

Arsenite Oxidation and Treatment by Ultrasound/Iron in Aqueous Solutions

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Introduction

Arsenic is present in natural waters and soils in two oxidation states, As(III) and As(V), which are characterized by different chemical behavior, bioavailability, and toxicity. The oxidation of As(III) to As(V) is an effective pathway to reduce As(III) toxicity and its mobility in nature. The direct oxidation of water soluble As(III) by molecular oxygen is always a slow process with a half life of approximately 1 year.¹⁾ Recently, many methods have been applied for the oxidation of As(III) to the less toxic As(V), including photocatalysis, zero-valent iron, Fenton's reaction, and ozonation.^{2,3)}

Sonochemistry has attracted attention among the different advanced oxidation processes (AOPs) used in remediation because of its simple operational requirements and its ability to use simple oxidants. In addition, several techniques such as precipitation/coagulation, ion exchange, adsorption onto activated alumina and other oxyhydroxides, and electro dialysis^{4,5)} are available for removing arsenic from ground water.

An ultrasound/ferrous [US/Fe(II)] process has been applied in the oxidation and treatment of As(III). The mechanism of As(III) oxidation and treatment by the US/Fe(II) process is depicted in Fig. 1. As(III) will be oxidized into As(V) by the hydroxide radical ($\cdot\text{OH}$) and H_2O_2 produced by US, as well as $\cdot\text{OH}$ produced by a Fenton's-like reaction. Furthermore, the precipitated $\text{Fe}(\text{OH})_3(\text{s})$ produced through the oxidation of Fe(II) into Fe(III) will be the source for the arsenic removal by the mechanism of precipitation in the form of FeAsO_4 or FeHAsO_4 , as well as complexation on the surface of the precipitated $\text{Fe}(\text{OH})_3(\text{s})$.

The objective of this study was to investigate the Fe(II) implantation quantity, and As(III) removal kinetics and mechanism during As(III) oxidation treatment by using the US/Fe(II) process.

Materials and Methods

2.1 Materials

All the chemicals used in this study were of analytical grade and were used without further purification: Sodium (meta) arsenite (NaAsO_2), purity 94%, iron sulfate heptahydrate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$), purity >99%. All the solutions were prepared with deionized (DI) water. A stock solution containing 0.2 mg L⁻¹ of As(III) was prepared and diluted to the required initial concentration of As(III). The initial concentration of Fe(II) was varied from 0.4 to 16 mg L⁻¹.

2.2 Reactor setup and analytical methods

Figure 2 shows a schematic of the sono-reactor used in this study. The reactor was made up of a glass cup-horn type with 1 L capacity equipped with an ultrasonic cup-horn type transducer (Mirae Ultrasonic MEGA-100). The applied frequencies were 450 kHz and a maximum power of 100 W, which were applied by a single piezoelectric transducer (PZT; Tamura). The diameter of each transducer was 10 cm and 500mL of the solution was used. The temperature in the solution was measured using a thermometer (Tecpel DTM-318) at several locations during ultrasound irradiation and the ultrasonic power was modified by the calorimetry method.⁶⁻⁸ Then, the filtrate was collected using an anionexchange cartridge [Supelclean_ LCSAX solid phase extraction (SPE) 3 mL, 57017]. Through this step, As(V) is retained in the anion-exchange resin and only As(III) remains in the filtrate. Then, As(III) concentrations were measured using an inductively coupled plasma atomic emission spectrometer (ICP-AES; USA 5300DV). The

stability of the SPE cartridge has already been described elsewhere. The result of mass balance with As(III) and As(V) indicated that no arsenic was unaccounted for in the experiments. X-ray diffraction (XRD) analyses were conducted for the selected freeze-dried powdered samples of precipitate iron sludge (PIS) by use of a PANalytical X'Pert Pro diffractometer (fitted with an X'Celerator) with a Cu K_α radiation source at a scan speed of 2.5° min⁻¹. The phase identification of PIS was also carried out by means of the X'Pert accompanying software program High Score Plus and the reference intensity ratio method international center for diffraction data (ICDD) PDF-4+ database.

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