REMOVAL OF RESIDUAL OIL FROM PALM OIL MILL EFFLUENT (POME) BY REVERSE OSMOSIS MEMBRANE

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Abstract: Malaysia is one of the largest producers of palm oil. Most of the palm oil processing is carried out in palm oil mills where oil is extracted from palm oil fruit bunch. Two sources of oil from fruit bunch are fleshy mesocarp of fruit (45-55% oil) and kernels (50% oil). It is estimated that for every tonne of fruit bunch processed produces 1.5 tonne of palm oil mill effluent (POME). POME is a mixture of sterilizer condensate, separator sludge and hydrocyclone wastewater. Fresh POME is a colloidal suspension of 95 - 96 % water, 0.6 - 0.7 % oil and 4 - 5 % total solids including 2 - 4 % suspended solids which is mainly debris from palm fruit mesocarp. It is acidic (pH 4-5), hot (80 – 90°C) and contains high amount of total solids (40 500 mg/l) and oil (4000 mg/l). POME was first pretreated to remove the high content of suspended solids and residual oil using flocculation, solvent extraction and adsorption processes. Lastly C-series membrane was used to remove any residual oil remaining after the pretreatment processes. Operating pressure and pH were varied in order to find the optimum conditions for membrane separation process. It was found that the optimum removal of residual oil was achieved at a system pressure of 10 bars and pH 9. At these conditions, the oil concentration was decreased from 100 mg/l to 51 mg/l after 30 min of filtration.

Keywords: Palm Oil Mill Effluent (POME), Flocculation, Solvent extraction, Adsorption, Reverse osmosis

INTRODUCTION

Over the last 30 years, the Malaysian palm oil industry has grown to become the most important agriculture based industry. In 1998, Malaysia produced 8.33 million tons crude palm oil (CPO) and 1.1 million tons of crude palm kernel oil (CPKO). Palm oil and its product have becomes the country's major export revenue earner valued at about RM 22.6 billion. This accounted for about 60.5 percent of the export earnings from commodity and commodity based products in 1998 and has helped to a large extent reduce the impact of the economic crisis faced by the country.

Large quantities of water are required in palm oil milling – about five to seven tonnes to produce one tone of palm oil [5]. Two to three tones are used as boiler feedwater and the remainder as process water (for dilution and washing). About half the water used ends up as palm oil mill effluent (POME) and the rest lost as steam through sterilizer exhaust, leakages and wash water.

POME is a mixture of sterilizer condensate, separator sludge and hydrocyclone wastewater. Fresh POME is a colloidal suspension of 95 - 96 % water, 0.6 - 0.7 % oil and 4 - 5 % total solids including 2 - 4 % suspended solids which are mainly debris from palm fruit mesocarp. It is acidic (pH 4-5), hot (80 – 90°C) and non-toxic (no chemicals are added during oil extraction). Other characteristics are shown in Table 1 [5].

Table 1: Characteristics of palm oil mill effluent

Parameter	Concentration*
pH	4.7
Oil and grease	4 000
Total solids	40 500

*All parameters in mg/L except pH.

In the early history of the industry (1960 – 1970), when the numbers of mills were small, POME was conveniently discharged into nearby rivers to be diluted by the volume of river water. However, with the rapid expansion of the palm oil industry coupled with increased environmental awareness, the industry has had to treat its effluent to an acceptable level before discharge. Realizing the potential pollution that can be caused by the industry, the Government has enacted the Environment Quality Regulations for the palm oil industry in 1978. The DOE has set the discharge standards for POME in Table 2.

Table 2: Parameter limits for watersource discharge of POME

*Biochemical oxygen demand (BOD) (mg/L)	100
Suspended solids (mg/L)	400
Oil and grease (mg/L)	50
Ammoniacal nitrogen (mg/L)	150
Total nitrogen (mg/L)	200
PH	5-9

* BOD – sample incubated for 3 days at 30 °C.

Over the last two decades, several innovative treatment technologies have been successfully developed and employed by palm oil mills to treat their POME [1, 4]. They are based on anaerobic, aerobic and facultative processes that rely on suitable bacteria to break down the organic matters (pollutants). These conventional biological treatments of anaerobic and aerobic or facultative digestion systems need proper maintenance and monitoring as the processes rely solely on microorganisms to break down the pollutants. The microorganisms are very sensitive to changes in the environment and thus great care has to be taken to ensure that a conducive environment is maintained for the microorganisms to thrive in. It requires skilful and attention and commitment.

In Malaysia, evaporation has been commercially used to produce natural rubber serum concentrate from wastewater generated by latex factories [3]. A similar technology was evaluated for process POME [6]. POME containing 3-4% total solids was used as feed for the evaporation process. A concentrate of 20-30% solids content was produced which contains high plant nutrient and is a good feed material for making fertilizer. On the other hand, about 85% of the water in the POME can be recovered as distillate. The quality of the distillate is good and can be reused as boiler feedwater or process water with minimal chemical treatment. However, energy requirements is the major constrain in this process. It is reported that 1 kg of steam is used to evaporate 1 kg of water from POME.

POME has been found to contain many valuable plant nutrients in substantial amount. This positive development has resulted in a paradigm shift in the management of POME. It has changed the concept of treatment and disposal to beneficial utilization. It is believed that membrane separation technology will be able to treat POME in a more beneficial way.

Recently, membrane anaerobic system (MAS) was applied on the treatment of POME [2]. In the study, the system was used subjected to increasing organic loading rates (OLR) and a total of six steady states were attained. The first steady state influent COD concentration was 39,910 mg/l increasing to the final or sixth steady state COD concentration of 68,310 mg/l. the efficiency of COD removal was between 91.7 to 94.2% with an average hydraulic retention time of 3.03 days. A crossflow ultrafiltration module was used to filter the final effluent and simultaneously retain biomass in the anaerobic reactor. The permeate produced in the study had a high colour content, but the permeate turbidity was low (less than 10 NTU) indicating that the colour was due to dissolved solids of lower molecular weights than the 200,000 MWCO of the ultrafiltration membrane used. The low operating pressure of 1.5 bar was deliberately chosen to reduce solids deposition and provide self-cleaning shear effects on the ultrafiltration membrane surface and pores.

MATERIAL AND METHODS

Fresh sample of POME was collected from Felcra Nasaruddin Palm Oil Mill, Ipoh, Perak. Six technical grade solvents which are hexane, benzene, pentane, petroleum benzene, petroleum ether and heptane were used in the solvent extraction process. For the adsorption process, a sample of synthetic rubber latex with 15.98 m^2g^{-1} surface area was used as an adsorbent. Four different types of ultrafiltration membranes (G-series membrane; GN, GM, GK and GH) and one type of reverse osmosis membrane (CE membrane) were tested to extract the residual oil from POME. The molecular weight cut off (MWCO) of GN, GM, GK and GH is 10000, 8000, 3500 and 2500 respectively. The effective membrane surface area was 21.24 cm^2.

Figure 1 shows the schematic diagram of membrane separation process rig that is used in this project. This unit contains a membrane cell, flow in and flow out pressure gauges and high-pressure pump. An ultrafiltration membrane was placed inside the membrane cell. Ionized water was first fed to the pressure membrane cell. After stabilization of about 15 minutes, permeate and control valves were closed until the desired pressure was achieved (10 bars). Then, the permeate valve was opened. Control valve was used to control the pressure of the system if necessary. This procedure was continued for another 15 minutes to stabilize the membrane. The feed was then changed to the sample of POME. The system was left for stabilization for 15 minutes. After 30 minutes of running the system, permeate flux was recorded. The turbidity (NTU) value was later analyzed. After 5 hours, the feed was changed back to ionized tank in order to clean and remove any particles off the system. The parameters varied were types of membranes used, pH of the sample (4 – 9) and pressure of the system (10 – 15 bars).

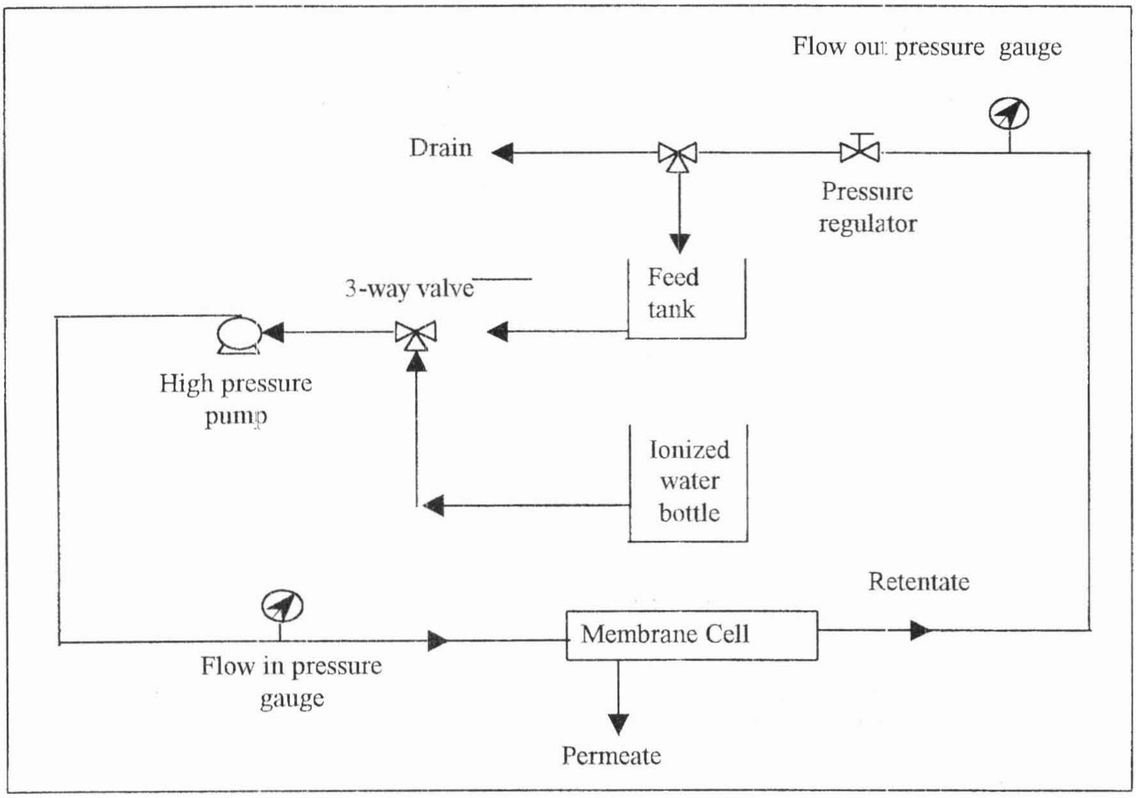

Figure 1: Schematic Diagram of the Membrane Separation Process Rig

RESULTS AND DISCUSSIONS

For solvent extraction process, the best ratio of solvent to POME was obtained at 0.6 with mixing rate of 200 rpm and mixing time of 20 min. This result was achieved at pH 4. Among the six solvents tested in this study, n-hexane was found to be the best solvent to extract almost 56.4% residual oil from the sample of POME.

Adsorption of residual oil increased as the dosage of synthetic rubber was increased until at 300 g dm^{-3} where 67.2% of residual oil was adsorbed. The optimum mixing rate was showed at 100 rpm at mixing time of 3 hours. The best removal of residual oil was obtained at pH 9.

Table 3 simplifies the results obtained after membrane separation process using reverse osmosis membrane. It shown that the percentage of oil removal increased as the pressure decrease and the pH increase. Increasing the pressure would force more water to pass through the membrane. Since the movement of oil across the membrane was determined by the flow of water, the greater reduction of oil was achieved at pressure of 10 bar compared with 15 bar. Meanwhile, higher oil removal was obtained at pH 9. This is probably because decreasing the pH of the feed solution minimized the effect of concentration polarization and membrane fouling. Therefore, higher permeate flux was obtained at acidic pH and hence reduce the percentage removal of oil.

Table 3: Percentage oil removal using ultrafiltration and reverse osmosis membrane

Membrane Type	Oil Removal(%)		
	pH \ Pressure	10 bar	15 bar
CE(GH)	4	40.3	35.7
CE(GK)	4	39.7	34.6
CE(GM)	4	28.01	26.12
CE(GN)	4	27.3	25.73
CE(GH)	7	41.9	36.4
CE(GK)	7	40.4	34.71
CE(GM)	7	31.3	27.2
CE(GN)	7	31.9	26.35
CE(GH)	9	49.23	40.11
CE(GK)	9	47.69	39.56
CE(GM)	9	41.56	33.4
CE(GN)	9	41.75	32.9

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