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Chemical precipitation of palm oil mill effluent (POME)

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Abstract

An alternative method of treating the palm oil mill effluent (POME) within a short period without involving a vast land area is coagulation and flocculation**.** The four different types of coagulant combinations are aluminium sulphate, ferric chloride, ferric sulphate and ammonium sulphate with commercial polymer SR316 as flocculant were investigated as pre-treatment in POME. The treatment using 10%w/w of ferric sulphate, 1% w/w of aluminium sulphate and 1% w/w of ammonium sulphate as coagulants, followed by commercial polymer SR316 as flocculant can reduce turbidity and COD at 97% and 64%, respectively. The effectiveness of coagulation and flocculation has reduced the pollutant load and eased the biological treatment system of POME.

Keywords: palm oil mill effluent (POME), coagulation, flocculation, turbidity, COD

1.0 Introduction

As the result of the dramatically rise in world oils and fats market, there is a significance growth and expansion on palm oil industries. South East Asia is known as the major production of palm oil from *Elaeis guineensis*, especially in Indonesia and Malaysia. Malaysia currently accounts for 51 % of world palm oil production and 62% of world exports. The total oil palm planted areas have been increased to 4.0 millions hectares in year 2005. Realising the dramatic increasing of this sector; therefore, it is crucial to treat POME in a properly manner to an acceptable level before it is discharge to the environment.

The operation of palm oil mill requires large volume of water and subsequently discharges high volume of palm oil mill effluent (POME). A Significant quantity of water needed in the palm oil mill extraction. Through the analysis, 1.0-1.5 tonnes of water is required to process one tonne of fresh fruit bunches (Ma, 2000). POME is complex in nature and content highly organic matter. At any conventional palm oil mill processes, it has been estimated each tonnes of crude palm oil produced, approximate 2.5 to 3.5 m^3 of POME are generated (Ahmad *et al.,* 2003). If such wastewater is discharged to the environment without a proper treatment, it can pollute the watercourse, river and as well as receiving bodies.

Several conventional treatment methods were reported to be used in treating POME which involved the use of aerobic, anaerobic and facultative ponds zero discharge technology, land application, ultrafiltration as well as membrane technology [1 – 7]. In Malaysia, one of the most attractive and commonly approach adopted by the palm oil milling is by anaerobic pond

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or ditch digestion systems followed by the facultative pond. However, the retention times of the anaerobic and facultative pond/ditch systems vary from 20-200 days and 10-15 days respectively [8]. Although these systems seems to be the most effective biological treatment method, the constraints lies on the availability of sufficient land for building the ponds and the length of the retention time taken to treat the POME. Apart of that, a large number of water resources are needed during the biological treatment as well. Alternatively, the feasibility of treating POME within a short period of time without involving a vast area of land by using coagulating and flocculating agents may offer a solution to the treatment problems. The use of chemicals in the treatment of wastewaters has been reported to be successful by many researchers [8].

Coagulation is the unit process where applying chemicals for the purpose of destablising the mutual repulsion of the particles and causing them to bind together through the perikinetic flocculation whereby the aggregation of particles in size range from 0.01 to 1 μm [9]. Coagulant is the chemical that added into the wastewater to destabilise the colloid particles so that floc formation can result during the sequencing flocculation process. Selection of coagulant is important for the effectiveness of the coagulation and clarification processes.

There are several chemicals that been conventionally and commercially used as coagulant in the water and wastewater treatment. Aluminium and iron salts are widely used as coagulants in water and wastewater treatment. Each of the coagulant affect the destabilisation degree of the colloid particles differently. They are effective in removing wide range of impurities from water, including colloidal particles and as well as dissolved organic substances [10]. The higher the valance of the counter-ion, the more its destabilising effect and lesser dose needed for coagulation [11]. The formation of the hydrolytic products formed from metal salt coagulants occurred in a very short time and they are readily absorbed onto the colloid particles and then cause destabilisation of their electrical charge. Apart of that, uniform pH of the wastewater during the coagulation process is essential for the enhancement of hydrolytic reaction. Flocculation is conducted under conditions of lower mixing intensity to prevent shear and degradation of the growing floc particles. Flocculation is the transport steps that bring the collisions between destabilised colloid particles need to form the larger particles than those obtained by coagulation and can be removed readily by settling and then filtration.

This study forms part of a larger study which investigated the used of coagulation and flocculation as the pre-treatment method to treat POME. The objective of this paper is to ascertain which combined coagulants with polymer has the potential to form a larger floc and higher removal of turbidity and COD. It is anticipated that the data obtained would help to identify which combination of coagulants which would be useful in the pre-treatment of POME.

2.0 Experimental and Analytical

2.1 Palm Oil Mill Effluent (POME)

The raw POME was obtained from a commercial palm oil mill and stored in a fridge to prevent from any biological activity. The effluent was taken from the mixing pond which consists of wastewater originating from the sterilizer condensate and clarification of crude oil. POME samples obtained shows high solid content with COD of 25,300 mg/L with pH of 4.55.

The main characteristics of POME in general are shown in Table 1. The data shown that POME has a high value of biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total solid content. POME is a colloidal suspension of 95-96% water, 0.6-0.7% oil and 4-5% total solids including 24% suspended solids

Table 1 Characteristic of Palm Oil Mill Effluent (POME) [12]

pH	4.7
Oil and grease	4,000 mg/L
Biological oxygen demand (BOD)	25,000 mg/L
Chemical oxygen demand (COD)	50,000 mg/L
Total solid (TS)	40,500 mg/L
Suspended solid (SS)	18,000 mg/L
Total volatile solid (TVS)	34,000 mg/L

2.2 Coagulant and Flocculant

Coagulation and flocculation processes for POME were tested in accordance with the procedure outlined in the Standard Methods [13] and the chemicals used in this experiment is tabulated in Table 2. For this study, jar test were conducted. The objective of the jar test is to determine the dosage which coagulant should be introduced to the wastewater. The test procedure was conducted by filling each of the beaker with 500 mL of POME to be treated, after measuring pH, turbidity and COD of raw POME. Ariffin *et al* [14] stated that coagulation and flocculation processes of POME reached a significant removal of organic matter at pH 3. The experiments were initiated by adding the same quantities of coagulants i.e. Type A, Type B and Type C at 10 mL in the different beakers. The POME was stirred rapidly at 300 rpm for 1 minute, followed by slow mixing of 100 rpm for 20 minutes. Then, flocculant (5 mL) was added with slow mixing of 50 rpm for 20 minutes. Commercial polymer SR316 as flocculant used in this study is a high molecular weight polyacrylamide developed by Flowmore Engineering Sdn. Bhd. It is diluted to a 1% w/w solution according to the supplier's instruction.

Table 2 Chemicals for coagulation process

Type A	A1	Aluminium sulphate (5% w/w), Ferric chloride (1% w/w), and Ammonium sulphate (1% w/w)	Type C	C1	Aluminium sulphate (1% w/w), Ferric chloride (5% w/w), and Ammonium sulphate (1% w/w)
	A2	Aluminium sulphate (10% w/w), Ferric chloride (1% w/w), and Ammonium sulphate (1% w/w)		C2	Aluminium sulphate (1% w/w), Ferric chloride (10% w/w), and Ammonium sulphate (1% w/w)
	A3	Aluminium sulphate (20% w/w), Ferric chloride (1% w/w), and Ammonium sulphate (1% w/w)		C3	Aluminium sulphate (1% w/w), Ferric chloride (20% w/w), and Ammonium sulphate (1% w/w)
Type B	B1	Aluminium sulphate (5% w/w), Ferric sulphate (1% w/w), and Ammonium sulphate (1% w/w)	Type D	D1	Aluminium sulphate (1% w/w), Ferric sulphate (5% w/w), and Ammonium sulphate (1% w/w)
	B2	Aluminium sulphate (10% w/w), Ferric sulphate (1% w/w), and Ammonium sulphate (1% w/w)		D2	Aluminium sulphate (1% w/w), Ferric sulphate (10% w/w), and Ammonium sulphate (1% w/w)
	B3	Aluminium sulphate (20% w/w), Ferric sulphate (1% w/w), and Ammonium sulphate (1% w/w)		D3	Aluminium sulphate (1% w/w), Ferric sulphate (20% w/w), and Ammonium sulphate (1% w/w)

2.3 Coagulation and Flocculation Processes

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2.4 Settling and Filtration Processes

Agitation was stopped and flocs formed were allowed to settle for 1 hour. Settling of the flocs after the coagulation and flocculation processes was needed to separate the flocs. Samples of supernatant were collected and turbidity and COD of the supernatant were measured.

3.0 Results and Discussion

Figure 1 and 2 show the COD and turbidity removal results from the four different combinations of coagulants with commercial polymer SR316 after the coagulation and flocculation processes of POME. Temperature, pH, mixing time, mixing speed and flocculant dosing were the constant parameters throughout the experiments. The turbidity and COD removal efficiency are plotted against the type and dose of coagulants.

Turbidity and COD removal efficiency for the coagulants Type A is shown in Figure 1. The figure shows that the COD removal efficiency has a similar trend as the dosage of the main coagulant increased from 5% w/w to 20% w/w. No further improvement in turbidity removal was obtained as the Type A dosage was increased to 20% w/w of aluminium sulphate. The used of aluminium sulphate at a higher dosage did not improve coagulation and flocculation of the POME. There is an average of 93% and 56% removal of the original turbidity and COD values, respectively.

Figure 2 shows the turbidity and COD removal of POME by coagulants Type B. As seems in the figure, 98% of turbidity removal was achieved in B1. The figure also shows that at B2 there is a significant dropping of COD removal from 60% to 40%. Additionally, 50% of COD removal was achieved when the dosage of main coagulant, aluminium sulphate is increased to 20% w/w. Therefore, it would be possibility of charge reversal for Type B coagulants when the dosage of aluminium sulphate different from B1 to B3. As concluded, B1 retained as the optimum dosage for coagulants Type B for turbidity and COD removal efficiency.

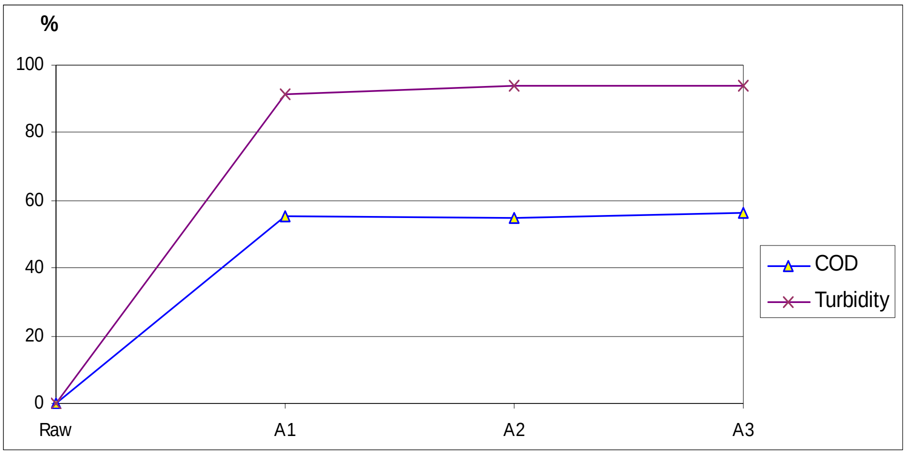

Figure 1 COD & Turbidity Removal by Coagulants Type A

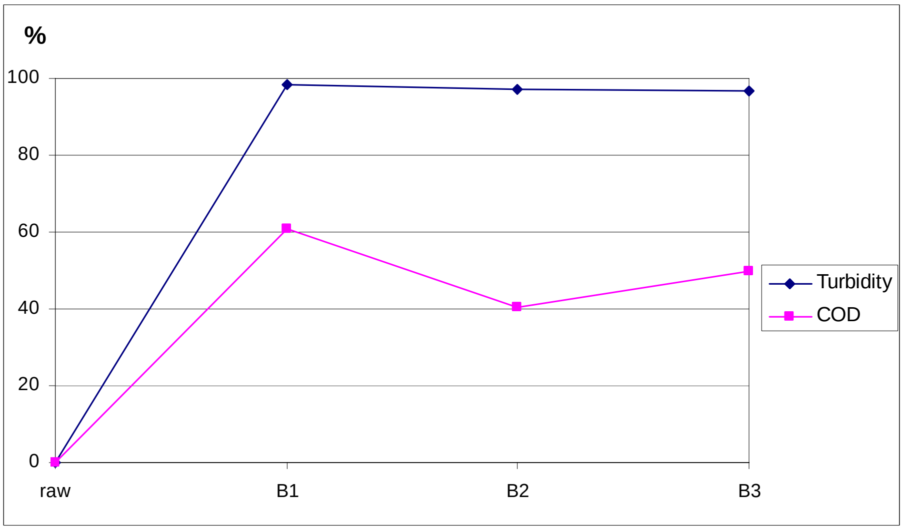

Figure 2 COD & Turbidity Removal by Coagulant Type B

Figure 3 clearly demonstrates that with the presence of ferric chloride as main coagulant, a better removal efficiency compared Type A and Type B coagulants in Figure 1 and 2 was achieved. The turbidity removal efficiency achieved 97% using C1. Alternatively, C2 with 10% w/w of ferric chloride, 1% w/w of aluminium sulphate and 1% w/w of ammonium sulphate was found at 62% of the COD removal.

Type D consists of ferric sulphate as the main coagulant. It can be observed from Figure 4 that 99% turbidity removal has been achieved in D1. By increasing the percentage of the ferric sulphate to 10% w/w, the removal efficiency of COD also increased. It is noted that there is a significant dropping of COD removal for the combination of Type D coagulants with SR316. It would be possibility of charge reversal from D2 to D3. Overdosing of the coagulant may leads to the surface charge of the particles reversed and consequence affected the efficiency of COD removal.

Results shown in Figure 5 clearly demonstrate the comparative turbidity removal efficiency results by treatment of the POME with four different types of coagulant combinations. D1 observed the highest turbidity removal at 99% in the supernatant. While, B1 and C1 coagulants have the same optimum turbidity removal efficiency (98% of removal). Furthermore, the increasing of dosage of the coagulant, above 5% w/w led to deterioration in the performance, the turbidity removal at 5% w/w was still better than that at 10% w/w and

20% w/w of the Type B, Type C and Type D. For Type A coagulant, the turbidity removal increased from 5% w/w of aluminium sulphate to 10% w/w, and then decreased at 20% w/w. These were due to the possibility of at the high level of coagulant dosage in POME, leads to incomplete of the precipitation.

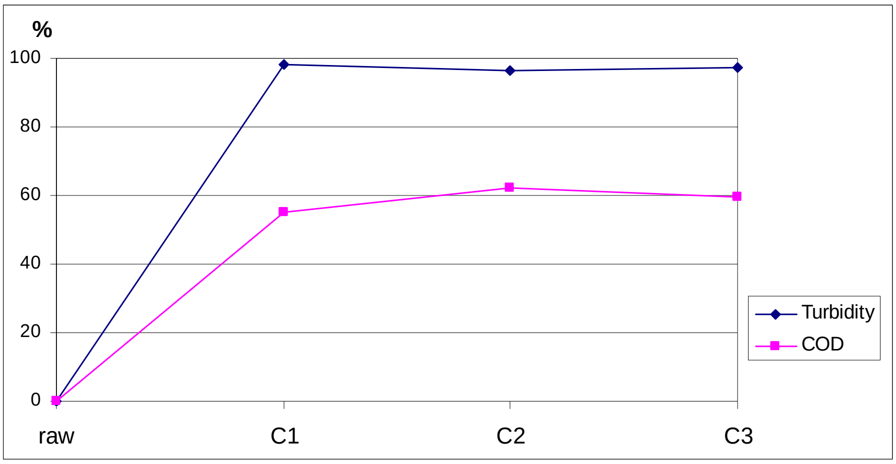

Figure 3 COD & Turbidity Removal by Coagulant Type C

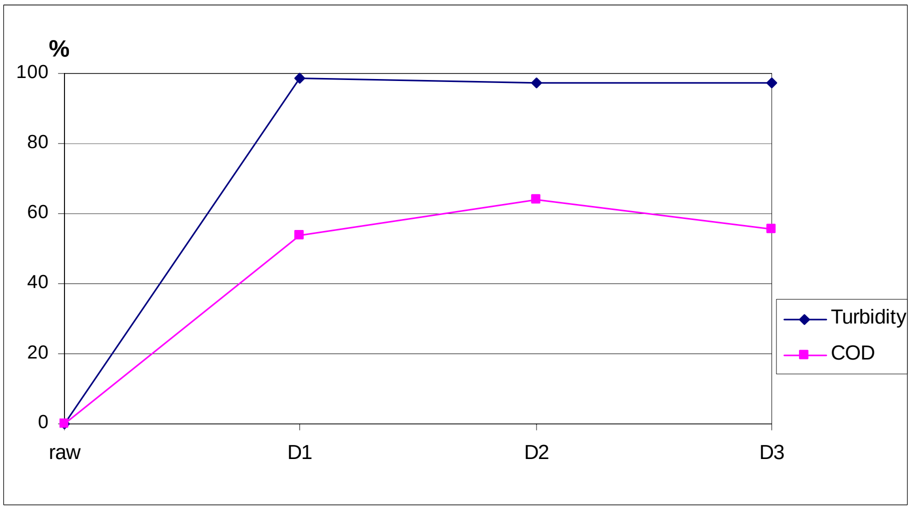

Figure 4 COD & Turbidity Removal by Coagulant Type D

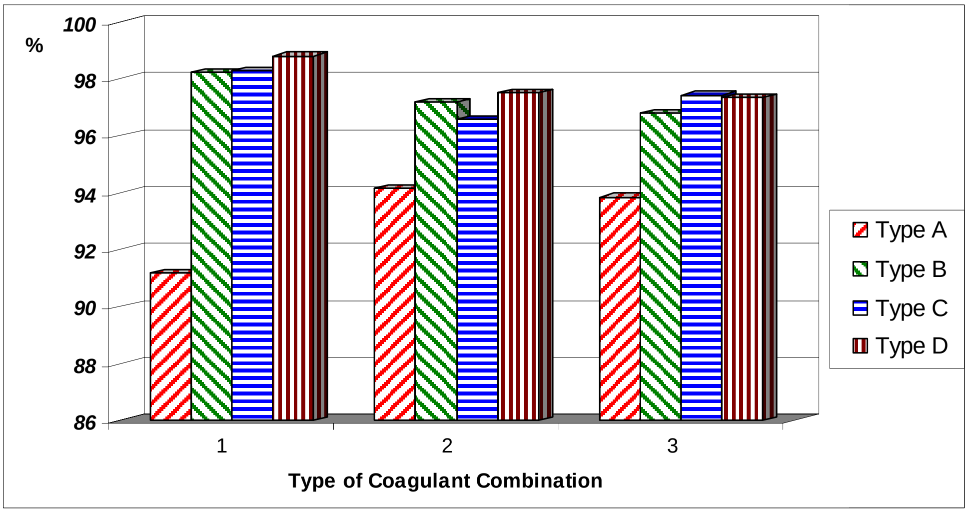

Figure 5 Turbidity Removal with different type of coagulants

Figure 6 indicated the removal of COD after the coagulation and flocculation processes for the four different combinations of coagulants i.e. Type A, B, C and D with commercial polymer SR316. As seen in Figure 6, it is noted that for the combination of Type A and Type B (aluminium sulphate as the main coagulant) coagulants with SR316 do not show better removal of COD if compared to Type C and Type D whereby ferric salts act as the main coagulant. When ferric salts were used as main coagulant, no much restabilisation occurred compared to aluminium sulphate as the main coagulant. The occurrence of restabilisation of colloid particles with aluminium sulphate but not with ferric salts could be due to the pH of raw POME. Ng and colleagues studied the POME treatment by using alum [4]. They found that alum were not effective for POME treatment. Aluminium sulphate precipitates occurs at a higher pH values than for precipitates resulting from ferric salts

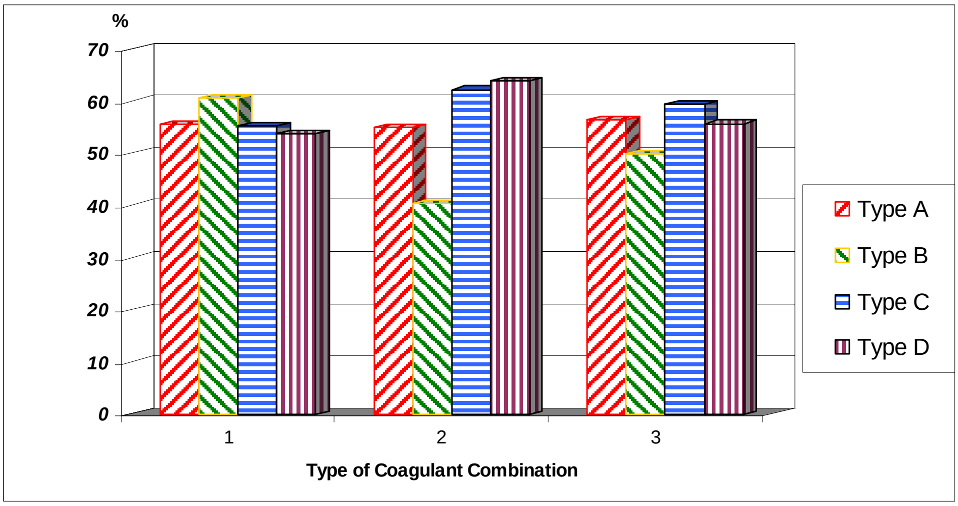

Figure 6 COD Removal with different type of coagulants

Furthermore, for a combination of coagulants Type C and Type D with commercial polymer SR316, it was found that ferric salts able to achieve a higher COD removal. Though, it is speculated that ferric salts might have better coagulating capability than aluminium sulphate. For instance 62% and 64% of COD removals were achieved for Type C2 and Type D2 coagulants after coagulation and flocculation processes. In general, from the study, this jar test revealed that the POME was best treated when (Type D2) 10%w/w of ferric sulphate, 1% w/w of aluminium sulphate and 1% w/w of ammonium sulphate with commercial polymer SR316 (1% w/w).

4.0 Conclusion

The investigation looked into the feasibility of treating POME of very high turbidity and COD value. The result of the study showed that coagulation and flocculation were able to reduce turbidity by 97% and COD removal at 64% by combination of coagulants Type D2 i.e. 10% w/w of ferric sulphate, 1% w/w of alum and 1% w/w of ammonium sulphate with commercial polymer SR316. This pre-treatment method for POME can significantly reduce the total pollution strength of the effluent before entering the biological treatment system. This offers an alternative for innovation to the current conventional treatment system where the backend load of the wastewater treatment is reduced at the earlier stages. However, much study is needed to study the economics of using these coagulant combinations and also the utilisation of the recovered chemically treated sludge of the POME.

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