Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

Applied Clay Science 29 (2005) 15–21

Applied Clay Science

www.elsevier.com/locate/clay

Zinc adsorption on Na-rectorite and effect of static magnetic field on the adsorption

Gaoke Zhang[a,*], Ying Liu[a], Yi Xie[a], Xia Yang[a], Bo Hu[a], Shixi Ouyang[b], Hanxing Liu[b], Huiyan Wang[a]

[a] *School of Resources and Environmental Engineering, Wuhan University of Technology, 122 Luoshi Road, Wuhan 430070, P.R. China*
[b] *State Key Lab of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, 122 Luoshi Road, Wuhan 430070, P.R. China*

Received 11 September 2003; received in revised form 3 May 2004; accepted 2 September 2004
Available online 11 November 2004

Abstract

Rectorite is a kind of rare clay minerals. In this work, the sorption of Zn^{2+} on Na-rectorite and the effects of static magnetic field on the sorption have been studied. The result from this study indicated that: (1) apparent equilibrium for the sorption of zinc onto Na-rectorite is attained within the first hour; (2) the maximum of the increment of Zn^{2+} adsorbed by Na-rectorite is obtained between pH 4 and pH 6; (3) magnetic treatment enhances the zeta potential of Na-rectorite dispersions in the absence of Zn^{2+} and reduces that of the dispersions in the presence of Zn^{2+}; (4) magnetic treatment promotes the sorption of Zn^{2+} onto Na-rectorite, especially at the low Zn^{2+} concentration; (5) the effects of static magnetic field decrease the pH of Na-rectorite dispersions whether containing zinc or not. The mechanisms of static magnetic field on the sorption of Zn^{2+} on Na-rectorite were discussed.

Keywords: Na-rectorite; Zinc; Magnetic field; Zeta potential; Adsorption

1. Introduction

Clay minerals have applications in cost effective sorbents for the removal of heavy metals (e.g. Krishna et al., 2000; Coles and Yong, 2002), in catalysis (e.g. Shimizu et al., 2002), in photodegradation (e.g. Ooka et al., 2003), in nanomaterials (e.g. Schoonheydt, 2002), in antibacterial materials (e.g. Herrera et al., 2000; Ohashi and Oya, 1992; Oya et al., 1991), in drug carriers (e.g. Hoyo et al., 1996). Such an extensive usefulness of clays is a result of their high specific surface area, chemical and physical stability, and a variety of surface and structural properties. The interaction between transition metals ion and clay minerals is an attractive subject in the field of surface chemistry, soil science, catalysis, and pollution studies. Zinc is a kind of transition metals. The fixation of Zn^{2+} by Ca-montmorillonite appears to be controlled by ionic

---

* Corresponding author. Fax: +86 278 7212127.
E-mail address: gkzhang@mail.whut.edu.cn (G. Zhang).

0169-1317/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.clay.2004.09.001

exchange in low ionic strength solution (Auboiroux et al., 1996). Na-montmorillonite is a good sorbent of Zn^{2+} (Abollino et al., 2003; Weiss et al., 1998). Cothenbach et al. (1998) investigated the potential of montmorillonite, Al-montmorillonite, and gravel sludge to immobilize zinc ion in agricultural soil. Kraepiel et al. (1999) gave a model for metal ion adsorption on montmorillonite. The sorption of Zn^{2+} on Ca-montmorillonite was modeled in terms of cation exchange and surface complexation by Bradbury and Baeyens (1999). The adsorption of Zn^{2+} on kaolinite is proposed to involve formation of two bidentate surface complexes (Ikhsan et al., 1999). Modified clay sorbents exhibit much higher adsorption capacity for zinc ions than that of natural clays (Vengris et al., 2001). Sorption of zinc ions by Lithuanian glauconite was studied by Smith et al. (1996). The acid–base behavior of sepiolite and its interaction with Zn^{2+} have been characterized by Vico (2003). Zinc ion-exchanged smectite clays were effectively applied as insoluble, readily solid acid catalyst to liquid-phase Friedel-Crafts reactions (Yusuke et al., 1998). Limed-treated montmorillonite is used to adsorb Zn^{2+} in a wide range of Zn^{2+} concentrations (Tsai and Vesilind, 1999). Dehydration, diffusion and entrapment of zinc ions in bentonite were studied by Ma and Uren (1998). Rectorite is a uncommon natural clay that is represented by regular (1:1) interstratification of dioctahedral mica and dioctahedral smectite layers. Only a few studies of the interaction between metal ions and rectorite were reported.

Various magnetic effects, such as on the scale prevention (Higashitani et al., 1993; Gehr et al., 1995; Holysz et al., 2002), the corrosion of metal surfaces (Bikulèius et al., 2003) and thin film materials (Vidal et al., 2002) have been reported. The effects of magnetic exposure on the ion-exchange process between ion-exchange resins and the electrolyte solution were investigated by Oshitani et al. (1999b). The film mass transfer always decreases when the sample is exposed to the magnetic field. The influence of the magnetic field on sorption ability of cation-exchange resins is illustrated by sorption of trivalent metal ions from a solution containing sodium chloride and Fe^{3+} ions in low concentrations (Krylova et al., 1998). Oshitani et al. (1999a) investigated magnetic effects on electrolyte solutions in pulse and alternating fields. The magnetic exposure reduced the coagulation rate, the zeta potential, the diffusion coefficient, and the surface potential of the colloidal particles (Higashitani and Oshitani, 1998). The magnetic exposure also reduced the zeta potential and diffusivity of nonmagnetic polystyrene latex particles (Higashitani et al., 1995).

2. Experimental

2.1. Rectorite

The rectorite used came from Zhongxiang, Hubei, P.R. China. The particle size fraction ≤2 μm (Stokes diameter) was obtained by the sedimentation–centrifugation procedure. A saturated sodium form of rectorite (Na-rectorite) was prepared from this fraction by shaking with 1 mol/l NaCl solution. Following multiple saturation treatments, the samples were washed with deionized water until excess Cl^- was totally eliminated (undetected by $AgNO_3$) and air dried. The cation exchange capacity of Na-rectorite is 48.7 meq/100 g.

2.2. Methods

An adjustable permanent magnet apparatus was used to generate static fields, which was known to be a sufficiently strong field to make the solution magnetized (Higashitani and Oshitani, 1998; Oshitani et al., 1999b). The magnetic flux density in the space within which the sample was placed is variable up to 0.57 T.

Adsorption experiments were performed in well-tight polyethylene 50 ml bottles at 25 °C. Samples of Na-rectorite, 0.30 g dry weight, were suspended in 50 ml $ZnCl_2$ solution with Zn^{2+} concentrations between 0.5 and 16 mmol/l. The magnetic treatment of the solution was performed by placing the samples between magnets for 2–40 min at 25 °C. The pH of dispersions was adjusted with diluted hydrochloric acid or NaOH solution to values between pH 2 and 9.7. The pH conditions were remained constant by adding the hydrochloric acid or NaOH if necessary during the experiments. The dispersions were shaken for 6 h and allowed to last 10 h. All pH measurements were made with a combined pH electrode connected to a digital voltmeter. After separation by centrifugation, Zn^{2+} concentrations in equilibrium and initial solutions were determined by atomic absorption spectrometry (VARIAN-SPECTRAA-30A). The amounts of Zn^{2+} adsorbed by Na-rectorite were obtained by the difference. Zeta potentials of Na-rectorite dispersions were measured with a zetameter (BDL-B,