Synthesis and characterization of mesoporous alumina and their performances for removing arsenic(V)

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HIGHLIGHTS

- Arsenic is a toxic and carcinogenic element, and adsorption has attracted much attention.
- Mesoporous alumina was used as an effective adsorbent for removing arsenic(V).
- Arsenic species, pH and adsorption mechanism were investigated and illustrated.
- Calcination temperature plays a crucial role in determining the performance of adsorbent.
- The presence of SiO\textsubscript{4}^-, PO\textsubscript{3}^4 and F\textsuperscript{-} caused the sharp reduce on arsenic(V) removal.

ABSTRACT

Mesoporous alumina, synthesized by combining the three-block copolymer Pluronic P123 as a template with aluminum hydroxide sol at room temperature followed by isolation and calcining, was employed as an effective adsorbent for removing arsenic(V) in the pH region of 2.5–7.0. Arsenic adsorption data of MA(400) are well fitted by the Langmuir isotherm model and the maximum adsorption capacity is 36.6 mg/g at near neutral (pH = 6.6 ± 0.1). Calcination temperature plays an important role in determining the performance of MA(400), MA(600) and MA(800) for removing arsenic(V), and the corresponding As(V) removal is in the order of MA(400) >> MA(600) > MA(800). The kinetics data were well fitted to pseudo-second-order, which implies that “surface reaction” might be the rate limiting step. Thermodynamic parameters illustrated that As(V) adsorption over MA(400) was a spontaneous and endothermic process. Adsorption energy (2.61 kJ/mol) is less than 8 kJ/mol, indicating the adsorption process may be dominated by physisorption. The influence of coexisting anions on As(V) removal demonstrated that the removal was slightly affected by the presence of NO\textsubscript{3} and SO\textsubscript{4}^2, while the presence of SiO\textsubscript{4}^-, PO\textsubscript{3}^4 and F\textsuperscript{-} caused a sharp fall in removal effectiveness, especially when the ratio of coexisting anion concentration to As(V) was larger than 1.12.

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1. Introduction

Human activities and natural phenomena have caused releases of arsenic (As) into groundwater and surface water, creating potentially serious environmental problems for humans and other living organisms. It is well-documented that arsenic contamination has led to serious health risks such as cancer in lung, bladder, kidney and skin, as well as other skin changes for many countries all over the world [1]. Current estimates are that, e.g., 35–50 million people in the West Bengal and Bangladesh area, more than 10 million people in Vietnam, and over 20 million people in China are exposed to harmful arsenic intake through potable water consumption [2,3]. It is well-known that the inorganic arsenic species (arsenate and arsenite) are the predominant species in most environments and the corresponding toxicities of inorganic arsenic species are much higher than those of organic arsenic species [4–6]. Therefore, there is an urgent demand for developing highly effective, reliable, and economical techniques to remove inorganic arsenic species from contaminated groundwater and surface water. Compared with other conventional techniques including oxidation, coagulation/precipitation, filtration, ion exchange, membrane/reverse osmosis and biological treatment, adsorption has attracted much attention due to the following advantages: (i) it usually does not need a large volume and additional chemicals, (ii) it is easier to set up as a POE/POU (point of entry/point of use) arsenic removal process [7], (iii) it does not produce harmful byproducts [8,9] and can be more cost-effective [10].

In general, the adsorbent plays a key role in determining the performance of an adsorption system. Activated alumina is one