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Tackling colour issue of anaerobically-treated palm oil mill effluent using membrane technology

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ABSTRACT

In this work, the performances of membranes with different properties were evaluated for their capabilities in treating anaerobically-treated palm oil mill effluent (AT-POME). Unlike raw POME, AT-POME is the effluent that has been biologically treated to reduce mainly the organic compounds present in the effluent. The treated effluent however still demonstrates brownish by the time it is discharged to receiving water bodies. The samples treated by membranes were assessed with respect to two colour parameters, i.e. absorbance at 370 nm wavelength and ADMI value. Other parameters also considered were total organic carbon (TOC) and total nitrogen (TN). Results showed that nanofiltration membrane (NF270) always demonstrated greater colour removal efficiencies in comparison to ultrafiltration membranes (UF 10 kDa and UF 30kDa). The NF270 membrane achieved 97.4–97.9% colour removal compared to 72.4–75.4% and 48.1–50.5% shown by UF 10 kDa and UF 30 kDa, respectively. Further sample quality analyses revealed that NF membrane could achieve higher TOC and TN removal than those of UF membranes. Although NF membrane demonstrated excellent separation, its performance was compromised by low water flux (6.58 L/m^2 h at 10 bar). Since the treated effluent is not targeted for reuse, employing UF 10 kDa membrane with reasonably good rejection rate coupled high water flux (9.66 L/m^2 h at 5 bar) is considered good enough to meet the discharged requirements. Further investigations have shown that UF 10 kDa membrane is less susceptible to fouling when it is operated at low pressure and for the fouled membrane, chemical cleaning could be employed to retrieve water flux.

1. Introduction

Palm oil industry in Malaysia that occupies 77 percent of total local agricultural land is the biggest contributor to the rural economic [1]. According to an industry report, the world demand for crude palm oil (CPO) in 2011/12 contributed 28.2 percent to the world's total oil and fats production [2]. Other statistic revealed that Malaysia and Indonesia are the two biggest producers of CPO in the world with total production capacity recorded at 47.6 million tonnes in 2013 [3].

However, a large amount of water is required for palm oil milling which typically consumes 5–7.5 tonnes of water for each ton of CPO produced [4]. According to Wah et al. [5], 1.4×10^6 m^3 of fresh water that consumed for 9.85×10^5 tonne of CPO production in May 2001 have discharged approximately 7.39×10^5 m^3 effluent. To ensure the effluent can be safely discharged to receiving water bodies, industries in generally employ biological treatment process to reduce effluent's biological oxygen demand (BOD) and chemical oxygen demand (COD) value. However, the major drawback of conventional biological process for palm oil mill effluent (POME) treatment is the insignificant reduction of colour in which the treated POME still demonstrates brownish by the time the treated effluent is discharged. The presence of lignin and its degraded products such as tannin and humic acids that derived from crushed palm nut, lipids and fatty acids during the extraction process is the main

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Table 1
Characteristics of AT-POME.

Parameter	Average value
pH	8.22
Colour (ABS374)	4.55
Colour (ADMI)	2040
Total nitrogen (TN)	104.4 ppm
Total organic carbon (TOC)	758 ppm
Turbidity	1.62 NTU
Odour	Not detected

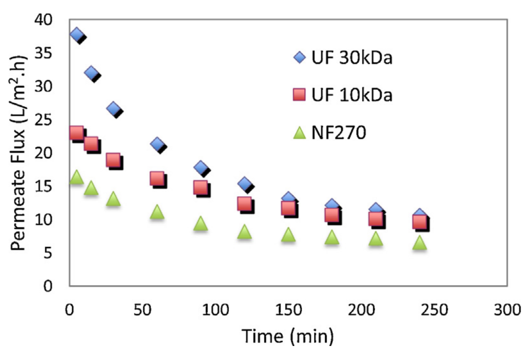

Fig. 1. Permeate flux of membrane in treating AT-POME (Operating pressure: UF membranes (5 bar) and NF membrane (10 bar)).

reason causing the effluent to display colour [6]. The existence of lignin and tannin is due to the degradation of lignocellulosic compounds.

Although the treated POME released to the watercourses has been biologically treated and could consistently meet the local discharged standard of COD and BOD, public is still concerned on the large amount of brownish treated POME discharged to the watercourses. According to the Department of Environment of Malaysia, the discharge control for POME is only restricted on BOD, suspended solids, oil and grease, ammoniacal-nitrogen, total nitrogen, pH and temperature. Previous relevant research works are mainly focused on the efficiency on BOD and COD reduction on particular treatment process [7–9]. As the living standard among the public increases, the demand on clean water also increases. This has caused the public began to raise their concerns regarding the anaerobically-treated POME (AT-POME) brownish nature. In the past, research works have focused mainly on the efficiency of a treatment process in reducing COD and BOD value of POME. Works reporting reduction of colour intensity of POME in particular AT-POME are rarely found.

A literature search revealed that evaporation, adsorption and advanced oxidation process have been previously attempted to remove colour from POME. However, these techniques are associated with respective drawbacks. For instance, evaporation method requires high-energy usage to recover water from treated effluent, even though it can produce solid residual that can be used as fertilizers [10]. The efficiency of adsorption on the other hand varies depending on the type and property of adsorbent used. It has been previously reported that the reduction of colour can be as high as 100 % using palm kernel shell at solution of pH 2 [11]. However, the cost of producing this kind of activated carbon is not cheap. Natural clay – montmorillonite was also used as adsorbent in reducing colour of POME, but its adsorption rate tends to reduce significantly with operation period following saturation [12–13].

Ozonation technique proposed by Facta et al. [14] requires high power to completely eliminate the colour. Advanced oxidation process such as ozonation and Fenton-like process had been studied for reducing BOD, COD and colour of treated POME. The dosage of ozonation however will contribute to environmental issue owing to

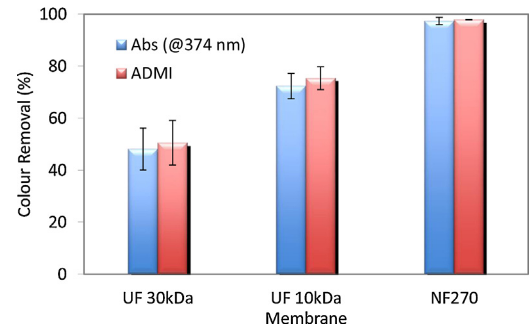

Fig. 2. The efficiencies of UF and NF membranes in reducing colour intensity of AT-POME.

the reactive oxygen species that present in the POME while Fenton-like process which uses iron oxide as catalyst requires additional unit operator to separate the heterogeneous catalyst from the final treated effluent.

As a comparison, membrane separation provides a promising and simple approach to treating the wastewater based on molecular size. Ultrafiltration (UF) membrane had been previously utilized in the POME treatment to remove organic compounds. However, the usage of membrane had been restricted by the serious fouling issue resulted from high suspended solid contents in the POME. Therefore, in order to mitigate fouling issue, it is more practical to use membrane to remove colour after the suspended solids had been removed by other pre-treatment process. The efficiency of membrane technology in particular nanofiltration (NF) in removing colour has been proven in many industries. NF membrane has been used to treat textile wastewater containing dye compounds ranging from 200 to 1000 g/mol [15–16]. In most of the cases reported, it is found that NF membrane could easily achieve complete elimination of nano-sized dye compounds, producing permeate of high quality [5]. Hence, the presence of humic acid, tannin and lignin with molecular weight of 200–1000 g/mol is very likey to be separated by membrane technology. The main objective of this work is to study the performances of three commercial membranes ranging from tight UF (30 kDa and 10 kDa) to typical thin film composite (TFC) NF membrane in removing colour of AT-POME. Other parameters also considered in this work are total organic carbon (TOC) and total nitrogen (TN) removal efficiency. It is also the aim of this work to study the effect of operating pressure and cleaning process on the performances of membrane that is used in AT-POME treatment process.

2. Experimental

2.1. Effluent sampling

The AT-POME sample was collected from PPNJ Palm Oil Mill Kahang, Johor, Malaysia and was stored in a refrigerator at 4 °C prior to use. The collected sample was then analysed with respect to colour, TN, TOC, turbidity, odour and pH and the results are summarized in Table 1. All tests were conducted following the standard method—colour (wavelength at 374 nm and ADMI method), TN (APHA 4500), TOC (APHA 5310B) and turbidity (using HACH portable turbidimeter). Since there is no yet a standard established for determining the colour of AT-POME, two commonly used colour parameters for wastewater quality characterization are thus considered in this study.