Alexandria Engineering Journal (2015) 54, 777–786

HOSTED BY

ELSEVIER

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

Improvement of Methylene Blue removal by electrocoagulation/banana peel adsorption coupling in a batch system

Helder Pereira de Carvalho [a,*], Jiguo Huang [a], Meixia Zhao [a], Gang Liu [a], Lili Dong [b,c], Xingjuan Liu [a]

[a] *Key Laboratory of Groundwater Resources and Environment, Ministry of Education, Jilin University, Changchun 130026, PR China*
[b] *Key Laboratory of Songliao Aquatic Environment, Ministry of Education, Jilin Jianzhu University, Changchun 130118, PR China*
[c] *School of Environment, Northeast Normal University, Changchun 130117, PR China*

Received 16 September 2014; revised 31 March 2015; accepted 5 April 2015
Available online 24 April 2015

KEYWORDS

Electrocoagulation;
Banana peel;
Adsorption;
Methylene Blue;
Kinetics;
Energy consumption

Abstract The present work studies the improvement of Methylene Blue (MB) from aqueous solutions by an electrocoagulation (EC)/banana peel (BP) adsorption coupling process. The kinetics of this coupling process was studied using different amounts of adsorbent material in order to identify the most appropriate dosage, for enhancing wastewater treatment. The influence of current density on the removal efficiency and energy consumption of the EC/BP coupling process was also determined.

The coupling between electrocoagulation and BP showed that the addition of an appropriate BP dosage resulted in the enhancement of the removal rate of dyes especially at lower current densities, and in a considerable reduction in the contact time compared to the conventional simple EC process and simple adsorption process, having achieved efficiency removal of approximately 99%.

Based on the high removal efficiency, short contact time and low energy consumption, the EC/BP coupling method could be recommended instead of the conventional simple EC.

1. Introduction

The disposal of textile wastewater is currently a major problem from a global viewpoint [1]. It has gained increased attention because the extensive release of synthetic dyes has caused considerable environmental pollution [2]. Importantly, the accumulation of dyes in water can seriously damage food chains of human and animals [3,4]. Gupta Suhas [5] pinpointed the need of some systematized studies on separation/degradation processes of dyes, and the consideration of wastewater treatment at the source underlines the importance of developing technologies that are simple, reliable, adaptable and relatively cheap. In this way, an increasing interest has been shown in combining process such as electrocoagulation, electro-oxidation, adsorption, ozonation [6] and reverse osmosis [7].

* Corresponding author. Tel.: +86 13604436250.
E-mail address: helarc2008@gmail.com (H.P. de Carvalho).
Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2015.04.003
1110-0168 © 2015 Faculty of Engineering, Alexandria University. Production and hosting by Elsevier B.V.

The electrocoagulation process provides a simple, reliable, and cost-effective method for the treatment of wastewater without the need for additional chemicals, and thus, without the production of secondary pollution [8–11]. It also reduces the amount of sludge which needs to be disposed [12]. The separation by electrocoagulation of pollutants such as hydrocarbons [13,14], dyes [15–18], heavy metal ions [19,20], leachate [21], and various other ions such as boron [22] and fluorine [23] has been reported.

EC utilizes a direct current source between metal electrodes partially submerged in electrolyte. The electric current causes the dissolution of the metal plates into the wastewater [24]. The most widely electrode materials are aluminum and iron, because they are cheap and very effective [25]. In the case of electrocoagulation with Al, the anodic reaction leads to soluble Al^{3+}:

$$Al_{(s)} \rightarrow Al^{3+} + 3e^- \quad (1)$$

and the cathodic reaction produces hydroxide ion and H_2 gas:

$$3H_2O + e^- \rightarrow (3/2)H_{2(g)} + 3OH^- \quad (2)$$

Some researchers consider that reaction shown in Eq. (3) occurs to form amorphous $Al(OH)_3$ (gel) [26,27]. The flocs formed of the amorphous $Al(OH)_3$ have large surface area, which is beneficial for rapid adsorption of soluble organic compounds and trapping of colloidal particles [24].

$$Al^{3+} + 3OH^- \rightarrow Al(OH)_{3(gel)} \quad (3)$$

Other researchers suggest that the reaction shown in Eq. (4) takes place at the metal-solution interface before $Al(OH)_{3(gel)}$ can be formed in solution. The soluble $Al(OH)_4^-$ species is a precursor for Al_{13} polymer formation, the most effective specie of polyaluminum coagulant [28–30]. The Al_{13} polymer removes soluble organic compounds by charge neutralization and sweep flocculation [31]. Decolorization efficiency mainly depends on the total dissolved aluminum (Al_T) and the ratio of Al_{13} polymer to Al_T [24]. In fact, dye removal from wastewaters is a combined effect of the actions of $Al(OH)_{3(gel)}$ and Al_{13} polymer [26,32].

$$Al^{3+} + 4OH^- \rightarrow Al(OH)_4^- \quad (4)$$

On the other hand, Avsar et al. stated that the main disadvantage of conventional EC consists in the formation of an impermeable oxide film on the cathode [33], resulting in higher energy consumptions and lower efficiencies [33–37]. One of the ways to enhance conventional EC systems aside from the changing polarity of electrodes [38] has been suggested by Narayanan and Ganesan, who reported the use of granular active carbon (GAC), which might be a more efficient and faster separation technique compared to conventional EC [39]. Similar studies have also been reported by Secula et al. [40,38]. On the other hand, coupling the electrocoagulation technique with BP adsorption was not reported before, and it deserves attention because BP is an effective and low-cost coagulant and therefore ideal for application in developing countries.

The main aim of the present work was to investigate the efficiency of coupling the electrocoagulation technique with BP adsorption for removing Methylene Blue from aqueous solution. Cell voltage and solution pH were monitored during the electrocoagulation process. The unit energy demand (UED), the unit electrode material demand (UEMD) and the charge loading (Q_e) were also determined and discussed. A pseudo-first order kinetic model was tested on both simple EC and EC/BP coupling processes to determine the values of rate constant and half time under various experimental conditions. Based on the rate constant values and energy consumption (E_{con}), optimization of the coupling process by adding different amounts of BP was evaluated. The influence of current density on the enhancement of removal efficiency and E_{con} of the EC/BP coupling process was established.

2. Experimental

2.1. Materials

Bananas were purchased at a local market (Changchun, China) and were manually peeled immediately. The banana peels were washed with distilled water to remove the surface adhered particles and water-soluble materials. Then it was sliced, spread on trays and over dried at 60 °C for 48 h. The dried slices were ground and sieved to obtain a particle size range of 60 mesh and stored in plastic bottle for further use. No other chemical or physical treatments were used prior to experiments.

Methylene Blue (MB, C.I. No. 52015, $C_{16}H_{18}ClN_3S \cdot 3H_2O$, MW = 373.90 $gmol^{-1}$), was purchased from Shanghai Jinsui Bio-Technology Co., Ltd. (Shanghai, China) (Fig. 1).

Solutions of MB (volume 1 L) were prepared before each experimental run by dissolving certain amounts of dye in ultra-purified water.

To adjust the solution conductivity, a weight of 1 g of NaCl (Beijing Shiji, Beijing Chemical works, China) was dissolved in synthetic dye solutions (volume 1 L).

2.2. Electrocoagulation experiments

The electrocoagulation reactor consisted in a parallel-plate electrocoagulation cell provided with two facing electrodes and with six perforated tubes attached to its bottom to maintain a uniform gas flow and stirring into the cell. The experimental setup used in this study is shown in Fig. 2. The effective area of the each electrode plate was 97 cm^2. The anode and cathode were positioned vertically and fixed at a distance of 1 cm from each other. The electrodes were aluminum and stainless steel (SS-304) plate connected to a digital DC power supply (WYJ, 0–30 V; 0–5 A; DC Regulated Power Supply Double Way Output, TESTMART, Shanghai, China). The electrodes were polished with fine-grained emery paper, washed with 1 N H_2SO_4 and then with distilled water before each run. All the runs were performed at room temperature 20 ± 1 °C.

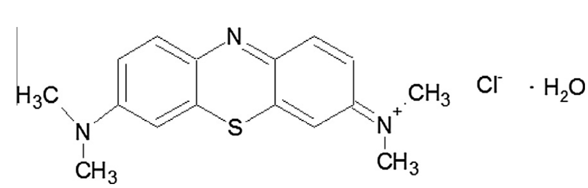

Figure 1 Chemical structure of Methylene Blue.