Environmental Technology & Innovation 8 (2017) 399–410

Contents lists available at ScienceDirect

Environmental Technology & Innovation

journal homepage: www.elsevier.com/locate/eti

Performance of magnetic talc titanium oxide composite for thorium ions adsorption from acidic solution

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HIGHLIGHTS

- Prepared magnetic talc titanium oxide has been investigated for thorium adsorption.
- Adsorption of Th^{+4} on magnetic talc titanium oxide depends on pH and ionic strength.
- Adsorption of Th^{+4} ions on prepared composite surface obey Langmuir isotherm.
- Adsorption process is not controlled only by intra-particle diffusion.
- Adsorption process can be expressed well by pseudo-second order.

ARTICLE INFO

Article history:
Received 25 August 2016
Received in revised form 5 September 2017
Accepted 12 September 2017
Available online 23 September 2017

Keywords:
Magnetic talc
Titanium oxide
Composites
Thorium ions
Adsorption

ABSTRACT

The magnetic talc titanium oxide composite was prepared, characterized and tested for thorium removal from acidic solution using batch experiment technique. The obtained results showed that the thorium adsorption was pH dependent. The maximum adsorption occurred at pH range from 3 to 4. Also, the results showed that the temperature had no effect on the adsorption efficiency. Testing of different adsorption isotherms revealed that the achieved experimental data was fitting well with the Langmuir isotherm model with 54.5 mg/g as theoretical capacity. The kinetics studies showed that the adsorption process was not controlled only by intra-particle diffusion and could be expressed by pseudo-second-order model.

1. Introduction

Talc, the hydrated magnesium sheet silicate has the chemical formula $Mg_3Si_4O_{10}$ $(OH)_2$. Talc elementary sheet is composed of octahedral magnesium hydroxide structures sandwiched between sheets of silicon–oxygen tetrahedral, in which the components are linked by ionic and covalent bonds. Different types of the talc can be formed; the features of each type differ from one to other depending on its parent rock type and origin which may be the key role in its usability. The natural talc is characterized by being colorless, odorless, imperceptible, insoluble and inert, low electrical conductivity, heat resistance, different particle size presence and large surface area (Perez-Maqueda et al., 2004; Nkoumbou et al., 2008a; Wallqvist et al., 2009). These wide features make the talc effective for so many applications.

From such applications are its uses in different kinds of industries as pharmaceuticals, pesticides, paper, food, plastics, ceramics, paint, textiles and as metals ions adsorbent (Goren et al., 2006; Neto and Moreno, 2007). The high sorption capacities of the modified talc for metal ions can be of great use for the recovery of valuable metals or the treatment of contaminated water. A large number of talc derivatives are obtained with the aim of adsorbing metal ions and treating water (Neto and Moreno, 2007) by including new functional groups onto the talc structure. In other words, the chemical

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http://dx.doi.org/10.1016/j.eti.2017.09.004

Table 1
Chemical composition of the original talc.

Metal oxide	SiO_2	MgO	CaO	Al_2O_3	Na_2O	K_2O	Fe^{+3}	L.O.I
%	56.9	29.1	2.9	0.6	0. 44	0.5	–	9.4

Table 2
Chemical composition of liquid waste liquor.

pH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	Co_3^{2-}	SO_4^{-}	Th^{4+}	U^{+2}	Cr^{2+}	Pb^{2+}
2.5	2018	890	32 256	1123	36 256	2010	2265	95	40	6.2	4.3

modification of talc to generate new metallic functional materials is of primary interest because such procedure would enhance the original physio chemical properties depending on nature of the introduced group.

Different talc modification forms are mentioned in the literature as magnetic talc nano-composites (Katayoon et al., 2014), polyethylene-talc (Wittmann and Lotz, 1986), inorganic and organic acid treated talc surface (Luciana et al., 2011) and amino modified talc (Da Fonseca and Airoldi, 2001). In this study, the talc material is modified by magnetite and titanium oxide, in order to activate the talc surface as well as increasing the surface area, the matter that will enhance the adsorption capacity of thorium ions from waste solution.

The addition of magnetite particles is because being highly efficient materials for heavy metal ion removal by adsorption, the metal ion adsorption by magnetite was demonstrated through a combination of electrostatic attraction and ligand exchange (Bremmell and Addai-Mensah, 2005). The magnetite particles can be rapidly and easily separated from aqueous solutions using an external magnetic field due to their magnetic property. The addition of titanium ions prevents co-aggregation of the magnetite particles as well as increasing the surface area.

Thorium is a highly toxic radioactive metal element, exists naturally in a tetravalent valency (Syed, 1999). Thorium has been widely applied in nuclear power reactors and as refractory material for crucibles, tubes, rods, etc., anti-reflection coating in optics, making ceramics, gas lantern mantles, an additive for special glass, alloying metal for some aerospace industry and aviation components, welding alloys, catalyst in organic chemistry and fuel for generating nuclear energy etc., (Metaxas et al., 2003).

These uses lead to the presence of different wastes containing ions of thorium, where its removal becomes a must due to the acute toxicological effects for the human. From such toxicological effect are those reported by Jain et al. (2006) angiosarcoma, dermatitis, kidney tumors, lymphoma, as well as other tumors of the blood system reported by Agency for Toxic Substances Disease Registry (1990) and progressive or irreversible renal injury (Aydin and Soylak, 2007; Benkhedda et al., 2005). The movement of thorium ions in the environment is generally controlled by sorption reactions, complexation, colloid formation, etc. (Chen and Wang, 2007a,b). In recent years, the adsorption of thorium ions on various materials has been studied extensively (Zuo et al., 2011; Bursali et al., 2010).

In the present study, the magnetic talc titanium oxide composite (**MT-TOC**) has been synthesized, characterized and tested for thorium ions adsorption. Factors that influence the thorium adsorption onto **MT-TOC** as solution pH, contact time, adsorbent dose, ionic strength and initial thorium concentration, as well as a case study, have been studied in detail. The adsorption isotherms and kinetics models have been also calculated from the obtained results of the controlling factors.

2. Materials and methods

2.1. Chemicals and reagents

The used chemicals of analytical grade were purchased from Merck Co. and used without further purification. Deionized water was used in all experiment steps. The stock solution of Th (IV) was prepared by dissolving exact amounts of $Th(NO_3)_4.5H_2O$ in concentrated nitric acid solution to avoid the hydrolysis of Th(IV). The thorium ions concentration was determined spectrophotometrically using Thoron (0.1%, w/v) as a chromomeric agent at a wavelength of 540 nm (Grimaldi and Fletcher, 1956).

2.2. Talc and liquid waste composition

The talc sample as the raw material for adsorbent preparation in the present study was obtained from Missikat, eastern desert area, Egypt. The talc sample was crushed, ground, homogenized then sieved using 250 μm sieves size. The chemical composition of the sample was illustrated in Table 1.

The used liquid waste sample in this study was obtained from the Nuclear Materials Authority laboratories waste solutions and its chemical composition was tabulated in Table 2.

The major oxides SiO_2, Al_2O_3, P_2O_5 were analyzed using the spectrophotometer method. The content of Na^+ and K^+ were estimated as oxides by the flame photometric technique. Total Fe^{+3}, MgO and CaO percent were determined by titration method. The loss on Ignition (L.O.I) was determined gravimetrically. The technique of the analysis was according to Shapiro and Brannock (1962). The estimated error for the major constituent is not more than ±2%. Cr^{2+} and Pb^{2+} were determined