



## Removal of arsenic contaminants with magnetic $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> nanoparticles

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### HIGHLIGHTS

- ▶ An easy-used method is developed to synthesize  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> nanoparticles.
- ▶ The  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> nanoparticles have high adsorption capacity for As(III) and As(V).
- ▶ The adsorption of arsenic by  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> obeys Langmuir adsorption model.
- ▶ The adsorbent can be separated from wastewater by a magnetic field over 0.35 T.
- ▶ The adsorbent keeps 40% of its initial adsorption capacity after 6 recycles.

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### ABSTRACT

Magnetic  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> nanoparticles synthesized by a co-precipitation method at room temperature have been used to remove As(III) and As(V) from their aqueous solutions. The adsorption of As(III) or As(V) was found to be saturated within 30 min and has been interpreted in terms of a Langmuir model at different temperatures. The adsorption capacities for As(III) reached 59.25, 67.02, and 74.83 mg/g at 10, 30 and 50 °C, respectively. For As(V), the adsorption capacities at these temperatures were 88.44, 95.37, and 105.25 mg/g, respectively. The effects of pH and competing ions on the adsorption of arsenite and arsenate have also been examined. The adsorption capacity remained unchanged in the range of pH 3 to 11. The presence of Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, and NO<sub>3</sub><sup>-</sup> had no effect on the adsorption capacity. However, the presence of PO<sub>4</sub><sup>3-</sup>, which has a similar outer electronic structure to that of the arsenic species, led to a significant reduction in the adsorption capacity. It is concluded from FTIR and XPS analyses that chemical binding with —OH on the adsorbent surface is responsible for the adsorption of As(III) and As(V). The saturated magnetic  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> nanoparticles could be recovered by applying a magnetic field of strength greater than 0.35 T. Arsenic compounds were eluted from the magnetic adsorbent following treatment with 1 M NaOH, leading to regeneration of the magnetic  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> nanoparticles. The nanoparticles retained over 40% of their initial adsorption capacity for arsenic compounds after 6 cycles.

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### 1. Introduction

Arsenic, a kind of metalloid [1], is identified as one of the most toxic contaminants found in the environment. Recent years have witnessed the emergence of arsenic contamination in water as a global environmental problem, accompanying the rapid growth of modern industry and agriculture. According to a survey of World Health Organization (WHO) [2], millions of people have been poisoned as a result of the endemic arsenic contamination around the world. For instance, the average concentration of arsenic in the domestic groundwater of Bangladesh is 2 mg/L. In some regions, the concentration of arsenic exceeds 12 mg/L, over 1000 times higher than the limit value of the WHO standard, that is,

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0.01 mg/L [3] in drinking water. It has been reported that over 85 million citizens in Bangladesh have consumed water with excessive arsenic, and that more than 200,000 people die from various diseases caused by arsenic poisoning each year, such as renal failure, cancer, diabetes mellitus and so forth [4]. The removal of arsenic contamination is, unfortunately, not easy, and it can easily pass through food chains and drinking water into the body [5]. Furthermore, arsenic shows a strong tendency for accumulation in the human body and thus threatens long-term health [6]. As a result, there have been growing efforts worldwide to remove arsenic contaminants [7,8]. To date, oxidation, co-precipitation, adsorption, membrane separation, and biological removal have been the main remediation technologies for arsenic contamination in water [2]. Among them, adsorption [9] is one of the most extensively investigated methods. So far, thousands of arsenic adsorbents have been studied, and the high adsorption capacities and relatively low costs [10] of the granules of iron oxides or hydroxides and their modified