Application of Electrocoagulation for Turbidity Removal in Waste Solutions

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Abstract: *The treatment method applied for the wastewater depends on the type of pollutants present in wastewater. In recent years, electrocoagulation (EC) process has been attracting a great attention for removal of turbidity from many industrial effluents such as cardboard paper mill, sewage water, container washing wastewater, metal cutting wastewaters, marble processing wastewater, etc., because of the flexibility and the environmental compatibility. An extensive analysis of the literature has been made and it was found that none of the authors has tried to study the EC treatment of printing industry effluent such as a waste fountain solution. In this paper, removal of turbidity from waste fountain solution by batch EC process was investigated by using different combinations of aluminium or iron electrodes which were run in bipolar connection systems. The application of the EC process on the waste fountain solution showed satisfactory removal efficiencies of turbidity.*

*Key**words:** Electrocoagulation treatment, waste fountain solution, turbidity*

1 Introduction

The treatment method applied for the wastewater depends on the type of pollutants present in wastewater. Some of them are coagulation, foam flotation, filtration, ion exchange, aerobic and anaerobic treatment, advanced oxidation processes, solvent extraction, adsorption, electrolysis, microbial reduction, and activated sludge. These methods require substantial financial input in terms of raw material and complexity in process parameters, and hence, their use is restricted because of cost factors overriding the importance of pollution control [1]. Recently, there has been considerable interest in identifying new technologies that are capable of meeting more stringent treatment standards. For this purpose, EC has the potential to be the distinct economic and environmental choice for treatment of various industrial wastewaters [2]. EC provides some significant advantages such as quite compact and easy operation and automation, no chemical additives, a shorter retention time, height sedimentation velocities, easier dewatering, and reduced amount of sludge due to the lower water content [2, 3].

In recent years, EC process has been attracting a great attention for removal of turbidity from many industrial effluents such as cardboard paper mill [4], sewage water [5], container washing wastewater [6], metal cutting wastewaters [2], marble processing wastewater [7, 8], egg processing effluent [3], etc., because of the flexibility and the environmental compatibility. An extensive analysis of the literature has been made and it was found that none of the authors has tried to study the EC treatment of printing industry effluent such as a waste fountain solution.

Materials being used in the printing industry are very diverse and complex and they influence the quality of printing products to a great extent. The knowing of the structure and characteristics of the materials and their exploitative properties conditions the choice of the optimal technological procedure in the printing industry [9] and appropriate treatment of the resulting waste material on the other side.

The objective of this study is to investigate the maximum turbidity removal from waste fountain solution by EC treatment. The EC treatment was carried out with different four aluminium or iron electrode combinations, current densities, and operating times.

2 Materials and Methods

2.1 The Waste Fountain Solution

The waste fountain solution was sampled from the Graphic Centre of the Department of Graphic Engineering and Design at the Faculty of Technical Sciences (Novi Sad, Republic of Serbia). TheKBA Rapida 75 4/0 sheet-fed offset press (manufacturer Koenig & Bauer Group, Germany) was used for printing posters. The processing sheet-fed offset printing inks (manufacturer TOYO INK CO., LTD., Japan) and initial FountMax Blue 30.30 AF fountain solution, produced by Fujifilm, were used during the sheet-fed offset printing process [10].

2.2 The EC Treatment of the Waste Fountain Solution

All of the EC experiments were conducted in an EC reactor mainly consisted of four components: (1) a direct current (DC) power supply, (2) an electrolytic EC cell, (3) a magnetic bar, and (4) a magnetic stirrer. The characteristics of the electrode and EC cell are given in Table 1. Also, four sets of experiments were performed with different electrode combinations: (1) four iron electrodes, (2) four aluminium electrodes, (3) two aluminium (one was anode) and two iron electrodes, and (4) two iron (one was anode) and two aluminium electrodes. Only the outer electrodes were connected to the DC power supply (DF 1730LCD), and anodic and cathodic reactions occurred on each surface of the inner electrode when the current passed through the electrodes.

Table 1
Operating conditions for EC treatment of waste fountain solution

Characteristic	Parameter	Value
Electrode	Material of anode/cathode	Al/Al; Al/Fe; Fe/Fe; Fe/Al
	Number	4
	Shape	Rectangular plate
	Dimension (height x width x thickness) (cm)	10 x 5 x 0.1
	Total surface area (cm^2)	100
	Active surface area (cm^2)	40
EC cell	Material	Borosilicate glass
	Volume of cell (mL)	250
	Volume of sample (mL)	220
	Interelectrode distance (cm)	1.0
	Curent density (mA cm^{-2})	2; 4; 8
	Operation time (min)	1; 5; 10; 20; 40; 60
	Connection mode	Bipolar parallel
	Stirring mechanism and rpm	Magnetic and 450

In each batch EC experiment, 220 mL aliquots of the waste fountain solution (collected from a waste chamber) added with the same amount of potassium chloride (0.50 g) were stirred at 450 rpm by a magnetic stirrer (IKA colour squid). The stirrer speed was found to be sufficient to provide well mixing in the EC cell, and yet was not strong enough to break up the flocs formed during the treatment process.

To follow the progress of the EC process, samples of 15 mL have periodically been taken from the EC cell at certain operating times (1, 5, 10, 20, 40 and 60 min). Upon the completion of the process, the test samples were centrifuged (Centrifuge Tehtnica Železniki, Slovenia) at 2000 rpm for 15 min and the supernatant was analyzed.

For each electrode combination three optimum current density values of 2, 4 and 8 mA cm^{-2} were applied for the inter-electrode distance of 1.0 cm. The aluminium and iron electrodes were prepared in an appropriate way in order to ensure electrode surface reproducibility. Before each run, the electrode surface has first been mechanically polished with abrasive paper, rinsed with deionized water and immersed for 10 min in a 5 M solution of hydrochloric acid (35%) in order to avoid any effects occurring due to a different prehistory of the electrodes. Thereafter, the electrodes were washed again with deionized water and dried [10].

2.3 Determination of Turbidity Removal from Waste Fountain Solution

Turbidity was determined by HI 93703 microprocessor turbiditymeter (HANNA Instruments, Portugal) according to the standard EPA 180.1 method [11]. Turbidity was performed in triplicate and mean values were used. The relative standard deviations (% RSD) obtained (n = 3) were below 2%.

The removal efficiency of turbidity (RET) by the EC process was calculated according to the following equation [7, 8, 12]:

$$RET = \frac{T_o - T_t}{T_o} \cdot 100 \ \ (\%) \qquad (1)$$

where T_o and T_t are the initial (before the electrolysis) and final (at a certain operating EC time) value of the turbidity (NTU), respectively.

3 Results and Discussion

With an increase in the current density from 2 to 8 mA cm^{-2}, there is a substantial increase in the removal efficiency of turbidity in the EC process (Figure 1) for all electrode combinations. At a high current density, the extent of anodic dissolution of aluminium and iron were increases, resulting in a greater amount of precipitate and removal of turbidity [12]. Also, removal efficiency of turbidity increases with the increase of electrolysis time for all electrode combinations, which is in accordance with the results of other authors [7].

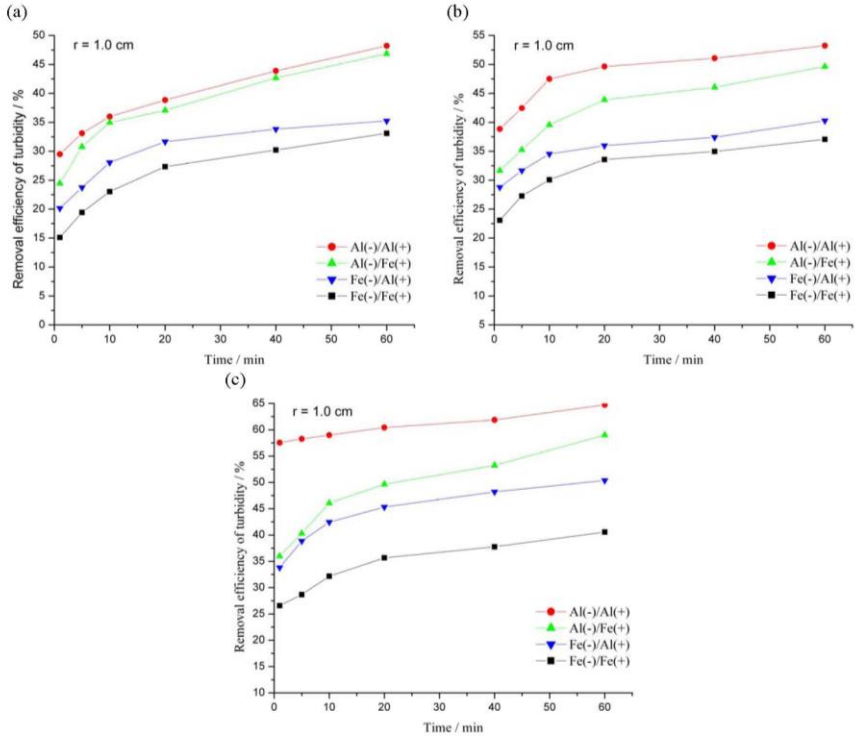

Figure 1

The removal efficiency of turbidity from the waste fountain solution at current densities of (a) 2 mA cm^{-2}, (b) 4 mA cm^{-2} and (c) 8 mA cm^{-2} (four electrode combinations and interelectrode distance of 1.0 cm)

The removal efficiency of turbidity from the waste fountain solution decreases in the following order of electrode combinations: Al(−)/Al(+) > Al(−)/Fe(+) > Fe(−)/Al(+) > Fe(−)/Fe(+). The results indicate that the removal efficiency of turbidity at 8 mA cm^{-2} and 60 minutes increase in the following order: aluminium/aluminium (64.7%), aluminium/iron (58.9%), iron/aluminium (50.4%), and iron/iron (40.6%) electrode combinations. A relatively clean and stable effluent could be achieved by using aluminium electrode combinations in the EC process. Here, use of iron electrode combinations resulted in a greenish effluent, colour of which changed into yellow along the EC process, emphasizing that the electrode provides an extra turbidity loading into the effluent. The forming of greenish and yellow effluent after the process might be originated due to the Fe^{2+} and/or Fe^{3+} ions dissolved from the surface of the electrode [7, 8].

Conclusion

The effective electrode combinations for the removal efficiency of turbidity from waste fountain solution in the EC treatment are in the following order: Al(−)/Al(+) > Al(−)/Fe(+) > Fe(−)/Al(+) > Fe(−)/Fe(+). The application of the EC process on the waste fountain solution showed satisfactory removal efficiencies (64.7%) of turbidity with Al(−)/Al(+) electrode combination at a current density of 8 mA cm^{-2} and inter-electrode distance of 1.0 cm, after 60 minutes. In the future, a combination of the EC process with other purification techniques, such as adsorption, could achieve a removal efficiency of turbidity higher than the results obtained in this study.

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