Removal of Arsenic from Contaminated Water with Zinc-Sulfide

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Abstract
To test the effectiveness of removing arsenic from a contaminated water sample with zinc-sulfide (ZnS) was observed. Samples of water were obtained from a tap and the campus pond at the University of Massachusetts at Amherst. These samples were run against a series of arsenic standards solutions for concentration determination. The arsenic contaminated samples were treated with the ZnS solution and chilled for arsenic-sulfide (AsS) precipitate to form. After a few days no precipitate was detected and it could be concluded that arsenic contaminated sample treatment with ZnS is ineffective.

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Introduction

In January 2001, the EPA revised the standard Maximum Contaminant Level (MCL) for arsenic in drinking water from 50 parts per billion (ppb) to 10 ppb (or 0.01 g/mL) (1). When levels of arsenic rise above the accepted 10 ppb limit, health risk becomes the main factor. Prolonged exposure to arsenic has been found out to be a long-term cause of skin lesions, gangrene, cardiovascular disease, pulmonary disease, neurological disease, hypertension, peripheral vascular disease, diabetes mellitus, skin cancer, bladder cancer, lung cancer and cancer of the kidneys (5). In high concentrations, arsenic poisoning can also lead to an acute condition called arsenicosis, as well as heart and blood vessels. The National Resources Defense Council (NRDC) analyzed data compiled by the EPA about arsenic in drinking water for 25 states. Those analyses indicate that more than 34 million Americans drink tap water containing levels of arsenic that pose unacceptable cancer risks. The NRDC consider it likely that as many as 56 million people in just those 25 states have been drinking water with arsenic at unsafe levels (1). Due to the fact that so many people have been consuming water with carcinogenic levels of arsenic in it, scientists have been developing several effective arsenic removal procedures. There has already been success in removing arsenic from drinking water through chemical reactions with zero-valent iron. The use of nanofiltration membranes displayed a high removal rate. Another effective method of reducing arsenic in water came from the use of a photocatalyst and absorbent.

Between June 2003 and June 2004, Batch experiments and X-ray photoelectron spectroscopic (XPS) analyses were performed to study the reactions between arsenate As(V), arsenite As(III) and zero-valent iron Fe(0) (2). The samples were purged with nitrogen gas in the pH range of 4–7 and the results showed that the As(III) removal rate was higher than that for As(V) when iron filings were mixed with arsenic solutions. The XPS spectra of the reactions showed the reduction of As(III) to As(0). Soluble As(III) was formed when As(V) reacted with iron under anoxic conditions. However, no As(0) was detected on the iron coupons after 5 days of reaction in the As(V)–Fe(0) system. The removal of the arsenic by iron was caused by an electrochemical reduction of As(III) to sparsely soluble As(0) and adsorption of As(III) and As(V) to iron hydroxides (2). When the solutions were tested in open air, the removal rates of As(V) and As(III) were found to be much higher than under anoxic conditions. The rapid removal of As(III) and As(V) was due to adsorption of ferric hydroxides that were formed readily through oxidation of iron by dissolved oxygen (2).

Between September 2003 and August 2004 the removal of arsenic from synthetic and surface water by nanofiltration (NF) membrane was reported. In synthetic solutions, arsenic rejection experiments included variation of arsenic retentate concentration, transmembrane pressure, cross flow velocity and temperature. Arsenic rejection increased with arsenic retentate concentration. Arsenic was removed 93–99% from synthetic feed waters containing between 100 and 382 g/L As(V) (3). The results showed permeate arsenic concentrations of 5 g/L. Under studied conditions, arsenic rejection was independent of transmembrane pressure, cross flow velocity and temperature. In surface water the average rejection of As V was 95% (3). The mean concentration of As in collected permeate was found to be 8 g/L (3).

Between December 2003 and July 2004 a method for the removal of inorganic arsenic(III) from aqueous media was evaluated. This method involves the combined use
of TiO2-photocatalyst and an adsorbent, which has a high ability of As(V) adsorption, under photo-irradiation (4). When an aqueous solution of As(III) was stirred and exposed to sunlight, or a xenon lamp, in the presence of TiO2 suspension, As(III) oxidizes to As(V) (4). When an aqueous solution of As(III) was stirred with a mixed suspension of TiO2 and an adsorbent for As(V) (activated alumina) under sunlight, the arsenic removal reached 89% after 24 hours (4).

Our research group proposed to try a new method for removing arsenic from drinking water by absorption with ZnS. The theory behind the experiment was that arsenic, with an electronegativity of 2.18, would attract the sulfide away from zinc, which has an electronegativity of 1.65 (6). The arsenic-sulfide would form a reddish-orange precipitate which could then be filtered out of the water sample.

**Experimental**

For the start of the experiment a liter of water was obtained from the campus pond and another liter from the tap in Professor Tyson’s lab from the University of Massachusetts at Amherst’s campus. 20mL of nitric acid were added to each liter of water sample. The results were water samples of 2% nitric acid. Then the arsenic stock solution was made by taking 0.1mL of a 1000ppm arsenic solution and diluted it to 10mL, making a 10ppm stock solution. From this stock solution 8 standards were prepared with concentrations of 0, 5, 10, 50, 100, 200, 500, 1000, all up to 50mL. 50mL samples of both the tap & pond water samples we prepared as well as 100ppm spiked samples both of the water samples in question. Before the samples were run in the Flame Atomic Absorbance Spectrometer (FAAS) they were treated with 4% L-cysteine & 2% L-ascorbic acid to reduce the As(V) to As(III) so that hydride generation could be used to obtain a reading. The solutions were placed in a microwave for a minute to speed up the process. All the samples were then run through the FAAS and the absorbance was recorded. The results of the FAAS produced the following graph:

(Figure 1) Absorbance vs. As(III) Concentrations in parts per billion.
The results of treating arsenic contaminated water with ZnS proved to be ineffective. There was no AsS precipitate formed from reaction with the sulfide in the water samples.
solution. There could be a few factors which affected this result. Firstly, we used an As(V) solution to react with the ZnS, perhaps experiment would have worked if the arsenic solution was As(III). Secondly, the ZnS readily dissolved in the water and whenever choosing a good solvent for a reaction one of the qualifications is that the compound does not readily dissolve at room temperature. Maybe another sulfide combination which required some heating to dissolve the compound would lead to AsS precipitate. Had we had more time in the semester these variables could have been tested to determine exactly what the problem was with the procedure. Unfortunately since this experiment was developed by our group we have nothing with which to compare to check for mistakes.

Conclusion

As it stands our conclusion for arsenic contaminated water treatment with zinc-sulfide is ineffective. Maybe some day we will have the time to re-run the experiment testing all of the variables affecting the results.

Works Cited


