Subsurface Iron Removal and Hand-pump Adsorptive Arsenic Removal: the influence of iron catalyzed oxidation on arsenic adsorption and surface regeneration in household filters

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In the past, Subsurface Iron Removal (SIR) was proposed as a technology to co-remove arsenic from groundwater. Oxygen-rich water is injected through the tube well displacing the groundwater containing iron, arsenic and other constituents. In the aquifer an oxidation zone is formed where soluble iron oxidizes and converts to fresh iron hydroxides, precipitating on the soil grains adsorbing other elements such as arsenic (van Halem et al. 2009). Therefore, water with low iron concentrations and trace metal elements can be abstracted. However, during a field study in Bangladesh, SIR is proven to be very efficient, but co-removal of arsenic was not as effective and the WHO guideline for arsenic in drinking water was not achieved (Borges Freitas et al. 2013).

In order to achieve long-term water production below the WHO guideline another treatment step would be needed. The aim was to benefit from the SIR technique and the hand-pump infrastructure to combine with a low-cost adsorptive arsenic filter integrated at hand-pump level, referred to as hand-pump adsorptive arsenic removal filter (HAR). The objectives of this study were: (i) study the arsenic removal capacity of Granular Ferric Hydroxide (GFH) and Composite Iron Matrix (CIM) in both synthetic and natural groundwater conditions; (ii) investigate the influence of Fe(II) on arsenic adsorption and lengthening lifetime of filter; (iii) propose a design configuration for the engineered SIR/HAR.

Batch experiments were conducted using synthetic and natural groundwater, both in similar groundwater matrix conditions of pH, As(III) and Fe(II) concentrations. In synthetic groundwater the maximum adsorption capacity was found to be 18.7 µg As(V)/g GFH, 7.8 µg As(V)/g CIM, 5.5 µg As(III)/g GFH and 2 µg As(III)/g CIM. GFH had a higher adsorption capacity for both As(III) and As(V), compared to the adsorption capacity of the CIM. As expected, the results indicated that As(V) had a stronger affinity for both GFH and CIM, compared to the uncharged As(III) at neutral pH. Freundlich isotherms of As_total-GFH and As_total-CIM systems in natural groundwater under the influence of competing anions were also determined. The maximum adsorption capacity was found to be approximately 31 µg/g and 17.3 µg/g for the As_total-CIM and As_total-GFH systems, respectively. Results showed that both GFH and CIM are effective in reducing arsenic concentrations. However in these specific water matrix arsenic had a stronger affinity for CIM, possibly due to CIM’s zerovalent iron properties.

Small column experiments were conducted using synthetic groundwater, to investigate the effect of the presence and absence of Fe(II) on arsenic exhausted GFH and CIM, and its influence on lengthening lifetime of the media. After GFH was saturated with arsenic As, the experiment was followed by two steps: (i) Fe(II); (ii) aerated buffers. Therefore arsenic concentrations reduced significantly around 62% less. Thus significant regeneration of GFH’s surface occurred, i.e., due to the Fe oxidation step, Fe oxides formed in the column establishing surface complexation with GFH.

In the same first step of oxic conditions and absence of Fe(II), exhaustion of CIM did not totally occurred. CIM is a zerovalent iron and a reactive surface, thus arsenic is removed by surface corrosion. CIM is a source of additional iron and the presence of oxygen corrodes the Fe(0), creating new adsorption sites. After Fe(II) was added, oxidation of dissolved Fe(II) with dissolved oxygen increases: (i) surface corrosion, thus more sorption sites; (ii) the production of reactive intermediates such as H₂O₂, which, together with Fe(II), can oxidize As(III) to the more strongly sorbing As(V).

Research is ongoing to understand the effect of Fe(II) in the lengthening lifetime of household filters and the importance of Fenton reactions in the production of H₂O₂ for As(III) oxidation in the presence and absence of Fe(II) and other groundwater elements under different surfaces. A proposed design configuration suggests that the application of SIR/HAR might prove a sustainable solution to supply arsenic-free water to rural families of developing countries.
References
