

Decolorization and COD Removal of Palm Oil Mill Wastewater by Electrocoagulation

K. Sontaya, B. Pitiyont, and V. Punsuvon

Abstract—The objective of this study is to investigate the performance of the electrocoagulation process for color and COD removal in palm oil wastewater using a 10 L batch reactor. Iron was used as electrodes and the distance between electrodes was 2cm. The effects of operating parameters: current voltage (6, 12 and 18 volt), reaction time (5, 15, 30, 45 and 60min) and initial pH (4 and 9) of treatment efficiency were examined. The result showed that decolorization and COD removal efficiency increased with the increase in current voltage and reaction time. The proper condition for decolorization achieved at initial pH 4 and 9 were current voltage of 12 volt, reaction time 30min. The decolorization efficiency reached 90.4% and 88.9%, respectively. COD removal was achieved at current voltage 12 volt, reaction time 15min. COD removal efficiency was 89.2% and 83.0%, respectively. From the results, to show electrocoagulation process can treat palm oil mill wastewater in both acidic and basic condition at high efficiency for color and COD removal. Consequently, electrocoagulation process can be used or applied as a post-treatment step to improve the quality of the final discharge in term of color and residual COD removal.

Keywords—COD removal, decolorization, electrocoagulation, iron electrode, palm oil mill wastewater.

I. INTRODUCTION

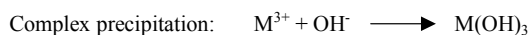
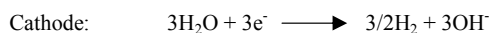
PALM oil production is one of the major important industries in Thailand. The total production of crude palm oil was 800,000 tones/year. However, the production of this amount of crude palm oil results in larger amounts of palm oil mill (POM) wastewater. The characteristic of POM wastewater have a high concentration in organic contents, color and total solids. In this reason the treatment of POM wastewater is an important process before discharge to environment. It has been reported that 85% of the POM wastewater treatment is using biological treatment processes [1].

They are considered to be environmentally friendly, and in most cases, cost – effective, however, a large area is needed.

Electrocoagulation (EC) as an electrochemical method is becoming an effective technology to be used for water and wastewater treatment process and recovery of valuable chemicals from wastewater containing textile dyes, oil, heavy metals, complex organic compounds and also municipal

wastewater. EC not only provides a fast rate of pollutant removal and simplicity of operation but no chemical additive is required, therefore, would produce less amount of sludge [2]-[5]. These beneficial properties of EC are better than conventional physicochemical treatment processes. Recently, EC has also been successfully applied to remove oil and COD from the oily wastewater that comes from restaurants and the mechanical and metallurgical industries [6], [7]. Numerous EC process have been tested as a pre - treatment step or post - treatment step of biological process used for the treatment of olive mill wastewater. In the study conducted by Hanafi et al. [8], EC can remove more than 70% of COD (20,000mg/L), polyphenols (200mg/L) and dark color after 15min of treatment by the addition of 2g/L NaCl, initial pH 4.2 and current density 250 A/m². The EC has also been combined with ultrafiltration as a post - treatment method to treat olive mill wastewater [9].

EC process basically involves in situ generating M³⁺ ions in the electrolyte solution using sacrificial anodes (typically aluminum, iron or stainless steel) with the simultaneous formation of hydroxide ions and hydrogen gas at the cathode. Finally, M³⁺ and OH⁻ ions generated by electrode reaction that transform into M(OH)_{3(s)} [10], [11] according to



The hydrogen gas naturally evolved in EC would also keep floating of the flocs. This phenomenon is considered to be one of the advantage in EC.

The objective of this study is to assess the efficiency of electrocoagulation process of palm oil mill wastewater using iron electrode. The effect of operation parameters such as current voltage, reaction time and initial pH have been examined on color and COD Removal Efficiency.

II. MATERIALS AND METHODS

A. Experimental Setup

The electrocoagulation setup is schematically shown in Fig. 1. The EC unit consisted of an 10L electrochemical reactor, a DC power supply providing a current of 6, 12 and 18 volt and iron electrodes with dimension of 9cm x 9cm x 0.2cm the distance between electrodes was 2cm which is a typical value in EC cells. The electrode were washed thoroughly with distilled water, brushed and dried at 105°C for 1 hr prior use.

K. Sontaya and B. Pitiyont are with the Department of Environmental Technology and Management, Faculty of Environment, Kasetsart University, P.O. Box 1072, PhahonYothin Rd, Chatuchak, Bangkok 10903, Thailand. (corresponding author to provide phone +66(8) - 583 - 3224 - 2; e-mail: sontaya.ko@gmail.com; fscibop@ku.ac.th)

V. Punsuvon is with the Department of chemistry, Faculty of Science Kasetsart University, P.O. Box 1072, PhahonYothin Rd, Chatuchak, Bangkok 10903, Thailand.

All the runs were performed at the room temperature. In each run, 7,000ml of the POM wastewater was introduced into the electrolytic cell

The experiments were conducted in a batch mode. To investigate the effect of current and color and COD removal efficiencies, EC process was carried out using various current voltages at 6, 12 and 18 volt. The effect of initial pH on the process performance was also studied at 4 and 9 with the reaction time of 5, 10, 15, 30, 45 and 60min. At the end of EC, all samples were allowed to settle for 20min before analysis.

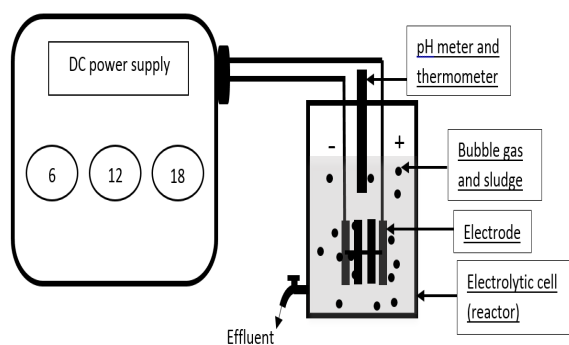


Fig. 1 Diagram of experiment setup for electrocoagulation process

B. Palm Oil Mill (POM) Wastewater

Palm oil mill wastewater was obtained from a palm oil mill plant located in south of Thailand which was treated before by biological treatment. POM was stored in closed containers at ambient temperature. The main characteristics of POM wastewater was given in Table I.

TABLE I
THE CHARACTERISTIC OF POM WASTEWATER

parameters	value
COD (mg/L)	1,414
BOD ₅ (mg/L)	133
SS (mg/L)	520
Oil and Grease (mg/L)	n.d.
pH	9
Conductivity (mS/cm)	2.894
Temperature (°C)	30.7

n.d. = not detected

C. Analysis

BOD₅, COD values, SS, oil and grease were determined according to standard methods [12], pH was measured by using EC 30 pH meter. Color concentration was measured using UV/vis spectrophotometer (Perkin Elmer Lambda 650) at a wavelength corresponding to the maximum absorbance of POM wastewater (maximum absorbance I_{max} = 383 nm). The color removal efficiency R(%) after EC was calculated using the following formula:

$$R(\%) = \frac{C_0 - C}{C_0} \times 100$$

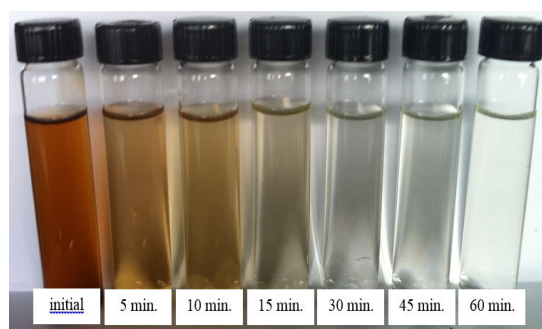
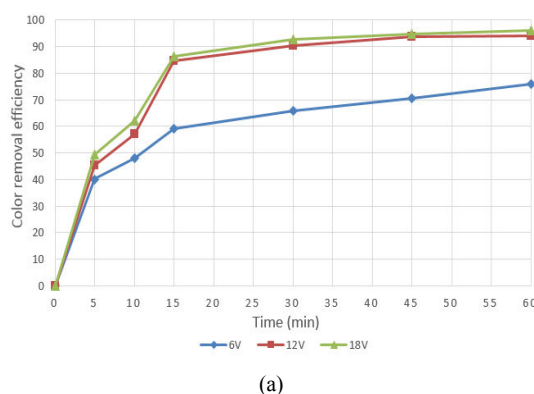
where C_0 and C are respectively absorbances of POM wastewater before and after electrocoagulation.

III. RESULTS AND DISCUSSION

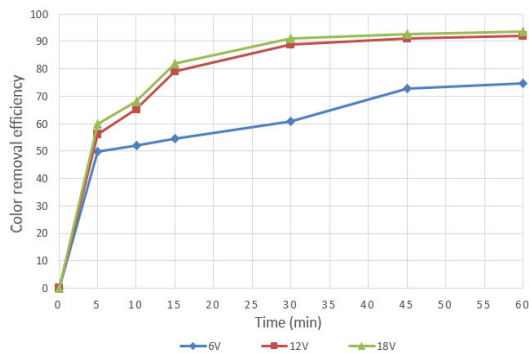
Decolorization and COD removal efficiency were investigated in term of initial pH and reaction time or electrolysis time in order to evaluate the optimum conditions from wastewater.

A. Efficiency of Decolorization at Initial pH 4 and Initial pH 9

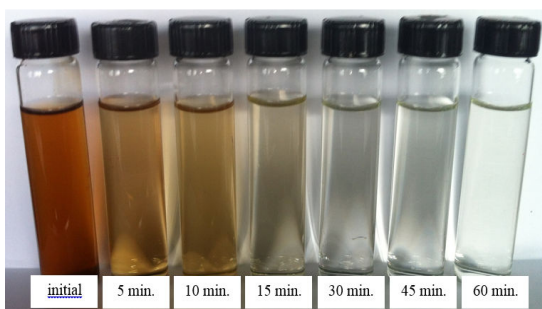
Fig. 2 shows the decolorization efficiency with reaction time at various current voltages. The experimental results showed that the color removal efficiency increased with the current voltage. At initial pH 4, the decolorization efficiency rose to 93.7% and 94.8% respectively, after 45 and 60min at 12 volt and 94.0% and 96.0%, respectively, at a high current voltage of 18 volt. However, considering economic feasibility, it can be observed that > 90% of color removal was reached after 30min for current voltage of 12 and 18 volt. The same tendency of the results was observed for initial pH 9. The decolorization efficiency rose to 94.8% and 96.0% respectively, after 45 and 60min at 12 volt and 92.7% and 93.5%, respectively, at a high current voltage of 18 volt. In general, at lower and higher pH, iron is increasingly soluble. Increasing the current voltage can influence the release of iron hydroxide ions which turn effect the color removal efficiency. Reaction time also influences the EC efficiency. Increasing reaction time results in increasing removal efficiency.



(b)



(c)

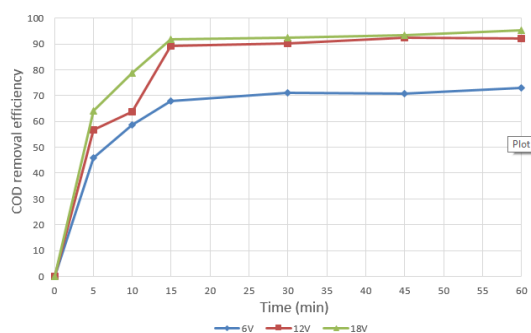


(d)

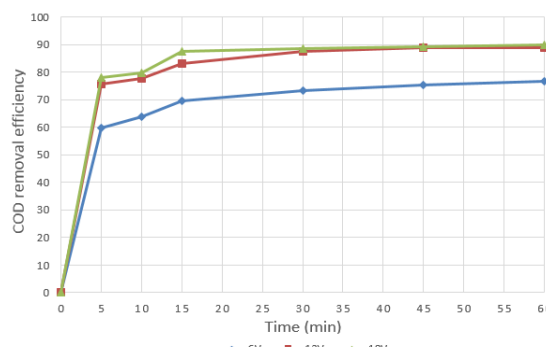
Fig. 2 Efficiency of electrocoagulation process for color removal by iron electrode (a), (b) initial pH 4 and (c), (d) initial pH 9

B. Efficiency of COD Removal at Initial pH 4 and Initial pH 9

The efficiency of COD removal shows the same tendency with color removal efficiency. Fig 3 shows the COD removal as a function of reaction time. It can be observed that COD removal efficiency increased to a specific level, then, the efficiency tended to decrease. The optimum operating conditions for COD removal, in term of economic feasibility, is reaction time 15 min, initial pH 4 for current voltage of 12 volt and 18 volt (89.2% and 91.8%, respectively).



(a)



(b)

Fig. 3 Efficiency of electrocoagulation process for COD removal by iron electrode (a) initial pH 4 (b) initial pH 9

At initial pH 9, COD removal efficiency was observed lower than at lower pH. The removal efficiency of COD was between 89 - 90% for a current voltage of 12 and 18 volt at 60 min reaction time. At a high current voltage, the extent of iron dissolution increases, resulting in a higher removal of organic compounds in POM wastewater. Analysis of the concentration of iron at both initial pH 4 and pH 9, a current voltage of 12 volt revealed that iron tended to decrease after reaction time 30 min and simultaneously increased after 60min as shown in Fig. 4.

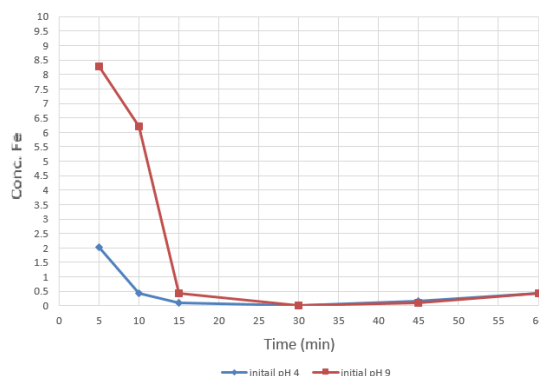


Fig. 4 Concentration of iron after treatment at /30 minutes under current voltage 12 volt

IV. CONCLUSIONS

Electrocoagulation is one of most effective techniques for wastewater treatment process. The decolorization and COD removal of POM wastewater by this EC process was affected by current voltage and reaction time. The resulted showed that the current voltage is the most important parameter for controlling the reaction rate within the EC reactor. EC process shows a high color and COD removal efficiency of the POM wastewater. Proper conditions based on this experiment are 12 volt of electrical voltage at 30min reaction time for color removal and at 15min for COD removal in both of acidic and basic conditions. The efficiencies of color removal are 90.4% and 88.9%, respectively. COD removal is 89.2% and 83.0%,

respectively. Consequently, the electrocoagulation can be used or applied as a post-treatment step to improve the quality of the final discharge in term of color and residual COD removal by iron electrode.

ACKNOWLEDGMENT

We are thankful of Thailand Research Fund (TRF) and Graduate School, Kasetsart University, Thailand for partial financial support.

REFERENCES

- [1] K. Gobi, M. D. Mashitah and V. M. Vadivelu. "Development and utilization of aerobic granules for the palm oil mill (POM) wastewater treatment" *Chemical Engineering Journal*, vol.174, pp.213– 220, Sep.2011.
- [2] U. U. Tezcan, S. Ugur, A. S. Koparal and O. U. Bakir. "Electrocoagulation of olive mill wastewaters" *Separation and Purification Technology*, vol.52, pp.136–141, Nov. 2006
- [3] G. Mouedhen, M. Feki, M. P. Wery and H. F. Ayedi. "Behavior of aluminum electrodes in electrocoagulation process" *Journal of Hazardous Materials*, vol.150, pp.124–135, Jan. 2008.
- [4] L. H. andez, D. C. Barrera, G. M. Roa, B. Bilyeu and N. F. Urena. "Influence of the anodic material on electrocoagulation performance" *Chemical Engineering Journal*, vol.148, pp.97 – 105, May. 2009.
- [5] A. Bukhari, "Investigation of the electro-coagulation treatment process for the removal of total suspended solids and turbidity from municipal wastewater" *Bioresour. Technology*, vol.99, pp. 914–921, Mar. (2008)
- [6] X. Xu and X. Zhu. "Treatment of refinery oily wastewater by electrocoagulation process" *Chemosphere*, vol.56. pp.889 – 894, Sep. 2004.
- [7] M. Tir and M. N. Moulai "Optimization of oil removal from oily wastewater by electrocoagulation using response surface method" *Journal of Hazardous Materials*, vol.158, pp.107–115.2008.
- [8] F. Hanafi, O. Assobhei, and M. Mountadar, "Detoxification and discoloration of Moroccan olive mill wastewater by electrocoagulation", *Journal of Hazardous Materials*, vol.174, pp. 807–812, Feb. 2010.
- [9] O. Yahiaoui, H. Lounici, N. Abdi, N. Drouiche, N. Ghaffour, A. Pauss, and N. Mameri, "Treatment of olive mill waste water by the combination of ultra filtration and bipolar electrochemical reactor processes" *Chemical Engineering and Processing: Process Intensification*, vol.50, pp. 37–41, Jan. 2011.
- [10] E. Murat, M. Kirlaroglu, T. S. Aktas and E. Yaksel "The effect of alternating current electrocoagulation on dye removal from aqueous solutions" *Chemical engineering journal*, vol.153, pp.16 – 22, May. 2009.
- [11] M. Rebhun and M. Lurie "Control of organic-matter by coagulation and floc separation" *Water Science and Technology*, vol.27, pp. 1–20. 1993.
- [12] APHA "Standard method for the examination of water and wastewater" "20th edition, 1998.