Comparing iron and sand mixed media, iron coated sand and conventional media slow sand filters for arsenic removal from groundwater

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Abstract

Arsenic contamination of groundwater is a major public health concern in Bangladesh. In the recent years slow sand filters (SSF) augmented with iron have been proven to be a simple, low-cost, decentralized technique for efficient arsenic removal from groundwater. In this research three pilot-scale SSF (flowrate 6 $L \cdot h^{-1}$) were tested regarding their ability to remove arsenic from groundwater in conditions similar to what is found in countries like Bangladesh (70 $\mu g \cdot L^{-1}$ (As(III)), 26^0C). The setup was built with two mixed media filters, i.e. sand mixed with iron (corrosive iron matter (CIM)) and iron coated sand, and a conventional slow sand filter used as a reference. The results showed that the filter containing CIM was capable to remove arsenic below the WHO guideline concentration of 10 $\mu g \cdot L^{-1}$ even when the inlet concentration exceeded 150 $\mu g\ L^{-1}$. After 200 days of continuous operation, the effluent arsenic concentration started increasing, indicating depletion or saturation of the CIM layer. The concentration, however, never exceeded the Bangladeshi government standard of 50 $\mu g\ L^{-1}$. The iron coated sand filter also removed arsenic. However, its effluent presented higher average concentrations, i.e. 42 $\mu g \cdot L^{-1}$. The reference SSF, as expected, did not remove arsenic. The effluent quality monitoring showed that the filtration did not affect parameters such as pH, conductivity, manganese and iron concentration. Redox potential and dissolved oxygen (DO) were lowered in the CIM filter, due to oxygen depletion by oxidation of zero-valent iron to hydrous ferric oxides (HFO). The presence of HFO and iron species such as lepidocrocite and goethite was confirmed by Raman spectroscopy of the filter media. q-PCR analysis of the filter media excluded possible biological mechanism of arsenic removal.

Keywords
Arsenic, groundwater, slow sand filer, corrosive iron matter, iron coated sand

INTRODUCTION AND RESULTS

Arsenic contamination of groundwater is a major public health concern in southern Asia, particularly in Bangladesh. [1, 2] After 14-year study about the arsenic problem in Bangladesh Chakraborti et al. estimated that around 36 million inhabitants could be drinking water contaminated above the World Health Organization (WHO) guideline of 10 $\mu g \cdot L^{-1}$ [1] and about 22 million above the 50 $\mu g \cdot L^{-1}$ limit established by the Bangladeshi government. In a more recent work the same authors mentioned that from 51,731 investigated handmade tube-wells, 43% had arsenic

concentrations above 10 µg·L^{-1} and 27% above 50 µg·L^{-1}.[2] Furthermore, in 7,7% of the investigated wells the arsenic concentration exceeded 300 µg·L^{-1} and in 0,6% the concentration was higher than 1 mg·L^{-1}. In this research three pilot-scale slow sand filters (SSF) were tested and compared regarding their ability to remove arsenic from groundwater. One conventional slow sand filter (used as reference) and two mixed media (sand and iron) filters. The mixed media filters were prepared with different types of iron materials mixed into the sand media. In one filter iron was added in the form of corrosive iron matter (CIM), the other filter contained iron coated sand. To represent conditions in countries with large arsenic contamination problems like Bangladesh, the filters were placed in a climate room at 26^0C and supplied with water containing arsenic at a concentration ~70 µg L^{-1} i.e. the average arsenic concentration in these regions[1]. The main objective was to verify the performance of the filters regarding arsenic removal in such conditions. Figure 1 is a representation of (part) of the obtained results.

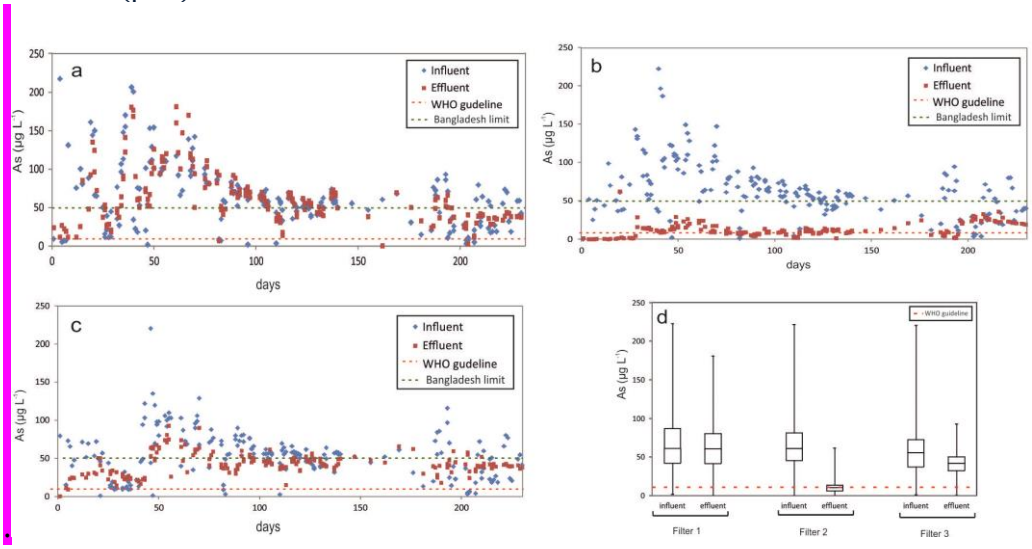

Figure 1. Arsenic removal by three different mixed media slow sand filters: concentrations measured throughout the experimental period in (a) Filter 1, (b) Filter 2, (c) Filter 3 and (d) boxplots summarizing results presented in plots a-c.

From the figure it is possible to see that filter II (sand + CIM), represented by plot 1b, presented effluent concentration level below the WHO guideline for the whole extension of the experiments. Filter III (iron coated sand), represented by plot 1c, did remove arsenic, however could not comprise with WHO level. Filter I (conventional slow san filter), as expected, did not remove arsenic. Plot 1d is a box plot representation of the inlet and outlet encountered arsenic concentration values for the three filters.

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