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Fabrication of β-cyclodextrin conjugated magnetic HNT/iron oxide composite for high-efficient decontamination of U(VI)

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HIGHLIGHTS

- A novel magnetic CD/HNT/iron oxide composite was synthesized by using chemical method.
- The maximum sorption amount of U(VI) on CD/HNT/iron oxide was higher than that on many other materials.
- CD/HNT/iron oxide exhibited satisfying removal efficacy for simulated mixed wastewater.
- CD/HNT/iron oxide could be easily separated from aqueous solution with a permanent magnet.
- CD/HNT/iron oxide could be used for the purification of actual U(VI)-bearing effluents.

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ABSTRACT

In this study, β-cyclodextrin (β-CD) was chemically grafted onto halloysite nanotube/iron oxides (HNT/iron oxides) to prepare a novel magnetic CD/HNT/iron oxide composite. The XRD pattern and FT-IR spectra analysis provide evidence for the successful grafting of β-CD on HNT/iron oxide surfaces. Elemental analysis indicates that the grafted β-CD amount in CD/HNT/iron oxide composite is 112 mg/g. Batch technique was adopted to investigate the removal efficiency of U(VI) from aqueous solutions by CD/HNT/iron oxide as a function of various environmental factors. The sorption reversibility and performance of CD/HNT/iron oxide in simulated effluent disposal were also tested. The sorption kinetic data can be well fitted by the pseudo-second-order model. The pH-dependent sorption suggests an optimal pH value of 7.0 for using CD/HNT/iron oxide in the decontamination of U(VI) from aqueous solutions. The sorption irreversibility at pH 5.5 was attributed to the inner-sphere binding of U(VI) on CD/HNT/iron oxide surface sites. The maximum sorption capacity of U(VI) on CD/HNT/iron oxide is considerably higher than that of some other reported materials. Related data show that CD/HNT/iron oxide exhibits satisfactory treatment efficiency for the simulated wastewater. It is worth noting that CD/HNT/iron oxide could be easily separated from aqueous solution by using a permanent magnet. By integrating the experimental results presented in this study, it is clear that CD/HNT/iron oxide can be potentially used as a cost-effective material for the purification of actual U(VI)-bearing effluents.

1. Introduction

Water radioactive pollution has become a serious environmental problem all over the world. A series of hazardous radionuclides (e.g., ^{235}U, ^{238}U, ^{235}Np, ^{239}Pu and ^{247}Cm, etc.) were discharged into aquatic systems through various nuclear processes, such as mining operations, refining of nuclear fuel, aboveground/underground nuclear tests, nuclear energy processing facilities and nuclear power plant accidents [1,2]. Uranium(VI), a chemical homolog of hexavalent actinides, is an irreplaceable material in nuclear fuel cycle. The potential risk of uranium-containing water system is a significant environmental concern due to its long half-life ($t_{1/2}$ (^{235}U) = $7.04 \times 10^8 a$; $t_{1/2}$ (^{238}U) = $4.47 \times 10^9 a$) [3]. Exposure to uranium can result in serious biochemical and radioactive harms to biological organization such as skin corrosion, toxic hepatitis, kidney damage, histopathological system damage and even cancers. In view of this point, a series of regulations have been proposed in the past decades to limit U(VI) concentration in environmental mediums. For instance, the guideline values for U(VI) concentration in drinking water were set to be 15 μg/L and 30 μg/L by World Health Organization and US Environmental Protection Agency, respectively [4].

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