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REMOVAL OF ARSENIC FROM NATURAL WATER BY CO-PRECIPITATION USING FERRIC CHLORIDE AND ALUMINUM SULFATE; COMPARISON OF CO-PRECIPITANT EFFICIENCY USING EXPERIMENTAL DESIGN

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Introduction

Co-precipitation is a potential technique for the removal of As(III) and As(V) and suitable for arsenic contamination at high level. Ferric chloride and aluminum sulfate are effective co-precipitants. An experimental design with response surface methodology (RSM) is an alternative technique to evaluate an optimized condition using a less number of experiments and to investigate the interactive effects of factors. The objective of this work is to use a full factorial design to evaluate the optimized conditions for As(III) and As(V) removal using ferric chloride and aluminum sulfate. Moreover, theses optimized conditions were used to remove arsenic from contaminated natural water.

Co-precipitation process

The co-precipitants were added to each 10 mL of solution containing 90 mg L^{-1} of arsenic. After adding the co-precipitant, the pH of solution was adjusted using HCl and/or NaOH, followed by a rapid mixing for few minutes, a slow mixing for 30 minutes and a settling for 30 minutes, respectively. After co-precipitation process, the solution was centrifuged at 3200 rpm for 10 minutes, and the supernatant was taken and subject to residual arsenic determination using ICP-OES.

Results and discussion

1. Full Factorial Design

Table 1 Levels of each factor for As(III) using $FeCl_3$

factor	level		
	-1	0	1
pH	5	7.5	10
Fe ion conc. (mg L^{-1})	75	150	225

Table 2 Levels of each factor for As(V) using $FeCl_3$

factor	level		
	-1	0	1
pH	4	6.5	9
Fe ion conc. (mg L^{-1})	75	150	225

Table 3 Levels of each factor for As(III) using Aluminum sulfate

factor	level		
	-1	0	1
pH	5	7.5	10
Al ion conc. (mg L^{-1})	45	90	135

Table 4 Levels of each factor for As(V) using Aluminum sulfate

factor	level		
	-1	0	1
pH	4	6.5	9
Al ion conc. (mg L^{-1})	45	90	135

Calculated quadratic regression models are shown in these equations

$$\%As(III)\ removal = 80.54+2.73X_1+18.79X_2-7.25X_1^2-6.91X_2^2+0.39X_1X_2 \quad (As(III)\text{-}Fe)$$

$$\%As(V)\ removal = 97.75-13.10X_1+17.23X_2-9.84X_1^2-14.28X_2^2+5.51X_1X_2 \quad (As(V)\text{-}Fe)$$

$$\%As(III)\ removal = 13.38+3.01X_1+1.77X_2-5.89X_1^2-0.42X_2^2+1.42X_1X_2 \quad (As(III)\text{-}Al)$$

$$\%As(V)\ removal = 95.30-10.26X_1+16.13X_2-20.36X_1^2-9.43X_2^2+5.35X_1X_2 \quad (As(V)\text{-}Al)$$

Table 5 Observed and predicted value for % arsenic removal using ferric chloride and aluminum sulfate

run	coded		Ferric chloride				Aluminum sulfate			
	X_1	X_2	%As(III) removal		%As(V) removal		%As(III) removal		%As(V) removal	
			Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted
1	-1	-1	45.7±0.07	45.2	74.8±0.8	75.0	4.0±0.5	3.7	64.1±0.6	65.0
2	0	-1	54.8±0.6	54.8	68.1±0.6	66.2	10.0±0.2	11.2	69.8±0.4	69.7
3	1	-1	49.9±1.2	49.9	36.1±11.4	37.8	7.7±0.8	6.9	34.6±1.8	33.8
4	-1	0	69.6±0.3	70.6	99.8±0.05	101.0	4.9±1.3	4.5	85.7±0.9	85.2
5	0	0	81.4±0.6	80.5	97.3±0.04	97.8	13.6±0.2	13.4	97.8±0.04	95.3
6	1	0	76.1±0.7	76.0	76.5±0.00	74.8	9.9±0.6	10.5	61.7±0.6	64.7
7	-1	1	82.6±0.7	82.0	99.9±0.02	98.5	3.7±0.4	4.4	86.9±0.8	86.6
8	0	1	91.9±0.04	92.4	99.3±0.05	100.7	15.6±0.3	14.7	99.5±0.07	102.0
9	1	1	88.3±0.5	88.3	83.3±0.6	83.3	13.1±0.3	13.3	78.9±1.4	76.7

2. Contour plots

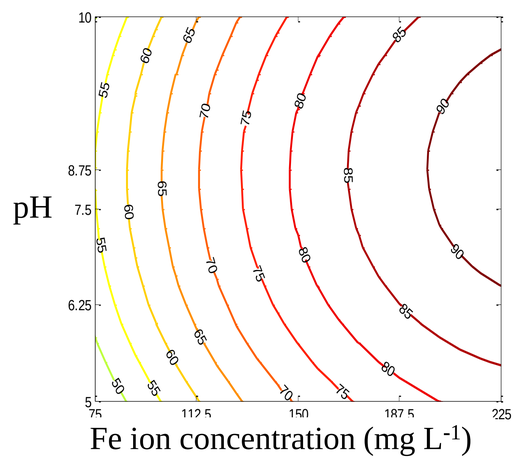

Fig. 1. Contour plot of As(III) removal efficiency using ferric chloride

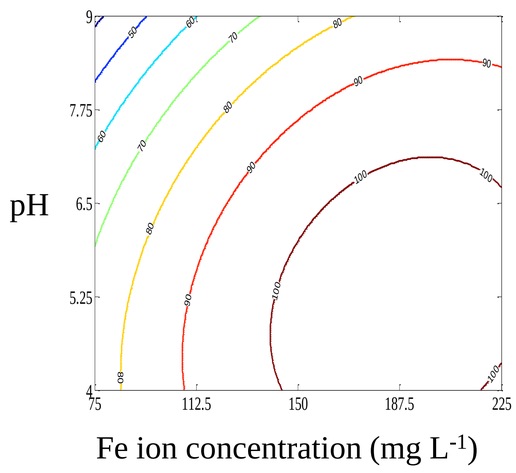

Fig. 2. Contour plot of As(V) removal efficiency using ferric chloride.

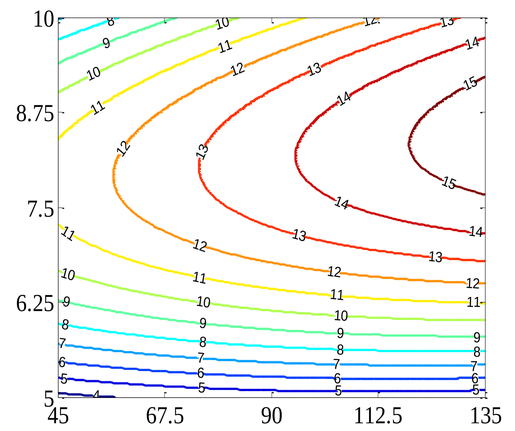

Fig. 3. Contour plot of As(III) removal efficiency using aluminum sulfate.

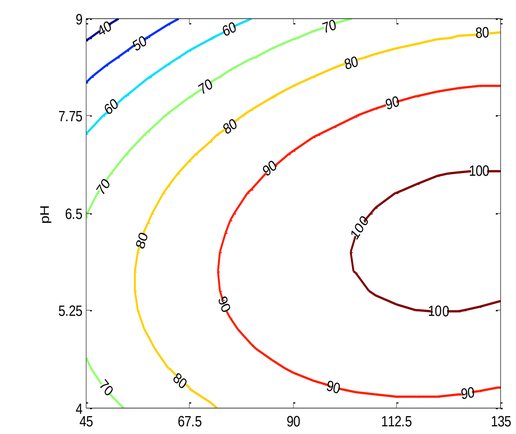

Fig. 4. Contour plot of As(V) removal efficiency using aluminum sulfate.

3. Application in arsenic removal from natural water

The optimized conditions for using ferric chloride is at pH 7 and concentration of ferric ion equal to 225 mg L^{-1} for As(III) and As(V). In case of using aluminum sulfate as co-precipitant, the same pH and concentration of Al^{3+} ion at 135 mg L^{-1} are the optimized condition. These conditions were used to remove arsenic in natural water (as shown in Table 6).

Table 6 Removal efficiency of arsenic from water samples

	Ferric chloride		Aluminum sulfate	
	As(III)	As(V)	As(III)	As(V)
%arsenic removal	96.1 ±0.8	99.1±0.1	17.1±0.31	96.1±1.4

Conclusion

As(III) and As(V) removal by co-precipitation using ferric chloride and aluminum sulfate were investigated using a full factorial design. The optimized conditions for arsenic removal were determined from RSM plot. High removal efficiencies of As(III) and As(V) at a level of 90 mg L^{-1} were 90% and 99%, respectively using the optimized conditions at pH 7 and 225 mg L^{-1} of ferric ion concentration. While using aluminum sulfate, only As(V) can be effectively removed close to 100% using pH 7 and Al^{3+} ion concentration of 135 mg L^{-1}.

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