Available online at www.derpharmachemica.com

Scholars Research Library

Der Pharma Chemica, 2013, 5(3):190-196
(http://derpharmachemica.com/archive.html)

ISSN 0975-413X
CODEN (USA): PCHHAX

Removal of phenol during ultrafiltration of Palm oil mill effluent (POME): Effect of pH, ionic strength, pressure and temperature

Muhammad Said, Akil Ahmad and Abdul Wahab Mohammad*

Department of Chemical and Process Engineering, Faculty of Engineering & Built Environment,
University Kebangsaan Malaysia, Bangi, Selangor, Malaysia

ABSTRACT

In this work, the effect of pH, ionic strength, pressure and temperature on phenol removal from POME using an ultrafiltration (UF) membrane were studied. Characterization of PES membrane and PES saturated with phenol were done on the basis of FT-IR and SEM analysis. The optimum pH for phenol removal was found to be 3.15 up to 88% with ionic strength 0.1M using NaCl. The addition of ionic strength increase the binding effect among particle and hydrophobicity character of particles, leading an accumulation of phenol on the surface and finally lead to the formation of a thick cake layer therefore significant phenol removal were achieved. Maximum phenol removal was achieved at pressure 2 bar and temperature 50 ˚C up to 97.8 and 99.8%, respectively. The overall results showed that the PES membrane managed to remove significantly phenol content from raw POME solution.

Keywords: PES membrane, pH, Ionic strength, Phenol, Palm oil mill effluent

---

INTRODUCTION

Palm oil industry is growing rapidly and has become a very important agriculture-based industry in many countries such as Malaysia and Indonesia. However, wet process of palm oil milling consumes a large amount of process water. It is estimated that for 1 tonne of crude palm oil produced, 5-7.5 tonnes of water are required, and more than 50% of the water will end up as palm oil mill effluent (POME) [1]. Various studies on the treatment of POME have been reported and have been thoroughly reviewed recently. One particular aspect that has not been widely investigated is on the removal of phenol and phenolic compounds from POME. This study is focusing specifically on the use of ultrafiltration (UF) membrane for secondary treatment of POME and its effect on removal of phenol and phenolic compounds.

Phenol and phenolic compounds are usually derived from the pulp and paper industry, wood preservation, mining and coal combustion, and also palm oil [2]. Phenol has long been known as a dangerous organic pollutant because it is harmful to organisms, even at a low concentration. Phenol is very soluble in water, oil, carbon disulphide and a variety of phenolic compounds [3]. For humans, phenol has a toxic effect that can spread rapidly by absorption through the skin and eyes. Inside the human body, phenol damages the function of the liver, kidneys, lungs, and vascular system. Due to the negative effects, the presence of phenol must be removed.

Several conventional treatments of phenol and phenolic compound removal that are usually used to remove phenol, such as distillation, adsorption, evaporation and oxidation, still do not give satisfactory results, not only due to the large cost of material and energy but also as a result of generating hazardous by-products. Other than physico-chemical processes, biological treatment processes have also been applied in the removal of phenol. Membrane technology has been used to remove the phenol compounds, whether it is stand-alone or in combination with other technologies such as adsorption [4], photocatalytic processes [5], enzymatic reaction in the dead-end and cross-flow filtration[6, 7] and membrane bioreactor (MBR) [8].

Limkhuansuwan and Chaiprasert, [9] have carried out research using fermentative lactic acid bacteria to reduce colour of molasses and palm oil mill effluent phenolic compounds. The results showed the percentage of phenol content and colour removed by 34% and 15.88%, respectively. Although it achieves the high value of reduction but it also has the drawback i.e. fears the accumulation of high levels of phenol in the body of microorganisms, excess phenol can inhibit the growth of microorganisms, and it is required a long time for acclimatization.

Ko and Chen [10] investigated the effect of the addition of Laccase on the Polyethersulphone (PES) and Polysulphone (Psf) membrane with varied amounts of MWCO on the removal of three phenols (Guaiacol, Catechol, and m-cresol). The addition of Laccase enhanced the phenols removal. A smaller membrane pore size had higher removal efficiency than a larger pore size. The existence of Laccase increased the molecular weight of the three phenols.

Susanto, et.al [11] used PES membranes and Cellulose membranes to treat the synthetic wastewater contains polyphenolic compounds from green tea. A significant reduction was achieved in accordance with the effect of membrane properties and the feed solution. The results were supported by the data of surface hydrophilicity, charge, and chemistry.

Fractionation and concentration of lignin from Kraft black liquor has been investigated by Walberg et al. [12]. Three membranes with different cut-offs were used. The results showed that the retention of lignin was 80% for 4kDa MWCO. The highest lignin concentration was 190g/l where 78% of total dry matter was lignin.

The objective of this study was to further understand the behaviour of POME filtration in UF membrane in terms of phenol removal. PES membrane with MWCO of 25kDa was used in the study. Various parameters (effect of pH, ionic strength, pressure and temperature) were carried out to check the phenol removal. The findings of this study may be used to elucidate the mechanism and performance of UF membranes as a secondary pre-treatment prior to nanofiltration or reverse osmosis processes.

MATERIALS AND METHODS

POME samples were derived from the final pond of West Palm Oil Mill, Carey Island, Klang, Malaysia. Characterisations were conducted to determine the content of Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), colour, turbidity, and Phenol levels by using a Hach DR/2010 spectrophotometer. The average value is taken from three repeated experiments. Detailed composition and features of the waste water are summarised in Table 2. The reduction in the solution parameters was calculated by the following equation:

$$C\,(\%) = \left(\left(1 - \frac{Cp}{Cs}\right) x\ 100 \qquad (1)$$

where C_p is the concentration in the permeate solution, and C_s is the concentration in the feed sample.

A PES membrane with MWCO of 25kDa was purchased from Sterlitech Corporation. All membranes had a diameter of 76mm with an active area of 28.7cm^2. Before starting the experiment, the membrane was soaked for 12 hours in ultrapure water. Then, the membrane was rinsed and compacted for 30 min at pressure of 3 bars. The pure water fluxes were determined at different pressures (0.5-2.5 Bar). The membrane was put at the bottom of the stirrer cell. The stirred cell (Amicon 8200, Millipore.co, USA) had a single blade stirrer and was also equipped with an acrylic solution reservoir of 1000ml. The solution reservoir was connected to a nitrogen line at various pressures, and the pressure at the permeate side was at atmospheric.

The samples were prepared before pouring into the stirrer cell. The pH was adjusted by adding of HCl (0.1M) and NaOH (0.1M), and NaCl powder was used for the ionic strength. The experiment was done by pouring 200mL of POME-enriched solution into the Ultrafiltration Amicon 8200. The volume of permeated samples was collected within 240 min.

RESULTS AND DISCUSSION

1.1. Characterization of membrane

The FT-IR analysis of PES membrane and PES with phenol is shown in Fig. 1 a and b. According to FT-IR spectra of PES membrane, the band peaks at 3408 cm-1, 2925 cm-1, 1578 cm-1, 1485 cm-1, 1256 cm-1 and 1108 cm-1 correspond to the stretching frequencies of OH (H2O), -CH, aromatic bands of PES membrane, C-O-C and symmetric vibration of SO2 groups. The intensity of the peak at 1475 cm−1, attributed to C–S vibration. From the figure 1b, a sharp peak appears in the range 3395 cm-1 which indicates that the membrane surface contained phenolic group (O-H group). It confirms the presence of phenol at the surface of PES membrane.

Table 1. Characteristic of Raw POME in final pond from local palm oil mill factory

Parameter	Feed sample
COD (mg/L)	**12,040**
TSS (mg/L)	**3103**
Colour (PtCo)	**54,200**
Turbidity (NTU)	**23,750**
pH	**7.43**

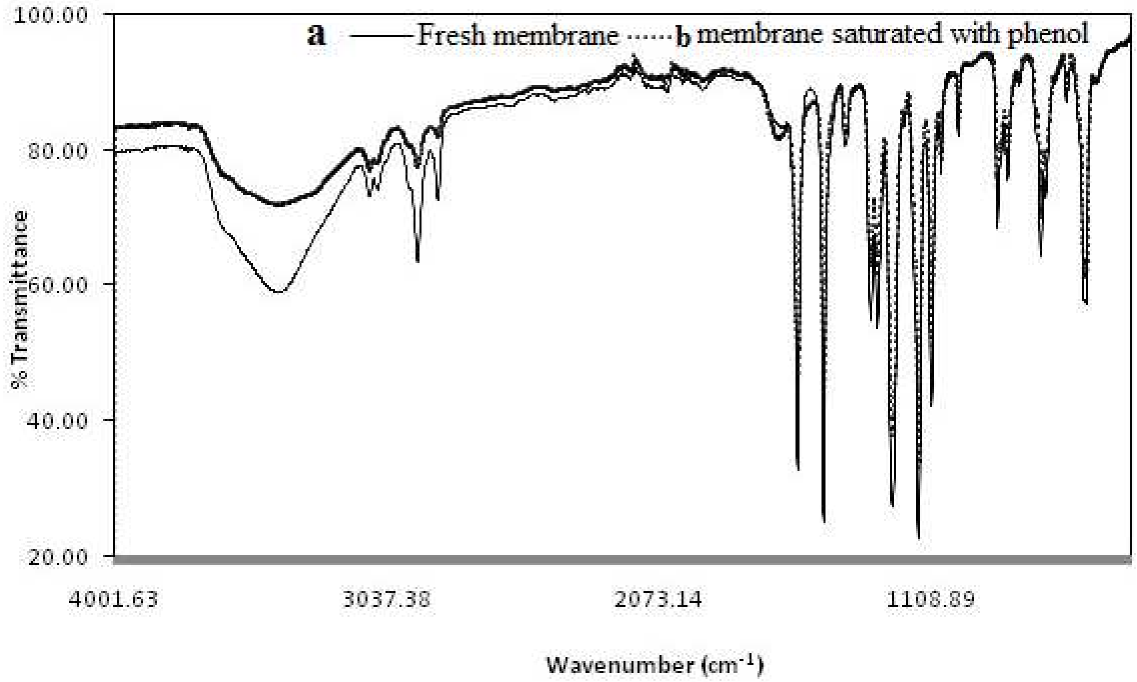

Figure 1a. FT-IR spectra of fresh and b) membrane saturated with phenol

Scanning Electron Microscopy (SEM) can be used to investigate the morphology of the membrane surfaces. SEM images show the surface morphology of fresh and phenol adsorbed on PES membrane (Figure 2a and b). SEM images of PES membrane and PES with phenol shows that entire membrane surface seemed to be covered by phenol molecules. Therefore, the “actual” surface morphology during filtration would be more significantly different with the original PES membrane. High resolution SEM images clearly shows that the accumulation of phenol particles on the surface of PES membrane (Fig. 2c).

Some of general parameters that measure this global pollutant content, like COD, TSS, turbidity, pH and color are shown in Table 1.

1.2. Effect of pH

The solution of POME pH is one of the important parameter to control the phenol removal. The obtained data for the phenol removal from POME solution of different pH in the range (3.15–12.68) is presented in Fig. 3. Maximum phenol removal was found onto the PES membrane in the highly acidic medium. In effect, both PES membranes and phenol having negative charges in their surfaces and, consequently, could repulse species with negative charges by electrostatic forces. At pH 3.15, phenol removal was found to maximum and therefore its anionic form could be repulsed by the negatively charged membrane surfaces. In conclusion, the maximum phenol removal in the PES membrane can be attributed to the contribution of two affecting factors: the repulsive forces from the charged surface plus the moderate adsorption capacity of the hydrophobic PES membrane.

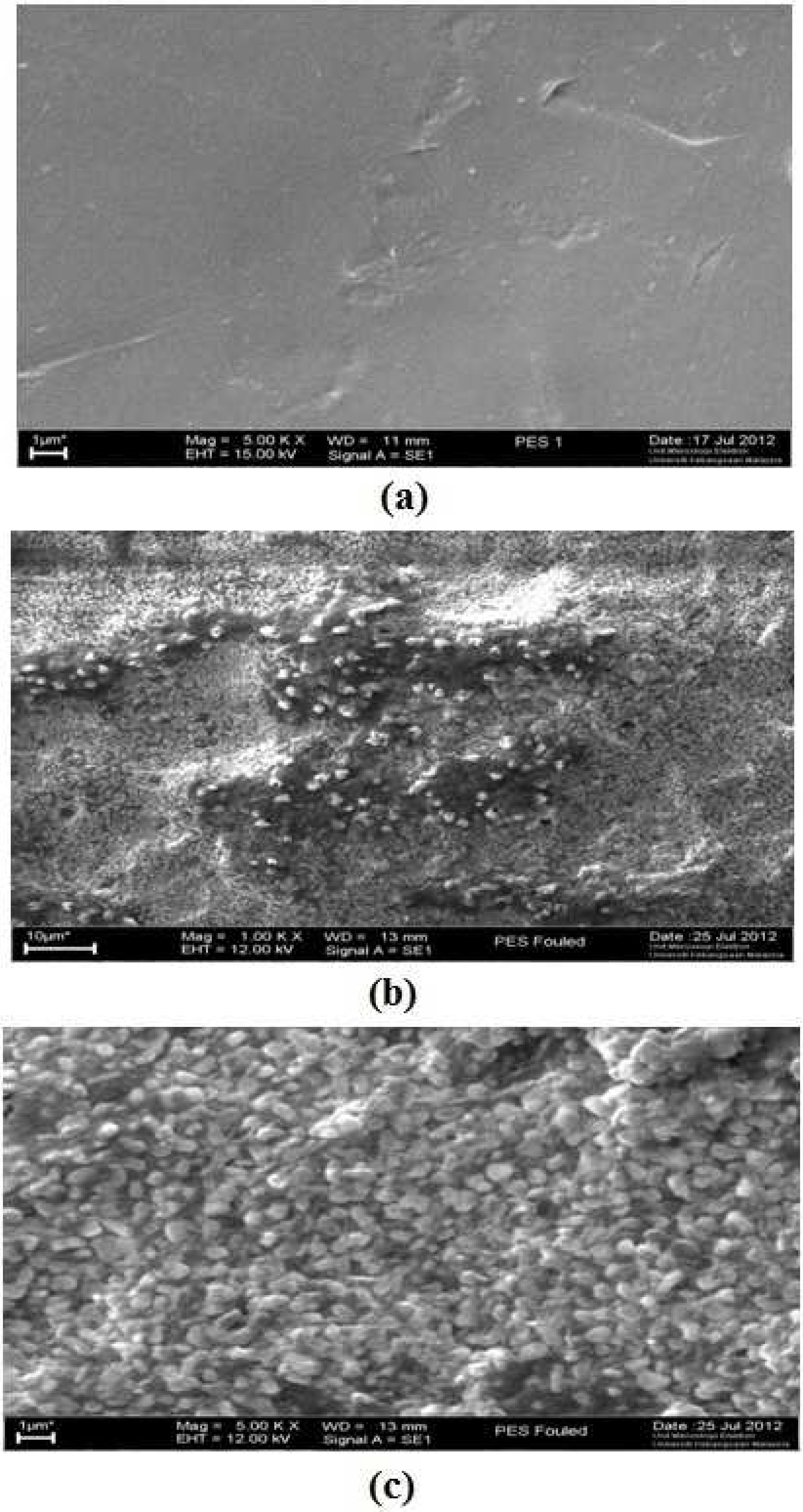

Figure 2. SEM of PES membrane: a) Fresh membrane b) membrane with phenol (1000x magnificent) and c) membrane with phenol (5000x magnificent).

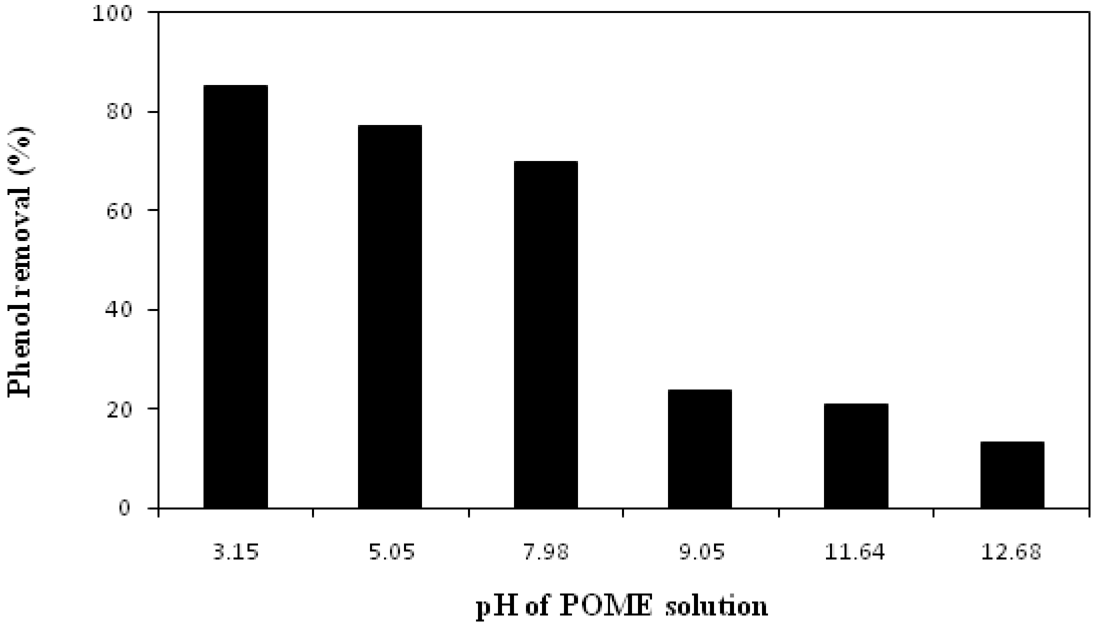

Figure 3. The effect of pH on phenol removal

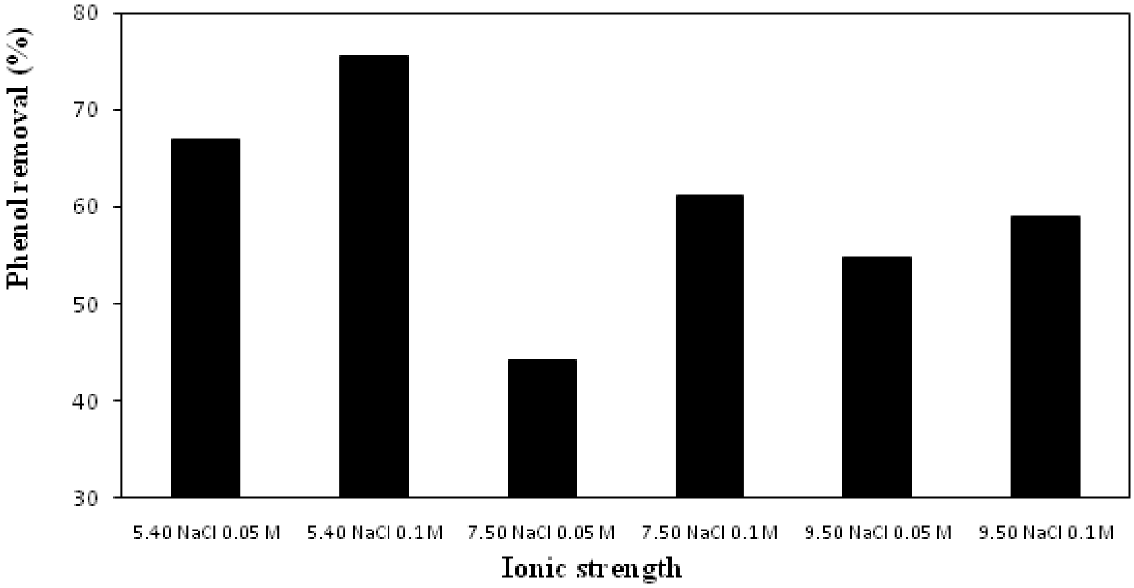

Figure 4. The effect of ionic strength on phenol removal

1.3. Effect of Ionic Strength

To investigate the effect of ionic strength on phenol removal, NaCl was added into POME solution. The addition of NaCl was done at two concentrations: 0.05M and 0.1M. From Figure 4, high phenol removal was achieved up to 78% at 0.1M NaCl concentration (pH 5.40). This phenomenon can be explained as follows: with the addition of NaCl, there is a reduction of repulsive force between particles in the POME solution and the surface of the membrane. The attraction between the particles and membrane lead to the accelerated accumulation of phenol on the membrane surface and finally lead to the formation of a thick cake layer.

The increase of NaCl concentration influenced the hydrophobicity character of the membrane. When the concentration of NaCl increased, the hydrophobic character in the membrane also increased. The higher hydrophobic character meant that the membrane was more attracted to binding with particles than water. Effect of ionic strength on phenol removal is shown in figure 4.

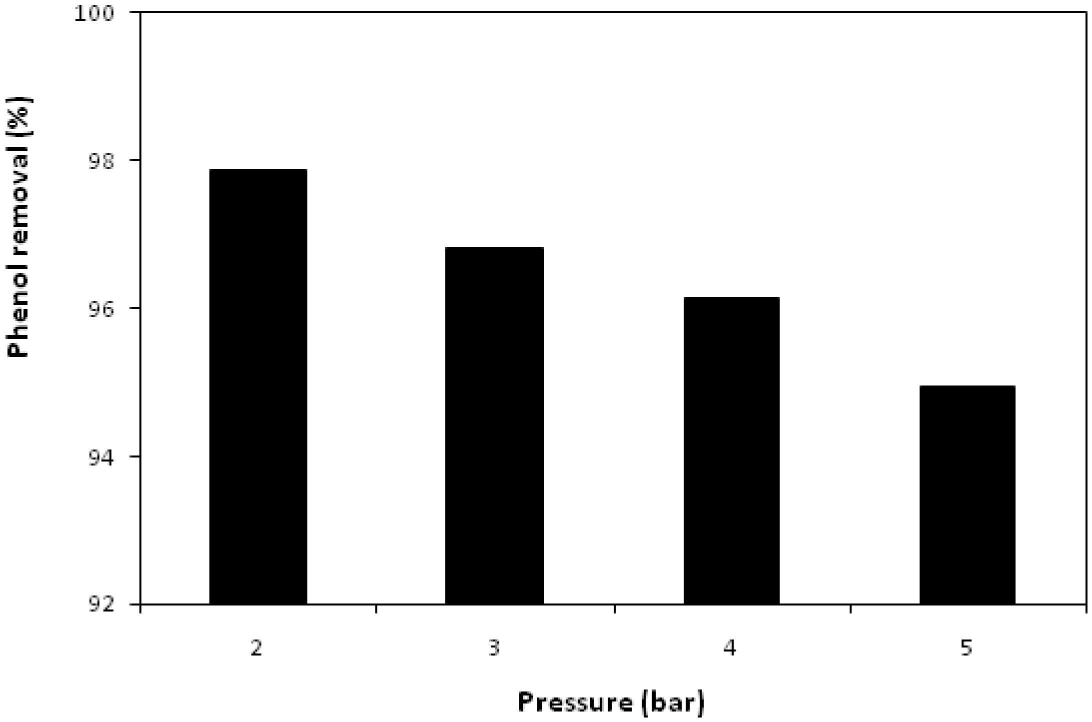

Figure 5. The effect of pressure on phenol removal

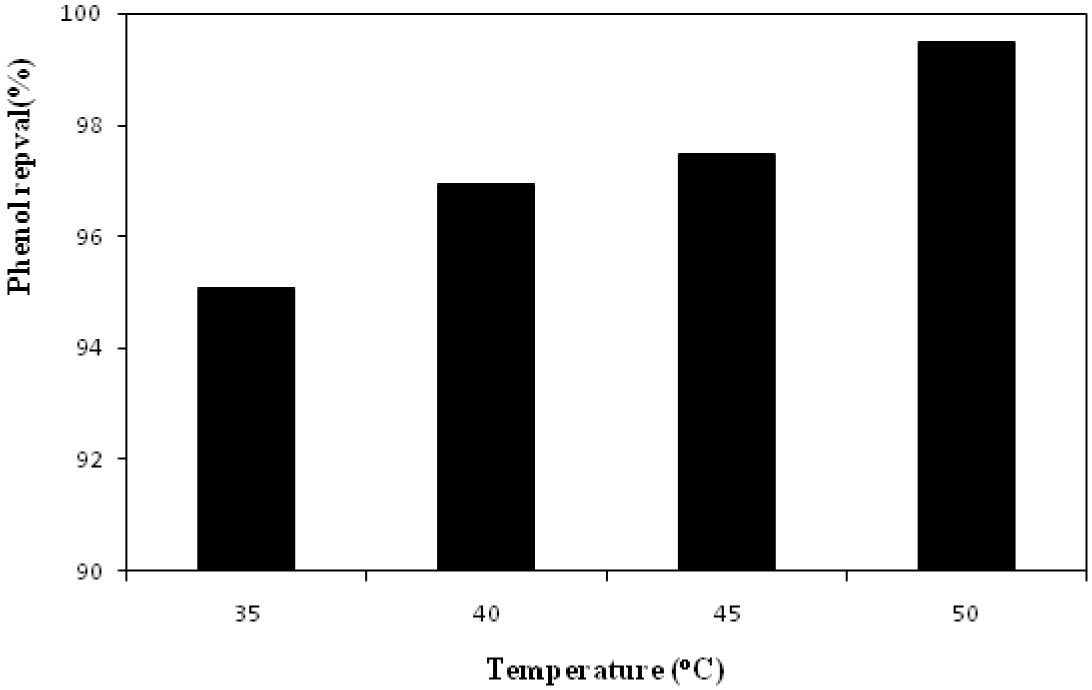

Figure 6. The effect of temperature on phenol removal

1.4. Effect of Pressure

The pressure plays an important role in the phenol removal during filtration process. The effect of pressure on phenol removal from PES membrane is shown in figure 5. From the figure higher phenol removal was at lower pressure. At pressure 2 bar almost 98 % phenol was completely removed from PES membrane.

1.5. Effect of Temperature

The effect of temperature on phenol removal from the PES membrane is presented in figure 6. On increasing the temperature the solubility and diffusion rate increases as a result transfer of particles from the membrane is easier to the bulk solution. However, membrane has a certain heat resistance properties. Up to 50 ºC membrane shows high phenol removal from the POME solution.

CONCLUSION

The removal of phenol from POME solution with PES membrane has been investigated in this study. The effects of pH and ionic strength on phenol removal have been studied. Six different pH conditions (3.15-12.68) and two concentrations (0.05-0.1M) of sodium chloride were used for phenol removal in the POME solution using PES membranes. The hydrophobic nature of PES membrane makes it to adsorb particles than water to remove phenol from the surface. This condition leads an accumulation of phenol on the surface and finally formation of a thick cake layer. The adsorption of phenol may influenced by the hydrogen bonding between phenol and the PES membranes.

Acknowledgement
The authors would like to thank the West Palm Oil Mill Plantation, Carey Island, Klang, Malaysia for the supplying the POME samples to conduct this study. The financial support from University Kebangsaan Malaysia through the project INDUSTRI-2011-010 and MOHE Top-Down Long Term Research Grant Scheme Project 4L804 is also acknowledged.

REFERENCES

[1] T.Y. Wu, A.W. Mohammad, M. Jahim, N. Anuar, *Biochemical Engineering Journal* **2007**, 35, 309.
[2] A. Lante, A. Crapisi, A. Krastanov, P. Spettoli, *Process Biochemistry* **2000**, 36, 51.
[3] M. Ahmaruzzaman, *Advances in Colloid and Interface Science* **2008**, 143, 48.
[4] A. Bódalo, J.L. Gómez, M. Gómez, G. León, A.M. Hidalgo, M.A. Ruíz, *Desalination* **2008**, 223, 323.
[5] X.Y. Bi, W. Peng, J. Hong, H.Y. Xie, S.C. Sia, J.L. Han, *Journal of Environmental Science* **2007**, 19, 1510.
[6] G. Akay, E. Erhan, B. Keskinler, O.F. Algur, *Journal of Membrane Science* **2002**, 206, 61.
[7] E. Erhan, B. Keskinler, G. Akay, O.F. Algur, *Journal of Membrane Science* 2002, **206**: 361.
[8] A. Barrios-Martinez, E. Barbot, B. Marrot, P. Moulin, N. Roche, *Journal of Membrane Science* **2006**, 281, 288.
[9] V. Limkhuansuwan, P. Chaiprasert, *Journal of Environmental Sciences* **2010**, 22, 1209.
[10] C.H. Ko, S.S. Chen, *Bioresources technology* **2008**, 99, 2293.
[11] H. Susanto, Y. Feng, M. Ulbricht, Journal of Food Engineering, **2009,** 91, 333.
[12] O. Wallberg, A.S. Jonsson, R. Wimmerstedt, *Desalination*, **2003**, 154, 187.