9 783037 858288

ISBN:978-3-03785-828-8

Applied Mechanics and Materials Vol. 391, 2013

ISSN: 1660-9336 Electronically available at *http://www.scientific.net*

Technologies of Mechanical Engineering Industry

Shishir Kumar Sahu

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Edited by
Shishir Kumar Sahu

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Technologies of Mechanical Engineering Industry

Selected, peer reviewed papers from the
2013 2nd International Conference on
Advances in Mechanics Engineering
(ICAME 2013),
July 13-14, 2013, Jakarta, Indonesia

Edited by

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Trans Tech Publications Ltd
Kreuzstrasse 10
CH-8635 Durnten-Zurich
Switzerland
http://www.ttp.net

Volume 391 of
Applied Mechanics and Materials
ISSN print 1660-9336
ISSN cd 1660-9336
ISSN web 1662-7482

Full text available online at *http://www.scientific.net*

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doi:10.4028/www.scientific.net/AMM.391.29

Reduction of Metal Contents in Coal Stockpile Wastewater using Electrocoagulation

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Keywords: reduction, coal stockpile, wastewater, electrocoagulation

Abstract. Stockpile wastewater consisted of ferrous metal, manganese metal and total suspended solid (TSS). In addition, it also has high acidity (pH) which is possibly harmful to the environment. This research objectives were to reduce ferrous and manganese metal in coal stockpile wastewater using electrocoagulation technique using aluminum electrode with variation in electrics current and processing time. The most effective conditions in reducing ferrous and manganese concentrations with electric current of ± 2.5 A in 90 minutes. Effectivity in ferrous and manganese metal reduction was 98.7% and 99.6%, respectively. The final concentration of ferrous and manganese metal was 0.08 mg/L and 0.01 mg/L respectively. Optimum concentration of TSS reduction was 83.7% with the final concentration of 72 mg/L. The wastewater pH value became 7,1. Finally, the results demonstrated that the electrocoagulation process using aluminium electrode is a reliable technique for removal of pollutants from coal stockpile wastewater.

Introduction

Coal stockpile causes severe environmental problems due to generation of strong wastewater associated with high total suspended solid (TSS) and metal contents. Washing coal in the stockpile by rain will result in acidic wastewater that can harm the environment [1]. One of the pollutants that are often found in aquatic environments is a heavy metal. Heavy metals such as ferrous (Fe) and manganese (Mn) when exceed the threshold levels, can be danger and become a toxic. Thus, they will influence aquatic organisms, as well as human users, directly or indirectly.

In the recent years, investigations have been focused on the treatment of wastewaters using electrocoagulation [11]. Electrocoagulation is an electrochemical method for treating polluted water which has been successfully applied not only for treatment of soluble or colloidal pollutants, such as slaughterhouse wastewater [2], vegetable oil refinery [3], dairy industry wastewater [4], wastewaters containing heavy metals [5], but also fluoride and humic acid removal [6]. Electrocoagulation involves the generation of coagulants in situ by dissolving electrically either aluminium or iron electrodes, respectively. The metal ions generation takes place at the anode and hydrogen gas is released from the cathode. The hydrogen gas would also help to float the flocculated particles out of the water. The electrodes can be arranged in a monopolar or bipolar mode. The materials can be aluminium or iron in plate form or packed form of scraps such as steel turnings and milling [7].

An examination of the chemical reactions occurring in the electrocoagulation process shows that the main reactions occurring at the electrodes (aluminium electrodes) are

$$\text{Anode} \;:\; Al \longrightarrow Al^{3+}{}_{(aq)} + 3e \qquad (1)$$
$$\text{Cathode} : 3H_2O + 3e \longrightarrow 3/2H_2 + 3OH^-$$

The cathode may also be chemically attacked by OH^- ions generated during H_2 evolution at high pH [8]:

$$2Al + 6H_2O + 2OH^- \longrightarrow 2Al(OH)_4^- + 3H_2 \qquad (2)$$

This research objectives were to reduce ferrous and manganese metal in coal stockpile wastewater using electrocoagulation technique using aluminum electrode with variation in electrics current and processing time.

Material and Methods

The wastewater used in this study was taken from the stockpile Muara Telang, South Sumatra, Indonesia. This effluent initially contained high concentrations of ferrous and manganese metals, and total suspended solids. In this study, real coal stockpile wastewater has been treated using aluminium electrodes in a batch reactor. This study elucidates the effects of parameter such as applied current and process time on the ferrous and manganese metals removal efficiencies. Aluminum electrodes used were 7 cm x 6.7 cm x 3 cm in size (Fig. 1). The volume of the solution of each batch was 1 L. After electrocoagulation tub filled with waste, the current is turned on to using 12 V adapter. The current varies from ± 1.5 to ± 2.5 A with processing times were 60-120 minutes. As the electrocoagulation started, the deposited sediment filtered out of from the results. Characteristics electrocoagulation process is determined by measuring the levels of Fe, Mn, pH, and TSS in clear output after filtered.

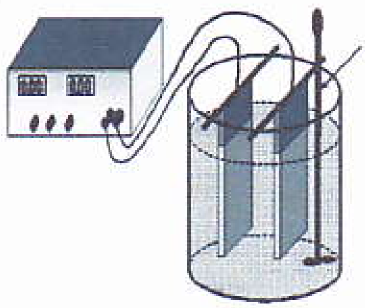

Fig 1. Experimental setup of electrocoagulation unit

Results and Discussion

Characteristics of coal stockpile wastewater. The results of baseline characteristics of wastewater prior to the processing are presented in Table 1.

Table 1. Initial analysis of coal stockpile wastewater

Parameter	Result analysis	Standard quality coal wastewater*
Fe metal content (mg/L)	6.34	7
Mn metal content (mg/L)	2.47	4
TSS content (mg/L)	443	200
pH value	3.58	6-9

**South Sumatra Governor Regulation No. 8 of 2012 [9]*

Concentrations of Fe and Mn in coal stockpile wastewater taken from the Muara Telang did not exceed the standard quality of coal wastewater. It is due to several factors, such as, the influence of rainfall, the number of existing coal stockpile and the residence time in the coal stockpile. Oxidation Fe^{2+} and Mn^{2+} by oxygen in the air to Fe^{3+} and Mn^{4+} caused turbidity in the water. Colloidal particles during electrocoagulation process will destabilized floc-forming larger floc. The formation of H_2 gas at the cathode causes shinking floc, resulting in the accumulation of floc-containing gas at the surface of the water in the form of a layer of sludge [10].

Effect of processing time for reduction metal contents. The electrical current causes the dis-solution of metal electrodes into wastewater whic is usually iron and aluminium. The dissolved metal ions, at an appropriate pH, can form wide ranges of coagulated species and metal hydroxides destabilize and aggregate the suspended particles and adsorb dissolved contaminants [7].

The effect of varying electrical current and processing time on electrocoagulation process of real coal stockpile treatment were determined. The supply of current to the electrocoagulation system determines the amount of Al^{3+} ion released from the respective electrodes and the quantity of resulting coagulant. Thus, more Al^{3+} ions get dissolved into the solution. Also, it is well known that electrical current not only determines the coagulants dosage rate but also the bubble production rate and size and the flocs growth which can influence the treatment efficiency of the electrocoagulation process.

Fig. 2 illustrate the effect of processing time on the metal contents. Reduction of ferrous metal was achieved after 90 minutes electrocoagulation for 2.5 A. It is clear that by increasing processing time, the metal concentration has decreased from 6,34 to 0.08 mg/L. In currents to ± 2.5 A with processing time 105 and 120 minutes had passed Fe concentration values. This occurs because the saturated electrodes were used. Aluminum electrodes have been reduced ability to attract Fe ions in the effluent at the strong currents ± 2.5 A. At the processing time of 105 minutes and 120 minutes, the entire surface of the electrode was covered by Fe ions. The impact of these conditions led to a decline in the magnetic field magnitude. When the magnetic field between the electrodes is large enough, the system of dominant ionic metals compete to stick to the electrode. However, the oxidation at the anode is still high, even if the solution appears to be more turbid. Most of the turbidity caused by floc $Al(OH)_3$ which finally settles.

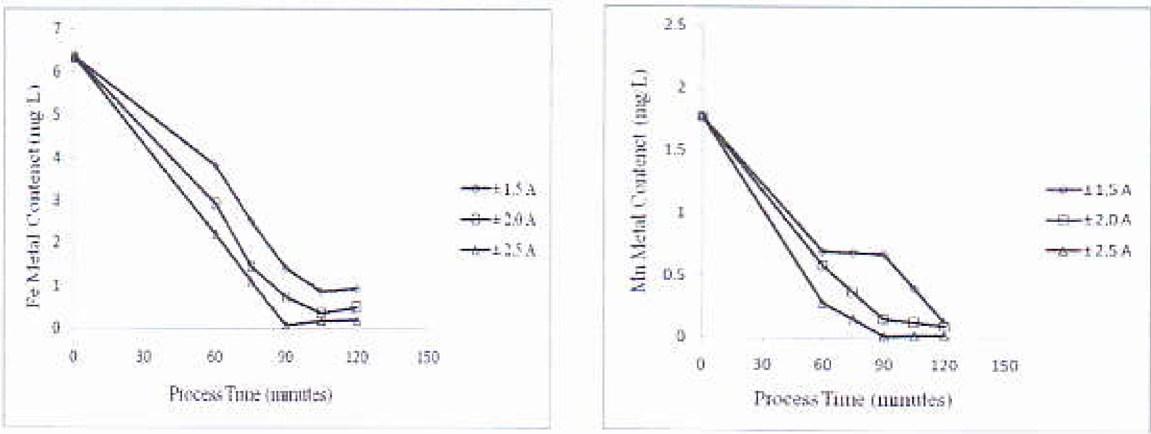

Fig 2. Effect of processing time for reduction metal contents

At the time of processing wastewater using electrocoagulation method, processing time of 60 minutes will result in Mn metal content greater than the processing time of 120 minutes. Similarly, the use of currents ± 1.5 A, Mn metal concentrations greater than the use of currents ± 2.0 A, while the use of strong currents ± 2.0 A greater than the use of the concentration of ± 2.5 A. This is because the processing time and the strong electric current used will affect the aluminum electrode to destabilize pollutants in wastewater.

The best results in decreased concentrations of Mn metal is in currents up to ± 2.5 A and processing time is 90 minutes. This occurs because the saturated electrodes were used. Aluminum electrodes has been reduced ability to attract Mn ions in the effluent at the strong currents ± 2.5 A and the processing time of 105 minutes. At 120 minutes, the entire electrode surface is covered by Mn ions.

Effect of processing time for pH increase. It is shown in Fig. 3 that the pH in coal stockpile wastewater is 3.58 and it is within the range of standards of coal wastewater effluent 6-9 pH [9]. The pH increased rapidly until pH reached 6 and then remained constant. This is because the aluminum electrodes used were saturated.

The increase in pH in the electrocoagulation process occurs due to the alkalization process. As Al^{3+} ions were added the water soluble reaction will take place, where hydroxyl ions from water hydrolysis produces $Al(OH)_3$ and hydrogen ions. Then, bicarbonate contained in the water will react with H^+ ions. The formation of CO_2 will reduce the pH for weak acid H_2CO_3. As the electrical current increased, the Al^{3+} becomes more soluble, and the ions H^+ formed is also growing. In this electrocoagulation process, the formation of hydrogen gas is at the cathode.

In this study, the pH of the wastewater tends to rise with increasing the processing time and the electric current. The resulted pH ranges from 6-7 pH. Therefore, the longer processing time, the concentration of the wastewater will be reduced and the value of pH will tend to rise. We found that the best combination of the processing time and the electrical current is 90 minutes and ± 2.5 A, respectively. This cobination will result in a pH of 7.1.

The best results in the increase in pH that occurs in strong currents to ± 2.5, processing time is 90 minutes. These results are selected because the strong currents to ± 2.5, process time of 90 minutes produces pH value 7.1.

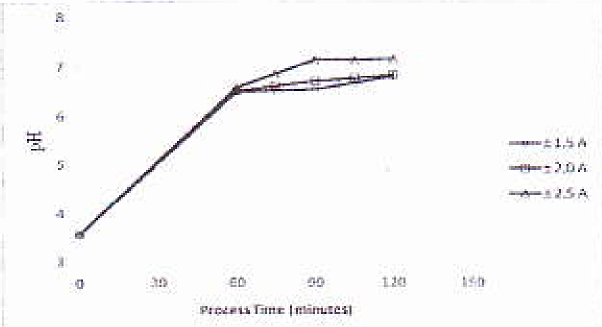

Fig 3. Effect of processing time for pH increase

Effect of processing time for total suspended solid (TSS). Total suspended solid is easy to recognize as it physically can be seen. High TSS concentration in wastewater means it is low-quality waste and potentially harmful to the ecosystem. TSS is one of important requirements for the licensing of wastewater disposal into the environment.

It is shown in Fig. 4 that the TSS in coal stockpile wastewater is 443 mg/L and it is out the range of standard of coal wastewater 200 mg/L. The TSS decreased rapidly until reached 103 mg/L [9]. We found that the best condition of the processing time and electrical curent is 120 minutes and ±2.5 A, respectively. This condition will result in a TSS of 72 mg/L.

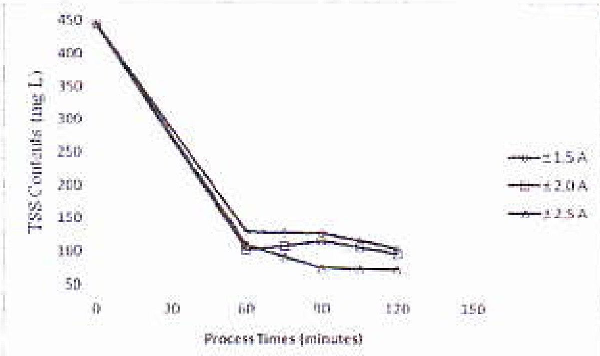

Fig. 4 Effect of processing time for TSS decrease

Conclusion

The electrocoagulation studies were conducted to evaluate the influence of various experimental parameter, which are electric current and electrolysis time in reducing pollutants from coal stockpile wastewater. The results indicated that the treatment rate increases as the electrical current and processing time increased. In addition, we found that electrocoagulation technique could reduce the Fe and Mn concentration as well as increase the pH by using a combination of electrical current and processing time of ± 2.5 A and 90 minutes, respectively. On the other hand, the TSS levels could be decreased using electrical current of ± 2.5 A and proccesing time 120 minutes.

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