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

Electrocoagulation (EC) used as an electrochemical wastewater treatment is an efective an simply form of use am electrochemical cell. EC involves the generation of metallic hydroxides by the electrodisolution 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 veen improved to minimize electrical power consumption and maximize effluent throughput rates. It has proven to be competitive and effective in the treatment of wate 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. Previuos investigations had optimized the removal of chromioum[1,3], fluoryde, 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 artifical watewater 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 cm^2 each one was used. The distance between electrodes was 5 mm. The current was aplyed with a Pasco DC regultated power suply (0 – 32 V, 0 – 10 A). The volume of artificial wastewater was 1600 mL.

Artificial wastewater was prepeared 250 ppm of cadmium, 250 ppm of cadmium, 250 ppm of coper, 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 adition of potasium chloride. pH was adjusted by adding sodium hydroxide or hdrochloric 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 ammount of heavy metals was analyzed by a Perkin Elmer Analyst 300 atomic absorption spectroscopy.

Heavy metal removal were evaluated by equation 1

$$Re(\%) = \frac{x_0 - x_f}{x_0} * 100 \quad (1)$$

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)

Name Mean	Low Actual	High Actual	Low Coded	High Coded	Mean
pH	6.00	8.00	-1.00	1.00	7.00
I (A)	1.00	3.00	-1.00	1.00	2.00

Table 1: Experimental design conditions.

The time for all the experiments were 30 min. Experimental data were fitted to a second order polynomial model. Regresion coeficients 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 dor 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.

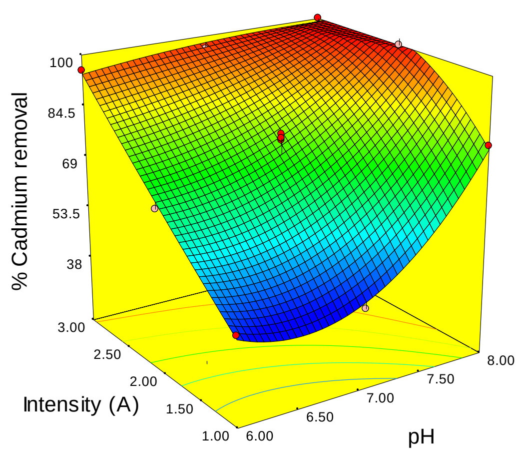

Figure 1: Response surface for cadmium removal.

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	*8.320E-003*		

R-Squared 0.9286

Table 3: ANOVA for zinc removal.

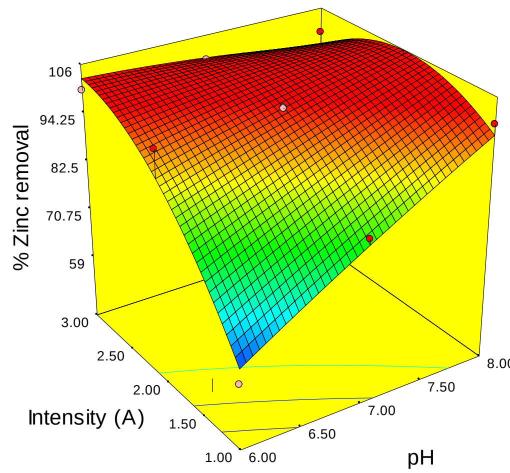

Figure 2: Response surface for zinc removal.

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.

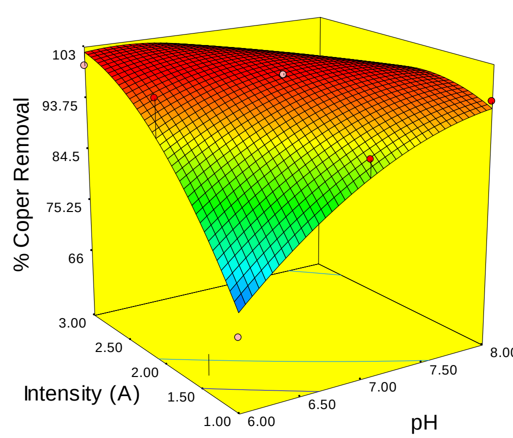

Figure 3: Response surface for copper removal.

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 precense of high COD was evaluated. Removlas of more than 90% where finded for a process time of one hour. A higer 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.

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