Arsenic Removal using Electrocoagulation Process

Vaıyakone P.[1], Soriano R.[1,*], Morales-Corpuz, M.V.A.[1], De Sales L.[1]

1 Environmental Engineering Program, National Graduate School of Engineering, University of the Philippines, 1101 Diliman, Quezon City, Philippines

*corresponding author: e-mail: roger_soriano@yahoo.com

Abstract

Contamination of water resources with Arsenic poses serious health concerns because of its toxic and carcinogenic nature. Detection of Arsenic at concentrations higher than 10 parts per billion (ppb) in some Philippine water resources confirmed the need for further studies on the contamination and for the investigation of potential treatment technologies.

This study examined the removal of Arsenic from synthetic contaminated water, with initial concentrations of 100 ppb and 300 ppb, using electrocoagulation process. The electrocoagulation batch reactor utilised combined iron and aluminum electrodes, in parallel configuration. Employing a Box-Behnken experiment design for response surface modeling (RSM), three factors were investigated with each factor varied at three levels – pH of the wastewater solution current density and reaction time.

Results showed that at optimum parameters of pH 7, 25 A/m^2 current density and 40 minutes reaction time, the electro coagulation reactor is able to reduce the 100 ppb Arsenic in water by 99.20%. At optimum parameters of pH 7, 20 A/m^2 current density, and 40 minutes reaction time, the reactor is cable to reduce 300 ppb Arsenic in water by 98.23%.

Keywords: arsenic removal, electrocoagulation

1. Introduction

The impact to health of Arsenic, being a naturally occurring compound, is mainly through ingestion of groundwater having high concentrations of this compound. In areas where arsenic forms part of the geological feature of a site, arsenic poisoning were documented. The Philippines also have documented cases of arsenic poisoning particularly in Pampanga, which necessitated government intervention (DDR Team Philippines, 2015).

A potential treatment technology to remove arsenic from groundwater is electrocoagulation. In this method, the metal ions produced from the dissolution of electrodes serve as coagulants in this process (Cenkin&Belevstev, 1985). Metal hydroxides also form to remove flocculated materials from the water.

This study aims to investigate the removal of arsenic from synthetic wastewater using electrocoagulation process. It aims to determine the effects of pH, current density, and reaction time to arsenic removal and to optimize these process conditions used in the treatment.

2. Materials and Methods

2.1. Experimental Set Up

The experiment was conducted using reactor, of dimensions 21 cm*21cm*25 cm. The reactor has iron plates as anode and aluminum plates as cathode. Electrodes were placed at 2 cm distance from each other and dipped in the solution at a depth of 19cm. The electrodes were connected to a digital DC power supply (Alexan DC power supply, 10-30V. 5A) with constant current and constant-voltage option.

Synthetic wastewater with arsenic, at initial concentrations 100 ppb and 300 ppb, were used in the study. Effluent concentrations of arsenic were measured using the inductively coupled plasma atomic emission spectroscopy (ICP-AES).

Three factors were investigated with each factor varied at three levels – pH of the wastewater, current density and reaction time.

Table 1. Parameter variation used in Box-Behnken design.

Factors	Unit	Level		
		Low level (-1)	Middle level (0)	High level (+1)
pH		4	7	10
Current density	A/m^2	10	20	30
Reaction Time	Min	20	40	60

2.2 Statistical Analysis

The analysis of variance (ANOVA) was done, with confidence limit at $\alpha = 0.05$. Optimum values of the selected variables have been obtained by solving the quadratic regression model. Response surface plots were also generated.

Surface equation for a 3-variable design of experiment is given by:

$$As_{removal} = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 C + \beta_{12} AB + \beta_{13} AC + \beta_{23} BC + \beta_1 A^2 + \beta_2 B^2 + \beta_3 C^2$$

(Equation 1)

where $As_{removal}$ is the percentage of arsenic removal, β_0 is the polynomial , $\beta_1, \beta_2, \beta_3$ are linear regression coefficient, $\beta_{12}, \beta_{13}, \beta_{23}$ are quadratic interaction regression coefficients, and A,B,C are the coded-values for factors 1,2 and 3 respectively.

3. Results and Discussion

As shown in the graphs in **Figure 1**, the arsenic removal generally increases as pH increases until it reached the pH of 7. Arsenic removal also generally increases with current density and reaches peak of 20-25 A/m^2. As the current density increases, the generation of ions from the electrodes also increases, leading to more flocs generated and eventually removal of arsenic from water. As the reaction time increases,the removal also increases, where the peak removal is observed at 40 minutes.

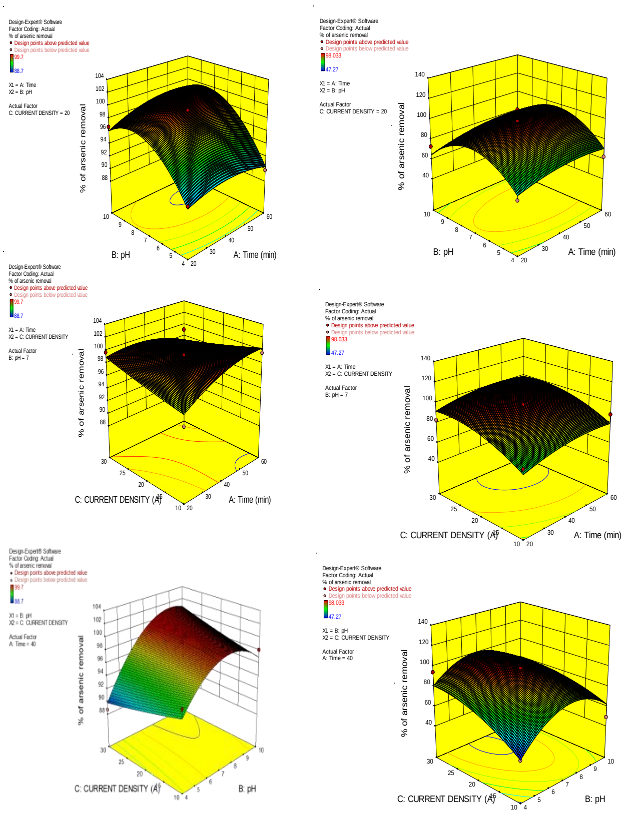

Figure 1. Response surfaces of pH, current density, and time to arsenic removal for 100 ppb As wastewater (left column) and 300 ppb As wastewater (right column).

Optimization of process conditions showed that For the 100 ppb arsenic wastewater, the optimum condition for electrocoagulation was determined at pH 7.0, current density of 25 A/m^2, and reaction time of 40 min, where predicted removal was 99.20% of the arsenic. On the other hand, for the 300 ppb arsenic wastewater, the optimum condition for electrocoagulation was determined at pH 7.0, current density of 20 A/m^2, and reaction time of 40 min, where predicted removal was 98.23%.

Using the Box Benhken design, the following quadratic equation was generated to predict the optimum conditions:

$$As_{removal} = 98.03 + 4.74\text{A} + 1.50\text{B} + 10.86C + 1.05\,AB - 1.17AC - 5.79BC - 5.26\text{A}^2 - 23.95\text{B}^2 - 8.18C^2$$

where C and B^2 were found to be significant model terms.

4. Conclusions and Recommendations

This study used a synthetic arsenic-contaminated wastewater – 100 ppb and 300 ppb concentrations – for the electrocoagulation experiment. By manipulating the various process variables e.g.pH, current density, and reaction time, and with the aid of Box-Behnken design the electrocoagulation process was able to demonstrate significant removals of arsenic.In future works, it is also important to consider the other parameters – such as electrode distance and types of electrodes – that can affect the rate of electrocoagulation process.

References

Farrell, W.J., Peggy, O.D., Colklin, M.(2001). Electrochemical and spectroscopic study of arsenate removal from water using zero-valent ion media. Environ. Sci. Technol. 35,10, 2026-2032

Gomes, J.A.G.(2007). Arsenic removal by electrocoagulation using combined Al-Fe electrode system and characterization of products. Journal of Hazardous Materials. Vol 139, Issue 2, 220-231

Sonia Aredes, Bern Klein, Marek Pawlik.(2013). The removal of arsenic from water using natural iron oxide minerals. Journal of Cleaner Production. Vol 29-30, 208-213

P. Ratna Kumar, Sanjeev Chaudhari, Kartic C. Khilar, S.P. Mahajan. (2004). Removal of arsenic from water by electrocoagulation. Chemosphere, Vol 55, Issue 9, 1245-1252

Dutch Risk Reduction Team Mission Report (DRR Team Philippines) (2015): Reducing the risk of water related disaster.

Chek, L; Eripret, C.; Park, S. H; Tabatabai, S.A.A; Vronska, O.; Tambruric,B; Kim,J.H; Shon, H. K (2017). Coagulation performance and flocculation characteristics of polytitanium tetrachloride (PTC) compared with titanium tetrachloride (TiCl4) and ferric chloride(FeCl3) in algal turbid water. Separation and Purification Technology.Vol 175, 99-106

V.E. Cenkin, A.N. Belevstev. (1985). Electrochemical treatment of industrial Waste water, Eff. Water Treat. J. 25(7):243