INFLUENCE OF THE SETTLEABILITY PARAMETERS FOR PALM OIL MILL EFFLUENT (POME) PRETREATMENT BY USING *MORINGA OLEIFERA* SEEDS AS AN ENVIRONMENTAL FRIENDLY COAGULANT

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ABSTRACT

Palm Oil Mill Effluent (POME) treatment is an important issue for the minimization of pollution. POME is a highly polluting effluent containing various forms of organics and inorganic suspended solids. The coagulation - flocculation process using *Moringa oleifera* seeds after oil extraction (MOAE) as a natural coagulant presents a viable alternative for the treatment of POME. A series of jar tests were conducted to determine the parameters involved during coagulation-flocculation process. The influence of the different operating parameters over the sediment volumetric percentage, settling velocity, sludge volume index and residual conductivity of the POME treated supernatant to achieve good settleability parameters in the physicochemical treatment of POME wastewater were studied. The operating parameters were the effect of stirring speed, mixing time, pH, MOAE dosage and temperature. The pretreatment using MOAE with NALCO 7751 flocculant resulted in 99.2% suspended solids removal and 52.5% COD reduction.

Keywords: *Moringa oleifera* seeds; POME, Settleability Parameters; Jar Test; Coagulation-Flocculation Process

INTRODUCTION

Southeast Asia is currently dominant region of production of oil palm (*Elaeis guineensis* Jacq.), with Malaysia being the leading producer and exporter of palm oil. Oil palm production in Malaysia presently occupies around 3.7 Mha, of which over 2 Mha are in peninsular Malaysia and the rest in the east Malaysian states of Sabah and Sarawak [1]. In year 2004-2005, the amount of crude palm oil production increased to 13.0 Mt [2]. With such a huge amount of palm oil production, the quantity of wastes produced is also high. The three main sources of liquid effluent from a conventional palm oil mill are sterilizer condensate, hydrocyclone waste and separator sludge. In most mills, all three wastewater streams, amounting to about 3 t per tonne of palm oil produced are combined together resulting in a viscous brown liquid. The mixed Palm Oil Mill Effluent (POME) is highly polluting and characterized by low pH, high Biological and Chemical Oxygen Demands (BOD and COD, respectively) and suspended solids. This waste, if not disposed of properly, will pollute the surrounding environment [3].

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, it is doubtful that the surrounding plantations receiving it could efficiently absorb all the treated effluent. Another new technology 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 80% of water recovery from POME, a major drawback is the high energy requirement [4].

Therefore, an alternative POME treatment with an environmentally friendly coagulant and biodegradable flocculant using coagulation - flocculation process is required. This process could lead to an improvement in effluent treatment and reducing the treatment cost. Application of natural coagulant in POME wastewater using physical treatment from coagulation - flocculation process could present a new alternative of POME treatment. The use of chemical coagulant or flocculant such as alum (aluminium sulphate) or polyaluminium chloride (PAC) is not accurate choice in POME treatment. Alum and PAC have an aluminium content which has a number of disadvantages: a high concentration of aluminium in water may be associated with human health problems [5], may be toxic for aquatic life and produce a large volume of sludge. Besides, high cost of these chemicals, disposal of sludge with a high concentration of residual metal could be difficult. Thus, selections from natural, environmentally friendly coagulant and biodegradable flocculant are the better alternatives to be used in POME treatment. In recent years, there has been a resurgence of interest to use natural materials due to their cost and associated health and environmental concerns of synthetic organic polymers and inorganic chemicals. The biodegradable nature of *Moringa oleifera* seed makes it a preferred choice over the other materials.

Moringa oleifera is a multi purpose tree with most of its parts being useful for a number of applications and it is being referred to as the *'miracle tree'* [6]. The crude *Moringa oleifera* seed extract is commonly used for water purification at household level in some areas. For instance villagers in Sudan have been traditionally using the *Moringa oleifera* seed to purify water from the Nile River [7]. Recently efforts are being made to use it for water purification at treatment plants for community water supply. Several studies have reported the use of crude extracts from the seed for coagulation [7-10]. Muyibi and Evison [10] reported that *Moringa oleifera* seed could achieve turbidity removal between of 92% to 99%. Coagulation effectiveness of *Moringa oleifera* varies depending on the initial turbidity. It is very effective for high turbidity waters and shows similar coagulation effects as alum [8].

In this research project, a study has been carried out to examine the pretreatment of POME with *Moringa oleifera* seeds after extraction of oil (MOAE) as an environmentally friendly coagulant, along with biodegradable flocculant (NALCO 7751) are reported and conducted in Jar Test. In order to find out the good settleability parameters were also studied with the influence of sediment volumetric percentage, settling velocity, sludge volume index and residual conductivity. The effect of temperature is needed to be studied since POME is discharged at temperature of $75^{o}C$ - $85^{o}C$ from palm oil mills.

MATERIALS AND METHODS

POME Sample Collection. POME sample was collected from United Palm Oil Mill, Nibong Tebal, Penang and are cooled to room temperature. The characteristics of POME were obtained following APHA Standard Methods of Examination of Water and Wastewater [11] as shown in Table 1. Although the characteristics of POME could vary but, in order to minimize the effect of different characteristics of POME, the experiments were repeated with different samples of POME to obtain the average results that can be applied to the treatment of different POME samples.

Table 1: Typical characteristic of Palm Oil Mill Effluent

Parameters	***Range***	**Average value**
Temperature (^oC)	75 - 90	80
pH	4.0 – 4.8	4.5
Suspended solid, SS (mg/L)	11,500 – 22,000	17,927
Total Solid, TS (mg/L)	36,500 – 42,600	39,470
Chemical Oxygen Demand, COD (mg/L)	30,000 – 50,400	40,200
Oil and Grease (mg/L)	1,300 – 4,700	2,658
Total Kjeldahl Nitrogen, TKN (mg/L)	660 - 890	800

Coagulant Preparation. The dry *Moringa oleifera* seeds were obtained from Nibong Tebal, Penang, Malaysia. The seed wings and coat were removed manually, good quality seeds were then selected, and the kernel was grounded to a fine powder. Oil content of dry *Moringa oleifera* seeds was extracted with n-hexane as a solvent using Soxhlet apparatus. The extraction was carried out for about 8 hours. Stock solution of the *Moringa oleifera* cake after extraction of oil was prepared by dissolving 5 grams of this cake in 100 mL distilled water. The mixture was stirred in a blender (Model National MX-798S) for two minutes to extract the active ingredients. The resulting suspension was filtered through a muslin cloth. The flocculant (NALCO 7751) was obtained from Merck Sdn. Bhd., Malaysia. The chemical description of milky white liquid flocculant (NALCO 7751) is a formulation of water-soluble polymer, ammonium sulfate and inorganic acid(s). This flocculant was chosen in this research because the material safety data sheet (MSDS) of this flocculant shows that it is non-hazardous and biodegradable. Its also did not contain aluminium in the flocculant. Thus, this flocculant is safe and suitable for POME treatment.

Determination of the Settleability Parameters. The influence of the different operating parameters on the following responses such as sediment volumetric percentage, settling velocity, sludge volume index and residual conductivity in the supernatant of the POME treated to achieve good settleability parameters in the physicochemical treatment of POME wastewater in order to attain a high level of suspended solids and COD removal. The operating parameters studied were the effect of stirring speed, mixing time, pH, *Moringa oleifera* dosage and temperature.

(i) Sediment Percentage (SP). The sediment percentage is the ratio between the volumes beneath the supernatant (suspension interface after 90 min of sedimentation, V_{90}) and the initial wastewater volume, V_o expressed as a percentage.

(ii) Settling Velocity (v_s). The mean settling velocity corresponds to the first 30 min of the settling process and is expressed in centimeters per minute. It is given by the following expression [12]:

$$V_s = \frac{mh_o}{V_o} \qquad (1)$$

where h_o is the height (cm) of the initial column of POME wastewater, V_o is the initial wastewater volume (cm^3) and m is the slope obtained from a plot of the data volume beneath the interface (cm^3) versus time (min).

(iii) Sludge Volume Index (SVI). The sludge volume index (cm^3/g) is the ratio between the volume and the weight of sludge formed after 30 min of settling. It is given by the following expression [12]:

$$SVI = \frac{V_{30}}{V_o\,TSS} \qquad (2)$$

where V_{30} is the volume below the supernatant - suspension interface after 30 min of sedimentation (cm^3), V_o is the initial wastewater volume expressed in liters, and TSS is the total suspended solids content of the POME wastewater in grams per liter.

(iv) Residual Conductivity (K_f). The final conductivity of the supernatant after 90 min of settling was determined using a Benchtop Conductivity/TEMP Meter model EcoMet C75 conductivity meter equipped with a CAT probe.

Coagulation Flocculation Process. In the present study, a series of experiments were carried out using *Moringa oleifera* after oil extraction (MOAE) as a coagulant with flocculant (NALCO 7751) to determine the optimal conditions of settleability parameters due to stirring speed, mixing time, pH, coagulant dosage, and temperature for good sedimentation (in removal of suspended solids and COD reduction), producing the smallest volume of sludge and the lowest possible residual conductivity. The operating parameters used in the trials were stirring speed (50, 75, 100 and 150 rpm), mixing time (5, 15 and 30 min), pH (4 - 9), coagulant dose (500 - 6000 mg/L of MOAE) and temperature (30, 40, 55 and 70^oC).

RESULTS AND DISCUSSION

Settleability Parameters. The settleability parameters in the physico - chemical treatment are important to achieve high removal of suspended solids and organic matter for an efficient and economical treatment of wastewater. The settleability parameters indicate the performance of coagulation - flocculation process. The larger floc size of particles increase the settling velocity (v_s) value while the sludge volume index (SVI) was measures the compaction of the sediment. The sediment percentage (SP) also relates to the floc size and to all the other parameters. The residual conductivity (K_f) reflects the concentration of the salts (mostly due to the coagulant) that remained in the supernatant.

(i) Influence of Stirring Speed on the Settleability Parameters. Adequate mixing is necessary when the coagulant is added and during the formation and growth of the floc. As particle size increases, stirring could break existing flocs to small particles. Although, stirring speed was found to have only a moderate influence on the coagulation process. Fig. 1 shows the influence of stirring speed on the settleability parameters during POME treatment. It can be observed from the figure that the stirring speed of 150 rpm, resulted in the lowest sediment percentage (SP = 70%), and the greatest settling velocity (ν_s = 0.25 cm/min). The sludge volume index decreased to 295 cm^3/g (150 rpm) from 325 cm^3/g (50 rpm). Low values of the sludge volume index usually coincide with the compaction of the sludge when large size of the flocs was obtained. The lowest residual conductivity value was 7.89 mS/cm of the supernatant after treatment and was also obtained at 150 rpm.

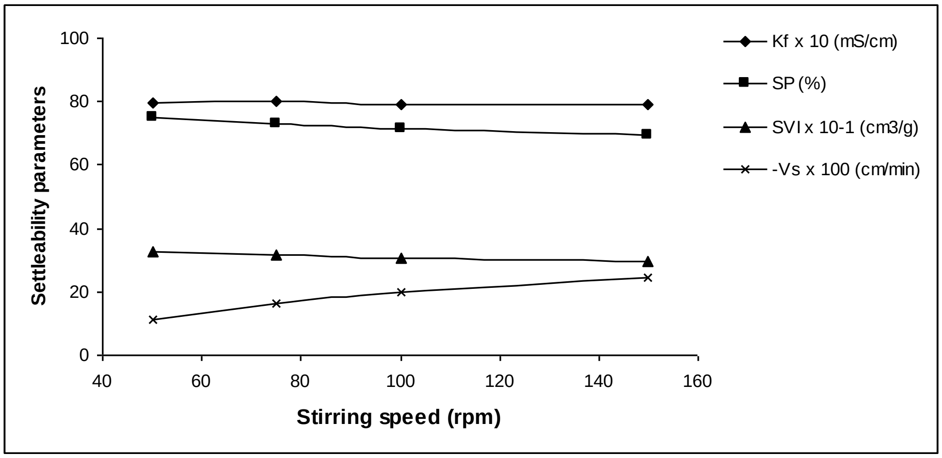

Figure 1: Effect of stirring speed on the settleability parameters in POME wastewater. Coagulant dosage was 4000 mg/L of MOAE; mixing time was 5 min; pH=5; T=30^{o}C.

(ii) Influence of Mixing Time on the Settleability Parameters. The mixing time of the coagulant (MOAE) in the POME wastewater treatment influences the process. Fig. 2 shows the effect of mixing time on the settleability parameters. It can be seen in Fig. 2 that the shortest time of 5 min was enough for formation of the largest flocs (maximum ν_s of 0.28 cm/min) and the smallest volume of sludge (SP = 68%). This indicates that prolonged stirring lead to the breaking of the bonds between the coagulant (MOAE) and the colloidal particles. The sludge volume index remained practically constant (SVI ≈ 300 cm^3/g). The lowest residual conductivity (K_f = 7.50 mS/cm) was also found for a 5 min mixing time. It therefore seems that, although the effect is only moderate, longer mixing times lead to breaking of the flocs [13], with a reduction in settling velocity and a rise in sediment percentage and residual conductivity.

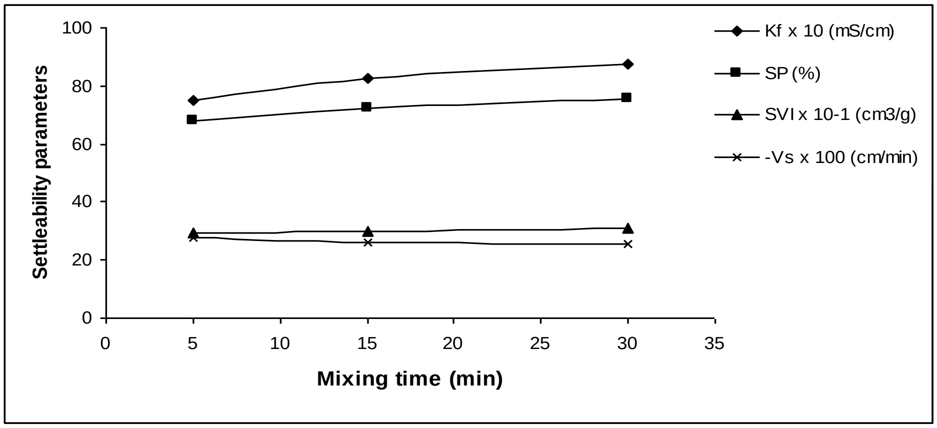

Figure 2: Effect of mixing time on the settleability parameters in POME wastewater. Coagulant dosage was 4000 mg/L of MOAE; stirring speed was 150 rpm; pH=5; T=30°C.

(iii) Influence of pH on the Settleability Parameters. The pH is one of the important factors affecting the performance of the coagulation - flocculation process. It affects the effectiveness of the charge adsorption - neutralization mechanism, while at higher pH the sweep floc coagulation mechanism predominates. The influence of pH on the sedimentation was studied (Fig. 3). As the pH increased from 4 to 5, the sediment percentage (SP) and sludge volume index (SVI) increased, while the settling velocity (ν_s) decreased and smaller flocs were produced, which undergo less compression and hence occupied a greater volume. It could be observed that at pH 5, the removal of suspended solids and COD reduction was increase, probably due to destabilization or neutralization of the particle's charges. Once the pH 5 was increased, there was an increase in the residual conductivity, indicating a greater presence of the OH^- ion in the supernatant of the treated POME.

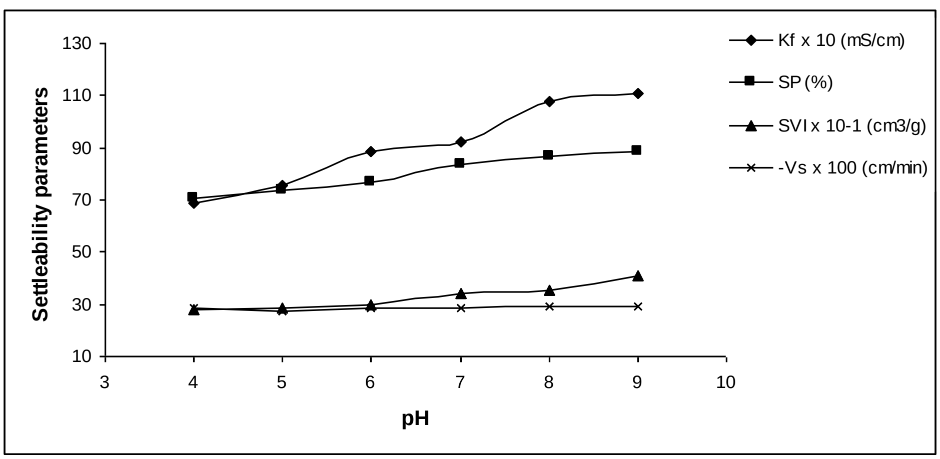

Figure 3: Effect of pH on the settleability parameters in POME wastewater. Coagulant dosage was 4000 mg/L of MOAE; stirring speed was 150 rpm; mix time was 5 min; T=30°C.

(iv) Influence of Coagulant Dosage on the Settleability Parameters. The influence of the coagulant dosage of *Moringa oleifera* after oil extraction (MOAE) was studied, varying the dosage from 500 mg/L to 6000 mg/L keeping all other variables maintained constant. Fig. 4 shows the effect of the coagulant dosage on the settleability parameters (SVI, SP and ν_s) and residual conductivity (K_f) of the supernatant after treatment. The sediment percentage (SP) and sludge volume index (SVI) decreased with increase in the dosage of MOAE from 500 mg/L to 4000 mg/L. Although over 4000 mg/L MOAE, the sediment percentage and sludge volume index were increased. The settling velocity increased with an increase of the coagulant dosage. The residual conductivity was reduced with further addition of the coagulant. With a high coagulant dosage, sweep floc mechanism of coagulation process prevailed and resulted in the reduction of the floc growth rate.

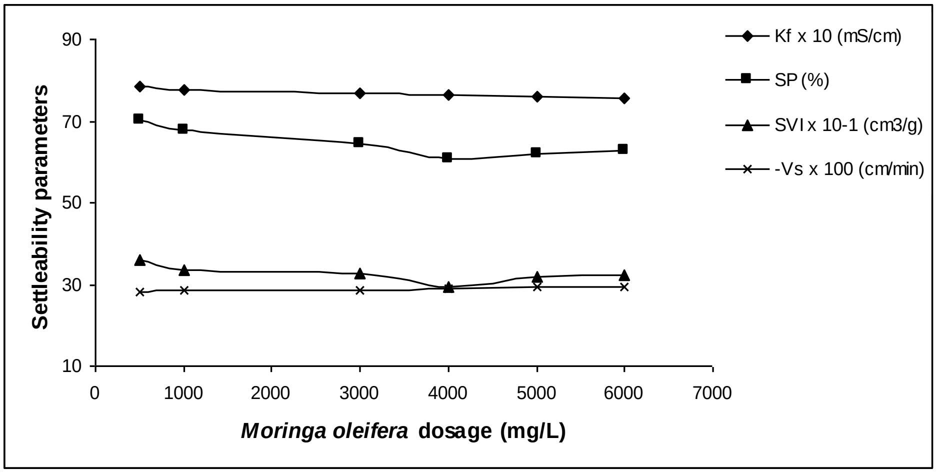

Figure 4: Effect of MOAE dosage on the settleability parameters in POME wastewater. pH = 5; stirring speed was 150 rpm; mix time was 5 min; T=30^{o}C.

(v) Influence of Temperature on the Settleability Parameters. The effect of temperature was studied using *Moringa oleifera* after oil extraction (MOAE) combined with flocculant (NALCO 7751). To increase the efficiency of the coagulation-flocculation process, NALCO 7751 flocculant was introduce with MOAE in order to improve the removal efficiency of suspended solids and COD reduction. Table 2 presents the effect of temperature on suspended solids and COD reduction during coagulation - flocculation process. It can be observed from the table that an increase in the temperature from 30^{o}C to 70^{o}C reduced the efficiency of the coagulation - flocculation process for the removal of suspended solids and COD reduction. The temperature effect may be due to the destabilization of charge on the suspended solids in POME wastewater. Once the temperature of POME is increased with the addition of the coagulant with flocculant or polyelectrolyte, the floc particles size was smaller compare to the size of floc particles at the temperature of 30^{o}C. This might be due to the particle transport processes or particle collision rates and through the effect on viscosity (concentration) in POME. The floc strength becomes weaker with the increase of temperature and the 'macrofloc' can be easily broken.

Table 2: Effect of temperature on 500 mL of raw POME using *Moringa oleifera* after oil extraction at 4000 mg/L dosage with 7000 mg/L of flocculant (NALCO 7751) dosage.

Temperature (^oC)	*Suspended solids removal (%)*	*COD reduction (%)*
30^{o}C	99.2	52.5
40^{o}C	99.0	49.8
55^{o}C	98.6	47.3
70^{o}C	98.5	42.3

CONCLUSIONS

This study demonstrates that *Moringa oleifera* seeds after oil extraction (MOAE) have the potential to become new source of environmentally friendly and natural coagulant for POME pretreatment. It was found that the combination of MOAE with the flocculant (NALCO 7751), the removal of suspended solids was increased to 99.2% and COD reduction as 52.5%. The removal of suspended solids and COD reduction is affected by the stirring speed, mixing time, pH, MOAE dosage and operating temperature. This positive development of POME pretreatment with natural coagulant and biodegradable flocculant would be a paradigm shift in the management of POME treatment. An additional benefit was that 25% by weight of edible oil could be extracted from *Moringa oleifera* seeds as a by-product, making this coagulant more economical in the treatment of POME.

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