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ORIGINAL ARTICLE

Kinetics studies of uranium sorption by powdered corn cob in batch and fixed bed system

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ABSTRACT

Sorption of uranium (VI) from aqueous solution onto powdered corn cob has been carried out using batch and fixed-bed technique. The experimental results in batch technique were fitted well with pseudo second-order kinetics model. In the fixed bed technique, Thomas and Bohart–Adams models were evaluated by linear regression analysis for U(VI) uptake in different flow rates, bed heights and initial concentrations. The column experimental data were fitted well with Thomas mode (r^2 = 0.999), but the Bohart–Adams model (r^2 = 0.911), predicted poor performance of fixed-bed column.

Introduction

The growth of technology in nuclear industries has led to the emergence of many of environmental pollution problems, it is so important to develop number of methods for removing hazardous elements from industrial liquid wastes. Uranium is the important element in nuclear applications. Nuclear power is derived from uranium, which has no significant commercial use other than as a fuel for electricity generation. For this reason, the recovery, concentration and purification of uranium are of great importance. Because of the expected shortage of uranium in near future, researches are to be directed to the recovery of uranium from nonconventional resources such as sea water, industrial waste waters, mine waste water, and other waste sources in relation to the pollution of the natural environment [1,2]. The most commonly used methods for the removal of heavy metals from wastewater are chemical precipitation; membrane processes, ion exchange, solvent extraction, photocatalysis and adsorption [3]. Adsorption process has long been used in the removal of heavy metals and other hazardous materials such as, color, odor and organic pollution.

Although activated carbon is widely applied for pollutant removal, natural materials which are relatively cheaper and eco-friendly have also been successfully employed as adsorbents for heavy metal removal from aqueous solutions and

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Nomenclature

C_e	equilibrium concentration (mg/L)	q	adsorption capacity (mg of U(VI)/g adsorbent)
C_0	influent (initial) concentration (mg/L)	q_e	adsorption capacity at equilibrium, (mg of U(VI)/g adsorbent)
C_t	effluent concentration (mg/L)	q_t	adsorption capacity at time t (mg of U(VI)/g adsorbent)
F	linear flow rate (L/min)	r^2	correlation coefficient
k_1	pseudo first-order adsorption rate constant (L/min)	t	time (min)
k_2	pseudo second-order adsorption rate constant (g/mg min)	τ	the time required for 50% adsorbate breakthrough (min)
K_{Th}	Thomas rate constant (L min^{-1} mg^{-1})	V	volume of the solution (l)
K_{AB}	Adam–Bohart constant (L mg^{-1} min^{-1})	x	mass of adsorbent in the column (g)
M	mass of adsorbent (g)	Z	bed depth of column (cm)
N_0	saturation concentration (mg/L)		
Q	flow rate (mL/min)		

wastewaters due to their availability, low-cost, unique chemical composition and renewability. The reduced running cost has been the focal point for research on application of natural materials. Cost is a very important factor when considering material for use as adsorbents. The recent attention in this field is evident in the number of research currently being done on the use of low cost agricultural wastes for metal removal from aqueous solution. Among the numerous adsorbents, Agriculture material is one of the most widely used and economic adsorbent in the adsorption process such as coir pith [4], orange peels [5], palm-shell [6], rice straw [7], cellulose beads [8] sunflower [9], has been investigated. The objective of this study was to investigate the adsorption potential of uranium (VI) onto powdered Corn cob (PCC) in batch and fixed-bed technique. In batch process kinetics of uranium removal onto PCC at different parameters (temperature, pH, initial concentration, and adsorbent dose) are investigated. The performance of fixed-bed column was evaluated by Thomas and Bohart–Adams models at different flow rates, bed heights and initial concentrations.

Material and methods

Preparation of adsorbent material

Corn cob is an agricultural by-product generated in Middle East. Corn cobs were washed with distilled water several times to remove dirt and particulate materials. The washed Corn cobs were dried at 80 °C. The dried corncobs were ground and sieved to obtain powdered Corn cob (PCC), of a particle size 300–425 μm and stored in dissector for further use.

Preparation of uranium stock solution

All chemicals and reagents used in this work were analytical grade. Stock solution of uranium (VI) was prepared by dissolving appropriate amounts of $UO_2(NO_3)_2{\cdot}6H_2O$, Aldrich, USA, in distilled water. For experiments the required concentration was prepared by dilution. The concentrations of U(VI) in solution were determined spectrophotometrically employing Shimadzu UV–VIS-1601 spectrophotometer using arsenazo (III) as complexing reagent [10].

Sorption experiments in batch technique

Batch experiments were first carried out to determine the potential of PCC to adsorb U(VI)) from aqueous solution and to investigate the optimum parameters of adsorption (adsorbent dose, contact time, pH, temperature, and initial concentration). 50 mL of different concentrations (25–100 mg/L) of U(VI) solutions with a range of pH values from 3 to 10 was transferred in a conical flask with 0.3 g of PCC. The solution was agitated at 200 rpm in a thermostatic shaker water bath for different time (10–180 min) at different temperature (303, 313, 323 and 333 K). The samples were withdrawn and centrifuged at 5000 rpm for 5 min and the supernatant solutions were analyzed. The pH of the solutions was adjusted with 0.1 M Na_2CO_3 or 0.1 N HCl.

Sorption capacity and removal efficiency

Sorption capacity (q) of U(VI) was defined as:

$$q = (C_0 - C_e)V/M \tag{1}$$

In addition, the removal efficiency (R_e) is calculated according to the following equation:

$$R_e(\%) = [(C_0 - C_e)/C_0] \times 100 \tag{2}$$

Sorption kinetics in batch technique

Kinetics of sorption of U(VI) onto PCC was analyzed using two kinetic models (pseudo first-order and pseudo second-order models). The comparing between data of experiments and models was analyzed by the correlation coefficients (r^2).

Pseudo-first-order model

Lagergren's equation of pseudo first-order model describes the sorption capacity of solids in solid–liquid systems [11,12]. It is supposed that one adsorbate is adsorbed onto one sorption site on adsorbent surface.

The linear form of pseudo first order model was given by equation:

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303}t \tag{3}$$