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Preparation of a novel electrospun polyvinyl alcohol/titanium oxide nanofiber adsorbent modified with mercapto groups for uranium(VI) and thorium(IV) removal from aqueous solution

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HIGHLIGHTS

- The synthesized novel adsorbent was characterized by FTIR, SEM and BET analysis.
- The sorption affinity of metal ions was Th(IV) > U(VI) for both utilized systems.
- We observed physical sorption mechanism and endothermic sorption for both metal ions.
- The U(VI) and Th(IV) sorption onto the nanofiber did not change after five cycles.
- In the binary system, the inhibitory effect of Th(IV) ion was greater than U(VI) ion.

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ABSTRACT

A novel polyvinyl alcohol (PVA)/titanium oxide (TiO_2) nanofiber adsorbent modified with mercapto groups was synthesized by electrospinning. The adsorbent was characterized by Scanning Electron Microscopy (SEM), Fourier Transform Infrared (FTIR) and Brunauer–Emmett–Teller (BET) analysis. The influence of several variables such as TiO_2 and mercapto contents, adsorbent dose, pH, contact time, initial concentration of U(VI) and Th(IV) ions and temperature were studied in batch experiments. The results showed that the sorption capacities of both metal ions for the modified PVA/TiO_2 nanofibers were remarkably greater than those of the unmodified nanofibers. The kinetic data were described with pseudo-first-order, pseudo-second-order and double-exponential models. Three isotherm models, namely Freundlich, Langmuir and Dubinin–Radushkevich were used for analysis of equilibrium data. The maximum sorption capacities of U(VI) and Th(IV) by Langmuir isotherm are estimated to be 196.1 and 238.1 (mg/g) at 45 °C with pH of 4.5 and 5.0, respectively. Calculation of ΔG°, ΔH° and ΔS° showed that the nature of both metal ions sorption onto the nanofiber was endothermic and spontaneous and was favored at higher temperature. The sorption capacity did not change remarkably after five cycles of sorption–desorption. The selectivity order of uranium and thorium sorption onto the adsorbent was Th(IV) > U(VI). The inhibitory effect of competitive Th(IV) ion on the U(VI) sorption was greater than the inhibitory effect of competitive U(VI) ion on the Th(IV) sorption in the binary systems. Also the inhibitory effect was increased with increase of concentration of metal ions.

1. Introduction

Radioactive waste originates from the nuclear industrial activities and some human activities such as exploitation of ores [1]. The appraisal of water pollution, which depends on the presence of radionuclide in the ground, is of major environmental concern [2]. Uranium and thorium are the poisonous radioactive elements. The toxic nature of these radionuclides has been a serious health problem for many years [1]. For example, these elements affect the human health by creation such diseases as the lung and liver cancers [3,4]. In addition, the recovery and removal of uranium and thorium is a principal purpose for industry and saving clean water resources [1,5]. Solvent extraction [6], chemical precipitation [7,8], reverse osmosis and membrane separation [9], ion exchange [10], electroflotation [11], coagulation [12] and sorption processes [13] are some techniques for removing heavy metal ions from aqueous solution. Sorption and ion exchange are the most popular methods for the removal of heavy metal ions from aqueous solution. High efficiency, simple operation and environmental compatibility are some of the

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