Optimizing the removal of Heavy Metals of an artificial wastewater by electrocoagulation using response surface methodology

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ABSTRACT

The Response Surface Methodology (RSM) was employed to investigate the effects of pH and current density on the removal of cadmium, copper and zinc in an artificial wastewater with a large COD by electrocoagulation technique. Six iron electrodes were used in a 2 l reactor with agitation. A regulated AC/DC power supply was used maintained a constant voltage/current. The wastewater was prepared in the laboratory in order to ensure the reproducibility of the measurements. The initial and final concentrations were measured by atomic absorption spectrometer. Removal of more than 99% was obtained during the process for 60 minutes of application time. The conditions for optimal removal were at pH of 8 and a intensity of 3A for cadmium, pH of 7.02 and Intensity of 3 A for copper and zinc.

Keywords: electrocoagulation, wastewater, heavy metal removal

1 INTRODUCTION

The treatment of wastewater generated by industry is a important enviromental problem due to the diversity of contaminants. Water with high COD and BOD demand usually has a strong odor and color. The BOD is the main source of nutrients for microorganisms, some of those pathogens. The heavy metals like chromium, used in metallurgical, refractory, tannery an chemical industry is extremely dangerous. Can cause liver necrosis, nephritis or even death in man. Nikel, cooper zinc can cause also a large variety of deceaseses, even death.[1-4]

Electrocoagulation (EC) used as an electrochemical wastewater treatment is an effective an simply form of use am electrochemical cell. EC involves the generation of metallic hydroxides by the electrolysis of soluble anodes to create floc. [1]

Treatment of wastewater by Ec was practiced for most of the past century with limited success and popularity. However in the last few years, its usage has been increased as the technology has been improved to minimize electrical power consumption and maximize effluent throughput rates. It has proven to be competitive and effective in the treatment of water and wastewater to remove metals, anions, dyes, organic mater, suspended solids, colloids and even arsenic.

The surface response methodology (RSM) can be used fot the optimizing of the process variables of EC. Previous investigations had optimized the removal of chromium[1,3], fluorode, organic matter, even biodiesel wastewater[5].

In the present study RSM was used employing a trial version of Design Expert v 7.0.0 for the removal of heavy metals from an artificial wastewater with high COD and heavy metal concentrations. Iron electrodes were used. Optimal conditions for each of the heavy metals were finded.

2 EXPERIMENTAL

2.1 Initial Setup

A 2 L electrocoagulation cell and six iron electrodes with an area of 120 cm² each one was used. The distance between electrodes was 5 mm. The current was applied with a Pasco DC regulated power supply (0 – 32 V, 0 – 10 A). The volume of artificial wastewater was 1600 mL.

Artificial wastewater was prepared 250 ppm of cadmium, 250 ppm of cadmium, 250 ppm of copper, 250 ppm of zinc. 10,000 ppm of COD was added with Potassium hydrogen phthalate, for increase the color and oil and grease 25 ppm of Congo Red and 200 ppm of oil were added. The conductivity was adjusted to 100 µs/cm by the addition of potassium chloride. pH was adjusted by adding sodium hydroxide or hydrochloric acid 1M.

2.2 Analytical Methods

pH was measured by a Schott Lab 860 pH-meter. Schott Conductivity Meter Lab 960 was used for conductivity measurements.

Samples were filtred by syringe filters of 0.45 µm. The amount of heavy metals was analyzed by a Perkin Elmer Analyst 300 atomic absorption spectroscopy.

Heavy metal removal were evaluated by equation 1

\[ Re(\%) = \frac{x_0 - x_f}{x_0} \times 100 \]  (1)

Where Re is the fraction of heavy metal removed, \( x_0 \) and \( x_f \) are the initial and final concentration of heavy metal in the solution.
2.3 Experimental Design

A central composite SRM experimental design was used. The factors evaluated were pH and Current intensity (I).

<table>
<thead>
<tr>
<th>Name</th>
<th>Mean</th>
<th>Low Actual</th>
<th>High Actual</th>
<th>Low Coded</th>
<th>High Coded</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.00</td>
<td>8.00</td>
<td>-1.00</td>
<td>1.00</td>
<td>7.00</td>
<td></td>
</tr>
<tr>
<td>I (A)</td>
<td>1.00</td>
<td>3.00</td>
<td>-1.00</td>
<td>1.00</td>
<td>2.00</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Experimental design conditions.

The time for all the experiments were 30 min. Experimental data were fitted to a second order polynomial model. Regression coefficients were obtained.

3 RESULTS AND ANALYSIS

The fit of the second order model was obtained. The analysis of variance (ANOVA) of regression parameters of the predicted response surface for the removal of Cd, Cu and Zn. The ANOVA results shows that the model is significant for the removal of the heavy metals (tables 2-4). The surface response plots are shown in the figures 1-3.

Source | Sum of Squares | df | Mean Square | F value | Pr>F |
-------|----------------|----|-------------|---------|------|
Model  | 4064.48        | 5  | 812.90      | 23.49   | 0.0003 |
Residual | 242.22        | 7  | 34.60       |         |       |
Lack of Fit | 208.87       | 3  | 69.62       | 8.35    | 0.0339 |
Pure Error | 33.35        | 4  | 8.34        |         |       |

R-Squared 0.9438
Table 2: ANOVA for cadmium removal.

Source | Sum of Squares | df | Mean Square | F value | Pr>F |
-------|----------------|----|-------------|---------|------|
Model  | 1561.32        | 5  | 312.26      | 18.19   | 0.0007 |
Residual | 120.14        | 7  | 17.16       |         |       |
Lack of Fit | 120.10       | 3  | 40.03       | 4811.83 | < 0.0001 |
Pure Error | 0.033        | 4  | 8.32E-003   |         |       |

R-SQUARED 0.8978
Table 3: ANOVA for zinc removal.

Source | Sum of Squares | df | Mean Square | F value | Pr>F |
-------|----------------|----|-------------|---------|------|
Model  | 909.40         | 5  | 181.88      | 12.30   | 0.0023 |
Residual | 103.49        | 7  | 14.78       |         |       |
Lack of Fit | 103.30       | 3  | 34.43       | 741.81  | 0.0001 |
Pure Error | 0.19         | 4  | 0.046       |         |       |

R-SQUARED 0.8978
Table 4: ANOVA for copper removal.
The quadratic model give different values for the optimum removal of the heavy metals studied. pH: 8.00, I: 3.00 A for cadmium, pH: 6.39 and I: 2.78 A for zinc and pH: 7.37, I: 2.20 A for copper.

4 CONCLUSIONS

In the present study, the electrochemical treatment for heavy metals removal in presence of high COD was evaluated. Removals of more than 90% were found for a process time of one hour. A higher density current not necessary represents a larger removal of the heavy metals studied. The RSM has proved the importance of an experimental design in order to optimize the power consumption for this process.

REFERENCES