

Adsorption Characteristic of As(V) onto Fe-XAD7-DEHPA Resin

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Abstract: The adsorption performance of a polymeric resin was evaluated in the removal process of As(V) from aqueous solutions. The studied resin was an Amberlite XAD7 which was impregnated with di(2-ethylhexyl) phosphoric acid (DEHPA) as extractant through the dry method of impregnation. The XAD7-DEHPA resin was loaded with Fe(III) ions, because of the affinity of iron towards arsenic ions. The adsorption performance of the studied material was evaluated studying the effects of various physico-chemical parameters (contact time, temperature and As(V) initial concentration). The material showed good sorption performance for the removal of arsenic from a synthetic aqueous solution.

Keywords: Fe-XAD7-DEHPA, dry method of impregnation, arsenic removal

1. Introduction

Groundwater, which is usually free from microbiological contaminants and may be supplied without much treatment, is generally considered a safe source of drinking water. However, contamination of potable ground water by arsenic has become a global environmental concern in recent years, with fresh reports of arsenic contamination at high concentrations with every passing year that can have severe human health implications [1-5]. Based on the impact on human health, the world health organization (WHO) has recommended that the arsenic concentration remain below 10 µg/L in drinking water [6-10].

Literature survey reveals that there are a good number of approaches for arsenic remediation from drinking water. Amongst the various methods like oxidation-reduction, precipitation, co precipitation, sorption, electrolysis and cementation, solvent extraction, ion exchange, ion flotation and bioremediation [2, 11-13] proposed to negotiate the problem of arsenic contamination in drinking water, sorption technique is, however, the most common and is considered to be an effective method. Various types of adsorbents have been developed by researchers for the removal of arsenic from water like: coconut husk carbon, MnO₂ coated sand, basic yttrium carbonate, several iron compounds or iron containing wastes, activated alumina, carbon from fly ash, granular titanium dioxide and hybrid polymeric sorbents [2, 6-9, 14].

The use of macro porous organic polymer supports, with a high surface area and good mechanical stability, is found more suitable for the removal of toxic elements from dilute solution, due to their faster kinetics, ease of regeneration and high adsorption capacity [15-23].

In this study the Amberlite XAD7 resin was impregnated, through the most widely used method (dry method), with di(2-ethylhexyl) phosphoric acid (DEHPA). Because the iron compounds in general were found to be very efficient adsorbents for arsenic removal from water

due to the high affinity of arsenic towards iron [1, 5-9, 14], the XAD7-DEHPA was loaded with Fe(III) ions.

The study investigate the adsorption characteristic of As(V) onto Fe-XAD7-DEHPA resin.

2. Experimental

The Amberlite XAD7 resin (supplied by Rohm and Hass Co.) was impregnated with di(2-ethylhexyl)phosphoric acid (DEHPA) through dry method. The DEHPA ~ 98.5% used as extractant, was supplied by BHD Chemicals Ltd Poole England and used as received. One gram of fresh XAD7 has been placed for 24 h in ethanol (Chimopar Romania) containing 0.1 g/ml extractant (DEHPA). The polymeric beads have been separated through a porous filter using a vacuum pump, washed with water and dried at 50°C for 24 h [24]. In view of arsenic (V) adsorption the DEHPA-impregnated XAD-7 resin was loaded with Fe(III) ions. In this aim the XAD7-DEHPA resin was equilibrated with a 50 mg/L Fe³⁺ solution for 24 h. Fe-XAD7-DEHPA resin was separated through a porous filter using a vacuum pump, washed with distilled water and dried at 50°C for 24 h.

In order to establish the adsorption performance of the material, the influence of contact time, temperature and initial concentration of arsenic on the adsorption capacity and on the arsenic removal degree was investigated.

The adsorption capacity q_t (µg/g) of the Fe-XAD7-DEHPA towards As(V) ions was calculated with the following equation [1-5, 8-10]:

$$q = \frac{(C_0 - C_t) V}{m} \quad [\mu\text{g As(V)}/\text{g Fe-XAD7-DEHPA}] \quad (1)$$

where C_0 and C_t are the concentrations of As(V) ions (µg/L) in the solution initially ($t = 0$) and after a time t (min), respectively, V is the volume of the solution (L) and m is the mass of adsorbent employed (g).

Another parameter of interest is the removal degree of As(V) ions, η (%), which may be calculated from the relationship:

$$\eta = \frac{(C_0 - C_t)}{C_0} 100 \quad [\%] \quad (2)$$

where C_0 and C_t have the same meanings as before.

To study the effect of contact time on adsorption at three temperatures $25 \pm 1^\circ\text{C}$, $30 \pm 1^\circ\text{C}$ and $45 \pm 1^\circ\text{C}$, the experiments were carried out with samples of 0.1 g Fe-XAD7-DEHPA in 25 mL of 100 $\mu\text{g/L}$ As(V) solutions. The suspensions were kept in contact different times: 1, 2, 4, 6, 8, 10, and 24 h. To maintain the temperature of the suspensions at the desired value the samples were immersed in a bath of a mechanical shaker bath (without shaking) MTA Kutesz, Hungary with a standard thermocouple. After contact time elapsed, the suspensions were filtered and the residual concentration of As(V) ions in the filtrates was determined by means of atomic absorption spectrometry using a Varian SpectraAA 110 atomic absorption spectrometer with a Varian VGA 77 hydride generation system. Similar experiments were performed to study the influence of the As(V) initial concentration (range: 30-300 $\mu\text{g/L}$). The samples were kept in contact for 10 h at room temperature $25 \pm 1^\circ\text{C}$. The filtrate was collected for As(V) analysis.

The various chemicals employed in the experiments were of A.R. grade and used without further purification. Distilled water was used throughout.

3. Results and Discussion

3.1. Influence of contact time

The effect of the contact time on the adsorption of As(V) onto Fe-XAD7-DEHPA resin at an initial concentration of 100 $\mu\text{g/L}$ and at three different temperatures are presented in figure 1.

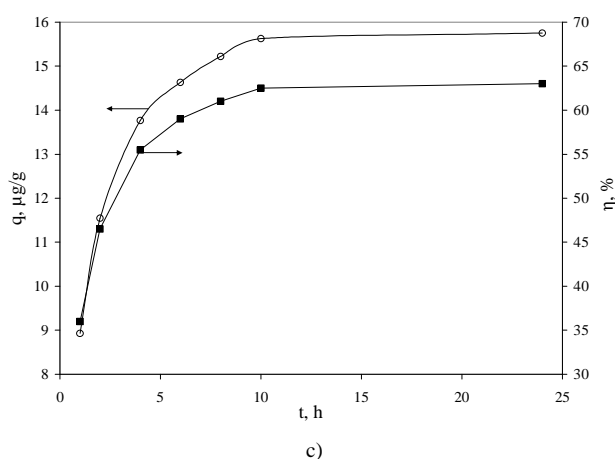
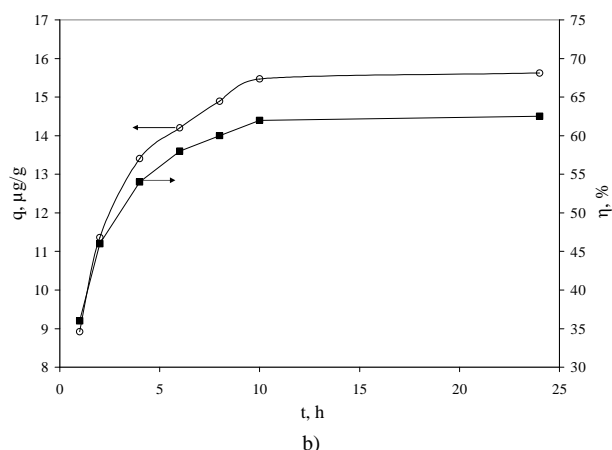
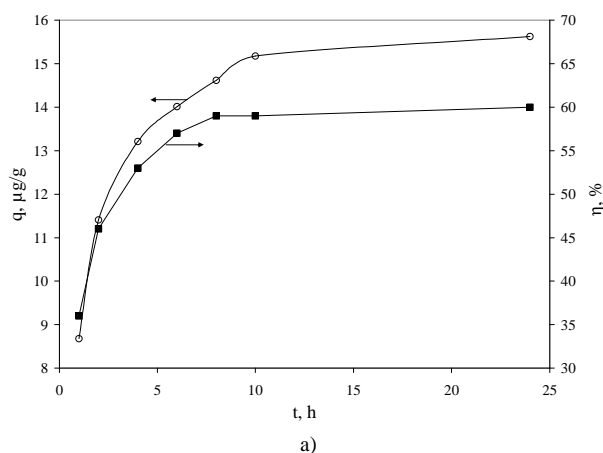


Figure 1. Effect of contact time on the As(V) adsorption onto Fe-XAD7-DEHPA $C_0=100 \mu\text{g/L}$, $m=0.1 \text{ g}$, $v=0.025 \text{ L}$
a) 298 K b) 303K c) 318 K

It can be seen that the adsorption capacity and the arsenic removal degree increase with contact time increasing up to certain value and then there was no further increase in adsorption. Experimental results indicate that the maximum amount of the adsorption is reached in about 10 h for all the studied temperatures. We can conclude that the equilibrium time is achieved in 10 h.

3.2. Influence of temperature

Figure 2 shows the influence of temperature on the adsorption of As(V) from aqueous solution by Fe-XAD7-DEHPA at the equilibrium time of 10 h.

It can be seen that the adsorption capacity of the adsorbent increase slowly with the temperature increasing. Because the influence is not significant we can chose as the optimum temperature for As(V) adsorption from aqueous solution onto Fe-XAD7-DEHPA the ambient temperature $25 \pm 1^\circ\text{C}$. Under this work conditions ($T=298 \text{ K}$, $t=10 \text{ h}$, $C_0=100 \mu\text{g/g}$, $m=0.1 \text{ g}$ and $v=0.025 \text{ L}$) the adsorption capacity of Fe-XAD7-DEHPA resin in the adsorption process of As(V) from aqueous solution is 15.6 $\mu\text{g/g}$.

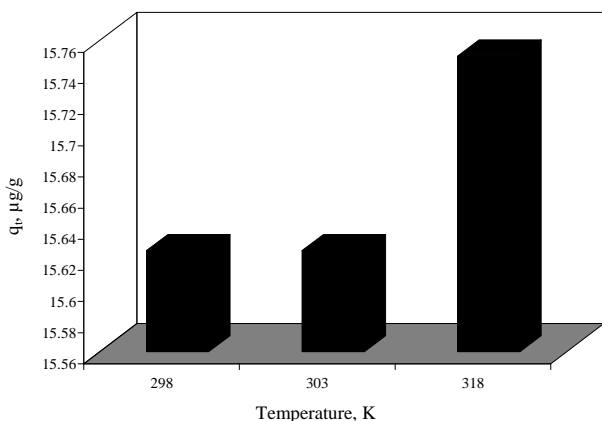


Figure 2. Effect temperature on the As(V) adsorption onto Fe-XAD7-DEHPA
 $C_0=100 \mu\text{g/L}$, $m=0.1 \text{ g}$, $v=0.025 \text{ L}$, $t=10 \text{ h}$

3.3. Influence of As(V) initial concentration

The plot of As(V) adsorbed by the Fe-XAD7-DEHPA resin versus the metal concentrations in the equilibrated solution is presented in figure 3. This set of the experiments was performed at $25 \pm 1^\circ\text{C}$ by varying the metal concentration from 30 to 300 $\mu\text{g/L}$ while keeping other experimental conditions constant. There is continuous increase of adsorption capacity with the increase of As(V) concentration, until the equilibrium is reached yet the arsenic removal degree decrease. With the increase of the concentration of As(V) in solution, the availability of arsenate ions also increases at the solid-solution interface resulting in the increase of sorption performance. However, the saturated point of sorption is reached when the limited active surface sites on the adsorbents are covered fully by sorbate. Further the heterogenous nature of the adsorbent with regards to the distribution of the binding sites predicts that all the active sites are not equally effective. The sites which have higher affinity towards As(V) might have contributed to sorption. Under this work conditions the maximum absorption capacity of the Fe-XAD7-DEHPA achieved in the removal process of As(V) from aqueous solution is 17.6 $\mu\text{g/g}$.

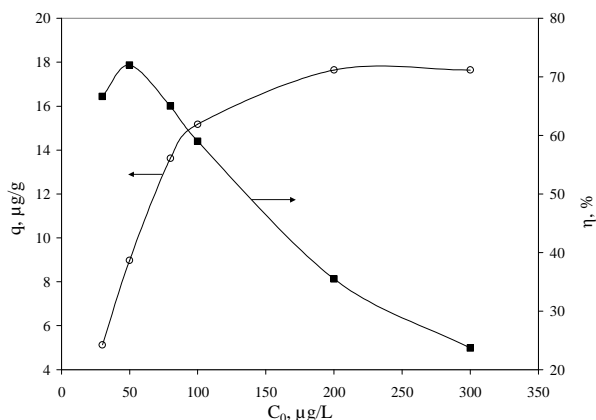


Figure 3. Effect of initial concentration on the As(V) adsorption onto Fe-XAD7-DEHPA
 $m=0.1 \text{ g}$, $v=0.025 \text{ L}$, $t=10 \text{ h}$, $T=298 \text{ K}$

4. Conclusions

The adsorption performance of a Fe-XAD7-DEHPA resin for the removal process of As(V) was evaluated. The resin was impregnated with the DEHPA through the dry method, and then the Fe(III) ions were loaded onto the resin, because of the affinity of iron towards arsenic ions.

The adsorption performance of the studied material was evaluated studying the effects of various physico-chemical parameters. The equilibrium is reached in 10 h of contact between the sorbate and adsorbent. Temperature dependence of sorption reveals the slowly increase in adsorption performance of the adsorbent with temperature. The optimum temperature for As(V) adsorption from aqueous solution onto Fe-XAD7-DEHPA is the ambient temperature $25 \pm 1^\circ\text{C}$. Under this work conditions the maximum absorption capacity of the Fe-XAD7-DEHPA achieved in the removal process of As(V) from aqueous solution is 17.6 $\mu\text{g/g}$.

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