*Supplement*

**Design of a solar reactor for the removal of uranium from simulated nuclear wastewater with oil-apatite ELM system**

Ali Aghababai Beni \*

Department of Chemical Engineering, Shahrekord Branch, Islamic Azad University, Shahrekord, Iran.

\*Corresponding author: aliaghababai@yahoo.com; tel: +98-913-978-1836

**Details of solar reactor geometry**

**E:\desktop\SHAHID HEMMAT\ALI BENI\solar oil reactor HAP\z FIG\FIGURE\s1.tif**

**Fig. S1.** Details of solar reactor geometry

**Development of regression model equation**

According to experimental results and its predicted results in **Table S1**, based on the quadratic model, for modeling of response surface Eq. (1) was proposed by CCD in the RSM.

= +80.03 2.89 +3.60 +13.50 +4.40 +12.12 0.3344 0.3281 0.4844 +0.1038 +0.6606 +0.5631 +0.0200 +2.35 +2.64 1.47 1.85 5.61 8.61 4.74 6.87 (1)

Where is the uranium(VI) ions removal efficiency (%), , , , and are uranium(VI) concentration (), NHAP concentration (), pH and retention time (min), respectively. A positive sign against each term of the Eq. (1) indicates a synergistic effect and the negative sign indicates a synergistic effect on the response surface ().

The actual versus predicted responses in **Fig. S2 a** shown approximately a linear relationship with partial variation. The normal plot of residuals in **Fig. S2 b** is similar to a straight line indicating that the errors are evenly distributed and therefore support the least squares fit.

According to **Fig. S2 c-d**, the residuals versus the predicted response and the residuals versus the experimental run exhibit the residuals has been distributed above and below the x-axis with unusual structure and no obvious pattern. Also, the values for model equation was 0.926, the adjusted and predicted were 0.879 and 0.723, respectively with difference less than 0.2. The analysis of variance (ANOVA) helps to check the accuracy and validity of the proposed model. According to **Table S2**, based on ANOVA, this model was highly significant with F-value 18.88 and p-value 0.0001 also, all of the factors (, , , and ) were significant. So, the model is acceptable for the predicted results and the optimization of affecting factors on the uranium(VI) removal efficiency.

**Table S1.** Experimental design matrix and results.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Actual level of factors** | | | | | **Responses** | | |
| **Run** | () | () |  | () | () | **Actual** | **Predicted** | **Residual** |
| 1 | 260 | 10.13 | 7.5 | 35 | 32.5 | 78.15 | 80.03 | -1.88 |
| 2 | 140 | 15.06 | 9.75 | 47.5 | 46.25 | 52.23 | 55.72 | -3.49 |
| 3 | 380 | 5.19 | 9.75 | 47.5 | 46.25 | 47.81 | 42.78 | 5.03 |
| 4 | 140 | 15.06 | 9.75 | 47.5 | 18.75 | 33.45 | 39.87 | -6.42 |
| 5 | 380 | 15.06 | 9.75 | 47.5 | 18.75 | 29.65 | 32.90 | -3.25 |
| 6 | 140 | 5.19 | 9.75 | 47.5 | 46.25 | 51.25 | 48.01 | 3.24 |
| 7 | 260 | 10.13 | 7.5 | 35 | 60 | 80.52 | 76.81 | 3.71 |
| 8 | 380 | 5.19 | 9.75 | 22.5 | 46.25 | 44.07 | 43.72 | 0.3537 |
| 9 | 140 | 5.19 | 5.25 | 47.5 | 46.25 | 81.34 | 84.31 | -2.97 |
| 10 | 260 | 10.13 | 7.5 | 35 | 32.5 | 70.05 | 80.03 | -9.98 |
| 11 | 260 | 10.13 | 7.5 | 35 | 32.5 | 86.63 | 80.03 | 6.60 |
| 12 | 380 | 15.06 | 9.75 | 47.5 | 46.25 | 48.45 | 49.16 | -0.7088 |
| 13 | 260 | 20.00 | 7.5 | 35 | 32.5 | 87.52 | 64.78 | 22.74 |
| 14 | 260 | 0.25 | 7.5 | 35 | 32.5 | 35.16 | 50.38 | -15.22 |
| 15 | 500 | 10.13 | 7.5 | 35 | 32.5 | 65.32 | 66.84 | -1.52 |
| 16 | 380 | 15.06 | 5.25 | 47.5 | 46.25 | 80.36 | 86.79 | -6.43 |
| 17 | 260 | 10.13 | 12 | 35 | 32.5 | 14.25 | 18.59 | -4.34 |
| 18 | 140 | 5.19 | 5.25 | 47.5 | 18.75 | 57.45 | 57.98 | -0.5341 |
| 19 | 380 | 5.19 | 9.75 | 22.5 | 18.75 | 25.35 | 21.64 | 3.71 |
| 20 | 140 | 15.06 | 5.25 | 47.5 | 46.25 | 89.25 | 94.67 | -5.42 |
| 21 | 140 | 15.06 | 9.75 | 22.5 | 18.75 | 30.36 | 30.72 | -0.3583 |
| 22 | 140 | 5.19 | 5.25 | 22.5 | 46.25 | 75.14 | 73.92 | 1.22 |
| 23 | 380 | 5.19 | 5.25 | 47.5 | 18.75 | 52.87 | 51.03 | 1.84 |
| 24 | 260 | 10.13 | 7.5 | 35 | 32.5 | 75.25 | 80.03 | -4.78 |
| 25 | 260 | 10.13 | 7.5 | 35 | 32.5 | 80.85 | 80.03 | 0.8183 |
| 26 | 140 | 15.06 | 5.25 | 22.5 | 46.25 | 78.5 | 82.03 | -3.53 |
| 27 | 260 | 10.13 | 7.5 | 60 | 32.5 | 78.25 | 69.89 | 8.36 |
| 28 | 260 | 10.13 | 3 | 35 | 32.5 | 84.45 | 72.59 | 11.86 |
| 29 | 260 | 10.13 | 7.5 | 35 | 5 | 32.14 | 28.33 | 3.81 |
| 30 | 380 | 5.19 | 5.25 | 47.5 | 46.25 | 76.46 | 77.78 | -1.32 |
| 31 | 260 | 10.13 | 7.5 | 35 | 32.5 | 76.45 | 80.03 | -3.58 |
| 32 | 380 | 15.06 | 9.75 | 22.5 | 46.25 | 45.85 | 47.84 | -1.99 |
| 33 | 140 | 15.06 | 5.25 | 47.5 | 18.75 | 66.52 | 68.26 | -1.74 |
| 34 | 380 | 15.06 | 5.25 | 22.5 | 18.75 | 38.75 | 43.37 | -4.62 |
| 35 | 20 | 10.13 | 7.5 | 35 | 32.5 | 87.45 | 78.41 | 9.04 |
| 36 | 140 | 5.19 | 9.75 | 22.5 | 18.75 | 29.54 | 25.34 | 4.20 |
| 37 | 380 | 5.19 | 5.25 | 22.5 | 46.25 | 73.84 | 69.33 | 4.51 |
| 38 | 380 | 5.19 | 9.75 | 47.5 | 18.75 | 28.25 | 26.60 | 1.65 |
| 39 | 380 | 15.06 | 5.25 | 22.5 | 46.25 | 74.45 | 76.09 | -1.64 |
| 40 | 380 | 5.19 | 5.25 | 22.5 | 18.75 | 37.65 | 36.69 | 0.9624 |
| 41 | 140 | 5.19 | 5.25 | 22.5 | 18.75 | 41.35 | 41.70 | -0.3508 |
| 42 | 140 | 5.19 | 9.75 | 47.5 | 18.75 | 32.17 | 32.24 | -0.0698 |
| 43 | 380 | 15.06 | 9.75 | 22.5 | 18.75 | 26.74 | 25.68 | 1.06 |
| 44 | 380 | 15.06 | 5.25 | 47.5 | 18.75 | 56.32 | 59.97 | -3.65 |
| 45 | 260 | 10.13 | 7.5 | 35 | 32.5 | 80.57 | 80.03 | 0.5383 |
| 46 | 140 | 15.06 | 9.75 | 22.5 | 46.25 | 49.21 | 52.46 | -3.25 |
| 47 | 140 | 5.19 | 9.75 | 22.5 | 46.25 | 48.45 | 47.00 | 1.45 |
| 48 | 260 | 10.13 | 7.5 | 10 | 32.5 | 51.45 | 52.29 | -0.8362 |
| 49 | 140 | 15.06 | 5.25 | 22.5 | 18.75 | 42.14 | 49.72 | -7.58 |
| 50 | 260 | 10.13 | 7.5 | 35 | 32.5 | 84.78 | 80.03 | 4.75 |

**Table S2.** ANOVA for response surface quadratic model for uranium(VI) removal efficiency.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Sum of Squares** | **Degree of freedom** | **Mean Square** | **F-value** | **p-value** |  |
| Model | 21018.50 | 20 | 1050.93 | 18.27 | < 0.0001 | significant |
|  | 334.89 | 1 | 334.89 | 5.82 | 0.0224 | significant |
|  | 518.11 | 1 | 518.11 | 9.01 | 0.0055 | significant |
|  | 7288.92 | 1 | 7288.92 | 126.73 | < 0.0001 | significant |
|  | 774.75 | 1 | 774.75 | 13.47 | 0.0010 | significant |
|  | 5877.23 | 1 | 5877.23 | 102.19 | < 0.0001 | significant |
|  | 3.58 | 1 | 3.58 | 0.0622 | 0.8048 | not significant |
|  | 3.45 | 1 | 3.45 | 0.0599 | 0.8084 | not significant |
|  | 7.51 | 1 | 7.51 | 0.1305 | 0.7205 | not significant |
|  | 0.3444 | 1 | 0.3444 | 0.0060 | 0.9388 | not significant |
|  | 13.97 | 1 | 13.97 | 0.2428 | 0.6259 | not significant |
|  | 10.15 | 1 | 10.15 | 0.1764 | 0.6775 | not significant |
|  | 0.0128 | 1 | 0.0128 | 0.0002 | 0.9882 | not significant |
|  | 176.06 | 1 | 176.06 | 3.06 | 0.0908 | not significant |
|  | 223.03 | 1 | 223.03 | 3.88 | 0.0585 | not significant |
|  | 69.50 | 1 | 69.50 | 1.21 | 0.2807 | not significant |
|  | 109.77 | 1 | 109.77 | 1.91 | 0.1777 | not significant |
|  | 1008.32 | 1 | 1008.32 | 17.53 | 0.0002 | significant |
|  | 2372.71 | 1 | 2372.71 | 41.26 | < 0.0001 | significant |
|  | 717.71 | 1 | 717.71 | 12.48 | 0.0014 | significant |
|  | 1508.49 | 1 | 1508.49 | 26.23 | < 0.0001 | significant |
| Residual | 1667.88 | 29 | 57.51 |  |  |  |
| Lack of Fit | 1469.04 | 22 | 66.77 | 2.35 | 0.1241 | not significant |
| Pure Error | 198.84 | 7 | 28.41 |  |  |  |
| Cor Total | 22686.38 | 49 |  |  |  |  |

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**E:\desktop\SHAHID HEMMAT\ALI BENI\solar oil reactor HAP\mohasebat exl\FIGURE\2 (b).tif**

**E:\desktop\SHAHID HEMMAT\ALI BENI\solar oil reactor HAP\mohasebat exl\FIGURE\2 (c).tif**

**E:\desktop\SHAHID HEMMAT\ALI BENI\solar oil reactor HAP\mohasebat exl\FIGURE\2 (d).tif**

**Fig. S2.** Comparison of experimental and predicted response (%) (a), Diagnostics and model graphs for pulp yield: normal plot of residuals (b), residuals versus predicted (c), residuals versus run numbers (d).

Contact me if you have any questions.