ORIGINAL ARTICLE

Pre-treatment and membrane ultrafiltration using treated palm oil mill effluent (POME)

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Abstract

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Treatment of palm oil mill effluent (POME) has always been a topic of research in Malaysia. This effluent that is extremely rich in organic content needs to be properly treated to minimize environmental hazards before it is released into watercourses. The common practice for treating POME in Malaysia involves a combination of aerobic and anaerobic methods. The purpose of tertiary treatment is to allow the treated water to be reused in the mill operations for other purposes such as feed water. The proposed treatment will also ensure the industry to meet a more stringent discharge standard in terms of the BOD, COD and nitrogen values. In this study membrane ultrafiltration is used as the tertiary treatment method. Before the actual membrane operation was conducted, the samples were pre-treated using three separate method namely filtration, centrifugation and coagulation. It was found that the combination of filtration-ultrafiltration treatment POME produced the best-treated sample quality in terms of pollutant contents elimination, namely % BOD, % COD and % nitrogen removal.

Key words : membrane technology, ultrafiltration, POME

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Palm oil industry is at present, the largest agro-based industry in Malaysia. It accounts for 49.5% of world production and 64.5% of world exports in 1998. In that year alone, Malaysia produced 7,425,000 tonnes of palm oil for world-wide export (Industrial Processes and The Environment Handbook No.3, 1999), which was approximately 618,750 tonnes per month. In May 2001, the amount of crude palm oil production increased, hitting a high of 985,063 tonnes (Palm Oil Link, 2001).

Given this huge amount of palm oil production, the quantity of resources needed and the quantity of wastes produced are therefore expected to be great. A typical palm oil mill releases liquid effluent, known as palm oil mill effluent (POME), gaseous emissions from boilers and incinerators, solid waste materials and by-products that include empty fruit bunches (EFB), potash ash, palm kernel, fiber and shells. These wastes, if not disposed of properly, will have great impacts on the surrounding environment.

Wastewater that is not treated properly will lead to water pollution. Inappropriate handling and disposal of solid wastes from boilers, incinerators, and sludge separators will cause environmental degradation such as air pollution, noise pollution and odour emission.

Compared to gaseous emissions and solid waste production, water and wastewater management in crude palm oil mills has long been a topic of research and discussion. This is due to the large amount of water needed for palm oil mill extraction and the indiscriminate discharge of untreated or partially treated POME into public watercourses.

POME treatment technology

During the processing of fresh fruit bunches (FFB), water is the most needed resource. To process one tonne of FFB, typically 1.5 m^3 of water is used (Industrial Processes and The Environment Handbook No.3, 1999). Out of this amount, 50% will be released as POME and the rest of the water is lost as steam and boiler blow down, wash waters and leakage.

Based on the statistical value of total crude palm oil production in May 2001, the production of 985,063 tonnes of crude palm oil means a total of 1,477,595 m^3 of water was used, and 738,797 m^3 was released as POME, in that month alone. Without proper treatment, this wastewater will pollute watercourses receiving it.

The current treatment technology of POME typically consists of biological aerobic and anaerobic digestion. Biologically treated effluent is disposed of via land application system, thus providing essential nutrients for growing plants. This method may be a good choice for disposal of treated effluent. However, considering the rate of daily wastewater production, for example, approximately 26 m^3 per day for an average palm oil mill with an operating capacity of 35 tonnes FFB per day, it is doubtful that the surrounding plantations receiving it could efficiently absorb all the treated effluent.

Another new technology under research is the zero waste evaporation technology. By evaporating the POME, water can be recovered while the residual solid content can be utilized as fertilizer. Although this method reclaims about 80% of water from POME, a major drawback is the high energy requirement (Ma, 1996).

Since the ultimate goal of wastewater management is towards zero discharge, the best wastewater treatment scheme is inevitably a treatment that allows 100% reuse and recycling of wastewater. If one considers the volume of water needed by the crude palm oil milling industry, the practice of releasing treated wastewater without further reuse in-house is a wasteful exercise.

Another alternative to minimize fresh water and energy consumption is to reuse wastewater directly from the final treatment pond. This could be as feed water for boiler or hydro cyclone. However, if this is the solution, a higher quality of treated water is required especially when it is to be used as boiler feed water. The current treatment system of anaerobic followed by aerobic degradation is not capable of producing such high quality treated effluent.

A possible technological solution to produce higher quality effluent is through the use of membrane technology at the tertiary treatment stage. Membrane treatment is capable of providing a highly efficient treatment, requires minimal energy, and does not introduce any additives to the waste stream.

There are many membrane process applications on water and wastewater treatment that has proven to be efficient. Membrane technology covers a large spectrum of separation techniques, ranging from reverse osmosis to microfiltration. Among the various membrane processing technologies, ultrafiltration offers 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.

Although the biologically treated POME is already low in biodegradable organic contents, it still possesses significant amount of persistent cellulosic materials and oily residues that usually occur in the form of macromolecules.

With membrane ultrafiltration, these molecules could be separated from the waste stream thus producing a higher quality effluent. In this research project, a study has been carried out to examine the feasibility of using membrane ultrafiltration for the final treatment of POME extracted from the aerobic treatment pond. The general objectives are to

(i) Evaluate the effectiveness of membrane ultrafiltration of treated POME and
(ii) Investigate the possibilities of water reuse and water recycling of the membrane-filtered treated POME.

Methodology

The experimental part of this study followed the sequence as shown below:

Sample collection

An adequate quantity of sample was collected from a palm oil mill. A portion of the raw sample was preserved and the characteristics of the raw sample were analysed.

(i) Pre-treatment of samples

Three types of pre-treatment were applied separately to compare the effectiveness of each treatment. These treatments were:

A) Filtration
B) Centrifugation
C) Coagulation

(ii) Stirred-cell ultrafiltration

After pre-treatment, samples were ultrafiltered using a bench-scale stirred cell ultrafiltration unit (Spectrum Molecular/Por Stirred Cell-Model No.20062). The membrane material used was 76-mm Spectrum Cellulose Ester Disc with MWCO of 5000. A few aspects were studied. The following parameters were investigated:

a) Pure water flux

Pure water flux characteristics for the membrane was obtained by filtering deionised water at an increment of every 1 bar of transmembrane pressure (from 1 bar to 7 bar).

b) Sample Flux

Flux for each pre-treated sample was obtained for comparison purpose. The flux was observed in the range of 1 bar to 7 bar of transmembrane pressure.

c) Variation of pH value of sample

In order to investigate the effect of pH value on rejection characteristics (COD, total solids, suspended solids, ammoniacal nitrogen, total nitrogen and colour), ultrafiltration of filtered and centrifuged samples were conducted at two different pH values at transmembrane pressures of 4.5 bar and 7.0 bar. The two pH values were pH 8 (original value of effluent) and pH 2.2 (pH at iso-electric point of cellulose membrane)(Bowen and Clark, 1984).

Ultrafiltration of the sample that was pretreated with coagulation technique was lastly carried out at the pH value that gave better rejection characteristics on the filtered and coagulated samples.

d) Variation of transmembrane pressure

To study the effect of pressure on rejection characteristics, samples pre-treated using filtration and centrifugation methods were ultrafiltered at 2 different values of TMP. Duplicate runs for each sample at TMP of 4.5 bar and 7.0 bar were undertaken. The TMP that gave the better rejection characteristics was then applied for ultrafiltration of the sample that was pre-treated using the coagulation technique.

(iii) Characteristic analysis of samples

In order to evaluate the efficiency of membrane ultrafiltration, selected parameters were chosen to characterize the various samples (raw, pre-treated and permeate). These parameters are of great importance for effluent characterization and the values need to meet the level of statutory discharge limits in the Environmental Quality Act (Prevailing Effluent Discharge Standards for Crude Palm Oil Mills, 1984) before being released into watercourses. The parameters are Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN), Total Kjeldahl Nitrogen (TKN), suspended solids (SS), turbidity and colour.

Results and Discussion

To study the overall treatment efficiency of pre-treatment followed by ultrafiltration, a comparison between untreated and treated sample is necessary.

a) Filtration – ultrafiltration pretreatment

From Figure 1, it is clear that the filtration-ultrafiltration system was able to bring down parameter measurements extensively. Suspended solids, turbidity and colour content were the best

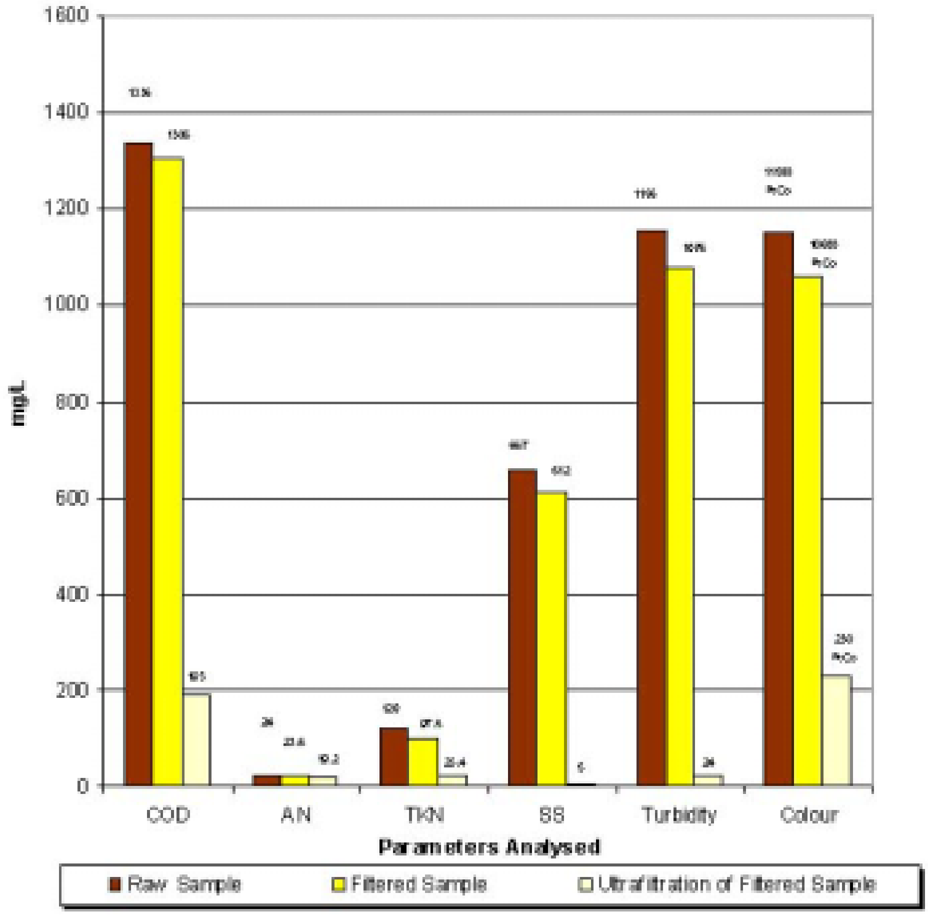

Figure 1. Characteristics of raw, filtered and ultrafiltered filtered sample

treated parameters, with percentage removal reaching 99.2%, 7.9% and 98.2% respectively. COD level was reduced to less than 200 mg/L from the original 1336 mg/L. Total nitrogen concentration was 25.4 mg/L after treatment, showing a 78.8% reduction. Ammoniacal nitrogen only recorded a 5.8 mg/L improvement, equivalent to 21.3% percentage reduction.

b) Centrifugation – ultrafiltration pre-treatment

For centrifugation-ultrafiltration system, as shown in Figure 2, the final quality of the treated sample was not as remarkable. Though elimination of suspended solids, turbidity and colour content were over 90%, the final level of suspended solids (40 mg/L), turbidity (100 mg/L) and colour (800 PtCo) were rather high compared to those achieved by filtration-ultrafiltration. The next parameter, COD, could only be treated to a concentration of 591 mg/L from the initial 1336 mg/L, which was 55.8% removal. Total nitrogen was at a level of 39.5 mg/L after treatment while concentration of ammoniacal nitrogen after treatment was 17.2 mg/L.

c) Coagulation – ultrafiltration pre-treatment

The third system, coagulation-ultrafiltration, performed moderately compared to the previous systems. Besides the outstanding 100% removal of suspended solids, removal of turbidity was 77.2%, bringing the turbidity value from 1113 mg/L to 90 mg/L. Colour removal was 76.9%, recording a 740 PtCo of treated sample (refer Figure 3). Reduction of COD, total nitrogen and ammoniacal nitrogen was 49.5%, 14.2% and 10.9% respectively.

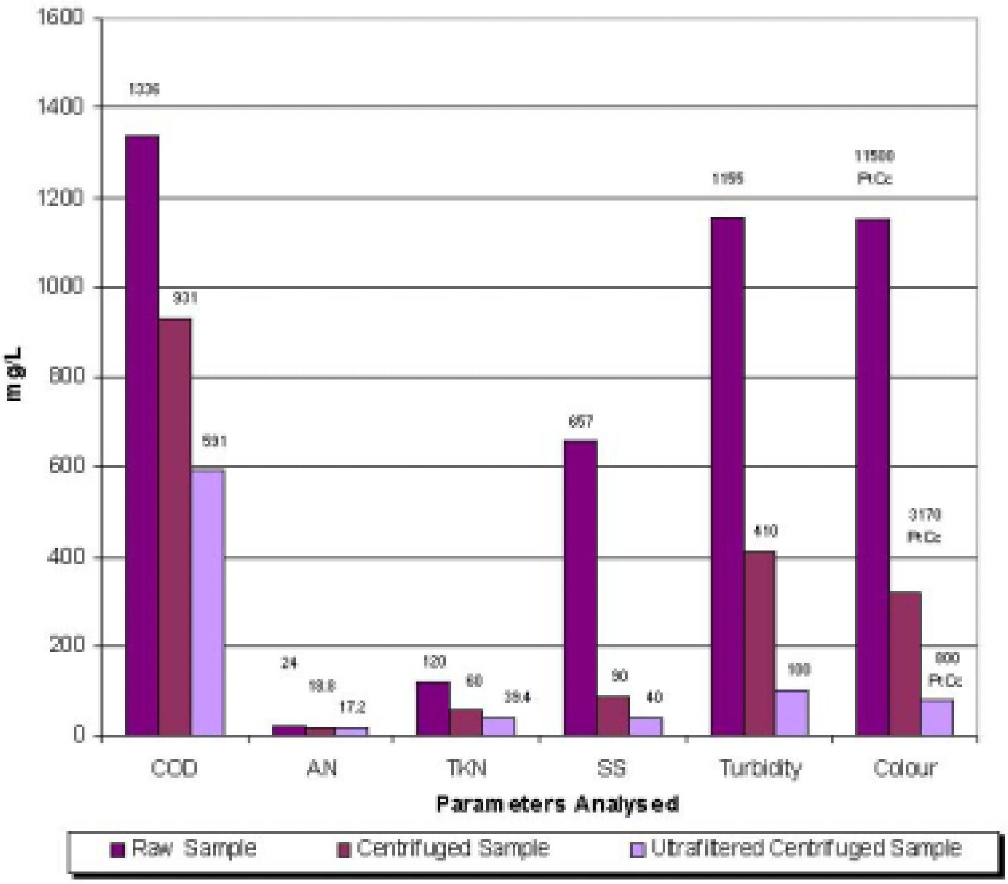

Figure 2. Characteristics of raw, centrifuged and ultrafiltered centrifuged sample

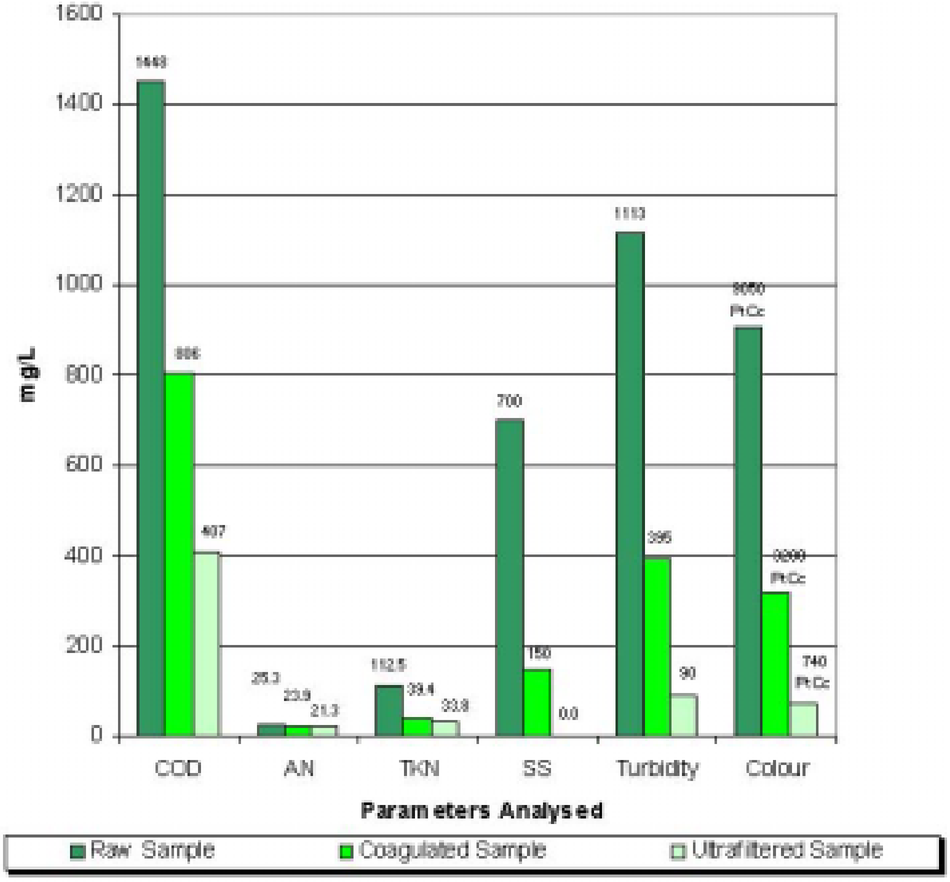

Figure 3. Characteristics of raw, coagulated and ultrafiltered coagulated sample

d) Comparison of overall treatment efficiencies

A graph comparing overall the treatment efficiencies of every treatment system is depicted in Figure 4. From the horizontal bars, filtration-ultrafiltration recorded four highest reduction measurements, which were colour, turbidity, total nitrogen and COD, while coagulation-ultrafiltration was best for suspended solids removal and centrifugation-ultrafiltration was only good in treating ammoniacal nitrogen.

Energy wise, filtration is also the best alternative for pre-treatment. Centrifugation requires energy input to supply centrifugal force, coagulation needs energy supply for mixing purposes. Filtration, on the other hand, only requires a filter system with occasional cleaning when granular sand filter bed is used.

The overall treatment results once again showed correlation among colour, turbidity and suspended solids. Thus, it could be concluded that colour in the POME effluent is apparent colour caused by suspended matters. It could be treated more easily than true colour, as once the suspended solids are removed, the colour will disappear as well.

The low reduction of COD, ammoniacal nitrogen and total nitrogen implies that they are caused by fine soluble compounds, with molecular weight below 5 000. To reduce it with membrane ultrafiltration will be a challenge as membrane with MWCO less than 5 000 has even smaller pores such that the potential for fouling would be higher.

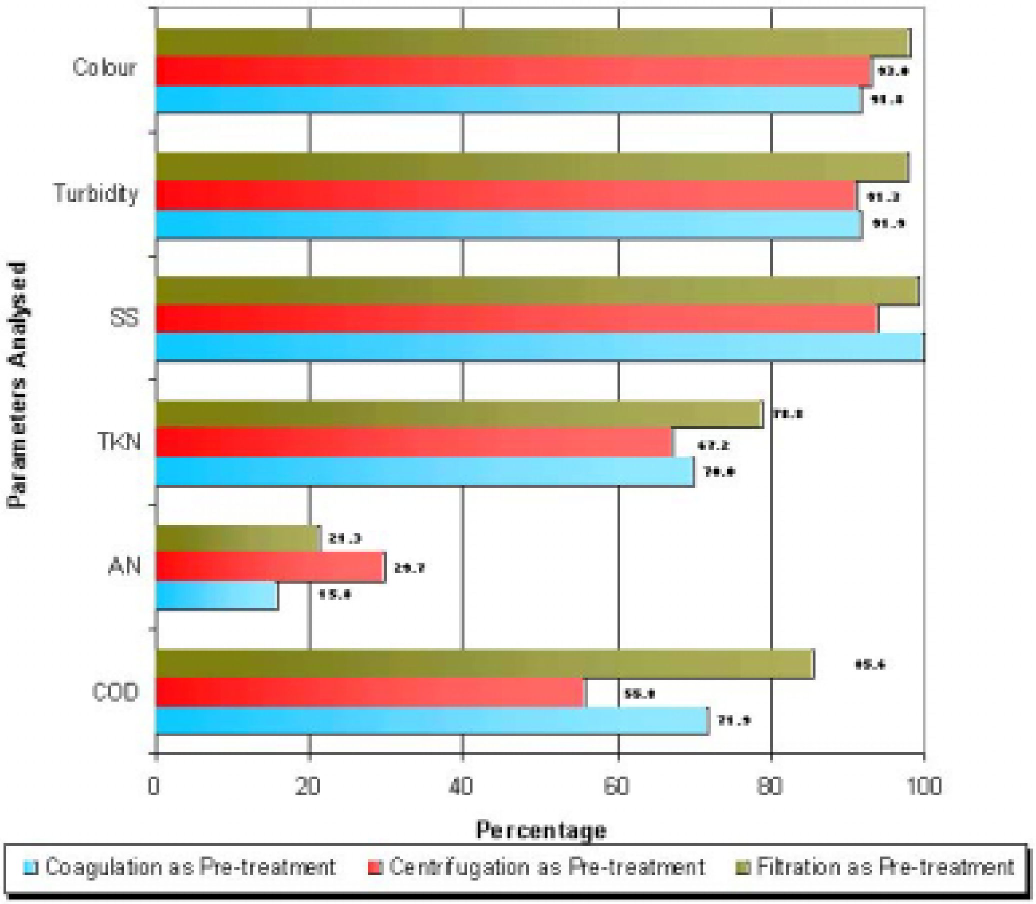

Figure 4. Overall treatment efficiency of ultrafiltration with different pre-treatments

Conclusions

From the results obtained from the experimental studies, centrifugation and coagulation each gave a different pre-treatment quality that was better than the filtration method of pre-treatment. Coagulation was able to reduce total nitrogen, suspended solids, turbidity and colour as much as an average of 68%. Centrifugation, on the other hand, recorded an average of 68.3% reduction of those parameters. Filtration, however, only achieved an average elimination of 10.1%.

Nevertheless, the overall treatment quality provided a totally different picture. Combination of filtration-ultrafiltration treatment gave the best overall treatment efficiency, with an overall reduction of 93.4% for total nitrogen, suspended solids, turbidity and colour content. For the treatment combination of centrifugation-ultrafiltration, the average removal efficiency was only 86.4% while coagulation-ultrafiltration treatment only managed to achieve an average of 67.1% removal.

The effect of transmembrane pressure on solute rejection was such that solute rejection tends to decrease with increasing transmem brane pressure. By applying larger transmembrane pressure on the membrane, pores are opened up thus providing wider paths for the solute to pass through. This is an advantage for membrane application in actual industry as lower transmembrane pressure gives better efficiency and at the same time requires less energy consumption.

Influence of pH on solute retention was also significant. The original pH of sample (pH 8) provided the best rejection environment compared with pH 2.2, which represented the lower pH range. Thus, treated POME can be fed directly to the membrane treatment plant after adequate cooling without any need of additives or adjustments on the chemical properties of the treated POME.

Filtration-ultrafiltration effluent showed characteristics close to the new effluent discharge standards proposed to be implemented in year 2005. To conclude, ultrafiltration treatment of treated POME proved to have good potential in treated POME treatment to comply with regulations that gets more stringent with time.

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