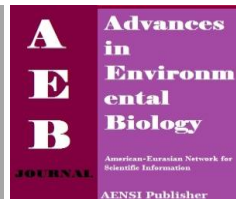




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## Removal of Organics from Treated Palm Oil Mill Effluent (POME) Using Powdered Activated Carbon (PAC)

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### ABSTRACT

Millions of tonne of treated palm oil mill effluent (POME) discharged into the water body in Malaysia after the anaerobic-aerobic treatment as 'clean' waste. However, treated POME potentially can become the alternative of water resource for reclamation and reuse on-site. Therefore, further treatment is needed due to high organic content in treated POME. The removal of organics in terms of chemical oxygen demand (COD) and total suspended solids (TSS) were studied using the commercial powdered activated carbon (PAC) as adsorbent in a batch process. This study shows the effect of process conditions such as PAC dosage, agitation and contact time influenced the removal of COD and TSS in treated POME with equilibrium values of 3.00 g, 150 rpm and 15 minutes respectively. The COD and TSS adsorption was suit with the Freundlich isotherm model with  $R^2$  values 0.9812 and 0.9362 respectively.

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## INTRODUCTION

In Malaysia, palm oil industry is one of the largest water consumers, where the water is largely used as process water to extract oil from fresh fruit bunches (FFB). The major concern in the industry is the production of POME which very high in organics content. Table 1 is the comparison of characteristics of raw POME and the regulatory discharge limit into the water body employed in Malaysia. 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 [1].

Parveen *et al.*[2] estimated that for every tonne crude palm oil (CPO) processed from processed FFB requires 5 – 7.5 tonnes of water and more than 50% of the water ends up as wastewater, while Ahmad *et al.*[3] reported 0.7 m<sup>3</sup> POME was generated for every tonne of FFB processed. Thus, in a year of 2011 only, the estimated wastewater generated as palm oil mill effluent (POME) was about 65 × 10<sup>6</sup> m<sup>3</sup>. Even after anaerobic-aerobic treatment of POME, this huge amount of treated POME which is discharged into the water body still can be considered high in organics content.

Adsorption process is one of the promising approaches for the removal of organics in water and wastewater. Previous studies show that adsorption is efficient for the removal of wide range of organic compounds, and different type of adsorbents has been produced to remove organics content of water and industrial effluent. Adsorbent made of oil palm empty fruit bunches was used by [4] to remove COD, colour and turbidity with combination of other treatment process as pretreatment with efficiency 89%, 97.9% and 98.9%, respectively from biologically treated POME. While Aber and Sheydaei[5] removed COD from dying factory with efficiency 75% using activated carbon fibre. Kutty *et al.*[6] used microwave incinerated rice husk ash (MIRHA) to adsorb anaerobically treated POME and found 41% of COD removal. Igwe *et al.*[7] used boiler fly ash to remove TSS from palm oil mill effluent.

The objective of this study is to investigate the effect of adsorption process conditions i.e. PAC dosage, agitation and contact time for COD and TSS removal in treated POME using powdered activated carbon (PAC), and to determine the suitable adsorption isotherm models for both COD and TSS.

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**Table 1:** Characteristics of POME and Regulatory Discharge Limit

| Parameters | Mean value <sup>a</sup> | Regulatory Discharge Limit <sup>b</sup> |
|------------|-------------------------|---|
| pH         | 4.2                     | 5.0 – 9.0                               |
| COD (mg/L) | 51,000                  | -                                       |
| AN(mg/L)   | 35                      | 150                                     |
| SS (mg/L)  | 18,000                  | 400                                     |
| BOD (mg/L) | 25,000                  | 100                                     |
| TN (mg/L)  | 750                     | 200                                     |
| O&G (mg/L) | 6,000                   | 50                                      |

Sources:

<sup>a</sup>Malaysian Palm Oil Board (MPOB)[8].<sup>b</sup>Environmental Quality (Prescribed Premises)(Crude Palm Oil)(Amendment) Regulations 1982.

## MATERIALS AND METHODS

### Sample Collection and Characterization:

Treated POME sample was collected from West Oil Mill, Carey Island, Banting, Selangor and kept in the cold room at 4°C for sample preservation. The quality of treated POME was then characterized using spectrophotometer (Model DR2500, HACH). Table 2 shows the characteristics of treated POME as compared to the process water. The commercial powdered activated carbon (PAC) bought from Affigen Sdn Bhd was used as adsorbent for the study.

**Table 2:** Characteristics of Treated POME in West Oil Mill, Carey Island and Process Water.

| Parameters | Treated POME | Process Water              |
|------------|--------------|----------------------------|
| COD (mg/L) | 1300 – 1700  | <50 <sup>a</sup>           |
| TSS (mg/L) | 250 – 550    | 100 – 1500 <sup>b</sup>    |
| TDS (mg/L) | 1000 – 1300  | 3000 <sup>b</sup>          |
| pH         | 8.3 – 8.6    | 8.5 – 9.5(8*) <sup>b</sup> |

Sources:

<sup>a</sup>U.S EPA, Guidelines for Water Reuse (2004), for Chevron Refinery boiler makeup water applied in North Richmond Water Reclamation Plant., California.<sup>b</sup>British Standard Specification (BSS), 2468; 1978.

\* refers to the tolerance levels employed by BSS.

### Adsorption Study:

The treated POME was put into a 100 mL Erlenmeyer flask for adsorption study. A shaker (Model SK-60, United Kingdom) was used for the adsorption study. The influence of different operational conditions i.e. adsorbent dosage (0.50 – 4.00 g), contact time (15 – 120 min), and agitation (100 – 200rpm) were studied for COD and TSS removal in treated POME. After the adsorption, the sample was centrifuged (4000 rpm, 5 minutes) and filtered to discard the PAC residual. The filtrate then characterized for its quality. Finally, the COD and SS removal percent was calculated by equation (1) and (2) respectively:

$$\text{COD removal (\%)} = \frac{\text{COD}_i - \text{COD}_f}{\text{COD}_i} \times 100 \quad (1)$$

$$\text{TSS removal (\%)} = \frac{\text{TSS}_i - \text{TSS}_f}{\text{TSS}_i} \times 100 \quad (2)$$

where  $\text{COD}_i$  and  $\text{COD}_f$  are the initial and final COD values of treated POME (in mg/L), and  $\text{TSS}_i$  and  $\text{TSS}_f$  are the initial and final TSS treated POME (in mg/L).

### Adsorption Isotherms Models:

Adsorption equilibrium tests were done in a batch mode to determine the adsorption isotherm model using different dosage mass of PAC (0.50, 1.00, 2.00, 3.00 and 4.00 g) at pH 8.3 – 8.6 (as received from POME treatment plant), agitated at 150 rpm for 60 min.. Equation 3 shows the amount of adsorbate adsorbed at equilibrium per unit mass adsorbent (mg/g),  $q_e$ , where  $V$  is the sample volume (L),  $C_o$ (mg/L) is the adsorbate initial concentration,  $C_e$ (mg/L) is the adsorbate concentration after at equilibrium, and  $m$  is the adsorbent mass (g).

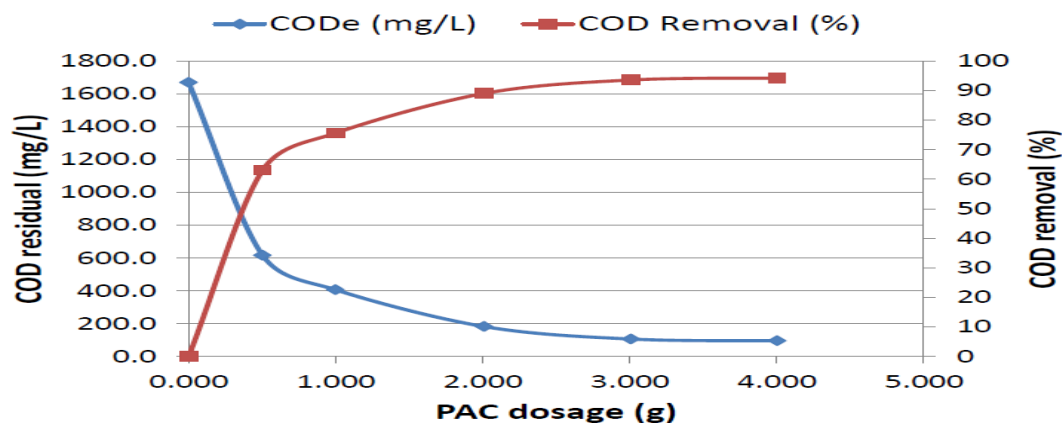
$$q_e = V \frac{C_o - C_e}{m} \quad (3)$$

## RESULTS AND DISCUSSION

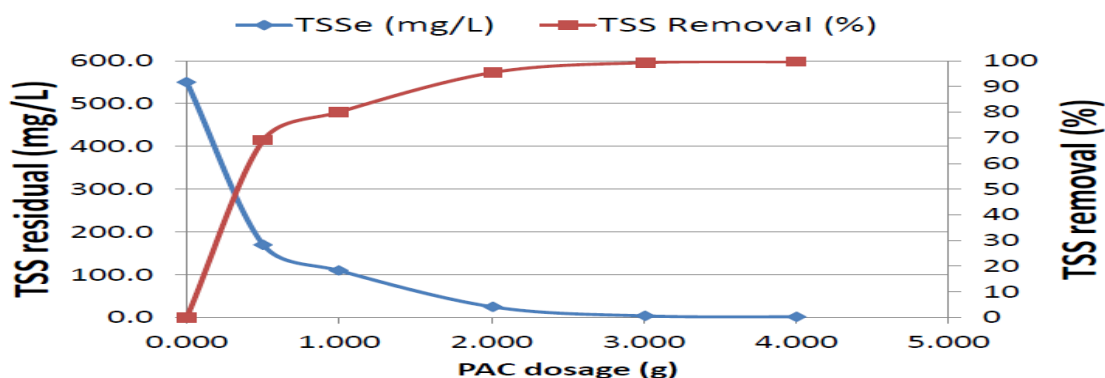
*Effect of Process Conditions:*

Figure 1 and 2 shows the effect of PAC dosage on COD and TSS adsorption where the removal of the COD and TSS increase as the PAC dosage increase. The small increment of COD and TSS removal after 3g of PAC dosage indicates that the COD and TSS removal is almost at equilibrium at this dosage.

The higher removal of COD and TSS as the PAC dosage increase may be due to the pore structure, high adsorption capacity, and active surfaces which makes activated carbon suitable for adsorbing organic molecules [9]. Higher dosage also means more surface area of active sites for COD and TSS adsorption to occur.

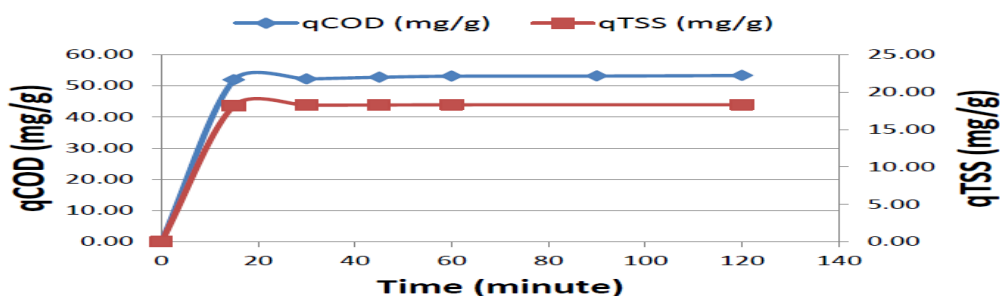


**Fig. 1:** PAC dosage variations at  $COD_i = 1700$  mg/L,  $V = 100$  mL, contact time = 60 min, & agitation = 150 rpm.



**Fig. 2:** PAC dosage variations at  $TSS_i = 550$  mg/L,  $V = 100$  mL, contact time = 60 min, & agitation = 150 rpm.

Figure 3 shows the effect of contact time for COD and TSS removal respectively. This figure shows that both COD and TSS removal were happened at a very short of time (less than 15 minutes), thus making the adsorption process alternatively can be done in continuous process instead of batch mode. It also implied that rapid adsorption for COD and TSS were occurred during the adsorption where the major sites for adsorption mainly took place on the external surface of the PAC. If the major sites for the adsorption occurred majorly in internal surface within the pores of the activated carbon, the adsorption process should take longer time [10].



**Fig. 3:** Amount COD & TSS adsorbed at different contact time (min). PAC dosage = 3.0 g,  $V = 100$  mL, & agitation = 150 rpm.

Meanwhile, the effect of agitation on COD and TSS adsorption can be seen in Figure 4 where the adsorption for COD and TSS increased as the higher agitation applied. However, very small removal increment shows after the 150 rpm agitation applied which indicates this to be the equilibrium agitation for adsorption of COD and TSS. Higher agitation gives the adsorbate adsorbed faster since the agitation is related to the mechanism of migration behavior of the adsorbates onto the surface active sites of the adsorbent[11].

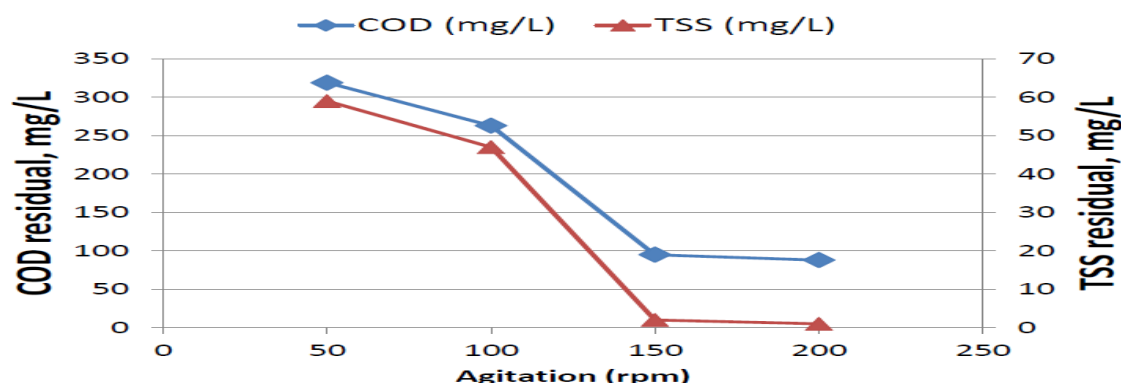


Fig. 4: Effect of agitation on COD and TSS using PAC dosage = 3.0 g, V = 100 mL, & contact time = 15 min.

#### COD and TSS Isotherm Models:

The Langmuir and Freundlich isotherm models were employed in this study to analyze the adsorption capacity of PAC as adsorption isotherm models. The Langmuir isotherm is based on assumption of monolayer adsorption, while the Freundlich isotherm based on the adsorption onto the heterogeneous surface and multilayer adsorption [12].

$$\frac{1}{q_e} = \frac{1}{q_o} + \frac{1}{b \cdot Q_o \cdot C_e} \quad (4)$$

$$\log q_e = \log k_f + \frac{1}{n} \log C_e \quad (5)$$

Equation (4) and (5) is the linearized Langmuir and Freundlich isotherm respectively, where  $q_o$ (mg/g) is the adsorption capacity,  $k_L$ (L/mg) is the Langmuir constant,  $C_e$ (mg/L) is the adsorbate concentration after at equilibrium,  $k_f$  is the Freundlich adsorption capacity and  $1/n$  is the Freundlich adsorption intensity. Table 3 shows the isotherm constants both for COD and TSS adsorption using Langmuir and Freundlich isotherm models. It is clearly shown that the Freundlich isotherm model is best suit for COD and TSS with  $R^2$  value of 0.9812 and 0.9362 respectively. The representation of COD isotherm model using Freundlich isotherm is also established by other industrial pollutants such as fermentation effluent[13], refinery petroleum effluent [14], and dyeing industrial wastewater [5].

Although the COD isotherm likely to be represented by the Freundlich isotherm model, it can be seen from Table 3 the correlation coefficients for Langmuir isotherm is only slightly less than in Freundlich isotherm. Thus, the Langmuir isotherm for COD cannot be totally rejected in equilibrium studies. The linearized form of Langmuir and Freundlich expressions for COD and TSS removal by PAC can be represented as below:

Linearized Langmuir equation,

$$\text{COD}; \frac{1}{C_e} = 2.0873 \cdot \frac{1}{q_e} + 0.002 \quad (6)$$

$$\text{TSS}; \frac{1}{C_e} = 0.1054 \cdot \frac{1}{q_e} + 0.0234 \quad (7)$$

Linearized Freundlich equation,

$$\text{COD}; \log q_e = 0.8173 \cdot \log C_e + 0.0123 \quad (8)$$

$$\text{TSS}; \log q_e = 0.3376 \log C_e + 1.0235 \quad (9)$$

**Table 3:** Langmuir and Freundlich isotherm constants in COD and TSS removal using adsorption on PAC in treated POME.

| Parameter  | Model    | Isotherm | Value    |       |        |
|------------|----------|----------|----------|-------|--------|
| Constant   |          |          |          |       |        |
| COD        | Langmuir | $Q_0$    | 500      |       |        |
|            |          | $b$      | 9.598E-4 |       |        |
|            |          | $R^2$    | 0.9652   |       |        |
| Freundlich |          | $k_f$    | 1.0287   |       |        |
|            |          | $1/n$    | 0.8173   | $R^2$ | 0.9812 |
|            |          |          | 42.735   |       |        |
| TSS        | Langmuir | $Q_0$    | 0.222    |       |        |
|            |          | $b$      | 0.8841   |       |        |
|            |          | $R^2$    | 10.556   |       |        |
| Freundlich |          | $k_f$    | 0.3376   | $R^2$ | 0.9362 |
|            |          | $1/n$    |          |       |        |
|            |          |          |          |       |        |

### Conclusions:

The adsorption study conducted in laboratory-scale shows that PAC as adsorbent is capable of removing organics i.e. COD and TSS in treated POME. The removal for COD and TSS were found increased as the PAC dosage increased. The removal was also affected by the agitation and contact time with equilibrium values of 150rpm and 15 minutes respectively. Based on the adsorption study, the COD and TSS were fitted to Freundlich isotherm model with  $R^2$  values 0.9812 and 0.9362 respectively. The efficiency of adsorption process for organics removal in treated POME as shown in this study seems very optimistic for the reclamation of the treated POME.

### ACKNOWLEDGEMENT

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