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Contributed Paper

Decolorization of Methylene Blue Solution by Electrocoagulation Using Aluminum Electrodes

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Abstract

In the present work, the electrocoagulation process and its performance of dye removal using aluminium as electrodes were investigated. Methylene blue solution was used as synthetic dye wastewater for dye removal efficiency. The optimal condition of electrocoagulation operation for dye removal was examined including current density (10-30 mA/cm^2), concentration of NaCl (1.5-6.0 g/L) and electrolysis time (2-15 min). The efficiency of dye removal was evaluated by the absorbance of the methylene blue solution at 664 nm. The results showed that the increasing current density from 10 to 30 mA/cm^2 enhanced the dye removal efficiency to 88%. The high NaCl concentration of 6 g/L with the electrolysis time of 10 minute provided the dye removal efficiency approximately 92%. In addition, the 15 min of electrolysis time provided the slightly higher efficiency with 93%. However, it has to be noted that with increasing the electrolysis time and current density caused high formation of sludge that can prevent the interaction of electrocoagulation process and increase the use of energy consumption.

Keywords: electrocoagulation, electrolysis time, current density, dye removal

1. Introduction

Aluminium (Al) is one of metals which widely used in various industries such as construction, transportation, electrical component and packaging. Several thousand tons of Al is used every year, and in the meantime, a lot of Al scrap is also generated. The Al scrap can be reused as secondary Al in industrial sectors after melting. However, the Al recycling process is still unsuccessful in Thailand. Thus, the Al scrap is mostly disposed as an industrail waste.

According to the specific properties of Al including high hardness, good conductive material for both thermal and electrical, light weight and no rusting occurs, these good properties convince the authors to enhance the value of Al scrap. One alternative to use the scrap of Al sheet for environmental application is proposed in this preliminary research; using Al sheet as electrodes in an electrocoagulation (EC) system for wastewater treatment.

Electrochemical technology consists of four significant processes; electrodeposition, electrocoagulation, electroflotation and electrooxidation [1]. Among of above processes, the EC is a recent innovation for wastewater treatment with high removal efficiency for several pollutants; oil and grease, metal, nutrient, turbidity and colour [2-3]. Three types of electrodes have been used in the EC system, which were aluminium (Al-Al), iron (Fe-Fe) and hybrid of Al/Fe. In the EC system with Al monopolar electrodes, the chemical reactions are presented in equations (1) - (3). The aluminium oxide particles ($Al(OH)_3$) are formed and floated to the surface by H_2 gas [4]. The aluminium oxide particles adsorb the destabilized pollutants to be scum (or sludge) at the surface and also deposited as sediment at the system base. The EC has been feasible economically in operating cost, efficient technically process and applicable practically to industrial wastewater [5-6].

$$\text{Anode: } Al \rightarrow Al^{3+} + 3e^{-} \quad (1)$$

$$\text{Cathode: } 3H_2O + 3e^{-} \rightarrow \frac{3}{2} H_2 + 3OH^{-} \quad (2)$$

$$\text{Redox: } Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^{+} \quad (3)$$

A common pollutant is commonly found in industrial wastewater is organic carbon, which is measured in biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The characteristic of industrial wastewater is various, which depends on type of industry and manufacturing process (i.e., high turbidity and colour in the wastewater from painting and dye industries). Although the wastewater is treated efficiently by current technologies of biological process and physicochemical process, the alternative which is effective and low cost from using industrial waste becomes a challenge.

In this research, the performance of EC on removing dye from the synthetic industrial wastewater was studied. The particular EC system was developed to enhance its activity, and Al sheet was used as electrodes. The methylene blue solution represented the industrial wastewater in this preliminary. Three factors of current density, electrolysis time and sodium chloride (NaCl) concentration which were significant operating factors [7-9] were varied to find out the best condition for dye removal.

2. MATERIALS AND METHODS

2.1 Wastewater Preparation

The methylene blue solution was represented the industrial wastewater in this research. This is because the methylene blue contains high carbon as similar as general wastewater, and contains nitrogen which is another common pollutant in the wastewater. The structure of methylene blue is shown in figure 1. Significantly, the efficiency of dye removal can be measured by colour reduction. The concentration of methylene blue solution was controlled at 1×10^{-5} M [10].

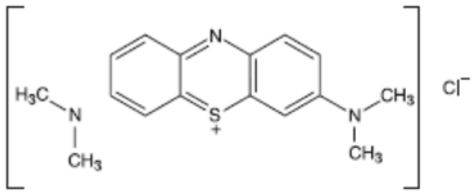

Figure 1. Structure of methylene blue.

2.2 Electrocoagulation System

The EC system was set up as shown in figure 2; its dimension was 8 × 8 × 16.5 cm. (width × length × height) and working volume was around 0.5 L. The six Al sheets were placed as monopolar electrodes, which interelectrodes distance was 1 cm. The effective electrodes area was approximately 246 cm^2. The EC system was place on a magnetic stirrer and connected to a direct current power supply (0-30 V/20 A).

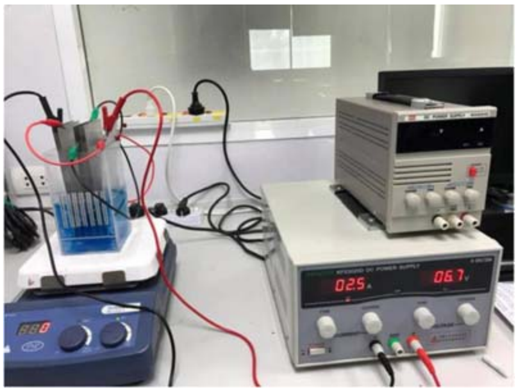

Figure 2. Experimental set-up.

2.3 Experiment Procedure

The methylene blue solution of 0.5 L was added to the EC system. Then, three operating factors of current density (10-30 mA/cm^2), electrolysis time (2-15 minutes) and NaCl concentration (1.5-6.0 g/L) were varied. The other factors of electrical potential, temperature and mixing speed were controlled at 5 volts, 25 °C and 250 rpm respectively. At the end of experiments, the solution was centrifuged at 5,000 rpm to remove the sludge. The centrifuged solution was measured the absorbance by UV-Visible spectrophotometer (UV-6100 Double Beam spectrophotometer) from 400-800 nm. The efficiency of dry removal was calculated in equation (1).

Effeciency (%) =

$$1 - \frac{\text{Final absorbance at 664 nm}}{\text{Initial absorbance at 664 nm}} \times 100 \qquad (1)$$

3. Results and Discussion

3.1 Effect of Current Density

The initial absorbance spectra of methylene blue solution presented the highest peak at 664 nm, thus the reduction of the highest peak was referred the dye removal efficiency. After treatment by EC, the results are shown in figures 3a. The peak at 664 nm decreased from 1.2 Abs at the initial to 0.8 Abs at the current density of 10 mA/cm^2, and further decreased to 0.3 and 0.2 Abs at the higher current densities. From figure 3b, the dye removal efficiency was increased by increasing current densities as linear relation. The efficiency was 34% at 10 mA/cm^2 and increased to 78% at 20 mA/cm^2 and reached the maximum of 88% at 30 mA/cm^2. This is because a large amount of aluminium hydroxide particles (i.e., $Al(OH)_3$) are generated at the higher current densities. The aluminium hydroxide particles act as coagulant to destabilize the colloid particles of dye, and remove the destabilized dye from the water

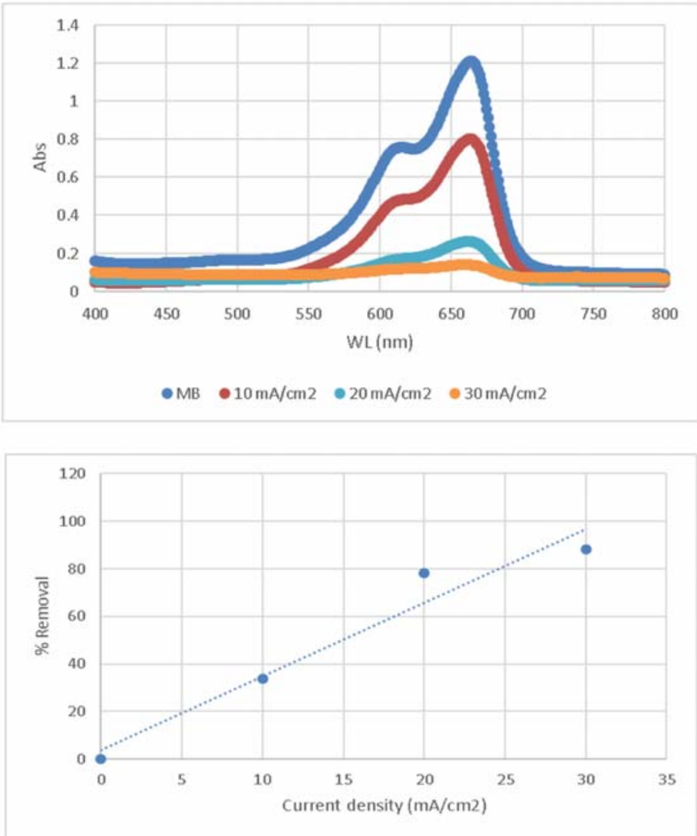

Figure 3. (a) Absorbance spectra and (b) dye removal efficiency at various current densities (electrolysis time 10 minutes and NaCl 2 g/L).

3.2 Effect of Electrolysis Time

At various electrolysis times, the dye removal efficiency was increased by increasing electrolysis times as exponential relation. The efficiency was sharply increased to 66% at 4 minutes, and continuously increased at the longer electrolysis times. The efficiency reached 88% at 10 minutes and then slightly increased to 93% at 15 minutes. In the meantime, the longer electrolysis times cause that high sludge was observed from Al electrode degradation. The high sludge occurrence can prevent the chemical interaction during the wastewater treatment by EC process and increase the energy consumption [6].

3.3 Effect of NaCl Concentration

At various NaCl from 1.5 to 6 g/L, the dye removal efficiency was in the same range of 85-92%. Since NaCl played a role as conductive solution, the chemical reaction cannot be occurred in the EC system without NaCl addition. In the meantime, the amount of NaCl addition had no relation to the enhancement of EC activity.

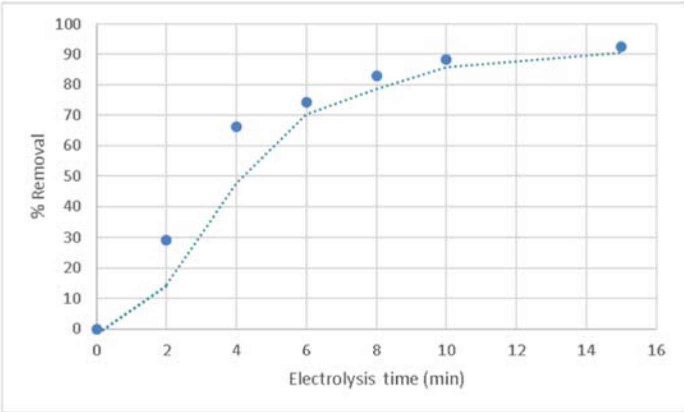

Figure 4. Dye removal efficiency at various electrolysis times (current density of 30 mA/cm^2 and NaCl 2 g/L).

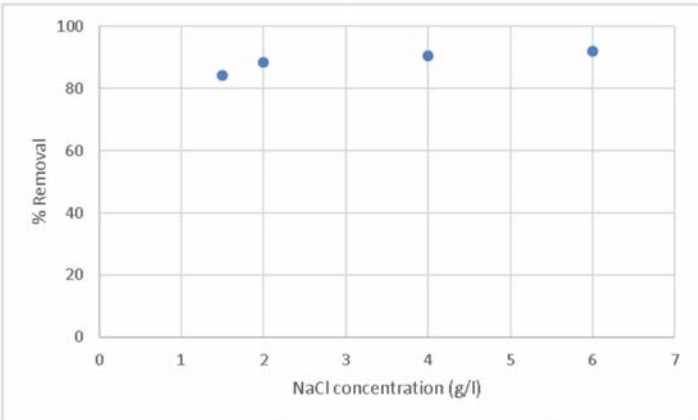

Figure 5. Dye removal efficiency at various NaCl concentrations (current density of 30 mA/cm^2 and electrolysis time 10 minutes).

At the end of experiments, the surface of Al electrodes was slightly decayed to produce the aluminium ions and form the coagulant as aluminium hydroxide. Further, the sludge of aluminium hydroxide particles and dye were observed at the water surface, as shown in figure 6. However, the water became clear and colourless after sludge removal.

Figure 6. Sludge occurrence after the treatment.

Conclusions

The scrap of Al sheets can be used as electrodes in the electrocoagulation process for wastewater treatment, especially dye removal. The efficiency of dye removal was enhanced by increasing current densities and electrolysis times. The increasing NaCl concentrations had no impacts on improving the EC performance, however the NaCl addition was necessary. The maximum of dye removal efficiency of 93% was found at the current density of 30 mA/cm^2, electrolysis times of 10 minutes and NaCl of 2 g/L. Under this condition, the solution was clear and colourless after the treatment.

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