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Sustainability of Palm Oil Industries: An Innovative Treatment via Membrane Technology

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Abstract: Malaysia is the largest producer of palm oil, the processing of oil palm Fresh Fruit Bunches (FFB) has resulted large amount Palm Oil Mill Effluent (POME). The highly polluting POME is identified as the major stumbling block to the development of palm oil industry in Malaysia. Hence, an integrated membrane process with physical-chemical treatment had been successfully achieved for treatment of POME. The role of membrane was explored significantly; where the chemical treated POME was further treated using ultrafiltration and reverse osmosis membrane. The concept of sustainable development in palm oil industries is achieved by recovering and recycling the crystal clear water and sludge as organic fertilizer from POME back to its process and plantations using the innovative membrane treatment. Consequently, zero discharge is achieved by eliminating the discharge of POME into the rivers.

Key words: Membrane technology, palm oil mill effluent, sustainable

INTRODUCTION

Water, essential to life, is drying up in many parts of the world. The United Nations' report on world water resource in 2006 has shown that more than 10 billion of the world's population lack of enough safe water to support basic needs and 40% of the people have no access to basic hygiene infrastructure. Water shortages, deterioration of water quality and environmental constraints, have led to an increased interest of recovering and recycling water in many parts of the world. In many European countries, water is recovered by membrane filtration and reused in agricultural irrigation, greenhouse horticulture, cooling processes, food and beverage industries, paper industry, poultry industry and textile industry. Progress in water reclamation technology has made the production of high-quality water from such sources possible. To resolve the matter of insufficient water for sustainable development, membrane processes will play an increasingly significant role as the dominant technology in water purification. Membrane technology can make a great contribution since membranes have the ability to produce water of exceptional purity that can be recycled for reuse in a variety of places (Howell, 2004).

Many parts of Malaysia face a lack of water, although the country has renewable water that is five times per head higher than that in many regions in the world and poor water management is the culprit. The country's per capita renewable water was about 5,000 m^3 $year^{-1}$ compared to many regions in the world that had less than 1,000 m^3. Obviously, this problem was attributed to unsustainable management of water resources rather than to the quantity of water available for domestic, industrial and agricultural uses. Water quality issues in Malaysia were expected to become increasingly important as the population continued to grow.

Although, Malaysia is a tropical country having ample of rainfalls, Malaysia has never been a smooth flow of water for even a week. It is not entirely due to drought that has a short supply of water. Urbanization and pollution are main reasons for water stress. In year 2006, seven of Malaysia's 146 river basins were categorized as polluted and all the polluted river basins were in Peninsular Malaysia, with Johor topping the list. In terms of river basin water quality, 80 river basins (55%) were clean, 59 (40%) slightly polluted and 7 (5%) were polluted. The major pollutants were Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (NH_3-N) and Suspended Solids (SS). High BOD was contributed largely by untreated or partially treated sewage and discharges from agro-based and manufacturing industries. The main sources of NH_3-N were domestic sewage and livestock farming, whilst the sources for SS were mostly earthworks and land clearing activities.

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Palm oil production is growing fast in line with the swelling world population and global demand. From the earliest days, oil palm thrives in countries with tropical climate and evenly distributed rainfall. Malaysia and Indonesia have therefore emerged as major producers of palm oil. Malaysia is the largest producer and exporter of palm oil (Latif Ahmad *et al*., 2003). Palm oil processing, similar to other agricultural and industrial activities, raised environmental issues particularly water pollution which adversely affects aquatic life and domestic water supply.

PALM OIL MILL EFFLUENT AND ITS LEGISLATION

Palm oil mills with wet milling process are accounted for major production of palm oil in the country and a significantly large quantity of water is used during the extraction of CPO from the Fresh Fruit Bunch (FFB). About half of the water used in extraction process will result in Palm Oil Mill Effluent (POME) (Thani *et al*., 1999). POME is a high volume liquid wastes which are non-toxic, organic in nature but have an unpleasant odour and are highly polluting (Hwang *et al*., 1978). About 2.5 t of POME are produced for every ton of oil extracted in an oil mill (Ho *et al*., 1984; Songip *et al*., 1996). Thus, in year 2008, 17.73 million tones of palm oil production resulted in about 44.33 million tones of POME.

Palm Oil Mill Effluent (POME) is a colloidal suspension of 95-96% water, 0.6-0.7% oil and 4-5% total solids including 2-4% suspended solids originating from the mixture of a sterilizer condensate, separator sludge and hydrocyclone wastewater (Ma, 2000; Prasertsan and Prasertsan, 1996). It is acidic (pH 4-5) and hot (80-90°C). The typical POME characteristics are shown in Table 1. If the POME is discharged untreated, the amount of Biochemical Oxygen Demand (BOD) produced in year 2008 was 1.108 million tonnes. By estimating each citizen produces 14.6 kg of BOD every year (Doorn *et al*., 2006), this pollution load is equivalent to the waste generated by 75 million people which is about thrice the population of Malaysia.

Currently, the majority of palm oil mills have adopted conventional biological treatment of anaerobic or facultative digestion which needs large treatment area and long treatment periods (80-120 days). In addition, the microorganisms which are the COD and BOD digester require intensive care as they are sensitive to the surrounding temperature and pH. Thus, skilled and experienced workers are needed for complete maintenance and control to ensure the biological treatment is implemented in an order manner. High content of suspended solids and organic matters in the effluent discharge can cause severe pollution of waterways due to oxygen-depletion and other related effects. Thus, riverine communities and users of rivers and streams are very vulnerable to the adverse pollution impact of indiscriminate discharge of palm oil mill effluent.

In Malaysia, the oil palm industry is deeply committed to comply with a wide array of environmental laws. The government enacted the Environment Quality Act in 1974 and specific regulations for POME in 1977. The parameter limits for watercourse discharge is shown in Table 2. Nevertheless, even though strong emphasis has been placed on research and development of various aspects of palm oil cultivation and management, from planting techniques to waste management technologies, many mills are still unable to adhere to the established standard discharge regulations. This has consequently led to a dramatic increase in the number of polluted rivers.

Table 1: Characteristics of palm oil mill effluent (Ma, 2000; Chow, 1991)

Parameters	Concentration*
pH	4.7
Oil and grease	4,000
Biochemical oxygen demand	25,000
Chemical Oxygen Demand (COD)	50,000
Total solids	40,500
Suspended solids	18,000
Total volatile solids	34,000
Ammoniacal nitrogen	35
Total nitrogen	750
Elements	
Phosphorus	180
Potassium	2,270
Magnesium	615
Calcium	439
Boron	7.6
Iron	46.5
Manganese	2.0
Copper	0.89
Zinc	2.3

*All parameter's units in mg L^{-1} except pH

Table 2: Parameter limits for watercourse discharge

	Limits according to period of discharge		
Parameters	1.7.1978 - 30.6.1979	1.7.1981 - 30.6.1982	1.1.1984 and thereafter
BOD 3 day, 30°C (mg L^{-1})	5,000	500	100
COD (mg L^{-1})	10,000	1,000	-
Total solids (mg L^{-1})	4,000	1,500	-
Suspended solids (mg L^{-1})	1,200	400	400
Oil and grease (mg L^{-1})	150	50	50
Ammoniacal-nitrogen (mg L^{-1})	25	10	150*
Total nitrogen (mg L^{-1})	200	50	200*
pH	5.0-9.0	5.0-9.0	5.0-9.0
Temperature (°C)	45	45	45

*Value of filtered sample

MEMBRANE TECHNOLOGY

Facing the problems of water shortages and deterioration of water quality, the needs of environment conservation in order to ensure continuous clean supply of raw water for the future generation are indeed very important. The palm oil mill industry in Malaysia is the industry that produces the ever largest pollution load into the rivers of Malaysia. In order to prevent water pollution caused by the POME discharge without jeopardizing the continuous growth of palm oil as the most important commodity of Malaysia, a clean technology which is environmentally viable has been invented.

Therefore, the goal of the research invention is to introduce a POME treatment method using membrane separation technology by reclaiming the treated crystal clear water and recycling back the water to its process stream as boiler feed water, drinking water and general use water. Membrane technologies are well suited to the recycle and reuse of waste water. Membranes can selectively separate components over a wide range of particle sizes and molecular weights. Membrane technology has become a dignified separation technology over the past decennia (Sonune and Ghate, 2004). The membrane system requires only short treatment period (less than one day), small treatment area and little skill as the system is fully automated.

In recent years, membrane technologies such as microfiltration, ultrafiltration (UF), nanofiltration and Reverse Osmosis (RO) have become a more attractive for drinking water treatment compared to conventional clarification and also desalination and water reclamation. The main advantages of membranes technology are: (Xia *et al*., 2004) membrane equipment has a smaller foot print, separation based on size exclusion, invariable quality of produced water, constant production and water quality independent of feed water quality, easy automation and absence of bacterial regrowth and residual toxicity, no extraneous chemicals are needed and the plant can be highly automated and does not require highly skilled operators (Cheryan, 2005).

There are a number of studies that have been carried out for treating various types of wastewater by using membrane technology for the purpose of recovery and recycling of water. Wu *et al*. (2005) studied on combined system of a bio-activated carbon reactor and Membrane Separation (MS) module in textile dyeing wastewater where the effluent can be reclaimed and reused in a dyeing bath. Nandy *et al*. (2007) conducted water conservation through implementation of ultrafiltration and reverse osmosis system with recourse to recycling of effluent in textile industry. Qin *et al*. (2005) carried out aquaculture wastewater treatment and reuse by wind-driven reverse osmosis membrane technology where the permeate is recirculated to the fish tanks.

POME TREATMENT BY MEMBRANE TECHNOLOGY

POME (Palm Oil Mill Effluent) samples used in this research were obtained from a nearby palm oil mill. The raw POME (70°C) was cooled to room temperature (25°C) before subjected to the series of treatments which included the coagulation-flocculation process and activated carbon and membrane separation process (ultrafiltration and reverse osmosis) as shown in the Fig. 1. Figure 2 shows that the quality of the water improved from each stage of treatment in terms of color, odor and turbidity. The pretreatment processes successful in reducing almost 99.9% of suspended solids content, 95.0% of oil and grease, 86.3% of BOD and 85.0% of COD in POME before entered the membrane treatment (Ahmad *et al*., 2005). This is the mitigation approach to reduce membrane fouling.

Moringa oleifera seed, a biodegradable coagulant could replace the conventional chemical coagulants such as alum and PAC. The suspended solids removal from the raw POME was high after using the *M. oleifera* seeds (after oil extraction) and flocculant (NALCO 7751) with the 99% removal of suspended solids. A further advantage in the usage of *Moringa* seeds includes as safe, natural and environmental friendly coagulant (Bhatia *et al*., 2007).

Table 3 shows POME characteristic after every stage of treatment where the chemical analyses of the RO permeate water complied with the drinking water quality

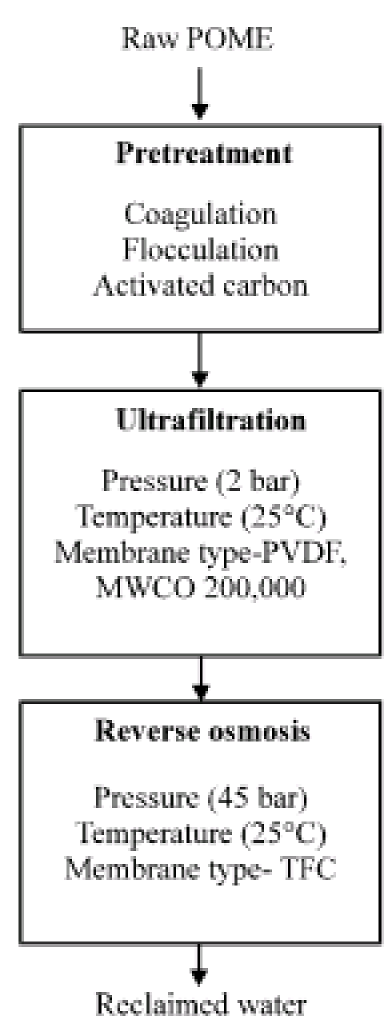

Fig. 1: Flowchart of POME treatment using membrane technology

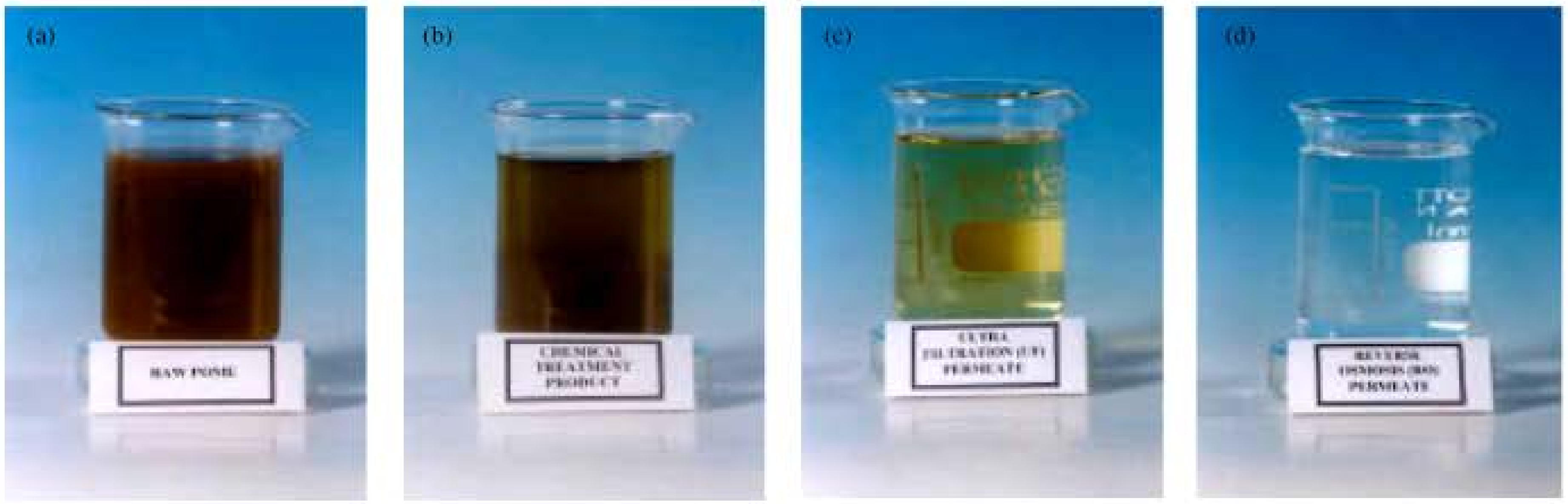

Fig. 2: The quality of water after each stage of treatment using pilot plant scale analysis. (a) Raw POME, (b) Supernatant after chemical physical pretreatment, (c) Permeate of ultrafiltration and (d) Permeate of reverse osmosis (drinking water)

Table 3: The POME characteristic of every stage of treatment and the drinking water standard set by US Environmental Protection Agency (USEPA) (Ahmad *et al*., 2006)

Parameters	POME	Pretreatment	Ultrafiltration	Reverse osmosis	USEPA standard
pH	4.7	4.9	5.66	6.63	6.5-8.5
Color (color units)	151	128	54	ND	15
Odor, threshold odor number	300	150	70	ND	3
Turbidity (NTU)	11,000	34	0.65	0.02	<0.5
COD (mg L^{-1})	50,000	15,000	12,400	88	NR
Total dissolved solids (mg L^{-1})	20,500	8850	6640	130	500
Oil and grease (mg L^{-1})	4,000	80	ND	ND	0.3
Nitrogen (organic) (mg L^{-1})	750	748	710	0.50	NR
Ammoniacal nitrogen (mg L^{-1})	35	37	30	0.50	NR
Al (mg L^{-1})	3.9	0.52	0.34	ND	0.05-0.2
K (mg L^{-1})	2270	1169	360	5.45	NR
Mg (mg L^{-1})	615	589	181	2.74	150
Ca (mg L^{-1})	439	421	129	1.95	NR
Fe (mg L^{-1})	46.5	13.53	0.07	ND	0.3
Mn (mg L^{-1})	2	1.24	0.44	ND	0.05
Cu (mg L^{-1})	0.89	0.11	0.11	0.03	1.3
Zn (mg L^{-1})	2.3	0.08	0.04	0.01	5

ND: Not detectable, NR: Not required

standard set by USEPA (US Environment Protection Agency). The treatment of POME in the present studies gave more than 99% removal of COD, total dissolved solids, nitrogen (organic) and almost 99% removal of ammoniacal nitrogen. The proposed treatment method had completely removed the color, odor, turbidity, oil and grease with the final pH of 6.63. The minerals and heavy metals analysis according to Table 3 shows a great reduction in their concentrations and thus well below the Maximum Contaminant Level (MCL) set by the USEPA for drinking water standard. Therefore, the analysis of the reclaimed water quality proves that the reclaimed water complied with the drinking water quality standards of USEPA (Ahmad *et al*., 2006).

For processing every 30 metric tonnes FFB, it requires 45 metric tonnes water and it generates 20 metric tonnes of effluent that required to be treated. By applying membrane technology system for treating POME, it is estimated that 85% of water from the effluent can be recycled (Latif Ahmad *et al*., 2003). This can reduce the operating costs as well as to protect our environment since no wastewater (POME) is going to be discharged to the environment.

Membrane cleaning was done by flushing water, followed by low concentration of sodium hydroxide, water and low concentration of nitric acid. The flux after cleaning was 90.83 and 88.39% of the initial flux value for the UF and RO, respectively. By using chemical cleaning, it was showed that the membrane fouling was primarily due to cake formation which was reversible. The cake layer could be easily removed when the membranes were cleaned with chemicals and the membrane performance can be restored to its initial state (Ahmad *et al*., 2006).

Sustainability, or sustainable development, has become an important environmental benchmark for both process industries and the service industries (Fane, 2007).

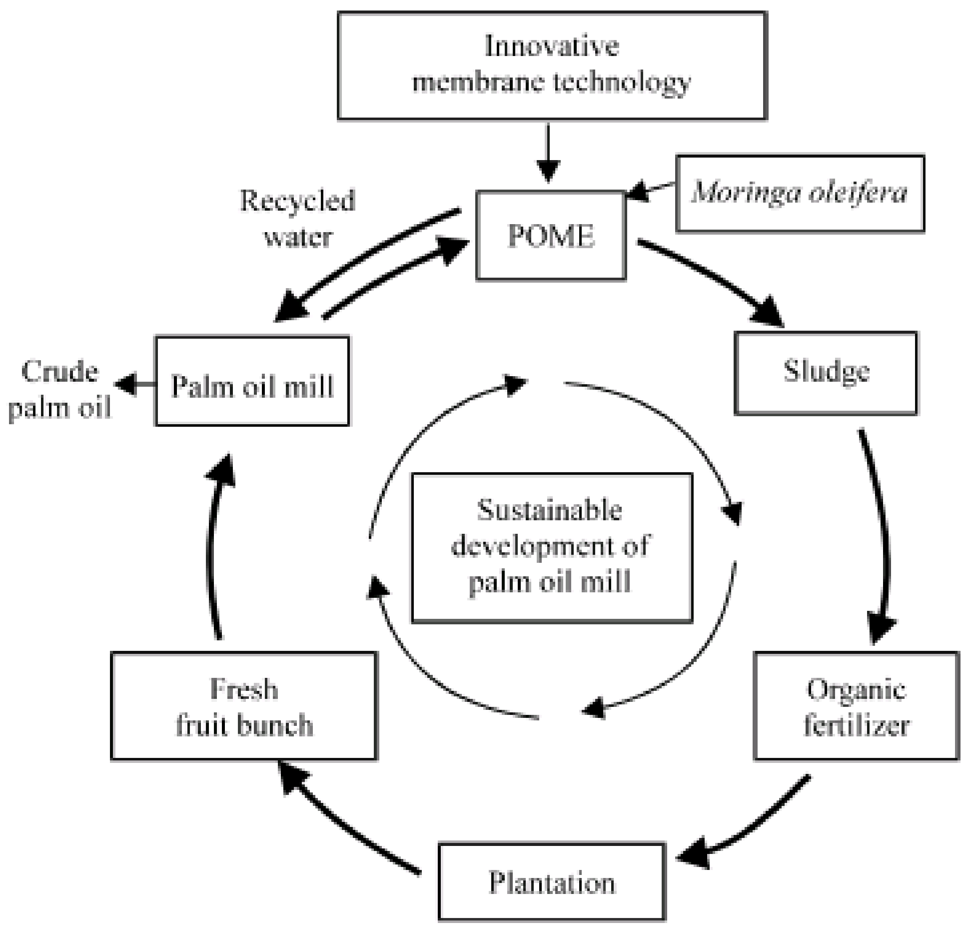

Fig. 3: Sustainable development of palm oil mill with zero discharge using membrane technology

Based on Fig. 3, sustainable development of the palm oil mills can be achieved by using the innovative membrane treatment. The membrane will reject the pollutants and recycles the crystal clear water back to its process. Thus, the water consumption in the mills is greatly reduced. Besides, the sludge generated can be used as the organic fertilizer which is recycled back to the plantations. Consequently, zero discharge is achieved by eliminating the discharge of POME into the rivers and this gives a high impact toward environmental conservation. A closed cycle for the complete process enables the sustainable development for the palm oil mills to be achieved through this study.

FUTURE OF MEMBRANE TECHNOLOGY IN WASTEWATER TREATMENT IN MALAYSIA

The main bottleneck of membrane separation problem is membrane fouling. Therefore, effective techniques of membrane cleaning need to be studied to mitigate membrane fouling to extend the life span of the membrane which enhances its attractiveness usage in wastewater treatment.

For the time being, there is no local membrane fabricator and the membrane is being imported and expensive. In order to have reasonable price and adequate supply of membrane, Malaysian made membrane should be produced. Research on synthesis, characterization and development of economically viable membrane suitable for wastewater treatment should be done. When membranes are made locally and membrane fouling can be solve, the rules and regulations set by the Department of Environment on the wastewater release to the river can be more stringent. By enforcing new rules, better environment quality and water quality can be achieved.

Membrane bioreactor (MBR) can also be used to replace the conventional treatment system as it offers many advantages such as superior effluent quality and a smaller footprint than that needed to treat the same amount of wastewater. Membrane processes will continue to play a key role in ensuring sufficient and superior water withstanding the various challenges and concerns to meet the growing demand for water. With advances in membrane technology addressing emerging contaminants and fouling, water reclamation will become a competitive option for meeting water demand.

CONCLUSION

Special focus has been given for palm oil industries since this is Malaysia most important agro based industry. Introducing membrane technology to treat POME would be a main technology revolution or turning point in palm oil industry. Most of the water content could be recovered and recycled for internal use at the mill by using membrane technology. Current invention is the green technology to prevent water shortages and deterioration of water quality, protect the environment and its ecological system besides ensuring the continuous growth of the palm oil as the most important commodity of Malaysia. In overall, this technology can ensure the sustainability development of our palm oil industries.

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