

Removal of arsenic compounds from water using iron-based materials

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Arsenite ($\text{As}^{\text{III}}\text{O}_3^{3-}$) and arsenate ($\text{As}^{\text{V}}\text{O}_4^{3-}$) represent a great threat to the environment. The properties of arsenic sulfide and related compounds have been known to physicians and professional poisoners since the fifth century BC.¹ Anthropogenic contaminations of all water types represent a danger in many countries. Arsenic compounds were used for many anthropogenic activities such as mining, agriculture, pharmacology, preservation of wood, glazier and in the last time in electronics.² Several recent reports highlight the emergency of arsenic contaminations of the surface and drinking water in Bangladesh,^{3,4} India,⁵ Nepal,⁶ Vietnam,⁷ Taiwan⁸ and Chile.⁹ In these countries, the arsenic concentrations are alarming when compared with the limit of 10 $\mu\text{g}/\text{l}$ in drinking water, which is suggested as a limiting safe-value by the World Health Organization (WHO) guidelines.¹⁰

Of the many techniques for removing arsenic compounds from water such as reversible osmosis, ion exchange and membrane filtration has found the greatest application adsorption of arsenic using sorbents.¹¹ Many materials have been tested for arsenic removal by adsorption such as volcanic ash, clay minerals, goethite, surface-treated carbon black or iron oxides.¹⁰ These materials are environmentally friendly but the limitation of all these materials is their low sorption capacity for arsenic removal. The weight ratio of the sorbent-to-arsenic ranges from 1000:1 to 100:1, at best 10:1.

Ferrate potassium K_2FeO_4 (Fe(VI)) is environmentally friendly and has strong oxidizing properties. Its redox potential ranges from 2.2 V in an acidic environment to 0.72 V in a basic environment. Fe(VI) in reaction with water is rapidly reduced and transformed to iron oxides

Fe(III) and produces molecular oxygen. In this reaction, formed iron oxide serves as a good adsorbent. These oxidation and adsorption effects of Fe(VI) bring very efficient purification of contaminated water.¹² We report the first example of arsenite and arsenate removal from water by incorporation of arsenic into the structure of nanocrystalline iron(III) oxide.

This work investigated the process of "in-situ" arsenic removal by Fe(VI) and to compare with the effect of arsenic sorption by maghemite and KFeO_2 . Sorption kinetics, the removal efficiency of arsenic in dependence of the amount of sorbent and the dependence on pH value were tested. For Fe(VI) sorption As(V) and As(III) was studied and for maghemite and KFeO_2 sorption As(V) was tested only. In all experiments, the amounts of arsenic were adjusted so that the concentration of arsenic was 100 mg/L. The weighed amounts of sorbent were dissolved in an aqueous solution containing arsenic species; the Erlenmeyer flasks containing reaction solutions (the final volumes of the solutions were 30 mL) were shaken on a conventional end-over-end shaker for 30 minutes and subsequently filtered through 450 nm syringe filters. Determinations of arsenic concentrations were carried out by AAS immediately after the separation of the sorbent from the solution. Samples of Fe(VI) were characterized using TEM, SQUID methods and Mössbauer spectroscopy.

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References

- [1] Greenwood & Earnshaw, A. Chemistry Elements. Food and Agriculture Organization of the United Nations, 1989.
- [2] Smith, E. et al., *Adv. Agron.*, 64 (1998) 149–195.
- [3] Hossain, M. F., *Agric. Ecosyst. Environ.*, 113 (2006) 1–16.
- [4] Chowdhury, U. K. et al., *Arsen. Expo. Heal. Eff.* iii, (1999) 165–182.
- [5] Das, D. et al., *Environ. Geochem. Heal.*, 18 (1996) 5–15.
- [6] Thakur, J. K. et al., *Water*, 3 (2010) 1–20.
- [7] Berg, M. et al. *Environ. Sci. Technol.*, 35 (2001) 2621–2626.
- [8] Chen, S.-L. et al., *Environ. Sci. Technol.*, 28 (1994) 877–881.
- [9] Ferreccio, C. et al., *J. Health Popul. Nutr.*, 24 (2006) 164–175.
- [10] Mohan, D. et al., *J. Hazard. Mater.*, 142 (2007) 1–53.
- [11] Bang, S. et al., *J. Hazard. Mater.*, 121 (2005) 61–67.
- [12] Sharma, V. K. et al., *J. Water Health*, 3 (2005) 45–58.