

Studies Regarding Strontium Adsorption onto Styrene-1% Divinylbenzene Grafted with Phosphonium Groups and Impregnated with Ionic Liquid

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Abstract

The paper presents the studies regarding the strontium ions removal from aqueous solution through adsorption onto a functionalized polymer impregnated with an ionic liquid. As a solid support styrene-1%divinylbenzene grafted with phosphonium groups was used and this was impregnated with 1-ethyl-3-methylimidazolium chloride ionic liquid. The impregnation of the studied ionic liquid onto the studied polymer solid support was realized through ultrasonication. The SEM, and energy dispersive EDX applied to the obtained adsorbents proved the fact that the polymer solid support was impregnated with the studied ionic liquids and also put in evidence the morphology changes of the solid support produced by its impregnation with these ionic liquids. The styrene-1% divinylbenzene functionalised with phosphonium groups and impregnated with 1-ethyl-3-methylimidazolium chloride developed a maximum adsorption capacity in the removal process of Sr^{2+} ions from aqueous solution of 1.28 mg Sr^{2+} /g of adsorbent. The equilibrium between the adsorbent and adsorbate is achieved in 60 minutes.

Introduction

The waste aqueous solution containing radionuclides may affect human health and the environment, therefore their treatment received considerable attention worldwide. It was noted that the solvent extraction process is very efficient in the recovery of radionuclides from aqueous solutions as alternative to conventional used methods. [1-4] The volatile organic compounds were substituted by the ionic liquids (ILs) due to their environmental benefits, such as: non-inflammable and non-volatile, good selectivity, sensitivity and reproductibility for metal extraction. [5-7] However, some disadvantages of ILs were found in some liquid-liquid extractions, such as: the use of high concentrations of ionic liquids, decomposition of ionic liquids in water which results in the loss of ionic liquids, high viscosity leading to dissolution and unfavorable diffusion difficulties of separation and recovery and low interface area. Therefore the immobilization of the ionic liquid onto an appropriate solid support is a solution to prevent these disadvantages. The use of ionic liquid impregnated solid support in the removal of radionuclides from aqueous solutions presents a link between the benefits of solvent extraction and solid supports so this application increases selectivity, achieving a high degree of adsorbent-adsorbed interaction and mechanical stability to the solid support. [8-12] The most relevant criteria for the selection of the solid support are surface properties and porosity. Many researchers use macroporous organic polymers as solid support due to their high specific surface area and mechanical stability, suitable for removing toxic elements from dilute solutions due to their high kinetics, ease of regeneration and high adsorption capacity. [13]. The paper presents the studies regarding the strontium ions removal from aqueous solution through adsorption onto a functionalized polymer impregnated with an ionic liquid. As a solid support styrene-1%divinylbenzene grafted with phosphonium groups was used and this was impregnated with 1-ethyl-3-methylimidazolium chloride ionic liquid.

Experimental

Obtaining of ionic liquid impregnated polymer

In a 100 mL Erlenmeyer glass were added 5 g of styrene-1%divinylbenzene grafted with phosphonium groups and 0.5 g of 1-ethyl-3-methylimidazolium chloride ionic liquid dissolved in 25 mL of ethanol. The impregnation was done by ultrasound at 30 °C and at 30 minutes working time. The samples obtained were separated by filtration, washed with ethanol and then dried in an oven at 50 °C for 24 hours. The surface morphology of the impregnated material was studied by scanning electron microscopy (SEM) using a Quanta FEG 250 microscope equipped with a EDAX ZAF detector.

Sr²⁺ adsorption onto the ionic liquid impregnated polymer

In order to determine the adsorption capacity of the ionic liquid impregnated polymer this was used as adsorbent materials in the removal process of Sr²⁺ ions from aqueous solutions. The Sr²⁺ adsorption was achieved by stirring, and for the samples shaking was used a MTA Kutesz shacker with a constant speed of stirring. In order to determine the adsorption capacity of the studied material this was treated with solutions containing different concentrations of Sr²⁺ (5, 15, 20, 25 and 30 mg / L). 1 g of the ionic liquid impregnated polymer was treated with 25 ml of Sr²⁺ solution. The samples were stirred for 1 hour and after stirring was filtered and the concentration of Sr²⁺ was determined by atomic emission spectrometry using an atomic absorption spectrometer Varian 280 SpectrAA with air/acetylene flame.

The adsorption capacity of the ionic liquid impregnated polymer was determined using the following equation:

$$q_e = \frac{(C_0 - C_e) \cdot V}{m}$$

where: C₀ and C_t are the concentrations of Sr²⁺ ions (mg/L) in the initial solution (t=0) and at equilibrium, V is the volume of the solution (L) and m is the mass of adsorbent (g).

It was also determined the dependence of the adsorption capacity of the ionic liquid impregnated polymer a function of stirring time. For this purpose 0.1g of the studied adsorbent was treated with 25 mL of Sr²⁺ solution having a concentration of 5 mg/L for different periods of time (range: from 15 to 240 minutes).

Results and discussion

Characterization of the ionic liquid impregnated polymer

The morphological structure of the studied adsorbent can be seen from the SEM image presented in Figure 1 a). The EDX spectra is shown in figure 1 b). By SEM and EDX were laid out the presence of the phosphonium and imidazolium groups and the chloride ions on polymeric support. This analyze put in evidence the fact that the studied polymeric support was impregnated with the studied ionic liquid (1-ethyl-3-methylimidazolium chloride).

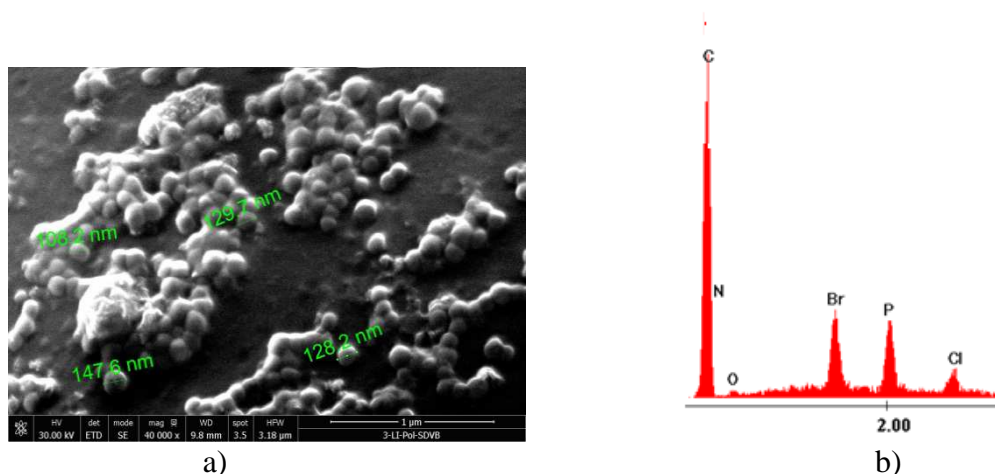


Figure 1. SEM image and EDX spectrum of the styrene-1%divinylbenzene grafted with phosphonium groups and impregnated with 1-ethyl-3-methylimidazolium chloride

Effect of Sr^{2+} initial concentration on the adsorption process efficiency

The equilibrium isotherm of Sr^{2+} adsorption onto the studied material is presented in figure 2. It can be observed that by increasing the initial concentration of the Sr^{2+} ions increase the amount of radionuclide adsorbed by 1 g of adsorbent, until it is achieved the equilibrium. The maximum adsorption capacity developed by the styrene-1%divinylbenzene grafted with phosphonium groups and impregnated with 1-ethyl-3-methylimidazolium chloride developed in the removal process of Sr^{2+} ions from aqueous solution is 1.28 mg Sr^{2+} /g of adsorbent.

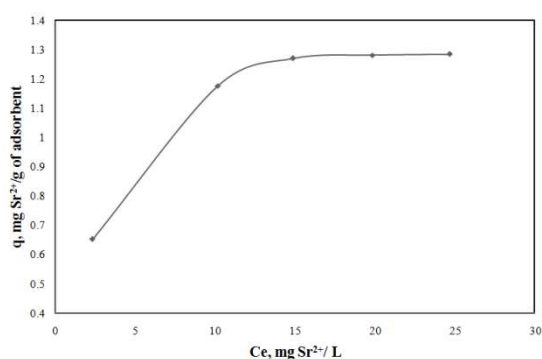


Figure 2. Isotherm of Sr^{2+} adsorption onto studied adsorbent

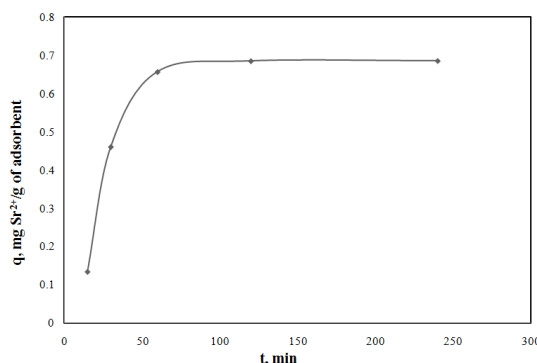


Figure 3. Effect of contact time on the adsorption capacity of the studied adsorbent

Effect of stirring time on the adsorption process efficiency

The experimental data regarding the dependence of the adsorption capacity of the studied adsorbent function of the stirring time are presented in figure 3. It can be notice that the stirring time increasing lead to the increase of the adsorption capacity, until it reach a constant value. The equilibrium between the adsorbent and adsorbate is achieved in 60 minutes.

Conclusion

In the present work was studied the removal of Sr^{2+} ions from aqueous solutions by adsorption onto styrene-1% divinylbenzene functionalised with phosphonium groups and impregnated with 1-ethyl-3-methylimidazolium chloride. The impregnation of the studied ionic liquid onto the studied polymer solid support was realised through ultrasonication which proved to be an efficient method because is not time consuming, combine the advantages of

the ionic liquids with those of the solid support, is used a smaller amount of the ionic liquid and there is no risk of loss of the extractant in the aqueous phase. The SEM, and energy dispersive EDX applied to the obtained adsorbents proved the fact that the polymer solid support was impregnated with the studied ionic liquids and also put in evidence the morphology changes of the solid support produced by its impregnation with these ionic liquids. From the experimental data it has been found that the adsorption capacity of the studied material increase with the increasing of the initial concentration of Sr^{2+} ions and with stirring time increasing. The styrene-1% divinylbenzene functionalised with phosphonium group and impregnated with 1-ethyl-3-methylimidazolium chloride developed a maximum adsorption capacity in the removal process of Sr^{2+} ions from aqueous solution of 1.28 mg Sr^{2+} /g of adsorbent. The equilibrium between the adsorbent and adsorbate is achieved in 60 minutes.

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