TREATMENT OF FOOD PROCESSING INDUSTRIAL WASTEWATER USING TWO STAGES ANAEROBIC SYSTEM

MUHAMMAD SHAHRUL SHAFENDY BIN IBRAHIM

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To my beloved parents, family, siblings and fellow friends. All of you will be always in my heart. Thank you so much for the care and support given

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ABSTRACT

The wastewater produced by food manufacturing industry is known for its high concentration of COD and suspended solid. In wastewater treatment, anaerobic process is favorable due to its low cost, biogas production, low sludge production and more. In this study, upflow anaerobic sludge bed (UASB) and hybrid-UASB (HUASB) reactors, were combined with anaerobic filter (AF) bioreactors forming two stages system to treat food processing industry wastewater. This study was focused on the performance of UASB-AF (R1) and HUASB-AF (R2) treatment systems and the granules development. Seed sludge was deposited into HUASB column up to a third of the height. Palm oil shells were then packed into the HUASB (above seed sludge) as well as AF reactors to promote growth of microorganisms. The R1 and R2 systems were operated simultaneously, fed with raw food manufacturing wastewater taken from Azhar Food Manufacturing Factory. Parameters measured to evaluate the performance of the process were pH, COD, NH_3-N, oil and grease and total phosphorus. The highest average COD removal efficiency, at 99%, were detected in R1 and R2 systems, both at OLR 10.56 g COD/L.d. Moreover, the presence of aggregated bio particles with diameter ranges from 2.934 to 5.00 mm were observed in both UASB and HUASB reactors. The highest percentage of 2.934 to 5.00 mm diameter granules were 7.6 % and 10.7% in the UASB and HUASB respectively. In addition, the highest removal rate coefficient, k values for UASB and HUASB were 2.1981 and 3.3950, occurred at OLR 8.59 and 10.56 g COD/L.d, respectively. Overall, the k values have proved that HUASB reactor had performed better than UASB reactor.

ABSTRAK

Air sisa yang dihasilkan oleh industri pembuatan makanan terkenal dengan kandungan COD dan pepejal terampai yang tinggi. Dalam rawatan air sisa, proses anaerobik selalu digunakan kerana kos yang rendah, pengeluaran biogas, pengeluaran enapcemar yang rendah dan lain-lain. Dalam kajian ini, aliran ke atas katil enapcemar anaerobik (UASB), dan hibrid-UASB (HUASB) telah digabungkan dengan penapis anaerobik (AF) bioreaktor menjadi sistem dua fasa untuk merawat air sisa pemprosesan makanan di industri. Kajian ini memberi tumpuan kepada prestasi sistem rawatan UASB-AF (R1) dan HUASB-AF (R2) serta pembesaran granul. Benih mikrob dalam bentuk enapcemar dimasukkan ke dalam bahagian bawah reaktor HUASB sehingga sepertiga ketinggian. Cengkerang kelapa sawit pula diletakkan ke dalam HUASB (bahagian atas) dan AF reaktor untuk menggalakkan pertumbuhan mikroorganisma. Sistem R1 dan R2 beroperasi pada masa yang sama, dipam dengan air sisa pemprosesan makanan yang diambil dari Azhar Food Manufacturing Factory. Parameter yang diukur untuk menilai prestasi proses adalah pH, COD, NH_3-N, minyak dan gris dan jumlah fosforus. Purata tertinggi kecekapan penyingkiran COD, dengan 99 %, telah dikesan di sistem R1 dan R2, kedua-dua pada OLR 10.56 g COD/L.d. Selain itu, kehadiran granul bio agregat dengan diameter antara 2.934-5.000 mm ditemui dalam UASB dan HUASB reaktor. Peratusan tertinggi kumpulan granul berdiameter 2.934-5.000 mm dalam UASB dan HUASB adalah 7.6% dan 10.7 % masing-masingnya . Di samping itu, nilai pekali penyingkiran k tertinggi untuk UASB dan HUASB adalah 2.1981 dan 3.3950, berlaku pada OLR 8.59 dan 10.56 g COD/L.d masing-masingnya. Secara keseluruhan, daripada nilai k membuktikan bahawa reaktor HUASB adalah lebih baik daripada reaktor UASB.

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LIST OF ABBREVATIONS

APHA	-	American Public Health Association
USEPA	-	US Environmental Protection Agency
UASB	-	Upflow Anaerobic Sludge Blanket
HUASB	-	Hybrid-UASB
AF	-	Anaerobic Filter
OLR	-	Organic Loading Rate
HRT	-	Hydraulic Retention Time
Q	-	Flow rate
POS	-	Palm Oil Shells
COD	-	Chemical Oxygen Demand
SS	-	Suspended solids
TSS	-	Total Suspended solids
VSS	-	Volatile suspended solid
SVI	-	Sludge volume index
SMA		Specific methanogenic activity
TP	-	Total Phosphorus
$N\text{-}NH_3$	-	Ammonia-Nitrogen
O&G	-	Oil and grease
SO_4^{2-}	-	Sulphate
CH_4	-	Methane
mg	-	milligram
L	-	Liter
%	-	Percentage
mL	-	Milliliter
mm	-	Millimeter
SEM	-	Scanning Electron Micrograph

VFA	-	Volatile fatty acid
LCFA	-	Long chain fatty acid
ECP	-	Extracellular polymer

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Water is important to all living things in this world. 70.9% of the Earth's surface is covered with water. The ocean holds about 97% of surface water, the glaciers and polar ice caps holds 2.4%, while the other 0.6% of water in this world can be found at lakes, rivers and ponds. Unfortunately, the water quality has deteriorated from time to time due to human's daily routines. Making matter worse is the production of wastewater discharged by domestic residences, commercial properties, industry and agriculture that cover a broad range of potential contaminants and concentrations.

Malaysia now is a major exporter of electronic and machinery, petroleum, textiles, clothing and footwear, palm oil and wood products (Zain *et al.*, 2004). The industrial processes inevitably results in uncontrollable and high production of wastewater which if not treated properly will contaminate the environment. There are many factories contributing to industrial wastewaters such as metal industry, complex organic chemicals industry, and food industry. Industrial wastewaters are considerably diverse in their nature, toxicity and treatability, and normally require pre-treatment before being discharged to sewer. Food processing in particular is very dissimilar to other types of industrial wastewater, being readily degradable and largely free from toxicity. However, it usually has high concentrations of biological oxygen demand (BOD) and suspended solid (Gray, 1999).

Compared to other industrial sectors, the food industry uses a much greater amount of water for each ton of product (Mavrov *et al.*, 2000). One of a well-known food industry, chips industry, is also getting bigger in Malaysia throughout the years.

The most commonly used raw material in chip manufacturing industry is tapioca. Tapioca is produced from treated and dried cassava (manioc) root. Tapioca can also be used for starch-processing plants and production of pellets and chips (Chavalparit *et al.*, 2009). The process for chips or any other food processing plants normally use immense volume of water, yielding large amounts of wastewater that must be treated. Excessive water use and wastewater production results in economic and environmental burdens to the industry. The usage of water for clean-up in food processing plants flushes loose meat, blood, soluble proteins, inorganic particles, and other food waste to the drain. The wastewater produced could be treated and recycled to the process (Chen *et al.*, 1999).

The social and economic requirement for low-cost, low-technology wastewater treatment technologies has stimulated study of more advanced level wastewater treatment, including the development of new reactor designs and operating conditions (McHugh *et al.*, 2003). One of the well-known treatment methods in treating industry wastewaters is the anaerobic treatment (Moawad *et al.*, 2009). Anaerobic process has been used for the treatment of concentrated domestic and industrial wastewater for well over century. Anaerobic treatment of wastewater can be traced from the beginning of wastewater treatment itself in the form of septic tank treatment process (Seghezo *et al.*, 1998).

The interest on anaerobic systems as the main biological step (secondary treatment) in wastewater treatment was kind of inadequate, until the establishment of upflow anaerobic sludge blanket (UASB) reactor in the early 70s though a similar system called the 'biolytic tank' had been previously used in the 1910 by Winslow and Phelps (1911). Now the UASB reactor is broadly used for the treatment of several types of wastewater (Seghezo *et al.*, 1998). Other than UASB, anaerobic filter (AF) technology is also another system that applies the concept of anaerobic digestion process. AF technology has become established as a high rate process for treating industrial wastewater (Wang *et al.*, 2006). Being inspired from the UASB and AF bioreactors, the hybrid-UASB, or also known as HUASB has become popular in anaerobic bioreactor section (Oktem *et al.*, 2007). HUASB has been successfully applied as part of the treatment system in palm oil mill effluent (Habeeb *et al.*, 2011), dairy wastewater (Banu et al, 2007) and many other high strength wastewaters.

There are times where wastewater treatment would make use of support media to enhance the efficiency. Activated carbons are widely known support media that exhibits high surface area and opened pore that allows adsorption of contaminants (Haji *et al.*, 2013). However, activated carbon usually increases the cost of treatment process. This drawback has stimulated more research to utilize agricultural by-products and wastes to be used as support media (Al-Qodah and Shawabkah, 2009). One of the most acknowledged agricultural industry in Malaysia is the palm oil industry. Fibre, shell, decanter cake and empty fruit bunch makes up for 30%, 6%, 3% and 28.5% of the fresh fruit bunch respectively (Rupani *et al.*, 2010). Previous studies showed that the surface area of the resulting activated carbon prepared from the palm oil shells (POS) on a pilot plant scale without any chemical activator was 950 m^2/g (Hussein *et al.*, 1996). It was also mentioned that raw materials of palm oil shell contain high carbon and low ash (Hamad *et al.*, 2010).

1.2 Problem Statement

The food manufacturing wastewater contains high concentrations of several organic compounds including carbohydrates, starches, proteins, vitamins, pectines and sugars which are accountable for high chemical oxygen demand (COD) and suspended solids (Kobya *et al.*, 2006). The wastewater resulted from a series of processes (cleaning, cutting, slicing, washing, frying, salting, coating and packing) is one of the significant source in environmental pollution. The produced wastewater streamed with different levels of pollution load (low, medium and high contamination) are normally collected and treated in an on-site installation or in a municipal sewage treatment plant (Mavrov *et al.*, 2000). However, it is believed that more efficient treatment is required to assure the wastewater released are in compliant with the Environment Regulation 2009 (Industrial Effluent).

Nowadays, there are various treatments that can be applied to treat the industrial wastewater. The commonly preferred treatment is anaerobic treatment due to its low cost and high effectiveness. Some of the well-established anaerobic bioreactors are UASB, HUASB and AF bioreactors. Although UASB, HUASB and AF reactors are able to treat the wastewater effectively on their own, there are still flaws and disadvantages that needed to be overcome. Some of the drawbacks of UASB, HUASB and AF reactors are the slow start-up period and instability of performance. To improve on this shortcoming, studies on two stage anaerobic treatments are diligently investigated to improve on the efficiency and start-up period of the anaerobic treatment.

Ke and Fang (2005) stated that two stage anaerobic treatment is a reliable treatment system with variety of reactor designs available and can be modified or upgraded to achieve increased stability and greater efficiencies than single stage systems. Excellent performance of two stage anaerobic system had been observed in researches by Stamatelatou *et al.,* (2012), Nidal *et al.* (2003), and many more. Halalsheh *et al.* (2010) especially had done a research on two stage treatment system comprised of UASB and AF reactors in treatment of concentrated sewage which shows great efficiency, stability, and shorter start-up period. On the other hand, this study had applied the UASB-AF and HUASB-AF two stage anaerobic treatment systems to study their performance in treating food industry wastewater.

1.3 Objective of the Study

The objectives of this study are:

a) To investigate the performance of individual UASB, HUASB and AF as well as combinations of UASB-AF and HUASB-AF
b) To characterize and study the development of sludge granulation in UASB and HUASB reactors
c) To determine the removal rate constant, k of the organic pollutants in UASB and HUASB reactors.

1.4 Scope of Study

The research focuses on the laboratory scale of anaerobic treatment on food industry wastewater using UASB-AF and HUASB-AF treatment systems. The food industry wastewater was taken from the Azhar Food Manufacturing Sdn. Bhd., Food Beverage. The performance of UASB-AF and HUASB-AF were studied based on the efficiency

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