Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 17 | No. 4 | pp. 1267-1271 | 2018

Original Research Paper | Open Access

Application of Electrocoagulation Process for Decolourisation of Palm Oil Mill Effluent (POME)

Shariff Ibrahim*†, Nur Syuhaidah Mohd Aris*, Borhannuddin Ariffin*, Yahaya Hawari and Megat Ahmad Kamal Megat Hanafiah***(****)**

*Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia
**Milling and Processing Unit, Engineering and Processing Division, Malaysian Palm Oil Board (MPOB), No 6, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia
***Faculty of Applied Sciences, Universiti Teknologi MARA, 26400, Jengka, Pahang, Malaysia
****Institute of Science (IOS), Universiti Teknologi MARA, Shah Alam, 40450, Shah Alam, Selangor, Malaysia
†Corresponding author: Shariff Ibrahim

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 20-12-2017
Accepted: 01-03-2018

Key Words:
Electrocoagulation
Coagulation
Palm oil mill effluent
Aluminium electrode
Floc

ABSTRACT

In this study, the decolourisation of Palm Oil Mill Effluent (POME) was investigated by electrocoagulation (EC) batch reactor utilizing aluminium plate electrodes. POME was characterized physicochemically for colour, chemical oxygen demand (COD), pH, conductivity and turbidity. The colour of POME was observed to be dark brown of 2707 PtCo with a high organic content of COD at 3909 mg/L and high turbidity at 755 NTU. The electrical conductivity was at 12.82 mS. The influence of various operating parameters such as pH (3 to 11), applied voltage (5 V to 20 V) and plate gap (7.5 to 11.5 cm) to the POME colour removal were investigated as well. The highest colour removal was spotted at pH 5, applied voltage of 20 V and plate gap of 9.5 cm with corresponding colour removal percentage of 89, 79 and 78%, respectively. The EC flocs examined using FESEM exhibited the amorphous spherical and rod-like shape structure.

INTRODUCTION

The existence of colour pollutants in a water system is undesirable due to mainly its physical appearance. Palm oil mill effluent (POME) is one of the many sources of coloured wastewater. POME is often associated with a dark colour and has extremely high level of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) together with a substantial amount of suspended solids (Chin et al. 2013). Palm oil extraction is a water intensive activity. In 2011, it is estimated that about 57 million tons of POME were generated in Malaysia alone (Kanu & Achi 2011). An intense dark brown colour that is always observed in any effluent from the vegetable oil extraction process, i.e. olive oil was due to polymerization of tannins and low molecular weight phenolic compounds (Onyla et al. 2001). This is certainly alarming as polyphenolic components were responsible for the phytotoxicity (Borja et al. 1998).

A wide range of techniques have been researched to remediate colour wastewater. These include adsorption, anaerobic treatment, coagulation, electrocoagulation, flotation, filtration, ion exchange, membrane separation and advanced oxidation (Anjaneyulu et al. 2005). Meanwhile, the attractiveness of using the coagulation process for colour removal has been explored by a number of researchers (Verma et al. 2012). Electrocoagulation (EC), a variation of the coagulation process has gained popularity, as this method does not employ chemicals, unlike chemical coagulation (CC).

Mechanism of electrocoagulation (EC): Instead of dissolution of a chemical coagulant as in CC, an electric oxidation of anode material in EC provides the coagulant to the system. Iron or aluminium is commonly employed as a sacrificial electrode material in the EC process. For aluminium electrodes, the anodic and cathodic reactions can be written as follows (Janpoor et al. 2011):

Oxidation at the anode:

$$Al\text{-}3e \rightarrow Al^{3+} \quad ...(1)$$

Reduction at the cathode:

$$3H_2O + 3e^- \rightarrow 3/2H_2 + 3OH^- \quad ...(2)$$

Then the generated Al^{3+} and OH^- ions react to form $Al(OH)_3$

$$Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^+ \quad ...(3)$$

$$Al(OH)_3 + OH^- \rightarrow Al(OH)^-_4 \quad ...(4)$$

The polymeric aluminium complexes are able to attract polluting species due to their feature of having both positive and negative charges (Ouaissa et al. 2014).

Presently, the research into EC has gained traction where various applications in urban as well as industrial effluent, especially for colloidal and organic matter removal have been explored (Kuokkanen et al. 2013). The EC treatment is straightforward in operation, where no chemical is added and at the same time reducing the production of sludge (Yazdanbakhsh et al. 2013). Studies that show the usefulness of EC for the treatment of effluent resulting from vegetable oil processing are presented in Table 1.

In this paper, we describe the applicability of EC for the removal of colour from POME. POME has been characterized namely for colour, chemical oxygen demand (COD), pH, conductivity and turbidity. The electrocoagulation tests were performed in batch mode using aluminium electrodes. The effects of voltage of EC unit and pH of POME on colour removal were investigated and discussed.

MATERIALS AND METHODS

Palm oil mill effluent (POME) sample: POME sample was collected from final discharge ponds at the palm oil mill factory located in Labu, Negeri Sembilan, Malaysia and kept at 4°C prior to usage.

Set up of EC batch reactor: The electrocoagulation experiments were conducted in a 4000 mL home-made Plexiglas batch reactor. A GW laboratory DC power supply (Model: GPS-3030D, USA) was used to supply the system with a working range of 0-30 V. Unless stated, throughout the experiment, a pair of aluminium plates of size 14 cm (L) × 14.5 cm (W) × 0.15 cm (H) were used, immersed in the sample to a depth of 8 cm. An electrode gap of 8.5 cm was fixed throughout the experiments. The experiments were conducted at room temperature for the POME sample (3000 mL) with constant stirring at 6 h EC operating time. Unless stated otherwise, for the EC operating parameters, original pH and electrical conductivity of POME at 7.63 and 12.82 mS respectively, were used. The EC voltage and stirrer speed were fixed at 10 V and 200 rpm, respectively.

Characterization of POME wastewater: POME has been characterized for its colour, chemical oxygen demand (COD), pH, conductivity, and turbidity according to standard methods (APHA 2005). POME colour was analysed using HACH spectrophotometer at maximum wavelength of 455 nm. The COD was measured using the HACH spectrophotometer (Model: DR2800, USA). The pH was measured using a HANNA instrument microprocessor pH meter (Model: pH 211, USA). The conductivity was measured using a EUTECH handheld conductivity meter. A HACH turbidimeter (Model: 2100P, USA) was used to measure the sample turbidity. The floc produced after the EC process was filtered, and oven dried at 70°C. The floc surface morphology was examined using a field emission scanning electron microscope (FESEM, Model: Zeiss Supra 40VP, Germany).

Effect of EC operating parameters: In a typical experiment, an initial sample was taken once the specified volume of wastewater was poured into the reactor. The 6 h operating time started when the DC power supply (Model: GPS-3030D, USA) was switched on. During the treatment process, POME samples of 5 mL were taken hourly before being analysed to determine the colour intensity.

The effects of EC operating parameters such as EC voltage (5-20 V), dose of supporting ions (NaCl) (0.33 to 1.67 g/L) and number of plates (2-8 plates) were investigated by varying one parameter while keeping the other parameters constant. As for effluent ionic conductivity, the original POME electrical conductivity of 12.82 mS was used for all the experiments unless mentioned elsewhere.

RESULTS AND DISCUSSION

Characterization of POME wastewater: Results for the characterization of POME before EC treatment are presented in Table 2. Visually, the POME is brownish in colour and contains high suspended solids as indicated by the high colour intensity (2707 PtCo), COD (3009 mg/L) and turbidity (755 NTU). The pH of POME is at neutrality (7.63) with conductivity at 12.82 mS. This value of conductivity is reported as adequate to function as an electrolyte during the EC treatment (Esfandyari et al. 2015).

Floc surface morphology analysis: The result of physical characterization of the flocs generated is shown in Fig. 1.

Table 1: EC treatment for POME and olive mill wastewater.

Type of wastewater	Anode material	Removal efficiency (%)	Reference
Palm oil mill effluent	Al	64 (COD)	(Phalakornkule et al. 2010)
Palm oil mill effluent	Al	42.94 (COD), 83.16 (turbidity)	(Nasution et al. 2014)
Olive mill wastewater	Stainless steel	70.8 (COD)	(Giannis et al. 2007)
Olive mill wastewater	Fe	99.89 (turbidity), 96.14 (COD), 89.97 (phenolic)	(Yazdanbakhsh et al. 2013)
Olive mill wastewater	Al, stainless steel, RuO_2/Ti	96 (COD), 94.4 (polyphenols), 91.4 (color), 88.7 (turbidity)	(Esfandyari et al. 2015)

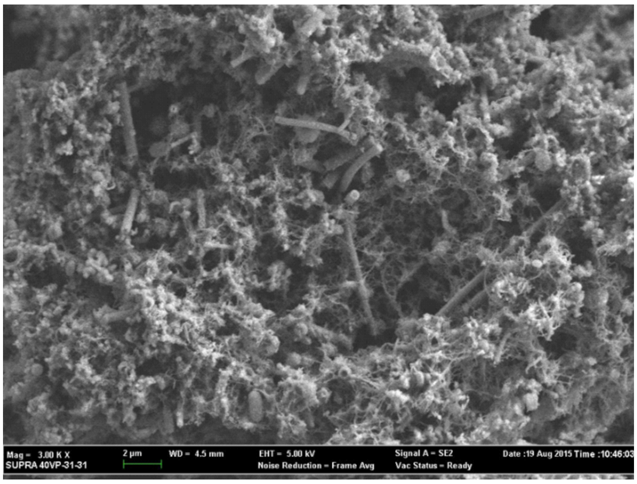

Fig.1: FESEM image of EC flocs at pH 9.

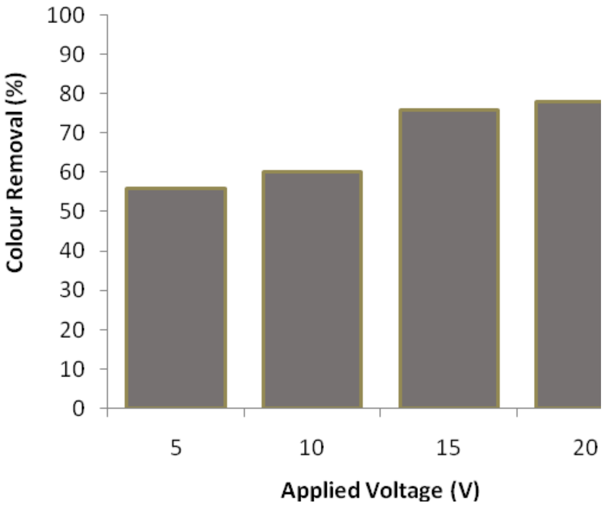

Fig. 2: POME colour removal at different applied voltage.

Table 2: Characterization of POME wastewater.

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

The FESEM image of the surface of EC flocs was recorded with a 3000 X magnification. It can be seen that the flocs have an amorphous structure which is consistent with work done by Can & Bayramoglu (2014). The spherical structure indicates the coagulated species, while the rod-like shape structure denotes the bridging of coagulated species (Smoczyñski et al. 2016).

Effect of applied voltage: The influence of voltage on the EC performance has been reported by many researchers (Bazrafshan et al. 2008, Drouiche et al. 2009). The supply of voltage to the electrocoagulation system indicates the amount of coagulant precursor and Al^{3+} released from the respective plates. For this work, the voltage has been varied from 5 to 20 V. It can be observed in Fig. 2 that the colour removal efficiency was improved from 56 to 78% as the applied voltage increased from 5 to 20 V. It was suggested that the more aluminium cations generated in the solution at higher voltages promoted more formation of coagulating species $Al(OH)_3$ (Bazrafshan et al. 2012) crucial to the formation of hydroxide flocs thus aiding the decolourisation rate. This pattern is in agreement with the work done by Adhoum & Monser (2004) in their research of phenolic compounds removal from olive mill wastewater by electrocoagulation.

Effect of NaCl dosage: Conductivity of the electrolyte solution is the key factor in an electrochemical process (Kim et al. 2002). The influence of POME ionic conductivity was evaluated by adding salt ions, NaCl solution at various doses ranging from 0.33 to 2.33 g/L to the EC system. The results presented in Fig. 3 indicate that the colour removal efficiency was influenced by the salt dosage. When the NaCl dosage was increased from 0.33 to 1.67 g/L, the colour removal efficiency increased from 41 to 74%. Adding salt solution, in this case chloride ions helped in destroying the passive layer on the aluminium electrode, thus easing the formation of coagulating species (Nandi & Patel 2017, Golder et al. 2006). However, colour removal was strangely observed to reduce to 60% when salt was further added (i.e., at 2.33 g/L). The formation of some transitory compounds such as $Al(OH)_2Cl$, $Al(OH)Cl_2$ and $AlCl_3$, which lowered the formation of $Al(OH)_3$, was reported to be responsible for this phenomena (Hanafi et al. 2010).

Effect of number of plates: The number of plates used in the EC process determines the surface area available for colour pollutant removal. For this, the number of electrode plates was varied from 2 to 8 to evaluate their impact on POME colour removal (Fig. 4). The colour removal percentage was maximised at 75% when 4 plates were used, but was decreased to about 64% for 6 and 8 plates. The lowest removal was observed when 2 plates were used. The higher percentage of colour removal at higher plate numbers occurred since more coagulant precursor (Al^{3+}) was formed. It was also due to a higher number of aluminium active area available, thus more coagulating species, $Al(OH)_3$ was generated (Janpoor et al. 2011). This phenomenon, however, was not shared at six and eight plates, where the removal

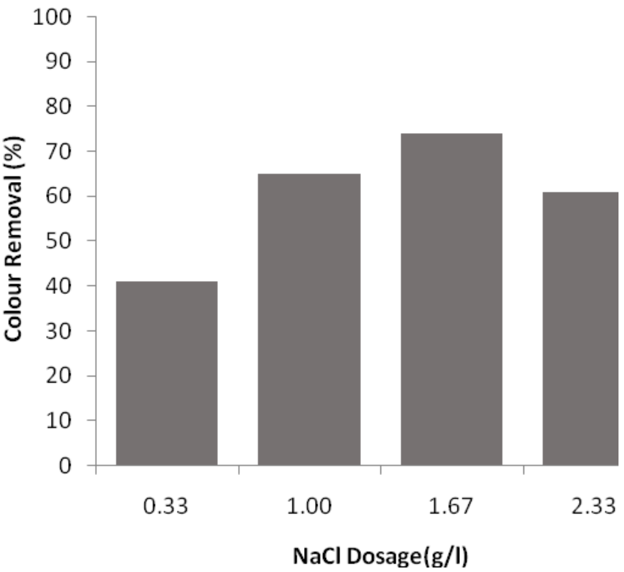

Fig. 3: Effect of NaCl dosage on POME colour removal.

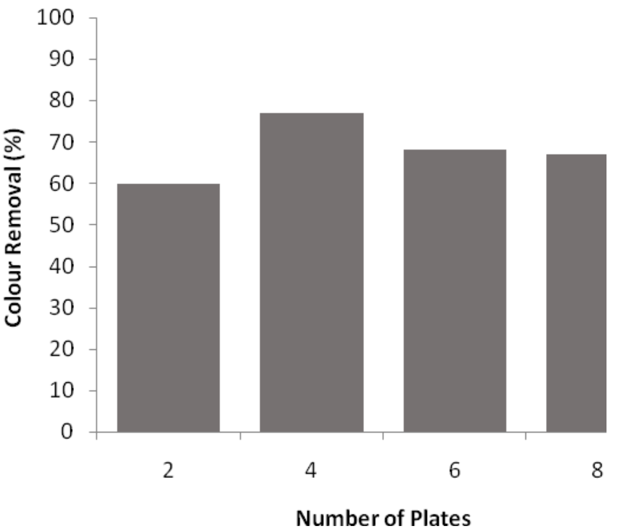

Fig. 4: Effect of number of plates on POME colour removal.

percentage reduces to about 65%. For this Khatibikamal et al. (2010) mentioned that, adding more plates above the optimized plate numbers did not necessarily translate to better removal, as extra plates could cause a decrease of electric current due to the solution's higher resistance. This may subsequently decrease the concentration of Al^{+3}. Thus, for better electrocoagulation efficiency, it is crucial to establish the optimized number of extra plates used.

CONCLUSIONS

In this study, decolourisation of POME using EC was conducted. Several physicochemical methods characterized POME sample. Few EC operating parameters were evaluated for POME colour removal. Some major conclusions are summarized as follows:

- Characterization studies indicated that POME had a high organic content, with intense colour. Conductivity of raw POME was observed as adequate as the electrolyte for EC process.
- EC voltage affected the percentage of colour removal, where the maximum removal was at 15 V.
- POME's increasing conductivity influenced the better percentage of colour removal, where the maximum removal was observed at 1.67 g/L NaCl.
- There was a maximum percentage removal when 4 plates of aluminium electrodes were used. Lower and higher number of plates were found to be ineffective.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the research grant funded by the Ministry of Higher Education (MOHE) via Research Management Centre, Universiti Teknologi MARA (FRGS: 600-RMI/FRGS 5/3 (2/2014)) and the research facilities provided by the Postgraduate School, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM). Special thanks are due to Malaysian Palm Oil Board (MPOB) and Palm Oil Mill Plant in Labu, Negeri Sembilan, and Mr. Shahril for coordinating the research activities.

REFERENCES

Adhoum, N. and Monser, L. 2004. Decolourization and removal of phenolic compounds from olive mill wastewater by electrocoagulation. Chemical Engineering and Processing: Process Intensification, 43(10): 1281-1287.

Anjaneyulu, Y., Chary, N.S. and Raj, D.S.S. 2005. Decolourization of industrial effluents - available methods and emerging technologies - a review. Reviews in Environmental Science and Bio/Technology, 4(4): 245-273.

Bazrafshan, E., Mahvi, A.H., Naseri, S. and Mesdaghinia, A.R. 2008. Performance evaluation of electrocoagulation process for removal of chromium (VI) from synthetic chromium solutions using iron and aluminum electrodes. Turkish Journal of Engineering and Environmental Sciences, 32(2): 59-66.

Bazrafshan, E., Moein, H., Kord Mostafapour, F. and Nakhaie, S. 2012. Application of electrocoagulation process for dairy wastewater treatment. Journal of Chemistry, 2013, Article. ID 640139:8.

Borja, R., Alba, J., Mancha, A., Martin, A., Alonso, V. and Sanchez, E. 1998. Comparative effect of different aerobic pretreatments on the kinetics and macroenergetic parameters of anaerobic digestion of olive mill wastewater in continuous mode. Bioprocess Engineering, 18(2): 127-134.

Can, O.T. and Bayramoglu, M. 2014. A comparative study on the structure-performance relationships of chemically and electrochemically coagulated $Al(OH)_3$ flocs. Industrial & Engineering Chemistry Research, 53(9): 3528-3538.

Chin, M.J., Poh, P.E., Tey, B.T., Chan, E.S. and Chin, K.L. 2013.

Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective. Renewable and Sustainable Energy Reviews, 26: 717-726.

Drouiche, N., Aoudj, S., Hecini, M., Ghaffour, N., Lounici, H. and Mameri, N. 2009. Study on the treatment of photovoltaic wastewater using electrocoagulation: Fluoride removal with aluminium electrodes-Characteristics of products. Journal of Hazardous Materials, 169(1): 65-69.

Esfandyari, Y., Mahdavi, Y., Seyedsalehi, M., Hoseini, M., Safari, G.H., Ghozikali, M.G., Kamani, H. and Jaafari, J. 2015. Degradation and biodegradability improvement of the olive mill wastewater by peroxi-electrocoagulation/electrooxidation-electroflotation process with bipolar aluminum electrodes. Environmental Science and Pollution Research, 22(8): 6288-6297.

Giannis, A., Kalaitzakis, M. and Diamadopoulos, E. 2007. Electrochemical treatment of olive mill wastewater. Journal of Chemical Technology and Biotechnology, 82(7): 663-671.

Golder, A.K., Samanta, A.N. and Ray, S. 2006. Anionic reactive dye removal from aqueous solution using a new adsorbent - sludge generated in removal of heavy metal by electrocoagulation. Chemical Engineering Journal, 122(1): 107-115.

Hanafi, F., Mountadar, M. and Assobhei, O. 2010. Combined electrocoagulation and fungal processes for the treatment of olive mill wastewater. In: Fourteenth International Water Technology Conference, IWTC, 14: 269-281.

Janpoor, F., Torabian, A. and Khatibikamal, V. 2011. Treatment of laundry waste water by electrocoagulation. Journal of Chemical Technology and Biotechnology, 86(8): 1113-1120.

Kanu, I. and Achi, O. 2011. Industrial effluents and their impact on water quality of receiving rivers in Nigeria. Journal of Applied Technology in Environmental Sanitation, 1(1): 75-86.

Khatibikamal, V., Torabian, A., Janpoor, F. and Hoshyaripour, G. 2010. Fluoride removal from industrial wastewater using electrocoagulation and its adsorption kinetics. Journal of Hazardous Materials, 179(1): 276-280.

Kim, T.H., Park, C., Shin, E.-B. and Kim, S. 2002. Decolorization of disperse and reactive dyes by continuous electrocoagulation process. Desalination, 150(2): 165-175.

Kuokkanen, V., Kuokkanen, T., Rämö, J. and Lassi, U. 2013. Recent applications of electrocoagulation in treatment of water and wastewater-a review. Green and Sustainable Chemistry, 3(02): 89-121.

Nandi, B.K. and Patel, S. 2017. Effects of operational parameters on the removal of brilliant green dye from aqueous solutions by electrocoagulation. Arabian Journal of Chemistry, 10(Supp. 2): 2961-2968.

Nasution, A., Ng, B.L., Ali, E., Yaakob, Z. and Kamarudin, S.K. 2014. Electrocoagulation of palm oil mill effluent for treatment and hydrogen production using response surface methodology. Polish Journal of Environmental Studies, 23(5): 1669-1677.

Onyla, C., Uyub, A., Akunna, J.C., Norulaini, N. and Omar, A. 2001. Increasing the fertilizer value of palm oil mill sludge: bioaugmentation in nitrification. Water Science and Technology, 44(10): 157-162.

Ouaissa, Y.A., Chabani, M., Amrane, A. and Bensmaili, A. 2014. Removal of tetracycline by electrocoagulation: Kinetic and isotherm modeling through adsorption. Journal of Environmental Chemical Engineering, 2(1): 177-184.

Phalakornkule, C., Mangmeemak, J., Intrachod, K. and Nuntakumjorn, B. 2010. Pretreatment of palm oil mill effluent by electrocoagulation and coagulation. Science Asia, 36: 142-149.

Smoczyñski, L., Ratnaweera, H., Kosobucka, M., Smoczyñski, M., Kalinowski, S. and Kvaal, K. 2016. Modelling the structure of sludge aggregates. Environmental Technology, 37(9): 1122-1132.

Verma, A.K., Dash, R.R. and Bhunia, P. 2012. A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters. Journal of Environmental Management, 93(1): 154-168.

Yazdanbakhsh, A., Massoudinejad, M., Arman, K. and Aghayani, E. 2013. Investigating the potential of electrocoagulation-flotation (ECF) process for pollutants removal from olive oil mill wastewater. J. Appl. Environ. Biol. Sci., 3(3): 22-28.