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Performance of Membrane Bioreactor in Palm Oil Mill Effluent Treatment: An Overview

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ABSTRACT

Malaysia is amongst the biggest palm oil manufacturer and exporter in the world associated with the high discharge of effluents. Membrane bioreactor (MBR) can be employed to treat the palm oil mill effluent (POME). However, data on MBR in treating POME is quite limited and could vary across different reported works. Thus, this study aims to provide some latest updates on the MBR technology in treating the POME. Based on the evaluation, separation of POME by using MBR can produce a good quality of effluent compared to conventional POME treatment. Mixed liquor suspended solids removal for a retention time of 11 days can be improved from 57.3% to 94.5 % using the MBR. According to analyses, when the MBR operating temperature falls into thermophilic region, the separation efficiency will start to decrease. Optimization of the MBR performance based on the operating temperature could be suggested in enhancing the overall MBR performance in treating POME.

Keywords: Membrane, POME, temperature, solid retention time, bioreactor

1.0 INTRODUCTION

In a developing country like Malaysia, a huge amount of industrial effluents containing a high amount of contaminants could bring harms to both human and environment [1]. Different methods have been used to treat the effluents such as membrane separation, gas flotation, biological treatment and coagulation. Membrane filtration is getting more attention due to several advantages such as high selectivity, economical and effective operation [2].

Membrane bioreactor (MBR) technology is one of the membrane filtration method that is widely used in wastewater treatment. MBR can be generally divided into submerged

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MBR or external MBR systems. MBR uses selective membrane either at the secondary or tertiary stage of the wastewater treatment to separate suspended solids to produce pollutant free effluent. MBRs composed of two primary parts, which are a biological unit (represented by activated sludge tank containing microbes and aeration system) and membrane module (containing membrane filtration system and pumping utilities) (Figure 1). In the biological part, mixed microbial consortium is normally employed in reducing organic load and biodegradation of POME. The microbial strains may consist of *Micrococcus luteus* 101PB, *Stenotrophomonas maltophilia* 102PB, *Bacillus cereus* 103PB, *Providencia vermicola* 104PB, *Klebsiella pneumoniae* 105PB, *Bacillus subtilis* 106PB, *Aspergillus fumigatus* 107PF, *Aspergillus nomius* 108PF, *Aspergillus niger* 109PF, and *Meyerozyma guilliermondii* 110PF [3]. From the membrane module part, MBR can produce an effluent free of bacteria and viruses [4]. Although MBR has many advantages such as small footprint requirement, high removal efficiency and dense sludge production. However, membrane fouling is amongst the most challenging problems for MBR in palm oil industries [5]. Membrane fouling can lead to a reduction in permeate flux, thus, requiring frequent physical and chemical cleanings. Frequent cleaning involving cleaning agents could easily reduce the membrane lifespan and overall efficiency.

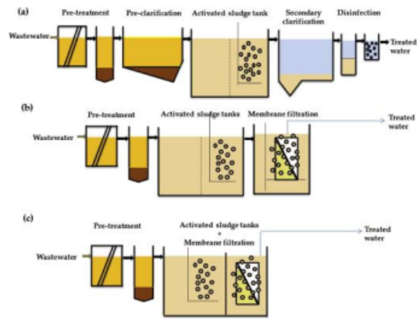

Figure 1 (a) conventional wastewater treatment process, (b) Side stream MBR (c) submerged MBR [3]

The efficiency of MBR highly depends on operating condition such as solution pH, hydraulic retention time (HRT), temperature, sludge retention time (SRT) and transmembrane pressure [6–7]. The general advantages and disadvantages of MBR that could potentially be used to enhance the POME treatment are tabulated in Table 1 [4], [8].

Table 1 General Advantages and Disadvantages of MBR [3], [7]

Advantages	Disadvantages
• Remove solid effectively and produce good quality effluent • Easily operates and maintains • Prevent bacterial infection • Does not require sedimentation and post-treatment	• High capital cost • High utilities cost • Requires frequent cleaning • Longer SRT

2.0 PERFORMANCE OF MBR

2.1 Performance of MBR in POME Treatment

POME is naturally acidic, which might cause damages to the polymeric membrane materials [9]. Thus, selection of suitable membrane material is crucial in ensuring the stability of the MBR system in a wider range of pH. Air floatation method can increase the condition of the POME by reducing the COD, TSS, turbidity, MLSS, MLVSS and fats/oil content before it is discharged. However, a long retention time is needed to bring the pH value back to the acceptable wastewater discharge range. The slow change in the pH value might be due to the presence of volatile fatty acid in the liquid [10]. MBR appears to be useful in POME treatment to remove the fatty acid while reducing the retention time.

Figure 2 shows the differences in pH values of the POME after treatment by using flotation method only and a combination of flotation and membrane treatment. Results show that the pH values for the POME treated by flotation method only are lower than the POME treated by the combination of flotation and membrane filtration. POME after flotation treatment still contains higher number of fatty acids, which explains the lower pH values compared to POME after treated with flotation and membrane filtration. The discharge of low pH POME might cause damages to the aquatic lives if it is not properly treated. Increasing the air flow rate in flotation treatment can slightly increase the pH value of the POME. However, when the flotation treatment was integrated with microfiltration, the solution pH was greatly enhanced from pH 5 to pH 6, which showed the effective removal of fatty acids from the POME by the microfiltration membrane.

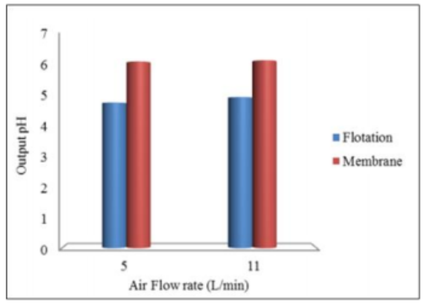

Figure 2 pH of POME after flotation without and with MBR [10]

Table 2 represents the removal efficiency based on five different indicators (chemical oxygen demand, total suspended solids, mixed liquor suspended solids, mixed liquor volatile suspended solids and fats/oil content). It was reported that the removal of the more volatile fatty acid from the POME could be enhanced at higher retention time. Additionally, higher removal also can be obtained by combining both flotation and membrane filtration. However, some important parameters such as the sizes of the bubbles, effect of fluctuations in the feed POME, and sludge removal rates were not detailed in the previous studies. Future works focusing on these parameters could be beneficial for an enhanced POME treatment.

Table 2 Removal Efficiency of Waste Parameters with and without the MBR for 5 and 11 Days of Retention Time [9], [10]

Retention time (Day)	**5**		**11**	
Removal Percentage (%)	Flotation Stage	Flotation with MBR	Flotation Stage	Flotation with MBR
COD (%)	26.8	97.1	35.5	97.0
TSS (%)	35.5	98.0	86.4	93.9
Turbidity (%)	48.2	99.8	57.7	99.8
MLSS (%)	58.8	90.2	57.3	94.5
MLVSS (%)	59.9	92.4	59.7	96.1
Fats/Oils (%)	38.8	99.5	52.6	99.9

2.2 Performance of MBR based on the Operating Temperature

Theoretically, higher temperature will give a higher rate of reaction. However, the operating temperature could be optimized to produce the most optimum performance in MBR.

Table 3 shows 6 sets of data having 30 or 50 days of solid retention time (SRT) at different operating temperature. Set 1, 2, 4 and 5 have the same raw POME properties, same retention times but different operating temperature. Results suggest that there could be an optimum temperature for the removal of COD. However, the optimum operating condition is not determined in that work. In these 4 sets of data, 3 experimental runs were conducted at mesophilic temperature ranged from 20 to 45 °C while another experimental run was conducted at a thermophilic temperature (46 to 55 °C). At the mesophilic temperature range, the COD removal efficiency for Set 4 was the highest at 93.39 % owing to the increase in the rate of reaction. For Set 1 and 2 which were at lower temperature, the microbial growth rate and reaction rate were lowered, leading to reduced removal of fatty acids and COD from the POME [11].

Set 5 at thermophilic temperature failed to produce the best COD removal efficiency even at the highest temperature. This observation can be explained by the high thermophilic temperature that might denature the microbes, slowing down the digestion of fatty acids in POME and resulted in lower separation efficiency [12]. However, this postulation was not supported by any of the existing works.

Table 3 Performance of Hybrid Anaerobic Bioreactors Operated under Different Temperatures and SRT

Set	1	2	3	4	5	6
Temperature, ◦C	25	35	35	45	55	55
SRT, days	30	30	50	30	30	50
Hydraulic retention time (HRT), days	12.5	12.5	7	12.5	12.5	7
Raw POME pH Value	4.21	4.21	6.46	4.21	4.21	6.46
Feed POME COD, mg/L	85858	85858	31600	85858	85858	33600
Removal efficiency of COD, %	65.59	69.91	99.15	93.39	79.23	92.95
Reference	[8]	[8]	[10]	[8]	[8]	[10]

3.0 CONCLUSION

MBR showed high efficiency in treating the palm oil mill effluent. Based on the previous studies, raw POME treated by only air flotation was not sufficient in meeting the discharge quality requirement. Integration of MBR with flotation treatment showed good performance in reducing the COD, TSS, turbidity, MLSS, MLVSS, and oil/grease content. Mesophilic temperature range for MBR at around 20 to 45 °C were shown to be effective in enhancing the performance of the MBR.

Nevertheless, if the temperature was increased up to the thermophilic region, the separation started to decrease. Possible explanation for the reduction in the MBR performance was due to the microbes in membrane bioreactor that was denatured at the high operating temperature.

There are also some recommendations for future study.

1. The SRT data used in the previous studies are quite limited. SRT is an important parameter in determining the retention of activated sludge in carrying out the biodegradation process. Partial removal of the sludge also could be suggested as part of the effort in determining the most ideal operating condition.
2. Data collection can be extended to the industrial-based MBR in palm oil mill. Currently, the data available is limited to a few of the published works. Some MBR systems in palm oil mills have been in operation for many years. However, the data from those MBR systems is not utilized in any of the published works.
3. Future direction for the MBR studies may focus on the optimization of controllable parameters from the industrial perspective, such as SRT, HRT, flotation bubble size and flowrate. In addition, anaerobic MBR systems are also showing good progress from recent works, which may be integrated for POME treatment while producing biogas for electricity supply in the near future [13–15].

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