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# Effect of Operating Parameters on Decolourisation of Palm Oil Mill Effluent (POME) using Electrocoagulation Process

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## ABSTRACT

Electrocoagulation has proven to be an effective method in the treatment of wastewater. This study evaluated the decolourisation of Palm Oil Mill Effluent (POME) using electrocoagulation (EC) batch reactor by utilising aluminium as sacrificial electrode. POME sample source from a final discharged pond at a palm oil mill was characterised for its colour, chemical oxygen demand (COD), pH, conductivity and turbidity; were found to be 2707 PtCo, 3909 mg/L, 7.63, 12.82 mS/cm and 755 NTU respectively. The respective effects of operating parameters such as pH (3 to 11), applied voltage (5 V to 20 V), plate gap (7.5 to 11.5 cm) and operating time (1 to 8 hours) were investigated. The decolourisation of POME was observed to increase with increasing voltage and operating time. Highest removal efficiency was observed at pH 5, 20 V applied voltage, 9.5 cm plate gap and at 8-hour operating time with colour removal efficiency of 89, 79, 78 and 64% respectively. From the findings, it can be concluded that electrocoagulation process using aluminium electrodes is a reliable technique for the removal of colour from POME.

*Keywords:* Aluminium electrode, effluent, electrocoagulation, POME

## INTRODUCTION

Malaysia is one of the world's largest palm oil producing country (Kanakaraju, Awangku Metosen, & Nori, 2016). The process of oil extraction results in the generation of liquid waste commonly known as palm oil mill effluent (POME), making crude palm oil production a water intensive activity. It is estimated that from 1 tonne of fresh fruit

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bunch (FFB) processed, about 0.67 tonnes of POME are produced. Consequently, in 2014, from 100.42 million tonnes of FFB, about 67.28 million tonnes of POME were generated in Malaysia (Bukhari, Nasrin, & Loh, 2016). POME distinct characteristics are its dark colour, high biochemical oxygen demand (BOD), chemical oxygen demand (COD), and substantial amount of suspended solids (Kanu & Achi, 2011). POME composed of 4–5% solids (mainly organic), 0.5–1% residual oil and about 95% water, and high concentration of organic nitrogen. In extraction of oil in plant-based wastewater, dark brown colour was ascribed to polymerisation of tannins and low molecular weight phenolic compounds as in olive mills wastewater (Adhoum & Monser, 2004).

Besides other traditional methods of remediation such as aerobic and anaerobic ponds, the feasibility of coagulation also was studied by numerous researchers. Electrocoagulation, is a variation of the coagulation process, other than the widely practiced chemical coagulation. Although both electrocoagulation (EC) and chemical coagulation (CC) are used for particle removal in water treatment, they differ in their dosing method. The coagulant is added by electrolytic oxidation in EC, whereas in CC the coagulant is added by the dissolution of a chemical (Harif, Khai, & Adin, 2012). Despite the limited research on EC, it actually has managed to explore an extensive range of applications for both colloidal as well as organic matter removal in sewage and effluent treatment (Kuokkanen, Kuokkanen, Rämö, & Lassi, 2013). Other than that, notable research on the utilization of EC for vegetable oil processing wastewater in the treatment of olive oil mills wastewater has been widely pursued by many researchers (Yazdanbakhsh, Massoudinejad, Arman, & Aghayani, 2013). Agustin, Sengpracha and Phutdhawong (2008) observed that, EC was capable of effectively removing the colour of POME, from intense dark brown to pale yellow.

In this study, POME was treated using electrocoagulation reactor via batch mode. It was characterised for its colour, COD, pH, conductivity and turbidity. Four significant EC operating parameters, namely pH, applied voltage, plate gap and operating time were investigated to assess the effectiveness of POME colour removal.

## MATERIALS AND METHOD

### Sample Collection

In order to carry out this work, samples of Palm Oil Mill Effluent (POME) from a Palm Oil Mill in the South of Malaysia, producing 20 tonnes per hour were used throughout this study. It was taken from final discharge pond placed after anaerobic pond. The POME was dark brown in colour and contained a large amount of suspended solids. The samples were kept in plastic bottles and refrigerated at 4°C before use.

### Experimental Set Up: EC Batch Reactor

A 3-litre EC batch reactor was set up in Figure 1. A GW Laboratory DC power supply (Model: GPS-3030D) with a working range of 0 – 30 V was used. A pair of aluminium or iron plates were used of size 14 cm (L) x 14.5 cm (W) x 0.15 cm (H), immersed in the sample to a depth of 8 cm. An electrode gap of 9.5 cm was fixed throughout the experiment. The sample was treated at room temperature with constant magnetic stirring. To eliminate electrode passivation at the anode due to the formation of an oxide film, it was rinsed with 1M dilute nitric acid solution after each experiment followed with deionized water.

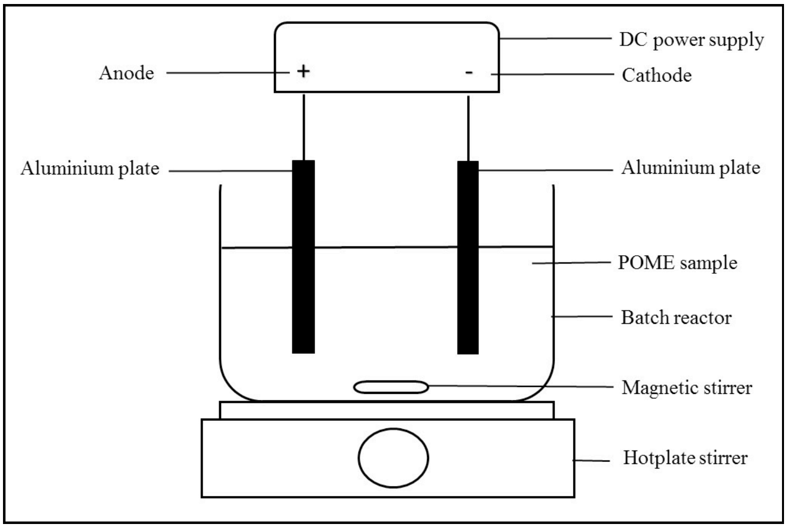

*Figure 1.* Schematic of EC batch reactor

## Mechanism of EC Process

Electrocoagulation involves three main stages; the dissolution of metal ions of anode to form coagulant through dispersed double layer compression, the destabilization of pollutants through ion neutralization and the aggregation of unstable phases forming flocs and sludge (Bouhezila, Hariti, Lounici, & Mameri, 2011). The electrocoagulation mechanism can be evaluated from the following equations (Tchamango, Nanseu-Njiki, Ngameni, Hadjiev, & Darchen, 2010).

At anode, the oxidation of aluminium produces $Al^{3+}$ species and the electrode reactions are:

$$Al_{(s)} \rightarrow Al^{3+} + 3e^- \qquad (1)$$

At cathode, the reduction of water takes place to form hydrogen bubbles and the reactions are:

$$2H_2O + 2e^- \rightarrow H_{2(g)} + 2OH^- \qquad (2)$$

In the EC reactor, the hydrogen bubbles undergo floatation. The $Al^{3+}$ ions undergo further reaction to form precipitates of $Al(OH)_3$ which produces flocs that combine water contaminants as a range of coagulant species. The reaction of the metal hydroxides formed are represented by the equations below:

At acidic condition: $$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_{3(s)} + 3H^+ \quad (3)$$

At alkaline condition: $$Al^{3+} + 3OH^- \rightarrow Al(OH)_3 \quad (4)$$

The pollutants and other dissolved contaminants were destabilized by the coagulants, $Al(OH)_3$. Other than that, an oxygen evolution takes place and the reaction as below:

$$2H_2O + 4e^- \rightarrow O_2 + 4H^+ \quad (5)$$

### Characterisation of POME Wastewater

The POME was characterised for its colour, chemical oxygen demand (COD), pH, conductivity and turbidity according to standard methods. POME colour was analysed using HACH spectrophotometer at wavelength maximum of 455 nm. The COD was measured using COD reactor and direct reading from HACH spectrophotometer (Model: DR2800 – Method 8025). The pH was measured using HANNA instrument microprocessor pH meter (Model: pH 211). The conductivity was measured using EUTECH handheld conductivity meter. HACH turbidimeter (Model: 2100P) was used to measure the turbidity of the sample.

### Effect of EC Operating Parameters

This investigation explored the behaviour of EC treatment of different operating variables. The effects of pH, applied voltage, plate gap and operating time were evaluated to study the decolourisation efficiency. At the beginning of each run, aluminium plates were placed into the reactor. The 6-hour operating time was started when the DC power supply was switched on. For the effect of pH, the pH was adjusted to pH 3 to 11 by adding drops of 0.5M sodium hydroxide (NaOH) or 0.5M hydrochloric acid (HCl). The voltage varied from 5 to 20 V to study the effects of applied voltage. The plate gap was studied from 7.5 to 11.5 cm. For the effect of operating time, EC process was conducted for 8 hours. During the treatment, POME samples were periodically collected at each hour from the reactor. The samples were filtered to analyse for colour intensity.

## RESULTS AND DISCUSSION

### Characterisation of POME Wastewater

The data for Characterisation of POME before EC treatment were presented in Table 1. The POME was dark brown in colour with high suspended solids and turbidity which was indicated by the high colour reading (2707 PtCo), COD (3009 mg/L) and turbidity (755 NTU). The pH of POME was at neutral (7.63). The conductivity of POME at 12.82 mS was adequate for an electrolyte during EC treatment as what being mentioned by Esfandyari et al. (2014).

Table 1
*Characterisation of POME wastewater*

| Characterisation | Value |
|---|---|
| Colour | 2707 PtCo |
| Chemical Oxygen Demand (COD) | 3009 mg/L |
| pH | 7.63 |
| Conductivity | 12.82 mS |
| Turbidity | 755 NTU |

## Effect of pH

The amount of $Al^{3+}$ ions generated depends strongly on pH. Thus, pH was studied in the range of 3 to 9. Based on the Figure 2, it was observed at pH 5, the highest colour removal was 89%, followed by pH 11, pH 9 and pH 3 with colour removal efficiency of 63%, 52% and 51% respectively. It was noted that the colour removal efficiency decreased when pH was lower and greater than 5. At lower pH (i.e. below 5), $Al(OH)_3$ tends to dissolve due to its amphoteric behaviour, whereas at higher pH (above 5), monomeric anions $Al(OH)_4^-$ was formed. Both of these situations were not favourable for POME colour removal. These observations were consistent with research done by Kobya and Delipinar (2008).

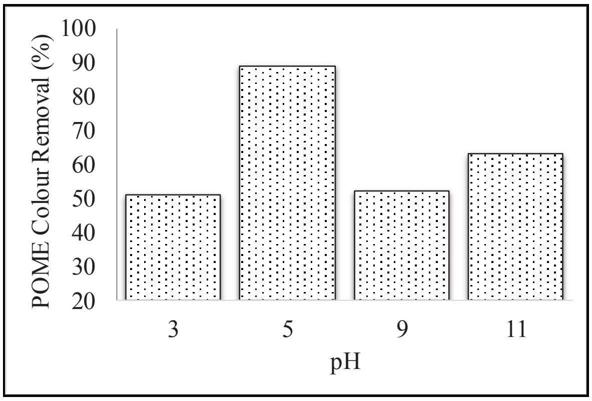

*Figure 2.* Effect of pH on POME colour removal

## Effect of Applied Voltage

The supply of voltage to the electrocoagulation system indicates the amount of $Al^{3+}$ released from the respective plates. The applied voltage was studied in the range of 5 to 20 V. The colour removal efficiency increased from 56 to 79% as the applied voltage was increased from 5 to 20 V (Sengil & Ozacar, 2006). Based on Faraday's law, as the voltage supply increased, the amount of aluminium ion ($Al^{3+}$) released from the plate and the quantity of resulting coagulant also increased and thus improved colour removal efficiency. The increased applied voltage causes the contact time between hydroxide flocs and colour pollutants to increase, thus floatation process is improved and colour pollutants are rapidly removed (Bazrafshan, Moein, Mostafapour, & Nakhaie, 2013). This behaviour is in accordance to work done by Adhoum and Monser (2004).

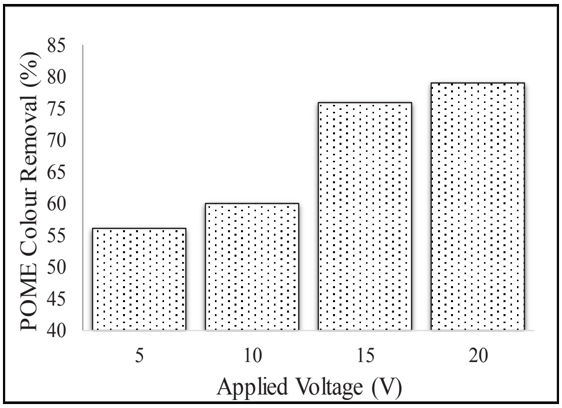

*Figure 3.* Effect of Applied Voltage on POME colour removal

## Effect of Plate Gap

The plate gap plays a crucial factor due the electrostatic field depends on the distance between the anode and the cathode (Khandegar & Saroha, 2012). The electrostatic field strength is substantial as it attracts the ions generated from the plates during the EC process (Bouhezila, Hariti, Lounici, & Mameri, 2011). The plate gap was varied from 7.5 to 11.5 cm. The colour removal efficiency reduces with increasing of plate gap. Maximum colour removal was observed at plate gap of 9.5 cm with 78% removal efficiency. Further the gap, it increases the travel time of the ions, thus leads to a decrease in electrostatic attraction as suggested by Khandegar and Saroha (2012), which subsequently reduces the formation of flocs.

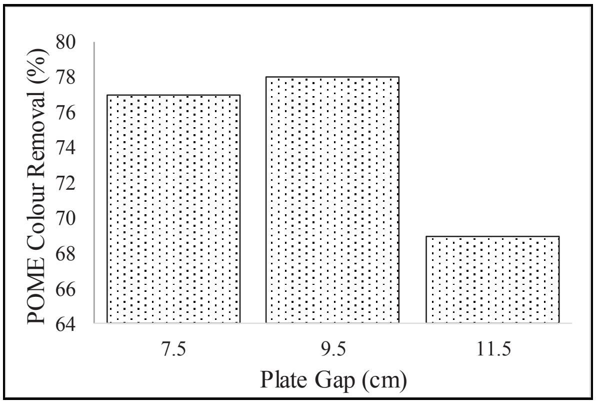

*Figure 4.* Effect of Plate Gap on POME colour removal

## Effect of Operating Time

Operating time is another EC parameter that affects colour removal efficiency. As shown in Figure 5, it was observed that for longer operating times (from 1 to 6 hours), there is an increase in the colour removal efficiency. Theoretically, based on Faraday's law, operation time affects the amount of aluminium ions released from the electrode (Bazrafshan, Moein, Mostafapour, & Nakhaie, 2012). In this process, EC involves two stages which are destabilization and accumulation. The first stage is usually short, whereas the second stage is relatively long (Ni'am, Othman, Sohaili, & Fauzia, 2007). There was a steep increase in the removal efficiency of 37% during the first hour (first stage). From second to eight hours, the removal efficiency increases slowly to 64% (second stage). This is due to the increased quantity of coagulant dissolving from the aluminium electrode, thus destabilize the double layer of the suspended metallic hydroxides (Zhao, Huang, Cheng, Wang, & Fu, 2014).

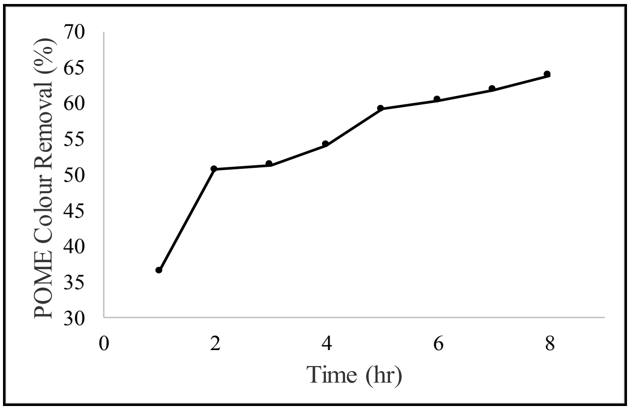

*Figure 5.* Effect of Operating Time on POME colour removal

## CONCLUSION

Batch electrocoagulation studies were conducted to assess the influence of various experimental parameters on the removal of colour pollutants from POME. pH 5 was observed to contribute the highest decolourisation yield of 89%. The treatment rate was shown to increase upon increasing of the applied voltage until 20V with the highest colour removal efficiency of 79%. Besides that, plate gap of 9.5 cm showed the highest decolourisation efficiency of 78%. With an increase in the operating time until 8 hours, there is an increase in colour removal efficiency of 68%. However, at 6 hours-operating time, the EC process reached equilibrium and became stable. Based on these findings, EC process was proven to be a feasible method to decolourize POME.

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