Impregnated Resins as Novel Sorbents for Removal of Toxic Metal Ions from Aqueous Solutions

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Abstract
In this study the performance of impregnated resin was evaluated as the sorbent for the removal of lead ions from aqueous solutions. It was observed that the lead removal efficiency depends on the sorbent dose, initial concentration of metal ions, pH of water and the contact time. The results of batch experiments showed the highest removal efficiency of Pb(II) ions from water (>99%) at L:S = 100:1 for the following conditions: initial concentration of metal ions of 10 mg/dm^3, pH = 6, and contact time of 60 min. The experimental equilibrium data were also described by sorption isotherms. Impregnated resin as novel sorbent has been found efficient and easily regenerable and can be used several times.

Keywords: impregnated resin, sorption, macrocyclic ligand, lead ions

1. Introduction

More strict environmental regulations on the discharge of toxic metals require developing various technologies for their removal from polluted streams. Adsorption processes are the most attractive methods for effective removal of metals ions from different aqueous solutions due to their high efficiency in a wide range of metal ion concentration, and easy handling under relatively flexible working conditions; one should also point out the selectivity and rapidity of these methods (Adhikari et al., 2011). However, the choice of an appropriate adsorbent is crucial for the achievement of full recovery of metal ions (Ghaedi et al., 2009). In the recent years, this has prompted a growing research interest into the modification and impregnation of a solid phase with macrocycles to increase the surface adsorption capacity and to enhance the removal efficiency of the sorbent (Zawierucha et al., 2014).

Novel types of resins incorporating macrocyclic ligands may be the best choice for the removal of a variety of metal ions. The modification of Amberlite XAD-4 with macrocyclic ligands results in the high capacity and selectivity of the impregnated resins. The extractant is retained in the micropores of an inert polymer without any chemical bonds onto the polymer matrix and the properties of the impregnated extractant are responsible for the adsorption of novel resin (Zawierucha et al., 2013).

Calixarenes and resorcinarenes are a new generation of highly selective carriers for heavy metal separation processes. They have high thermal stability and are known as interesting building blocks for the recognition of metal ions. An immense interest of researchers in these macrocyclic compounds is because of their easy synthesis, high yield, and functionalization of their aromatic core (narrow or wide rim) with different functional groups (Sliwa and Kozlowski, 2009).

Incorporation of calixarene based ionophores onto synthetic resins offers promising solution to the sorption technology. Calixarenes appended resins are highly selective, thermally stable and have of regeneration ability (Zawierucha et al., 2016).

In this study the efficiency and sorption characteristics of resin impregnated with resorcinarene derivative (Fig. 1) were evaluated. The Pb(II) removal efficiency of impregnated resin was determined under various conditions of treatment system.

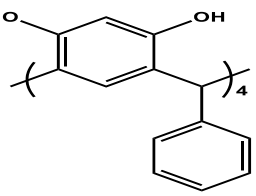

Figure 1. The structure of resorcinarene (**1**)

2. Materials and Methods

2.1. Impregnation of the stationary phase

A 2.0 g portion of dry Amberlite XAD-4 was placed in 20 mL of chloroform containing ligand **1** and stirred for 24 h. The resin was separated by filtration through a sintered glass funnel and washed with water to remove the solvent. The ligand **1** content was evaluated by solvent evaporation using gravimetric analysis. The amount of ligand **1** impregnated onto dry resin was calculated from the material balance. The impregnated resin was used as an air-dried product. Scanning electron microscopic study of the surface morphology of the "raw" (a) and impregnated (b) Amberlite XAD-4 resin is shown in Fig. 2.

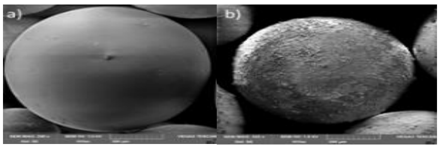

Figure 2. The “raw” (a) and impregnated (b) Amberlite XAD-4 res

2.2. Sorption experiments

Batch experiments were conducted by adding of impregnated resin (in the dose range of 0.01-0.5 g) into 10 cm^3 of lead cations sample solution at a 10 mg/dm^3 (up to 100 mg/dm^3 in the case of concentration change). The mixture was shaken at room temperature for a certain period of time (from 5 to 90 minutes) at 200 rpm (IKA KS IC Control 4000), the adsorbent was filtered off, and the lead ions in aqueous phase were measured by AAS (Unicam Solaar 939) or ICP MS (Elan 6000, PerkinElmer) depending on metal ions concentration.

3. Results and Discussion

The present work elaborates study on batch sorption of Pb(II) onto polymeric resin impregnated with resorcinarene derivative. The sorption may be controlled by optimization of process parameters. The impregnated resin has been found to sorb Pb(II) effectively of above 99% under following optimum conditions, i.e. 0.1 g of the resin, pH = 6.0, contact time of 60 min and 10 mg/dm^3 Pb(II) concentration.

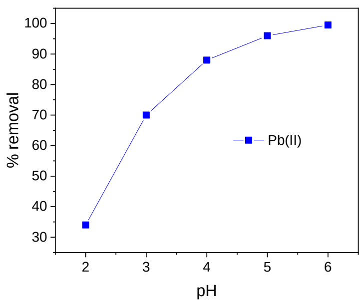

Figure 3. The effect of pH on Pb(II) ions removal from water (impregnated resin dose = 0,1 g, contact time = 60 min, concentration = 10 mg/dm^3)

The pH value is an important parameter for removal of metal ions from aqueous solution because it affects the solubility of the metal ions, concentration of the counter-ions on the functional groups of the sorbent and the degree of ionization of the metal during process. To examine the effect of pH on the Pb(II) removal efficiency, the pH was varied from 2.0 to 6.0. As is shown in Fig. 3, the uptake of Pb(II) depends on pH, where optimal metal removal efficiency occurs at pH 6.0 and decreases at lower pH.

The effect of metal concentrations on sorption of Pb(II) onto impregnated resin is shown in Fig. 4. The amount of Pb(II) sorbed consistently increased as the metal concentration increased, and it reached 398 mg/g at initial metal concentration of 100 mg/dm^3.

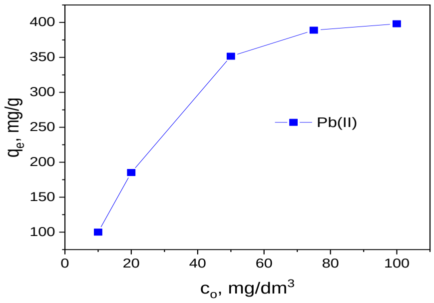

Figure 4. The effect of Pb(II) concentrations on the sorption capacity of impregnated resin

The use of sorption models to the experimental data shows that the mechanism of removal of lead ions onto resorcinarene impregnated resin is the physisorption.

Acknowledgements

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