Treatment of Palm Oil Mill Effluent (POME) using membrane technology

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Abstract

Raw POME has a high biochemical oxygen demand (BOD) which is about one hundred times more than that of sewage. If not properly treated, POME could pose as a high organic pollutant. Conventional ponding process has been an effective method to reduce the biological and chemical constituents of POME. This method, even though simple and reliable, generates large amounts of sludge and takes up large land areas. It is thus justifiable that many studies have been conducted to develop alternative methods for POME treatment with possibilities of resource recovery by smaller, higher efficiency treatment system. In this report, we assessed the current technologies of POME treatment system and also some other biological wastewater treatment systems. We found that membrane technology has high potential of becoming part of POME treatment system. With a high separation capability, there is a possibility of developing systems that can recover valuable pharmaceutical components from POME and also recovering high quality water by application of membrane technology to POME treatment systems. Initial lab work and the current treatment applications have led us to select centrifugation as membrane pretreatment method. This is quite a good estimation of the three-phase-decanter system. The aqueous phase from his process have already removed from 60% to 80% of chemical oxygen demand (COD), turbidity, color, and suspended solids. This will be the feed to the hollow fiber membrane modules. The modules were of 0.2 μm, 500K, 100K, and 30K MWCOs. Our system as it is, have an overall removal efficiency of 89.9% for COD, 92.9% for colour, 99.4% for suspended solids and 97.9% for turbidity. These values are comparable to works done by other researchers [1] [2]. We could expect better removal and efficiencies if our pretreatment system is optimized.

Keywords: membrane, ultrafiltration, POME, waste treatment

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1. Introduction

To date, Malaysia is the largest producer and exporter of palm oil products. The Malaysian palm oil milling and refining industries developed rapidly in the 1980's such that palm oil has emerged as one of the major oil commodities in the world oil and fats market. Approximately 11.9 million tonnes of crude palm oil (CPO) were produced that amounted to RM14.79 billion in the year 2002 (MPOPC 2003). Aside from being one of Malaysia's highest money earning industry, palm oil production is also one of the major potential, if unabated, organic polluters of the environment producing very high strength waste effluents. A conventional palm oil mill, diagrammatically described in Figure 1, produces about 2.5 m^3 of effluent for every tonne of palm oil produced. In 1992, Malaysia produced about 6.7 million tonnes of crude palm oil contributing to 15.9 million cubic metres of palm oil mill effluent (POME) [3]. Raw POME has a high biochemical oxygen demand (BOD) which is about one hundred times more than that of sewage. In 1998 there were 330 palm oil mills generating about 32.0 million tonnes of POME per year. The total BOD load generated was about 1,560 tonnes per day, equivalent to the domestic sewage generated by a population of 31.2 million people!

Realising the escalating situation, measures to counter pollution from POME have been deployed. In order to regulate the discharge of effluent from the crude palm oil (CPO) industry as well as to exercise other environmental control, the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Order, 1997 and the Environment Quality (Prescribed Premises) (Crude Palm Oil) Regulations, 1997 were promulgated under the Environmental Quality Act, 1974. The POME characteristics and standards discharge limit is detailed in Malaysian Department of the Environment (DOE), 1999.

Over the years, the problems of POME pollution have been overcome with use of anaerobic and facultative digestion to treat the waste. Another treatment process that can treat POME as well as recover the water is the evaporation process. About 85% of water in the POME can be recovered as distillate. Membrane separation technology is envisaged to treat POME in a more beneficial way. Works on recovery of bioflavonoid and other antioxidants have been cited (MPOB, 2003). Other zero waste technology has also been utilized by mill. Treated POME has also been applied to land.

Conversely, biological treatment systems need proper maintenance and monitoring as the process relies solely on sensitive microorganisms to break down the pollutants. Biological treatment facilities tend to be very large and require substantial acreage. They also lack esthetic qualities and generates vast amount of harmful, odorous and corrosive biogases. Furthermore, the treated wastewater cannot be reused in the plant. Energy requirement is a major constraint in the evaporation processes. Under standard conditions specific energy consumption is very high where 1 kg of steam is required per 1 kg of water evaporated. Membrane processes, if applied directly with raw POME are susceptible to fouling and degradation during use.

Newer technologies have been developed, amongst which is the three-phase decanter system which pellets the suspended solids and floats the oil. Membrane systems are increasingly being used as wastewater treatment systems along with other pretreatment units such as this. These systems range in its theme from zero waste generation to resource recovery.

This short write-up shall assess the use of hollow-fiber membrane systems after pretreatment of raw POME. Raw POME shall go through a physical process, namely the three-phase decanter system before being fed to a membrane unit. The objective is so permeate from the membrane unit will be of a certain quality that fits certain usage (boiler feedwater, etc.) or simply meet the standards of discharge. The proposed system is hoped to overcome the shortcomings of current technologies and applications. The system is modular and non-biological; hence it requires much less acreage and is more controllable. Non-biological systems are less susceptible to changes in the environment and does not generate as much sludge and biomass. The problem of biogas releases is also overcome thus removes any odorous and corrosive releases to the environment. Energy requirement is low in comparison to the evaporation processes.

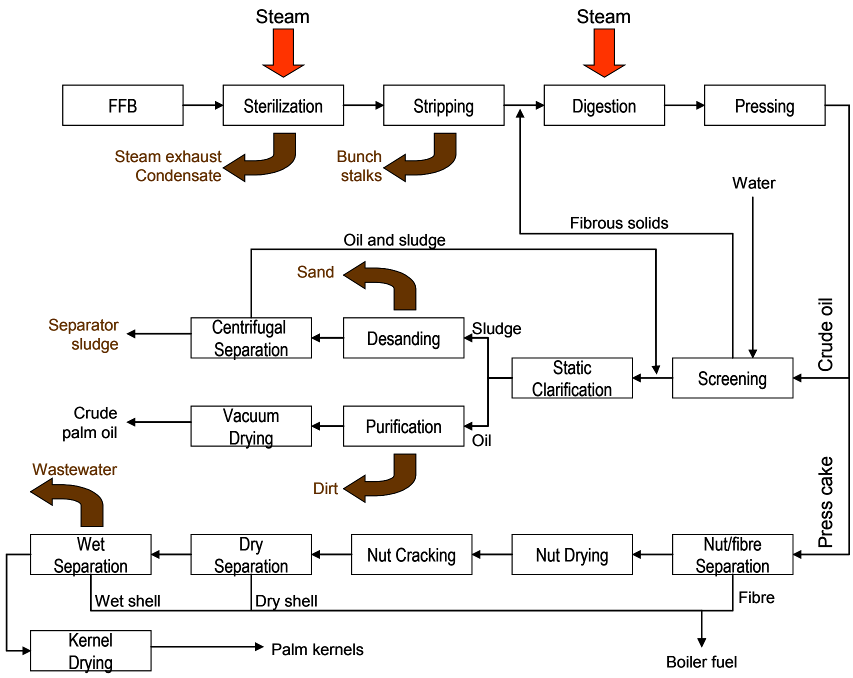

Figure 1: A typical palm oil milling process (MPOB, 2000)

2. Background information

2.1. Make-up of POME

Palm oil mill effluent is basically a mixture of sterilizer condensate, separator sludge, and hydrocyclone wastewater. Freshly produced POME is a colloidal suspension made up of 95%-96% water, 0.6%-0.7% oil, and 4%-5% total solids including 2%-4% suspended solids which are mainly debris from the palm fruit mesocarp (Whiting, 1978).

Table 1
Characteristics of palm oil mill effluent

Parameter*	Amount
pH	4.7
Oil and grease (O&G)	4 000
Biological oxygen demand (BOD_3)	25 000
Chemical oxygen demand (COD)	50 000
Total solids (TS)	40 500
Suspended solids (SS)	18 000
Total volatile solids (TVS)	34 000
Ammoniacal nitrogen (AN)	35
Total nitrogen (TN)	750

Notes:
*All parameters in mg/l except pH
BOD_3 – after incubation for 3 days at 30 °C

Treatment of POME by digestion process drastically reduces the BOD concentration but at the same time much of the nutrient content is also lost. With application of membrane technology, there is a possibility of recovering some valuable components from POME. Research by S. Ravigadevi (MPOB, 2003) saw the development of a novel process that provides an opportunity and a financial incentive to reduce pollution by recovering valuable antioxidants with potential health benefits.

Environmental Quality Regulation

When the Malaysian Environmental Quality Act 1974 and Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977 were promulgated and introduced, there were no proven technologies for treating palm oil mill effluent (POME). Much money and effort were therefore spent by both the private and public sectors, particularly PORIM, to develop cost-effective treatment technologies for palm oil industrial effluents. The unfailing R&D efforts have led to successful development of several treatment technologies for the industry, and they are discussed below.

Table 2
Comparison of current and membrane process for POME treatment

PROCESS / DESCRIPTION	PONDING	ANAEROBIC CONTACT & AERATION	ANAEROBIC TANK & LAND APPLICATION	EVAPORATION	**MEMBRANE TECHNOLOGY**
Acreage & Facilities	Large land area	Large land area	Large land area	Modular but complicated	**Modular**
Controllability & Susceptibility to Environmental Changes	Difficult and depend on MOs	Difficult and depend on MOs	Difficult and depend on MOs	Good & None	**Good & None**
Organic Loading	Small, 0.2-0.35kg/m^3.d BOD	Small, 0.8-1.0kg/m^3.d BOD	High, 4.8kg/m^3.d VS	Moderate	**Moderate**
Sludge Generation	Large	Large	Large	None	**Little, but can cause fouling**
Energy Requirement	Minimal	High	High	High	**Moderate**
Requirement of Further Treatment	Yes	Yes	Yes	Yes	**No**
Possibilities of Resource Recovery	No	No	No	Yes	**Yes**
Operating Cost & Maintenance	Cheap & Intensive	Cheap & Intensive	Cheap & Intensive	Cheap & Moderate	**Moderate & Expertise requires**

2.2. Process description and equipment setup

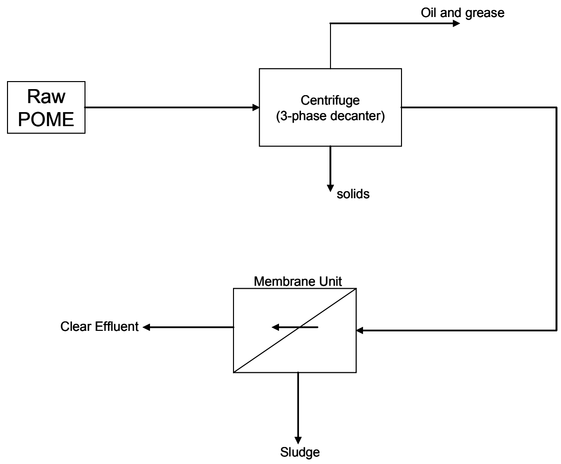

Figure 3: Flow diagram of research project

As mentioned before, raw POME from palm oil mills comes from the steriliser condensate, centrifugal sludge and hydrocyclone washing. The BOD here is somewhere in the lines of 25,000 mg/l. As described in Figure 3 the POME shall go through a series of pretreatment prior membrane treatment.

The following physical treatment of centrifugation is carried out to remove most of the solids suspensions in the effluent. It is simulated based on the three-phase decanter system that has already been used in some palm oil mills to date.

The membrane treatment is a bench scale unit at the Chemical Engineering Department, UM. Detail setup of this unit will be discussed further in the following sections.

2.3. Pretreatment of Sample

The raw POME was pretreated using the centrifugation technique to simulate the three phase decanter system on a bench scale. The aqueous phase was siphoned out for further treatment (membrane).

2.4. Hollow Fibre (HF) Membrane Filtration

The bench scale HF system can be described by Figure 4. The membrane modules are of polyethersulphone (PES) materials. For this research purpose, we have used the membrane modules that have been used for other purposes (i.e. pectin and star fruit juice). The details of the membrane modules used are summarized in the following table:

Table 3
Membrane modules used for the research project

MWCO	Total area (cm^2)	Material	Used
0.2 µm	16.0	PES	Yes
500,000	26.0	PES	Yes
100,000	26.0	PES	Yes
30,000	26.0	PES	Yes

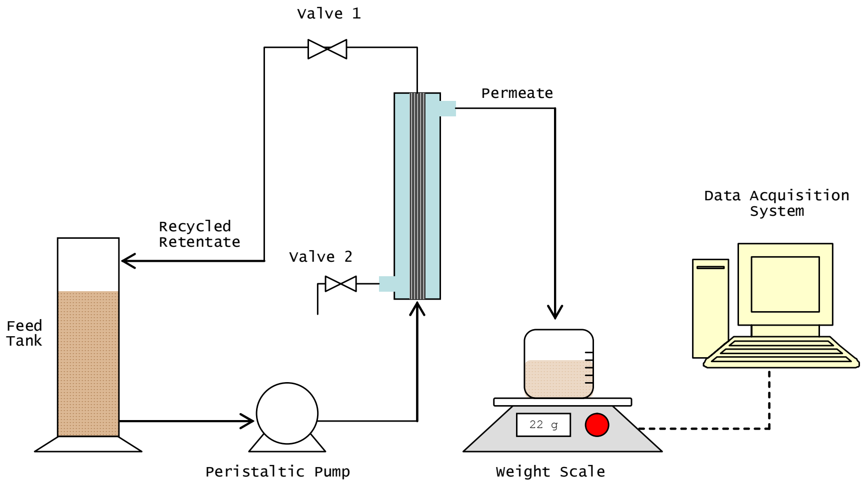

Figure 4: Experimental setup

2.5. Characterization and Analytical Methodology

Samples were analyzed for the specific parameters (listed below) before and after each run through the modules. Where applicable, samples were diluted. All the analyses were done using the Hach® analytical chemical equipment.

- *Chemical Oxygen Demand (COD)*
- *Suspended Solids*
- *Colour*
- *Turbidity*

3. Results and discussion

3.1. Experimental results

Table 4 lists the characteristics of raw POME pretreated with the centrifugation process and permeates coming out of the four membrane modules used, each having different MWCO. All the membranes were run with a common TMP at 1.7 bar and room temperature of 25 °C.

Table 4
Compositions of pretreated POME and permeates from different MWCOs

Samples	COD (mg/L)	Color (CoPt)	SS (mg/L)	Turbidity (FTU)	pH
Pretreated POME	39900	16700	700	2000	4.60
0.2 μm Permeate	13100	5900	200	600	4.69
500K Permeate	9900	5300	180	400	4.72
100K Permeate	8200	5200	130	320	4.73
30K Permeate	7100	3100	100	200	4.73

Run at 1.7 bar TMP and 25 °C

To better explain the values in Table 4, we shall further discuss the parameters in terms of removal efficiency. We shall assume that the removal efficiency illustrated in Figure 5 is the reduction of parameters (COD, colour, SS, turbidity) as opposed to raw POME (refer to Table 3.1).

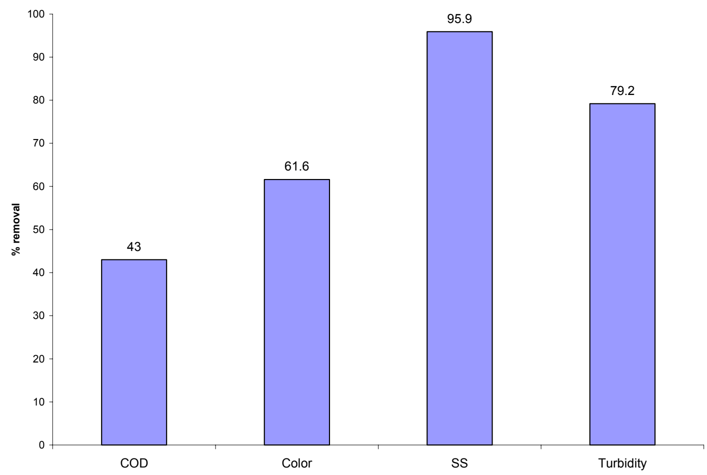

Figure 5: Percentage removals of components after centrifugation
(run at 1.7 bar TMP, 25 °C)

Based on Figure 5, we could see that the pretreatment has reduced a significant amount of pollutants in raw POME. The removal efficiency for COD is 43 %; colour is 61.6 %; suspended solids is 95.9 %; and turbidity is 79.2 %.

Based on Figure 6, we could see that the hollow fiber membrane module has further reduced pollutants in the pretreated POME. The overall efficiency for COD is 89 % based on raw POME by the system. Most of the COD has been removed by the 0.2 micron MWCO module. The following modules only remove a little more COD.

The overall efficiency for COD is 99.4 % based on raw POME by the system. Most of the COD is removed by the 30K MWCO module. The overall efficiency for turbidity is 97.9 % based on raw POME by the system. The overall efficiency for colour is 92.9 % based on raw POME by the system. Most of the colour is removed by the 30 K MWCO module. The maximum value of pH obtained is 4.73 using both the 100K and 30K MWCO modules.

On the overall, we could observe that higher removal efficiencies as MWCO is reduced. We should also take into consideration that the flux also decreases with MWCO. Furthermore, fouling rates are increased with the reduction of MWCO.

Looking at the trend for the removal efficiencies for COD, colour, SS and turbidity, we could, more or less estimate in which phase the pollutants are in. Even though SS is nearly eliminated, approximately 99.4 % removal, COD and colour is only removed up to 89.9 % and 92.9 % respectively. So, the COD and colour might be in the solution (dissolved solids) or they are in suspensions that are smaller than that can be retained by the 30K MWCO module. In the same context, the small change of pH towards 7 could be due to the constituents in the solution.

These values follow the logic of membrane application where a lower MWCO membrane retains smaller particles. Hence, the quality of permeate will be better if we utilize lower MWCO modules. Even though certain parameters has not met the discharge standards such as pH, the system proposed could be further enhanced by applying better pretreatment or lower MWCOs.

Colour can be further reduced by using more specific treatment systems such as activated carbon.

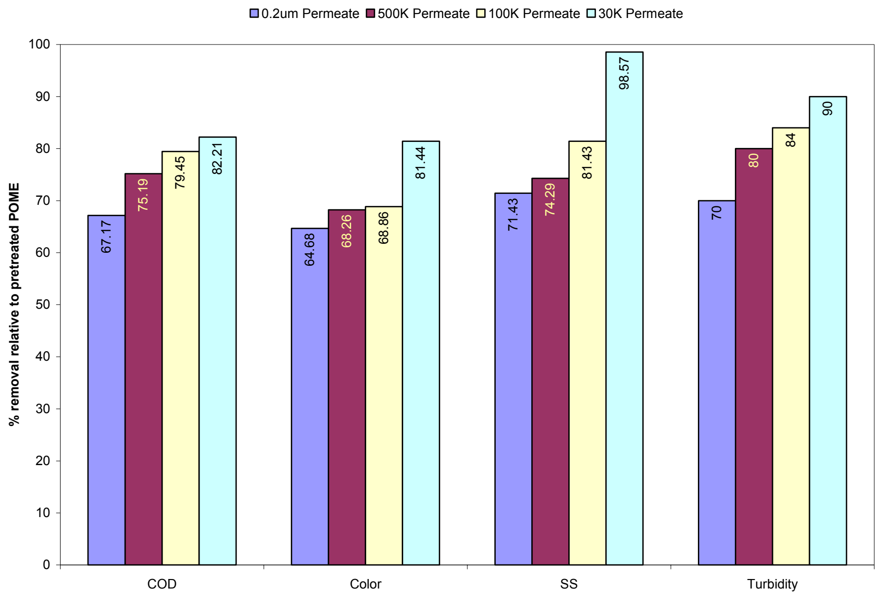

Figure 6: Percentage removal of pollutants for permeates relative of pretreated POME (run at 1.7 bar TMP, 25 °C)

For a system to be feasible, it is not justifiable just to talk about the removal but also to mention about the flux trend. As the removal efficiency increases we expect the flux to decrease. The flux drop per grams collected will also decrease. A lot of the suspensions were removed from the pretreated POME using 0.2 micron MWCO module.

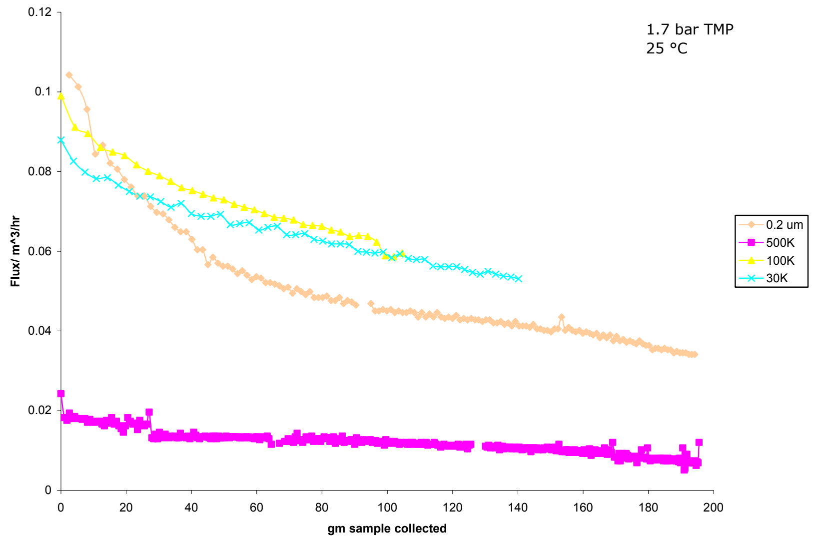

Figure 7 : Flux against grams of permeate collected for various MWCO

Ideally we expect graphs in decreasing manner as the MWCO reduces. Here, we were able to obtain the trend but the flux for the 500K was lest than the other 3 MWCO. This might be due to the fact that 500K was used on the pectin whereas the other 3 modules were used for star fruit juice.

4. Conclusion

From the research project results and discussion we are able to conclude the following:

1. Membrane technology is a practicable alternative treatment system for POME with possibilities of waste reduction and resource recovery.
2. The three-phase-decanter system can be used as pretreatment with sequential membrane filtration as treatment system for POME.
3. Sequential membrane modules have potential of high removal efficiencies.
4. Our system as it is, have an overall efficiency of 89.9% for COD, 92.9% for colour, 99.4% for suspended solids and 97.9% for turbidity.
5. Further treatment can be incorporated for more specific usage of permeate from the membrane modules.

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