# *Uranium sorption from aqueous solution by modified Padina sp. in a fixed-bed column*

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## Abstract

In this paper, the ability of *Padina* sp. to sorption of uranium from an aqueous solution was investigated in a fixed-bed column. The effects of important parameters, such as the flow rate, the influent concentration of uranium, and bed depth, were studied. The uptake of uranium ions was investigated by the modified brown algae biosorbent at different uranium input concentrations. The results showed that all three models Thomas, Adams-Buhart, and dose-response are suitable for predicting breakthrough curves in the uranium sorption.

**Keywords: Modeling; Biosorption; Fixed Bed Column; Uranium; *Padina* sp.; Removal**

## *Introduction*

Uranium is a natural element and is generally distributed in small quantities in many rocks, soils, and seawater. Highly toxic and radioactive uranium exists in nuclear wastes. Uranium 238 is one of the most important natural radionuclides with a concentration of about 3.2 µg/g in soil, except in areas rich in uranium ores. Uranium 238 is transported by their radioactive decay products through pathways to the soil, water, plants, and then to humans [1]. In this research, the effects of uranium concentration and flow rate of the input solution to the fixed-bed column containing the *Padina* sp. brown alga on the column performance were studied, and the breakthrough curves obtained were analyzed by the mathematical models.

## *Experimental*

### *Adsorbent preparation*

Biosorbent is a type of brown algae called *Padina* sp., which was prepared from the Sea of Oman and the Persian Gulf. First, the adsorbent was washed with deionized water and dried in sunlight. Then, it was crushed using a laboratory mortar and granulated with the standard 500-1000µm sieves [2]. To increase the adsorption capacity, the adsorbent was mixed with 0.1 M $CaCl_2$ solution and stirred for 6 hours in a rotary stirrer at a speed of 150 rpm at room temperature. Finally, the biomass was placed in an oven at 70 $^0$C for 12 hours to dry and granulated again with 500-1000µm sieves.

### *Chemical materials*

Solutions containing uranium ions, calcium ions were prepared in experiments, by deionized water and uranyl nitrate salt ($UO_2(NO_3)_2.6H_2O$) and calcium chloride ($CaCl_2.2H_2O$).

### *Laboratory system*

The laboratory system, continuous bed column with continuous flow used includes the following parts: three cylindrical glass pipes with an internal diameter of 1.5cm and heights of 8.5, 12, 15.5 cm, 2 holders, each of which includes a plastic mesh with a diameter of 1.5cm and a plastic cylinder with an outer diameter of 1.5cm, Peristaltic pump, column support base, inlet, and outlet hoses for liquid flow are used to flow the liquid on the adsorbent bed. The concentration of soluble uranium was measured by an Inductively Coupled Plasma-Atomic Emission Spectrometer(ICP-AES)

### *Test conditions*

All experiments were performed at room temperature, and pH 4.5. The uranium solution was passed through the column. The flow rates of the input uranium solution to columns 3.22, 5, and 6.78 mL/min injected into the column by a peristaltic pump and sampled from the outflow of the column at different times. These tests were carried out for uranium solutions at concentrations of 100, 250, and 400 mg/L.

### *Breakthrough curves and design parameters*

By examining the effluent concentrations against the time or volume of effluent from the column, the performance or efficiency of the fixed bed column was obtained. This is related to the breakthrough curve. The refractive index is a function of flow characteristics, adsorption equilibrium, and mass transfer coefficients [3].

## *Results and discussion*

### Effect of flow rate on breakthrough curve

To investigate the effect of the flow rate of the solution passing through the column on the adsorption rate of the column, experiments were performed at three flow rates of 3.22, 5, and 6.78 mL/min. According to Figure 1, it is clear that by increasing the intensity of the bed flow from 3.22 to 6.78 mL/min, the adsorption capacity of the column decreases.

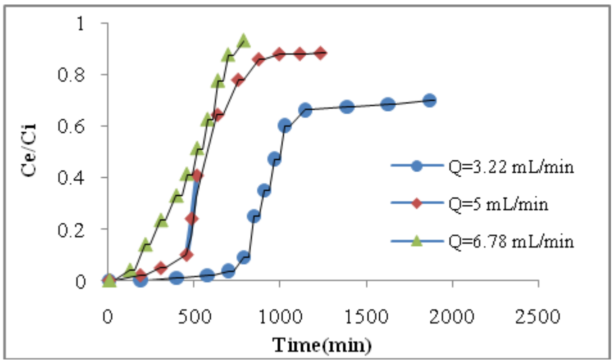


Figure 2. The Breakthrough curve of the effect of flow rate on uranium biosorption onto *Padina* sp. ($C_0$= 100 mg/L).

### Effect of influent uranium concentration on the breakthrough curve

To investigate the effect of column concentration on the adsorbent, the experiment was performed at three concentrations of 100, 250, and 400 mg/L. As the uranium concentration decreases, the time to reach the breaking curves and the full saturation curves increases.

### Effect of different bed depths on the breakthrough curve

This step investigates the effect of the height of the adsorbent bed used for the performance and adsorption of the column. An experiment was performed with an adsorbent at pH 4.5 in three values of 3.49, 4.57, and 5.96 g. As the height of the column increases, the adsorption capacity of the column also increases.

### Modeling of different bed depth column study results

According to the results obtained from the Thomas model, it was found that by increasing the concentration of the input solution to the column, the maximum capacity of $q_0$ obtained from the model increases, and the kinetic constant $K_{TH}$ decreases [4]. The results of the Thomas model are given in table 1.

**Table 2.**The Calculated constant of Thomas model at different conditions using non-linear regression analysis [4].

| $C_0$ (mg/L) | Q (mL/min) | Z (cm) | $K_{TH}$ (mL/min/mg) | $q_0$ (mg/g) | $R^2$ |
|---|---|---|---|---|---|
| 100 | 3.22 | 8.5 | 0.500 | 270.3614 | 0.963 |
| 250 | 5 | 12 | 0.014 | 335.877 | 0.938 |
| 400 | 6.78 | 15.5 | 0.006 | 408.919 | 0.890 |

Appropriate results were obtained from the dose-response model. The increase in $q_0$ obtained with this model, with increasing input concentration as well as its proximity to $q_0$ obtained from laboratory results, is similar to the Thomas model. In the theoretical results of the Adams-Buhart model, like the Thomas model, they had a good agreement with the experimental results in terms of constant adsorption process speed.

According to the graph and results obtained from all three models, they have a relatively good agreement with the laboratory results. Among the three models, the dose-response model is better suited to laboratory results.

### Conclusions

Uranium sorption from an aqueous solution was investigated by the *Padina* sp. brown alga, in a fixed bed column. Variables, such as influent concentration, flow rate, and column height, can affect the breakthrough curve. *Padina* sp. as an adsorbent to remove uranium from the solution was proved efficient. Also in this study, it was shown that the Thomas, Adams-Buhart, and dose-response models are in good agreement with laboratory results.

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