OPTIMIZATION OF HYBRID COAGULATION/FLOCCULATION-SAND FILTRATION SYSTEM FOR DECOLOURIZATION OF ANAEROBICALLY DIGESTED PALM OIL MILL EFFLUENT

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**FACULTY OF ENGINEERING
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ABSTRACT

The oil palm conventional biological ponding system was unable to fully decolourize the effluent due to the presence of lignin particles which are difficult to be biodegraded. The aim of this study is to propose coagulation/flocculation-depth filtration system as a pre-treatment for the decolourization of AnPOME. A non-toxic and biodegradable chemical i.e. calcium lactate was utilized as a coagulant/flocculants. During coagulation/flocculation studied, two types of condition had been conducted (i) calcium lactate as a destabilizer in a two tank system with an addition of different flocculant aids i.e. polydimethyldiallyl ammonium chloride (polyDADMAC), anionic polyacrylamide (APAM) and magnesium hydroxide. (ii) polyDADMAC as a destabilizer in a single tank system with an addition of different flocculant aids i.e. APAM, calcium lactate and magnesium hydroxide. The best combination had been identified at (i) 0.7 g/L of calcium lactate and (0.5-1.0) mg/L of APAM with ~64% of lignin removal. (ii) 8 mg/L of polyDADMAC and 6 mg/L of calcium lactate with ~68% of lignin removal. Based on removal and cost estimation studied, the combination of polyDADMAC and calcium lactate at a single tank system shown the best performance. To model and optimize the application of single tank system, an experiment was conducted using response surface methodology (RSM). Through a central composite design (CCD) method, the optimum pH, mixing speed, polyDADMAC dosage and calcium lactate dosage achieved were 6.66, 56.72 rpm, 5.27 mg/L and 2.78 mg/L, respectively. The optimum parameters had been investigated by varying the initial lignin concentration and additive, i.e. calcium chloride and ferric chloride. Different initial lignin concentration indicated different mechanism occured during coagulation/flocculation. While, calcium lactate can be used in replacement of traditional coagulants to be use with polyDADMAC. To enhance the performance of removal, the coagulated solution then was treated in a sand media. At 40 cm of sand bedheight and 767 $m^3/(d.m^2)$ loading rate, lignin achieved 71% of removal. The used of new sand shows 12% lignin removal higher compared with the use of recycled sand. The effect of different initial lignin concentration could achieved until ~90% of lignin removal. To evaluate the whole pre-treatment system, the experiment was conducted by using the real anaerobically digested palm oil mill effluent (AnPOME). At single coagulation/flocculation-sand filtration system, AnPOME achieved ~74% of colour removal. Finally, an integrated system which consisted of 2 stages of coagulation/flocculation-sand filtration and 1 stage of sand-ash-sand filtration able to treat AnPOME and achieved ~97% colour, ~90% lignin and ~74% ammonia nitrogen removal, respectively for non-filtered sample. It can be concluded that coagulation/flocculation-depth filtration system with polyDADMAC-calcium lactate as hybrid coagulants in a single tank system was suitable to be applied in a pre-treatment for the decolourization of AnPOME.

ABSTRAK

PENGOPTIMUM SISTEM HIBRID KOAGULASI/FLOKULASI-PENAPISAN PASIR UNTUK MENYAH WARNA AIR SISA KILANG MINYAK KELAPA SAWIT YANG TELAH DIHADAM SECARA ANAEROBIK

Sistem kolam konvensional yang telah digunakan secara tradisi bagi merawat air sisa daripada kilang minyak sawit tidak dapat merawat warna sepenuhnya disebabkan oleh kehadiran zarah lignin yang sukar untuk di biorosot. Kajian ini bertujuan untuk mencadangkan sistem coagulasi/flokulasi-penurasan sebagai proses pra-rawatan untuk merawat warna daripada AnPOME. Kalsium laktat yang merupakan bahan tidak toksik dan biorosot telah digunakan sebagai koagulan/flokulan. Semasa coagulasi/flokulasi, dua jenis situasi telah dijalankan (i) kalsium laktat sebagai penstabil dalam sistem dua tangki dengan penambahan flokulan yang berbeza iaitu polidiallyldimethyl ammonium klorida (polyDADMAC), polyacrylamide anionik (APAM) dan magnesium hidroksida. (ii) polyDADMAC sebagai penstabil dalam sistem tangki tunggal dengan penambahan flokulan yang berbeza iaitu APAM, kalsium laktat dan magnesium hidroksida. Gabungan terbaik telah dikenal pasti pada kombinasi (i) 0.7 g/L kalsium laktat dan 0.5-1.0 mg/L APAM dengan ~64% penyingkiran lignin. (ii) 8 mg/L polyDADMAC dan 6 mg/L kalsium laktat dengan ~68% penyingkiran lignin. Berdasarkan kajian penyingkiran dan anggaran kos, gabungan polyDADMAC dan kalsium laktat pada sistem tangki tunggal menunjukkan prestasi yang terbaik. Untuk menyeragamkan dan mengoptimumkan sistem tangki tunggal, satu eksperimen dijalankan dengan menggunakan kaedah gerak balas permukaan (RSM). Melalui kaedah reka bentuk komposit pusat (CCD), optimum awalan pH, kelajuan pencampuran, dos polyDADMAC dan dos kalsium laktat yang dicapai ialah 6.66, 56.72rpm, 5.27 mg/L dan 2.78 mg/L. Optimum parameter juga telah disiasat dengan mengubah awalan kepekatan lignin dan flokulan, iaitu kalsium klorida dan klorida ferik. Awalan kepekatan lignin yang berbeza menunjukkan mekanisme yang berbeza berlaku semasa coagulasi/flokulasi. Manakala, kalsium laktat boleh digunakan bagi menggantikan flokulan tradisional untuk digunakan bersama polyDADMAC. Untuk meningkatkan prestasi penyingkiran, larutan yang telah di coagulasi kemudian dituras dalam sebuah media pasir. Pada 40 cm ketinggian pasir dan 767 $m^3/(d.m^2)$ kadar muatan, lignin mencapai 71% penyingkiran. Penggunaan pasir baru menunjukkan 12% penyingkiran lignin yang lebih tinggi berbanding dengan penggunaan pasir yang telah dikitar semula. Kesan awalan kepekatan lignin yang berbeza telah disiasat dan penyingkiran lignin boleh dicapai sehingga ~90%. Untuk menilai keseluruhan sistem pra-rawatan, eksperimen telah dijalankan dengan menggunakan air sisa daripada kilang minyak sawit yang telah melalui proses rawatan daripada kolam anaerobik (AnPOME). Pada sistem tunggal coagulasi/flokulasi-penurasan pasir, AnPOME mencapai ~74% penyingkiran warna. Akhirnya, satu sistem bersepadu yang terdiri daripada 2 peringkat coagulasi/flokulasi-penurasan pasir dan 1 peringkat penurasan pasir-abu-pasir dapat merawat AnPOME dan mencapai penyingkiran sehingga ~97% warna, ~90% lignin dan ~74% ammonia nitrogen, bagi sampel yang tidak di tapis. Ia boleh disimpulkan bahawa sistem Koagulasi/flokulasi-penurasan dengan polyDADMAC-

kalsium laktat sebagai hibrid koagulan dalam sistem tangki tunggal sesuai untuk diaplikasikan dalam pra-rawatan untuk merawat warna daripada AnPOME.

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LIST OF ABBREVIATION

POME	-	Palm Oil Mill Effluent
AnPOME	-	Anaerobically Palm Oil Mill Effluent
COD	-	Chemical oxygen demand
BOD	-	Biological oxygen demand
NH^3-N	-	Ammonia nitrogen
LMMCC	-	Lower molecular mass coloured compounds
λ	-	Wavelength (nm)
mg/L	-	Milligram per litre
g/L	-	Gram per litre
RSM	-	Response surface methodology
CCD	-	Central composite design
DoE	-	Design of Experiment
ANOVA	-	Analysis of variance
PAM	-	Polyacrylamide
polyDADMAC	-	Polydimethyldiallyl ammonium chloride
C_p	-	Concentration of polyDADMAC
C_c	-	Concentration of calcium lactate
F	-	Filtered sample
NF	-	Non-Filtered sample

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CHAPTER 1

INTRODUCTION

1.1 Research background

In Malaysia, palm oil mill effluent (POME) is considered to be one of the dominant sources of environmental pollution. Most of palm oil mill treat their effluents with a biological treatment method which consists of anaerobic digestion followed by aerobic post treatment. Anaerobic treatment are widely accepted to be used due to its system that do not require high energy for aeration and allow the recovery of energy in the form of methane, in a closed system. However, the conventional system was reported to be inefficiency for fully decolourize the effluent discharge. In addition, the colour of anaerobically digested palm oil mill effluent (AnPOME) was reported to turn into a dark brown and contained bioflocs, anaerobic microorganisms and microfibrils. The colour of the effluent might be contributed by the residual lignin, tannin, humic acid- and fulvic acid-like substances that is unable to be degrade biologically as well as anaerobic fermentation by product such as melanoidin.

Hence, these studies suggested the treatment of AnPOME has to be followed by adequate pre-treatment methods in order to produce a standard set of discharge water that free from lignin. The treatment for the removal of lignin has been reported by several studies such as composting, adsorption, electrocoagulation and acidification/overliming treatment. The application of coagulation/flocculation and depth filtration as pre-treatment process could allowed on saving the cost of a plant size and capital cost. The used of calcium based as coagulants are believe to be very economically and have high efficiency to reduce colour contaminant from wastewater at neutral pH region. With RSM, the interaction of possible influencing parameters on treatment efficiency can be evaluated with a limited number of planned experiments. Until recently, there is no related study on coagulation/flocculation and depth filtration of AnPOME using calcium based coagulant had been conducted.

1.1.1 Aim and Objectives

The aim of this study is to propose a novel optimization of coagulation/flocculation in a single mixing tank with calcium lactate and polyDADMAC as coagulant/flocculants following sand filtration as pre-treatment for the decolourization of anaerobically treated palm oil mill effluent (AnPOME). The main objectives of these studies are:

a. To evaluate the coagulation/flocculation performance on lignin removal based on the tank system (double stirring scheme, single stirring scheme) and various strategies on coagulant/flocculants addition (metal-polymer-sedimentation; polymer-metal-sedimentation; metal-metal-sedimentation; polymer-polymer-sedimentation).

b. To model and optimise coagulation/flocculation parameters (coagulant and flocculant dosage, pH and mixing speed) for the treatment of lignin via response surface methodology (RSM).

c. To determine several parameters that effecting the depth filtration system (bedheight, loading rate, media, initial lignin concentration) and verify the coagulation/flocculation-sand filtration (without sedimentation) system by using AnPOME.

1.2 Scope Of Study

This thesis will go through seven chapters and each chapter will described on:
The scenario of the treatment system for POME in Malaysia will be described in **Chapter 1**. Following that, the performance of recent treatment system towards the water quality as well as the propose treatment that can be used to improve the treatment system. In **Chapter 2**, the lignin itself will be described based on its components especially from POME, colloidal, the adverse effect and its treatment towards a better water quality produce. In order to enhance the treatment system applied in this study, the selection of coagulation/flocculation as a pretreatment

had been justified based on several review paper from previous studies. Overview on coagulation/flocculation with different types of coagulant/flocculants was also been described in **chapter 2**. The selection types of coagulant/flocculants including varies type of polymers and calcium ions. **Chapter 2** also deals with an optimization studied by using RSM and depth filtration process to enhance the coagulation/flocculation of lignin. At the end of **Chapter 2**, there will be an outlined of the objectives of this work.

In order to achieve the objectives, **Chapter 3** explained the materials and detailed of the experimental procedures. Generally, the coagulation/flocculation process was conducted in two tank system which consists of rapid and slow mixing. **Chapter 4** will evaluated the performance of coagulation/flocculation process in two tank system and a single tank system for the removal of lignin based on several operating condition such as the type of coagulants, and cost estimation studies. In this work, the types and dosage effect of calcium lactate and polyDADMAC as coagulant and, magnesium hydroxide and APAM as flocculants towards the performance of lignin removal during coagulation/flocculation process were investigated and a detailed discussion was presented in **Chapter 4**. The performance was discussed based on the mechanism of lignin towards the coagulant/flocculants in coagulation/flocculation.

Chapter 5 present an optimization studies made by using response surface methodology (RSM) based on central composite design (CCD). An optimization was conducted to identified the interaction occur between several parameters such as the initial pH, coagulant and flocculants dosage, and mixing speed. In **Chapter 6**, a development made by adding depth filtration system into the proposed pre-treatment system of lignin removal. These studies focusing on sand and ash to be used as media in the depth filtration systems. The efficiency of the proposed pre-treatment system which consists of coagulation/flocculation-depth filtration (without sedimentation) will be evaluated by using AnPOME as a treated sample. Several parameters such as colour, lignin-tannin, ammonia nitrogen, COD and BOD will be analyzed. The paper is concluded in **Chapter 7** which summarized on the overall studies made and proposed an improvement that could be conducted in the future.