Journal of Radioanalytical and Nuclear Chemistry (2022) 331:403–414
https://doi.org/10.1007/s10967-021-08070-7

Application of kaolinite-based composite as an adsorbent for removal of uranyl ions from aqueous solution: kinetics and equilibrium study

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Received: 19 August 2021 / Accepted: 18 October 2021 / Published online: 29 October 2021

Abstract
Polyacrylamide (PAA)-kaolinite (K) composite adsorbent was synthesized using K and PAA hydrogel, in-situ polymerization method as synthesis method. Adsorbent performance of the PAA-K composite for UO_2^{2+} ions was optimized: 400 mg L^{-1} at pH 4.5 at 25 °C. Synthesized PAA-K composite was featured by FT-IR, SEM–EDX, and XRD techniques. The maximum UO_2^{2+} ions adsorption capacity of the PAA-K composite was found to be 0.0656 mol kg^{-1}. Thermodynamic parameters demonstrated that the behaviour of the adsorption was an endothermic and spontaneous. Finally, adsorption process suggested that the PAA-K composite had a significant adsorption capacity for the UO_2^{2+} ions.

Keywords Kaolinite · Polyacrylamide · Composite · Uranyl removal · Wastewater treatment

Introduction

Heavy metals found naturally in the earth's crust are important pollutants in water and wastewater due to their non-biodegradable and non-destructible structure [1]. Determination of heavy metals discharged from industrial activities into water bodies above the acceptable limit threatens public health and the ecosystem [2]. Uranium, heavy metal with chemical toxicity and radioactivity, exists in various forms under different conditions. The hexavalent uranyl ion (UO_2^{2+}), which is the most stable among these forms, causes irreversible kidney damage and increased carcinogenicity [3]. Also, uranium recovery is of great importance for the sustainable development of the nuclear industry. Therefore, it has become a very important issue to develop an effective method for removing and recovering uranium from water and wastewater.

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Recently, various methods have been used for the removal of uranyl ions from aqueous solutions such as membrane separation method [4], chemical precipitation [5], solvent extraction [6], ion Exchange[7], and adsorption [8–10] However, these methods have disadvantages such as high cost, secondary pollution, and ineffectiveness at low metal concentrations. Among these methods, adsorption, which is the most effective and convenient method for removing trace levels of ions, is of interest. Adsorption method has significant advantages for the treatment of heavy metal containing wastewater because of its advantages such as low cost, ease of application, high selectivity, environmental friendlines and high efficiency. The selection of the effective adsorbent is very significant in adsorption process. Because, an effective adsorbent should be an recyclable, economical, non-toxic, and easily accessible material. Many adsorbents have been used to remove heavy metal ions from aquatic solutions, such as chitosan [11], zeolite [12], bentonite [13], montmorillonite [14], dolomite [15], biomass [16], metal organic-frameworks [17].

Kaolinite is one of the well-known low-cost natural clays found in rocks as a crystalline structure. Kaoliniteite ($Al_2Si_2O_3(OH)_4$), the most important mineral of kaolinite, is a 1:1 aluminosilicate, whose layers are composed of a tetrahedral silica layer (SiO_4) bonded to an octahedral alumina layer (AlO_6) with shared oxygen atoms. The layers are held together by hydrogen bonding of adjacent silica and alumina layers [18]. Composed of metal oxides such as Al_2O_3, SiO_2,