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Coagulation of Palm Oil Mill Effluent (POME) at High Temperature

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Abstract: Aluminum sulfate or alum is traditionally used as a coagulant in wastewater treatment since it has proven its effectiveness in the removal suspended solid. In the current study, coagulation process is used as a pre-treatment to remove the high content of the suspended solids for membrane distillation treatment in raw Palm Oil Mill Effluent (POME) at high temperature. The performance in term of percentage suspended solids removal was evaluated to identify the optimum conditions for each of temperatures (30, 50, 60, 70 and 80°C). The operating parameters for the coagulation process which are coagulant dosages (1-6 g L^{-1}) and pH (4-8). The optimum temperature for coagulation process was found at 50°C with pH (6.5) and coagulant dosage (4 g L^{-1}). Thus, these finding shows it can be used as pretreatment before further treat by membrane distillation (MD) treatment.

Key words: Coagulation, palm oil mill effluent, pretreatment, alum, suspended solids

INTRODUCTION

Malaysia is an agro-based country that has a tropical climate and rich with natural resources. In the recent past, Malaysia has become one of the largest producers and exporters of palm oil and its products. In 2011, Malaysia produced 18,911,520 tonnes of crude palm oil and becoming as a second larger producer in an oil world ranking (http://www.mpob.gov.my/). However, the increasing in production and processing of oil palm and its derivatives also comes with its inherent disadvantages, namely environmental pollution and its adverse effects to human and aquatic life. Palm oil industry has been declared as one of the industries that contribute to wastewater problems in Malaysia. Each tones of crude palm oil is expected used 5.0 to 7.5 tones of water and more than 50% of water become as palm oil mill effluent (POME) (Ahmad *et al*., 2003).

POME usually discharged at a temperature of 80-90°C. In Malaysia, ponding system is the preferable treatment methods which is 85% mill used this system as their main treatment. Although, this treatment is operate at low temperature. The POME temperature is necessary to cool down until ambient temperature. POME took a few days to lessen the temperature in pond. Rather than took a few days to cool down the temperature, this paper would like to explore the coagulation at high temperature of POME. The comparison will make between ambient and high temperature. The purpose of the present study was to investigate the efficiency of coagulation process using Aluminium Sulphate in removal suspended solids at high temperature. The optimum experimental conditions such as coagulant dosage and pH were investigated for each of the temperatures from the experiment. The study at high temperature of raw POME can be utilized as a feeder for the treatment of POME with membrane distillation (MD).

MATERIALS AND METHODS

Experimental materials: Raw POME from United Palm Oil Mill, Sungai Kechil, Nibong Tebal, Penang was used as samples in the experiment. The samples were collected at a temperature ranging from 80 to 90°C. Aluminum Sulfate ($Al_2(SO_4)_3.16H_20$) was used as a coagulant agent in this experiment. Dilution for Hydrochloric acid (HCl) 2M and sodium hydroxide (NaOH) 2M were prepared and used during coagulation for pH adjustment.

Jar test procedure: The coagulation tests were carried out following standard practice for coagulation-flocculation testing of wastewater to evaluate the dosage and conditions required to achieve optimum results (Rishel and Ebeling, 2006). A fabricated jar test apparatus consists of four paddle rotors was used to coagulate POME. The jar test apparatus is able to stir simultaneously for four beakers at the same time. Initially, 250 mL of fresh raw POME were measured in each of six beakers at different temperatures. The Alum solutions were varies from (1, 2, 3, 4, 5 and 6 g L^{-1}). Two hundred and fifty milliliter from each of the solutions was destined to the beakers consisting fresh raw POME. Then, the beakers were topped-off to 500 mL with distilled water.

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The temperature of the beakers should be maintained during coagulation. The pH of the sample was adjusted in between pH 4 to 5 which is almost naturally pH POME by adding NaOH. The pH was constant during experiment at each of the temperatures in order to identify the optimum dosage of coagulant. After optimum dosage obtained, pH was varied for each beakers at (4, 5.5, 6.0, 6.5, 7.0, 7.5 and 8) to identify the optimum pH for each of temperatures studied. HCL and NaOH were used to adjust the pH of POME in the beakers. The optimum dosage was constant during coagulation. The solutions was introduced to rapid mixing at 150 rpm for 1 min followed by slow mixing at 40 rpm for 15 min. After mixing, the solutions were let settled for about 30 min. Then, the supernatant sample turbidity value was measured using Lovibond TurbiCheck. Coagulant doses and pH were investigated at different temperatures. The chemical analyses were conducted as per standard method (Ebeling *et al*., 2003).

RESULTS AND DISCUSSION

Effect of coagulant dosage at different temperature: Normally, fresh raw POME is discharged at high temperature at approximately 80 to 90°C. In this experiment, the effect of temperatures in the removal of suspended solids using various dosage of alum was investigated. Coagulation process is used to remove the suspended solids or colloids portion from POME. Different coagulant dosage at different temperatures was evaluated based on percentage suspended solids removal. Figure 1 shows the outcome of different coagulant dosage of alum towards the percentage of suspended solids removal.

The comparison between ambient (30-35°C) temperature and high temperatures (50, 60, 70, 80°C) were studied. The percentage of suspended solids removal is

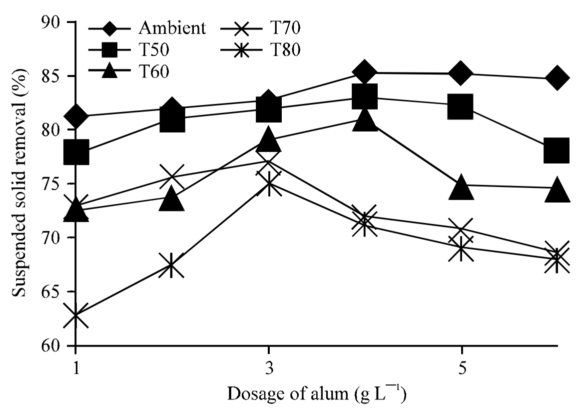

Fig. 1: Percentage suspended solid removal versus coagulant dosage at different temperatures

increasing with the increased in coagulant dosage until it achieved an optimum point for ambient temperature. The same trend was observed for the experiments run at higher temperatures. The increase in coagulant dosage after optimum point achieved did not show any further increase in the percentage suspended solids removal. The addition of the coagulant into the sample was led to destabilization of suspended solids as well as the coagulant itself. The coagulant plays as a role to complete destabilization of colloids in POME and bring them into contact and aggregate. Usually, coagulant has a positive charges is added into the POME to neutralize the negative charges on suspended solids. Introducing rapid mixing allowed particles to interact between coagulant and suspended solids. While at slow mixing resulting in the interaction with suspended solids and forces particles to attach each other thus encouraged the agglomeration (Boisvert *et al*., 1997). After agglomeration, the sedimentation process is allowed for them to settle. High percentage suspended solid removal could be achieved if a correct dosage applied during coagulation process.

It was observed that by increasing the coagulant dosage, the percentage removal of suspended solids decreased. Higher dosage of coagulant was led to a rapid precipitation due to oversaturation. It can be explained when the number of positive charge alum is more than negative charge of colloids in POME may caused reversal of charges when the coagulant dosage used higher than optimum point (Jekel, 1986; Stephenson and Duff, 1996; Norulaini *et al*., 2001). As results, after the optimum point, alum contributed to the increasing of suspended solids in water. It was proven that used of excess alum it may increased Sulfate ions and total solids in water which lead to another problem in wastewater (Stephenson and Duff, 1996). From figure, it must be noted that the percentage of suspended solids removal decrease as temperature increase from 50 to 80°C. The temperature effect contributed to the destabilization of charge on the suspended solids in POME (Bhatia *et al*., 2007). The coagulate particles become smaller compared with the coagulate particles at ambient temperature. This is because of particle transportation processes or particle collision rates and through the effect on the concentration (viscosity) in POME.

Consequently, at high temperature the coagulant strength become weaker because of high molecular weight and it is not easy to stabilize the particles which have high kinetic energy. The particles gain its kinetic energy from the endothermic process which is from heating. Smaller coagulate particles formed at high temperatures and the coagulate particles can be easily broken because of the coagulant and particles cannot stick together

(Bhatia *et al*., 2007). Coagulation process does not favour small sizes of coagulate. In this manner, the percentage suspended solid removal decrease with increases of temperature.

The best parameter value obtained from the jar test is 4 g L^{-1} of coagulant dosage at 50°C with 82% removal of suspended solids is achieved. It can be compared with ambient temperature which is 85% removal of suspended solids with the same coagulant dosage used. However, the coagulation using alum was successfully conducted even at 80°C with 71% of percentage suspended solid removal. The pretreatment is highly necessary for POME before it can undergo other treatment such as Membrane Distillation. Higher content of suspended solids could mitigate the membranes fouling and degradation (Ahmad *et al*., 2005).

Effect of pH at different temperature: In the present study, the effect of pH was studied in the range from 4 to 8 at optimum coagulant dosage in every studied temperature. Figure 2 shows the percentage suspended solids removal towards pH at different temperatures. In coagulation process, pH is one of the important factors in the removal of suspended solids, COD and color. The pH value was dropped once the coagulant added into the sample. In this experimental, pH value was adjusted by adding Sodium Hydroxide (NaOH) and Hydrochloric Acid (HCl).

The result shows that, the optimum pH obtained is at pH 6.5 with 90% suspended solids removal is at ambient temperature. At high temperature 86% suspended solids removal could be achieved at temperature 50°C. It can be conclude that, the percentage of suspended solids removal value is excellent at range pH 6 to 6.5 for POME at ambient as well as at high temperatures. Suorska *et al*. (2000) proved that the coagulant performed best in range 5.0 to 7.5. The percentage suspended solids removal is better in the range of acidic condition because the coagulation performance is high because of the unstable particles or colloids in POME (Sworska *et al*., 2000). From the observation, at low pH the sample appeared to be clear but there are still small particles presences in supernatant. As pH increased, the percentage suspended solids removal become poorer. The colour of POME changed to dark brown because of higher suspended solids presence when the pH shifted to alkaline and it may cause the reduction of percentage suspended solids value.

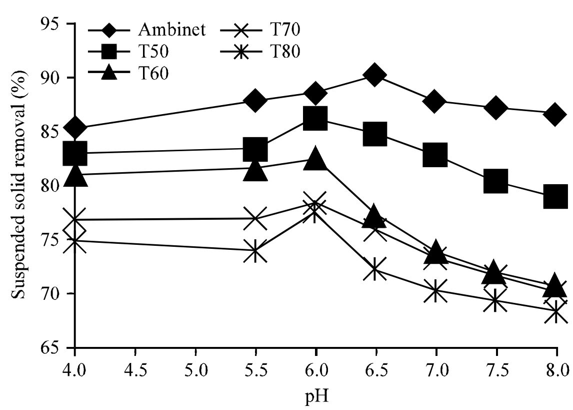

Fig. 2: Percentage suspended solid removal vs. pH at different temperatures

Figure 2 shows the percentage suspended solids removal was very poor at alkaline condition for every studied temperature. The coagulation is less efficient with the increase in pH value. As pH changed, the charges will change. The particles has tendency to be negatively charged at higher pH while remained as cationic charged at low pH (Ching *et al*., 1994). Less attracted to anionic charged due to less positive charge in POME. The charge balance is related to changes in H^+ and OH^- ions in order to maintain the ion balance with water at different pH (Norulaini *et al*., 2001; Bhatia *et al*., 2007). The percentage removal of turbidity drop slowly after achieved optimum pH for each temperature. This result shows that, after obtained the optimum condition in pH, alum in existing sample was led to dissolution of precipitate and indirectly introduces to the decreasing in percentage of suspended solids removal. In the pretreatment, optimum pH is required to be determined and best to be within the allowable pH in the final discharge treated effluent. This is because after membrane treatment, wastewater could be discharged safely to the environment without violating the regulations.

CONCLUSION

The purpose of this study is to observe the performance of coagulation process at higher temperatures. The percentage of turbidity removal was measured for different studied parameters which are coagulant dosage, pH and temperatures. The result showed that, the pretreatment process is able to remove the suspended solids in POME at optimum pH 6.5 and 90% of turbidity removal. However, at higher temperature, the excellent result was showed at temperature 50°C which is 86 % suspended solids removal at pH 6. The turbidity value is quit closed to the ambient temperature. It can be concluding that, at higher temperature the performance of coagulation process is can be done as pretreatment.

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REFERENCES

Ahmad, A.L., S. Ismail and S. Bhatia, 2003. Water recycling from Palm Oil Mill Effluent (POME) using membrane technology. Desalination, 157: 87-95.

Ahmad, A., S. Ismail and S. Bhatia, 2005. Optimization of coagulation-flocculation process for palm oil mill effluent using response surface methodology. Environ. Sci. Technol., 39: 2828-2834.

Bhatia, S., Z. Othman and A.L. Ahmad, 2007. Pretreatment of Palm Oil Mill Effluent (POME) using *Moringa oleifera* seeds as natural coagulant. J. Hazard. Mater., 145: 120-126.

Boisvert, J.P., T.C. To, A. Berrak and C. Jolicoeur, 1997. Phosphate adsorption in flocculation processes of aluminium sulphate and poly-aluminium-silicate-sulphate. Water Res., 31: 1939-1946.

Ching, H.W., T.S. Tanaka and M. Elimelech, 1994. Dynamics of coagulation of kaolin particles with ferric chloride. Water Research, 28: 559-569.

Ebeling, J.M., P.L. Sibrell, S.R. Ogden and S.T. Summerfelt, 2003. Evaluation of chemical coagulation-flocculation aids for the removal of suspended solids and phosphorus from intensive recirculating aquaculture effluent discharge.c Aquacul. Engin., 29: 23-42.

Jekel, M.R., 1986. Interactions of humic acids and aluminum salts in the flocculation process. Water Research, 20: 1535-1542.

Norulaini, N., A. Zuhair, M. Hakimi and M. Omar, 2001. Chemical coagulation of setileable solid-free palm oil mill effluent (Pome) for organic load reduction. J. Indust. Technol., 10: 55-72.

Rishel, K.L. and J.M. Ebeling, 2006. Screening and evaluation of alum and polymer combinations as coagulation/flocculation aids to treat effluents from intensive aquaculture systems. J. World Aquacul. Soc., 37: 191-199.

Stephenson, R.J. and S.J.B. Duff, 1996. Coagulation and precipitation of a mechanical pulping effluent. I. Removal of carbon, colour and turbidity. Water Res., 30: 781-792.

Sworska, A., Laskowski and G. Cymerman, 2000. Flocculation of the Syncrude fine tailings: Part I. Effect of pH, polymer dosage and Mg^{2+} and Ca^{2+} cations. Int. J. Miner. Proces., 60: 143-152.