Poll Res. 39 (2) : 221-226 (2020)

ISSN 0257–8050

THE EFFECTS OF CURRENT DENSITY, TREATMENT TIME AND pH ON THE REMOVAL OF COLOUR FROM SALINE LANDFILL LEACHATE USING ALUMINIUM ELECTRODE IN ELECTROCOAGULATION PROCESS

MOHD AZHAR ABD HAMID[1], HAMIDI ABDUL AZIZ[1, 2*], MOHD SUFFIAN YUSOFF[1, 2], AND SHEIKH ABDUL REZAN S. ABDUL HAMID[3]

[1]*School of Civil Engineering, Engineering Campus,Universiti Sains Malaysia, 14300, Nibong Tebal, Penang*
[2]*Solid Waste Management Cluster, Engineering Campus, Universiti Sains Malaysia Universiti Sains Malaysia, 14300, Nibong Tebal, Penang*
[3]*School of Materials and Mineral Resources Engineering Universiti Sains Malaysia, 14300, Nibong Tebal, Penang*

(Received 7 September, 2019; accepted 24 January, 2020)

ABSTRACT

This paper examines the significance influence of the operational condition such as current density (60 A/m^2 to 780 A/m^2), treatment time (5 min to 60 min) and pH (5 to 10) on the elimination of colour from Pulau Burung Municipal Landfill leachate which is saline in nature. A laboratory scale batch reactor was conducted using Aluminium electrode in a parallel-monopolar arrangement directly connected to the DC power supply (60V/5A) to increase the performance of the electrocoagulation reactor. The initial value of colour and salinity leachate electrolyte is 8427 Pt-Co and 15.13 ppt respectively was identified before the treatment process. The key influence of natural salinity leachate in this research is current density was observed at 540 A/m^2, treatment time at 60 min, optimum pH at 8 and the total colour removal obtained was up to 71%. The empirical findings in this study provide insights on the potential of utilizing electrocoagulation process as a viable option to remove highly colored leachate with adequate salinity without ancillary to the electrolyte.

KEY WORDS: Electrocoagulation, Leachate, Colour, Salinity

INTRODUCTION

Malaysia generates about 6.2 million/tons of solid waste annually or about 1.7 kg/person/day in urban area (Omran *et al.*, 2018). This volume is predicted to rise approximately 30,000 tons/day in the year 2020 due to increasing population and generation of waste (Johari *et al*., 2014). Currently, landfilling is still the main method and the best option for managing solid waste disposal (Nor *et al.*, 2010). However, quite a few of the sites are not equipped and provided with a proper leachate treatment (Malek and Shaaban, 2008). Based on Nasional Solid Waste Management Department (NSWMD), the total landfill site operating in Malaysia is 296. Out of 296, only a number of 166 landfills are still in operation while the remaining 130 are no longer in service. However, proper treatment of leachate must be conducted even after the landfills are out of operation. This is because leachate may still flow and without proper handling, it may cause detrimental effects towards the environment (Aziz *et al.*, 2010).

According to the previous study by Kamaruddin *et al.*, (2016), leachate exudes a strong, awful odour and dark colour in nature. Organic matters with some insoluble forms present to the colour in the landfill leachate that exhibited turbidity and suspended solids value (Aziz *et al.*, 2007). The most difficult parameters to treat and to comply with the discharge standards in Malaysia are colour, ammoniacal nitrogen, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and suspended solid (Huang *et al.,* 2016). Unfortunately, conventional treatments in practice are found to be ineffective to fully comply with the standards as shown in Table 1 (Environment quality act 1974).

Several types of physico-chemical treatment processes have been employed to achieve a acceptable removal of pollutants from the landfill leachate (Aziz *et al.*, 2010). Electrocoagulation (EC) is another interesting approach for the handling of landfill leachate. EC is an electrochemical and simple method which uses electrical current for the treatment of many forms of wastewater without the addition of chemical coagulants (Kobya *et al.,* 2008). Electrocoagulation has gained significant attention and has become one of the reliable methods for landfill leachate treatment as it offers a lot of advantages. This includes a reduction in sludge generation post-treatment, irrelevant need for chemical uses, unexacting method of operation, cost-friendliness and brief operating time (Huda *et al.,* 2017).

In electrocoagulation, the most significant factors that influence the efficiency of EC is electrode material (Song *et al.*, 2017). In most literature studies done on EC, it is highlighted that both electrodes are made of the same material. According to Akyol, (2012) and Bouhezila *et al.,* (2011), materials that have been identified to be used in the manufacturing of electrode metals includes magnesium, titanium, stainless steel, zinc, graphite, aluminium and iron. In practice, aluminium and iron are the most preferred materials for EC electrode. This is due to that they are inexpensive, easily available and effectively in removal efficiency (Cheballah *et al.,* 2015). However, the aluminium electrode was more effective than iron electrode in the elimination of soluble and insoluble organic mixtures such as colour, turbidity, suspended solids and COD (Fayad, 2018). Higher efficiency of aluminium electrode also was reported by Govindan *et al.,* (2015). The electrodes (metal sheets) are set in couples of two, called anodes and cathodes (Liu *et al.,* 2010). The reaction of the aluminium electrode in the electrocoagulation process is based on the equation below (Rosie *et al.,* 2012):

Aluminium electrode for anode:

$$A \qquad Al^{3+} + 3e^{-} \qquad ..(1)$$

Alkaline condition:

$$Al^{3+} + 3OH^{-} \qquad Al\,(OH)_3 \qquad ..(2)$$

Acidic condition:

$$Al^{3+} + 3H_2O \qquad Al\,(OH)_3 + 3H^{+} \qquad ..(3)$$

In terms of produced water treatment, the concern of the effect of variable salinity upon electrocoagulation efficiencies essential to be addressed. Electrolytes such as NaCl are widely used in the EC method to increase the conductivity of the electrolyte. NaCl is the most preferred due to its low price (Chen, 2004). The purpose of this research is on the ability of electrocoagulation technology to increase the removal efficiencies of colour in saline landfill leachate. The removal of colour is influenced by the natural salinity present in the leachate using the EC technology was investigated. For this purpose, the influence of current density, treatment time and pH were investigated using an aluminum electrode.

MATERIALS AND METHODS

Leachate Sampling

The electrolytic of landfill leachate were taken from January to April 2019 using 30 L polyethene container from Pulau Burung Landfill Site (PBLS) situated in the Byram forest reserve (Penang) at 5º12′12.1′′ N latitude and 100º25′30.2′′ E longitude. PBLS has an ordinary oceanic clay liner. This site produces a dark black-green liquid, which could be considered as high content of ammoniacal nitrogen, colour as well as a low Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) (Bashir *et al.*, 2009). The leachate produced is saline in nature as it is located along the coastal line. Samples were stored in and immediately transferred to a refrigerator at 4 ºC in following with the standard methods (APHA, 2017).

Chemical Reagent and Equipment

The chemicals, reagents and instrument used in this study were sulphuric acid, sodium hydroxide, HACH pH meter (APHA 4500-H+B), HACH DR 2800 (APHA 2120 C), 0.45 µm filter paper, NICE 47 mm filtration set, NICE measuring cylinder, beaker (brand Fisher), wire crocodile clip, aluminium plate (grade 6061), DC power supply (OJE Model PS6005, 60V/5A) and Heidolph MR Hei-Tec 220V magnetic stirrer. Analyses experiment parameter of colour and salinity was conducted according to the American Public Health Association (APHA, 2017) using HACH method 8025 and YSI Professional Plus respectively.

Analytical Method

All the analytical methods used were as per the American Public Health Association (APHA: 2017) using spectrometer DR 2800 HACH method: 8465.

Experimental set-up

The experiment commenced by first rinsing the electrocoagulation cell with pure water and later desiccated at room atmosphere electrolyte of 750 mL landfill leachate was transferred to EC cell. This intensity will permit and allow the formation of flocs to occur secondary to oxidation process. Note that the total volume of the EC cell is 1000 mL. DC power supply was used by connecting to terminal positive and negative charges at two pair Aluminum electrodes as anode and cathode separately. The electrodes were submerged in the leachate and the DC power supply was turn on immediately. The colour from the electrolyte solution was examined earlier before the EC process occurred. The total effective areas of the electrode were 35 cm² when immersed 70 mm in the electrolyte solution while the electrode size was 16 cm x 5 cm x 1 cm. The magnetic stirrer was set at a constant speed of 200 rpm while the spacing distance between both electrodes was 3 cm.

Colour Removal

The colour removal efficiency (Y %) was calculated from equation below:

$$Y\ (\%) = \left(\frac{C_o - C}{C_o}\right) x100 \qquad .. (4)$$

Where, C_0 is the concentration of the colour before electrocoagulation treatment (Pt-Co), and C is the concentration of colour after t min of electrocoagulation time (Pt-Co).

RESULTS AND DISCUSSION

In this research, the electrocoagulation process was influenced by affective elements such as current density, contact time and pH on removal of colour. A total of 35 samples of raw leachate were examined and analysed. This is done to determine which parameters are affective to electrocoagulation process.

Leachate Characteristics

Leachate characteristics of PBLS collected eight times during the period from January to April 2019 are shown in Table 1.

Table 1. Leachate characteristics of PBLS an average of 8 samples

No	Parameters	Average	Standard Discharge
1	BOD (mg/L)	220	20
2	COD (mg/L)	5096	400
3	Ammonia (mg/L)	2542	5
4	Colour (Pt-Co)	8427	100 ADMI
5	SS (mg/L)	1011	50
6	pH	7.82	6 – 9
7	Salinity (ppt)	15.13	-

The Effect of Current Density

The effect of current density and the influence of salinity on colour removal rate was studied by conducting the experiments at 60 A/m² to 780 A/m² with an increment of 60 A/m² for each interval. As presented in Figure 2 the removal rate of colour increased with the raise of current density from 60 A/m² to 540 A/m². Meanwhile, at the same range of current density, salinity curve is constant from the beginning of the experiment up till the 10th reading. It then faces a sudden deflation after current density 540 A/m² which indicates that the removal of colour and the influences of salinity is no longer significant. Based on Ulu *et al.*, (2014), when the number of iron produced by the electrode is higher, it will destabilize the pollutant molecules and when the current density is beyond the optimum condition, the restabilization of particles happen and reduce the removal. Khandegar and Saroha (2013) also reported that the performance of efficiency removal on EC process was due to the increase or decrease of electrolytic conductivity (salinity). Based on the graph, it can conclude that the maximum value of current density is 540 A/m² with the average natural salinity of 14 ppt in the electrolyte while the removal

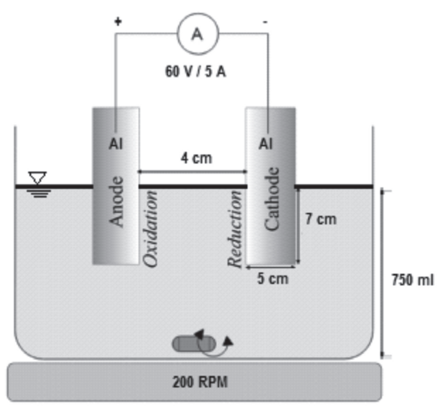

Fig. 1. Experimental setup for electrocoagulation proses

rate of colour is recorded at 61%. However, current density value obtained from this experiment is slightly higher than that disclosed by Huda *et al.*, (2017) which is at 286 A/m2 with 82.7% removal at the overall optimum condition. Nevertheless, it is needed to note that, unlike this study where raw leachate was utilized with saline in nature, they added 2 g/L Sodium Chloride (NaCl) in the electrolyte to increase the conductivity. The findings of this study are compatible with those of Pirsaheb *et al.*, (2016), had earlier reported 563 A/m^2 current density which is an almost similar to this optimum current density.

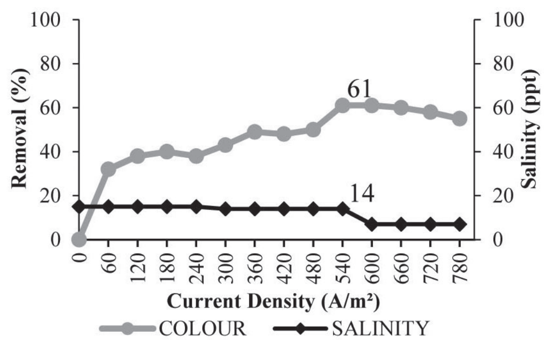

Fig. 2. The effect of varied current EC on removal colour (optimum: 540 A/m^2)

The Effect of Treatment Time

As the time of the electrolysis increased, the effectiveness of coagulation also increases because the ions formed more hydroxide molecules (Eskibalci and Ozkan, 2018). Figure 3, shows the reaction of time on the removal effectiveness of colour with respect to 5 min interval contact time until 70 min. At the average of 14 ppt salinity value, the maximum percentage removal was obtained during the 60 min streak treatment time with a percentage of 67% in the removal rate of colour. This condition is due to the high and constant NaCl concentrations (salinity) which not only rise the conductivity, but also commit strong oxidizing factor on the electrocoagulation method (Wei *et al.,* 2012). In the present of natural saline, the salinity curve remains stable from an initial 5 min to 60 min treatment time. However, the percentages removal was slightly decreased after the optimum treatment time at 60 min. According to the previous study by Joseph and Chigozie (2014), the concentration of iron ions and hydroxide will raise when electrolysis duration increase. Therefore, the optimum electrolysis duration chosen is 60 min. The findings observed in this study mirror those of the earlier studies that investigated the effect of treatment time. Huda *et al.*, (2017) also reported 60 min as the optimum time for electrocoagulation process.

The Effect of pH

The values of pH show important effect on the whole operation of the electrocoagulation technique (Chen *et al.*, 2014). Saraswat *et al.*, (2015) stated that the salinity induced pH changes, however the response is not in a linear condition. Without the need to add any electrolyte, the percentages removal of colour increased to more than 67% from pH 5 to pH 8 and the higher percentage removal of colour achieved was 71% at pH 8. As shown in Figure 4, the effect of salinity on pH resulted a stable condition from pH 5 to 8 at 15 ppt. The removal of colour, started to drop at pH 8 from 71% to 66% and the reduction of salinity values at this point was insignificant as it only dropped from 15 ppt to 14 ppt. Therefore, in the series of pH 5 to 10, the ideal pH chosen for this study is pH 8 with 71% removal of colour. The current findings seem to be consistent with Huda *et al.*, (2017) which found 7.73 is the best pH value for EC process.

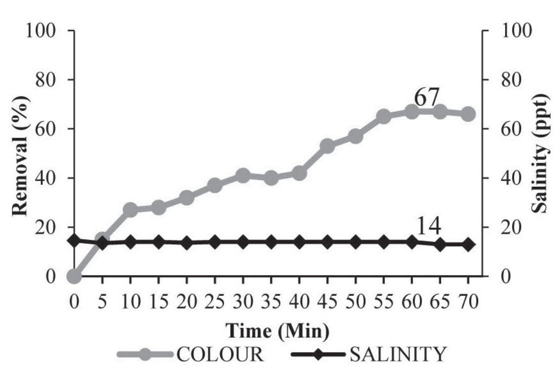

Fig. 3. The effect of varied treatment time EC on removal colour (optimum: 60 Min)

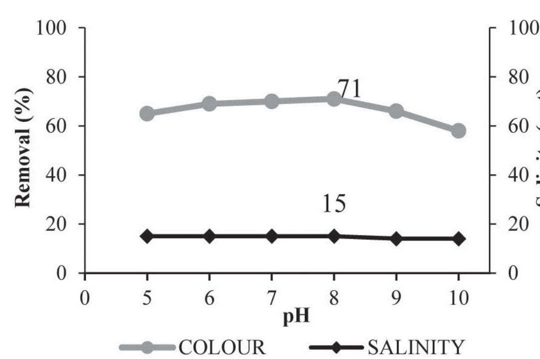

Fig. 4. The effect of varied pH, EC on removal, color (optimum: pH 8)

CONCLUSION

The investigation of this research showed that the optimum operational variables for current density, treatment time and pH were examined at 540 A/m^2, 60 min and pH 8, respectively. The best removal efficiencies of colour is more than 71% with respect due to nature salinity landfill leachate as the electrolyte. In general, this result in this study proved that the electrocoagulation technique can enhance the removal of colour in saline landfill leachate and improve its quality. A further study that focuses on combinations of aluminium and hybrid electrode to rise the removal performance of electrocoagulation is therefore suggested.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Sains Malaysia (USM) for the facilities accorded to the study. This work was partially funded by the Ministry of Higher Education Malaysia under the FRGS grant scheme (Grant No. 203. PAWAM.6071412) and USM RUI grant scheme (Grant No. 1001.PAWAM.8014081) for research associated with the Solid Waste Management Cluster, Engineering Campus, Universiti Sains Malaysia.

REFERENCES

Akyol, A. 2012. Treatment of paint manufacturing wastewater by electrocoagulation. *Desalination*. 285: 91-99.

APHA, 2017. *Standard Methods for the Examination of Water and Wastewater,* 23rd ed., American Public Health Association, Washington, DC, USA.)

Aziz, H.A., Alias, S., Adlan, M.N., Faridah, Asaari, A.H. and Zahari, M.S. 2007. Colour removal from landfill leachate by coagulation and flocculation processes. *Bioresour. Technol*. 98(1): 218-220.

Aziz, H.A., Foul, A.A., Isa, M.H. and Hung, Y.T. 2010. Physico-chemical treatment of anaerobic landfill leachate using activated carbon and zeolite: batch and column studies. *Int. J. Environ. Waste Manag*. 5(3/4): 269.

Bashir, M.J.K., Isa, M.H., Kutty, S.R.M., Awang, Z. Bin, Aziz, H.A., Mohajeri, S. and Farooqi, I.H., 2009. Landfill leachate treatment by electrochemical oxidation. *Waste Manag*. 29(9): 2534-2541.

Bouhezila, F., Hariti, M., Lounici, H. and Mameri, N. 2011. Treatment of the OUED SMAR town landfill leachate by an electrochemical reactor. *Desalination*. 280 : 347-353.

Cheballah, K., Sahmoune, A., Messaoudi, K., Drouiche, N. and Lounici, H. 2015. Simultaneous removal of hexavalent chromium and COD from industrial wastewater by bipolar electrocoagulation. *Chem. Eng. Process. Process Intensif*. 96 : 94-99.

Chen, G. 2004. Electrochemical technologies in wastewater treatment. *Purif. Technol*. 38(1): 11-41.

Chen, S., Shi, Y., Wang, W., Li, Z., Gao, J., Bao, K., Han, R., Zhang, R., 2014. Phosphorus Removal from Continuous Phosphate-Contaminated Water by Electrocoagulation using Aluminum and Iron Plates Alternately as Electrodes. *Sci. Technol*. 49(6): 939-945.

Eskibalci, M.F. and Ozkan, M.F. 2018. An investigation of the effect of NaCl concentration on the electrocoagulation of coal preparation plant tailings. *Physicochem. Probl. Miner. Process*. 54(3): 934-943.

Fayad, N. 2018. The application of electrocoagulation process for wastewater treatment and for the separation and purification of biological media. Grad. *Theses Diss*. 5-226.

Govindan, K., Raja, M., Uma Maheshwari, S., Noel, M., Oren, Y., 2015. Comparison and understanding of fluoride removal mechanism in $Ca^{2+,}$ Mg^{2+} and Al3+ ion assisted electrocoagulation process using Fe and Al electrodes. *J. Environ. Chem. Eng*. 3(3): 1784-1793.

Huang Y. F., Ang S.Y., Lee K. M. and Lee, T. S. 2016. Quality of Water Resources in Malaysia *Open Sciences Intech*.

Huda, N., Raman, A.A. and Ramesh, S. 2017. Optimization of electrocoagulation process for the treatment of landfill leachate. *IOP Conf. Ser. Mater. Sci. Eng*. 210.

Johari, A., Alkali, H., Hashim, H., Ahmed, S.I. and Mat, R. 2014. Municipal solid waste management and potential revenue from recycling in Malaysia. *Mod. Appl. Sci*. 8(4): 37-49.

Joseph, N.T. and Chigozie, U.F. 2014. Effective Decolorization of Eriochrome Black T , Furschin Basic and Malachite Green dyes from Synthetic Wastewater by Electrocoag-nanofiltration *Computer Science 2014 Vol II* 21(2) : 98-107.

Kamaruddin, M., Yusoff, M., Aziz, H. and Hung, Y. T. 2016. Sustainable treatment of landfill leachate. sew. landfill leachate *Environ. Sci. Pollut. Res*. 3-30.

Khandegar, V. and Saroha, A.K. 2013. Electrocoagulation for the treatment of textile industry effluent - A review. *J. Environ. Manage*. 128 : 949-963. Kobya, M., Ciftci, C., Bayramoglu, M. and Sensoy, M.T. 2008. Study on the treatment of waste metal cutting fluids using electrocoagulation. *Purif. Technol*. 60(3): 285-291.

Liu, H., Zhao, X. and Qu, J. 2010. Electrocoagulation in water treatment. *Electrochem. Environ*. 245-262.

Malek, M. I. A. and Shaaban, M. G. 2008. Landfill common method and practices of solid wastes disposal in Malaysia. *ISWA World Congr*, Singapore.

Nor Amani Filzah, M.K. and Suhaimi, A. T. 2010. Hazards due to polycyclic aromatic hydrocarbons (PAHs) and Heavy Metals at the Closed Kubang Badak Landfill, Selangor 1036-1041 1036-1041.

Omran, A., Mahmood, A. and Aziz, H.A. 2018. Current practice of solid waste management in Malaysia and its disposal. *Environ. Eng. Manag. J.* 6(4) : 295-300.

Pirsaheb, M., Azizi, E., Almasi, A., Soltanian, M., Khosravi, T., Ghayebzadeh, M. and Sharafi, K. 2016. Evaluating the efficiency of electrochemical process in removing COD and NH_4-N from landfill leachate. *Desalin. Water Treat*. 57 (15) : 6644-6651.

Rosie, Normala, -Putra, 2012. Electro coagulation for removal of chemical oxygen demand in sanitary landfill leachate. *International Journal of Environmental Sciences.* 3(2): 921-930.

Saraswat, R., Kouthanker, M., Kurtarkar, S.R., Nigam, R., Naqvi, S.W.A. and Linshy, V.N. 2015. Effect of salinity induced pH/alkalinity changes on benthic foraminifera: A laboratory culture experiment. *Estuar. Coast. Shelf Sci.* 153 : 96-107.

Song, P., Yang, Z., Zeng, G., Yang, X., Xu, H., Wang, L., Xu, R., Xiong, W. and Ahmad, K. 2017. Electrocoagulation treatment of arsenic in wastewaters: A comprehensive review. *Chem. Eng. J.* 317: 707-725.

Ulu, F., Bariºçi, S., Kobya, M., Särkkä, H. and Sillanpää, M., 2014. Removal of humic substances by electrocoagulation (EC) process and characterization of floc size growth mechanism under optimum conditions. *Purif. Technol*. 133 : 246-253.

Wei, M.C., Wang, K.S., Huang, C.L., Chiang, C.W., Chang, T.J., Lee, S.S. and Chang, S.H. 2012. Improvement of textile dye removal by electrocoagulation with low-cost steel wool cathode reactor. *Chem. Eng. J.* 192: 37-44.

.