Journal of Environmental Chemical Engineering 4 (2016) 704–710

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

Effect of separated cathode on the removal of dissolved organic carbon using anode oxidation, Fenton oxidation, and coagulation

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A R T I C L E I N F O

Article history:
Received 1 September 2015
Received in revised form 30 November 2015
Accepted 20 December 2015
Available online 22 December 2015

Keywords:
SC–AFC reactor
Anode oxidation
Fenton oxidation
Coagulation
Dissolved organic carbon

A B S T R A C T

Several countries face scarcity of water, particularly in arid and semi-arid countries such as Egypt. Water supply in Egypt is highly dependent on Nile water, which barely provides for human, agriculture, and industrial consumption. Drainage waste water (DWW) is used for agriculture purposes directly or after blending with Nile water (1:1). DWW contains high concentrations of dissolved organic carbon (DOC), which may prohibit its application. A new process to remove DOC was introduced when wastewater was treated for agriculture purposes. The new process is a combination of anode oxidation and Fenton oxidation coagulation (AFC) in which cathode electrodes were separated from anode electrodes by cation and anion exchange membrane (CEM and AEM). Results showed that the removed DOC was enhanced by applying a separated cathode (SC) system. The most influential factor affecting the treatment was Fe(II) dosage. Based on results obtained, a new reactor contains separated cathode in anode oxidation, Fenton oxidation, and Coagulation (SC–AFC) reactor was made. SC–AFC reactor may be used for hydrogen production simultaneously with the removed DOC since it provides high pH in cathode compartment.

1. Introduction

Water shortage, particularly in arid and semi-arid countries is considered one of most persistent issues. Currently, water scarcity is occurring throughout the world, even in countries that are considered rich in water supply. The agricultural sector consumes the largest amount (75%) of potable water. In highly populated countries, particularly in arid and semi-arid climates, water supply is considered the primary dilemma. The problem is now obvious in North Africa and west and central of Asia. Because of the huge consumption of water in agriculture, food production will be highly influenced and eventually lead to starvation. Take into consideration there are about 1–1.5 billion people suffering from limited access of potable water for domestic use, and 2.6 billion suffer from lack of proper sanitation, leading to millions of deaths per year. Also, existing water supply is subject to contamination, particularly in industrial and developing countries. Nowadays, Courtiers tend to desalt sea water to bloom desert. Egypt is facing the deficiency of water supply to overcome unlimited raises in population that requires adding new agriculture land to provide enough amounts of food. The problem will be catastrophic if the Nile Delta sinks because of climatic change by 2050. Another threat is expected via dam construction as seen in Ethiopia [1–9].

The Egyptian government has established five mega projects including Toshka, El Salam Canal, Sharq Al-Owainat, Darb El Arbaeen, and New Villages to invade the desert and subsequently add more agriculture land. One of these projects is Al Salam Canal, which depends on blinding of sewerage (drainage wastewater) and Nile water. Unfortunately, this project did not show noticeable progress in crop irrigation owing to the relatively high levels of dissolved organic carbon and salinity. Drainage wastewater is the fate of several industrial effluents such as dyes and pharmaceuticals [10–14].

All those challenges motivated us to introduce a practical technique to treat wastewater containing organic pollutants. A new process combining anode oxidation, Fenton oxidation, and coagulation was introduced in which cathode is separated from anode using CEM and AEM. Fulvic was used as substrate of dissolved organic carbon (DOC). The effect at four levels including H_2O_2 (mM), Fe(II) (mM), current (mA), and fulvic acid (ppm) was investigated using the Taguchi approach.

2. Materials and methods

2.1. Materials

Experiments of anode oxidation, Fenton oxidation, and coagulation were carried out in two rectangle boxes. The first box was made of glass with 0.6 thickness and internal dimensions

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http://dx.doi.org/10.1016/j.jece.2015.12.021
2213-3437/

of 10.5 cm long, 6 cm wide, and 16 cm high. This box was filled with 900 ml of working solution. The second box was made of acrylic and consisted of two rooms (working room (anode room) and cathode room) separated by CEM and AEM. The internal dimensions of the working room 10.5 cm long, 6 cm wide, and 16 cm high, also filled with 900 ml; however, the second room internal dimensions was 6 cm long, 3.5 cm wide, and 16 cm high. The AEM was faced to anode electrodes and CEM was faced to cathode electrodes. CEM and AEM were separated from each other by foam spacer as shown in Fig. 1. Two rods of electrodes were made of titanium (28.5 cm long, and 10.5 cm diameter) were used either as cathode or anode. The gap between the cathodes and anodes was fixed at 4 cm for the first box; however, in the second box the anodes and cathode were inserted in the middle of rooms. 12 cm of electrodes was immersed in the working solution.

CEM and AEM were brought from Membranes International Inc., Ringwood, NJ, USA. The characteristics of CEM and AEM are presented in Table 1. Variable transformer AC (0–250 V) connected with bridge to change AC to DC. Avometer UT53 was use to adjust the passed current.

Fulvic acid was separated from farm manure aged for 9 years [15]. The concentration of fulvic acid was detected using UV–vis spectrophotometer T 60 at a wavelength of 350 nm [16]. All chemicals were of analytical grade. $FeSO_4 \cdot 7H_2O$ from Gamma Laboratory Chemicals was used as source for ferrous ions. Hydrogen peroxide provided by Pinochet, Egypt had a purity of 30%.

2.2. Taguchi approach

The effect of four factors at four levels including current (50 mA, 100 mA, 150 mA, 200 mA), H_2O_2 (10 mM, 30 mM, 50 mM, 70 mM), Fe(II) (0 mM, 0.5 mM, 1.5 mM, 2.5 mM), fulvic acid (50 ppm, 100 ppm, 150 ppm, 200 ppm) was studied using Taguchi approach orthogonal array ($L_{16}OA$) (Table 2). S/N ratio (signal-to-noise ratio) was optimized by calculating the larger–the better (Table 3). More illustrated information regarding the Taguchi approach may be found in our previous studies [10,17–19].

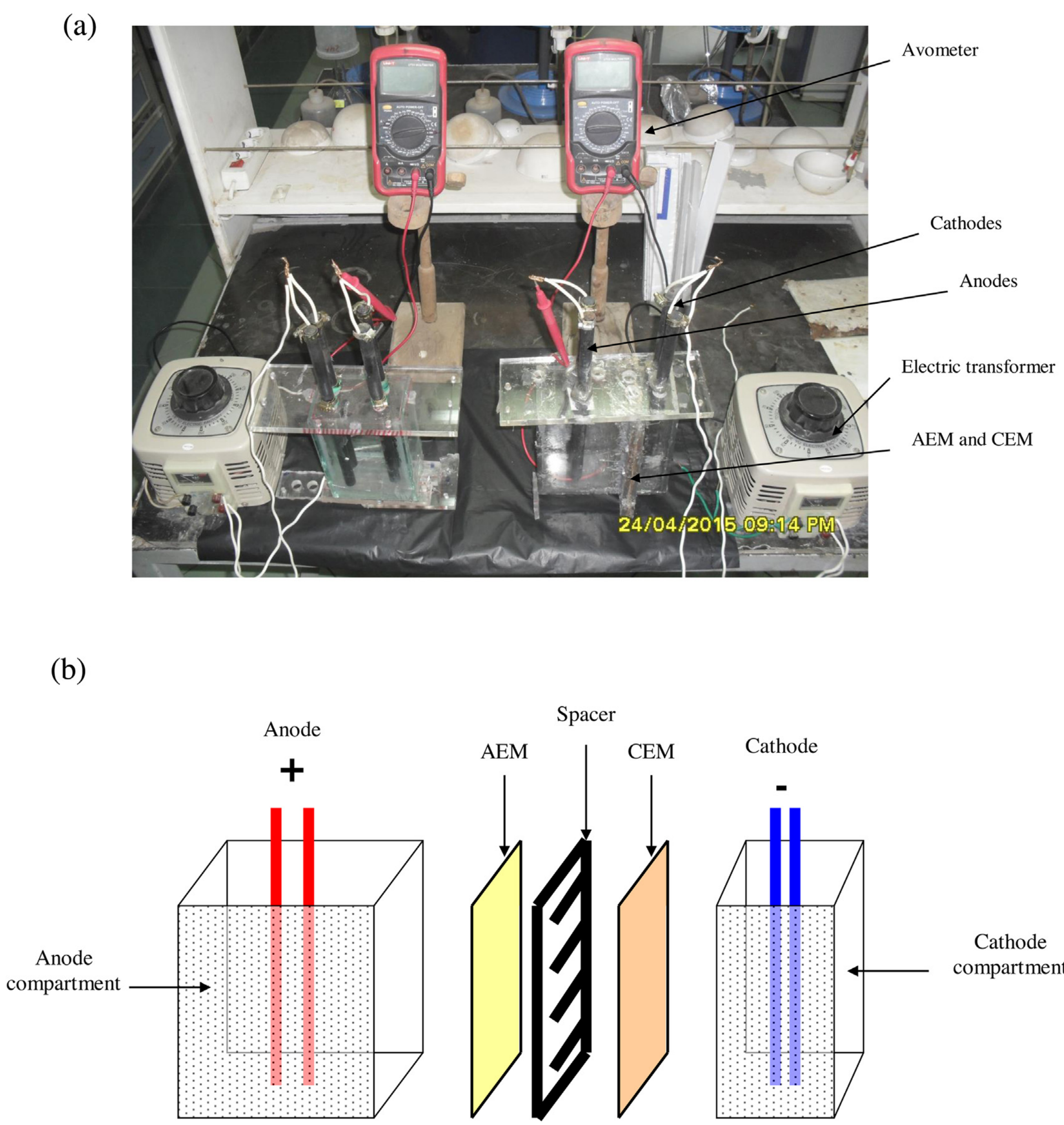

Fig. 1. (a) Photograph shows AO, FO, and coagulation apparatuses without CEM & AEM and with incorporating CEM & AEM and (b) schematic diagram shows the AO, FO, and coagulation apparatus with incorporating CEM & AEM.