POME have high biochemical oxygen demand (BOD), chemical oxygen demand (COD), oil and grease, total solids as well as suspended solids (SS) (Ma,1995). Discharging of POME into the water body may lead to severe pollution and might affect ecosystem of the water body as the POME with high COD and BOD value will deplete dissolved oxygen that can dissolve into the water. Consequently, fish and other aquatic organisms might die due to the depletion of dissolved oxygen in the water body (Madaki & Seng, 2013). There are various methods that have been developed by palm oil mill in Malaysia and applied to treat POME such as biological treatment (Rahim & Raj, 1982) and evaporation technology (Ma, 1995). Today, approximately 85% of POME treatment is based on conventional biological treatment methods of acidification, anaerobic, facultative, and aerobic degradation (Zhang et al., 2008). However, the conventional system which based on biological treatment often required long retention time, proper maintainance, and leads to environmental pollution issues (Ahmad & Chan, 2009). Although evaporation of POME can recovered up to 85% of water as distillate and the solid concentrate accumulated from process can be utilized as feed material for fertilizer manufacturing (Ma, 2000), the operating cost for evaporaton treatment is very high as the evaporation process consumed a great number of energy. Thus, the palm oil industry in Malaysia still stay struggling with the POME issue.

Membrane technology appears to be one of the high potential solution for wastewater treatment, attributed to its great advantages such as wide applicability, invariable quality of produced water, efficient, economical, and easy automation (Ahmad et al., 2009). The applications of membrane technology in general and reverse osmosis (RO) in particular for wastewater treatment include beverage industry (Tay & Jeyaseelan, 1995), tanneries wastewaters (Fababuj-Roger et al., 2007),chromium tanning processes (Cassano et al., 1997), and greasy wastewater (Cassano et al., 1999). In recent decades, the idea of water recycling and reusing has received increasing attentions, owing to the global concerns on the ever increasing water demand, whether it’s human consumption, agricultural application, or industrial use (Cicek, 2003).

Instead of discharging the industrial effluents into the streams, the effluents can be treated using membrane and reuse as the feed for boiler of factory. Boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat (Odigure et al., 2005). Most of the palm oil mill processing factories require large volumes of steam for continuous supply into the production line. The most pressing aspect of concerned is the boiler must be fed with the water of excellent quality in order to maintain high efficiency of its operation. Typically, boiler feed is supplied with fresh water which could result in high operation cost, particularly in the countries where the fresh water tariff is high. The alternative of reusing the treated POME wastewater that has been treated and purified by membranes would eventually help to reduce the total water consumptions and the quantity of wastewater discharge (Mavrov & Bélières, 2000).

The use of membrane technology in treating and recycling the wastewater has been demonstrated by a number of researchers. Masson and Deans (1996) developed a scheme for reusing secondary treated effluent. Under the scheme, secondary treated effluent from sewage treatment plant was treated by membrane filtration coupled with chemical treatment with the aim of producing boiler feed water to a power station in Australia. The use of RO membrane was proven to have largely reduced the chemical consumption due to the capability of RO membrane to remove the dissolved solids. Cuda et al. (2006) investigated the selection of wastewater treatment processes and reported that RO was better in treating large capacities of water with a higher level of total dissolved solids (TDS), compared to ion exchange process. Another successful experiences in producing boiler feed water using microfiltration (MF) followed by RO membrane from industrial wastewater, river water, and sweet wastewater was demonstrated by Nooijen et al. (1998).

For the secondary wastewater effluent from palm oil mill, it is expected that the integrated system combining the sand filter and activated carbon filter pretreatment and membrane technology should be able to improve the water quality to the level that can be recycle back as boiler feedwater or for other uses. Thus, the intend of this study is to test the feasibility of the pilot scale integrated system combining the sand filter and activated carbon filter (SF+AC) pretreatment coupled with nanofiltration(NF)/(RO) membranes.

2. MATERIALS AND METHODS

2.1 Chemicals and membranes

All of the chemicals used were analytical grade, unless stated otherwise. PhosVer 3 phosphate reagent, DPD total chlorine reagent, Nessler reagent, polyvinyl alcohol dispersing agent, mineral stabilizer, EGTA solution, EDTA solution, calcium and magnesium indicator, and alkali solution for calcium and magnesium test were purchased from Hach Company (Colorado, USA). Two types of spiral wound commercial membrane module, NF270-4040 and BW30-4040 purchased from Dow Filmtec, USA were used in this study. The specifications of the membranes used are illustrated in Table 1.

Table 1 Properties of NF270-4040 and BW30-4040 membranes used in the study

Membrane	Membrane Material	Stabilized Salt Rejection (%)	Maximum Operating Pressure	pH Range, Continuous Operation[a]	Maximum Operating Temperature[a]
NF270-4040	Polyamide thin-film composite	> 97.0	600 psi (41 bar)	2 - 11	113 ^{o}F (45 ^{o}C)
BW30-4040	Polyamide thin-film composite	99.5	600 psi (41 bar)	2 - 11	113 ^{o}F (45 ^{o}C)

[a] Maximum temperature for continuous operation above pH 10 is 95 ºF (35 ºC).

2.2 Membrane characterization

2.2.1 Field Emission Scanning Electron Microscope (FESEM) analysis

The cross-sectional of the commercial spiral wound membrane modules (BW30-4040 and NF270-4040) were probed using FESEM (SUPRA 35 VP, Carl Zeiss Inc.). The membranes were immersed into liquid nitrogen (N_2), cryogenically fractured and mounted vertically on the sample stud by using double sided Scotch tape to avoid the develop of static charge. A K 550 sputter coater was used to coat the outer surface of the membrane samples with a thin layer of gold (~ 20 nm thickness) under vacuum to provide electrical conductivity and to prevent the surface from being charged up.

2.3 Preparation of feed solution

The feed solution used for the experiment was collected from first aerobic digester pool after the closed anaerobic digester system at East Mill Sime Darby Palm Oil Plantation at Carey Island, Selangor, Malaysia. The collected aerobic POME was preserved in the cold room at temperature below 4°C, but above the freezing point, immediately after sampling to prevent the POME from undergoing microbial biodegradation.

During the membrane filtration treatment, the collected aerobic POME was diluted to around 150 mg/L COD value to imitate the biofilm treated POME in our previous study prior subjected to the pilot plant membrane filtration system for further treatment. The typical characteristics of diluted aerobic POME are summarized in Table 2.

Table 2 Typical characteristics of diluted aerobic POME

Parameter	Diluted aerobic POME
BOD (mg/L)	1500.00
COD (mg/L)	1486.67
TSS (mg/L)	385.00
TDS (mg/L)	2400.00
Colour (PtCo)	8263.33
Phosphorus (mg/L)	72.17
Turbidity (NTU)	283.67
Conductivity (mg/L)	4896.67
pH	7.61