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RESEARCH ARTICLE

THE CHARACTERIZATION AND MODELING OF COBALT IONS ADSORPTION ON PUMICE

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ABSTRACT

Metal contamination is one of the most serious global problems. This investigation deals with the use of Aksaray pumice for the adsorption of cobalt ions. The factors affecting the adsorption on Aksaray pumice were examined. Pumice activated at 873 K for two hours before contact with cobalt ions. UV-Vis spectrophotometer was used to measure cobalt ions concentrations. The response surface methodology was utilized to evolve the predictive model for adsorption of cobalt ions on Aksaray pumice. The experimental and predicted maximum removal efficiency of 40 % and 37 % was obtained, respectively. The results showed that Aksaray pumice can be used as adsorbent for cobalt ions.

Keywords: Response surface methodology, Adsorption, Cobalt ions, Aksaray pumice

1. INTRODUCTION

Heavy metals such as cobalt ions are highly toxic even in relatively small amount and do not undergo biodegradation [1]. Cobalt is widely used in numerous industries and high human exposure to cobalt can induce symptoms such as nervous system disorders [2]. Heavy metals are harmful if the levels of these metals are higher than the recommended limits. Drinking water maximum admissible limit is 100 (µg/L) (U.S. Environmental Protection Agency 2008) for cobalt. People can be exposed to cobalt ions through direct and indirect sources. Water is one of the important sources for cobalt for humans [3].

Pumice is one of the cheapest adsorbents to remove metal ions from wastewater [4]. Pumice is a natural low-cost adsorbent. The majority of inner micropores, are not connected in pumice. Pumice has irregular cavities and 60 to 75 percentage of silica [4-6].

Adsorption is most common method for removing heavy metal ions from wastewater because of its easiness and high efficiency in the removal of metal ions [7]. Conventional adsorption technique involves many experimental runs. The number of experiments can be reduced by applying the response surface methodology (RSM). RSM can prevent conventional method restrictions. [8-9].

Although, there are many studies related heavy metal adsorption, the cobalt ions adsorption on Aksaray pumice study with RSM contribute the adsorption research area. We aimed to investigate the performance of Aksaray pumice for the removal of cobalt ions in this study. We used RSM to predict the relationship between adsorbent factors (input variables) for Aksaray pumice.

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2. MATERIALS AND METHODS

2.1. Materials

The salt $CoCl_2x6H_2O$ solution were used for preparing of an aqueous solution. We obtain Cobalt (II) from Sigma-Aldrich. The pumice samples were provided by SDU, Pumice Lab., Isparta, Turkey.

2.2. Method

In order to remove water from micropores, pumice was treated with heat. The pumice samples were activated at 873 K for two hours prior to adding them into an aqueous solution. We mixed the samples after to adding them into an aqueous solution for 24 hrs with an orbital shaker. The shaking speed was 320 rpm.

Thereafter the mixtures were filled syringe and filtrated by filter.
We measured concentrations of cobalt ions in initial concentration and equilibrium concentration. The absorbance value was recorded from UV–Vis spectrophotometer (HACHDR/2000). The absorbance was read at a 620 nm wavelength. The maximum deviation was 5% in reproducibility of measurement. We determined removal efficiency Y% as:

$$Y = (1 - \frac{C_f}{C_0})x100\% \qquad (1)$$

Where C_0 was Co^{2+} concentration in feed solution (mg/L) and C_f was the final concentrations of Co^{2+} in solution (mg/L).

More details regarding experiment can be found in previous studies [10-11]**.**
We regulated the experimental analysis and modeling using RSM as a useful mathematical and statistical technique as described previously in detail [10-12]. The response (Y %) can be determined which is influenced by various input variables in RSM model.

RSM general form can be shown for adsorbent factors (input variables) as below [13-14]:

$$\hat{Y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 \qquad (2)$$

$$\beta = [\beta_0\ \beta_1\ \beta_2\ \beta_{11}\ \beta_{22}\ \beta_{12}]^T \qquad (3)$$

$$\beta = (X^T \cdot X)^{-1} \cdot X^T \cdot Y \qquad (4)$$

where: $\boldsymbol{\beta}$ – shown coefficients;
$\boldsymbol{X}$ – input coded values;
$\boldsymbol{Y}$–experimental response.

Adsorption of cobalt ions solutions onto Aksaray pumice;
- coded variables regression model:

$$\hat{Y} = 13.936 - 6.5x_2 + 6.227x_2^2 - 10.75x_1x_2 \qquad (5)$$

subjected to: $-1 \le x_i \le +1, \quad \forall i = 1,2$

We used Student's *t*-test for coefficients significance. The calculation details can be found in previous studies [10-12]**.** All calculations were done by means of MathCAD software.

3. RESULTS AND DISCUSSION

The accordance between experimental data and model was confirmed by applying Fischer's test. Degrees of freedom f1 = 7 and f2 = 1 and Fischer's test for a confidence level p = 0.05 was accomplished. Thus, the calculated value of the Ficsher's test was differentiated with the tabulated one (FT)(f1,f2). The mathematical model is adequate for the prediction non active cobalt removal by sorption since (FC =149.803) < (FT = 236.768) [14].

Table 1. Cobalt ions experimental design for Aksaray Pumice

Run number (N)	**Input values**				**Response**
	Dose of Sorbent		**Concentration of initial cobalt**		**Removal efficiency**
	SD (% *w/v*)	level [a] x_1	C_0 (*mg/L*)	level [a] x_2	*Y* (%)
1	0.5	1	100	1	7
2	0.25	-1	100	1	30
3	0.5	1	10	-1	30
4	0.25	-1	10	-1	10
5	0.5	1	55	0	14.5
6	0.25	-1	55	0	10.9
7	0.375	0	100	1	4
8	0.375	0	10	-1	40
9	0.375	0	55	0	16.4
10	0.375	0	55	0	30.9

[a] −1 = low value, 0 = center value, +1 = high value.

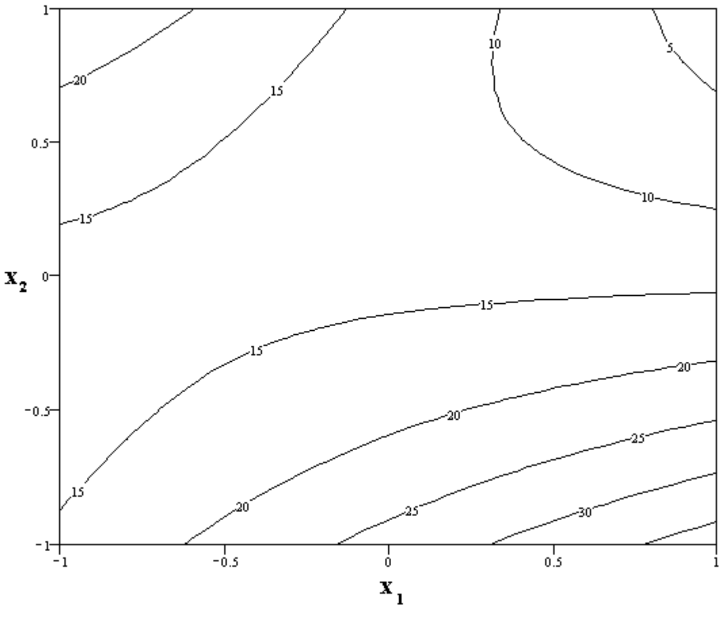

Figure 1. Response Surface Plot of Sorption Percentage response rely on dose of sorbent (x_1) and concentration of initial cobalt (x_2) for Aksaray pumice

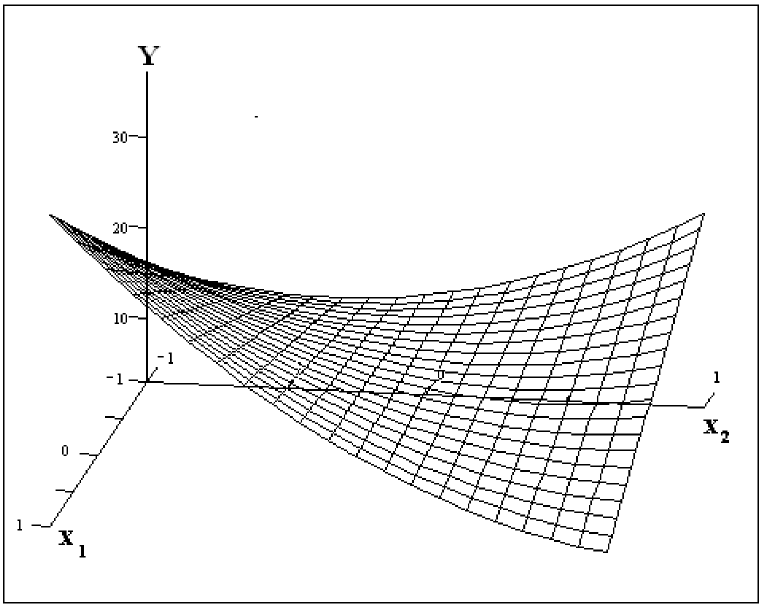

Figure 2. 3D-Response Surface Plot of Sorption Percentage (Y) response depending on dose of sorbent (x_1) and concentration of initial cobalt (x_2) for Aksaray Pumice

Figure 1 shows the sorption percentage dependence between the sorbent dosage and initial cobalt concentration. The contours diagram demonstrates that the raising of variables x_2 (Initial cobalt concentration) will decrease the sorption percentage. But the increasing of x_1 (sorbent dosage) will give higher values of the sorption percentage. Figure 2 shows response surface plot.

The maximum prediction value is 37 % for removal efficiency. The experimental minimum and maximum removal efficiency of 4 % and 40 % was obtained, respectively.

Determination of the optimum quantity of pumice affects the whole adsorption process. The main adsorption mechanism is that cations in the pumice structure can exchange with cations in the cobalt solutions. RSM was found an effective mathematical tool to determine the effect of the input variables and response [16-17].

4. CONCLUSION

The heavy metals existence in aqueous environments has harmful effects on human health, animals and plant growth. Many different materials are used as adsorbent in the adsorption process. Pumice is most abundant adsorbents for wastewater treatment. This study demonstrated that the adsorption of Co^{2+} by Aksaray pumice is altered by the sorbent dosage and initial cobalt concentration. In order to determine an empirical mathematical model that describes the dependence between the removal efficiency of cobalt ions and the process variables the design of experiment has been performed.

CONFLICT OF INTEREST

The author stated that there are no conflicts of interest regarding the publication of this article.

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