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# Comparison of electrocoagulation using iron and aluminium electrodes for biogas production wastewater treatment

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**Index Terms**
Electrocoagulation
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***Abstract***—The decolorization and Chemical Oxygen Demand (COD) removal of Biogas Production Wastewater (BPW) were investigated by using electrocoagulation (EC) in a batch experiment. Iron and aluminum electrodes were compared. Variations of current density (20, 35, 50 A/m$^2$), initial pH (4.5, natural, 8.5), and electrolysis time (30, 50, 100 minutes) were conducted for decolorization and COD removal efficiency of BPW. The result showed that decolorization efficiency and COD removal are 31% and 28% for aluminum electrodes at natural pH with 100 minutes of electrolysis time and a current density of 35 A/m$^2$. However, using iron electrodes could not remove color, and only 15.70% of COD could be removed at natural pH, 100 minutes of electrolysis time, and a current density of 50 A/m$^2$.



## I. INTRODUCTION

Discharge of wastewater to the ecological system affects the receiving water bodies. The high strength discharge wastewater impacts human health risk and ground water [1]. The discharge standard wastewater in Thailand issued the BOD, COD should not exceed 20, 120 mg/l, pH range should be 5.5 – 9.0 and color should not be complained. Biogas production wastewater (BPW) contains high COD, BOD and dark color which are similar to landfill leachate. BOD and COD concentration are in range of 2,210 and 13,900 mg/l [2] and [3]. This wastewater is difficult to treat by a single conventional treatment. There are many different wastewater treatments such as activated sludge, coagulation/flocculation combined with Fenton and solar photo-Fenton processes, electrochemical treatment [4] and [5]. Electrocoagulation (EC) process is one of the alternative electrochemical techniques due to being eco-friendly, easy to operate, having less retention time and reduction of added chemical. This technique involves a generation of coagulant from sacrificial anode by applying a direct current into a pair of electrode and cathode. In this EC process metal ion from sacrificial electrode is coagulant

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for precipitation or/and flotation process to remove a flocculated pollutant. Electrocoagulation (EC) process has attracted a great attention for treatment of industrial wastewater such as textile wastewater, livestock [6] etc. COD and color removal by EC were efficient [7]-[2].

In this study, investigation of COD and color removal from biogas production wastewater was carried out in electrocoagulation batch reaction by using direct current (DC). Aluminium or iron plate was compared as electrode. Variation of current density, initial pH, electrolysis time were also conducted to determine the EC performance. Biogas production wastewater was taken from Suphanburi province.

## II. MATERIALS AND METHOD

### A. *Wastewater Source and Analytical Procedure*

Biogas Production Wastewater (BPW) from a biogas production industry located in Suphanburi province was used in this experiment. The wastewater properties were analyzed and shown in Table 1. BPW samples were taken from effluent pond after passing through biogas fermentation pond. Chemical Oxygen Demand (COD), Total Dissolved solid (TDS), influent pH and effluent pH were examined. Wastewater color was determined by measuring the adsorbent at optical density (O.D.) of 472 nm by Spectrophotometer (lambda 25 uv/vis spectrometer).

### B. *Experimental Apparatus and Procedure*

The experimental setup was shown in Fig. 1. Electrocoagulation was carried out in 500 ml glass jar. The aluminium and iron plates were used as electrodes with setup as a parallel plate on top of glass jar. The rectangular electrode had a dimension of 100 mm x 50 mm x 4 mm (length x width x thick). Electrode was immersed in wastewater for depth of 30 mm and total effective area was 71 cm2. The distance between electrode was 25 mm and all electrodes were connected to direct current power supply unit (UTP3704s, 0-32V; 0-3A, China). All experiments were performed at room temperature (about 28oC). Wastewater was stirred during electrocoagulation at mixing rate of 60 rpm. Variation of current density values of 20, 35 and 50 A/m2 were compared. Performance of electrocoagulation was also compared by variation of electrolysis time of 30, 50 and 100 minutes. After finishing each experiment, electrode was scrubbed with sand paper No.1,000 to remove rust before using in the next experiment.

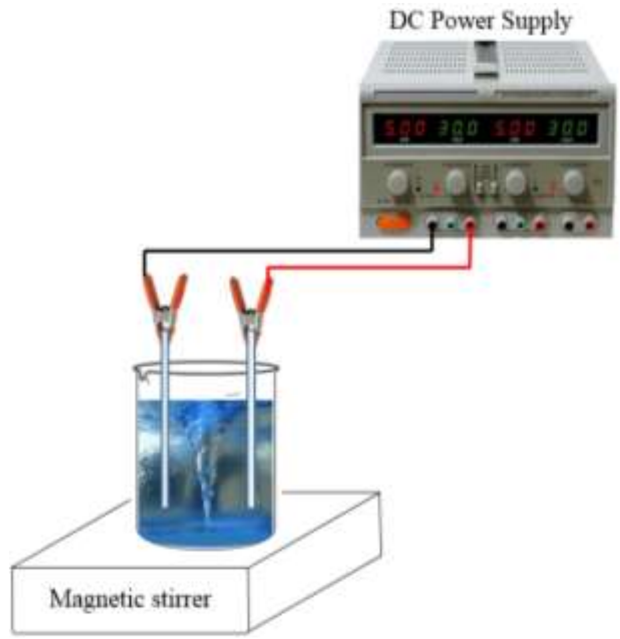


Fig. 1. Experimental setup of electrocoagulation process for biogas production wastewater treatment

### C. *Statistical Analysis*

All statistical analyses were performed using SPSS 16.0 by SPSS Inc. In all cases, significance was defined by $p$<0.05 and $p$<0.10. Tests for significant difference in each condition were conducted using one-way ANOVA with LSD.

## III. RESULT

Biogas production wastewater was collected and analyzed (Table I). COD and TDS were higher than wastewater discharge standard (Department of Industrial Work, Thailand) with black color. This kind of wastewater could not be directly discharged to natural water body.

TABLE I
BIOGAS PRODUCTION WASTEWATER QUALITY

| Parameter | Value |
|---|---|
| pH | 6.3 |
| COD (mg/L) | 13,900 |
| TDS (mg/L) | 6,834 |
| Color adsorbant at 472nm | 2.35 |

### D. *Variation of Current Density*

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Effect of current density on COD, color and TDS removal efficiency was studied by using aluminium or iron electrodes. Variation of current density at 20, 35 and 50 A/m2 was conducted with electrolysis time of 30 minutes. Increasing of current density had no effect on color and TDS removal efficiency (Fig. 2 and 3). Color and TDS removal efficiency were in range of 0.24–9.70% and 7.69–8.69% for aluminium electrode and (-41.67%)–(-60.43%) and 7.56–8.69% for iron electrode. But increasing of current density improved COD removal efficiency. COD removal efficiency was 6.00–13.67% with aluminium electrode and 2.64–8.63% with iron electrode (Fig. 4). Then current density of 35 and 50 A/m2 was used for aluminium and iron electrode with variation of initial pH.

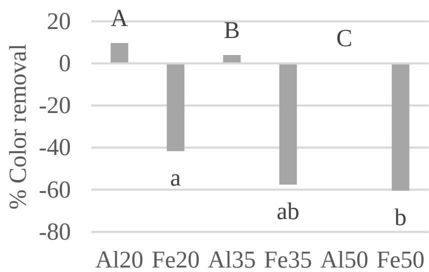


Fig. 2. Color removal efficiency after treating by EC with Al or Fe electrode at various current densities of 20, 35 and 50 A/m2.

Remark: The letter showed the difference in each current density (*p*<0.05). Capital letter is used for aluminium electrode and small letter is used for iron electrode

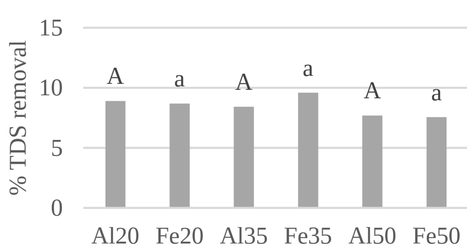


Fig. 3. TDS removal efficiency after treating by EC with Al or Fe electrode at various current densities of 20, 35 and 50 A/m2.

Remark: The letter showed the difference in each current density (p<0.05). Capital letter is used for aluminium electrode and small letter is used for iron electrode.

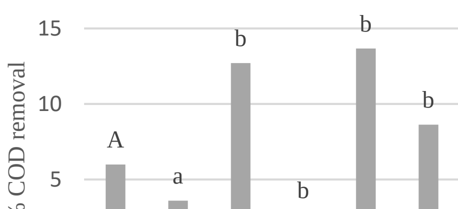


Fig. 4. COD removal efficiency after treating by EC with Al or Fe electrode at various current densities of 20,35 and 50 A/m$^2$

Remark: The letter showed the difference in each current density (p<0.05). Capital letter is used for aluminium electrode and small letter is used for iron electrode.

### *E. Variation of Initial pH*

Effect of initial pH on COD, color and TDS removal efficiency was studied by using aluminium or iron electrodes. Variation of initial pH at 4.5, 6.3 and 8.5 was conducted with electrolysis time of 30 minutes. Increasing of pH had no effect on TDS removal efficiency (Fig.5). But it had effect on color removal efficiency (Fig. 6). Color and TDS removal efficiency were in range of 3.98–13.71% and (-2.71%)–8.42% for aluminium electrode and (-15.57%)–(-60.43%) and (-2.45%)–7.56% for iron electrode. But increasing of initial pH did not improve COD removal efficiency. COD removal efficiency was 8.66%-(-9.96%) with aluminium electrode and (-22.94%)–8.63% with iron electrode (Fig. 7). Then initial pH of 6.3 was used for aluminium and iron electrode in variation of electrolysis time.

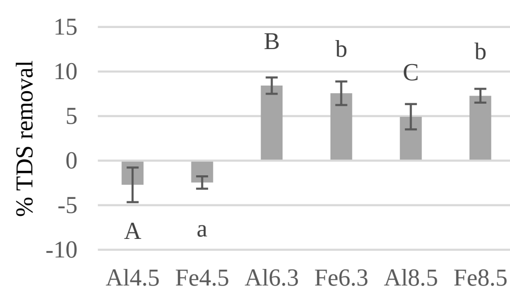


Fig. 5. TDS removal efficiency after treating by EC with Al or Fe electrode at various pH values of 4.5, 6.3 and 8.5 at current density of 35 A/m$^2$ for Al and 50 A/m$^2$ for Fe.
Remark: The letter showed the difference in each pH (p<0.05). Capital letter is used for aluminium electrode and small letter is used for iron electrode.

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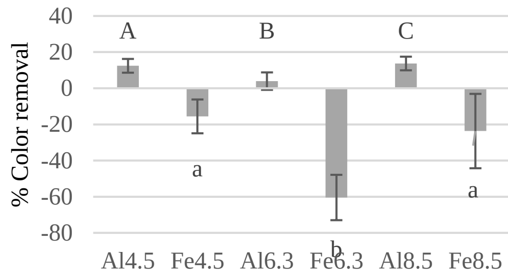


Fig. 6. Color removal efficiency after treating by EC with Al or Fe electrode at various pH values of 4.5, 6.3 and 8.5 at current density of 35 A/m² for Al and 50 A/m² for Fe.

Remark: The letter showed the difference in each pH ($p$<0.05). Capital letter is used for aluminium electrode and small letter is used for iron electrode.

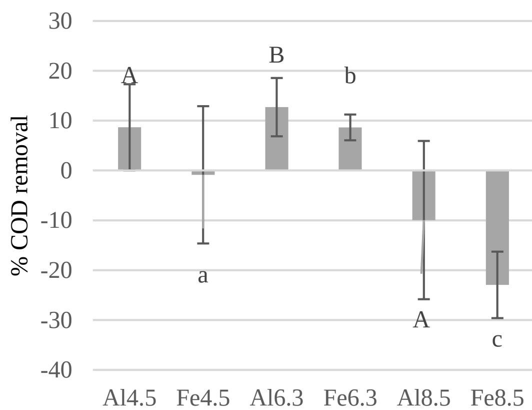


Fig. 7. COD removal efficiency after treating by EC with Al or Fe electrode at various pH values of 4.5, 6.3 and 8.5 at current density of 35 A/m² for Al and 50 A/m² for Fe.

Remark: The letter showed the difference in each pH ($p$<0.05). Capital letter is used for aluminium electrode and small letter is used for iron electrode.

### *F. Variation of Electrolysis Time*

Effect of electrolysis time on COD, color and TDS removal efficiency was studied by using aluminium or iron electrodes. Variation of electrolysis time at 30, 50 and 100 minutes was conducted with initial pH at 6.3. Increasing of time had effect on COD and TDS removal efficiency (Fig.8 and 9). COD and TDS removal efficiency were in range of 12.71–28.26% and 8.42–12.52% for aluminium electrode and 8.63–15.70% and 7.56–15.70% for iron electrode. But increasing of electrolysis time improved color removal efficiency. Color removal efficiency was 3.98%–(-17.98%) with aluminium electrode and (-60.43%) – (-52.68%) with iron electrode (Fig. 10).

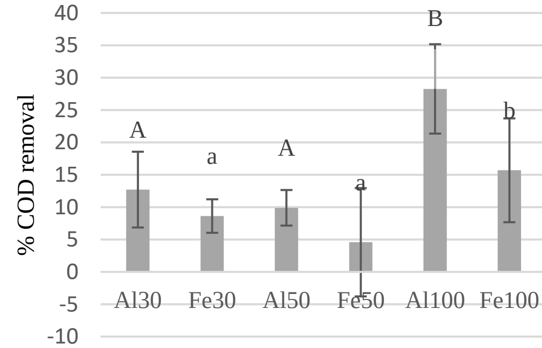


Fig. 8. COD removal efficiency after treating by EC with Al or Fe electrode at various time 30, 50 and 100 min at current density of 35 A/m² and natural pH for Al 50 A/m² and pH 6.3 for Fe.

Remark: The letter showed the difference in each electrolysis time (p<0.10). Capital letter is used for aluminium electrode and small letter is used for iron electrode.

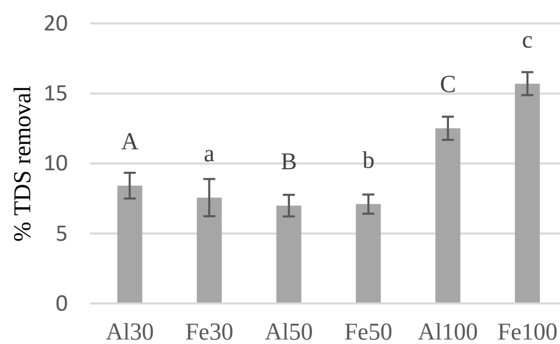


Fig. 9. TDS removal efficiency after treating by EC with Al or Fe electrode at various times of 30, 50 and 100 min at current density of 35 A/m² and natural pH for Al and 50 A/m² and natural pH for Fe.

Remark: The letter showed the difference in each electrolysis time ($p$<0.05). Capital letter is used for aluminium electrode and small letter is used for iron electrode.

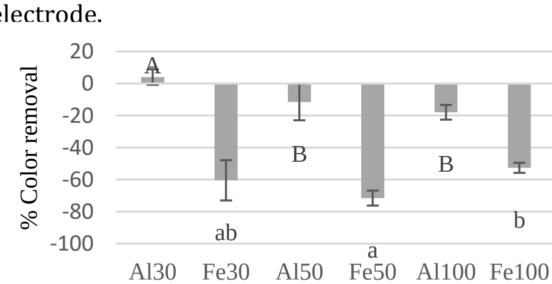


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Fig. 10. Color removal efficiency after treating by EC with Al or Fe electrode at various times of 30, 50 and 100 min at current density of 35 A/m$^2$ and natural pH for Al and 50 A/m$^2$ and natural pH for Fe.

Remark: The letter showed the difference in each electrolysis time ($p<0.05$). Capital letter is used for aluminium electrode and small letter is used for iron electrode.

## IV. DISCUSSION

According to variation of current density, the results showed that increase of current density could not improve TDS and color removal efficiency. While COD removal efficiency could be improved by rising current density. Using aluminium electrode gave better performance than iron electrode in color and COD removal. Optimum current density for aluminium electrode was 35A/m$^2$ and 50 A/m$^2$ for iron electrode. The increasing of current density, the extent of anodic dissolution of aluminium and iron increases resulted in a greater amount of hydroxide flocs for the removal of pollutants. Moreover, the rate of bubble-generation increases and the bubble size decreases with the increasing of current density, resulting in a faster removal of pollutants by $H_2$ flotation [8].

Variation of initial pH resulting in the amount of $Al(OH)_3$ and $Fe(OH)_2/Fe(OH)_3$ in electrolysis system. $Al(OH)_3$ is a dominant species at pH of 6 – 7 which is the effective form of coagulant. The highest COD and TDS removal efficiency was also found at pH of 6.3. On the other hand, lowest COD and TDS removal efficiency occurred at pH of 4 where $Al(OH)_3$ had lowest dissolution [9]. Fe (II) and Fe (III) were dissolved at pH lower than 4 then the effective color removal efficiency could be obtained at initial pH of 4. But iron electrode could not remove TDS and COD at initial pH of 4. The better result of TDS and COD removal was found at initial pH of 6.3. This may be due to soluble and miscible compounds that do not react at all with Fe(II) and/or Fe(III) and remain in solution. This is the case for glucose, lactose, isopropyl alcohol, phenol, sucrose, and similar compounds. A small amount of glucose can be adsorbed or absorbed on the floc and consequently be removed [9]. The fine floc could not be removed in this experiment. The COD could not be removed as well.

Extension of electrolysis time resulted in COD and TDS removal efficiency improvement. Even 30 and 50 minutes of electrolysis time did not show the significant difference. While the best performance was found at 100 minutes of electrolysis time ($p<0.1$) in both aluminium and iron electrode. Referring to Faraday's law, increasing of time also increases the amount of dissolution of electrode, $Al^{3+}$, $Fe^{2+}/Fe^{3+}$, that consequently coagulates the pollutants. Dark color in BPW could not be efficiently removed because the fine floc particle disturbed the color measurement by using spectrophotometer at 475 nm of wavelength. After centrifugation, color removal efficiency in both aluminium and iron electrode was increased up to 40% (data not shown).

## V. CONCLUSION

Increase of current density gave better COD removal efficiency and optimum current density for electrocoagulation was 35A/m2 for aluminium electrode and 50A/m2 for iron electrode. The highest COD and TDS removal efficiency was optimized at initial pH of 6.3. Extension of electrolysis time improved TDS and COD removal efficiency and 100 minutes of electrolysis time were the highest. Dark brown color of molasses could not be removed without centrifugation.

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