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Kanchan arsenic filters in Nepal: Constraints concerning removal efficiency

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Abstract

Unrequested health effects of a long-term intake of arsenic contaminated ground water have been known since a long time in Nepal and other countries in South-East Asia. Nowadays, so called Kanchan filters are installed in the lowland of Nepal but their removal efficiency has hardly ever been evaluated. This mini review reports about the constraints determined to influence the removal efficiency: Besides geological (mineralogy of the sediments), geochemical (pH, redox conditions, temperature, and solution composition) and handling (e.g. drying of the nail bed) issues, the maintenance of the filters by the involved residents is a major and underestimated concern.

Keywords: Arsenic, iron, decoupling, clay minerals, Kanchan filter, removal

1. Introduction

The crisis related to arsenic contaminated ground water was clearly underestimated in Nepal for a long time. The first report mentioning arsenic contamination above toxic levels in ground water in the Terai Basin of Nepal was ever published by [1]. But only 15 years later the authors of [2] pointed out that the population of the southern Indo-Gangetic Plain of Nepal (Terai) are affected the same way regarding enhanced arsenic in ground water as the inhabitants of e. g. Bangladesh. To remove arsenic from ground water so called Kanchan filters (KAF) were installed in Nepal in the early nineties (see e. g. [3]). Unfortunately, the long-term performance of these filters had rarely ever been evaluated. As a consequence, 2015 an still ongoing project to definitively describe the geological background, effectiveness and improvement of the Kanchan filters was started.

Arsenic in the sediments is predominantly bound to hydrous iron oxides and clay minerals. Depending on pH, redox conditions, temperature, solution composition and climate, the toxic elements can readily be dissolved into ground water. The removal efficiency of the filters is to a considerable degree affected by the condition regarding the nail bed, the lower sand layer, as well as the handling and maintenance by the concerned users [4-8].

2. Discussion

Since the fundamental work presented in [9] it was widely approved that As was released by desorption from As-rich Fe-oxyhydroxides existing as dispersed phases in the sediments enhanced by microbial degradation of sedimentary organic matter. Furthermore it is consensus, that an increase in pH and a negative Eh favor the desorption of arsenic. However, in this regard the role of phyllosilicates is evidently underestimated: The low average molar ratio Fe/As [5] the distinct decoupling of the concentration between Fe and As in the ground water in Nepal in addition to the striking correlation between As and the lithophile elements Na, K, Ca, Mn, Li, B, Sr and Mo advocate unambiguously for an origin of As from clay minerals (e. g. muscovite, biotite) as Na, K and Sr can easily be displaced from interlayers of phyllosilicates [5, 6, 10]. In addition to these findings related to the mineralic host of Arsenic, the author of [11] could not detect any reasonable quantity of Fe(III)hydr(oxides) by X-ray analysis of a sediment drill core - contrariwise clay minerals proofed to be very abundant in the same drill core.

In reference to the Kanchan filters, the mentioned low concentration of Fe in ground water is of major importance concerning their performance. Moreover, a short residence time of the ground water within the nail bed, a high pH and as well as considerable concentrations of As, Na, B, Mo and other trace elements [see 5] clearly limit the removal capacities of the filters. Dry nail beds instead of a constant immersion of the nails in ground water is another adverse effect regarding removal efficiency. Furthermore, the formation of siderite ($FeCO_3$) on the nails surface was observed by X-ray examinations from some of the monitored filters. The precipitation of siderite has two implications: The oxidation process enhancing the formation of rust on the nails is incomplete and siderite inhibits the adsorption of As on the nail surface [6].

Since 2015 at least 30 filters were controlled or adapted regularly and ground water samples were collected in pre-monsoon and post-monsoon seasons. The removal efficiency vary considerably from 5.81 % to 97.1 % [for details see 7,8]. Several reasons were determined to influence the removal efficiency: Partially uneven and dry nail bed or an irregular surface of the the bed, formation of siderite on the nail surface, short contact time between the nails and the ground water and a year-long use of the lower sand layer (e. g. reduction of the capacity to remove the exfoliated particles containing adsorbed As from the nails above).

3. Conclusion

The application of an upper sand layer above the nails improved the removal efficiency of the filters slightly: The inflow velocity was reduced, the nails were not displaced anymore while filling the filter with water. Future improvements have to be implemented according geochemical constraints: Low Fe contents of the ground water has to be counteracted by immersion of the nails in water, prolongated contact time with the nails. Installation of a tap to regulate the outflow and to ensure immersion of the nails in water has to be established. The low performance is often caused by neglection (e. g. displacement of the nails of the nail while pouring water to speedy causing an uneven nail bed) and poor maintenance (e. g. omitting to change the nails and the fine sand in the lower sand layer regularly). Proper instruction courses for the concerned users of the Kanchan filters have to be organized on a regular base in order to avoid mishandling.

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References

[1] Sharma, R. M. 1999. Research study on possible contamination of groundwater with arsenic in Jhapa, Morang, and Sunsari districts of Eastern Terai of Nepal. Report of WHO Project, DWSS Government of Nepal.

[2] Nakano, A., Kurosawa, K., Shamim, U. M., Tani, M. 2014. Geochemical assessment of arsenic contamination in well water and sediments from several communities in the Nawalparasi District of Nepal. Environ Earth Sci, 72, 3269-3280.

[3] Ngai, T. K. K., Shrestha, R. R., Dangol, B,. Maharjan, M., Murcott, S. E. 2007. Design for sustainable development – Household drinking water filter for arsenic and pathogen treatment in Nepal. J Environ Sci Health – A Tox Hazard Subst Environ Eng, 42, 1879-1888.

[4] Mueller, B. 2017. Arsenic in groundwater in the southern lowlands of Nepal and its mitigation options: A review. Environ Rev, 25, 296-305.

[5] Mueller, B., Hug, S. J. 2018. Climatic variations and de-coupling between arsenic and iron in arsenic contaminated ground water in the lowlands of Nepal. Chemosphere, 210, 347-358.

[6] Mueller, B. 2019. Ground water contamination by arsenic in Nepal: Lessons to be learned from geology. Austin Chem Eng, 6, 1064-1069.

[7] Mueller, B. 2020. First results of improved arsenic removal by redesigned Kanchan filters in the lowlands of Nepal. J Chem Appl, 2, 1-9.

[8] Mueller, B., Dangol, B., Ngai, T. K. K., Hug, S. J. 2020. Kanchan arsenic filters in the lowlands of Nepal – mode of operation, arsenic removal and future improvements. Submitted to. Environmental Geochemistry and Health, https://doi.org/10.1007/s10653-020-00718-9.

[9] Nickson, R. T., McArthur, J. M., Ravenscroft, P., Burgess, W. G., Ahmed, K. M. 2000. Mechanism of arsenic release to groundwater, Bangladesh and West Bengal. Appl Geochem, 15, 403-413.

[10] Guillot, S., Garçon, M., Weinman, .B, Gajurel, A,. Tisserand, D., France-Lanord, C., van Geen, A., Chakraborty, S., Huyghe, P., Upreti, B. N., Charlet, L. 2015. Origin of arsenic in Late Pleistocene to Holocene sediments in the Nawalparasi district (Terai, Nepal). Environm Earth Sci, DOI 10.1007/s12665-015-4277-y.

[11] Zweifel, E. R. Arsenic contamination in Nepal: Water treatment issues and geologic origin of the pollution. Master Thesis, Institute of Geography, University of Bern, 2018, 67 pp.