Cesium adsorption isotherm on swelling high-charged micas from aqueous solutions: Effect of temperature

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ABSTRACT

The potential use of a new family of synthetic swelling micas for cesium immobilization from aqueous solution was evaluated and the structural modifications after adsorption were analyzed. The results have revealed that they are good cesium adsorbents compared to natural clays and as the layer charge increases, the adsorption capacity and affinity increase. The cesium ions are adsorbed through a cation exchange mechanism, but an inner sphere complex with the basal O atoms of the tetrahedral sheet is favored. These findings imply that it is possible to design minerals with improved environmental applications.

Keywords: Cesium aqueous solution, synthetic mica, sorption isotherm, clay barrier, waste management; Actinides in Geology, Energy, and the Environment

INTRODUCTION

Along with the rapid development of nuclear industries, the contamination of radionuclides in the environment is a point of attention worldwide (Steinhauser 2014). Cesium isotopes (¹³⁷Cs, t¹/₂ = 30 yr and ¹³⁵Cs, t¹/₂ = 2 × 10⁶ yr) are one of the major constituents of the wastewater effluents from nuclear reprocessing units (Castrillejo et al. 2016) and due to their long half-lives and high solubility, they are the most hazardous nuclides in radioactive wastes. Given its chemical similarity to alkalis, Cs⁺ is readily assimilated by terrestrial and aquatic organisms and can gradually accumulate in the biological food chain (Nakao et al. 2008; Poinssot et al. 1999). Cesium strongly and selectively interacts with the phyllosilicate fraction of soil, sediment, and suspended particles (Zachara et al. 2002), but the interaction of Cs⁺ in a geological material is expected to be highly sensitive to the relative compositions of smectite/vermiculite and mica/illite (Fan et al. 2014).

The objective of any waste management is immobilization and isolation for the time necessary to lower its environmental activity and for this, several natural and artificial barriers are used. Numerous studies focused on using clays as a chemical barrier for retention and storage of radioactive materials have been reported, since they have a great capacity to adsorb and immobilize cations (Alba et al. 2001; Chorover et al. 2003; Rani and Sasidhar 2012; Takahashi et al. 1987; Villa-Alfageme et al. 2015). Clayey waste materials can retain radionuclides by sorption but also, under certain conditions, can produce a chemical reaction that generates new phases immobilizing the radioactive elements (Villa-Alfageme et al. 2015). Other features that make clays useful for retention of radioactive waste are their low permeability and high swelling capacity for absorption of ions, which predetermine their use as sealing barriers in multi-barrier systems when an underground geological repository for spent nuclear fuel and high-level radioactive wastes is constructed (Linares and Cuadros 1993).