Removal of simulated radionuclide Ce(III) from aqueous solution by as-synthesized chrysotile nanotubes

Leilei Cheng, Shaoming Yu *, Caicun Zha, Yunjin Yao, Xiaofeng Pan

School of Chemical Engineering, Hefei University of Technology, Anhui Key Laboratory of Controllable Chemical Reaction & Material Chemical Engineering, Hefei 230009, Anhui, PR China

HIGHLIGHTS

- Chrysotile nanotubes (ChNTs) were synthesized under hydrothermal conditions.
- ChNTs were characterized by XRD, FTIR, SEM, TEM, etc.
- The Langmuir model represented better to adsorption of Ce(III) on ChNTs.
- The maximum adsorption capacities (Qmax) for Ce(III) is 1.21 mmol g−1 at 348 ± 1 K.

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ABSTRACT

Chrysotile nanotubes (ChNTs) were synthesized under hydrothermal conditions for removing simulated radionuclide Ce(III). The prepared samples were characterized by X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM), Transmission Electron Microscopy (TEM) and N2 adsorption and desorption which show that as-synthesized ChNTs possess hollow structured, whose inner and outer diameters are ca. 8–15 nm and 30–50 nm respectively with inner aspect ratio to 20. The BET surface area and total pore volume were calculated to be 144.1 m2 g−1 and 0.39 cm3 g−1, respectively. In addition, the effects of contact time, solid content, pH and temperature were also investigated by batch technique. The adsorption kinetics and isotherms of ChNTs for Ce(III) indicate that the kinetic adsorption is well described by the pseudo-second-order model and the adsorption isotherm is fitted well by Langmuir model (Qmax = 1.21 × 10−3 mol g−1 at 348 ± 1 K). The thermodynamic parameters (i.e., ΔG°, ΔS° and ΔH°) of the adsorption for Ce(III) were determined from the temperature dependent adsorption isotherms at 298, 323 and 348 ± 1 K, respectively. The results indicate that the adsorption process of Ce(III) on ChNTs is spontaneous and endothermic.

1. Introduction

Nuclear power as a clean energy, which provides approximately 17% of the world’s electricity, has been widely applied in the world [1,2]. However, consequent high-level radioactive waste (HLW) is the priority problem related to the widely application of nuclear energy [3–5]. HLW, which is generated from commercial reprocessing facilities, contains various elements such as lanthanides, actinides and so on [6]. These can directly damage biological organization or produce reactive species (free radicals) that can subsequently react with bio-molecular when one inhales them from radiation source. For example, cancers, including lung cancer, bone cancer, etc. were induced in humans after exposure to radioactive contamination or ionizing radiation [7]. Various methods have been employed for removal of radioactive ions from aqueous media such as ion exchange, solvent extraction and adsorption [6,8–10]. Adsorption is considered one of the best techniques in terms of cost, simplicity of design and operation, especially for effluents with moderate and low concentrations. There are adsorbent materials such as activated carbon, which is used industrially for the removal of radioactive ions. Recently, minerals in their natural or modified forms have been investigated in the literature [11] as alternative potential adsorbents, such as asbestos.

Asbestos exhibits a hollow channel-like interior which belongs to the serpentinite group of minerals. Asbestos includes some magnesium silicates which crystallize in fibrous forms, such as chrysotile (Mg3Si2O5(OH)4), which is the most widespread material of this type [12]. Chrysotile as a natural fiber with particular morphology, high surface activity and crystalline structure, presents remarkable properties, such as surface adsorption ability [11]. Gollmann et al. [13] had reported chrysotile, in their pure form and after chemical