is revolutionizing microbial ecology and giving rise to various new applications in numerous research fields.

In wastewater treatment, microbial molecular ecology techniques have been applied mainly to the study of flocs (activated sludge) and biofilms that grow in aerobic treatment systems (trickling filters) (Sanz and Kochling, 2007). These techniques include: DGGE, FISH and Cloning of 16S rDNA (Jeremiah *et al.*, 2014).

1.3 Objectives

The main objective of this study is to evaluate the performance of SBR using *Organo-floc* as an organic coagulant in the biological treatment of anaerobically digested palm oil mill effluent (POME).

Further objectives of this study are:

i. To assess the potential and effectiveness of applying natural coagulant, *Organo-floc* as a primary coagulant and flocculant, for pre-treatment of POME and to apply the optimal condition using RSM - ANN.

ii. To investigate the aerobic treatment of anaerobically digested POME by using SBR to produce better quality effluents which comply with Environmental Quality Act.

iii. To identify the bacterial community using DGGE in an operating SBR as a useful indicator for evaluating reactor performance.

1.4 Scope of the Study

The scope of this study covers evaluation of organic coagulant which is a product from oil palm extract; *Organo-floc* supplied by WaterChem Pte. Ltd. (Singapore) as an alternative for the typical coagulants in pre-treatment process prior to SBR to treat anaerobic POME using 3L lab-scale SBR and microbial characterization to investigate microbial communities that are affected during the treatment process using DGGE.

Series of batch coagulation and flocculation processes with *Organo-floc* under different conditions, i.e. dosage and mixing time were conducted in order to determine their optimum conditions. *Organo-floc* was used as coagulant aid and its optimum dose was also determined. This research evaluate the potential and effectiveness of applying *Organo-floc* as a primary coagulant for pre-treatment of POME. A batch of coagulation processes using *Organo-floc* particles under different conditions in order to determine their optimum conditions. The performance was assessed in terms of BOD, TSS and COD reductions.The quality of effluent should comply EQA where the value of BOD is less than 100 mg/L, no specific standard of quality for TSS and COD but the suspended solid content have to be treated and shouldn't reach 400 mg/L.

1.5 Significant of the Study

Wastewater treatment facility is one of the most important components in the palm oil industry. This facility is normally used to treat a large volume of POME generated during the production of CPO before the effluent is safely discharged to the surrounding environment through water canal or river.

The problems associated with treatment of POME using a pond system are long retention time (90 - 120 days), large area requirement, high demand for maintenance, loss of nutrition and high emission of greenhouse gases (methane and carbon dioxide) from these systems to the atmosphere. Anaerobic biological treatment systems need proper maintenance and monitoring as the processes rely solely on microorganisms to break down the pollutants. There are many palm oil mills, which failed to comply with the DOE standard discharge limits even though they have applied biological treatment system in their mills due to very high organic load of the POME.

Coagulation–flocculation treatment employing an environmental friendly coagulant could lead to improved effluent treatment as well as gaining benefits through the recovery and recycling of water to the plant with minimum treatment prior to SBR. Natural organic coagulants have been studied as environmental friendly coagulants in recent years in water and wastewater treatment. It was reported that the chemical coagulation is the fastest way to reduce the organic load of the pre-treatment of POME using *Organo-floc* to get an acceptable and economical level. Thereby it can be treated using conventional treatment systems. With the increased worldwide concern on environmentally friendly production processes particularly the

emission of methane, it is important to develop an alternative concept for POME treatment. Therefore, the pre-treatment of POME using coagulation and flocculation processes has become an important feature, in order to efficiently reduce the organic load prior to subsequent treatment processes. Aluminium sulphate (alum), an inorganic salt, is the most widely used coagulant in wastewater treatment, due to its proven performance, cost-effectiveness and availability. However, the usage of this coagulant has been raised serious health and environmental concerns. These coagulants create hazardous activated sludge which contains residual aluminium which may cause side effects when discharged into the open water course. Compared with common chemical coagulant, organic coagulant (*Organo-floc*) is safe and as biopolymers are biodegradable, the sludge can be efficiently degraded by microorganisms.

Scientifically, the capabilities of molecular methods to shed light on how microbial communities function will continue to expand and generate much larger quantities of key to success in achieving better design of the reactor operation and control. This study intends to fill the existing knowledge gaps whereby data of SBR performance and information of the microbes during this period is essential for revealing the correlation between contaminants removal and microbial community.

1.6 Layout of the Thesis

This research thesis is organised in five parts, and essentially , first three chapters comprised of an introduction, literature review and material and methodology. Chapter 1 delineates the background of this study as well as environmental issues associated with POME and significant of this study. Chapter 2 encompasses the current prevailing situation in Malaysia and the efficiency of *Organo-floc* as a natural coagulant in the treatment of POME using SBR. *Organo-floc*, a natural coagulant, were evaluated as coagulation treatments for POME as pre-treatment process prior to SBR treatment for its efficacy. Subsequently, different adsorbent and adsorption techniques are demonstrated with a particular focus on biomaterials or in other words adsorbents prepared from agricultural wastes in treating POME. In the third chapter, study are investigated is explained and a brief review of materials, chemicals and equipment used to treat bio-chemically POME using SBR by adding *Organo-floc* as coagulant; are discussed in a theoretical description that are used in this research.

The fourth part of this document delineates the results and discussion and further sub-grouped into Chapter 4 to keep clarity and due to a significant difference in research approaches and outcomes. Finally, Chapter 5 accomplishes the research outcomes in conclusions and recommendations for future research.

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