MATEC Web of Conferences **250**, 06005 (2018) https://doi.org/10.1051/matecconf/201825006005
SEPKA-ISEED 2018

Addition of composite coagulant (polyaluminium chloride and tapioca flour) into electrocoagulation (aluminium and ferum electrodes) for treatment of stabilized leachate

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Abstract. Physical-chemical method such as electrocoagulation (EC) and coagulation-flocculation processes work well for the treatment of stabilized leachate. This study investigated the efficiency of combined treatment (electrocoagulation and conventional coagulation) in removing colour and ammonia nitrogen (NH_3-N) from stabilized leachate. For this combined treatment, the Fe and Al electrodes with the addition of composite coagulant (PAC and TF) were used. The considered factors were pH, current density, and duration of current flow. It was observed that, the highest removal of colour and NH_3N were 96% and 13% at applied current density of 100 A/m^2 that equal to 0.5 A and 20 minutes respectively. For single EC treatment, the highest removal was 88% for colour and 25% for NH_3N at 60 minutes by 150 A/m^2 that equal to 1.3A. Thus, it showed that the combined treatment performed better than single treatment in removing colour while reducing the current, and shorten the duration of current flow.

1 Introduction

Nowadays, the amount of solid waste increase day by day. There are various ways have been organized by the government to reduce the production of solid waste, however it just decreased 20% of the solid waste production [1]. The best method for disposal of solid waste is landfilling. There are three types of landfilling such as unsanitary landfill, sanitary landfill and open dumping. The safest method is sanitary landfill, because it is designed to minimize the impacts on public health and the environment. Although sanitary landfill is the best method it also has disadvantages such as the production of leachate

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Leachate is the dangerous liquid that produced by the percolation of water through the solid waste [3]. The colour of leachate is black or brown and it contains a lot of organic, non-organic, and heavy metals. There are a lot of conducted treatments to treat the leachate such as reverse osmosis, activated carbon, and nanofiltration [4]. Most of the treatments that have been applied are costly. Thus, the objective of this study is to investigate the effectiveness of low-cost treatment to treat the stabilized leachate in order to have a high removal of colour and NH_3-N. In this study, two methods are compared together to prove which treatment is more effective. The method used is single electrocoagulation (EC) and combined treatment which is electrocoagulation and coagulation-flocculation (EC-CC).

For EC, according to the previous literatures [5] aluminium (Al) and Ferum (Fe) are the most used electrodes. Some study used a lot of electrodes to treat the wastewater, which cause the treatment cost to increase [6]. Then, from previous study by Li (2011), Mosoumeh (2012) and Shivayogimath (2013) showed that higher current density and duration of current flow, resulted in effectiveness EC process [7, 8, 9]. Besides that, coagulation-flocculation process is widely used to treat wastewater however it still has disadvantages such as producing a lot of sludge and expensive coagulant needed [10]. The chemical coagulants become favored for water treatment because it has high efficiency to treat the wastewater but can cause several health problem [10]. Nowadays, chemical based coagulants are still being used however the percentage of chemical is reduced by combining the chemical coagulant with natural substance. It is more safe and good for environment as well. This combined coagulant is called as composite coagulant.

In addition, both electrocoagulation and coagulation-flocculation processes are chosen because it have the same mechanisms that occur during the treatment process, which is expected able to increase the effectiveness and reduce the existing used of current density, dose of coagulant, and duration of current flow. In this study, the single EC used Al as anode and Fe as cathode, while for combined treatment, the composite coagulant was added into the system, which is the combination of polyaluminium chloride (PAC) and Tapioca Flour (TF). PAC was chosen as the coagulant because high molecular weight and has good structure [11], for TF contains mixture of amylose and amylopectin. It can improved the coagulation ability through bridging mechanism [12].

2 Methodology

2.1 Study area and sampling

Leachate sample was collected at Simpang Renggam Landfill (SRL) that is located at Simpang Renggam, Johor, Malaysia. The leachate was collected from the detention pond. The characteristic of leachate was showed in table 1. Sampling and analytic procedure were conducted in accordance the American Public Health Association (APHA) standard method [13]. The Simpang renggam landfill leachate can be categorized as stabilized leachate because it has been operated for more than 10 years.

Table 1. Characteristic of Simpang Renggam landfill leachate.

Parameter	pH	Colour (Pt.Co)	Suspended solid (mg/l)	COD (mg/l)	NH_3-N (mg/l)	BOD_5 (mg/l)	Turbidity (NTU)
Value	8.3	6713	286	2660	577.04	137.85	197

*Average value for three month sampling from (January to March 2018)

2.2 Preparation of composite coagulant

The composite coagulant was made with the combination of polyaluminium chloride (PAC) (9% concentration) and Tapioca Flour (TF) (2% concentration) called as PACTF, and prepared according to Zin et al (2014). PAC and TF were placed in different beakers, then they were heated until 65-75^{0}C. After reaching the temperature, the TF was injected into the PAC solution using the peristaltic pump with flowrate of 2ml/min. Both beakers was stirred at speed 700-800 rpm at the controlled temperature. The coagulant can be used after 24 hours or stored at room temperature [14]. The concentration of coagulant used was 55 g/L and the dose that injected into the sample was 0.3g/L of PACTF.

2.3 Electrocoagulation (EC)

For this study, firstly the single EC process was carried out by using Al and Fe electrodes (200 cm x 7 cm). All the electrodes were washed with dilute HCl before conducting the experiments. A digital DC power supply (model 1739, 0-30 V, 0-2.0 A) was used to give a regulated electricity current. Then, the electrodes were dipped in the beaker to a depth of 9 cm and the distance between the electrodes was fixed at 5.5 cm. The solution was stirred with a magnetic stirrer at speed of 200 rpm [15]. During the experiments, the current density were verified. After 30 minutes of settling time, the removal of colour and ammonia nitrogen (NH_3-N) were measured.

2.4 Combined treatment (electrocoagulation-coagulation)

After the single treatment, the combined treatment was carried out by using Jar Test machine (Flocculator JTL5). The speed of rapid mixing is 200 rpm at 4 minutes and slow mixing is 30 rpm at 15 minutes [16]. Then, the current were supplied by DC power supply. The sample used for combined treatment is 1 L. After the sample was placed in 2 L beaker, the electrodes were dipped in the beaker to a depth 7 cm and the distance between electrodes was 9.5cm. The coagulant was injected into the solution, current were installed, and the mixing began [17]. During the experiment, the current was verified. After 30 minutes of settling time, the removal of colour and NH_3-N were measured. The schematic experiment set up was shown in Figure 1.

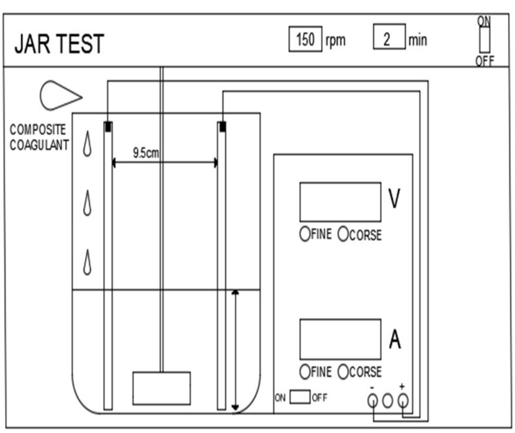


Fig. 1. The schematic experimental setup in this study.

3 Result And Discussion

3.1 Effect of current density

Current density plays an important role while considering the coagulant dose in the EC process [7]. For this study, the various range of current density was used and compared to analyse the performances of single and combined treatments. Current density can be written in A/m^2 that means the current was divided by surface area to get the value of current [15]. Thus, this study used the value of current density to make the comparison. The value of current density used was 50, 100, 150, 200, and 250 A/m^2. Figure 2 shows the effect of current on the removal efficiencies by the following conditions: pH 5 and 20 minutes electrolysis time (single) and pH 5, 0.3 g/l dose of PACTF and 20 minutes electrolysis time (combined). As shown in Figure 2, the removal of colour by combined treatment was better than single treatment. For single EC at 100 A/m^2 the removal of colour only 42% compare to combined treatment the removal was 96%. This showed that the addition of coagulant followed by suitable conditions could help the removal process. The used of PAC could add Al ions in the solution and help attracted the negative particles. Besides that, with the addition of TF, it was able to increase the size of flocs.

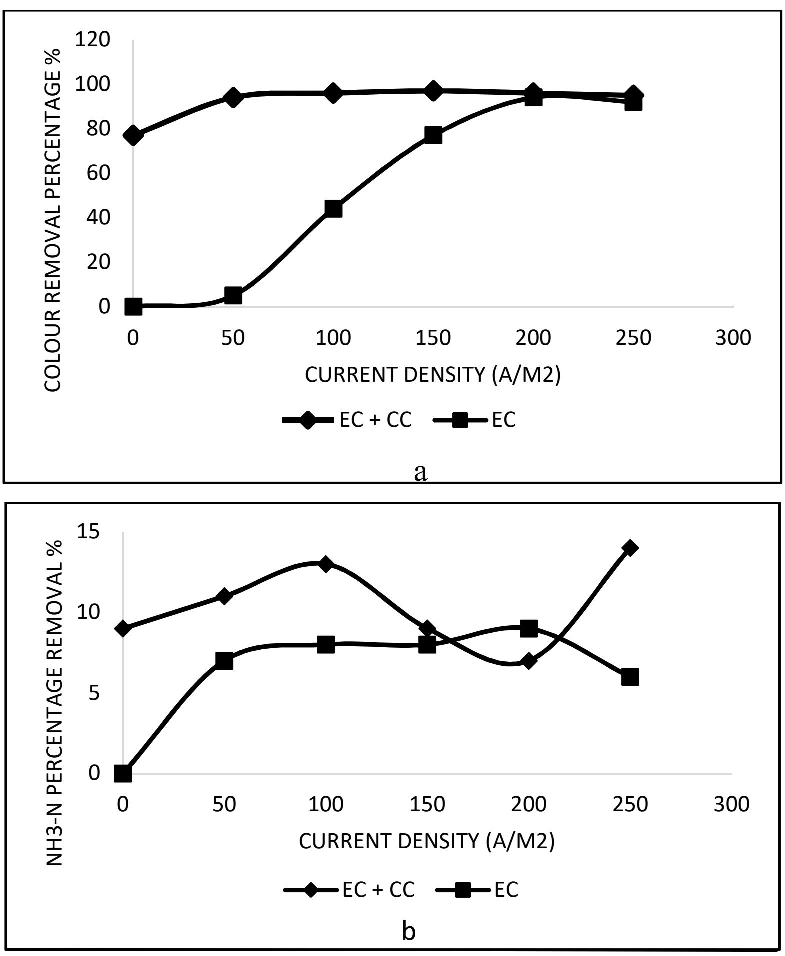


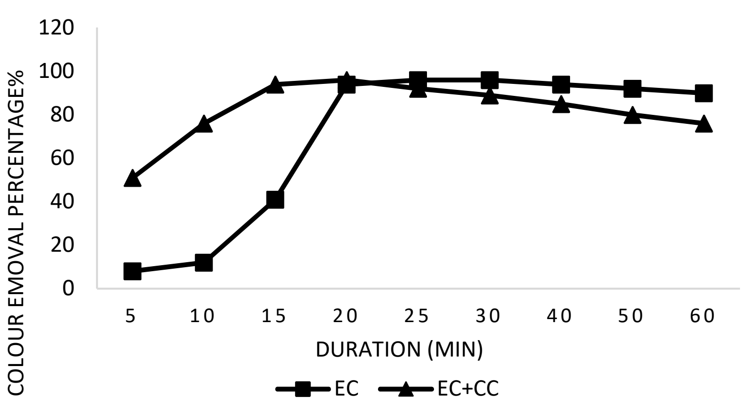
Fig. 2. Effect of applied current on removal of a) colour b) NH_3-N.

Ammonia Nitrogen (NH_3-N) can be categorized as chemical pollution that is difficult to be removed from the leachate. Based on previous study, physical-chemical treatment like EC showed low efficiency removal for NH_3-N [7]. In this study, it showed the NH_3-N removal was 14% at current 250 A/m^2 for combined treatment and for single the highest removal was 9% at 200 A/m^2. Figure 2b shows that the combined treatment removed NH_3-N better than single treatment. At current of 100 A/m^2, the removal for combined treatment was 13%, which 8% more than single treatment. Combined treatment had better removal because the addition of PACTF. The presence of TF in combined treatment helped to eliminate ammonia as well [18].

3.2 Effect of electrolysis time

The effect of electrolysis time was investigated in the range of 5 – 60 minutes by the following conditions: pH 5 and applied current of 200 A/m^2 (single), pH 5 and applied current of 100 A/m^2 (combined). As can be seen in Figure 3, the performance of combined treatment was better than single treatment in term of colour removal but for NH_3-N removal single EC performed better. The achieved highest removal of NH_3-N through single EC was 25% at 60 minutes and for combined treatment was only 15%. At 20 minutes, the removal of NH_3-N for single and combined treatment was only 9% and 13% respectively. Besides that, 60 minutes was not selected as the optimum condition because the longer electrolysis time and the decreasing removal of colour. Based on the Figure 3b, the removal of NH_3-N was less than 30%, it showed that the physical-chemical method was not suitable in removing the NH_3-N from leachate.

Based on Figure 3a the removal of colour decrease by increasing of electrolysis time, it happen when the electrode immersed at long time which might formed impermeable oxide film at cathode causing to loss efficiency of EC process [5]. The highest removal for colour by single and combined treatments was 94% and 96% at duration of 20 – 25 minutes respectively. For duration 60 minutes the removal was decrease as much 4% for single and 20% for combined treatment. Thus, 20 minute was set as the optimum condition because time was not too long and had high removal of colour. This optimum was determined by shorten electrolysis time because long electrolysis time would cause the cost of treatment increase.



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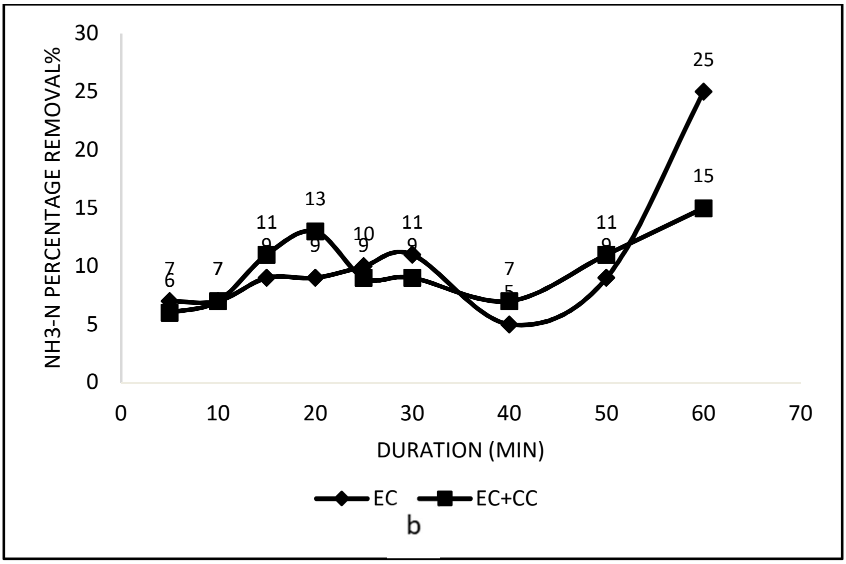

Fig. 3. Effect of duration of current flow on removal of a) colour b) NH_3-N.

4 Conclusion

Single EC and combined treatments were investigated in term of colour and NH_3-N removals under the influence of applied current and duration of current flow. Higher removal of colour was achieved by combined treatment of EC-CC compared to a single treatment of EC under influenced of applied current. The removal of colour at 100 A/m^2 and 20 minutes was 96%. The highest removal for NH_3-N was achieved by single EC under influence of electrolysis time. At the optimum condition, the percentage removal of colour and NH_3-N for single treatment only was 94% and 9%. These two treatments performed better at acidic condition. However, the best performance was recorded by combined treatment at pH 5, applied current was at 100 A/m^2, duration of current flow was 20 minutes and dose of coagulant at 0.3g/l with the percentage removal of colour and NH_3-N was 96% and 13% respectively. Thus, combined treatment was better than single treatment in term of removal efficiency, the reduction of applied current, and duration of current flow.

The author would like to gratefully acknowledge Ministry of Higher Education of Malaysia for the research financial support under Fundamental Research Grant Scheme (FRGS) vot. 1570

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