ADSORPTION OF LEAD AND NICKEL FROM AQUEOUS SOLUTION ON NATURAL SEPIOLITE

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ABSTRACT

Heavy metals are a serious environmental problem due to their toxicity and abundance. The capacity of a natural clay (sepiolite) for heavy metals adsorption, Pb^{2+} and Ni^{2+}, has been assessed using a batch method. The effect of mass of adsorbent on the process and the competitive adsorption between the two metals has been investigated. The adsorption of Pb^{2+} and Ni^{2+} increases with increasing dosage of natural sepiolite. The maximum removal of Pb^{2+} and Ni^{2+} by sepiolite, starting from a solution with both metals, was 98% and 59%, respectively. The experiments demonstrated that Pb^{2+} was adsorbed by natural sepiolite more efficiently than Ni^{2+}. The conclusion of this study is that natural sepiolite can efficiently adsorb cationic species, which may have an interesting environmental application such as the removal of those species from polluted waters.

Keywords: adsorption, sepiolite, lead, nickel, polluted waters

INTRODUCTION

Water pollution is one of the biggest environmental issues causing serious problems to living beings. The removal of various toxic substances from water and wastewater has been a core focus over the past decades [1]. Heavy metals are a serious environmental problem because of their toxicity and abundance. Among the existing methods for the treatment of wastewater as chemical precipitation, ultrafiltration, reverse osmosis or electrodialysis [2], adsorption process is one of the most attractive, especially when the adsorbent used is a low-cost material, occurring naturally in large quantities. Sepiolite is a natural mineral clay, a fibrous hydrated magnesium silicate comprising two tetrahedral silica sheets with a central magnesia sheet. The silica sheets are segmented and the inversion of silica sheets gives rise to tunnels in the structure. These characteristics make sepiolite a powerful adsorbent for heavy metals [3].
The objective of this study is to investigate the ability of natural sepiolite to remove Pb^{2+} and Ni^{2+} from aqueous solutions.

EXPERIMENTAL

Sepiolite used in this study was supplied by TOLSA and characterized by Scanning Electron Microscopy (SEM).
The effect of natural sepiolite dosage on the removal of Pb^{2+} and of Ni^{2+} from aqueous solutions, was tested in batch assays. The experiments were performed using a single element solution of Pb^{2+} or of Ni^{2+}. Natural sepiolite dosages of 0.1, 0.2, 0.5, 1 and 1.5 g were mixed in flasks with 200 mL solutions with 60 $mg.L^{-1}$ of Pb^{2+} or of Ni^{2+}, at room temperature (25±1ºC). After 43 hours of orbital isothermal mixing, liquid samples were collected, filtered and Pb^{2+} or Ni^{2+} concentrations were measured by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES).
In other assays, the competitive adsorption between Pb^{2+} and Ni^{2+} was evaluated. 1.5 g of natural sepiolite was mixed with 200 mL of Pb^{2+} and Ni^{2+} solution, both at 60 $mg.L^{-1}$. For 43 hours of orbital isothermal agitation, samples were collected, filtered and Pb^{2+} and Ni^{2+} concentrations were measured by ICP-OES. The blank experiments were simultaneously carried out without addition of adsorbent to test possible adsorption and/or precipitation of the metals on the container walls. Preliminary experiments showed that metals losses due to adsorption/precipitation onto the container walls were negligible. Removal ratio of the metal ions was calculated using the Eq. 1:

$$\text{Removal } \% = \frac{Ci - Cf}{Ci} \times 100 \qquad (1)$$

where Ci and Cf are the concentrations of each ion in the initial solution and in the collected sample ($mg.L^{-1}$), respectively.

RESULTS

Natural sepiolite characterization

Sepiolite is a fibrous silicate clay mineral, rich in magnesium with a structure of layers and chains. The surface of this natural adsorbent was characterized by SEM (Fig 1. A and B). The observed textural features confirmed that the studied samples have a fibrous morphology (Fig 1. B).

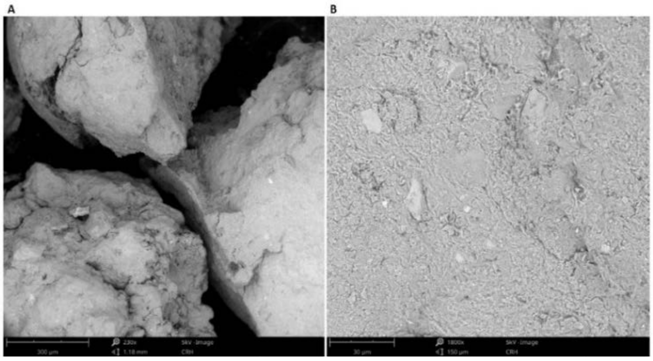

Fig 6. SEM images of natural sepiolite (A) and detailed photography of its surface (B).

Effects of natural sepiolite dosage on adsorption of a single element solution of Pb^{2+} or Ni^{2+}

The effect of amount of adsorbent on the adsorption of a single element, Pb^{2+} or Ni^{2+}, by natural sepiolite was assessed. The results are presented in Fig 2. As expected, the adsorption of Pb^{2+} and Ni^{2+} increases with increasing dosage of sepiolite. This effect is explained by the increase in available adsorption sites with the increase in adsorbent mass. As shown in Fig 2, a greater adsorption of Pb^{2+} (48%) in comparison with Ni^{2+} (12%) is reached with 0.1 g of sorbent. Indeed, the adsorbed quantity of Pb^{2+} reached a maximum value using 1 g of sepiolite, whereas the plateau is not reached for Ni^{2+}. When the dosage of sepiolite exceeds 0.5 g, the Pb^{2+} adsorptive capacity increased slowly.

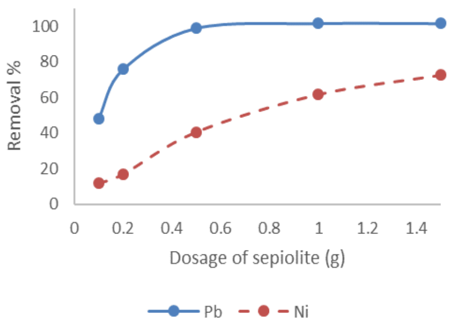

Fig 7. Effect of sepiolite dosage on the adsorption of Pb^{2+} or Ni^{2+}, 60 $mg.L^{-1}$, starting from individual solutions.

Competitive adsorption between Pb^{2+} and Ni^{2+}

The competitive adsorption between Pb^{2+} and Ni^{2+} by natural sepiolite was evaluated. The results are presented in Fig 3. The adsorption curves present similar features, regardless the element. The results show a first phase of a rapid adsorption (4 h), which can be explained by a direct adsorption on the surface of the sepiolite particles, and then presents a slower adsorption, may be due to a slow diffusion of the metals into the interior pores of the sepiolite, finally reaching the equilibrium state. The maximum removal of Pb^{2+} and Ni^{2+} by natural sepiolite from a solution with both metals was 98% and 59%, respectively.

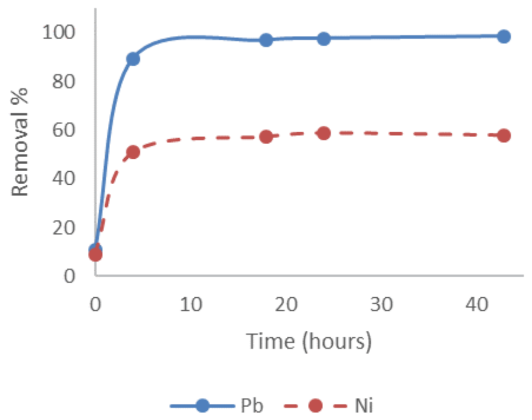

Fig 8. Competitive adsorption between Pb^{2+} and Ni^{2+}, both at 60 $mg.L^{-1}$

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