DEGRADATION OF PALM OIL MILL SECONDARY EFFLUENT (POMSE) USING BIOSTRUCTURE

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Perpustakaan Sultanah Zanariah,
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Sir,

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DEGRADATION OF PALM OIL MILL SECONDARY EFFLUENT (POMSE)
USING BIOSTRUCTURE
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Thank You

Sincerely yours,

……………………………….

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Faculty of Civil Engineering,
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013-7467722

Specially dedicated to my beloved Ummi and Baba:

Hajjah Siti Zainab Idris and Allahyarham Haji Abd Wahid Nok,

For your everlasting love and support…

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ABSTRACT

Biostructure treatment is one of the latest biotechnology applications in environmental engineering. In this study, the biostructure treatment was used to treat the palm oil mill secondary effluent (POMSE). Biostructure is comprised of cement, aggregates, sand, zeolite, lightweight aggregates, granular activated carbon (GAC), water and microorganisms. In this study, biofilm was developed to increase the biostructure's performance. Seven types of microbes were used consist of microbe A, B, C, S_1, S_2, ADL_1 and ADL_2, which were isolated from textile wastewater, Sg Segget and fermented food. The microorganisms grew on the surface of the biostructure in the form of biofilm and degrade the waste, hence treating the POMSE. The three reactors that were used to treat POMSE in this study comprised of reactor A (10 biostructures), reactor B (5 biostructures) and reactor C (without biostructure) that acted as a control. Results obtained showed that 10 biostructures in the 5-liter batch reactor gave the average removal of colour of 51%, COD of 42%, TOC of 42% and SS of 80% in 4 days HRT, whereas 5 biostructures able to remove 48% colour, 37% COD, 35% TOC and 70% SS. The results showed that the efficiencies of the biostructure treatment depend on the surface area of biostructures and the retention time. More biostructures resulted in higher degradation of POMSE. From the survivability test, only three out of seven microbes developed at the early stage of biofilm development survived at the end of the experiments, namely microbe A, B and ADL_1. It can be concluded that biostructure treatment is a viable polishing treatment of POMSE before being discharged into the river.

ABSTRAK

Biostruktur adalah salah satu aplikasi bioteknologi terkini dalam kejuruteraan alam sekitar. Di dalam kajian ini, biostruktur telah digunakan untuk merawat air sisa sekunder dari kilang kelapa sawit. Biostruktur dihasilkan daripada campuran simen, aggregat, pasir, zeolite, aggregat ringan, karbon teraktif, air dan campuran mikroorganisma. Dalam kajian ini, biofilem telah dibentuk bagi meningkatkan keberkesanan biostruktur. Tujuh jenis mikrob telah digunakan iaitu mikrob A, B, C, S_1, S_2, ADL_1 dan ADL_2, yang telah dipencilkan dari air sisa tekstil, Sungai Segget dan sumber makanan tertapai. Mikroorganisma hidup pada permukaan biostruktur dalam bentuk biofilem dan mendegradasi, seterusnya merawat airsisa tersebut. Tiga reaktor telah digunakan dalam kajian ini iaitu reaktor A (10 biostruktur), reaktor B (5 biostruktur) dan reaktor C (tanpa biostruktur) sebagai kawalan. Keputusan ujikaji mendapati bahawa 10 biostruktur di dalam 5 liter sampel telah menghasilkan peratus pengurangan sehingga 51% penyahwarnaan, 42% COD, 42% TOC dan 80% pepejal terampai dalam 4 hari masa tahanan, manakala 5 biostruktur mampu mengurangkan 48% warna, 37% COD, 35% TOC dan 70% pepejal terampai dalam tempoh masa yang sama. Keputusan menunjukkan bahawa keberkesanan biostruktur adalah bergantung kepada luas permukaannya dan masa tahanan. Lebih banyak biostruktur yang digunakan memberikan lebih kemampuan degradasi terhadap airsisa tersebut. Daripada ujian kebolehupayaan, hanya tiga daripada tujuh mikrob yang dibentuk sebagai biofilem pada peringkat awal berupaya hidup sehingga ke akhir eksperimen, iaitu mikrob A, B dan ADL_1. Dapat disimpulkan bahawa biostruktur berupaya menjadi salah satu teknik rawatan air sisa sekunder kilang kelapa sawit sebelum dilepaskan ke sungai.

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LIST OF ABBREVIATIONS/ TERMS

ADMI	American Dye Manufacturer Institute
APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
EQA	Environmental Quality Act
FFB	Fresh Fruit Brunch
GAC	Granular Activated Carbon
HRT	Hydraulic Retention Time
POME	Palm Oil Mill Effluent
POMSE	Palm Oil Mill Secondary Effluent
SS	Suspended Solid
TOC	Total Organic Carbon

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CHAPTER I

INTRODUCTION

1.1 Introduction

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

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

As the production of palm oil increased, more palm oil mill effluent (POME) is generated annually. Currently about 3.0 million hectares of land are under palm oil cultivation with 300 palm oil mills processing the fresh fruit bunches of palm. The total annual quantity of wastewater generated is estimated to be $1.8\times10^6 m^3$

(Ahmad *et al.*, 2003). This situation contributed to more study on the technology of treatment of the POME, due to the large amount of water needed for palm oil mill extraction and the discharge of partially treated effluent into public watercourses.

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

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

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

1.2 Problem Statement

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

Recently, various treatment processes have been designed to encounter the problem issued from POME. Biological treatment is the commonly used method as POME has high organic content which can be degraded by microorganisms (Kon, 2006). However, the application of biological processes is normally incapable of complying with the standard requirements set by the regulator (Ooi, 2006). In addition, the treated POME is still coloured and contains high concentration of non-biodegradable organics which requires further treatment.

In this study, biostructure treatment technology was used as a polishing treatment for palm oil mill secondary effluent (POMSE). This technology involved the application of selected microorganisms to improve the quality of the effluent. biostructure was formulated through a stringent process of mixing the precise amount of cement, sand small aggregates and environmental friendly microorganisms (Azhar, 2006). This method is one of the latest microbial technologies used in environmental engineering.

1.3 Aim and Objectives of Study

The aim of this study was to develop an economical polishing treatment of POMSE that fulfills the standard in the regulation. The objectives of the study were:

i. To investigate the feasibility of biostructure in degradation of POMSE;

ii. To determine the effects of the gross surface area of biostructure in the treatment process; and

iii. To determine the role of the bioaugmented bacteria and their survivability on the biostructure.

1.4 Scope of Study

This study comprises of a series of laboratory scale experiment. POMSE from a palm oil mill in Kulai, Johor was used. This study covered:

i. Development of biostructure at laboratory scale using the basic component of concrete with the addition of zeolite, lightweight aggregates and granular activated carbon (GAC);

ii. Development of biofilm on the biostructure surface:

iii. Three laboratory scale reactors were developed for the treatment of POMSE; and

iv. Sampling and analysis of colour, COD, total organic carbon (TOC), suspended solid (SS) and viable count of bacteria.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The industry of palm oil is facing serious challenges to meet the environmental regulations stated by government. Besides earning a high profit, palm oil processing mills discharge a large amount of effluent (Ahmad *et al.*, 2005). Without proper treatment, this wastewater will pollute the watercourses.

Palm oil mill effluent contains 'lignocellulosic' wastes with a spectrum of carbohydrates, a range of nitrogenous compounds, free organic acids and an assembly of minor organic and mineral constituents (Marttinen *et al.*, 2003). Released into rivers without treatment, this viscous brown sludge would choke aquatic life and pollute water supplies.

2.2 Palm Oil Industry Background

In the early 1970s, Malaysia's economic development was based on the agricultural sector. Large areas of forest were converted into oil palm estates. By the end 1980s, the oil palm estate covered one third of the country's cultivated area.

As a result of expansion in oil palm based industry, during 1975-1985, crude palm oil production rose from 1.3 million tones to 4.1 million tones making it the country second largest earner of foreign exchange by 1984 (ESCAP, 2005). Figure 2.1 shows the processes involved in palm oil industry.

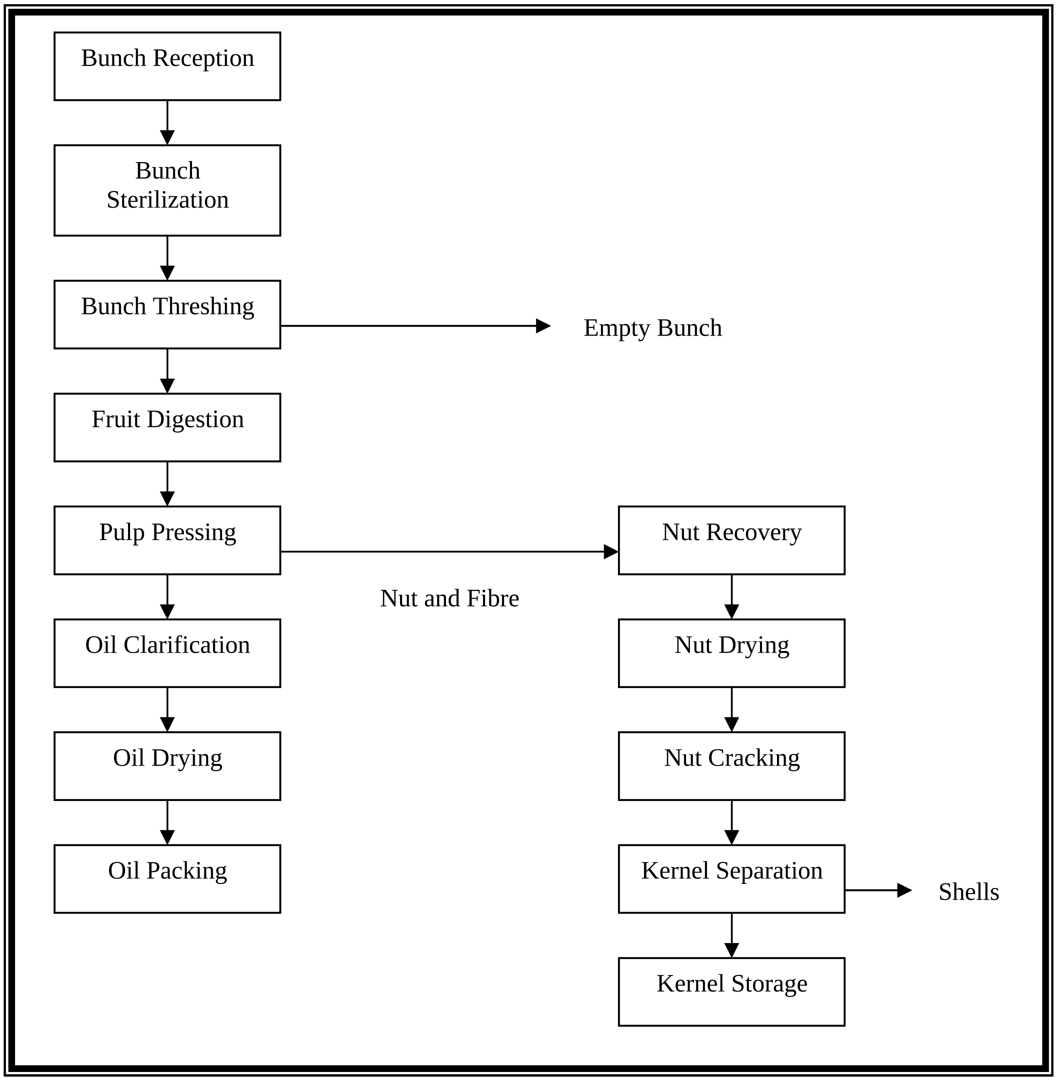

Figure 2.1: Process of Palm Oil Industry (FAO Corporate Document Repository, 2004).

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

In 2004, more than 40 million tonnes of POME was generated from 372 mills in Malaysia (Hassan *et al.*, 2004). In order to prevent pollution from this effluent, POME has to be treated to fulfill a few characteristics as which have been stated by Department of Environment Malaysia. The respective standard for discharge limit is shown in Table 2.1.

Table 2.1: Standard Discharge Limit by the Department of Environment Malaysia (DOE)

Parameters	**Limits**
BOD_3, (mg/L)	100
Suspended solids (mg/L)	400
Oil and grease (mg/L)	50
Ammonical nitrogen (mg/L)	150
Total nitrogen (mg/L)	200
pH	5.0 – 9.0
Temperature (C)	45

2.3 Palm Oil Mill Effluent Characteristics

The raw POME has extremely high content of degradable organic matter, which is due in part to the presence of unrecovered palm oil. Fresh POME is a colloidal suspension containing 95-96% water, 0.6-0.7% oil and 2-4% suspended solids that are mainly debris from palm fruit mesocarp generated from three sources which are sterilizer condensate, separator sludge and hydrocyclone (Ahmad *et al.*, 2005). The general characteristics of raw POME are shown in Table 2.2.

Table 2.2: General Characteristics of Raw POME (Hassan *et al*., 2004)

Parameter	POME
pH	3.4 - 5.2
Biochemical oxygen demand (BOD)	10,250 – 43,750
Chemical oxygen demand (COD)	15,000 – 100,000
Suspended solids	5,000 – 54,000
Ammonical nitrogen	4 - 80
Total nitrogen	180 – 1,400
Oil and grease	150 – 18,000

*all unit in mg/L except for pH.

2.4 Technology of Palm Oil Mill Effluent Treatment

Recently, various treatment processes have been designed to encounter the problem issued from the POME. The Malaysian palm oil industry has applied various effluent treatment technology which are anaerobic and facultative ponds, tank digestion and mechanical aeration, tank digestion and facultative ponds, decanter and facultative ponds and physico-chemical and biological treatment (Krishnan *et al.*, 2006).

2.4.1 Pre treatment of Palm Oil Mill Effluent

According to Ahmad *et al.*, (2003), flocculation, extraction, adsorption and membrane separation can remove suspended solid and residual oil from POME effectively. In this case, membrane separation was applied to remove any residual suspended solids and oil remaining after the pretreatments. The treatment efficiency of the processes was measured as percentage removal of suspended solids and oil respectively. For flocculation, the optimum performance was achieved using 4,000 $mgdm^{-3}$ of alum and mixer speed of 150 rpm for one hour. At these conditions, the turbidity was decreased from 14,080 NTU to 983 NTU. It was found that the solvent extraction process gave a 95% reduction in residual oil as compared with 88% obtained using the adsorption process. From the findings, it showed that membrane separation technology is a better treatment technology in terms of water recovery and its recycling (Ahmad *et al*., 2003).

Bhatia, (2006), had covered the suitability of the coagulation–flocculation process using *Moringa oleifera* seeds after oil extraction as a natural and environmentally friendly coagulant for POME treatment. The performance of *Moringa oleifera* coagulant was studied along with the flocculant in removal of SS, organic components and increasement of the floc size.

The optimum values of the operating parameters obtained from the laboratory jar test were applied in a pilot-scale treatment plant. Pilot-scale pretreatment resulted to 99.7% suspended solids removal, 71.5% COD reduction, 68.2% BOD reduction, 100% oil and grease removal and 91% TKN removal.

2.4.2 Aeration System

Aeration is one of the effluent treatment processes where water and air were in contact with one another to supply dissolved oxygen (DO) to the microorganisms. Hui, (2005), had conducted a study based on the different method of aeration in POME treatment. For this study, three types of aeration system were used which are Diffused Air (DA), Oxygen Enriched Air (OEA) and Pure Oxygen (PO). The oxygen purity for PO is 100%, OEA about 35% and followed by DA 20.9%. The findings showed that the higher purity oxygen, the DO in POME will increase. The PO aeration able to remove 88.1% of BOD, followed by OEA 63.7% and DA 62.9% BOD removal (Hui, 2005).

2.4.3 Aerobic and Anaerobic Treatment

Modified Upflow Anaerobic Sludge Blanket (UASB) using modulated palm fibre as a fixed bed is an alternative way to treat POME. A study was conducted to determine the organic and nutrient removal convincing fixed bed reactor and upflow design (Jini, 2006). The variables tested were concentration of COD, phosphorus, ammoniacal nitrogen, and reduction of TSS and VSS. From the results, it showed that shorter anaerobic period was appropriate for ammonia removal due to nitrification process, while COD and PO_4 removal was significantly removed under longer period and larger dilution factor. The most relevant organic reduction rate was at 4 hours HRT.

According to Zinatizadeh *et al.*, (2005), anaerobic treatment is the most suitable method for the treatment of effluents containing high concentration of organic carbon. Anaerobic treatment using up-flow anaerobic sludge fixed film (UASFF) reactor shows the good result which can reduce 95% of COD at an average organic loading rate (OLR) of 15 g COD/L/day. COD removal of 96% was obtained at an OLR of 10.6 g COD/L/day with hydraulic retention time (HRT) of 4 days.

According to the study done by Vijayaraghavan *et al.*, (2006), treatment of POME was investigated using aerobic oxidation based on an activated sludge process. The efficiency of the activated sludge process was evaluated by treating digested and diluted raw POME anaerobically. As a result, it showed that at the end of 36 hours of HRT, the highest COD removal efficiency was 83%, whereas at 24 hours HRT, the percentage removal of COD was 57%.

2.4.4 Membrane Treatment System

Membrane technology is viewed to be more beneficial in treating POME. There are many membrane process applications in water and wastewater treatment that have been proven to be efficient. Membrane technology covers a large spectrum