Comments on "Effect of groundwater iron and phosphate on the efficacy of arsenic removal by iron-amended BioSand Filters"

C. Noubactep

Angewandte Geologie, Universität Göttingen, Goldschmidtstraße 3, D - 37077 Göttingen, Germany.

e-mail: cnoubac@gwdg.de; Tel. +49 551 39 3191, Fax. +49 551 399379

In a recent study, Chiew et al. (1) reported on the performance of Kanchan arsenic filter (KAF) for arsenic and pathogen removal in rural Cambodia. As-contaminated groundwater sources were spiked with lab cultured E. coli and MS2 and filtered through KAF devices. The KAF, designed and distributed in Nepal by Ngai et al. (2), is rigorously a conventional BioSand filter (BSF) amended with a Fe-oxide-producing unit for arsenic removal (Fe^0 unit). The results of Chiew et al. (1) partly revealed no significant difference between the KAF and the BSF as shown by a reference system without Fe^0 unit. Therefore, the discussion on KAF efficiency based on Fe/P ratio is surprising for two reasons: (i) iron can not be expected to quantitatively dissolve at pH > 5 (3), and (ii) Fe-oxides are a well known PO_4^{3-}-removing agent (4).

Upon proper designing, KAF should combine pathogen removal in the BSF and arsenic removal in the Fe^0 unit (2). Furthermore, beside As, nitrate and pathogen should also be removed or inactivated in the Fe^0 unit (5). The reported results contradict this theoretical prediction and the results achieved in Nepal (2). This discrepancy suggests the existence of experimental biases. A possible bias consisted in flushing influent water for 10 min. During this time, interactions of O_2 (air) and dissolved Fe^{II} species may have afforded precipitation of iron hydroxides, possibly lowering the As concentration of the influent. In addition, introducing colloidal iron hydroxides in the Fe^0 unit could impair Fe^0 reactivity by covering its surface or filling the pore space. The conclusions of Chiew et al. (1) support the view of

Schmidt and Cairncross (6) that widespread promotion of household water treatment is premature.

On the other hand, the argument that added Fe^0 (5 kg) were inefficient due to insufficient contact time with the water is not acceptable. In fact, only 1980 litres of water was filtered during the whole experiment (22 weeks). This volume corresponds at the most to 737 g As, yielding a molar ratio Fe/As $\geq$ 8,364. Therefore, submerging the Fe^0 bed could enable a better As removal efficiency provided the used material is of adequate reactivity. Accordingly, even though Chiew et al. (1) have not exactly reproduced the original KAF design (2), the reported discrepancy in As removal may be mostly attributed to the difference in the intrinsic reactivity of used iron nails (Fe^0).

Despite large variability in microbial and chemical contaminant levels, natural waters used as drinking water could be regarded as low-level contaminated waters. In fact, contaminant concentrations are larger than accepted drinking water standards but still relatively low (here, $[As]_0 \leq 372$ μg/L). Dissolved species will certainly interact with forming and transforming iron oxides and will be removed from the aqueous solution by several mechanisms including; adsorption and co-precipitation (5). This conclusion, based on the state-of-art knowledge on contaminant removal in Fe^0/H_2O systems, shows that a well-designed iron filter can properly produce safe drinking water. The unique challenge is to find out efficient ways to characterize Fe^0 reactivity and proper selected material for domestic use.

The ability of Fe^0 filters to produce safe drinking water has been already demonstrated in the framework of SONO filter development towards 3-Kolshi filters (7). In fact, the 3-Kolshi filters containing only 3 kg Fe^0 were very efficient for arsenic removal but were abandoned because of rapid decrease of water flow rate (porosity loss). Because the porosity loss of the filter is due to the expansive nature of corrosion products formation, the 100 % Fe^0 bed can be replaced by a bed containing an optimal proportion of Fe^0 for efficient contaminant removal and an inert material as filling material. The theoretical ratio between the volume of corrosion products and the volume of iron consumed during the corrosion process varies between 2.0 for Fe_3O_4 and 6.40 for $Fe(OH)_3.2H_2O$ (8). Lowering the proportion of Fe^0 in the filter will certainly extend its service live. Fe^0 can be mixed with sand, gravel or pumice.

In conclusion the reported failure of KAF in Cambodia is mainly due to the paucity of scientific understanding of the complex chemical and physical processes involved in the process of aqueous contaminant removal by Fe^0. It is expected that immersing the Fe^0 unit will increase the KAF treatment efficiency. However, the universal use of KAF filters depends on the ability of researchers to develop reliable strategies to accurately test the long-term reactivity of Fe^0 material for these devices.

References

(1) Chiew, H.; Sampson, M.L.; Huch, S.; Ken, S.; Bostick, B.C. Effect of Groundwater Iron and Phosphate on the Efficacy of Arsenic Removal by Iron-Amended BioSand Filters. *Environ. Sci. Technol*. **2009**, 43, 6295-6300.

(2) Ngai, T.K.K.; Shrestha, R.R.; Dangol, B.; Maharjan, M.; Murcott, S.E. Design for sustainable development – Household drinking water filter for arsenic and pathogen treatment in Nepal. *J. Environ. Sci. Health* **2007**, A42, 1879-1888.

(3) Aleksanyan, A.Y.; Podobaev, A.N.; Reformatskaya, I.I. Steady-state anodic dissolution of iron in neutral and close-to-neutral media. *Protect. Met.* **2007**, 43, 66-69.

(4) Zeng, L.; Li, X.; Liu, J. Adsorptive removal of phosphate from aqueous solutions using iron oxide tailings. *Water Res*. **2004**, 38, 1318-1326.

(5) Noubactep, C. A critical review on the mechanism of contaminant removal in Fe^0–H_2O systems. *Environ. Technol*. **2008**, 29, 909-920.

(6) Schmidt, W.-P.; Cairncross, S. Household water treatment in poor populations: Is there enough evidence for scaling up now? *Environ. Sci. Technol*. **2009**, 43, 986-992.

(7) Hussan, A.; Munir, A.K.M. A simple and effective arsenic filter based on composite iron matrix: Development and deployment studies for groundwater of Bangladesh. *J. Environ. Sci. Health* **2007**, A42, 1869–1878.

(8) Caré, S.; Nguyen, Q.T.; L'Hostis, V.; Berthaud, Y. Mechanical properties of the rust layer induced by impressed current method in reinforced mortar. Cement Concrete Res. **2008**, 38, 1079-1091.