Membrane ultrafiltration of treated Palm Oil Mill Effluent (POME)

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Abstract

The oil palm industry and its processing have always been linked with the environment. The wastes generated have significant impact on the environment if not properly managed. Palm oil mill effluent (POME), which is the liquid discharge, comprises mainly organic compounds originating from biodegradable materials and is readily decomposed by anaerobic and aerobic microorganisms. The current treatment technology of POME is largely biological in nature. These processes require large acreage of land and do not always achieve the discharge limits. This paper described a study on the potential use of membrane technology to treat POME from the final discharge pond. The first part of the study investigated the establishment of characteristics of the various ponds within the current POME wastewater treatment plant. The membrane study essentially used hollow fiber membrane of MWCO ranging from 30K to 100K. The results showed that the hollow fiber membrane with MWCO 100K gave higher fluxes compared to the MWCO 30K, however the former membrane gave better quality permeate. The quality of permeate achieved from the membrane with MWCO 30K gave reductions in COD, SS, TKN and ammoniacal-N of 97.66%, 98%, 53.85% and 61.91% respectively. However color removal may require further treatment.

Keywords: membrane, ultrafiltration, POME, waste treatment

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1. Introduction

The palm oil industry is a Malaysian success story. From a mere 55000 ha in 1960, the oil palm planted area expanded to 3.5 million hectares by 2001, occupying 60% of the agriculture land in the country[1]. Therefore, a large quantity of waste is produced due to the huge amount of palm oil production. A typical crude palm oil mill releases liquid effluent known as palm oil mill effluent, gaseous emissions from the boiler and incinerator, solid waste materials such as empty fruit bunches (EFB), fibre and shells and by-products including potash ash and palm kernels. These wastes result in significant environmental problems if not disposed in the proper manner.

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Palm oil mill effluent (POME) is composed of highly polluted effluent that originates from the sterilizer and oil room and low polluted effluent that comes from steam condensate, cooling water, boiler discharge and sanitary effluent. The current treatment technology for POME is biological digestion, which is a combination of aerobic and anaerobic ponds. Membrane technology is one of the possible technology solutions to treat the high organic content effluent at the tertiary treatment stage. Membrane treatment is a physical process alternative that is capable of providing a highly efficient treatment, requires minimal energy and does not introduce any additives to the waste system. Among the various membrane processing techniques, ultrafiltration presents an attractive option for wastewater treatment. It is a low pressure-driven membrane process retaining most effectively macromolecules sized within 0.001 – 0.02 μm. Membrane ultrafiltration is capable of producing a higher quality effluent that can successfully meet the increasingly stringent effluent discharge standards set out in the Environmental Quality Act, 1974.

2. Objectives of study

This investigation is focused on examining the feasibility of using membrane ultrafiltration for the treatment of the final discharge pond water in the palm oil mill. However, the first stage of the study involved establishing the characteristics of effluent from the various ponds within the whole wastewater treatment plant. The second stage of the study then focused on the final discharge pond where samples were subjected to the following objectives:

- Investigate the fluxes obtained using two different sizes of the hollow fibre membrane module at various TMPs
- Determine the permeate quality using the above ultrafiltration modules

3. Experimental methodology

An adequate quantity of POME sample was collected from the Labu Palm Oil Mill in Labu, Negri Sembilan. The samples were placed in airtight containers and kept in a cold room where the temperature was maintained at 4°C. The samples consisted of the following:

- Sample A- Raw pond
- Sample B- Acidification pond
- Sample C- Anaerobic pond
- Sample D- Extended Aeration pond
- Sample E- Final Discharge pond

The samples were tested for the following characteristics: BOD_5, COD, Suspended Solids (SS), Total Kjedahl Nitrogen (TKN), Ammoniacal Nitrogen, Turbidity, Color and pH. The analytical tests followed the procedures as given in Hach Water Analysis Handbook[2], except for SS which followed the Standard Method for the Analysis of Water & Wastewater[3].

For the ultrafiltration studies, two different sizes of hollow fibre membrane were used to carry out the filtration process, namely the hollow fibre modules with MWCO of 30,000 and 100,000. The membrane material for the hollow fibre is polyethersulphone. The complete experimental set up is bench scale as shown in Figure 1.

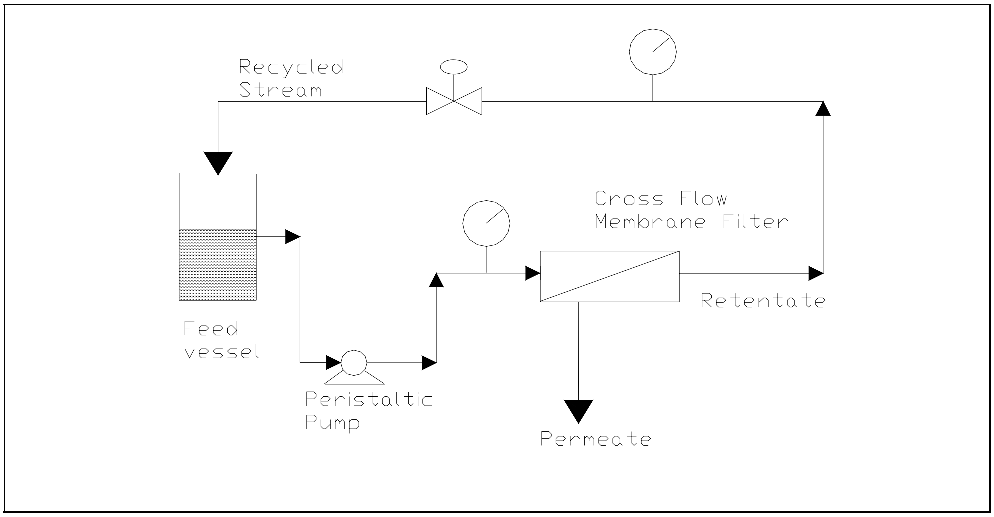


Figure 1: Experimental Set Up

Before the actual experimental runs were conducted, membrane cleaning and preparation were done according to the manufacturer's specifications. The feed tank was filled with 1000 mL of POME sample. The pH and temperature of the feed were recorded before the membrane filtration proceeded. The TMP for the ultrafiltration runs was varied between 0 - 2.50 bar. Once the permeate flow reached steady state, samples of 10 mL of permeate were collected for a total of 100 mL. The time for collecting the permeate samples were duly recorded. The permeate was kept for further analytical tests namely, COD, Suspended Solids, TKN, Ammoniacal Nitrogen, pH, Turbidity and Color. The above procedure was repeated for both two types of MWCO using samples from the final discharge pond.

The membrane was cleaned periodically using the cleaning procedures as recommended above to minimize the fouling effect and also lengthen the lifetime of the membrane.

4. Results and discussion

4.1. Characteristics of effluent from the various ponds

The effluent treatment plant at Labu palm oil mill utilizes biological treatment comprising a 5-ponds system. Raw POME generated from the milling processes is discharged to the raw pond followed by the acidification pond. Adequate hydraulic retention time is provided for the settling process to take place in the raw pond and acid is added in the acidification pond to stabilize the pH of POME. Anaerobic degradation occurs in the anaerobic pond followed by aerobic treatment provided by aeration devices in the following extended aeration pond. Finally, the treated POME is stored in a settling pond prior to discharge to the watercourse**.**

Table 1 gives the summary of results of the effluent characteristic from the various ponds. Figure 2 show the actual values of effluent quality of raw POME and the treated POME from the final discharge pond. The overall efficiency of treatment achieved through this ponding system is shown in Figure 3 (based on the raw POME values). The most significant reductions were those of BOD_5 (97.4%), COD (89.77%), Suspended Solid (93.94%), TKN (94.40%) and 97.98% in ammoniacal nitrogen content. The color and turbidity reductions were 96.53% and 79.71% respectively.

Table 1
Results of the effluent characteristic from the various ponds

Ponding system	BOD5 (mg/L)	COD (mg/L)	SS (mg/L)	TKN (mg/L)	AN (mg/L)	Turbidity (NTU)	Color (PtCo)
Raw Pond	192.60	10020	2475	468.25	260	1725	8150
Acidification pond	192.90	3605	1425	240	260	1725	7500
Anaerobic pond	16.70	2164	525	176.25	335	750	6150
Exteded Aeration pond	20.50	2166	900	26.25	45	1350	7900
Final Pond	5.00	1025	150	48.75	5.25	350	2825

* All the results above were the mean of three values.

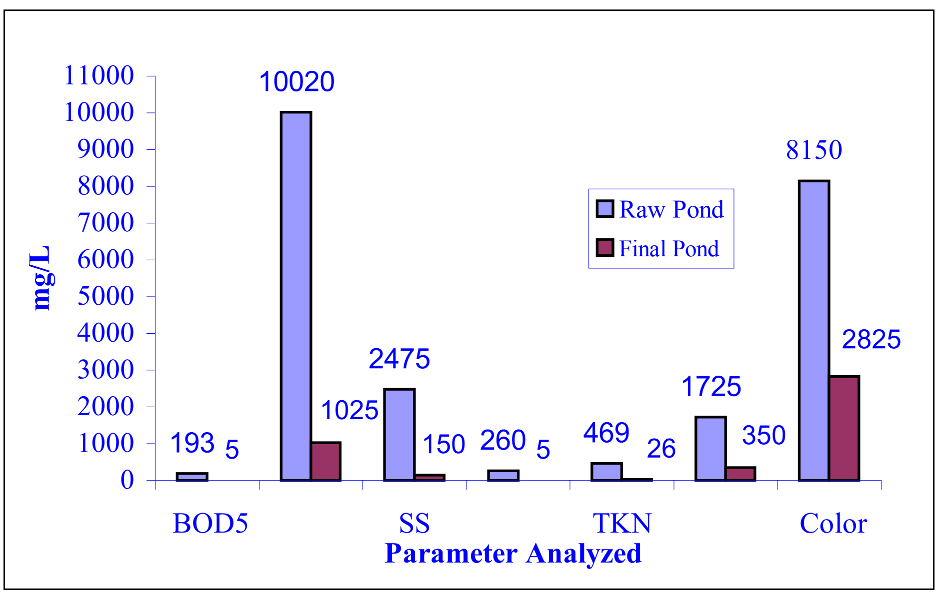


Figure 2: Characteristics of selected parameters for raw pond and final pond.

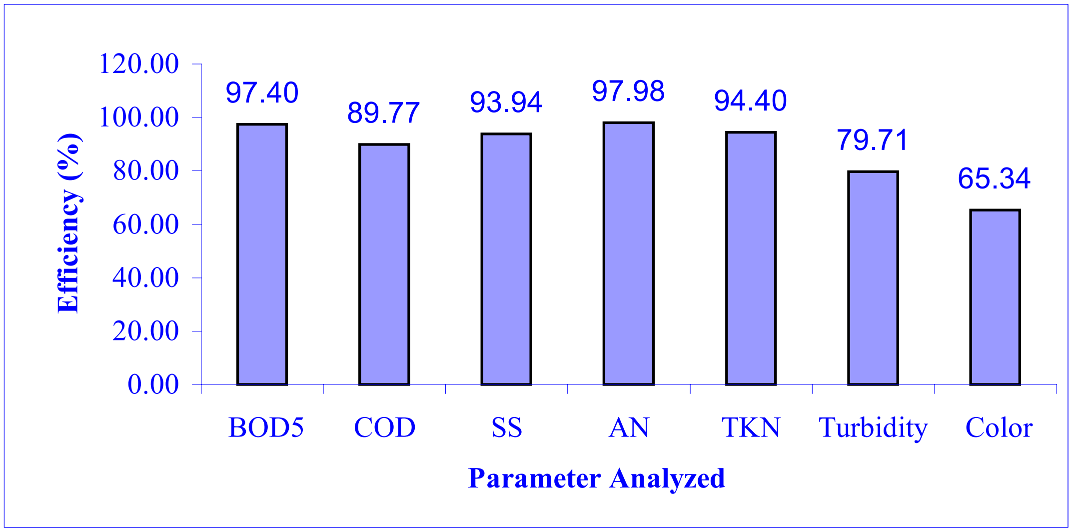


Figure 3: Efficiency of biological treatment based on selected parameters in raw pond and final pond

Results of the treated POME from the final pond are compared with the Prevailing Discharge Standards for Crude Palm Oil Mills 1984 (Environmental Quality Act) and are shown in Table 2. From the this table, it can be seen that the sample collected still possessed a high COD content, although no limit is given in the discharge standard. Ammoniacal Nitrogen, Total Kjeldahl Nitrogen and Suspended Solid were all below the permit limits. A reasonable pH level was observed at 8.41, which is within the discharge limit. However, the sample exhibited high intensity in color content (2825 unit PtCo).

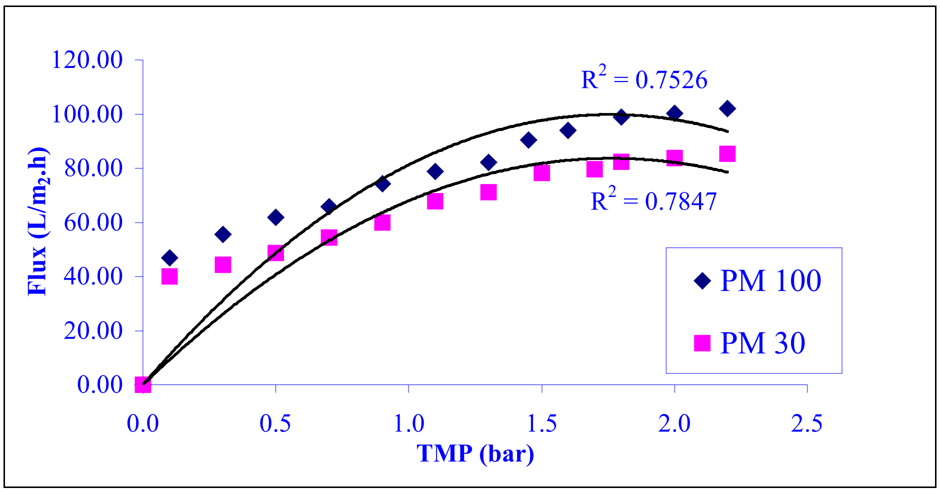
Table 2
Results of characteristic test for final discharge pond POME

Parameters	Average Result (3 samples)	Limit of Discharge (Environmental Quality Act 1984)
1. COD, mg/L	1025	-
2. Suspended Solid, mg/L	150	400
3. Ammoniacal Nitrogen, mg/L	5.25	150
4. Total Kjeldahl Nitrogen, mg/L	26.25	200
5. Color, PtCo	2825	-
6. Turbidity, NTU	350	-
7. pH	8.41	5-9

4.2. Ultrafiltration studies

The second part of the study involved ultrafiltration studies on samples of treated POME from the final discharge pond. The results presented in the following discussion focus on the permeate flux and permeate quality obtained using the two membrane modules described earlier in the experimental section.

Figure 4 shows the flux obtained at various TMP from the hollow fibre modules used. The general trend of flux-TMP relationship for both types of MWCO shows a declining flux with increasing TMP. PM 100 hollow fibre module achieved the highest initial flux The high shear rate within the thin channels of the hollow fibre is thought to contribute significantly towards the high fluxes obtained.



(PM 100 and PM 30)

Figure 4: Permeate flux versus TMP for hollow fiber membrane

A comparison of efficiency of reduction obtained using the various modules was also made. The parameters used for comparison are suspended solid (SS), turbidity, color, COD, total kjeldahl nitrogen (TKN) and ammoniacal nitrogen (AN). The results are as shown in Figure 5 below.

From Figure 5, it is obvious that the ultrafiltration system was able to significantly reduced the parameters analyzed. PM 30 showed the best performance among the three modules. The most significant elimination was achieved in suspended solids which was reduced to 3.00 mg/L from the original 150 mg/L. COD level was reduced to 24 mg/L from the original 1025 mg/L. Total Kjeldahl Nitrogen was 22.5 mg/L after treatment compared with 48.75 mg/L. The final level of color is still high at 650 PtCo and may require further treatment before discharge depending on the intended reuse of treated water. As expected the lower MWCO membrane is able to retain smaller particles and hence produced a higher quality of permeate. Both membrane modules reduced the parameter analyzed below the discharge standards (Environmental Quality Act, 1984). However color removal may be a future concern that needs to be further studied.

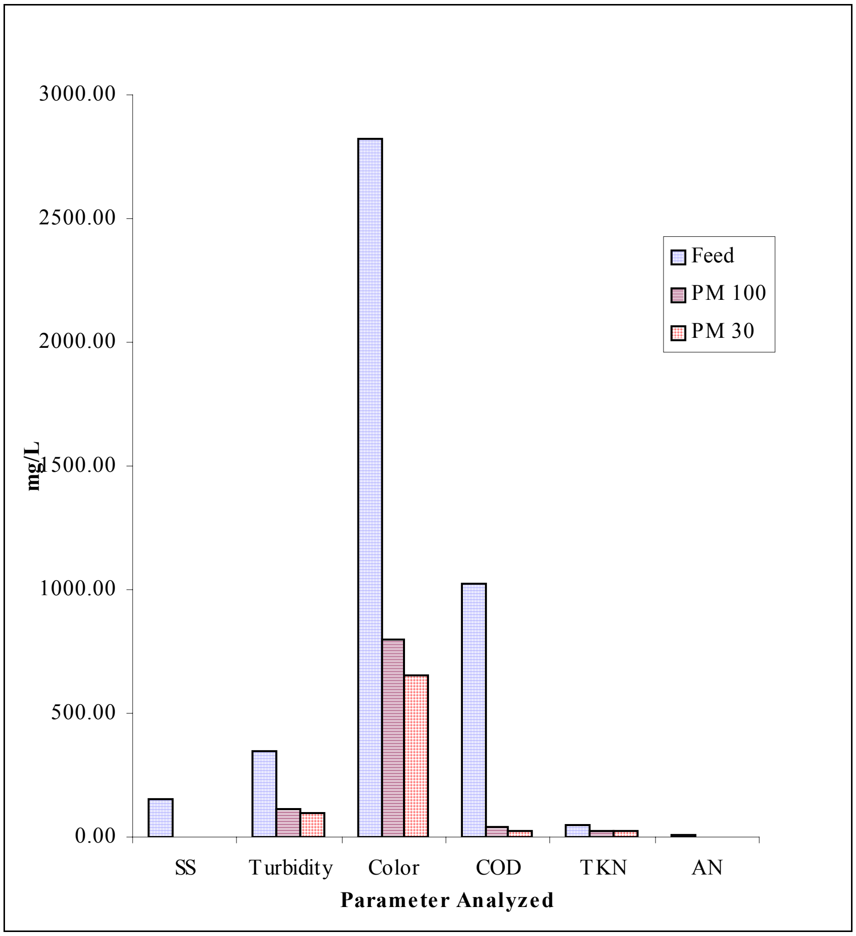


Figure 5: Reduction in effluent quality parameters using hollow fibre membrane

Table 3
Reduction in effluent quality parameters from hollow fibre membranes

Parameter (final pond)	**PM 30 Efficiency (%)**	**PM 100 Efficiency (%)**
Suspended solids	98.00	97.33
Turbidity	73.43	68.00
Color	76.99	71.68
Chemical Oxygen Demand, COD	97.66	96.29

Soluble Biodegradable COD	80.95	52.38
Total Kjeldahl Nitrogen, TKN	53.85	46.15
Ammoniacal Nitrogen, AN	61.91	42.86

* All the results above were mean of three values.

5. Conclusions

The results obtained from the experimental studies showed that the present ponding system is capable of achieving the present discharge limits although colour remains a problem. However it is anticipated that in future the disharge limits will become more stringent and this will require further treatment. In this respect membrane technology shows a promising option to improve the effluent qualityas well as can be considered for reuse in the mill for other purposes. As expected the lower MWCO module resulted in better quality permeate.

Acknowledgement

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