Removal of Arsenic from Pregnant Leaching Solution Using Electrochemical Coagulation Method

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1 .Introduction

Arsenic is a metalloid element in group A of the periodic table and is widely used as semiconductor materials, alloys, pharmaceuticals, preservatives and so on. Exposure to arsenic can adversely affect the skin, liver, bladder, cardiovascular system, gastrointestinal tract, respiratory tract and nervous system. Mineral resources and smelting industry in Kerman province have historically been the two leading industries in the wastewater production process containing various arsenic sources. Recently, the electrocoagulation process is used as a suitable method to remove arsenic from water. Due to its effectiveness in rapid removal of arsenic from effluents, electrocoagulation has attracted more attention. In this study, Box-Behnken's BBD response surface design was used to optimize and evaluate the effect of key electrocoagulation process variables such as pH, electrolysis time and current density on the efficiency of arsenic removal process.

2. Material and Method

The samples used in this research which were obtained from the simulation of leaching process, kept at 4°C and used without any dilution. The values of some quality parameters of PLS solution are given in Table 1.

Table (1) Characteristics of PLS sample prepared from processing plant

Parameter	Value
As (g/l)	4
pH	4.5

Samples collected from the electrocoagulation reactor are discharged. The electrocoagulation process produces two products, which include produced sludge and purified water. The electrocoagulation process was performed in a glass reactor with a capacity of 6 liters (dimensions 30 × 20 × 10 cm) and an effective volume of 5 liters. 6 aluminum electrodes with dimensions of 20 × 2 cm were used as anodes and cathodes. The effective surface area of the electrode was 90 cm^2 and the distance between the cathode and the anode was 2 cm. During each test, the electrodes were connected to the positive or negative output of the power supply. On the other hand, the arsenic removal efficiency is calculated using the following equation:

$$\%\mathbf{Y} = \frac{C_0 - C_i}{C_i} \times 100 \qquad (1)$$

Surface response is a statistical tool that is generally implemented to optimize the major effects of variables that affect some responses according to the current state of the process, and the Box-Behnken test design in the surface response method. It is an important design tool used to optimize processes. Box-Behnken provides comprehensive results and accurate information even for a small number of experiments and the interactive effects of the operational parameters on all responses. In this research, Box-Behnken test design in response surface method with three numerical factors at three levels was examined to investigate the interactive effect of process variables such as pH (X_1), electrolysis time (X_2), current density (X_3) and to evaluate the efficiency of arsenic removal (Y) of the leaching tank solution.

Table. 2 Range of independent variables and their levels

Variable (unit)	Numerical variable		
	Level		
	-1	0	1
X_2, pH	5	7	9
X_1, Electrolysis time (min)	30	75	120
X_3, Current density (A/m^2)	10	40	70

3. Results and discussion

According to the created experimental plan, 17 experiments were performed. F-value of 18.75 (Table 3) was obtained for the arsenic removal efficiency, which resulted in an acceptable change in the mean values. Obviously, the prediction of the regression model was obtained at 95% confidence interval, and also in examining the normal distribution of data, the residual values indicated how the model confirms the ANOVA hypotheses. The analysis showed that the application of these linear polynomial equations can be desirable for the evaluation the percentage of arsenic removal by electrocoagulation method.

Most electrochemical processes are influenced by pH, electrolysis time, and current density, which are the most important parameters for regulating the reaction rate. The pH of the experiments changed in the range of 5 to 7. It is assumed that the pH range for optimal electrocoagulation performance (using iron anode) is 5-7 and the operating

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conditions are suitable for complete oxidation at pH 7, where these ions are highly soluble with low adsorption ratio. Experiments were evaluated with electrolysis time ranging from 30 to 120 min at pH: 7, and at current density: 40 A/m^2. The results obtained showed that the optimal time for arsenic removal is 120 minutes. The results also show that the percentage of arsenic removal increased with increasing electrolysis time. The results showed that with increasing current density, the percentage of arsenic removal increased. This increased the number of clots by dissolving the anode, which is highly dependent on the contaminant and provides favorable conditions for arsenic uptake. In addition, the production of more hydrogen gas by high flow helps to increase the flotation of coagulated materials.

One of the main objectives of this study is to obtain the optimal conditions for maximum removal of arsenic from the PLS solution of the copper processing plant using electrocoagulation method. According to Table 3, in order to optimize the test conditions, the arsenic removal efficiency was 97.16% and these values were confirmed by creating favorable conditions by performing additional tests. Mean values of 96.88% of the experiments were obtained, which was in close agreement with the predicted values.

Table. 3 Comparison of confirmed and predicted values of arsenic removal efficiency by electrocoagulation process under maximum optimal conditions.

Response	optimum condition			Experimental	Predicted
	X_1	X_2	X_3		
% As removal	6.50	114	65.3	96.88	97.16

Notes: Where X_1 = pH, X_2 = electrolysis time (min), X_3 = current density (A/m^2)

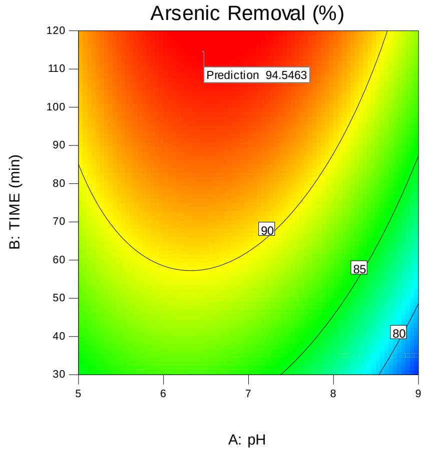

Fig. 1 Two-dimensional diagram of the optimal conditions for obtaining maximum arsenic removal (current density: 47/86 A/m^2).

4. Conclusion

In this research, Box-Behnken test design was used to investigate and optimize process variables such as initial pH, current density, electrolysis time, and electrode type for the removal process of arsenic ions from PLS solution using electrocoagulation method in a mineral processing plant. The results showed that the arsenic removal efficiency decreased continuously with increasing pH and as the electrolysis time increased, an increase in the arsenic removal performance was observed and on the other hand, the amount of metal ions in solution increased with increasing current density. As the current density increases from 10 to 70 A/m^2, the percentage of arsenic removal efficiency increased.

Based on the results, in order to optimize the test conditions, the amount of arsenic removal was 96.88% and in order to evaluate the optimal conditions, three experiments were performed under optimal conditions and the average values obtained from real tests showed the validity of optimal conditions.