POST-TREATMENT OF PALM OIL MILL EFFLUENT USING MODIFIED SEQUENCING BATCH REACTOR AUGMENTED WITH ZEOLITE

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by

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LIST OF ABBREVIATIONS

BET	Brunauer-Emmer-Teller
BOD	Biological Oxygen Demand
CCD	Central Composite Design
CEC	Cation Exchange Capacity
cfu	Colony Forming Units
COD	Chemical Oxygen Demand
CPO	Crude Palm Oil
HDPE	High Density Polyethylene
MLVSS	Mixed liquor volatile suspended solids
MNDWQS	Malaysian National Drinking Water Quality Standards
MWW	Municipal Wastewater
NG	Not Given
Neg	Negative
POME	Palm Oil Mill Effluent
PSA	Particle Size Analyze
Rem	Removal
rpm	Round Per Minute
RSM	Response Surface Methodology

SBR	Sequencing Batch Reactor
SSA	Specific Surface Area
SEM	Scanning Electron Microscope
SERC	Science and Engineering Research Centre
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TS	Total Solids
TSS	Total Suspended Solids
UASB	Up flow Anaerobic Sludge Blanket
UNFCCC	United Nations Framework Convention on Climate Change Program
UOPM	United Oil Palm Mill
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USM	Universiti Sains Malaysia
VSS	Volatile Suspended Solids
XRF	X-Ray Fluorescence

LIST OF SYMBOLS

µm	Micrometer
nm	Nano meter
O	Oxygen
H	Hydrogen
C	Carbon
Al	Aluminum
Fe	Ferron
Ca	Calcium
C^o	Degree Celsius
L	Liter
W	Weight
N	North
E	East
g	Gram
h	Hour
ha	Hectare
Å	Angstrom
R^2	Coefficient of Determination

PASCA-OLAHAN EFLUEN KILANG KELAPA SAWIT MENGGUNAKAN REAKTOR KELOMPOK PERJUJUKAN TERUBAHSUAI DITINGKATKAN DENGAN ZEOLITE

ABSTRAK

Salah satu sistem olahan air sisa adalah penjujukan reaktor kelompok (PRK). Pasca olahan effluen kilang kelapa sawit (EKKS) dengan aplikasi air sisa bandar dan penggunaan zeolit semulajadi dalam sistem PRK aerobic terubahsuai. EKKS mengandungi kepekatan pencemar organik yang sangat tinggi, kepekatan elemen logam toksik yang rendah bersama kandungan mikrob yang rendah. Aplikasi terus air sisa bandar sebagai pembekal mikrob dan zeolite sebagai penggumpal semulajadi dalam PRK diubahsuai dijalankan bagi menghapuskan aklimitasi enapcemar bagi menjimatkan kos dan masa operasi melalui proses aerobik. Pengudaraan digunakan untuk mengadun dan sebagai sumber oksigen dalam sistem PRK. Kajian kelompok dijalankan dengan 5, 10, 15, 20, 25, 30 dan 35 g/L zeolite. 15 g/L zeolite dikenalpasti sebagai dos yang optimum. Zeolit semulajadi yang digunakan mempunyai saiz dari 75 µm to 150 µm. Kaedah Permukaan Tindak Balas (RSM) dan Rekabentuk Komposit Pusat (CCD) digunakan bagi mendapatkan keadaan operasi optimum (pembolehubah bebas) bagi nisbah air sisa bandar kepada EKKS, kadar pengudaraan dan masa sentuh. Tujuh parameter dipilih sebagai pembolehubah tanggungan (respons) iaitu Jumlah Pepejal

Terampai, Keperluan Oksigen Biologi, Keperluan Oksigen Kimia, Nitrogen Ammonia, Jumlah Nitrogen dan Jumlah Fosforus. Hasil pengumpulan data menunjukkan, kaedah rawatan tunggal mampu mengolah EKKS dalam masa yang singkat tanpa memerlukan proses aklimitasi enap cemar. Dalam keadaan optimum dengan nisbah air sisa bandar kepada EKKS (58.7 v/v,%), kadar pengudaraan (6.85 L/min) dan masa sentuh (17.9 jam) bagi PRK, keberkesanan pengurangan TSS, BOD, COD, warna, nitrogen ammonia, jumlah nitrogen dan jumlah fosforus adalah 99.16%, 90.67%, 98.4%, 84.34%, 98.33%, 96.26% dan 93.49% setiapnya. Mekanisme penyingkiran adalah melalui degradasi mikrob, penggumpalan, kapasiti penukaran kation dan penjerapan permukaan. Kesan spesifik oleh air sisa bandar melalui proses olahan mikrobiologi dengan bantuan zeolite bagi pertimbuhan mikrob dan penggumpalan bahan tidak boleh terdegradasi adalah aspek utama keberkesanan. Gabungan air sisa bandar dan EKKS ditingkatkan dengan bantuan zeolite semulajadi dalam sistem PRK terubahsuai aerobik boleh digunapakai sebagai kaedah mikrobiologi yang berkebolehan untuk rawatan EKKS dengan kos yang efektif dan dalam masa yang singkat.

POST-TREATMENT OF PALM OIL MILL EFFLUENT USING MODIFIED SEQUENCING BATCH REACTOR AUGMENTED WITH ZEOLITE

ABSTRACT

One of the biological treatment system for wastewater treatment is sequencing batch reactor (SBR). Post-treatment of palm oil mill effluent by direct application of municipal wastewater and augmentation of natural zeolite in aerobic modified SBR system. POME contain extremely high concentration of organic pollutants, very low concentration of toxic metallic elements, and low microbial content. Direct application of municipal wastewater as microbial supply and zeolite as natural coagulant in modified aerobic sequencing batch reactor (SBR) conducted in order to decreasing operation time and cost of operation process through the aerobic treatment. Aeration used for mixing and oxygen source in SBR system. Batch study carried out with 5, 10, 15, 20, 25, 30, and 35 g/L zeolite. 15g/L zeolite collected as optimum adsorbent dosage. The size of natural zeolite ranged from 75 µm to 150 µm. Response Surface Methodology (RSM) and Central Composite Design (CCD) were used for collecting the optimum operating conditions (independent variables) which were ratio of municipal wastewater (MWW) to POME, aeration flow and contact time. Seven parameters namely total suspended solids (TSS), biological oxygen demand (BOD_5), chemical oxygen demand (COD), ammonia nitrogen (NH_3-N), total nitrogen and total phosphorus selected as dependent parameters (responses). Collected results indicates that this single

treatment method has capability for effective POME treatment in short time without requiring to sludge acclimatization process. In the optimum condition of municipal wastewater to POME ratio (58.7 v/v; %), aeration rate (6.85 L/min) and contact time (17.9h) for the SBR, efficiency of the reduction for TSS, BOD, COD, colour, ammonia nitrogen, total nitrogen and phosphorus were 99.16%, 90.67%, 98.4%, 84.34%, 98.33%, 96.26% and 93.49% respectively. Mechanism of removal mostly were microbial biodegradation, coagulation, cation exchangeable capacity, and surface adsorbent. Specific effect of municipal wastewater through the microbiological treatment process and assistance influence of zeolite for microbial growth and non-degradable maters coagulation are main aspects of efficiency. Combining municipal wastewater with POME and augmenting with natural zeolite in aerobic modified SBR system, could be considered as a capable microbiological method for POME in cost effective and short time treatment.

CHAPTER ONE

INTRODUCTION

1.1 Overview

Nowadays, oil palm production in Malaysia reached to 20,000,000 tons (MPOB, 2016). Activities of 426 mills, production and by products have a positive effect on the Malaysian economy. Other side of this industry is environmental impacts of palm oil industry which means 60,000,000 tons effluent being a major concern for Malaysia as the leader of scientific researches in green improvement. Due to aforementioned facts, the palm oil industry as main agroindustry; faces a big challenge in balancing the economic viability, environmental protection and sustainable development. Thus, there is an urgent need to finding a suitable way to keep our economy growth while preserving the environment (Chin et al., 2013).

The conventional treatment method for palm oil mill effluent is ponding system which is an easy operation, time consuming process in several ponds or digesting system, with high cost operation in a big land area and environmental impacts (Mansor et al., 2017). On the other hand, this method is highly dependent to land application and rivers as final destination of effluent discharge. Unfortunately, inability of this anaerobic-aerobic method in passing discharge standards (Bhatia et al., 2007) has led to concerning on numerous scientific researches on high efficiency, cost effective, easy operation and short time treatment methods. Ponding system which has been applied in 85% of oil palm industry is the most common commercial treatment method (Poh and Chong 2009) while the remaining 15% are operated by

using tank digestion system. Finding effective treatment method for Palm Oil Mill Effluent (POME) will be more serious when Malaysian authorities aim to strengthen standard limits to BOD_5 equals to 20 mg/L (Liew et al., 2015) .

Anaerobic digestion of POME in covered ponds which known as methane production process, have positive attraction on environmental footprint by decreasing the greenhouse gas emission and methane gas collection despite the, expensive construction, high maintenance fee, operation, high land requirement caused to slow improving trend in this traditional treatment system. This method is based on the microbial activity in anaerobic circumstances on organic matter in aquatic nutrient media for methane production. Raw POME is an acidic media with temperature of 80-90 ^{o}C (Chin et al., 2013) will caused low content of microbial population. Long period of time is required for available microbial population to adapt and starting digestion process. However, low biodegradability of lignin compounds (Oswal et al., 2002), makes the digestion process longer as well as decreasing in pollutant removal efficiency and methane production. Further studies should be conducted to develop innovative methods to reduce the cost of treatment and increase treated water quality (Mansor et al., 2017).

1.2 Problem Statement

Biological treatment could be a high effective treatment method for wastewater with high biodegradability index and low concentration of non-biodegradable compound such as lignin (Pérez et al., 2002). Approximately 50 % of POME pollutants are low or non-biodegradable organic matters which should be separate from fine, easily degradable organic compound such as fatty acids by suitable coagulation mechanism (Ahmad et al., 2005a). Efficiency of pollutant removal can

be improved using aerobic sequencing batch reactor (SBR) (Wang and Li, 2009). Augmentation of municipal wastewater is an advanced treatment technique for enhancing the efficiency of pollutant removal in strength wastewaters and often have been used in landfill leachate (Mojiri et al., 2014, Aziz et al., 2011b). Activated sludge recognized as one of the most effective aerobic treatment meanwhile, it is the least applied by oil palm mills since of its higher operation cost (Chan et al., 2010). In a SBR system sludge acclimatization is necessary for microorganisms adaptation to new condition, and it takes 10 days when treating landfill leachate (Aziz et al., 2011b). On the other hand, high concentration of ammonia nitrogen is another factor cause low efficiency of SBR treatment and high concentration of ammonia nitrogen which is very toxic for microorganisms population and gradually could be protected by sludge acclimatization process (Aziz et al., 2011b). Since POME has nontoxic properties (Rupani et al., 2010) and contain very low concentration or absence of hazardous heavy metals such as Pb and Cu (Agustin et al., 2008), Cd and Cr (Ubani et al., 2017).

The knowledge of natural adsorbent (zeolite) application in SBR for POME treatment contain some gaps and need more development. Literature indicate that single pollutant removal such as oil (Shavandi et al., 2012a) and heavy metal (Shavandi et al., 2012b) have been studied in POME which the main pollutants are BOD_5, COD, TSS and color (Liew et al., 2015).

Since of two major types of pollutants (biodegradable and capable for coagulation) in POME a new finding is needed to present direct application of municipal wastewater as microbial community supplier and natural adsorbent as coagulation and microbial biofilm formation is required as a novel combined microbiological treatment method for POME in aerobic SBR system.