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Treatment of Coal Stockpile Wastewater by Electrocoagulation Using Aluminum Electrodes

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Abstract. The performance of electrocoagulation using aluminum electrodes for the removal total suspended solid and heavy metals from actual coal stockpile wastewater was studied. In a batch electrochemical cell experimental setup, two monopolar aluminum (Al) plate were used as electrodes (anode and cathode). The effects of relevant coal stockpile wastewater characteristics such as pH and total suspended solid (TSS), and important process variables such as current density and operating time on heavy metals removal efficiencies have been explored. Preliminary results show that the electrocoagulation process is able to enhance the removal of total suspended solid and heavy metal contents. The batch experiment results showed that the high heavy metals contained coal stockpile wastewater can be effectively treated using electrocoagulation. The overall heavy metals removal efficiencies have been obtained at 89.7% for ferrous and 94.6% for manganese, respectively. The removal rates of those elements were increase with operating time. Therefore, electrocoagulation technique to removal high content of heavy metal and TSS from coal stockpile wastewater is found effective and environmental friendly.

Introduction

Electrocoagulation (EC) is becoming a popular process to be used for wastewater treatment. The reuse of wastewater has become an absolute necessity. Demands to the cleaning industrial and domestic wastewater to avoid environmental pollution and especially contamination of pure water resource are becoming national and international issues. Innovative, cheap and effective methods of purifying and cleaning wastewater before discharging into any other water system are needed. EC is not a new technology [1]. EC due to some advantages over chemical coagulation is becoming a popular process to be used for wastewater treatment.

The electrocoagulation is simple and efficient method for the treatment of many water and wastewaters. It has not been widely accepted because of high initial capital costs as compared to other treatment technologies. In recent years, many investigations have been especially focused on the use of EC owing to the increase in environmental restrictions on effluent wastewater [2-3].

The use of electrocoagulation for the treatment of wastewater has been reported by various authors, and several differences were found in comparison to the chemical coagulation process. A literature survey indicates that EC is in efficient treatment process for different waste, e.g. soluble oils, liquid from the food, textile industries, or cellulose and effluents from the paper industry [4-5]. Electrocoagulation is an effective process for the destabilisation of finely dispersed particles by removing hydrocarbons, greases, suspended solids and heavy metals from different types of wastewater [6-7]. EC has been proposed in recent years as an effective method to treat various wastewaters such as: landfill leachate, saline wastewater, laundry wastewater, and chemical mechanical polishing wastewater [8].

Aluminum or iron were usually used as electrode and their cations are generated by dissolution of sacrificial anodes upon the application of a direct current [3, 5, 7]. Electrocoagulation technique for treatment of wastewater samples have been conducted on a laboratory scale and good removal of COD, color, turbidity, and dissolve solids at varying opening conditions have been obtained [3, 4, 8].

Experimental
This study is to investigate the effect of electrocoagulation process. This research is mainly focused on the capability of EC technology to improve wastewater quality, such as to increase removal efficiencies of TSS and heavy metals (ferrous and manganese).

Coal stockpile wastewater samples. Coal stockpile wastewater was obtained from the coal stockpile which located at Muara Telang, Banyuasin District, South Sumatera Province, Indonesia. The composition of wastewater then characterized to identify the total suspended solids, ferrous and manganese metals contents.

Experimental device. The batch experimental setup is schematically shown in Fig. 1. The electrochemical unit consists of an electrocoagulation cell, a D.C power supply and the electrodes (aluminum). There are two monopolar electrodes having same dimension (100 mm x 100 mm x 2 mm) as an anode and a chatode which spacing of 20 mm. In order to maintain an unchanged composition and avoid the association of the flocs in the solution, the stirrer was turned on and set at 100 rpm. All the electrodes were washed with dilute HCl before every experiments conducted. Every experiment was performed at the room temperature [9].

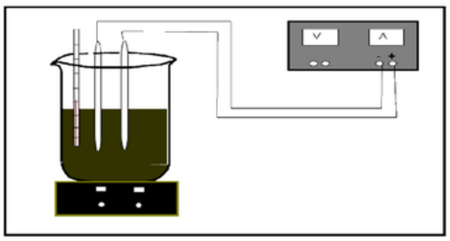

Fig.1 Schematic diagram of experimental setup

Experiment procedure. The experiments were carried out in a batch mode. For each experiment, a coal stockpile wastewater sample of 500 ml was collected in the electrocoagulation cell with two electrodes dipped into the sample. Five different of high current densities; 200 A/m^2, 400 A/m^2, 600 A/m^2, 800 A/m^2 and 1000 A/m^2 were applied. In each current density applied, operating time of 60, 75, 90, 105, 120 min were used. After the experiment, the treated sample was then kept undisturbed for 15 min in order to allow the flocs to settle. Subsequently, after settling the sample of supernatant was collected to perform the analysis of pH, TSS, and metal contents of iron and manganese.

Result and discussion

Characteristic of coal stockpile wastewater. Table 1 shown the characteristic of the coal stockpile wastewater sample used before the treatment.

Table 1. Characteristic of coal stockpile wastewater

Parameter	Value	Threshold standard*
pH	4.8	6-9
TSS (mg/L)	324	200
Fe (mg/L)	7.86	7
Mn (mg/L)	6.44	4

** South Sumatra Governor Regulation No.8 of 2012*

Effect of current density. In all the electrocoagulation process, current density is the most important parameter in controlling the reaction rate. Rising current density resulted to an increase in the removal efficiency of TSS, metal contents of Fe and Mn. Fig. 2 shows the removal efficiency of TSS, metal content of Fe and Mn against current density applied to the aluminum electrodes in the electrocoagulation process. When the current density increases, the efficiency of ion production in anode and cathode also increase, leading to the floc production increment. So that, 94.6%, 89.7% and 76.7% of Mn, Fe and TSS percentage of removal was obtained by using 1000 A/m^2 during 120 minutes of electrocoagulation process compared to the 53.7%, 59.1% and 38.6% of Mn, Fe and TSS respectively by using only 200 A/m^2. The optimum of current density of 1000 A/m^2 was used for this treatment in 120 minutes. Theoretically, based on Faraday's law, operating time effects the amount of released electrode in a system with aluminum electrodes and determines the amount of produced Al^{3+} from this electrodes [11]. EC process includes two steps, destabilization and accumulation. The first step is usually short, and the second one is relatively long. With increase in operating time, both energy and electrode consumption increase and this shows that operating time is very important parameter due to affecting the cost efectiveness of EC process in polluted waters [12].

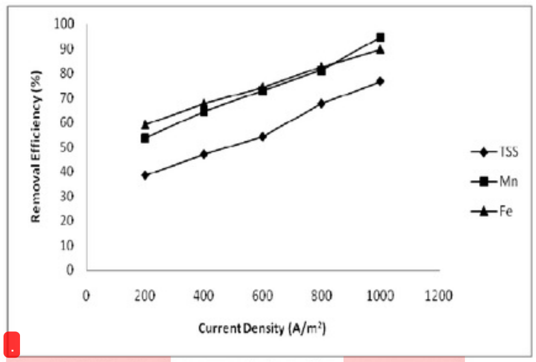

Fig. 2 Effect of current density on removal efficiency of Mn, Fe and TSS

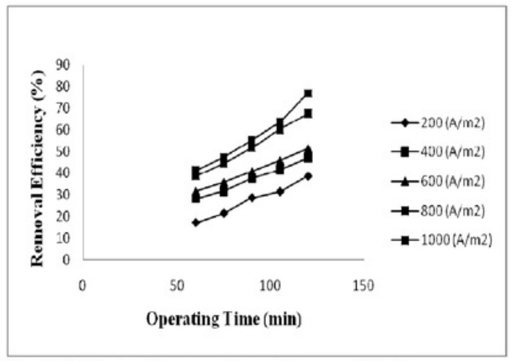

Fig.3 Effect of operating time on TSS

Effect of operating time. In the presence study, as it can be seen from Fig. 3, 4, and 5, more than 50% of wastewater quality parameters were removed in the first minutes (only 60 min), especially for current density 1000 A/m^2, while in later minutes, the percentage of removal was low. Furthermore, as the operating time was increased, comparable increases in the pollutants removal rate were observed for all current densities. On the other hand, for a given time, the removal efficiency increasing significantly with an increase in current density.

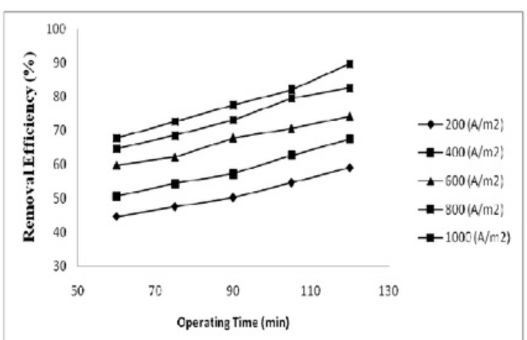

Fig. 4 Effect of operating time on Fe metal

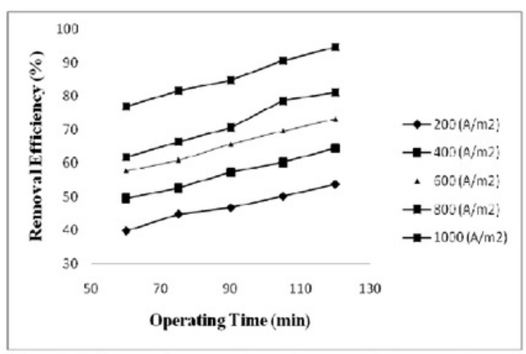

Fig. 5 Effect of operating time on Mn metal

As an example, after 120 min operating time (Fig. 5), it can be seen that 53.7%, 64.6%, 73.1%, 81.2%, and 94.6% of Mn were removed for applied current density of 200, 400, 600, 800, and 1000 A/m^2, respectively. This was describes to the fact that at high current, the amount of oxidized metal increased, resulting in a greater amount of precipitate for the removal of pollutants. Similarly trends were observed for other quality parameters of coal stockpile wastewater.

Conclusion

Batch electrocoagulation studies were performed to evaluate the influenced of various experimental parameters such as applied current density and operating time on the removal of pollutant from coal stockpile wastewater. The results of this study have shown the applicability of electrocoagulation in the treatment of real coal stockpile wastewater. The treatment rate was shown to increase upon increasing the applied current density and operating time. The highest current density the quickest treatment with an effective reduction of TSS, Fe and Mn concentration.

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